WMO Global Ozone Research and Monitoring Project
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Report of the Eighth Meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer

(Geneva, Switzerland, 2 to 4 May 2011)
REPORT OF THE
EIGHTH MEETING OF THE OZONE RESEARCH MANAGERS
OF THE PARTIES TO THE VIENNA CONVENTION FOR THE
PROTECTION OF THE OZONE LAYER

(Geneva, 2 - 4 May 2011)
TABLE OF CONTENTS

INTRODUCTION .................................................................................................................................................................................... 1

OPENING OF THE MEETING .................................................................................................................................................................. 1
Opening Statement (Marco González, Ozone Secretariat) .............................................................................................................................. 1
Welcome Address (Tetsuo Nakazawa, WMO) ....................................................................................................................................... 2
The 2010 Ozone Assessment: Addressing the Needs of the Parties (Paul Newman, Co-Chair, SAP) ......................................................... 3
Keynote address: Science Highlights from the 2010 Ozone Assessment (A. R. Ravishankara, Co-Chair, SAP) .................................. 3
The Interface between the ORMs and the Scientific Ozone Assessments (Michael Kurylo, Chair, 7th ORM) ........................................ 4
Election of the Chairperson ..................................................................................................................................................................... 4
Adoption of the 8th ORM Agenda ........................................................................................................................................................ 4

SESSION 1: INTRODUCTORY SESSION: THE VIENNA CONVENTION
Review of the recommendations of the Seventh Meeting of the Ozone Research Managers, Geneva, May 2008 (WMO Global Ozone Report No. 51) and the Resultant Decisions of the Eighth Conference of the Parties to the Vienna Convention, Doha, November 2008 (Michael Kurylo, Chair, 7th ORM) ................................................................................... 5
Activities under the Vienna Convention Trust Fund for Research and Systematic Observation Relevant to the Vienna Convention (Megumi Seki, Ozone Secretariat; Karel Vanicek, CHMI; and Geir Braathen, WMO) ................................................................. 5
Appointment of Discussion Leaders and Rapporteurs for the Various Recommendation Areas – Research Needs, Systematic Observations, Data Archiving, Capacity Building (8th ORM Chair) ................................................................................................................. 8

SESSION 2: THE STATE OF THE OZONE LAYER AND INTERACTIONS BETWEEN OZONE LAYER DEPLETION AND CLIMATE CHANGE
The Current and Future States of the Ozone Layer (Greg Bodeker, Bodeker Scientific) ........................................................................ 8
Links between Ozone and Climate (Paul Newman, Co-Chair, SAP) .................................................................................................. 9
Influences of Ozone-Layer Depletion and Climate Change on UV Radiation: Impacts on Human Health and the Environment (Janet Bornman and Nigel Paul, Co-Chairs, EEAP) ................................................................. 9

SESSION 3: INTERNATIONAL MONITORING PROGRAMMES
The WMO Global Atmosphere Watch (GAW) Programme (Liisa Jalkanen, WMO) ................................................................................... 10
The Network for the Detection of Atmospheric Composition Change (NDACC) (I. Stuart McDermid, NASA/JPL) .................................................. 11
International Ozonesonde Activities (Russ Schnell, NOAA) ................................................................................................................... 12
Global Climate Observing System (GCOS) Including GRUAN (Greg Bodeker, Bodeker Scientific) ......................................................... 12
Integrated Global Atmospheric Chemistry Observations for Ozone and UV (IGACO-Ozone/UV) (Geir Braathen, WMO) ................. 13
The New SPARC ODS Lifetime Assessment (Stefan Reimann, Empa) ................................................................................................... 14
Ground-Based Networks for Measuring Ozone- and Climate-Related Trace Gases (Stefan Reimann, Empa) ......................................... 14
Atmospheric Concentrations of ODSs and ODS Substitutes: Scenarios and Trends (Guus Velders, National Institute of Public Health and the Environment (RIVM)) ........................................................................................................... 15
SESSION 4: SATELLITE RESEARCH AND MONITORING

The Stratospheric Processes and their Role in Climate Project of WCRP: The Joint SPARC/IoC/WMO/NDACC Initiative on Past Trends in the Vertical Distribution of Ozone (Johannes Stähelin, ETH Zürich) ......................................................................................................................... 15

Lessons Learned in Creating Long-Term O3 Datasets: Recommendations for the Future (P. K. Bhartia, NASA) .......................................................... 16

Current and Planned Ozone and Climate Observations from Space ................................................................................................................................. 16

U.S. Satellite Programmes: NASA, NOAA, and Other Agencies (Ken Jucks, NASA) ............................................................................................................. 16

European Space Agency Activities (Jean-Christopher Lambert, IASB-BIRA) .................................................................................................................. 17

KNMI (Peter van Velthoven) .................................................................................................................................................................................. 18

EUMETSAT and O3MSAF (Geir Braathen, WMO, for Lars Prahm, EUMETSAT) ........................................................................................................ 18

Japanese Aerospace Exploration Agency / SMILES (Hideaki Nakane, NIES) ........................................................................................................ 19

Summary of the Key Issues in Space-Based Measurements: Identification of Future Needs and Opportunities (Jean-Christopher Lambert, IASB-BIRA) .................................................................................................................. 19

SESSION 5: NATIONAL AND REGIONAL REPORTS ON OZONE RESEARCH AND MONITORING

Region 1: Africa .................................................................................................................................................................................................................... 21

Region 2: Asia .................................................................................................................................................................................................................. 21

Region 3: South America ...................................................................................................................................................................................... 22

Region 4: North America, Central America, and the Caribbean .......................................................................................................................... 23

Region 5: South West Pacific .................................................................................................................................................................................. 24

Antarctica ........................................................................................................................................................................................................... 25

Region 6: Europe ........................................................................................................................................................................................................ 26

SESSION 6: DISCUSSION OF RECOMMENDATIONS

Recommendations ............................................................................................................................................................................................................. 31

Research Needs ........................................................................................................................................................................................................ 31

Systematic Observations .................................................................................................................................................................................. 33

Data Archiving ..................................................................................................................................................................................................... 36

Capacity Building ................................................................................................................................................................................................... 38

Closure of the Meeting .................................................................................................................................................................................................. 41

Annex A: List of Participants ....................................................................................................................................................................................... 43

Annex B: Agenda ...................................................................................................................................................................................................... 51

Annex C: National Reports .................................................................................................................................................................................................. 55
INTRODUCTION

The eighth meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer was held at the Headquarters of the World Meteorological Organization (WMO) in Geneva, from 2 to 4 May 2011.

The meeting was organized by the Ozone Secretariat of the United Nations Environment Programme (UNEP) in cooperation with the World Meteorological Organization (WMO), in accordance with decision I/6 of the Conference of the Parties to the Vienna Convention for the Protection of the Ozone Layer. A list of participants is provided in annex A to the present report.

OPENING OF THE MEETING

The meeting started on Monday, 2 May 2011.

Opening Statement (Marco González)

Mr Marco González, Executive Secretary of the Ozone Secretariat, welcomed the participants and thanked WMO for their efforts in co-organizing the meeting. He emphasized the successes of the Vienna Convention and its Montreal Protocol on Substances that Deplete the Ozone Layer, including their achievement of universal ratification, reduction of over 98% of production and consumption of most ODSs worldwide, and the expected recovery of the ozone layer by around middle of this century. The important basis for that success was the independent assessment of the latest information on scientific, environmental, technical and economic aspects of ozone layer depletion and protection carried out by the three assessment panels at least every four years, involving hundreds of scientists and experts around the world. He thanked the panels and their co-chairs present in the meeting for undertaking the enormous task and producing excellent reports.

Mr González stated that the strengthened links among the assessment panels, the Ozone Research Managers, and scientists and experts working in international programmes relevant to systematic observation and monitoring enhanced opportunities for training, learning, and development of new avenues of cooperation. He praised the negotiators for their wisdom and foresightedness in establishing and improving over time an institutional framework and modalities of operation that enabled the science, the technological development as well as the economic feasibility to be the basis for the implementation of the international ozone regime.

With regard to the agenda of the 8ORM, he recalled the substantial changes that were made to the agenda of the 7ORM as compared with the traditional meetings of the ORM. Those changes included, for example, expanding the number of international programmes to be addressed, and the consolidation of the national presentations into regional ones, and made the meeting run effectively and efficiently. With the help of the Chair of the 7ORM, the 8ORM agenda was built on the 7ORM agenda. Thanking the countries for the submission of the national reports, Mr González encouraged the Ozone Research Managers to ensure that their key issues are reflected appropriately in the regional presentations, as well as in the recommendations emanating from the meeting. The ORM recommendations will then be presented to the Ninth Meeting of the Conference of the Parties to the Vienna Convention, which is scheduled to be held jointly with the Twenty-Third Meeting of the Parties to the Montreal Protocol from 14 to 18 November 2011 in Bali. He also informed the meeting that the members of the Bureau of the Vienna Convention were participating in the 8ORM, and were to meet immediately after the 8ORM to discuss its outcomes with a view to supporting the ORM recommendations and bringing them to the attention of the Conference of the Parties.

Mr González also stated that the impacts of the implementation of the Montreal Protocol, including the accelerated HFC phase-out and the potential phase-out of high-GWP alternatives such as HFCs on the ozone layer, as well as climate, need to be monitored and understood. He emphasized the reliance of the Parties to the Vienna Convention and the Montreal Protocol on the scientific community to continue the observations and research to enhance the understanding of the atmospheric processes where uncertainties remain.
Welcome Address (Tetsuo Nakazawa)

On behalf of WMO, Mr Nakazawa, Chief of the World Weather Research Division of WMO’s Research Department, opened his statement by welcoming all the delegates of the Parties as well as invited experts. He also welcomed the colleagues from UNEP’s Ozone Secretariat. He mentioned that these meetings have been held about every three years since the early 1990s, and that all of them, with the exception of the one in 2005, have been held at WMO in Geneva. He pointed out the excellent collaboration between UNEP and WMO in the planning and organization of these meetings. The collaboration between UNEP and WMO in ozone matters dates back to the 1970s.

He reminded the attendees that the Vienna Convention calls for extensive cooperation between Parties on research and systematic observation, with emphasis on measurements of the ozone layer, as well as in the promotion of training, taking into account the particular needs of developing countries and countries with economies in transition.

The Vienna Convention Trust Fund for Research and Systematic Observation provides funding for instrument calibration and capacity building. Several activities have taken place with support from this fund and he reminded the audience that they would hear more about that later in the meeting.

Such activities are important for the quality of the observational data, which are used in the WMO/UNEP Scientific Assessment of Ozone Depletion. The most recent issue of this important assessment was announced on the International Day for the Preservation of the Ozone Layer on 16 September 2010. The full report is now printed and available to the delegates at this meeting. Mr Nakazawa addressed a special welcome the co-chairs of the Scientific Assessment Panel, the Environmental Effects Assessment Panel, the Technology and Economic Assessment Panel, as well as several experts who have been involved in the writing the 2010 Ozone Assessment.

Then Mr Nakazawa emphasized the importance of the WMO Global Atmosphere Watch (GAW) Programme in providing essential data for the study of ozone depletion, and in forming a bridge between the advanced monitoring and research capabilities of developed countries on the one hand, and the expert help and financial assistance needed by developing countries on the other.

Recovery of the ozone layer has yet to be observed, despite decreasing levels of ozone-depleting substances (ODSs) in the atmosphere, so observation of stratospheric ozone and of species causing ozone depletion must remain a high priority for the coming decades. This should be accomplished through collaboration and coordination between GAW and affiliated networks and research programmes, such as AGAGE, GCOS, NDACC, the NOAA networks, SHADOZ, TCCON, WCRP, and others.

Due to the great success of the Montreal Protocol on Substances that Deplete the Ozone Layer, it has become a general opinion that the ozone depletion problem is solved. In the meantime, climate change, due to man-made emissions of greenhouse gases, has become the major environmental issue of global importance. Consequently, the ozone problem is now considered to be of much lesser importance than before.

In recent years, however, it has become apparent that there are close links between climate change and stratospheric ozone. These links operate in both directions. Changes in climate are expected to have an increasing influence on stratospheric ozone in the coming decades. These changes derive principally from the emissions of long-lived greenhouse gases, mainly carbon dioxide, associated with human activities. On the other hand, changes in ozone have an effect on climate. One such example is the impact of the Antarctic ozone hole on surface climate. It is becoming evident that the strengthening of the south polar vortex in spring, as a consequence of severe ozone depletion, leads to important changes in surface temperature and wind patterns.
The annually recurring Antarctic ozone hole and the severe ozone loss that took place in the Arctic in the winter and spring of 2011 show that ozone depletion still represents a serious environmental problem, and that we have to remain vigilant when it comes to monitoring and research. Substantial Arctic springtime ozone loss in the case of a cold stratospheric winter, such as experienced in 2011, has been foreseen by the WMO/UNEP Ozone Assessment, but one is not able to forecast such events. This shows that the scientists have a good understanding of the mechanisms leading to ozone loss, but it also shows that one needs a better understanding of the interactions between ozone and climate.

In conclusion, Mr Nakazawa emphasized that the challenges of protecting the environment for the generations to come can only be met through continuing international cooperative efforts, as exemplified by the Ozone Research Managers’ meeting.

Finally, Mr Nakazawa wished the attendees good luck in the discussions leading to the recommendations to the Parties of the Vienna Convention for the Protection of the Ozone Layer.

The 2010 Ozone Assessment: Addressing the Needs of the Parties
(Paul Newman, Co-Chair of the SAP)

On behalf of the Scientific Assessment Panel (SAP) Co-Chairs, Mr Paul Newman (NASA Goddard Space Flight Center) presented information on: 1) the basis of the SAP within the Vienna Convention and the Montreal Protocol, 2) the role of the science assessments to the Montreal Protocol, and 3) the specific requests of Parties to the Montreal Protocol for the “Scientific Assessment of Ozone Depletion: 2010.” The presentation covered the timeline of the production of the Assessment, and showed the chapter structure of the Assessment. The 2010 Assessment has been printed, and is the process of being distributed.

Keynote address: Science Highlights from the 2010 Ozone Assessment
(A. R. Ravishankara, Co-Chair, SAP)

Mr A. R. Ravishankara presented the highlights of the findings from the most recent Science Assessment Panel (SAP) Report on behalf of the Assessment Co-Chairs.

He first presented the key findings using the figure from the Executive Summary of the report, and then delved into the detailed findings on the following: (1) emissions and abundances of ozone-depleting substances (ODSs); (2) the effects of climate change on the ozone layer and that of the ozone layer on the climate; (3) the Antarctic ozone hole and its expected future; (4) global ozone and its future; and (5) the surface UV-level changes due to stratospheric ozone depletion to date, and that expected for the future.

Specifically, he noted the following: (1) The abundances of ODSs in the atmosphere are responding as expected to the controls of the Montreal Protocol; (2) the trend is clearly decreasing – EESC is decreasing in both the troposphere and the stratosphere, with a slight lag between the stratosphere and the troposphere that is understood; (3) CCl4 continues to decrease in the atmosphere, but its abundance is not consistent with reported emissions and known lifetimes; (4) errors in reporting, errors in analysis of reported data, and/or unknown sources are likely responsible for the year-to-year discrepancies; (5) the ozone layer and climate change are intricately coupled, and climate change will become increasingly more important to the future ozone layer; (6) the ozone hole that occurs in austral springtime is projected to recover later in the century than any other region of the globe; (7) the Antarctic ozone hole is much less influenced by climate change than other areas of the globe; (8) control of ODSs by the Montreal Protocol has protected the ozone layer from much higher levels of depletion that would have occurred without the Protocol; (9) globally, the ozone layer is projected to recover to its 1980 level before the middle of this century; (10) the ozone layer and surface ultraviolet (UV) radiation are responding as expected to the ODS reductions achieved under the Montreal Protocol; (11) the Montreal Protocol, with its amendments and adjustments, benefited mitigation of climate change via control of ODSs, which are also greenhouse gases; and (12) HFCs, which are substitutes for ODSs, do not deplete
ozone (ODP = 0), but some of them are potent greenhouse gases – projected GWP-weighted emissions of HFCs by 2025 ≈ GWP-weighted emissions of CFCs at their peak in 1988.

In addition to these science findings, some general information for the Parties also was provided. They included the following: (a) the influence of the ozone hole on surface climate are clearly visible; (b) unabated emissions of ODSs at the 1970 levels would have been very detrimental to the ozone layer and, hence, to the surface UV. Mr Ravishankara noted the very large ozone depletions in the tropics and the very large increases in surface UV, and he listed the options for further limiting future emissions of ODSs that could advance recovery dates by a few years. However, the impact of these potential emission reductions on future ozone levels would be less than what has already been accomplished by the Montreal Protocol as long as emissions of ODSs are not increased in the future. Finally, some specific options for policy makers, and expected gains from such actions, were noted.

The Interface between the ORMs and the Scientific Ozone Assessments
(Michael Kurylo, Chairperson of 7ORM)

As Chair of the 7th Meeting of Ozone Research Managers (7ORM) that was held in Geneva Switzerland in 2008, Mr Michael J. Kurylo provided an overview on the role of the meetings of Ozone Research Managers and their interface with the WMO/UNEP assessments under the Montreal Protocol. He reminded the delegates that the purpose of each ORM meeting is to review ongoing research and monitoring programmes for ozone and UV-B, with an emphasis on (i) assessing research (including measurement calibration and archiving) related to the health and environmental effects of ozone modifications, (ii) identifying research and monitoring gaps, (iii) ensuring national and international coordination, and (iv) developing a set of recommendations for future research and expanded cooperation in developed and developing countries. He described the highly complementary, but distinctly different, roles of the ORM reports and the three WMO-UNEP Assessments (Scientific, Environmental Effects, Technology and Economic). Whereas all are required under the Vienna Convention and its Montreal Protocol and serve as communication devices between the research community (striving for better understanding) and decision makers (for informed action), the Assessments enable the Parties to evaluate control measurements under the Montreal Protocol. The Assessments constitute neither policy recommendations nor research planning documents but provide input for both. The ORM reports, on the other hand, specifically address research and monitoring needs in light of the scientific understanding provided by the Assessments and do make specific recommendations to the Parties regarding international funding for improved research coordination and networking. He then briefly summarized the 8th ORM agenda items, which include (i) a review of 7th ORM Recommendations, (ii) presentations on the state of the ozone layer including climate links, (iii) updates on international monitoring programmes, (iv) satellite research and monitoring programmes (present and future), (v) regional reports on ozone research and monitoring taking into account the available national reports, and (vi) development of current recommendations (for research, systematic observations, capacity building, data archiving) derived from all of the information provided and presented.

Election of the Chairperson

Mr Michael Kurylo (United States of America) was unanimously elected Chair of the 8ORM meeting.

Adoption of the 8th ORM Agenda

The agenda was unanimously adopted as contained in Annex B. The summaries of the presentations given under sessions 1 to 6 are provided below. Full presentations are also available separately.
SESSION 1: INTRODUCTORY SESSION: THE VIENNA CONVENTION

Review of the recommendations of the Seventh Meeting of the Ozone Research Managers, Geneva, May 2008 (WMO Global Ozone Report No. 51) and the Resultant Decisions of the Eighth Conference of the Parties to the Vienna Convention, Doha, November 2008 (Michael Kurylo, Chairperson of 7ORM)

As Chair of the 7th Meeting of Ozone Research Managers that was held in Geneva, Switzerland, in May 2008, Mr Michael J. Kurylo reviewed the recommendations from that meeting and the resultant decisions of the Eighth Meeting of the Conference of the Parties to the Vienna Convention held in Doha, Qatar, in November 2008. The 7th ORM recommendations were formulated against a background of information from the 2006 Scientific Assessment of Ozone Depletion that (i) stratospheric ozone will remain vulnerable to chemical depletion by chlorine and bromine chemicals for much of the current century, and (ii) while the rate of ozone depletion at mid-latitudes has slowed in recent years due to the decline in EESC, polar ozone loss remains large and is highly variable. Further, the complexities of ozone and UV science require (i) the continuation and expansion of systematic measurement and analysis capabilities for tracking the evolution of ozone- and climate-related source gases and parameters, (ii) detection and tracking the stabilization and expected recovery of stratospheric ozone, (iii) attribution of changes in radiation forcing to changes in the ozone profile or to other atmospheric changes, and (iv) derivation of a global record of ground-level UV radiation. These requirements led to specific recommendations in the areas of research, systematic observations, data archiving, and capacity building that are detailed in the full report of the 7th ORM, which can be obtained at <http://ozone.unep.org/Meeting_Documents/research-mgrs/7orm/index.shtml> and <http://www.wmo.int/pages/prog/arep/gaw/ozone/7thORM.html>. These recommendations were presented at the 8th COP and formed the basis by the parties to enact

• Decision VIII/2 (Recommendations Adopted by the Ozone Research Managers at their Seventh Meeting), which urged the Parties to make every attempt at implementing the 7th ORM recommendations in all four areas.
  o In particular, in the area of atmospheric measurements the Doha Declaration urges “the Governments of the world to seek to ensure full coverage of the relevant data gathering programmes, in order to ensure that the atmosphere including its stratospheric ozone and its interrelation with climatic change is kept under continuous observation”

• Decision VIII/3 (Vienna Convention Trust Fund for Financing Activities on Research and Systematic Observations Relevant to the Vienna Convention for the Protection of the Ozone Layer), which urged the Parties to make voluntary financial contributions to the Trust Fund and requested continued cooperation with respect to the Trust Fund between the UNEP Ozone Secretariat and the WMO.

• Decision VIII/4 (Financial Matters: Financial Reports and Budgets), which urged all Parties to pay their outstanding and future contributions and requested the Executive Director to extend the Vienna Convention Trust Fund to December 31, 2015.


Activities under the Vienna Convention Trust Fund for Research and Systematic Observation Relevant to the Vienna Convention

History and Financial Status of the Trust Fund (Meg Seki, Ozone Secretariat)

The Trust Fund for Research and Systematic Observation is a special fund established under the Vienna Convention, in accordance with decision VI/2 of the Parties at the 6th Meeting of the Conference of the Parties (COP6) in November 2002. Paragraph 2 of the decision requested
UNEP in consultation with WMO to establish an extra budgetary fund for financing activities on research and systematic observations relevant to the Vienna Convention, in developing countries and countries with economies in transition (CEIT). The same decision stated the primary aim of the Fund as “to provide complementary support for the continued maintenance and calibration of the existing WMO Global Atmospheric Watch ground-based stations for monitoring column ozone, ozone profiles, and ultraviolet radiation in the developing countries and in the CEIT, to address balanced global coverage,” and at the same time to consider “... supporting other activities identified by the Ozone Research Managers and in consultation with the Co-Chairs of the Scientific Assessment and Environmental Effects Assessment Panels, for the improvement of the observation network and relevant research.”

Attention was drawn to paragraph 8 of the decision that requested the WMO and UNEP to draw to the attention of the Parties opportunities for meeting common objectives among conventions in particular the United Nations Framework Convention on Climate Change. Any ideas that the ORM may identify would be communicated to the Parties.

The status of implementation of the Trust Fund and its activities was as follows:

- The Trust Fund was established in February 2003 in consultation with WMO, and in conformance with the relevant rules and regulations of the UN and of the Environment Fund of UNEP.
- The terms of reference for the administration of the Fund were also put in place at the same time and were circulated to all Parties in March 2003.
- Annual letters were sent to the Parties inviting them to make voluntary contributions to the Fund, together with reports on the activities carried out and the financial status.
- A memorandum of understanding (MOU) between the UNEP Ozone Secretariat and WMO on the institutional arrangements for making decisions on the allocation of monies from the Fund, was concluded in 2005 and approved by the Parties at COP6. The MOU set out the cycle for funding Maintenance and Calibration projects and Research and Monitoring projects.

To date, the total funds received in the Trust Fund amounted to US$246,307. Contributing countries included Czech Republic, Estonia, Finland, France, Kazakhstan, South Africa, Spain, Switzerland, and the United Kingdom. Activities carried out under the Trust Fund included the following:

- A Dobson Inter-Calibration Workshop, Egypt, 23 February to 12 March 2004
- Brewer calibration in Kathmandu, Nepal and Bandung, Indonesia in September 2006
- An intercomparison exercise for all African Dobson instruments, Irene, South Africa, 12 to 30 October 2009
- A Dobson data quality workshop, in Hradec Králové, Czech Republic, 14 to 18 February 2011

The remaining balance in the Fund currently stands at US$90,707.

**Report on the Dobson Data Quality Workshop Funded by the Trust Fund (Karel Vanicek, CHMI)**

The Workshop was held 14-18 February 2011 in Hradec Králové, Czech Republic, as a technological meeting of Dobson total ozone data managers and experts from the central GAW facilities. The action was initiated by the recommendation of the 7ORM. The SAG-Ozone of the GAW provided expert guidance, and the Solar and Ozone Observatory Hradec Králové of the Czech Hydrometeorological Institute (CHMI) took the responsibility for the local arrangements. Financial support was provided by the Vienna Convention Trust Fund through the UNEP-MP and WMO Secretariats and by the Czech Government. The main goals of the Workshop were:
• To bring together managers of the archive data sets from the Dobson stations and provide guidance on how to reevaluate and reprocess important past data.

• To collect the primary (0-level) Dobson data sets and calibration metadata from the stations to be archived in the WOUDC.

• To present the actual scientific themes and results on operation of the Dobson instruments and data quality assurance at the stations given by invited experts.

The agenda of the meeting was for morning scientific presentations and afternoon interviews of experts from the RDCCs, WOUDC, and satellite instrument operators who use the Dobson data for verification with the station data managers. The interviews covered discussions on calibration and data analysis, transfer of the digitized 0-level observation data and the calibration metadata from stations to the WOUDC database, and consultations on application of the freeware tools for the Dobson data processing quality control.

The Workshop was attended by 34 participants, including 21 station data managers of 51 Dobson stations. This represented about 70% of the currently active Dobson stations. A unified template of the information of the individual stations was developed to be available for all stations in the network. The participants became knowledgeable of the problems in the earlier data, and methods of reprocessing using the freeware developed by the RDCCs.

To continue this activity, the BORM should mandate all Dobson stations to submit the level-0 observational and calibration data to the WOUDC, as well as the level-1 analysis. As a certain number of stations with long-term records or stations located in important regions were not present at the Workshop, the templates will be sent to them with proper comments by the appropriate RDCCs. A recommendation is stated to arrange a second workshop in Toronto in conjunction with the Quadrennial Ozone symposium in 2012 to assess the progress of the project. More details about the Workshop are available at <www.dobsonworkshop.cz>.

Other Activities (Geir Braathen, WMO)

Mr Braathen began by showing a list of the five activities that have been carried out so far (2004-2011) with funding from the Vienna Convention Trust Fund for Research and Systematic Observation. He then focused on the Dobson intercomparison that took place in Irene, South Africa, in October-November 2009. The following instruments took part:

• Dobson # 083, NOAA (USA)
• Dobson # 063, German Weather Service
• Dobson # 105, BoM (Australia)
• Dobson # 035, SAWS, Cape Town
• Dobson # 132, SAWS, Springbok
• Dobson # 089, SAWS, Irene
• Dobson # 015, Maun, Botswana
• Dobson # 057, Seychelles

In addition, the following instruments took part in the extension of the campaign from 15-26 November 2009:

• Shimatzu # 5703, Lagos, Nigeria
• Dobson # 015, Maun, Botswana
• Dobson # 057, Seychelles
• Dobson # 018, Nairobi, Kenya
All the participating instruments are now well-calibrated and in good operating condition, except for D057 from Mahe, which still remains within a marginal calibration error. This instrument may need better expert attention before the next IC event, which is to be scheduled in 3 to 4 years time from now. Overall, most of the objectives of the intercomparisons were met satisfactorily.

The Dobson spectrophotometer from Cairo was calibrated in Germany in May 2010. It is being investigated how one can attend to the Dobson instrument from Tamanrasset, Algeria, which did not take part in the Irene intercomparison.

Appointment of Discussion Leaders and Rapporteurs for the Various Recommendation Areas – Research Needs, Systematic Observations, Data Archiving, Capacity Building

(8th ORM Chair)

Discussion leaders and rapporteurs for the recommendation areas were selected as follows:

P. Newman and A.R. Ravishankara were chosen to introduce the area of "Research Needs". K. Jucks and J. Pyle were chosen as rapporteurs.

P.K. Bhartia and S. Reimann would lead the discussion on "Systematic Observations" with J.-C. Lambert and N. Larsen as rapporteurs.

"Data Archiving" was going to be introduced by K. Vanicek with J. Staehelin and G. Bodeker as rapporteurs.

A.-L. Ajavon and S. McDermid took on the task to lead the discussion on "Capacity Building" with G. Braathen and B. McArthur as rapporteurs.

SESSION 2: THE STATE OF THE OZONE LAYER AND INTERACTIONS BETWEEN OZONE LAYER DEPLETION AND CLIMATE CHANGE

The Current and Future States of the Ozone Layer (Greg Bodeker, Bodeker Scientific)

Mr Greg Bodeker’s talk summarized the state of the ozone layer to-date, highlighting the various factors that have affected past changes in ozone including: the anomalously weak ozone holes in the early half of the 2000s, the large dynamically induced decrease in southern mid-latitude ozone in the mid-1980s, the hemispheric asymmetry in the response of ozone to the Mt. Pinatubo volcanic eruption, the solar cycle in tropical ozone, and the increase in northern mid-latitude ozone in the past year or two. The talk also highlighted observed decreases in tropical lower stratospheric ozone to-date, and chemistry-climate model projections of a continued decline. This highlighted the urgent need to maintain and expand ozone observations in the tropics. Measures of the severity of the Antarctic ozone hole show behaviour that is broadly consistent with changes in stratospheric halogen loading. The talk also discussed the unusually severe Arctic ozone depletion in 2011, which is consistent with a long-term cooling of the Arctic stratosphere. The causes for this long-term cooling remain unexplained. Ozone over mid-latitudes was shown to be no longer decreasing, and at some sites has shown modest increases. Chemistry-climate models are able to track these mid-latitude ozone changes. Future changes in global mean total column ozone show a return to 1980 levels between 2028 and 2040, and that, by the end of the century, global-mean total-column ozone will be above 1960 levels. This elevation above 1960 levels results from greenhouse gas-induced cooling of the upper stratosphere, which shifts the ozone equilibrium in favour of ozone. However, ozone in the tropical lower stratosphere is projected to continue to decline through the 21st century, most likely as a result of increasing strength of the Brewer-Dobson circulation. Two potential future threats to the ozone layer, viz. geoengineering by sulfate aerosol injection and increased biogenic emissions of brominated very-short-lived substances, were presented.
Links between Ozone and Climate (*Paul Newman, Co-Chair of the SAP*)

Mr Paul A. Newman presented material on behalf of the Scientific Assessment Panel (SAP). This presentation was largely based upon the findings of Chapter 4, “Stratospheric Changes and Climate,” by Mr Piers Forster and Mr David Thompson (WMO/UNEP, 2011). Ozone-depleting substances (e.g., CFCs) are powerful greenhouse gases (GHGs), but they will decrease over the course of the 21st century as a result of the Montreal Protocol. GHGs (mainly CO₂) are modifying the stratosphere by cooling the upper stratosphere, and probably accelerating the Brewer-Dobson circulation. The ozone hole has affected the Southern Hemisphere surface climate. Models demonstrate that the ozone hole is the dominant driver of the observed changes in surface winds over the Southern Hemisphere mid-to-high latitudes during Austral summer. These changes have contributed to the observed warming over the Antarctic Peninsula and cooling over the high plateau. The changes in the winds also have been linked to regional changes in precipitation, increases in sea ice around Antarctica, warming of the Southern Ocean, and a local decrease in the ocean sink of CO₂.

Influences of Ozone-Layer Depletion and Climate Change on UV Radiation: Impacts on Human Health and the Environment (*Janet Bornman and Nigel Paul, Co-Chairs, EEAP*)

The Panel considered the environmental effects of ozone depletion and their strong interactions with climate change, emphasising the expected consequences for life on earth. It was noted that the effects on human health, ecosystems and construction materials were not only dependent on stratospheric ozone levels, but also are likely to be increasingly dependent on changing land-use, climate change variables, such as cloud cover, and pollution. At low latitudes, where UV radiation is relatively high, cloud cover is likely to decrease, which may result in additional sun-burning UV radiation.

The key effects of UV-B radiation on human health include increased cataract and melanoma of the eye, decreased immunity for certain diseases, and increased skin cancer incidence. Even though skin cancer incidence is currently high in some regions, the Montreal Protocol has meant that large increases in the shorter wavelengths of UV radiation (UV-B, 280-315 nm), which can cause skin damage, have been avoided, preventing further major increases in skin cancer rates. Current research is providing more information on the interactions of climate variables, such as temperature, which can exacerbate UV radiation effects on health. At the same time, results from work on Vitamin D benefits for human health highlight the need for a balanced lifestyle to allow for sufficient Vitamin D production from UV-B radiation, while ensuring minimal risks for skin cancer and UV-related eye diseases. This lifestyle choice is complicated, since Vitamin D production by UV-B radiation depends on many factors including individual differences, age and season. There is a greater need for the research-based information to be communicated to the public.

The interactions of climate change variables and UV radiation exposure are also evident in terrestrial and aquatic ecosystems. Decreased plant productivity in areas of large ozone depletion has been observed and further changes in ecosystem structure and function due to UV radiation and climate are predicted. Rising temperature, rainfall, extreme droughts and increasing carbon dioxide levels together with UV radiation result in complex responses and feedbacks, raising concerns of significant implications for food security and food quality. The balance between increased inputs of organic matter into oceans and the breakdown of this matter by UV radiation will vary between different oceanic regions. However, in many areas, reduced concentrations of organic matter will result in greater penetration of UV-B radiation thus increasing exposure of organisms to the radiation.

Nutrient cycling through terrestrial and aquatic ecosystems and carbon dioxide loss to the atmosphere are accelerated by UV radiation and climate change. For example, the projected warmer and drier conditions will increase UV-induced breakdown of dead plant material and release of carbon and other elements. Increases in nitrogen run-off from land also contribute to ozone depletion and greenhouse gas emissions. Because of the role of oceans as a sink for carbon dioxide, increased atmospheric emissions contribute to the acidification of the water with
negative effects for skeletal formation in calcified organisms, and this enhances their vulnerability to the damaging effects of UV exposure.

Air quality of the troposphere at low and middle latitudes has implications for human health and the environment. It is predicted that the decrease in UV-B radiation in the atmosphere resulting from stratospheric ozone recovery is likely to lead to increased photochemical smog. This is because UV radiation initiates the formation of hydroxyl radicals, which act as atmospheric ‘cleaning agents’, so less UV radiation will lead to less of these radicals, and hence increased air pollution. Current research indicates that low concentrations of the breakdown products of HCFCs and HFCs (e.g., trifluoroacetic acid) do not constitute a significant risk to human health or the environment.

Research on the effects of climate change and UV radiation on construction materials such as plastics and wood indicate increased damage by UV radiation in combination with high temperatures, humidity and atmospheric pollutants. The use of a range of protective stabilisers and wood-plastic composites have increased the service lifetimes of outdoor materials, despite the degrading effects of UV radiation and rising temperatures.

The environmental effects assessment has found that while many of the effects of UV-B radiation are well-defined, the magnitude of those effects in relation to predicted future UV-B levels, and especially interactions and feedbacks with the effects of climate change, remain a substantial research challenge.

SESSION 3: INTERNATIONAL MONITORING PROGRAMMES

The WMO Global Atmosphere Watch (GAW) Programme (Liisa Jalkanen, WMO)

Ms Jalkanen started her presentation by explaining that WMO is a specialized agency of the United Nations. WMO has 189 Members, and the Organization is managed through the WMO Congress (every four years) and the Executive Council (annually). The WMO Secretariat in Geneva has a staff of 280 people. The technical departments of WMO are: Observing and Information Systems (OBS), Climate and Water (CLW), Weather and Disaster Risk Reduction Services (WDS), and Research (RES). The Research Department consists of the World Climate Research Programme (WCRP), the World Weather Research Division (WWRD), and the Atmospheric Environment Research Division (AER), which has the responsibility to coordinate the Global Atmosphere Watch (GAW) Programme. Ms Jalkanen next gave an overview of the GAW mission:

- Systematic long-term monitoring of atmospheric chemical and physical parameters globally
- Analysis and assessment
- Development of predictive capability, including the GAW Urban Research Meteorology and Environment programme (GURME) and the Sand and Dust Storm Warning System

In the GAW Programme, observations are carried out in the following areas:

- Stratospheric ozone
- Greenhouse gases (CO₂, CH₄, N₂O, CFCs)
- Reactive gases (O₃, CO, VOC, NOₓ, SO₂)
- Precipitation Chemistry
- Aerosols (chemical and physical properties and aerosol optical depth)
- Solar UV radiation

The GAW Station Information System (GAWSIS) is an on-line searchable database with comprehensive information on all GAW stations, their measurement programmes, contact persons,
and links to data in the WMO-GAW World Data Centres. It is hosted by Empa, Switzerland, and can be found here <http://gaw.empa.ch/gawsis/>. The strategy for GAW is described in the current strategic plan, valid for the 2008-2015 time period. It can be found here <ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw172-26sept07.pdf>.

There is constant focus in GAW on quality assurance and quality control (QA/QC). The GAW QA/QC system impacts all aspects of atmospheric chemistry observations, including training of station personnel, assessment of infrastructures, operations and the quality of observations at the sites, documentation of data submitted to the WDCs, and improvement of the quality and documentation of legacy data at the WDCs.

The primary objectives of the GAW QA/QC system are to ensure that the data in the WDCs are consistent, of known and adequate quality, supported by comprehensive metadata, and sufficiently complete to describe global atmospheric states with respect to spatial and temporal distribution.

WMO-GAW is contributing to the Global Climate Observing System (GCOS). WMO-GAW global atmospheric CO₂, CH₄, and N₂O monitoring networks are “comprehensive” networks, and the GAW Dobson, Brewer, and ozonesonde networks are “baseline” networks of GCOS. Similar status is being sought for aerosol networks.

There is increasing focus in GAW on the delivery of data in near-real time (NRT). A pilot project has been established to promote NRT delivery of ozone and aerosol data to allow ingestion into atmospheric models in support of improved weather forecasts, surface UV, and air quality. WMO ozone bulletins need ozone data in NRT. Large, integrated projects, such as GEMS and MACC need ozone and aerosol data in NRT for model validation. Delivery of data in NRT can help to detect problems at stations at an early stage. A second pilot project deals with harmonization and interoperability of the WMO-GAW World Data Centres with the aim that these data centres become nodes in the WMO Information System (WIS).

GAW data are used in international assessments in support of various environmental conventions. Examples are the WMO/UNEP Scientific Assessment on Ozone Depletion, the GESAMP Precipitation Assessment, the UNEP Black Carbon and Ozone Assessment, and the IGAC Megacity Assessment.

There also is focus in GAW on outreach and products that can be used by the media. Examples are the WMO Greenhouse Gas Bulletin <http://www.wmo.int/pages/prog/arep/gaw/ghg/GHGbulletin.html> and the WMO Antarctic Ozone Bulletin <http://www.wmo.int/pages/prog/arep/gaw/ozone/index.html>.

The GAW Urban Research Meteorology and Environment programme (GURME) focuses on air-quality forecasting, workshops, and training. A number of workshops have been held in recent years in many parts of the world, with focus on meteorology, chemistry, and emissions; forecasting approaches; forecasting operations, communication, and use of products; observing systems (meteorological and chemical), including the use of satellites; model training (e.g., WRF and WRF/Chem); impact prediction/analysis (health, heat wave, agriculture); and case studies.

Before closing the presentation, Ms Jalkanen gave a description of the MeteoWorld Pavilion at the Shanghai 2010 World Expo.

The Network for the Detection of Atmospheric Composition Change (NDACC) (I. Stuart McDermid, NASA/JPL)

The international Network for the Detection of Atmospheric Composition Change (NDACC) was formed to provide a consistent standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed research stations. Officially operational since 1991, the NDACC was conceived and formalized during the late 1980s in response to the need to document and understand worldwide stratospheric perturbations...
resulting from increased anthropogenic emissions into the atmosphere of long-lived halogenated source gases with strong ozone-depleting and global-warming potentials.

The initial objective of the NDACC was to monitor, from pole to pole, the temporal evolution of the stratosphere, including its protective ozone layer, and to understand the causes (i.e., natural versus anthropogenic, chemical versus dynamical) of the observed changes and their impacts on the troposphere and at the ground. This dual goal of long-term global measurement and understanding led to the implementation of a ground-based network NDACC stations equipped with a suite of remote measurement instruments, allowing the quasi-simultaneous study of a large number of chemical compounds and physical parameters.

Due to its worldwide dimension, the NDACC was recognized as a major component of the international atmospheric research effort. As such, it was endorsed by national and international scientific agencies, including the United Nations Environmental Programme (UNEP) and the International Ozone Commission (IOC) of the International Association of Meteorology and Atmospheric Physics (IAMAP). It was also recognized by the World Meteorological Organization (WMO) as a major contributor to its Global Atmosphere Watch (GAW) Programme.

While the Network remains committed to monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer (its decay, likely stabilization, and expected recovery), its priorities and measurement capabilities have broadened considerably to encompass:

- Detecting trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere
- Establishing links between climate change and atmospheric composition
- Calibrating and validating space-based measurements of the atmosphere
- Supporting process-focused scientific field campaigns
- Testing and improving theoretical models of the atmosphere

The objectives of the NDACC require high-precision measurements of a broad range of chemical species, long-lived tracers and atmospheric parameters that influence ozone and climate. To achieve this, a variety of ground-based remote sensing instruments were selected for their capability for continuous, long-term operation. Another desire of the NDACC was to have stations located to provide as much latitudinal coverage as possible.

All NDACC data more than two years old are public data <http://www.ndacc.org>. Additionally some PIs have authorized their data for early release. These data are available as soon as they are catalogued in the database.

**International Ozonesonde Activities (e.g., NOAA South Pole Programme, The Southern Hemisphere Additional Ozonesondes Network (SHADOZ)) (Russ Schnell, NOAA)**

The international ozonesonde programme is vibrant and producing high-quality data. The MATCH and SHADOZ programmes provide new, excellent data in the Arctic and the tropics, respectively. The record spring 2011 stratospheric ozone depletion was well-captured by the MATCH network. The SHADOZ programme has provided new information on the effects of the ENSO and the QBO on tropical tropospheric and stratospheric ozone. Numerous intercomparisons between the two main ozonesonde types, dual ozonesonde flights, and comparison preparation procedures has helped reduce the uncertainty between respective ozonesonde profiles. Ozonesonde profiles agree well with satellite measurements. Ozonesondes will have a long future tenure, as they are relatively cheap and reliable measurements.

**Global Climate Observing System (GCOS) Including GRUAN (Greg Bodeker, Bodeker Scientific)**

Mr Greg Bodeker’s talk began with an overview of essential climate variables (ECVs) within GCOS, and highlighted that ozone is an ECV. As such, ozone is recognized as a climate variable that is both currently feasible for global implementation and has a high impact with respect to the
UNFCCC and IPCC requirements. The presentation gave an overview of the 20 GCOS climate-monitoring principles, and the 12 GCOS guidelines for the generation of climate data records for ECVs. The talk then transitioned to a presentation of the GCOS Reference Upper Air Network (GRUAN). GRUAN is a network for ground-based reference observations for climate in the free atmosphere in the frame of GCOS. At present, 15 stations are participating in GRUAN, but this is envisaged to grow to between 30 and 40 sites across the globe when GRUAN becomes fully operational in 2013. The four stated goals of GRUAN were presented:

- To provide vertical profiles of reference measurements suitable for reliably detecting changes in global and regional climate on multi-decadal time scales. Uniformity and coherence of standard operating procedures at GRUAN stations and the resultant homogeneity of GRUAN climate data records provide a global reference for operational upper-air network stations.
- To provide a calibrated reference standard for global satellite-based measurements of atmospheric essential climate variables.
- To fully characterize the properties of the atmospheric column. This is necessary for process understanding and for radiative-transfer modelling.
- To ensure that potential gaps in satellite programmes do not invalidate the long-term climate record, as well as the operational philosophy for GRUAN.

The definition of a reference observation was presented together with a summary the significant effort that that will be invested in GRUAN to derive robust estimates of the uncertainties on all measurements.

**Integrated Global Atmospheric Chemistry Observations for Ozone and UV (IGACO-Ozone/UV)** *(Geir Braathen, WMO)*

Mr Braathen began by showing the IGACO report of 2004, which serves as a strategy for parameters to be measured in the field of atmospheric chemistry. That report was published in September 2004. He then showed an organigram putting the IGACO-Ozone/UV initiative in context among various international programmes and organisations.

The IGACO-Ozone/UV project office was established at the Finnish Meteorological Institute in August 2005, and its web site [http://www.igaco-o3.fi](http://www.igaco-o3.fi) gives an update on activities that have been carried out under the IGACO umbrella. The IGACO-Ozone/UV Implementation Plan was published in April 2009 as a report in the Global Atmosphere Watch report series (GAW # 182, [http://www.wmo.int/pages/prog/arep/gaw/documents/TD_No1465_GAW182_web.pdf](http://www.wmo.int/pages/prog/arep/gaw/documents/TD_No1465_GAW182_web.pdf)).

Several workshops have been arranged since early 2006. Information about these workshops can be found at the IGACO-Ozone/UV web site at FMI. Since 2008, a series of so-called “Ozone Theme Meetings” have been held at WMO in Geneva. The purpose of these meetings has been to bring together investigators representing different ozone-measurement techniques. At the meeting held in April 2008, it became apparent that various groups measuring ozone in the UV region use different ozone absorption cross sections. The next two Ozone Theme Meetings, in 2009 and 2010, were devoted to discussions of the possible transition from Bass and Paur (B&P, 1985) to Brion, Daumont, and Malicet (BDM, early to mid 1990s) ozone cross sections.

WMO and the International Ozone Commission of IAMAS established an ad hoc expert team in the spring of 2009, with the mandate to review the literature on ozone cross sections; assess the consequences of a change; make a recommendation whether to carry out a change; and, in case a change is recommended, give guidelines and a timeline for implementing new cross sections.

Mr Braathen showed the outcome of several studies on the consequence of replacing B&P with BDM. For the Dobson spectrophotometer, there is virtually no effect of such a change. For the Brewer spectrophotometer, such a transition will lead to an approximately 3% reduction in the
ozone column. For Umkehr measurements, stray-light issues represent a substantial problem, so the effects of a change from B&P to BDM will be relatively small, and of the same order of magnitude, but opposite in sign, to the effect of taking the temperature dependence into account. For DIAL ozone lidars, the change from B&P to BDM has only a small effect on the integrated ozone amount, since one expects an ozone increase of 1.5 in the upper stratosphere, and a decrease of the same magnitude in the lower stratosphere in the tropics. For satellites, the effect of changing from B&P to BDM depends on the instrument in question. Typically, a change from B&P to BDM will lead to an increase in total ozone of about 1-3%. More information about IGACO-Ozone/UV and the cross section study can be found at <http://www.igaco-o3.fi> and <http://igaco-o3.fmi.fi/ACSO/index.html>

The New SPARC ODS Lifetime Assessment (Stefan Reimann, Empa)

In the past, lifetimes of ozone-depleting substances (ODSs) have been calculated using different methods, such as tracer-tracer ratios in the stratosphere and 2- and 3-dimensional models. Recently, results from state-of-the-art models suggest that some of the lifetimes could be considerably longer than values used in the last UNEP/WMO ozone assessments. In fact, these values have not been thoroughly tested since the 1998 UNEP/WMO ozone assessment.

With a new initiative under the SPARC project, the lifetimes of a representative set of ODSs will be re-evaluated using extensive datasets available since 1998 in combination with the newest generation of global models. Of highest interest in this respect is the lifetime of CFC-11, as revisions in the CFC-11 lifetime would affect calculated values for ozone-depletion potentials (ODPs) and best-estimate lifetimes of many other halocarbons. Furthermore, the effect of climate change (e.g., potentially enhanced Brewer-Dobson circulation) onto the lifetimes of ODSs and their replacement compounds will be tested.

Ground-Based Networks for Measuring Ozone- and Climate-Related Trace Gases (Stefan Reimann, Empa)

Ground-based, continuous in situ measurements of ozone-depleting substances (ODSs) are performed within the two global networks of NOAA/ESRL and AGAGE. Furthermore, ground-based column measurements are included in the global NDACC network. These measurements have a long-term use to detect trends and to estimate their global sources. These numbers then can be compared to those of bottom-up inventories, which are, for example, available from UNEP on a country basis.

Continuous measurements, however, also can be used for further purposes. One of the issues which has become increasingly important is the usage of the data from regional representative stations to estimate the regional emissions of ODSs. This is especially important to check compliance with international treaties. Examples illustrate how this could be used to monitor the emissions of CFCs and other long-lived ODSs in China. Furthermore, these measurements also can be used to monitor the advanced phase-out for HCFCs. For CH₃Br, a relatively fast-reacting compound regulated under the Montreal Protocol, European emissions could be followed by continuous measurements. It could be shown that the phase-out in Europe was in compliance with critical use exemptions for CH₃Br, and virtually stopped in 2008.

For the future, continuous measurements could potentially also be used to monitor a phase-out of long-lived HFCs, which is in discussion to be placed under the umbrella of the Montreal Protocol. Furthermore, new fast-reacting unsaturated HFCs (also called hydrofluoroolefines, HFOs) have been introduced into the market. These substances have very small global-warming potential, but potential disadvantages include the usage of long-lived ODSs in the production process, and are partly degraded to environmentally stable products.

Finally, many short-lived natural halocarbons are already measured in the existing networks. These measurements can be used as background information if, for example, plans come through to install huge biofuel plants based on marine algae, which are well-known to emit these substances.
Atmospheric Concentrations of ODSs and ODS Substitutes: Scenarios and Trends
(Guus Velders, National Institute of Public Health and the Environment, RIVM)

New scenarios of ozone-depleting substances (ODSs) have been developed for the WMO/UNEP Scientific Assessment of Ozone Depletion, 2010. Mr Guus Velders presented the main results of Chapter 5 of this Assessment related to new scenarios, the reductions in emissions of ODSs already achieved, the options for policymakers to further reduce future emissions, and scenarios of hydrofluorocarbons (HFCs) as ODS substitutes. The effects of the scenarios on the future of atmospheric chlorine and bromine loading was discussed, as well as the effects on radiative forcing of climate.

The Montreal Protocol is working. It has protected the stratospheric ozone layer from much higher levels of depletion by phasing out production and consumption of ODSs. It has also made large contributions toward reducing global greenhouse-gas emissions, because many ODSs are potent greenhouse gases. In 2010, the decrease in annual ODS emissions under the Montreal Protocol is estimated to be about 10 GtCO2-eq per year, which is about five times larger than the annual emissions-reduction target for the first commitment period (2008–2012) of the Kyoto Protocol. HFCs are being used more and more to replace ODSs in refrigeration, air conditioning, and foam-blowing applications. Projections suggest that unmitigated HFC growth could result in GWP-weighted emissions up to 8.8 GtCO2-eq per year by 2050, comparable to the GWP-weighted emissions of chlorofluorocarbons (CFCs) at their peak in 1988.

Due to the ongoing success of the Montreal Protocol in reducing the production, emissions, and abundances of controlled ODSs, other compounds and activities not controlled by the Montreal Protocol are becoming relatively more important to stratospheric ozone levels. For example, the anthropogenic ODP-weighted emission of nitrous oxide is larger than that of any current halogenated ODS emission.

SESSION 4: SATELLITE RESEARCH AND MONITORING

The Stratospheric Processes and their Role in Climate Project of WCRP: The Joint SPARC/IO3C/WMO/NDACC Initiative on Past Trends in the Vertical Distribution of Ozone
(Johannes Stähelin, ETH Zürich)

High-quality ozone profile measurements are crucial to assess the status of the global ozone layer. During the 1990s, ozone profile trends deduced from different instruments (satellite instruments SAGE I and II, SBUV, and ground-based instruments) showed substantial discrepancies. A cooperative effort allowed to solve this problem (see SPARC/IOC/GAW “Assessment of Trends in the Vertical Distribution of Ozone” (Edited by N. Harris, R. Hudson, and C. Phillips) published in 1998 (SPARC Report No. 1 and WMO Ozone Research and Monitoring Project Report, No. 43).

Until about the second part of the 1990s, (profile) ozone measurements were primarily used to describe the effect of anthropogenic emissions of ozone-depleting substances (ODSs) on the ozone layer. Stratospheric concentrations of ODSs (EESC: equivalent effective stratospheric chlorine) peaked in the second part of the 1990s, and subsequently started to decrease slowly as a consequence of the successful implementation of the Montreal Protocol. However, in addition to ODSs, climate change affects the present ozone layer as well (e.g., enhancement of Dobson Brewer circulation), and, therefore, the information on ozone profile trends is also crucial for comparison with numerical simulations describing in a quantitative way the interaction between the ozone layer and climate change.

Instrumental records of satellite instruments onboard SAGE, and other important instruments onboard the UARS satellite contain critical long-term ozone-profile information, but these instruments stopped operating in 2005; whereas, different to the first assessment, many ground-based series (e.g., from NDACC and GAW) are much longer than in the earlier assessment. In order to obtain the best available ozone-profile information, a bottom-up cooperative activity on “Understanding Past Changes in the Vertical Distribution of Ozone” was
started with a workshop which took place in Geneva 25-27 January 2011. It become clear at the workshop that real opportunities for progress using satellite and ground-based data exist, and an action plan was developed; the activities will be based on existing plans (including ESA/NASA and NDACC/WMO). Overall coordination will be performed by Neil Harris, Johannes Stähelin, and Rich Stolarski. The work will be performed, particularly in the first part, by different working groups. The main activities include:

- Long-term satellite data quality (1970 - now) (Ray Wang, Johanna Tamminen)
- The last decade of satellite data (Michel van Roozendael, Lucien Froidevaux)
- Ozonesondes (Herman Smit, Sam Oltmans)
- Umkehr (Dobson and Brewer) (Tom McElroy, Irina Petropavlovsikh)
- Other ground-based measurements (lidar, FTIR, and microwave) through NDACC Working Groups (S. Godin-Beekman, T. Leblanc, J. Hannigan, M. De Mazière, N. Kämpfer, G. Neduloha)
- Approaches to producing multi-instrument ozone data (Neil Harris, Greg Bodeker)

The synthesis is planned to lead to a short assessment. A description of ground-based instrumental records and their stabilities is expected to provide important scientific papers and/or reports, but should not be integral part of the assessment. The activity is planned to provide an important input in the next WMO/UNEP Assessment.

Lessons Learned in Creating Long-Term Ozone Datasets: Recommendations for the Future
(P. K. Bhartia, NASA)

Mr P. K. Bhartia (NASA Goddard Space Flight Center) discussed lessons learned during the creation of long-term ozone datasets by him and his colleagues in the U.S. The longest satellite record of total ozone and ozone profile, produced by a series of SBUV instruments on NASA and NOAA satellites, now spans 41 years. Though the total-ozone record from SBUV is of very high quality, questions have been raised about the quality of the profile record, primarily due to disagreements between SBUV and SAGE records. Recent studies indicate that these differences may be due in large part to the poor quality of upper stratospheric temperature data, which are needed to compare SAGE and SBUV profiles. In addition, NDAAC microwave instruments show that upper stratospheric ozone may have significant local-time variation during daytime. These variations complicate the analysis of SBUV data, since the NOAA SBUV/2 measurements have been made at widely varying local times. Excellent agreement between NOAA-18 SBUV/2 and Aura/MLS instruments, which measure at the same local time and do not require temperature data for comparison, show that the SBUV instruments are capable of producing high-quality ozone profile data throughout the stratosphere, albeit at lower vertical resolution than limb-viewing sensors. However, correction of the long-term SBUV record for local time effects would require the resolution of large discrepancies in the diurnal variations of ozone reported by the NDAAC microwave instruments.

Current and Planned Ozone and Climate Observations from Space

U.S. Satellite Programmes: NASA, NOAA, and Other Agencies (Ken Jucks, NASA)

Through the collaboration between U.S. agencies NASA and NOAA, there is a long history of obtaining space-based solar backscatter UV observations of ozone columns in order to monitor the long-term changes in ozone from 1970 until the present using a combination of SBUV and TOMS instruments. Such observations are ongoing with the OMI instrument on the EOS Aura satellite. These will be continued in the future using OMPS observations on the NPOESS series. Continued observations are critical to maintain a well-characterized science data record for ozone. The OMPS on the initial NPOESS platform (NPP) also will contain a limb-scanning capability similar to that done with the NASA SAGE series, SCIAMACHI, and OSIRIS. Limb capability is not currently planned for the later NPOESS satellites.
NASA has been obtaining a very comprehensive set of observations of ozone and ozone-related instrumentation with the EOS Aura satellite using four instruments. This followed on the successful observations of the NASA UARS satellite. The EOS Aura satellite provides highly useful science-quality data sets in the stratosphere and troposphere for many key species, such as ozone, ClO, HCl, OH, HO2, HNO3, NO2, and CFCs. Depending on the instrument, some of these observations will end between 2011 and 2013. The satellite has enough fuel to last to 2015. The next phase of satellite observations from NASA will come from the NRC Decadal Survey missions. The first three that have relevance to ozone science will not provide the types of observations provided by Aura. The most relevant mission is the Global Atmospheric Chemistry Mission (GACM), which will most likely be launched after 2020, if at all. This will certainly result in a serious gap in the space-based observations of the key molecules observed by Aura. It is possible that the role of filling the data gap of these key atmospheric constituents via limb sounding could be filled by a venture-class mission, such as one containing a solar occultation FTS on an inclined orbit, along with other instruments. These small missions have yet to be approved, and it is not certain which discipline within NASA would place as a priority for these missions. Since monitoring and understanding the science of ozone abundances is a mandate to NASA, it should strongly consider such a mission, possibly in collaboration with an international partner.

**European Space Agency Activities (Jean-Christopher Lambert, IASB-BIRA)**

The European Space Agency (ESA) launched its second Earth Remote Sensing polar-orbiting platform (ERS-2) in 1995, with the Global Ozone Monitoring Experiment (GOME) onboard. Sixteen years later, the instrument is still operating, although only with partial coverage since the failure of the satellite tape recorder in June 2003. GOME measures the column and profile of ozone, as well as the column of NO2, BrO, OClO, SO2, and HCHO, cloud parameters, and aerosols. Decommissioning of the ERS-2 mission will start during mid 2011. Following the success of GOME, three improved GOME-2 instruments were delivered by ESA to the EUMETSAT, which launched the first one in October 2006 onboard MetOp-A.

Envisat was launched by ESA in 2002, carrying Global Monitoring by Occultation of Stars (GOMOS), Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), and Scanning Imaging Absorption Spectrometer for Atmospheric ChartographY (SCIAMACHY), plus other instruments observing the oceans, land, and ice. All together, the three atmospheric chemistry instruments of Envisat measure a variety of parameters from the ground up to the mesosphere, including ozone and ozone-related species, air-quality indicators, greenhouse gases, and aerosols of various types. Nine years after launch, the satellite and the instruments perform well, and ESA has developed technical solution to extend the mission by three years until 2013, based on a decrease of orbit altitude.

Within its Earth Explorer Programme (seven small satellites), ADM-AEOLUS and EARTHCARE will be launched in the coming years to improve knowledge about atmospheric winds, cloud, and aerosol information.

In the framework of Global Monitoring of Environment and Security (GMES), a major European contribution to GEOSS, ESA will deliver the space segment, consisting of five GMES Sentinel missions: SAR imaging (Sentinel 1), hyperspectral imaging (Sentinel 2), ocean monitoring (Sentinel 3), a geostationary atmospheric mission measuring at high temporal resolution the columns of ozone, NO2, BrO, SO2, HCHO, CO, CH4, aerosols, etc. (Sentinel 4 on Meteosat Third Generation, MTG, to be operated by EUMETSAT), and a low Earth orbit atmospheric mission measuring similar species (Sentinel 5 on post-EPS to be operated by EUMETSAT). To fill in the gap between Envisat and the GMES Sentinels S4 and S5, an S5 precursor mission is being developed.

During 2010, ESA launched the Climate Change Initiative (CCI) Programme, aiming at quantifying the state of the climate system to advance our knowledge of climate change, and to support the work of UNFCCC and IPCC for mitigation of and adaptation to climate change. CCI is based on the delivery of climate variables derived from satellite data sets, and includes all aspects
of their availability, including data acquisition, calibration and validation, long-term algorithm maintenance, data curation, and reprocessing, as necessary, all within the context of an internationally agreed-upon set of priorities. CCI currently includes the atmospheric Essential Climate Variables ozone, greenhouse-gases, cloud, and aerosol. More information on CCI can be found at <http://www.esa-cci.org/>.

**KNMI (Peter van Velthoven, KNMI)**

Mr Peter van Velthoven (KNMI, the Netherlands) presented the status of the Ozone Monitoring Instrument (OMI), the plans for the Tropospheric Monitoring Instrument (TROPOMI), the ozone column and profile retrieval of OMI and GOME-2, and their 30-year multi-sensor reanalysis.

Radiometrically, the OMI instrument has been extremely stable for more than six years now. The UV degradation is less than about 1%. The mission will be extended up to at least 2013. This would be required in order to obtain a sufficient number of years of overlap with newer instruments such as OMPS, for which launch is planned by the end of 2011.

In 2011, KNMI plans a consistent reprocessing of the 2004-2011 OMI DOAS total-ozone retrieval (currently version 1.1.1), which includes several improvements of the OMI DOAS total-ozone retrieval, e.g., Brion-Daumont-Malicet ozone cross sections instead of Bass–Pau ones, spectral calibration of all ground pixels, and improved treatment of sea-ice pixels. TROPOMI is planned to be launched on the ESA Sentinel-5 Precursor mission in 2014. Compared to OMI, it will have six times better spatial resolution, better signal-to noise ratio, cloud information from the oxygen A band, and CO and CH₄ observations in SWIR.

KNMI produces global-ozone profile products based on the EOS Aura OMI instrument (October 2004 through present) and the MetOp-A GOME-2 instrument (2007 through present). The OMI profiles have been evaluated mostly with MLS, but also with sondes, SAGE, and GOMOS.

A major effort has been the multi-sensor reanalysis (MSR) of total ozone performed with the TM3-DAM model (Van der A et al., 2010), based upon total ozone datasets retrieved from 14 different satellite instruments and the Dobson-Brewer surface networks (1978-2008).

**EUMETSAT and O₃MSAF (Geir Braathen, WMO, for Lars Prahm, EUMETSAT)**

Mr Geir Braathen started out by reading from the letter received from Mr Lars Prahm, Director General of EUMETSAT. In this letter, Mr Prahm states that the Ozone Secretariat, UNEP, and WMO can be assured about EUMETSAT’s continued contribution to ozone monitoring with their Polar-Orbiting Satellite Programme, i.e., the MetOp satellites. Mr Prahm also assures that EUMETSAT continues to develop pertinent research and applications, in particular in the framework of the Ozone Monitoring Satellite Application Facility (O₃MSAF).

Mr Braathen then continued by showing information available on the EUMETSAT web site. The present EUMETSAT system includes two generations of geostationary Meteosat satellites, whose global overview is complemented by the detailed observations provided by the polar-orbiting MetOp satellite, and the marine observer, Jason-2, a joint project of European and U.S. space agencies.

The prime objective of the EUMETSAT Polar System (EPS) MetOp mission series is to provide continuous, long-term data sets in support of operational meteorological and environmental forecasting and global climate monitoring. The EPS programme consists of a series of three polar-orbiting MetOp satellites, to be flown successively for more than 14 years from 2006, together with the relevant ground facilities. MetOp-2 was launched on 19 October 2006. Once in orbit, the satellites are alphabetically ordered, so the first satellite that was launched is called MetOp-A. Each satellite has a nominal lifetime in orbit of five years, with a six-month overlap
between the consecutive satellites (i.e., between MetOp-A and MetOp-B, and between MetOp-B and MetOp-C), providing more than 14 years of service.

The O3MSAF provides products both in near-real time (NRT) and in offline mode. The NRT products include total ozone, profile ozone, total NO$_2$, tropospheric NO$_2$, and clear-sky UV index. Mr Braathen showed some examples of these products, including a utility that allows global UV-index maps to be shown in Google Earth, and an animation that shows the difference in Arctic total ozone between 2010 and 20011.


**Japanese Aerospace Exploration Agency / SMILES (Hideaki Nakane, NIES)**

Mr Hideaki gave a summary of the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES). SMILES had been performing very well as expected, but unfortunately stopped its operation on 21 April 2011. SMILES made high-sensitivity measurements with lower noise than other instruments, and reasonable retrieval results are coming out. Diurnal variation of species such as ClO and BrO is one of the unique outcomes contributing to scientific issues in the middle atmosphere. Mr Hideaki noted that further comparison with reference data and validation data are needed to derive more stable and confident retrieval results.

**Summary of the Key Issues in Space-Based Measurements: Identification of Future Needs and Opportunities (Jean-Christopher Lambert, IASB-BIRA)**

Research and monitoring relevant to the Vienna Convention and the Montreal Protocol require satellite measurements of atmospheric composition for the following, nonexhaustive list of activities: monitoring of the ozone vertical column and the ozone vertical distribution, and assessment of their past changes; monitoring of key species involved in the ozone photochemistry (e.g., nitrogen oxides, HCl, ClO, BrO, and polar stratospheric clouds); monitoring of compounds regulated by the Montreal Protocol and amendments and their substitutes; monitoring of their degradation products; investigation of the coupling between atmospheric chemistry, dynamics and climate; and improvement of modelling tools like chemistry-transport models (CTMs), general circulation models (GCMs) and data assimilation systems (DAs). In the context of the 8ORM meeting, updated information on current and future satellite programmes was received from the following space agencies and institutes (by alphabetical order): the Belgian Institute for Space Aeronomy (BIRA-IASB), the Canadian Space Agency (CSA), the German Aerospace Centre (DLR), the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the Japan Aerospace Exploration Agency (JAXA), the Royal Netherlands Meteorological Institute (KNMI), the U.S. National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA), and the National Satellite Meteorological Center (NSMC) of the China Meteorological Administration (CMA).

Three series of low-orbit polar missions are taking over the long-term, global monitoring of the ozone column and of the ozone profile (at low vertical resolution), initiated with the TOMS/SBUV and GOME/SCIAMACHY/OMI series started in 1978 and 1995, respectively; three GOME-2 onboard EUMETSAT EPS MetOp (MetOp-A launched on 19 October 2006, MetOp-B to be launched in 2012); three TOU/SBUS onboard NSMC/CMA FengYun-3 (FY-3A launched on 27 May 2008); and OMPS onboard NOAA NPP/JPSS (launch foreseen in 2025). Similar instrumentation is expected to continue operation in the post-EPS timeframe with the ESA/EUMETSAT GMES Sentinel 5 (launch around 2020) and NASA’s GACM (project for 2025), with a Sentinel 5 Precursor to be launched in 2014 by ESA as a gap-filler mission. Geostationary capabilities are envisaged in 2018 with ESA/EUMETSAT GMES Sentinel 4, and after 2020 with NASA’s GEO-CAPE, as well as pseudo-geostationary capabilities from a Molniya orbit for the high latitudes (CSA concept studies). These latter missions will offer access to short-term variations at high spatial resolution, but with limited geographical coverage.
There is a serious concern about ozone-profiling capabilities at high vertical resolution after the current era of Odin (since 2001), Envisat (since 2002), SCISAT ACE (since 2003) and EOS Aura (since 2004). After the loss of ERBS SAGE-II, UARS HALOE, UARS MLS, and Meteor-3M SAGE-III in 2005, Aura HIRDLS and JEM SMILES stopped operation in 2009 and 2010, respectively, and Aura MLS lost two channels. Although its three atmospheric composition instruments perform satisfactorily, fuel reserves of Envisat will not allow operation far beyond 2013. At the time being, there are several concept studies and projects, e.g., to operate ACE-FTS on future platforms, and to develop the ALTIUS limb instrument for the lightweight PROBA platform. PREMIER, an IR and microwave limb instrument, is a candidate for ESA’s Earth Explorer 7 (around 2016). However, there is no firm programme guaranteeing appropriate continuation of solar occultation and limb profilers after OMPS on NPP (launch in 2012) and SAGE-III on ISS (launch in 2014).

Despite the clear 7ORM recommendations, a similar concern persists for observations of ozone-related species and parameters (e.g., ozone hole diagnostics and regulated compounds and substitutes), of water vapour and of temperature, performed so far by the same missions. Current plans show a necessary tendency to nadir-viewing sensors focusing instead on air quality, aerosols, greenhouse gases, and climate issues, and a serious data gap is anticipated. Space agencies are aware of the problem. Solutions for maintaining sufficient ozone-related capabilities are being studied, but there are no firm commitments yet.

Ground-based networks (Brewer and Dobson spectrophotometers, DOAS UV-visible and FTIR spectrometers, lidars, ozonesondes, millimeterwave radiometers, and ground-level in situ measurements) constitute the primary source of correlative observations for the vital validation of satellite data. Such networks should be maintained, and even extended, to cover a wider range of atmospheric states and regions of interest. The recent decrease in the number of stations reporting data to WOUDC might become a concern if this reduction of facilities continues. The deployment of needed facilities in the tropics and the Southern Hemisphere is encouraged. For some species and instruments, further effort is needed to improve the station-to-station homogeneity of networks, and to consolidate long-term data records, especially in view of data assessments addressing the links between atmospheric composition changes and climate change.

With the increasing interest for interactions between ozone and climate issues, ground-based and satellite measurement systems are facing new challenges and more stringent data-quality requirements. To guarantee interoperability of the systems, traceability of the data quality, and fitness for purpose of the data, enhanced cooperation between space agencies, within ground-based networks, and between ground-based networks, satellite teams, and generic data users, is highly desirable in the fields of instrument calibration, level-1-to-2 retrieval algorithm development, geophysical validation, data access and data policy, methods for data integration and merging (including comparisons with models and data assimilation), communication, training, and education. Traceability and consistency of quality-assurance methods and of quality information from end-to-end, that is, from the acquisition of binary data by the instrument to the delivery of four-dimensional atmospheric fields by modelling and assimilation systems, is of particular concern. Multi-mission/multi-sensor/multi-agency projects and strategies like the GEO Quality Assurance framework for Earth Observation (QA4EO), the Global Space-based Inter-Calibration System (GSICS), SPARC assessments, NASA’s GOZCARDS and ESA’s Climate Change Initiative, and topical intercomparison campaigns aiming at understanding and reducing discrepancies between different types of observations, are warmly encouraged. These new steps in the integrated exploitation of satellite and ground-based data may require the development of dedicated methods and tools, and should be supported by adequate research activities.
SESSION 5: NATIONAL AND REGIONAL REPORTS ON OZONE RESEARCH AND MONITORING

In this session, each representative of a region presented the regional and national situations with ozone monitoring and research, focusing on the key issues raised by the countries in the region based on the national reports submitted for this meeting.

Region 1: Africa (Gerrie Coetzee, South African Weather Service)

Mr Coetzee reported that, in most African countries, the Ozone Units/Offices have kept active, and are involved in the phasing out efforts of the ozone-depleting substances, even as Africa is a small industrial polluting continent. Most reports from countries report the success of their contributions adhering to the Montreal Protocol; however, components from the Vienna Convention’s ozone-related monitoring and research is visibly lacking.

Existing long-term (ozone-relevant) ground observations are extremely scarce. Time is running out, but, on the other hand, it can never be too late for establishing and increasing relevant observation programmes. Many countries of Africa are calling for these actions through collaboration. (Please see the individual reports for additional detail.)

Good ground-based observations are limited to only a few countries. All other countries express the need to take part in systematic observations – even basic programmes. One realises, that each country does not need an extensive WMO GAW Global station, but at least some in-country, with a moderate regional observation programme, would stimulate further capacity and result in advantages to the global community.

The presentations give a graphical map of current ozone- and related monitoring activities from the reports received. Recommendations are included, but many remain left and still valid from the 7ORM, to gain further momentum.

Region 2: Asia (Tetsuro Uekubo, Japan Meteorological Agency; Hideaki Nakane, National Institute for Environmental Studies, Japan)

1. Systematic observations and data analyses in Japan and Asia
   According to the National Reports (9 countries from RA II):
   • Ozone and UV are being monitored operationally
   • Some countries that operate M-124 ozonometers need financial or technical support to replace the instruments
   • JMA has been operating the QA/SAC and the RDCC under the WMO’s GAW Programme
   • Long-term measurements of ozone and improvements in analyses allowed long-term trends and its height resolved changes

2. Research topics in Japan and Asian region
   Stratospheric ozone and related climate changes in Asian region are characterized by large amounts and trends of emissions of HCFCs and HFCs, latitudinal differences in the stratosphere-troposphere exchange and Brewer-Dobson circulation, and latitudinal differences in the total ozone distribution. In this connection, various observational and modelling studies have been carried out:
   • Emission maps of HCFCs and HFCs were obtained by an inverse modelling method using the high-frequency measurements network data of HCFCs and HFCs in Japan, China, and Korea.
   • Measurements of tracer species in the stratosphere over Sanriku, Japan contributed to determining the age of stratospheric air, in which the necessity of taking into account gravitational separation and methane oxidation was demonstrated.
• Improvement in temperature bias in CCSR/NIES CCM was successfully carried out, and it resulted in improvement in water vapour modelling in the tropical lower stratosphere.

3. Recommendations to 8ORM

• Operational monitoring of ozone and UV with the QA/SAC and the RDCC under the GAW programme of WMO is essential, and should be continued.

• Systematic observations and data analyses to evaluate the changing state of the ozone layer, including detection of ozone recovery and change in age of air, etc., should be continued in cooperation with international monitoring networks such as the WMO/GAW programme, NDACC, AGAGE, and SHADOZ.

• A systematic calibration programme and well-coordinated monitoring network should be established to detect variations and long-term trends in ground-level UV radiation.

• Studies on chemical and dynamic processes, especially on Brewer-Dobson circulation, cross-tropopause transport, and the ozone budget near the tropopause region also should be continued.

• Further improvement of chemistry climate models (CCMs) is needed to allow more precise prediction of future changes in the ozone layer.

• Reevaluation of chemical-reaction data, including photochemical data for stratospheric modelling, is urgently required to resolve discrepancies between observations and model calculations.

• Studies on the effects of increased UV radiation on human health, ecosystems, air quality, and biogeochemical cycles are strongly recommended, especially the effects of increased UV radiation under rising temperature conditions.

Region 3: South America (Claudio Casiccia Salgado, Universidad de Magallanes)

Mr Casiccia Salgado presented a summary of accomplishments from the recommendations from 7ORM:

• There is a strong political decision to sustain ozone and UV investigations. Some projects are supported directly with national funds. Other institutions as such as universities and research institutions also participate in these research fields.

• Collaboration with international projects was also strengthened with both logistic and scientific support.

• The Regional Calibration Center at the Argentine National Weather Service accomplished the scheduled tasks with the 2010 intercomparisons of South-American Dobson instruments, UV-biometers, and surface-ozone instruments.

• New sophisticated equipment has been incorporated by several Argentine and Chilean institutions: a lidar in Rio Gallegos, developed and constructed in Argentina; and an ozonesonde (LMG6), in Punta Arenas, Chile.

• The UV index is forecasted and broadcast daily along the three countries.

• The prevention of sunburn-related skin diseases and skin cancer for the population has been taken as a subject of Public Health, with official annual diffusion campaigns.

• Over 40 papers in top-ranked journals have been published by Argentine, Chilean, and Colombian research groups on ozone and UV and its effects between 2008 and 2011.

Mr Casiccia Salgado then presented the Region 3 recommendations to 8ORM:

• In future years, Antarctica and the Southern Cone of South America must continue to be considered the most critical region in the world related to ozone depletion and its consequences.
• South American countries are in a privileged geographical situation to support ozone and UV monitoring.

• The Antarctic ozone hole must be monitored continuously by all means for many years. Permanent ground-based and satellite-based instruments are an essential component for this task.

• The current monitoring networks must be maintained in qualified operation. Regular calibration campaigns of ozone- and UV-measuring instruments are essential in South America.

• The ozone layer is both acting in response to current climate variability and change, as well as affecting climate over the Southern Hemisphere. Studies and monitoring of coupled climate change and ozone variability must be emphasized in South America and in the Antarctic Continent.

**Region 4: North America, Central America and the Caribbean**

**USA (Kenneth W. Jucks, NASA; Russ Schnell, NOAA)**

The CFCs controlled under the Montreal Protocol are decreasing, whereas the replacement HFCs are increasing with apparent large-scale production in developing countries. The total equivalent chlorine in the atmosphere is decreasing, with a return to pre-ozone-hole levels in the Antarctic possibly in the 2070 time frame. Pole-to-pole aircraft profiles show that CFC-11 is well-mixed pole-to-pole, whereas HCFC-22 is Northern Hemisphere-centric. Antarctic UV measurements show that, when depleted ozone is over a station such as Palmer, the UV index is almost as high as the maximum ever measured in Colorado. N₂O will be the predominate contributor to the atmospheric ODP in the 21st century. There is a possibility that tetrafluoropropene (CF₃CF=CH₂), a potential substitute for HFC-134a, will produce trifluoroacetic acid (TFA) in clouds. TFA is a toxic substance in water.

The U.S. agencies place high attention to focused ground-based and airborne campaigns designed to address critical questions that are highlighted in past ORM reports and the Ozone SAP reports. These campaigns serve to improve our understanding of key physical and chemical processes that control the levels of ozone. Some of these programmes are designed to help understand the contributions of short-lived halocarbons in the atmosphere, as well as the transport processes that control the levels of water vapour in the stratosphere and tropical upper troposphere. These campaigns are designed to coordinate strongly with the various NASA and international satellite observations, both for satellite validation and to enhance the observations of both the satellites and the data from the campaigns.

**Canada (Bruce McArthur, Environment Canada)**

Canada operates an eight-station Brewer Ozone Spectrophotometer Network and a ten-station ozonesonde network. The Brewer observations are transmitted in near-real-time to the Canadian Meteorological Centre for use in the UV-index forecast. The ozonesonde network has historically been used as a means of monitoring the ozone layer, but more recently interest has increased to operate this network in near-real-time also. The forecasting of the UV index and the overall health of Canadians has led to significant efforts in providing ozone and UV information on the web, and in developing new algorithms for the estimation of erythemal UV and vitamin D uptake for the health community.

The Canadian Space Agency has worked collaboratively with the atmospheric science community in both government and academia to develop a significant role in the space-based observation of stratospheric ozone and related chemical constituents. OSIRIS, onboard Odin, and the Canadian ACE satellite are providing valuable data on the overall health of the ozone layer. The success of these instruments has aided the development of Eureka, NU, as a satellite validation centre, and has encouraged the analyses of multiple datasets beyond these instruments.
Canada has supported ozone and UV observations by hosting the WMO World Ozone and UV Data Centre (WOUDC) since its inception. It will turn 50 years old in 2012. Canadian scientists sit on both the GAW SAG-UV and SAG-Ozone, and have been involved as authors and coordinating authors of the UNEP/WMO Ozone Assessments. In further support of the WMO ozone programme, Canada maintains the World Brewer Ozone Triad, frequently leads the Biennial Brewer Users Group meetings, and provides $30,000 U.S. annually to the WMO Brewer Trust Fund to support technical training and Brewer calibration activities in developing economies.

Central America, Mexico and the Caribbean (Geir Braathen, WMO, for Juan Carlos Peláez Chávez, Instituto de Meteorología)

The only countries that reported on ozone-related activities were Mexico and Cuba. In Mexico, there are measurements of total ozone at the Solar Radiation Observatory of the Universidad Nacional Autónoma de México (UNAM), and of UV radiation at eight stations in Mexico City carried out by Red Automática de Monitoreo Ambiental (RAMA) under metrological control of the Solar Radiation Observatory, UNAM.

In Cuba, there are measurements of total ozone and UV radiation in Havana. From 1984 to 2000, the total-ozone observations were done with a filter ozonometer. Since 2000, the observations have been carried out with Dobson instrument # 67. This instrument was used in the 2003, 2006, and 2010 Dobson intercomparisons in Buenos Aires, Argentina.

Total-ozone data from Mexico and Cuba have been reported to the WMO-GAW World Ozone and UV radiation Data Centre in Toronto. Data from Mexico City (STN 192) have been reported up to April 2000. Data from Havana (STN 311) are up-to-date as of March 2011.

In Mexico plans are to continue the total-ozone measurements, and there is a proposal to extend the UV-radiation measurements to the whole national territory, taking advantage of existing meteorological stations. In Cuba, there are plans to establish a network covering the whole country with nine stations for UV-A and UV-B observations. These instruments will be collocated with existing instruments for global solar radiation at meteorological stations. Cuba is asking for international collaboration to allow for the replacement of thermopile-based devices with instruments of higher quality and known performance.

Skin cancer is the fastest growing type of cancer in Cuba. In addition, the greatest number of medical consultations given to visiting tourists is related to excessive exposure to solar radiation. Increased knowledge of solar UV radiation would improve the health of both the local population and of visiting foreigners, mostly from Canada and Europe.

The “SPARC Report on the Evaluation of Chemistry Climate Models”, (Final Review Meeting in Toledo, Spain, November 9-11, 2009) states that models consistently predict a partial recovery of tropical ozone followed by a decrease in the second half of the 21st century. The long-term decrease will be found mainly in the lower stratosphere. It is important that UV-monitoring instruments be calibrated every two years or better. Based on the points above, this is seen as necessary to establish a Regional Reference and Calibration Laboratory for UV instruments for WMO Regions III and IV.

It is proposed that funds through the Vienna Convention Trust Fund for Research and Systematic Observations, UNEP’s Compliance Assistance Programme (CAP), or other funding sources be utilized for the participation of personnel from Central America at training courses, such as the excellent Dobson Data Quality Workshop held in Hradec Králové in February 2011. It is also proposed that developing countries receive international funds for participation at workshops and symposia.

Region 5: South West Pacific (Janet Bornman, University of Waikato)

Ms Bornman gave an overview of ozone-related activities in Region 5, South West Pacific, based on national reports from Australia, Cook Islands, and Samoa. Ms Bornman also collected information from New Zealand. In Australia, ozone observations are carried out by the Bureau of
Meteorology. Dobson total-ozone observations go back to 1957, and are carried out at Brisbane, Macquarie Island, and Melbourne. Ozonesondes are launched from Macquarie Island, Melbourne, and Davis Station in Antarctica. Observations also are carried out by the University of Tasmania, Queensland University of Technology, and University of Wollongong (part of the Network for Detection of Atmospheric Composition Change, NDACC). Measurements of ozone-depleting gases take place at Cape Grim, Tasmania, and in Aspendale, Victoria. Australia recommends that data-archival facilities and instrument calibrations and intercomparisons be continued and further developed, e.g., through WMO and NDACC.

In New Zealand, ozone- and UV-related research takes place at the National Institute of Water and Atmospheric Research (NIWA) and at Bodeker Scientific. Many relevant observations are taken at Lauder, near Alexandra. This station is a global station in WMO’s Global Atmosphere Watch Programme, and also is part of the NDACC. Ozone, as well as a number of parameters related to ozone depletion, are measured with a variety of techniques such as Dobson spectrophotometry, UV-visible spectroscopy, infrared spectroscopy, microwave radiometry, electrochemical ozonesondes flown on balloons, ozone and aerosol lidars, and frostpoint hygrometers. Solar UV radiation is measured at a number of sites. There also are measurement activities outside of New Zealand, such as in Antarctica and Pacific Islands. Specific work in support of environmental conventions also is taking place. New Zealand asks for: 1) better quantification of how management of banks of ozone-depleting substances may affect the recovery of the global ozone layer, 2) in-depth assessment of when and where the ozone layer is likely to recover, 3) effects of stratospheric changes on surface climate change, and 4) more information on the positive and negative effects of UV exposure.

Cook Islands consist of 15 small islands. There is no existing ozone research in Cook Islands, but there is a GCOS Upper Air Network (GUAN) station where radiosondes are launched to measure temperature, humidity, and atmospheric pressure. This station could be equipped to launch ozonesondes, and the representative of Cook Islands asks whether international support would be available for this purpose.

The national report from Samoa deals mainly with the phase-out of ozone-depleting gases, since there are no ozone observations taking place on its territory.

Antarctica

Antarctica (Jonathan D. Shanklin, British Antarctic Survey)

The Antarctic observing network is much less dense than, for example, that of Europe. Individual stations carry out a multitude of observations including ozone, radiosonde, and surface climate. The length of record is critical for showing variation, with the Antarctic Peninsula warming having started long before the onset of the ozone hole, and is likely to include a component of natural regional change. Stations use varied techniques including Dobson, Brewer, SAOZ, and ozonesondes for ozone measurements. A few stations are now providing near-real time observations on the GTS, as well as data for the WMO ozone bulletins.

The original discovery of the ozone hole was, in part, a matter of luck, with Halley being ideally located to make the discovery and having a long, continuous Dobson data record. Data from the station do not yet provide good evidence for recovery of the ozone hole. The 2010 ozone hole was unusual compared to the majority of those seen since the discovery. History has set the limit for an ozone hole at 220 DU, so, although major ozone depletion in the Arctic took place in 2011, it did not qualify as an ozone hole.

Antarctic ice-core data often help to put recent data into context. CO₂ values today are rising much more rapidly than at any time in the last 150,000 years, and are at a higher level than at any time in the last 750,000 years. Changing CO₂, ozone, ODS, volcanic aerosol, and atmospheric dynamics all play a part in observed ozone amounts; however, while it is reasonable
to conclude that chemical ozone depletion over Antarctica is decreasing, we cannot yet say that the ozone hole is recovering.

**Czech Republic Activities in Antarctica (Michal Janouch, CHMI)**

In February 2010, the Solar and Ozone Observatory of the Czech Hydrometeorological Institute, in cooperation with the Argentine Antarctic Institute, installed Brewer ozone spectrophotometer (double MKIII) # 199, a fully automated instrument, at the Marambio Base. The instrument operates in the remote mode via satellite at the Marambio Station. This activity is part of the VAV project "The Contribution of the Czech Republic to the Detection of the State of the Ozone Layer and Solar UV Radiation in Antarctica," which is supported by the Czech Government as a cooperation between CHMI and the Argentine Antarctic Institute. The measurements performed with the Brewer instrument are deposited in the WOUDC, platform No. 233. More information can be found at <http://www.antarktida-ozon.cz>.

The aim of the present work is to improve scientific knowledge for global assessments on ozone depletion and climate change for the Montreal Protocol and the Vienna Convention, and to gain a better understanding of processes in the upper troposphere and lower stratosphere through modelling and data analysis. Studies of the long-term variability in extratropical large-scale transport are also being performed to improve long-term predictions of mid- and high-latitude ozone and UV radiation.

**Region 6: Europe**

**European Union (Jose M. Jimenez Mingo and Claus Brüning, European Commission)**

Collaborative research at the European level is mainly implemented through the Framework Programme for Research and Technological Development (FP) of the European Commission. Research projects funded within the previous programme (FP6-2003/2006) are in their final phase, and most of the expected results have been achieved. The four European Commission-supported projects in this area (SCOUT-O3, QUANTIFY, GEOMON, and ATTICA) had an overall budget of 32M€. The emphasis of SCOUT-O3 was on ozone-climate interaction, QUANTIFY focused on the impact of emissions from the transport sector on climate change and ozone depletion, and GEOMON supported atmospheric observations. ATTICA was designed as a support action to assess the impact of the transport sector (aviation, land traffic, shipping) on climate change and ozone depletion.

Stratospheric research remains a priority in the ongoing programme (FP7-2007/2013). Research under the Environment theme supports the implementation of relevant international environmental commitments, protocols, and initiatives, such as the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto and Montreal Protocols. Research is an essential component in the increasing efforts of the European Commission to combat climate change and stratospheric ozone depletion. Activities include health risks associated with changing UV radiation levels.

Two major research projects (RECONCILE and SHIVA) are presently funded under FP7, focussing on climate-chemistry interactions in the stratosphere related to ozone depletion. In addition, the ICEPURE project focuses on the quantification of changing surface-UV radiation levels and its impact on human health, and the MACC project combines state-of-the-art atmospheric modelling with Earth observation data. A new project (NORS) is currently in preparation to enhance GMES applications in the atmosphere.

These projects comprise the backbone of the European Commission’s stratospheric research, thereby maintaining a critical mass essential for future contributions to international ozone and UV assessments. They also provide effective coordination mechanisms for the joint use of European research facilities to promote integrated interdisciplinary research, thereby
addressing the scientific problems in a holistic way. As a result, European research has contributed significantly to the international Scientific Assessment of Ozone Depletion, 2010.

The complexity of the atmospheric processes, the scale of the scientific problems, and the potential devastating impact on humans and the ecosystems caused by climate change, stratospheric ozone depletion, and changing UV radiation require real interdisciplinary research collaboration. Research will be conducted in the coming years focusing on the climate-stratospheric interaction. Open scientific questions to be considered in coming calls include atmospheric chemistry and climate change interactions; links between climate change, atmospheric pollution, and UV-radiation and its impacts on ecosystems; effects of climate change on the stratosphere; lower-middle atmosphere interactions; and substitute gases with reduced global warming potential

Belgium (Jean-Christopher Lambert, IASB-BIRA)

Mr Lambert highlighted some of the Belgian monitoring and research activities related to the stratospheric ozone layer and its links with climate. Activities involve the Belgian Federal Public Planning Service Science Policy (BELSPO), the Belgian Institute for Space Aeronomy (BIRA-IASB), the Royal Meteorological Institute of Belgium (RMIB), University of Brussels (ULB), and University of Liège (ULg).

The ground-based monitoring activities include the long-term monitoring of ozone; ODSs and substitutes; source gases like CH₄ and N₂O; nitrogen compounds; the budgets of chlorine, fluorine, and bromine compounds; and ground-level UV-B radiation. Ground-based measurements are taken by a suite of complementary instrumentation including Brewer and Dobson UV spectrophotometers, balloonborne electrochemical ozonesondes, DOAS UV-visible and FTIR spectrometers, and spectral UV instruments. They are operated at a variety of Network for the Detection of Atmospheric Composition Change (NDACC) and WMO's Global Atmosphere Watch (GAW) sites: Uccle (Belgium), Harestua (Norway), the Jungfraujoch (Swiss Alps), Haute Provence Observatory (France), La Réunion Island, and the new Belgian station Princess Elisabeth in Antarctica. Many data records cover several decades. For example, the ozonesonde programme in Uccle started in 1969; the Dobson and Brewer measurements started in 1971 and 1983, respectively; and the FTIR data record at the Jungfraujoch provides trends of inorganic fluorine and chlorine with respect to levels in the early 1980s.

The remote sensing of ozone and related species from satellite sensors continues through various contributions to international satellite programmes such as ERS-2 GOME (operating since 1995); Envisat (GOMOS, MIPAS, and SCIAMACHY, operating since 2002); SCISAT ACE-FTS (since 2003); EOS-Aura OMI (since 2004); and MetOp-A (GOME-2 and IASI, since 2006). Plans for participation in future missions like MetOp-B (GOME-2 and IASI, launch in 2012); Sentinel 5 Precursor (2014); and Sentinels 4 (2018) and 5 (2020) is ongoing. Belgium is active in mission advisory and planning, instrumental developments, calibration, development of retrieval algorithms, generation of level-2 geophysical data products, support to implementation of scientific prototypes in operational data-processing chains, geophysical validation and QA monitoring, generation of level-3/4 data products through chemical data assimilation, and reevaluation of long-term data records. International cooperation is fostered through bodies and initiatives like CEOS, ESA Quality Working Groups, EUMETSAT O₃M-SAF, GAW, GMES, IO₃C, NDACC, and SPARC.

Research activities include trend assessments of the ozone column and vertical distribution, of ODSs; of stratospheric chlorine, fluorine, and bromine budgets; of other ozone-related substances like NO₂; of parameters like stratospheric aerosols; and of UV-B radiation; the study and monitoring of ozone loss in the Arctic; the study of sources, sinks, and transport of trace gases, on the global scale using satellite data and on the regional scale (polar, middle latitudes, tropics) using ground-based data; and studies to better understand and use the information offered by remotely sensed atmospheric data, e.g., the development of multi-dimensional observation operators used in satellite validation and data assimilation. Apart from analysis and interpretation of observational data, various models have been developed and used, including chemical transport
modelling of the troposphere and stratosphere, calculation of atmospheric trajectories and dispersion, long-term reanalysis of observations through a 4D variational chemical assimilation system, and prediction of chemical weather. In particular, the BASCOE 4D-var assimilation system is a component of EU's GMES Atmospheric Core Service.

**Czech Republic** (Karel Vanicek, CHMI)

Systematic monitoring of atmospheric ozone and UV solar radiation is performed in the Czech Republic (CR) by the CHMI within the frame of the GAW Programme. Routine daily observations of total ozone have been performed with the Dobson and Brewer spectrophotometers operated at the Solar and Ozone Observatory (SOO) in Hradec Králové since 1961. Since 1978, ozone profiles have been measured at the Upper Air Department of the CHMI in Prague with balloonborne ozonesondes. Vertical distribution of ozone is also measured by the Umkehr inverse technique with the Brewer spectrophotometers at the SOO.

The research activities are currently focused mainly on the creation of a 50-year Dobson-to-Brewer assimilated total-ozone data series from 1961 to 2010, the evaluation of the long-term changes of the ozone layer by the assimilated data set, and the investigation of the relation between the above changes and stratospheric dynamical processes. These activities are performed under the project “Long-Term Changes of the Ozone Layer over the Czech Republic,” which is supported by the Czech Grant Agency.

In the area of Capacity Building under GAW, CHMI recently contributed to organization of the “UNEP/WMO Dobson Data Quality Workshop,” <see www.dobsonworkshop.cz>, and to the relocation of two Dobson instruments from Norway to Uganda, and from Belgium to the Ukraine. These were the international actions realized as a contribution of the SOO to the activities of the RDCC –Europe.

**Germany** (Wolfgang Steinbrecht, Deutscher Wetterdienst)

Ozone research in Germany is a collective effort by about 20 institutions. Government agencies are generally more oriented towards long-term observations. Deutscher Wetterdienst, e.g., is doing ground-based monitoring in Germany, and Alfred-Wegener Institute performs ground-based monitoring at Arctic and Antarctic stations. The Bundesamt for Strahlenschutz operates the German UV-network. Deutsche Luft- und Raumfahrt (DLR) is processing and archiving European satellite data for the ozone layer. Several institutes, including University of Bremen, Karlsruhe Institute for Technology (KIT), and Forschungszentrum Jülich (FZJ), are heavily involved in satellite-instrument conception and advanced data analysis. Model simulations, e.g., for the Chemistry Climate Model VALidation (CCMVAL) activity, are undertaken at DLR, Max-Plank Institutes (MPIs), KIT, and FZJ. Several institutes, e.g., KIT and the Universities of Bremen, Frankfurt, and Heidelberg, are providing a host of advanced ozone and trace-gas measurements like FTIR, balloon samplers, etc. Activities focus on the Arctic and on long-term changes. Germany is well-integrated in international programmes like WMO-GAW and NDACC. It contributes actively, e.g., by hosting (together with Czechia) the WMO RA VI Dobson Calibration Center, by FZJ hosting the QA/QC Center for Ozonesondes, by AWI coordinating the MATCH campaigns for the quantification polar ozone losses, and by the University of Hannover taking an active role in international activities for UV monitoring.

**Nordic Countries** (Niels Larsen, Danish Meteorological Institute)

Mr Larsen presented ozone and UV-monitoring activities in the Nordic countries (Sweden, Norway, Finland, and Denmark, including Greenland). All countries perform ground-based Dobson, SAOZ, and/or Brewer total-ozone measurements, and report data to international databases (e.g., WOUDC, NDACC). Regular ozone soundings are performed from Greenland and Finland, as part of the MATCH campaign. Finland also maintains a programme for Antarctic ozone soundings. Ozone-profiling measurements by lidar are performed at Alomar in Norway. Regular UV measurements are performed in all countries, and Finland hosts the European UV spectral radiation database. Finland and Denmark participate in the EUMETSAT Ozone Satellite Application Facility (O3M-SAF). Research topics include ozone and UV analyses, climate and
chemistry transport modelling, data assimilation of satellite measurements, and modelling of personal UV exposure. Given the two-way interactions between climate change and the state of the ozone layer, the Nordic Ozone Research Managers express the need for continued monitoring of the recovery of the ozone layer.

**Poland** *(Bogumil Kois, IMWM)*

In Poland, the Institute of Meteorology and Water Management (IMWM) conducts ozonesonde monitoring. The ozone soundings have been performed at the Legionowo (52.40°N, 20.97°N) upper-air station since 1979.

Until May 1993, the OSE (BM type) ozone sensor with the METEORIT/MARZ radio sounding system was used. Since then, the ECC sensor and DigiCora/RS80/92 radio sounding system of Vaisala have been used. The ozone soundings are launched regularly on each Wednesday. Since 1995, additional ozone soundings have been performed for the purpose of the MATCH campaign (statistical evaluation of ozone chemical destruction in the polar vortex). Episodes of serious ozone loss have been observed during the displacements of the cold polar vortex in late winter / early spring.

On 16 April 2011, 12 UTC, when the polar vortex was moving across Poland, record-low total ozone (266D) was calculated from the ozone profile. In late April, ozone-depleted air masses originating from the polar vortex continued to move over Europe.

**Switzerland** *(René Stübi, MeteoSwiss)*

In this presentation, Mr Stübi gave an overview of the overall activities related to monitoring, calibration, international activities, and the Nairobi station support. The time series of the Umkehr, sondes, and microwave ozone profiles were presented, as well as the updated trends study.

The constant effort to improve the quality of the existing records was illustrated by two examples regarding 1) the mismatch of the Brewer and Dobson at the beginning of the 1990s, and 2) the mismatch of the ozonesonde record and the Jungfraujoch ozone data during the same time period. First, alternative reprocessings of the Brewer 040 record, either according to the standard network procedure (adjusted to the travelling reference B07) or simply based on the intrinsic instrument stability, were compared to the independent Dobson series. The standard calibration procedure series presents a larger difference compared to Dobson, and this raises the question of the appropriateness of the procedure. In the second example, the ozonesonde record was compared to the ground-based Jungfraujoch coincident data. An analysis of the 1988-2006 time series shows that the general behaviour of the ozone in the middle troposphere in the early 1990s is still not clear.

**Turkey** *(Yilmaz Acar, State Meteorological Service)*

The Turkish State Meteorological Service (TSMS) is responsible for observing and promoting research activities on measurements of ozone and UV radiation. Two methods are commonly used for ozone measurements in Ankara – the ECC ozonesonde and the Brewer spectrophotometer. Total ozone measurements have been made using the Brewer since November 2006. TSMS has used balloonborne ozonesondes since 1994 at the Ankara station. The Ankara station is a component of the WMO GAW Programme. Brewer and ozonesonde data are sent to the World Ozone and UV Radiation Data Centre. They are archived and published with the station ID 348 in Toronto.

Calibration of the Brewer #188 MKIII is performed biennially. The first Brewer calibration was carried out by International Ozone Services on 07–12 October 2008, and it was financially supported by the WMO. The second Brewer calibration was carried out by Kipp and Zonen on 22–29 September 2010.

UV radiation measurements are made at 11 different stations. UV radiometers are used to measure UV radiation at 10 stations in narrow band, and at 1 station in broadband, with various
instruments. Spectral UVB measurements using the Brewer #188 MKIII have been made 2006 in Ankara.

The TSMS and DWD global-model outputs for daily ozone and UV-index forecasts are published the TSMS website.

**United Kingdom (William Cook, Defra)**

Monitoring of column ozone is undertaken at four sites across the UK, using Brewer spectrophotometers at two sites (Northern and Southern England), a Dobson spectrophotometer at one site (Northern Scotland), and a SAOZ spectrometer (Wales) at the final site. Quality-controlled results from the sites in England and Scotland are reported to the WOUDC, and data from the site in Wales are reported to the NDACC network. The British Antarctic Survey continues column-ozone measurements at two sites, Halley (a Dobson spectrophotometer) and Rothera (a SAOZ spectrometer). A radiosonde programme also operates at both Halley and Rothera. Spectral UV measurements are made at two sites in England, with quality-controlled data reported to the WOUDC. Broadband UV measurements are made at seven sites across the UK, and these contribute to the global dataset.

ODS concentrations are measured at the AGAGE site at Mace Head, Ireland, and will soon be measured at a second site in the UK to allow increased accuracy in modelling UK emissions.

Research in the UK includes: developing the whole atmosphere chemistry model UKCA and its inclusion in a full Earth-system model; application of the ozone-data assimilation scheme to examine phenomena such as low-ozone events in the southern summer stratosphere; checking layers of the Earth’s atmosphere for halogenated ozone-depleting and greenhouse gases; Southern Hemisphere climate change in an era of ozone recovery; the SOLCLI consortium (influences of solar variability on atmospheric composition and climate); and the impact of the mesosphere on stratospheric ozone and climate.

Future research priorities include maintenance of long-term monitoring programmes, further improvements to modelling emissions of ODSs using data from AGAGE sites, and developing a greater understanding of the mechanisms for likely impacts of future climate change on ozone and vice versa.

**SESSION 6: DISCUSSION OF RECOMMENDATIONS**

Recommendations arising from the meeting were discussed under four topics. For each topic, selected resource persons made a short introductory presentation for each topic, followed by discussion. Rapporteurs identified for each topic led the drafting of the recommendations on the basis of the discussions. The national reports formed an important basis for the discussions and the recommendations. The resource persons and rapporteurs were as follows:

**Research Needs:** Introduction by Paul Newman and A. R. Ravishankara, Co-Chairs, SAP; Rapporteurs – Ken Jucks, USA, and John Pyle, Co-Chair, SAP

**Systematic Observations:** Introduction by P. K. Bhartia, USA, and Stefan Reimann, Switzerland; Rapporteurs – Jean-Christopher Lambert, Belgium, and Niels Larsen, Denmark

**Data Archiving:** Introduction by Karel Vanicek, Czech Republic; Rapporteurs – Greg Bodeker, New Zealand, and Johannes Stähelin, Switzerland

**Capacity Building:** Introduction by Ayité-Lô Ajavon, Co-Chair, SAP, and Stuart McDermid, USA; Rapporteurs – Geir Braathen, WMO, and Bruce McArthur, Canada
Recommendations

Research Needs

There are many questions that remain on the expected ozone recovery from the influence of ozone-depleting substances (ODSs). In particular, how do ozone depletion and climate change interact? Recent research reveals that ozone depletion has affected tropospheric climate. In addition, it is becoming clearer that greenhouse gases (GHGs) are altering the stratosphere— the cooling of the upper stratosphere by GHGs is expected to exceed 5K between the years 2000 and 2100, necessitating long-term observations of both ozone and temperature in the stratosphere. The ability to predict future ozone behaviour requires further improvements in the quantification of the roles of chemical and dynamical processes responsible for ozone production, loss, transport, and distribution, and their respective uncertainties. The development of realistic scenarios of the future abundances of anthropogenic and biogenic trace gases in the stratosphere and troposphere is required, particularly with respect to a changing climate. Simulations from the 2010 Scientific Assessment of Ozone Depletion indicate future increases of UV levels in the tropics, but decreases at mid- and high latitudes due to ozone changes. The 2010 report of the Environmental Effects Assessment Panel (EEAP) concluded that research on the impacts of increases in UV radiation resulting from stratospheric ozone depletion has substantially advanced the understanding of the processes by which changes in UV radiation affect a range of organisms and processes. For humans, this poses the risk of more skin cancer in the tropics, but also slightly increases the risk of UV doses that are too low for the production of sufficient Vitamin D at mid- high latitudes. Recent research has highlighted the interactions between the diverse effects of changing UV radiation due to ozone depletion and the effects of climate change. These interactions may lead to feedbacks into climate change (e.g., modification of carbon cycling in terrestrial and aquatic ecosystems), but this remains poorly defined.

A number of general issues are emerging. Coupled chemistry-climate models (CCMs) are more mature, but it is clear that more effort must be devoted to model improvement and validation. Earth System Models that include crude stratospheric ozone parameterizations are being developed, and these models should begin to incorporate improved CCM treatments of the solar forcing, dynamics, radiation, and photochemistry of ozone. In addition, long-term measurements represent an extremely important resource, and the continued and increased exploitation of these data for scientific process studies is strongly recommended. The dramatic contrast between the unusually large 2010 Northern Hemisphere ozone columns and the extreme 2011 Arctic ozone depletion has highlighted the close connection between ozone, meteorology, and climate. Finally, there is still a need for fundamental laboratory studies to estimate photochemical reaction rates, and to refine and update older measurements. In particular, photochemical parameters to improve our understanding of long-lived species and new industrial compounds in the atmosphere are very important.

Chemistry Climate

- Provide support for studies that quantify the chemical, radiative, and dynamical factors contributing to ozone-layer evolution in a changing atmosphere (i.e., ozone recovery from the effects of ODSs and ozone response to climate change), including studies of the unintended consequences of climate-change mitigation and adaptation strategies. There have been important advances since the 7th ORM in recognizing the close two-way coupling between ozone and climate (see WMO Synthesis and Assessment Report No. 52), but an evolving research effort in specific attribution studies is required. For example, while we are able to diagnose the large Arctic ozone loss of 2011, precise attribution is more controversial. Because of what we have learned to date, particular studies to advance our understanding would include:
  - Continued studies to improve our evolving understanding of the effects of climate change on ozone production, loss, transport, and distribution, as well as possible feedbacks.
Continued studies to improve our evolving understanding of the coupling and exchange between the upper troposphere and lower stratosphere, particularly as it applies to water vapour (including its long-term changes), short-lived halogen species, and ozone, and leading to an improved understanding of stratospheric temperatures, the stratospheric overturning circulation, and their connection to climate change.

Studies of aerosol and polar stratospheric cloud microphysics, and of cirrus in the tropical transition layer.

- Support studies to investigate the role and impact of changes in stratospheric ozone and ODSs on surface climate. Also, support studies of the influence of these stratospheric changes on tropospheric processes that are influenced by stratosphere-troposphere exchange and UV penetration.
- Support studies to improve our understanding of changes in aerosols relative to changes in volcanic activity, air pollution sources (sulphates), and proposed geoengineering approaches.
- Support studies of the effects of solar-cycle influence on climate, with special focus on the importance of middle-atmosphere chemical and dynamical processes, and their coupling to the Earth's surface using both observations and models.

Ozone-Depleting Substances

- The 2011 ozone assessment highlights some remaining uncertainty in ODS budgets (e.g., the inconsistency of CCl₄ emission estimates). Support studies aimed at understanding the emissions (both natural and anthropogenic), banks, and the tropospheric and stratospheric evolution of ozone-depleting substances, their substitutes, and other climate-related trace gases. This includes studies of the effects of climate change on the sources, sinks, and lifetimes of these gases, and the study of very short-lived species, especially in the tropics, where these species could potentially reach the stratosphere. Here, changes in terrestrial and marine biophysical processes could change the concentrations of many of these important species.

Underpinnings for Observations and Models

- Provide continued support for laboratory, photochemical, kinetic, and spectroscopic studies that relate to ozone evolution and its monitoring. These studies provide critical improvements to models (for example, they provide key inputs to determining lifetimes of ODSs), as well as retrievals of atmospheric parameters from satellites and ground-based instruments.
- All observational operations that rely on the optical properties of the atmospheric constituents are only as good as the spectroscopic parameters obtained by laboratory spectroscopic studies. Thus, there is a need for continued studies to improve the standardization and consistency of cross sections for ozone and related species in different wavelength regions (e.g., UV, IR, microwave). The ACSO effort on ozone absorption cross sections is progressing in the right direction, but has been limited so far to UV cross sections. Extension to visible and infrared parts of the spectrum is recommended, as well as similar studies for other species like NO₂ and HNO₃, where uncertainties on spectroscopic parameters remain a limiting factor.
- Support investigations to resolve the differences between tropical total-ozone column trend estimates, and those trends computed from satellite profiles.

Ultraviolet and Environmental Effects

- Support studies that allow quantitative disaggregation of the factors affecting UV radiation at the surface, so that the influence of factors other than ozone (e.g., cloud cover, aerosol abundance, albedo, and temperature) can be better assessed.
• Support studies on the effects of stratospheric ozone change, and the resulting changes in UV radiation and on human health, ecosystems, and materials. These studies should include quantitative analyses that will allow the assessment of the magnitude of specific impacts in relation to UV radiation changes. Research also should take account of the interactions between the effects of changes in UV radiation and those of climate change, particularly effects that may lead to feedbacks to climate change, for example, through altered carbon cycling or tropospheric chemistry.

• Support studies that look at the environmental effects of ODS substitutes, and their degradation products on other factors that affect human health and the environment.

Systematic Observations

Data Networks

Systematic observations are critical to understanding and monitoring long-term changes in atmospheric composition and the associated response in ground-level UV radiation. The ability to predict expected ozone recovery in a changing atmosphere and to understand the interactions with a changing climate requires observations of key trace gases and parameters highlighting the role of chemical and dynamical processes. Vertically resolved measurements, especially in the upper troposphere/lower stratosphere (UTLS) region and in the upper stratosphere, are of prime importance. Global data networks thus provide the backbone of our understanding of ozone, ozone- and climate-related trace gases, and UV, and involve many nations around the world. Their operations also provide training for atmospheric scientists in both developed and developing countries. The demands on these networks are high, in that they provide the basis for all research activities and decision-making. These networks fall into two categories, ground-based and space-based.

Ground-Based Networks

These networks cover a broad range of observations using a variety of in situ techniques (balloonborne sondes and ground-level concentration sensors), and remote-sensing techniques such as UV instruments (e.g., Brewer, Dobson, M124), DOAS UV/visible and FTIR spectrometers, lidars, microwave radiometers, and spectral-UV-monitoring instruments. The two key issues involve the maintenance of existing facilities and expansion as required by scientific needs. These networks must be maintained above a critical level of data quality and geographical coverage. Current challenges to understanding atmospheric responses require network growth in various regions of the globe to better elucidate trace-gas sources and sinks, atmospheric transport, and the various processes affecting atmospheric composition. Geographical areas having less than critical measurement coverage include developing countries, particularly in the tropics, central Asia, and the mid-latitudes of the Southern Hemisphere. Maintenance of the high-latitude networks also is critical, as they provide direct observations of polar ozone processes. Newly developed low-cost instruments for column ozone and other chemical species could play an important role in the expansion and improvement of ground-based networks. Recommendations related to the maintenance and growth of these networks are numerous.

• The recommendation from the 7th ORM regarding the redistribution of instruments from instrument-rich sites to those areas that are poorly populated with instruments has begun with a few redistributions to Asian and African countries where significant data gaps were noted. Continued implementation of this recommendation is needed along with infrastructure support, as appropriate.

• Following the 7th ORM, several stations within the former USSR network of M124 filter radiometers were phased out. However, the recommendation to operate the M124 in parallel with collocated Brewer and/or relocated Dobson instruments has been followed at only a few stations, and the geographical coverage of ozone measurements has been reduced considerably over Central Asia, with no suitable replacement. There is a need to restore minimal monitoring activities in the parts of the world where M124 instruments had previously operated.
• Brewers are the preferred instruments for all expansion efforts around the globe wherever a new ozone- and UV-monitoring programme is to be established. Unused Dobson instruments are a more economical way to expand these networks, and to introduce observations at new sites. Earlier recommendations in this area have been successfully followed in several cases, and it is recommended to further continue such efforts. The collocation of column- and profile-measuring instruments is especially important for cross-validation, and for separation of tropospheric and stratospheric signals.

• There is a need to continue and further expand Umkehr ozone-profile capabilities, thereby maintaining that time series in the upper stratosphere. This is the primary ground technique for observing the upper stratosphere, since sondes cannot reach these altitudes.

• After careful reevaluation of microwave ozone data to insure adequate quality in the upper stratosphere, new stations should be added, particularly in Polar Regions where Umkehr data are not available. In the upper stratosphere, there may be significant local time variation in ozone during daytime that needs to be accounted for in the data analysis.

• Balloonsonde networks provide critical high-resolution vertical profiles of ozone, water vapour, and temperature, and need to be maintained and expanded, since such data are critical to understanding the interactions between atmospheric composition and a changing climate. The recent decrease in ozonesonde stations reporting data to central data archives, especially over Asia, the Arctic, and North America, is a matter of significant concern.

• Specific suggestions for sondes include:
  ➢ Technical solutions should be implemented to allow ozonesondes to reach 30 km in order to cover the important UTLS region.
  ➢ Archived data reports of ozonesondes should include simultaneously obtained water-vapour profiles.
  ➢ Water-vapour profiles measured by meteorological radiosondes should be more openly available for ozone research and monitoring.

• Key networks that obtain altitude profile information of ozone and ozone-related species are obtained from instruments like DOAS UV-visible and FTIR spectrometers, lidars, and microwave radiometers. These networks should be maintained, as they form the primary non-space-based observations for many of these key species. In addition, these established high-quality observation networks should increase their collaboration to ensure economy of scales, share facilities, increased coverage, etc. Examples of such networks and coordinating bodies include GAW, NDACC, IGACO, GCOS, CEOS, AGAGE, NOAA ESRL, etc.

• With the phasing out of CFCs and other alternates, there is a need to expand monitoring capabilities to include newly emerging chemicals. Specific attention should be given to the following classes of compounds:
  ➢ Long-lived HFCs, as these are strong greenhouse gases, are current substitutes for CFCs and HCFCs, and are under consideration for phasedown under the Montreal Protocol.
  ➢ Short-lived anthropogenic halocarbons (e.g., unsaturated HFCs, known as HFOs or hydrofluorolefines) and their degradation products (e.g. trifluoroacetic acid), which already are used or have a potential to be used as substitutes for long-lived HFCs. The degradation products of such chemicals might impact, for example, the chemical composition of surface water through precipitation and deposition.
  ➢ Short-lived natural halocarbons such as the brominated chemicals CH₂Br₂ and CHBr₃, as their emissions are potentially sensitive to future climate change and mitigation strategies.

• Since the 7th ORM, efforts have been made to increase the use of more sophisticated instrumentation (e.g., UV-visible, FTIR, microwave, Raman lidars, airborne, and
Balloonborne), and they should continue. New techniques for water-vapour measurements are an example. Specifically:

- Balloon-based measurements of ozone-depleting substances should be maintained in order to check the behaviour of these substances in relation to climate change.
- Measurements of SF₆ and CO₂ are needed in support of age-of-air studies to assess changes in global atmospheric circulation.
- Standard Operating Procedures (SOPs) need to be established and implemented, and metadata guidelines also should be available for all operational instruments.

- There are multiple calibration sites around the world within the Global UV Monitoring System that are not tied together sufficiently. Hence, an international calibration infrastructure should be created. It should promote a quality-assured protocol such as that used by the NDACC network. These observation data sets should not be restricted, and should be widely deposited into WOUDC. These activities should be coordinated and supported by the Scientific Advisory Group for UV monitoring. In addition, plans for a future World Calibration Centre for UV should be implemented, together with the further implementation of public information services.

**Satellite Networks**

These critical networks are associated with the satellite programmes of a number of nations. They include the critical solar backscatter UV observations that have established the trends in midlatitude and polar total ozone since the 1970s. These observations must be continued via the current polar-orbiting systems MetOp, NPP, and FY-3 to ensure continuity until 2018. Further continuation beyond 2018 (e.g., post-EPS) must be planned now. The other critical satellite network is that of limb-sounding observations (including occultation, emission, and scattering) that provide high-vertical-resolution data of ozone and key ozone related parameters that are critical for understanding the science behind changes in ozone in the context of changing climate. In particular, these limb observations enable the characterization of ozone changes in the critical altitude regions of the upper troposphere/lower stratosphere, as well as the upper stratosphere. Based on current space agency plans, and despite obvious efforts to take into account the 7th ORM recommendations and implement gap-filler missions, there will be a serious gap in these types of satellite measurements. Many of these satellite observations also provide key meteorological data that are needed to understand fully stratospheric transport, which controls the distribution of ozone and the evolution of the ozone hole. Specific recommendations for satellite networks include:

- The continuation of the solar backscatter UV observations must be insured, as they constitute a key baseline set of measurements. All of the currently planned missions with solar backscatter instruments are needed to maintain this continuity of observations and maintain the measurement overlaps required for accurate trends determinations. Improvements of retrieval algorithms also are needed to expand capabilities at high altitudes and high solar-zenith angles.

- Satellite observations of high-vertical-resolution profiles using limb viewing for ozone and key molecules such as HCl, CFCs, ozone-relevant radicals and reservoirs, tracers of atmospheric motion, and water vapour are required in order to understand more accurately the changes in ozone as CFCs decline and climate change occurs.

- Special attention should be given to N₂O, as this gas is becoming one of the most important substances that can lead to ozone destruction. Likewise, attention should be paid to systematic water-vapour-profile measurements, as it is a strong driver for decadal climate variability.

- Availability of high-quality temperature-profile data remains an issue for satellite data retrievals and data comparisons.

- Gap-filling missions providing high vertical resolution of ozone and ozone-related parameters using techniques such as solar occultation FTS and limb-emission instruments
should be considered as a low-cost gap filler between the current limb satellite observations and the missions currently planned by the various space agencies. A few such missions have been proposed, and further development of these projects is encouraged.

- Measurements of stratospheric aerosols should be continued.
- Satellite data records have improved significantly in recent years, but problems persist in the UTLS region, particularly at high and low latitudes. Further improvements of calibration and of retrieval algorithms are needed to reach adequate data quality. Hence, it is recommended that an assessment of current temperature-profile data records and measurement capabilities be organized, and, where appropriate, recommendations for new temperature measurements systems be given.
- Satellite measurements of solar irradiance outside of the atmosphere and associated indexes (e.g., the Mg-II index) are needed to understand processes that control ozone photochemistry and the dynamics.

**Consistency and Complementary of Data Sets and Re-Evaluation of Data Records**

Needs common to both ground-based and satellite networks include insuring the consistency and complementarities of data sets, and the re-evaluation of data records. For example, there needs to be a systematic understanding of the differences and synergies between different data-observation techniques so that the data can be combined in an appropriate way. Intercomparison campaigns are desired, because they assist in defining and reducing the systematic differences in both identical and different measurement techniques. Examples include the SAUNA campaigns in 2006/2007 that were designed to understand calibration and stray-light issues in ground-based measurements, and to improve techniques for the comparison of remotely sensed data. Specific recommendations include:

- The need for better integration of ground-level, ground-based remote sensing, and satellite data. There are calibration/scale/storage issues between campaigns and continuous networks (e.g., for short-lived natural halocarbons) that would benefit from additional harmonization efforts. Efforts are thus recommended to strengthen the consistency (calibration and data quality) between short-term campaigns and long-term monitoring, e.g., via common transfer standards.
- The further development of methods and tools for a better-integrated use of complementary data with different scale, resolution etc. An example of this is the GEOMON project, in which data-merging techniques are being used to combine data records from different measurement systems, and multi-dimensional observation operators are being developed to better interpret remotely sensed data.

**Data Archiving**

Achievements in response to the recommendations made by the 7th ORM include:

- A Dobson Data Quality Workshop was held in Hradec Králové, Czech Republic, 14-18 February 2011.
- The NDACC has adopted the Hierarchical Data Format (HDF) as the standard for data archiving.
- A template for the submission of level-0 Dobson data and metadata has been drafted, and is to be approved by SAG-Ozone at the forthcoming meeting in October 2011.

Many of the recommendations made by the 7th ORM remain relevant, and are repeated and expanded on as necessary below.
Continuing Recommendations

Near-Real-Time and Historical Data

- Different uses of ozone and UV measurements need to be recognized. These uses impose different requirements on the data and on its archiving. For example, the use of ozone measurements in real-time or near-real-time data assimilation requires quick data submission (e.g., onto the GTS), whereas the use of ozone measurements for long-term trend detection requires very precise measurements, maintenance of the homogeneity of the time series, careful management of instrument changes, care in calibration, and derivation of uncertainties on the measurements before they are submitted to international archives (e.g., the World Ozone and Ultraviolet Data Centre, WOUDC). These very different timescales for data submission (i.e., hours vs. months) are not mutually exclusive, and must be recognized. Preliminary data and final archived data are likely to differ.

Archiving Support

- The archiving of raw data and metadata is a resource-intensive activity, and it is essential that funding agencies not only recognize the need for support for raw data and metadata archiving, but also make it clear that archiving of these ancillary data is expected as an important part of the measurement programme. Personnel tasked with making the measurements must be given the support for archiving raw data and metadata, both in national and international databases. However, such archiving of raw data in no way replaces the need for archiving the final data products.

Archiving Management

- Agencies funding measurement programmes are recommended to require that the measurements will be submitted to easily accessible archives in a timely manner. Proprietary data formats should be avoided for data archiving. Where possible, internationally accepted formats that can accommodate a wide range of data types, and that easily facilitate the bundling of raw data and metadata, should be used (e.g., HDF or NetCDF).

Databases

- The number of individual databases through which measurements may be obtained continues to proliferate. Efforts by international organizations to link various data centres (e.g., ozone, UV-radiation, GHG, meteorological) as a means of ensuring access to all available data should be encouraged (e.g., the WMO GAW Station Information System, GAW/SIS). Measurements made during field campaigns or through regional process studies also should be archived to allow free access by researchers.

Level-1 Data Management

- Changes in instruments, observers, retrieval algorithms, calibration protocols, ozone-absorption cross sections, and operating procedures cannot be avoided. Without such changes, improvements never would be possible. Therefore, such changes need to be managed. This includes the recognition that periodic reprocessing of historical raw data will be required to produce new improved versions of long-term homogeneous measurement time series. Archiving of final data products therefore needs to accommodate different versions of measurement records, as well as the ability to inform users of the archived data about the availability of new versions of the data.

New Recommendations

Level-0 and Metadata Archiving (High Priority)

- The extent to which any reprocessing can be achieved will depend on the archiving of the ‘rawest’ form of original data, as well as the archiving of a rich set of metadata describing all facets of the data processing. For example, the primary recommendation is for all
Dobson stations to submit level-0 observations and calibration data to the WOUDC, in addition to the level-1 analysis.

- The Brewer network already is submitting level-0 data to the WOUDC. To expand the current submission of the Brewer primary data and calibration metadata from the stations, the existing Brewer Data Management System (BDMS) implemented by Environment Canada is recommended for general use.

**Availability of Historical Data**

- Understanding the potential role of historical (i.e., pre-1980) ozone changes in forcing changes in surface UV radiation and climate is now acknowledged. Therefore, it is recommended that efforts to identify and recover these records be increased. Specific sites that are known to have historically available data that have not yet been submitted to international databases are documented in the Proceedings of the Symposium for the 20th Anniversary of the Montreal Protocol. Governments and agencies are encouraged to provide resources to undertake data salvage as a priority activity.

**Emission Inventories and Reporting**

- Comprehensive reporting of national ODS production and consumption will improve emissions inventories. Care should be taken when considering practical applications for inventories due to the high current levels of uncertainty.

**Education and Training**

- Holding workshops that provide training on metadata collection and processes for archiving data may support the effort to improve these activities within the ozone and research community. It is recommended that scheduling be encouraged at times when such workshops can be held easily (e.g., before or following meetings such as the Quadrennial Ozone Symposium, or in conjunction with instrument intercomparisons).

- Some countries not participating in the Dobson Data Quality Workshop mentioned above should be encouraged to do so (see workshop report). It is recommended that a letter be sent from WMO to the WMO Permanent Representatives/Ozone Research Managers of those countries that were, for various reasons, previously unable to participate in these activities.

**Capacity Building**

While there has been progress in capacity building since the 7th ORM, much remains to be accomplished. A number of key activities have been undertaken over the last three years that have had significant impact. In particular:

- The 2010 relocation of the unused Dobson instrument from Oslo, Norway to Kampala, Uganda, and the unused Dobson instrument from Uccle, Belgium to Kyev, Ukraine through the umbrella effort of the Regional Dobson Calibration Centre (RDCC)-Europe, including the support of Belgium, Norway, Czech Republic, Germany, USA, and WMO. These relocation efforts required the refurbishment and calibration of the unused instruments, and the training of observers.

- The transfer of knowledge and technology from the World Dobson Calibration Centre (WDCC), Boulder, USA to the Africa and South America RDCCs in 2009 and 2010.

- Brewer calibrations supported by the WMO Brewer Trust Fund (supported by Canada)
  - Calibration and maintenance of Brewer #160, Isfahan, Iran, October 2008
  - Calibration and maintenance of Brewer #051, Casablanca, Morocco, September 2009
  - Calibration and maintenance of Brewer #165, Casablanca, Morocco, September 2009
  - Calibration and maintenance of Brewer #180, Punta Arenas, Chile, November 2009
- Calibration and maintenance of Brewer #056, La Paz, Bolivia, November 2009
- Calibration and maintenance of Brewer #110, Cachoeira Paulista, Brazil, November 2009
- Calibration and maintenance of Brewer #167, Santa Maria, Brazil, November 2009
- Calibration and maintenance of Brewer #081, Cuiaba, Brazil, November 2009
- Calibration and maintenance of Brewer #073, Natal, Brazil, November/December 2009
- Calibration and maintenance of Brewer #116, Bandung, Indonesia, November 2010
- Calibration and maintenance of Brewer #092, Watukosek, Indonesia, November 2010

• Educational workshops such as:
  - The 2011 UNEP / WMO-GAW Dobson Data Quality Workshop held in Hradec Králové, Czech Republic
  - The WMO-GAW Biennial Brewer Users Workshops led by Canada in Northwich, UK (June 2007); Seoul, South Korea (October/November 2007); the half-day workshop in Tromsø, Norway (2008); and the Biennial Brewer Users Workshop held in Aosta, Italy (2009). The 13th Biennial Brewer Users Group Meeting, is tentatively scheduled for 12-16 September 2011 in Beijing, China.

Recognizing the success of these various workshops, it is recommended that their frequency be increased.

There have also been a number of countries that have contributed either directly or in-kind to the Vienna Convention Trust Fund (VCTF). Those countries include: Czech Republic, Estonia, Estonia, Finland, France, Kazakhstan, South Africa, Spain, Switzerland, and the United Kingdom. In addition, a number of countries have developed twinning relationships that have built both capacity and scientific relationships over this time period. The following are key examples of quality twinning relationships that can be used as models for further endeavours of this kind:

• Finland – Argentina
• Spain – Algeria
• Spain – Argentina
• Switzerland – Kenya
• UK – South Africa
• USA – SHADOZ network

The 8th ORM also recognizes that a number of other organizations (e.g., WMO GAW) support capacity-building activities such as the German GAWTEC (GAW Training and Education Centre). Nevertheless, capacity building is a long-term activity, and many of the recommendations of the 7th ORM are as fully applicable today as they were when first proposed (see section on Capacity Building (pages 32 and 33) under Recommendations, Report of the Seventh Meeting of the Ozone Research Managers, <http://ozone.unep.org/Meeting_Documents/research-mgrs/7orm/7orm-report.pdf>). The 8th ORM, under the guidance of the Bureau of the Vienna Convention, believes a small number of specific, actionable activities be undertaken before the 9th ORM. The following specific recommendations are in-line with the more general 7th ORM recommendations, and provide concrete means of increasing capacity in developing countries over the next three years.

• Recognizing that surplus equipment exists in many developed countries and could be made available for redeployment:
  - A mechanism be developed under the WMO GAW umbrella so that countries would
be able to donate good quality, operational equipment to the WMO for deployment to developing countries as a means to enhance the global operational network of ozone- and UV-observing stations.

- That GAW SAG-Ozone and SAG-UV be tasked with the responsibility of assessing the overall global needs for the distribution of this equipment.
- That the VCTF, if able, pay for training and aid in the establishment of these stations. It is recognized that agency collaborations (twinning) is preferable, but cannot always be established.

- That capacity building continue through workshop attendance by the professional and technical staff of developing countries. Specifically, the ORM recommends supporting attendance at:
  - The WMO-GAW Biennial Brewer Users Workshop, Beijing, September 2011
  - A second Dobson Workshop, following the success of the 2011 Czech workshop, to be held in 2013
  - That an ozone- and UV-observing workshop be held in association with the 2012 Quadrennial Ozone Symposium (QOS) in Toronto, Canada. This workshop would be developed specifically for scientists from developing countries, and would be held immediately preceding the QOS in order that the meeting could be attended as part of this capacity-building activity. In addition to serving as an educational forum on the various symposium topics, the workshop could help identify scientists who are capable of contributing to forthcoming scientific assessments. The International Ozone Commission should be invited to aid in the development of this workshop, and to waive registration fees for the workshop attendees. It is suggested that this course follow the symposium session topics, and that Session Chairs be encouraged to present two-to-three-hour courses and question-and-answer sessions within the workshop.
  - NASA has developed a specialized education programme to encourage the use of NASA Earth-observation data (GLOBE, [http://globe.gov/events/nasa-s-earth-climate-course-event]) within the NASA Explorer Schools project). The major space agencies are encouraged to develop courses of this type to be specifically directed towards scientists from developing countries. It is strongly recommended that at least two such courses be held before the 9th ORM, one by NASA for Region III, and one by ESA for Region I.

- In order to assess the effectiveness of these and future planned capacity-building activities, a set of metrics be developed by the SAP over the next 12 months. For example, these metrics could consist of one or more of the following:
  - The number of refereed publications in peer-reviewed journal from scientists in developing economies
  - The quantity and quality of data submitted to the WOUDC or other appropriate archives
  - Increased involvement in the Ozone Assessment through publications used, authors, reviewers, etc.

- That, where possible and appropriate, National Ozone Unit Officers in developing countries, being successful in the tasks of phasing out of ODSs in their countries:
  - Be given the responsibility of being the focal point for the distribution of information on, and the coordination of, monitoring and scientific activities, particularly in the area of capacity building.
  - Are the recipients of all information associated with upcoming capacity-building events for its redistribution to the country’s monitoring and scientific communities.
• That with the increasing access of high-speed Internet access, web-based training courses should be developed. These new courses could cover the various topics as reported on in the Scientific Ozone Assessment. It is recommended that the OzonAction Programme of the UNEP Paris Office coordinate the establishment and organization of such courses, and that the SAP encourage coordinating lead authors to develop and give such web-based courses over the next three years.

**Closure of the Meeting**

Statements of appreciation were made by Mr Geir Braathen on behalf of WMO, Mr Marco Gonzalez on behalf of UNEP and the Ozone Secretariat as well as the Parties to the Vienna Convention, and Mr Michael Kurylo, the Chair of the 8th ORM.
ANNEX A

WMO/UNEP EIGHTH MEETING OF THE OZONE RESEARCH MANAGERS OF THE PARTIES TO THE VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER
(Geneva, 2-4 May 2011)

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Group Photo of Participants at the Eighth Meeting of the Ozone Research Managers of the Parties to
the Vienna Convention for the Protection of the Ozone Layer
Geneva, Switzerland, 2-4 May 2011
WMO/UNEP EIGHTH MEETING OF THE OZONE RESEARCH MANAGERS
OF THE PARTIES TO THE VIENNA CONVENTION FOR THE
PROTECTION OF THE OZONE LAYER
(Geneva, 2-4 May 2011)

AGENDA

2 May (Monday)

08:00 onwards  Registration

09:00 – 09:50 hrs  Opening of the Meeting
  o  Opening Statement (Marco González, Executive Secretary, Ozone Secretariat)  (10 min.)
  o  Welcome Statement (Tetsuo Nakazawa, WMO)  (10 min.)
  o  The 2010 Ozone Assessment: Addressing the Needs of the Parties
    (Paul Newman, 2010 Scientific Assessment Panel Co-Chair)  (15 min)
  o  The Interface between the ORMs and the Scientific Ozone Assessments
    (Michael Kurylo, 7th ORM Chair)  (15 min.)

09:50 – 10:00 hrs  Election of the 8th ORM Chair (Marco González, Executive Secretary, Ozone Secretariat)

10:00 – 10:10 hrs  Adoption of the 8th ORM Agenda (8th ORM Chair)

SESSION 1: INTRODUCTORY SESSION: THE VIENNA CONVENTION


10:30 – 11:05 hrs  Activities under the Vienna Convention Trust Fund for Research and Systematic Observation Relevant to the Vienna Convention
  o  History and Financial Status of the Trust Fund, MOU between the Ozone Secretariat and WMO, etc. (Meg Seki, Ozone Secretariat)  (10 min.)
  o  Report on the Dobson Data Quality Workshop – Funded by the Trust Fund
    (Karel Vanicek, CHMI)  (15 min.)
  o  Other Activities (Geir Braathen, WMO)  (10 min.)

11:05 – 11:20  Appointment of Discussion Leaders and Rapporteurs for the Various Recommendation Areas – Research Needs, Systematic Observations, Data Archiving, Capacity Building (8th ORM Chair)

11:20 – 11:35 hrs  Q&A / Discussion
SESSION 2: THE STATE OF THE OZONE LAYER AND INTERACTIONS BETWEEN OZONE LAYER DEPLETION AND CLIMATE CHANGE

11:35 – 12:00 hrs  The Current and Future States of the Ozone Layer (Greg Bodeker, Bodeker Scientific)

12:00 – 13:00 hrs  LUNCH

13:00 – 13:20 hrs  Links between Ozone and Climate (Paul Newman, 2010 SAP Co-Chair)


13:40 – 14:00 hrs  Q&A / Discussion

SESSION 3: INTERNATIONAL MONITORING PROGRAMMES

14:00 – 14:20 hrs  The WMO Global Atmosphere Watch (GAW) Programme (Liisa Jalkanen, WMO)

14:20 – 14:40 hrs  The Network for the Detection of Atmospheric Composition Change (NDACC) (I. Stuart McDermid, NASA/JPL)

14:40 – 15:00 hrs  International Ozonesonde Activities (e.g., NOAA South Pole Programme, The Southern Hemisphere Additional Ozonesondes Network (SHADOZ)) (Russ Schnell, NOAA)

15:00 – 15:30  COFFEE/TEA

15:30 – 15:50 hrs  Global Climate Observing System (GCOS) Including GRUAN (Greg Bodeker, Bodeker Scientific)

15:50 – 16:10 hrs  Integrated Global Atmospheric Chemistry Observations for Ozone and UV (IGACO-Ozone/UV) (Geir Braathen, WMO)

16:10 – 16:25 hrs  The New SPARC ODS Lifetime Assessment (Stefan Reimann, Empa)

16:25 – 16:45 hrs  Ground-Based Networks for Measuring Ozone- and Climate-Related Trace Gases (Stefan Reimann, Empa)

16:45 - 17:05 hrs  Atmospheric Concentrations of ODSs and ODS Substitutes: Scenarios and Trends (Guus Velders, National Institute of Public Health and the Environment, RIVM)

17:05 – 17:30 hrs  Q&A / Discussion: Initial Framing of Recommendations

3 May (Tuesday)

SESSION 4: SATELLITE RESEARCH AND MONITORING

09:00 – 09:20 hrs  The Stratospheric Processes and their Role in Climate Project of WCRP: The Joint SPARC/IO3C/WMO/NDACC Initiative on Past Trends in the Vertical Distribution of Ozone (Johannes Stähelin, ETH Zürich)

09:20 – 09:50 hrs  Lessons Learned in Creating Long-Term Ozone Datasets: Recommendations for the Future (P. K. Bhartia, NASA)
09:50 – 11:00 hrs Current and Planned Ozone and Climate Observations from Space
  o U.S. Satellite Programmes: NASA, NOAA, and Other Agencies (Ken Jucks, NASA) {30 min.}
  o European Space Agency Activities (Jean-Christopher Lambert, IASB-BIRA) {25 min.}
  o KNMI Space-Based Measurement Activities (Peter van Velthoven) {15 min.}

11:00 – 11:20 hrs COFFEE/TEA

11:20 – 11:45 hrs Current and Planned Ozone and Climate Observations from Space (continued)
  o EUMETSAT and O3SAF (Geir Braathen for Lars Prahm, EUMETSAT) {10 min.}
  o Japanese Aerospace Exploration Agency / SMILES (Hideaki Nakane, NIES) {15 min.}

11:45 – 12:15 hrs Summary of the Key Issues in Space-Based Measurements: Identification of Future Needs and Opportunities (Jean-Christopher Lambert, IASB-BIRA)

12:15 – 13:20 hrs LUNCH


SESSION 5: NATIONAL AND REGIONAL REPORTS ON OZONE RESEARCH AND MONITORING

In this session, each representative of a region will present the regional and national situations with ozone monitoring and research, focusing on the key issues raised by the countries in the region based on the national reports submitted for this meeting. In particular, representatives are requested to highlight activities associated with the 7th ORM recommendations.

13:50 – 14:05 hrs Region 1: Africa (Gerrie Coetzee, South African Weather Service)

14:05 – 14:25 hrs Region 2: Asia (Hideaki Nakane, NIES, and Tetsuro Uekubo, JMA)

14:25 – 14:40 hrs Region 3: South America (Claudio Casiccia Salgado, Universidad de Magallanes)

14:40 – 15:35 hrs Region 4: North America, Central America, and the Caribbean
  o USA (Ken Jucks, NASA and Russ Schnell, NOAA) {20 min.}
  o Canada (Bruce McArthur, Environment Canada) {20 min.}
  o Central America, Mexico, and the Caribbean (Geir Braathen for Juan Carlos Peláez Chávez, Instituto de Meteorología)

15:35 – 15:50 COFFEE/TEA

15:50 – 16:10 hrs Region 5: South West Pacific (Janet Bornman, University of Waikato)

16:10 – 16:30 hrs Antarctica
  o Antarctica (Jonathan Shanklin, British Antarctic Survey)
  o Czech Republic Activities in Antarctica (Michal Janouch, CHMI)

16:30 – 18:25 hrs Region 6: Europe
  o European Union (José Mingo Jimenez, European Union)
  o Belgium (Jean-Christopher Lambert, IASB-BIRA)
  o Czech Republic (Karel Vanicek, CHMI)
  o Germany (Wolfgang Steinbrecht, Deutscher Wetterdienst)
  o Nordic Countries (Niels Larsen, DMI)
  o Poland (Bogumil Kois, IMWM)
  o Switzerland (René Stübi, MeteoSwiss)
  o Turkey (Yilmaz Acar, State Meteorological Service)
  o UK (William Cook, Defra)

18:25 – 18:45 hrs Discussion: Identification of Needs and Gaps
SESSION 6: DISCUSSION OF RECOMMENDATIONS

In this session, recommendations arising from the meeting will be discussed and agreed. Under each topic of recommendations, a short introductory presentation (10-15 min.) will be made, followed by discussions on the topic.

09:00 – 09:45 hrs   Research Needs: Introduction by Paul Newman and A. R. Ravishankara (Ken Jucks and John Pyle, Rapporteurs)

09:45 – 10:30 hrs   Systematic Observations: Introduction by P. K. Bhartia and Stefan Reimann, (Jean-Christopher Lambert and Niels Larsen, Rapporteurs)

10:30 – 11:15 hrs   Data Archiving: Introduction by Karel Vanicek (Johannes Stähelin and Greg Bodeker, Rapporteurs)

11:15 – 11:45 hrs   COFFEE/TEA

11:45 – 12:30 hrs   Capacity Building: Introduction by Ayité-Lô Ajavon and Stuart McDermid (Geir Braathen and Bruce McArthur, Rapporteurs)

12:30 – 13:00 hrs   Discussion of Draft Recommendations

13:00 – 14:30 hrs   LUNCH

14:30 – 16:30 hrs   Further Discussion and Adoption of Recommendations and Report

16:30 – 17:00 hrs   Other Matters

17:00   Closure of the Meeting
<table>
<thead>
<tr>
<th>Argentina</th>
<th>Germany</th>
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<tbody>
<tr>
<td>Armenia</td>
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<td>Togo</td>
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<td>European Union</td>
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<td>Gambia</td>
<td>Vietnam</td>
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<td>Zimbabwe</td>
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</table>
ARGENTINA - National Report


The frequent overpass of the Antarctic Ozone Hole each spring, the extreme UV radiation levels over the northwestern Andean Plateau and their effects put the territory of the Argentine Republic at a strategic situation for atmospheric ozone and solar UV radiation studies. Major issues related to the accomplishment of the 7th ORM recommendations during the period 2008-2011 are:

- Research within Argentine institutions in these subjects is at present significant. There is a strong political decision to sustain the investigations, as many of the research projects are economically supported directly by the Argentine State. Argentine private institutions participate also with increasing interest and support in these research fields.

- Support for collaboration with international projects was also strengthened with both logistic and scientific support, including monitoring and modeling of ozone, UV radiation and related parameters along the National territory and principally in the Argentine Antarctic stations.

- The Regional Calibration Center at the Argentine National Weather Service accomplished the scheduled tasks with the 2010 intercomparisons of South-American Dobson instruments, UV-Biometers and surface ozone instruments.

- New sophisticated equipment has been incorporated by several Argentine institutions (e.g. spectroradiometers), including instrumentation developed in Argentina (e.g. LIDAR).

- The efforts to maintain the monitoring networks are being fruitful. Several databases are reaching an extension of decades, allowing for an estimation of the climatological behavior of measured parameters.

- Satellite databases have been often used in many studies over the region.

- Data for international archiving are being sent currently to the corresponding databases.

- The extent of the springtime Antarctic Ozone Hole each year is still very significant and concerning for the region. Its pass over the continent several times within the period 2008-2011 emphasizes the need to closely follow its monitoring and study.

- The prevention of sunburning-related skin diseases and skin cancer for the population is taken as a subject of Public Health with annual diffusion campaigns. In November 2010, the Argentine Dermatological Society carried out the XVII National Campaign for the prevention of the skin cancer.

- There is an increasing trend to study the ozone-climate interactions within the frame of the Global Climate Change.

The present report is an update of the activities in Argentina and spans the period 2008-2011.

1. MONITORING

The following are the detailed measurement activities at the principal monitoring institutions and its contact address:
- Argentine National Weather Service (SMN)

Contact: MSc. Gerardo Carbajal Benítez
Servicio Meteorológico Nacional. Av. de los Constituyentes 3454, C1427BLS, Ciudad Autónoma de Buenos Aires. Phone: 54-11-51676767 int. 18306. Email: gcarbajal@smn.gov.ar.

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Total O₃ Column</th>
<th>Surface O₃</th>
<th>Vertical O₃ Profile</th>
<th>Broadband Surface UV irradiance</th>
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<td>La Quiaca</td>
<td>22.11°S, 65.57°W, 3459m. a.s.l.</td>
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<td>Pilar</td>
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<td>Mendoza</td>
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<td>Rosario</td>
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<td>Comodoro Rivadavia</td>
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<td>San Julián</td>
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<td>Ushuaia</td>
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<td>X</td>
<td>X</td>
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<td>Marambio</td>
<td>64.23°S, 56.72°W, 300m. a.s.l.</td>
<td>X</td>
<td>X</td>
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</table>

SMN is the WMO South-American Regional Calibration Center for Dobson Spectrophotometers and for UV-Biometers.

Projects in collaboration with: World Meteorological Organization, Finnish Meteorological Institute, Instituto Nacional de Meteorología (INM, Spain), Instituto Nacional de Tecnología Aeroespacial (INTA, Spain), Argentine Antarctic Institute.

- Argentine Antarctic Institute

Contact: Ing. Eduardo Calviño, Téc. Héctor A. Ochoa
Dirección Nacional del Antártico - Instituto Antártico Argentino. Dpto. Ciencias de la atmósfera
Cerrito 1248 - C1010AAZ - Capital Federal. Argentina. Phone: 54-11-4812-0071/72. Email: edcalvino@dna.gov.ar, haochoa@dna.gov.ar

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Total O₃ Column</th>
<th>Surface O₃</th>
<th>NO₂ (DOAS)</th>
<th>O₃ Profile</th>
<th>UV</th>
<th>LIDAR</th>
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<td>Marambio</td>
<td>64.23°S, 56.72°W, 300m. a.s.l.</td>
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<tr>
<td>San Martin</td>
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<tr>
<td>Belgrano II</td>
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Projects in collaboration with: Servicio Meteorológico Nacional (Argentina), Instituto de Física Atmosférica de Roma (IFAR, Italia), Instituto Nacional de Técnica Aeroespacial (INTA, España), el Instituto Nacional de Meteorología (INM, España), Instituto Meteorológico Finlandés (IMF, Finlandia), Observatorio Solar y de Ozono del Instituto Hidrometeorológico de la República Checa.
### Argentine National Institute of Genetics and Molecular Biology (INGEBI) - Capital Federal

Contact: Ing. Susana B. Diaz  

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument (Narrowband UV and PAR surface irradiances)</th>
<th>Last Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Salvador de Jujuy</td>
<td>24.17°S, 65.02°W, 1300m. a.s.l.</td>
<td>GUV-511</td>
<td>Next April 2011</td>
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<tr>
<td>Buenos Aires</td>
<td>34.58°S, 58.47°W, Sea level</td>
<td>GUV-511</td>
<td>2011</td>
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<tr>
<td>San Carlos de Bariloche</td>
<td>41.01°S, 71.42°W, 700 m. a.s.l.</td>
<td>GUV-511</td>
<td>2011</td>
</tr>
<tr>
<td>Trelew</td>
<td>43.25°S, 65.31°W, Sea level</td>
<td>GUV-511</td>
<td>2011</td>
</tr>
<tr>
<td>Ushuaia</td>
<td>54.83°S, 68.30°W, Sea level</td>
<td>GUV-511</td>
<td>Next Oct. 2011</td>
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</table>

Projects in collaboration with: National Science Foundation (NSF, USA), Centro Austral de Investigaciones Científicas (CADIC, Argentina), Dirección Nacional de Antártico (DNA, Argentina) y Dirección Nacional de Meteorología (INM, Spain), Instituto Nacional de Tecnología Aeroespacial (INTA, Spain), Programa Nacional para Investigaciones Antárticas (PNRA, Italy).

### Austral Center for Scientific Research (CADIC) - Tierra del Fuego

Contact: Ing. Susana B. Diaz  

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Measured Parameters</th>
<th>Instrument</th>
<th>Last Calibration</th>
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<tr>
<td>Ushuaia</td>
<td>54.83°S, 68.30°W, Sea level</td>
<td>Spectral solar irradiance (range: 280-620 nm)</td>
<td>SUV-100 spectroradiometer</td>
<td>2008 (every 15 days with secondary lamps)</td>
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<td></td>
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<td>Total O₃ Column, NOₓ</td>
<td>EVA 4</td>
<td>2010</td>
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<td></td>
<td></td>
<td>Narrowband UV and PAR solar irradiance</td>
<td>GUV-511</td>
<td>2008</td>
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<td>Narrowband UV and PAR solar irradiance</td>
<td>NILU-UV</td>
<td>2011</td>
</tr>
<tr>
<td></td>
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<td>Total O₃ Column Spectral solar irradiance</td>
<td>Brewer MKIV spectroradiometer</td>
<td>2010</td>
</tr>
</tbody>
</table>

Projects in collaboration with: National Science Foundation (NSF, USA), Instituto de Investigaciones en Ingeniería Genética y Biología Molecular (INGEBI, Argentina), Dirección Nacional de Antártico (DNA, Argentina) y Dirección Nacional de Meteorología (INM, Spain), Instituto Nacional de Tecnología Aeroespacial (INTA, Spain), Programa Nacional para Investigaciones Antárticas (PNRA, Italy).
- **Photo-Biological Station “Playa Union” - Chubut**

  Contact: Dr. Walter Helbling  
  Estación de Fotobiología Playa Unión. Casilla de Correos N°15 (9103). Rawson, Chubut, Argentina. Phone: 54-2965-498019. Email: whelbling@efpu.org.ar, efpu@efpu.org.ar

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Measured Parameters</th>
<th>Instrument</th>
</tr>
</thead>
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<tr>
<td>Playa Union</td>
<td>43.30°S, 65.03°W, 10m. a.s.l.</td>
<td>Surface broadband UVB, UVA and PAR solar irradiance</td>
<td>ELDONET surface spectrometer</td>
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<td></td>
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<td>Resolution: 1nm. Range: 190-1100 nm</td>
<td>Ocean Optics spectroradiometer</td>
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<tr>
<td></td>
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<td>Underwater broadband UVB, UVA and PAR solar irradiance</td>
<td>ELDONET submersible spectrometer</td>
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<td></td>
<td></td>
<td>Underwater solar irradiance</td>
<td>Ocean Optics submersible radiometer</td>
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<tr>
<td></td>
<td></td>
<td>- Weather station</td>
<td>- Laboratory equipment for biological-sample analysis</td>
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</tbody>
</table>

Projects in collaboration with: Universidad de Concepción (Chile), Universidade de Sao Paulo, Fundação Universidade Federal do Rio Grande e Instituto Nacional de Pesquisas Espaciais (Brasil), CONICET, Estación de Fotobiología Playa Unión, Instituto Nacional de Investigación y Desarrollo Pesquero (Argentina), University of South Florida (USA), Centro de Procesamiento de Imágenes y Fundación La Salle (Venezuela), Interamerican Institute for Global Change Research (IAI), National Natural Science Foundation of China.

- **Center for Laser Research and its Applications, CEILAP (CITEDEF-CONICET)**

  Contact: Dr. Eduardo J. Quel  
  CEILAP, Juan B. de La Salle 4397. B1603ALO - Villa Martelli, Buenos Aires. Argentina. Phone: 54-11-4709-8217. E-mail: equel@citefa.gov.ar

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Measurement</th>
<th>Institution</th>
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<tr>
<td>Río Gallegos</td>
<td>51.60°S, 69.32°W, 15m. a.s.l.</td>
<td>DIAL LIDAR</td>
<td>Ozone profile between 15-45 km</td>
<td>CEILAP/Argentina</td>
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<tr>
<td></td>
<td></td>
<td>YES UVB-1</td>
<td>UV erythemal irradiance</td>
<td>CEILAP/Argentina</td>
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<tr>
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<td>SAOZ UV-Vis. Spectrometer</td>
<td>Ozone and NO2 total column</td>
<td>SAOZ Network/France</td>
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<td>Pyranometer</td>
<td>Total solar radiation</td>
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<td>GUV 541</td>
<td>Spectral bands at 305, 313, 320, 340 and 380 nm</td>
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<td>Brewer Spectrophotometer S/N 124</td>
<td>Total ozone, NO2 and spectral UV every 0.5 nm</td>
<td>INPE/Brasil</td>
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<td>Milimetric waves radiometer</td>
<td>Upper stratospheric-mesospheric ozone profiles between 35 and 80 km</td>
<td>Nagoya University/Japan</td>
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Projects in collaboration with: Network for the Detection of Atmospheric Composition Change (NDACC/NOAA), Laboratorio de Ozono y Radiación Ultravioleta de la Universidad de Magallanes, Punta Arenas - Chile, Japan International Cooperation Agency.
- Institute of Physics of Rosario

Contact: Dr. Rubén Piacentini
Grupo de Radiación Solar – IFIR (CONICET/UNR). 27 de febrero 210bis, 2000, Rosario. Argentina. Phone: 54-341-4472824 int. 30. E-mail: ruben.piacentini@gmail.com

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<th>Location</th>
<th>Measured Parameters</th>
<th>Instrument</th>
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<tbody>
<tr>
<td>Rosario</td>
<td>32.96ºS, 60.62ºW, 25m. a.s.l.</td>
<td>UV erythemal irradiance</td>
<td>YES UVB-1</td>
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<td></td>
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<td>Total solar irradiance</td>
<td>Kipp &amp; Zonen CM5</td>
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<td>Broadband Total UV</td>
<td>Kahl TUVR</td>
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<td>Broadband UVB</td>
<td>EKO UVB</td>
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<td>Broadband UVA</td>
<td>EKO UVA</td>
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<td></td>
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<td>Surface air quality: CO, NOx and O₃</td>
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<td>Surface aerosols size: 0.25-30 µm</td>
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<td>Portable single monocromator spectroradiometer with optical fiber</td>
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<td>Automatic weather station</td>
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</tbody>
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Projects in collaboration with: CEILAP (Argentina), Universidad Federal de Pernambuco (Brasil), Japan International Cooperation Agency.

- Institute for Physical-Chemical Investigations – National University of Córdoba

Contact: Dra. Beatriz M. Toselli
Departamento de Físico Química – INFIQC. Facultad de Ciencias Químicas, Universidad Nacional de Córdoba. Ciudad Universitaria, 5000 Córdoba. Argentina. Email: tosellib@fcq.unc.edu.ar

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<tr>
<td>Córdoba</td>
<td>31.40ºS, 64.18ºW, 470m. a.s.l.</td>
<td>UV erythemal irradiance</td>
<td>YES UVB-1 (2)</td>
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<td></td>
<td></td>
<td>Total solar irradiance</td>
<td>YES TSP-700</td>
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<td></td>
<td></td>
<td>Spectroradiometer</td>
<td>Ocean Optics USB-4000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aerosols with size &lt;10 µm and &lt;2.5 µm</td>
<td>SKC Deployable particulate sampler</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aerosols size distribution</td>
<td>SIOUTAS-SKC</td>
</tr>
</tbody>
</table>

- Institute of Ecology “Fundación Miguel Lillo” - Tucumán

Contact: Dr. Juan A. González, Dr. Fernando Eduardo Prado
Instituto de Ecología - Fundacion Miguel Lillo. Miguel Lillo 251, 4000, Tucumán, Argentina. Email: lirios@cgcet.org.ar, fepra@csnat.unt.edu.ar

<table>
<thead>
<tr>
<th>Location</th>
<th>Measured Parameters</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Miguel de</td>
<td>26.83ºS, 65.22ºW, 400m. a.s.l.</td>
<td>UVB irradiance</td>
</tr>
</tbody>
</table>
Tucumán

PAR and Total solar irradiance

Projects in collaboration with: other Argentine institutions.

- Institute of the Bio-diversity and the Environment (INIBIOMA) - Río Negro

Contact: Dra. María Gabriela Perotti, Dra. María C. Diéguez, Dra. A. Patricia Perez
INIBIOMA-Centro regional Universitario Bariloche. Universidad Nacional del Comahue. Quintral 1250, 8400 Bariloche, Argentina. Phone: 54-2944-428505. Email: perottigaby@yahoo.com, dieguezmc@gmail.com, perezfotolab@gmail.com

<table>
<thead>
<tr>
<th>Location</th>
<th>Measured Parameters</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Carlos de Bariloche</td>
<td>Narrowband UV channels</td>
<td>GUV 500</td>
</tr>
<tr>
<td>41.15ºS, 71.28ºW, 700m. a.s.l.</td>
<td>Underwater broadband UV irradiance</td>
<td>Ocean Optics submersible spectrometer</td>
</tr>
</tbody>
</table>

During 2011 a new equipment will be installed:
- Automatic weather station
- CO₂ monitoring instrument
- Aerosols monitoring instrument
- Atmospheric Mercury monitoring instrument

Projects in collaboration with: other Argentine institutions, BBVA Foundation (Spain), European Union Program “Global mercury observation system”.

2. REGIONAL CALIBRATION ACTIVITIES

Three calibration activities of the South-American WMO Network instruments have taken place during 2010 at the Regional Calibration Center for South America - Buenos Aires Central Station of the Argentine National Weather Service. In September 2010 it was developed the IV Regional Intercomparison of surface ozone measurement instruments. In November 2010 it were realized the calibrations of both the Dobson ozone spectrometers and the UV erythemal solar irradiance instruments (UV-Biometers).

The World Meteorological Organization (WMO) Secretariat and the Argentine National Weather Service with close cooperation and assistance of the USA National Oceanic and Atmospheric Administration’s Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) coordinate Dobson calibrations.

The World Meteorological Organization (WMO) Secretariat and the Argentine National Weather Service with close cooperation and assistance of the Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, coordinate UV-Biometers calibration. The Solar Light 501A reference radiometer from PMOD/WRC was used as reference instrument for this intercomparison.

3. THEORY AND MODELING

- Program for the Study of Atmospheric Processes Related to the Global Change (PEPACG UCA/CONICET) – Capital Federal

Contact: Dr. Pablo O. Canziani
PEPACG is the principal research Group where modeling of the physical-chemical properties of the atmosphere, as well as climatological studies of the coupled troposphere-stratosphere system are carried out. Particularly, PEPACG study the dynamics and climatology of the coupled system Troposphere-Stratosphere over the Southern Hemisphere, included the ozone layer and solar UV radiation. PEPACG is cooperating with University of Reading (U.K.) in the development and application of an adaptive grid Chemistry Transport Model, called Adaptive Mesh Refinement or AMR-CTM, which is currently a 2-D model whose resolution adapts locally in order to better solve the evolving stratospheric features. Also included in this work is an interaction with Max-Planck Institut fur Atmospheric Chemie, University of Mainz, in order to install in the AMR-CTM the MECCA-MESSY Chemistry module. Work includes the development of a 2-D and 3-D trajectory code. Areas of study in the period 2008-2011 included: - Dynamic Climatology of the Tropopause over Argentina. - Sudden climate perturbations in the Southern Hemisphere’s troposphere and stratosphere. - Cirrus, Tropopause and interchanges troposphere-stratosphere over Argentina.

Modeling of UV radiative transfer in the atmosphere is still limited to 1-D codes using principally the Discrete Ordinates algorithm with semi-spherical correction in the direct component, which is useful for cases of homogeneous-layers composition of the atmosphere.

4. DISSEMINATION OF RESULTS

Data Reporting

The SMN sends total ozone measurements as well as the ozonesonde data routinely to the WOUDC. The database is currently being transformed to the required CSV format. Surface ozone retrievals are submitted to the corresponding center in Japan.

Information to the public

The SMN continues providing a daily national UV Index forecast map for clear and cloudy conditions both in its web page (http://www.smn.gov.ar) as well as to the massive diffusion media. All mentioned institutions often provide information to the media. During the ozone hole season SMN, CADIC and PEPACG send to the media frequent reports describing the ozone hole evolution, using satellite retrievals and ground-based information.

In turn, over 50 plenary conferences within congress and other open to the public were given in the different specialties in the period 2008-2011.

Each November, the Argentine Dermatological Society carries out the National Campaign for prevention of the skin cancer.
5. HIGHLIGHTED RESULTS 2008-2011

- Austral Spring Stratospheric and Tropospheric Circulation Interannual Variability [Agosta and Canziani, 2010]

Figure 2: a) October mean TOC 1979-2005 climatology (contours interval: 5DU). Composite residual TOC maps for upper (b) and lower (c) VarMax index quartiles (contour interval 10DU).

- Increased UV radiation at Southern Sub-polar Latitudes in the period 1997–2005 [Pazmiño et al., 2008]

Fig. 6. (1) Number of vortex occurrences (VO), (2) TOC differences and (3) UVI changes for September (a), October (b) and November (c) months over the 1997–2005 period. Latitude band 50°S–60°S is emphasized. Only data corresponding to reflectivity values lower than 27.5%, 22.5% and 12.5%, respectively, are considered.
- Small total O3 columns and high UV radiation over the southern tip of South America during the 2009 Antarctic O3 hole season [de Laat et al., 2010]

Figure 3. Time series of daily average (left) UVI values and (right) MSR total O3 columns (in DU) for the period 1 September – 1 January. The shaded areas indicate the occurrence intervals of total O3 columns and UVI values for 1979–2008 for the latitude band 52°–56°S. Occurrence intervals are calculated on a daily basis, and intervals are shown for 66%, 95% and 99% as well as the minimum and maximum MSR values. The numbers indicate the percentage of total O3 columns or UVI values that fall within this range. The red/yellow bars represent the 2009 values for the area 52°–56°S, 77°–65°W (see Figures 1 and 2). Mean values are indicated by the black dots, the 2σ root-mean-square of O3 and UVI values within the area are shown by the yellow bars, and the minimum and maximum range within the area are indicated by the red bars.

- UVR exposure for biological systems along a latitudinal gradient [Vernet et al., 2009]

Table 7. Statistics of the positive and negative UVR anomalies (1995-2002), a) for DNA and b) for phytoplankton photosynthesis-weighted irradiances.

<table>
<thead>
<tr>
<th>Site</th>
<th>Mean +/- Standard Deviation</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive Anomalies</td>
<td>Negative Anomalies</td>
</tr>
<tr>
<td>Jujuy</td>
<td>0.155 +/- 0.137</td>
<td>-0.138 +/- 0.115</td>
</tr>
<tr>
<td>Buenos Aires</td>
<td>0.098 +/- 0.094</td>
<td>-0.087 +/- 0.100</td>
</tr>
<tr>
<td>Santiago</td>
<td>0.059 +/- 0.055</td>
<td>-0.061 +/- 0.086</td>
</tr>
<tr>
<td>Valdivia</td>
<td>0.072 +/- 0.076</td>
<td>-0.061 +/- 0.083</td>
</tr>
<tr>
<td>Bariloche</td>
<td>0.070 +/- 0.078</td>
<td>-0.059 +/- 0.081</td>
</tr>
<tr>
<td>Trelew</td>
<td>0.063 +/- 0.069</td>
<td>-0.057 +/- 0.077</td>
</tr>
<tr>
<td>Punta Arenas</td>
<td>0.043 +/- 0.065</td>
<td>-0.027 +/- 0.034</td>
</tr>
<tr>
<td>Ushuaia</td>
<td>0.043 +/- 0.063</td>
<td>-0.028 +/- 0.034</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>Mean +/- Dev</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jujuy</td>
<td>0.594 +/- 0.477</td>
<td>-0.661 +/- 0.423</td>
</tr>
<tr>
<td>Buenos Aires</td>
<td>0.466 +/- 0.258</td>
<td>-0.531 +/- 0.421</td>
</tr>
<tr>
<td>Santiago</td>
<td>0.284 +/- 0.187</td>
<td>-0.377 +/- 0.375</td>
</tr>
<tr>
<td>Valdivia</td>
<td>0.474 +/- 0.260</td>
<td>-0.479 +/- 0.428</td>
</tr>
<tr>
<td>Bariloche</td>
<td>0.363 +/- 0.219</td>
<td>-0.488 +/- 0.439</td>
</tr>
<tr>
<td>Trelew</td>
<td>0.294 +/- 0.156</td>
<td>-0.435 +/- 0.392</td>
</tr>
<tr>
<td>Punta Arenas</td>
<td>0.327 +/- 0.292</td>
<td>-0.291 +/- 0.262</td>
</tr>
<tr>
<td>Ushuaia</td>
<td>0.300 +/- 0.293</td>
<td>-0.279 +/- 0.261</td>
</tr>
</tbody>
</table>

Table 7. Statistics of the positive and negative UVR anomalies (1995-2002), a) for DNA and b) for phytoplankton photosynthesis-weighted irradiances.
- Remote sensing of stratospheric O₃ and NO₂ using a portable and compact DOAS spectrometer [Raponi et al., 2011]

Figure 2. NO₂ VCD variability at Marambio Antarctic Station during (a) the sunrise and (b) the sunset.

Figure 3. O₃ VCD variability at Marambio Station, during (a) the sunrise and (b) the sunset.

- Effect of clouds on surface UV-B and total solar irradiance at Córdoba, Argentina [López et al., 2009]

Fig. 5. Modified Cloud Modification Factors (CMFm) as a function of wavelength for cirrus and cumulus. In the stratocumulus case the CMF was calculated.
- Leaves of Citrus aurantifolia’s sensibility to solar UV-B radiation [Ibáñez et al., 2008]

Fig. 2. Changes in the level of photosynthetic pigments in prior-developed and post-developed leaves of C. aurantifolia grown with and without solar UVBR. (a) Chlorophyll a; (b) chlorophyll b; (c) total chlorophyll; and (d) carotenoids. Data correspond to the mean of two independent experiments carried out during 2005 and 2006 year. Each bar represents the mean (±SD) of four replicates. Columns within a grouping marked by a different letter are significantly different at P<= 0.05.

- UVR-induced photoinhibition of summer marine phytoplankton communities from Patagonia [Villafañe et al., 2008]

Fig. 7. Output from the multiple linear regression models as compared to the data obtained for the assimilation numbers for the PAR treatment in IC (lg chl a)-1 h-1 (a), and for UVR inhibition (b). The thin lines and symbols are the experimental data while the thick lines are the modeled data; the broken lines represent the 95% limit. The vertical bars in each panel are the residuals from the models.
6. RELEVANT SCIENTIFIC PAPERS 2008-2011


Agosta E.A. and Canziani, P.O., Interannual variations in the Zonal Field of the subpolar latitudes Total Ozone Column during the Austral Spring. Geoacta, accepted 2010.


Lakkis S.G., P.O. Canziani, A comparative analysis of the temperature behavior and multiple tropopause events derived from GPS, radiosonde and reanalysis datasets over Argentina, as an example of Southern mid latitudes. Revista de Climatologia, 9, 1-14. 2009.

Pazmiño Andrea, Godin-Beekmann Sophie, Luccini Eduardo, Piacentini Rubén, Quel Eduardo and Hauchecorne Alain. Increased UV radiation due to polar ozone chemical depletion and vortex occurrences at southern sub-polar latitudes in the period [1997-2005]. Atmospheric Chemistry and Physics, 8, 5339-5352. 2008.


7. FUTURE PLANS

In view that the main problems concerning the ozone depletion and its consequences will affect particularly the Argentine territory and its neighborhood for many years, future research activities will be a continuation and extension of current investigations. Then, future plans and recommendations are basically similar to those of the ORM-2008. Among the principal subjects:

- Evolution of the total ozone column over the region. Trends of ozone and UV levels. Dynamics, chemistry and inter-annual variation of the Antarctic ozone hole.
- Study of the influence of the near vortex and ozone hole incursions over Patagonia
- Study the relationship between tropospheric and stratospheric dynamic and climatic behavior and the links with ozone change.
- Ozone and climate change interactions.
- The chemistry and dynamics of stratosphere-troposphere exchange.
- Cirrus clouds, the tropopause, and ozone.
- Effects of the UV radiation on the human health in the region. Biological effects of the UV radiation, especially on crops in the region.
- Studies of solar radiation and its components and biological effects in Antarctic Peninsula.
8. NEEDS AND RECOMMENDATIONS

- Antarctica and the Southern Cone of South-America must be still for many years considered the most critical region in the world related to ozone depletion and its consequences.

- The Antarctic Ozone Hole must be continuously monitored by all means for many years. Permanent ground-based and satellite-based instruments are an essential complement for this task.

- The current monitoring networks must be maintained in qualified operation. One main problem faced by Argentina, related to monitoring and research activities, has been the lack of adequate support to maintain such activities over time. This is particularly relevant since at this stage the ozone layer seems to be reaching the peak state of its depletion and sensitive monitoring and important research is necessary to determine the future evolution and the start of the possible recovery ozone layer and ozone hole.

- There is growing evidence that the ozone layer is both acting in response to current climate variability and change as well as affecting climate over the Southern Hemisphere. Such coupled studies are an important component of understanding needed to assess climate variability and climate change processes. Hence it is important to strength all atmospheric measurements relevant to both processes. This also requires a strong support in capacity building at the technician and research levels to continue both with monitoring and relevant research as proposed by SPARC-WCRP and its links with the various WCRP initiatives.

- The Argentine National Weather Service, main national institution for atmospheric monitoring, is still undergoing a mayor restructuring and requires support for its new strategies, in particular monitoring and calibration aspects, and replacement of obsolete and obsolescent equipment and facilities. It also requires including new monitoring activities to provide relevant information for both these topics, including long-term monitoring.

- It is essential that research activities be enhanced regionally and globally in the double-pronged aspect of ozone depletion and change within the framework of Climate Change due to the many joint aspects and couplings that are now starting to be known. Hence it is essential to sustain national and international projects regarding these as relevant issues.

- Until the recovery of the ozone layer does not become evident and sustained in time and as long as the international scientific community does not have a clear and fully developed picture of the linkages between the ozone layer, the stratosphere and the troposphere, within the scope of climate change and variability such research must be supported, nationally, regionally and internationally.

This report was prepared by Dr. Eduardo Luccini and Dr. Pablo Canziani, based on the infrastructure, activities and achievements of the Argentine institutions and research groups involved in Vienna-Convention-related monitoring and research activities. We gratefully acknowledge all the experts and institutions that provided the information to elaborate this Report.

*****
ARMENIA

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss.

The GAW regional station #410 Amberd carries out the measurements of total ozone. The station is equipped by Dobson spectrophotometer D-044 (Fig. 1).

The begun in 1990 measurements of total ozone on the local network ozone-observing station Arabkir in city Yerevan are continued. The station is equipped by filter ozonometer M-124.

The results of carried out in Armenia during 1991-2010 measurements of total ozone are presented on Fig. 2.

Profile measurements of ozone and other gases/variables relevant to ozone loss - not made.

UV measurements - not made.

Calibration activities - the calibration of Dobson spectrophotometer D-044 in European RDCC in Hohenpeissenberg was executed in 2010.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The results of measurements total ozone at Dobson-station Amberd showed, that after 1999 the general tendency to its decrease to a level 1993-94 was observed.

The study of connection between changes of total ozone and the morbidity of population by skin cancer begun in [1] is continued.
According to results and recommendations of DQ Workshop (Feb. 2001, Hradec Kralove, Czech Republic) is undertaken the reanalysis of Total Ozone data set for 2005-2010.

THEORY, MODELLING, AND OTHER RESEARCH

Using the climatic parameters of seasonal changes of total ozone above Armenia, carried out during 1990-2006, solar extraterrestrial spectrum in the wavelength range from 280nm to 400nm, coefficients of UV absorption by ozone, and the electronic map of surface with horizontal step of 300 m, is constructed the computer model of solar radiation transfer in atmosphere and of its distribution on the territory according to parameters of relief and albedo of surface.

In particular, are defined the climatic parameters of distributions of the hourly, daily, monthly and annual sums of UVR (also separately for UV-A and UV-B,C), UV Indexes and the times in order to receive of 1 MED (for 4 skin types) in various regions of country in various time of day, using erythematous CIE spectra of McKinlay and Diffey and Practical Guide “Global Solar UV Index”.

According to the recommendations of 7ORM the following researches are carried out.

- The results of last researches of influence of radiation on human health, begun in [1], will be published in this year.
- The processing of results of total ozone measurements, executed in 1990-1998 in different regions of Armenia is undertaken. The received data will be published this year.
- The comparative analysis of modern results of total ozone measurement at stations "Arabkir" (ozonemeter M-124) and "Amberd" (Dobson spectrophotometer) with the purpose to find correction of algorithm of calibration of filter-ozonometers connected with aging of filters.
- As a result of participation in Dobson Quality Workshop (February, 2011, SOO CHMI, Chech Republic) both received estimations and recommendations the recalculation of some data on measurement ozone at station "Amberd" is undertaken.

DISSEMINATION OF RESULTS

Data reporting

Monthly results of measurements of total ozone at station Amberd are regularly submitted in the WOUDC.

On the basis of results of measurements of total ozone at stations Amberd and Arabkir is continued the creation of local computer bank.

Are studied the climatic resources of different components of balance of UV solar radiation and with their decomposition on separate standard spectral intervals: UV, UV-A, UV-BC radiation, - in all regions of territory of Armenia.

Information to the public

Using the forecasts of total ozone distribution above northern hemisphere from WMO/GAW ozone mapping program and forecasts of cloudiness with use of the model of solar irradiation are developed the daily maps of forecasts of distribution of UV Indexes on the territory of Armenia. The forecasts of UV indexes for mostly inhabited areas of Armenia, calculated according to "UV Index for Public" (COST-713 Action UVB Forecasting) on the base of daily maps of UV Indexex, are included in the weather forecasts for dissemination to the public via mass media.

Relevant scientific papers


PROJECTS AND COLLABORATION

Execution of Dobson program is being implemented in scientific and methodical collaboration with DWD (Germany) and SOO CHMI (Czech Republic).

At the station Amberd is being created the first level station for EMEP for measurements of concentrations of pollution in precipitations and of solid particles in air, also of SO$_2$, NO$_X$ and surface ozone O$_3$.

The model of solar (in particular, UV) irradiation was developed for implementation of national project "Estimation of resources of solar radiation on the territory of Armenia" (2005-2007).

FUTURE PLANS

The results of modeling of a climatic regime of UV irradiation are used for development of results begun in [1] research of vulnerability of health of the village and urban population to increase of ultraviolet radiation and the influence on vulnerability of height of location in all regions of territory of Armenia. The research is based on long-term statistics on morbidity of the population of Armenia by skin cancer and on results of total ozone measurements.

NEEDS AND RECOMMENDATIONS

The capacities of weather station Amberd allow performing of national and international projects on monitoring of solar radiation, investigations of vertical distribution of ozone with balloon sondes, lidar observations, aerosol transfer and transboundary air pollution in region of South Caucasus.

The recommendation: it is necessary periodically to organize DQ Workshops.

Need: it is necessary for ozone-experts from developing countries enabling of short-term practice in leading scientific centres of the world for improving of their scientific and technical potential.
AUSTRALIA

1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss.

The Australian Government’s Bureau of Meteorology (BoM) has primary responsibility for monitoring total column ozone.

- The BoM Dobson network consists of stations located at Brisbane, Darwin, Macquarie Island, Melbourne, and Perth (Perth is operated in conjunction with NOAA). Brisbane, Macquarie Island and Melbourne have records stretching back to 1957.

A number of universities also undertake some total ozone monitoring:
- A Brewer spectrophotometer operated by the University of Tasmania (operating costs financed by the BoM).
- Two Mk IV Brewer spectrophotometers operated by the Queensland University of Technology.
- Remote sensing FTIR operated by the University of Wollongong (the measurements are made as part of the Network for the Detection of Atmospheric Composition Change, NDACC).

Measurements of ozone depleting substances (CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride and methyl chloroform) are made by GC-ECD and GC-MS techniques at Cape Grim, Tasmania, and Aspendale, Victoria by CSIRO and BoM.

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

Regular ozonesonde measurements are taken by the BoM at:
- Macquarie Island (weekly flights since 1994)
- Melbourne (weekly flights, with a program having operated from various locations around Melbourne since 1965).
- Davis station, Antarctica, in conjunction with the Australian Antarctic Division (AAD), since 2003. Flights are currently weekly for the whole year. In conjunction with these ozonesonde flights, the AAD operates a Rayleigh/Mie/Raman lidar at Davis to measure temperature and aerosol loading in the stratosphere.

1.3 UV measurements

1.3.1 Broadband measurements

The Australian Radiation and Nuclear Safety Agency (ARPANSA) has maintained a network of UV detectors in capital cities around Australia since 1989. In 1996 the instruments were changed over to Solar Light UVB 501 broadband biometers. Kingston, Tasmania was added in 2007 and more recently Canberra was added as a new site (December 2010). Biometers have also been collecting data at Macquarie Island since 2001 and the Australian Antarctic stations Mawson, since 2002, and both Davis and Casey since 1996. The sites in Antarctica are currently being upgraded with new biometers. The biometers are intercompared at Yallambie before placement in the field. Spectral measurements with traceable calibrations at Antarctic mainland stations commenced in 2010 at Davis and Mawson. In 2011 a Bentham spectral system was installed at Davis for at least two summers with the aim of providing a longer duration series of calibrated spectral measurements, with the aim to subsequently extend this to both Mawson and Casey as well.
The Queensland University of Technology uses Solar Light 501 UV biometers in Brisbane to provide a live UV Index update to the public, as well as operating a national network of Yankee UVB pyranometers, located in Brisbane, Townsville, Canberra and Hobart.

1.3.2 Narrowband filter instruments

N/A

1.3.3 Spectroradiometers

The BoM owns and operates two NIWA-designed spectroradiometers at Alice Springs and Melbourne.

A UV spectroradiometer generated data at Cape Grim between 1999 and 2006. A repaired spectrometer is awaiting site works for redeployment and a replacement system has been developed at BoM and is undergoing field testing.

ARPANSA currently uses a Bentham spectroradiometer based at the Melbourne site to simultaneously measure solar UVR and transfer a traceable calibration to the biometers before installation. This instrument commenced measurements in December 2008 and has been operating continuously since then.

1.4 Calibration activities

The BoM holds the RA V Dobson standard and operates the Regional Dobson Calibration Centre (RDCC) for Australia. The regional standard Dobson is inter-compared regularly with the world standard Dobson. ARPANSA meets the WMO's instrument specifications and characterization as a health advisory agency that provides the daily UV levels. CSIRO/BoM ODS measurements employ calibration standards supplied by the Scripps Institution for Oceanography (USA) and the data are regular compared to data collected at Cape Grim by NOAA (USA), U. East Anglia (UK) and NIES (Japan).

An Australian Dobson expert attended the WMO Dobson Data Quality Workshop recently held in Hradec Kralove, Czech Republic.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozonesonde and Dobson data from the Bureau network are available through the WOUDC and are frequently used for purposes such as satellite calibrations and trend analysis.

A clear-sky UV Index Climatology (1979-2007) has been developed and is available at: http://www.bom.gov.au/jsp/ncc/climate_averages/uv-index/index.jsp.

Analyses of ozonesonde data from Davis station (Antarctica) are used in the following areas;

- Investigation of polar ozone loss processes and ozone variability through project 737 of the Australian Antarctic program (e.g. Klekociuk and Tully, 2007; Innis and Klekociuk, 2006; see also http://cs-db.aad.gov.au/proms/public/projects/report_project_public.cfm?season=0708&project_no=737)
• Near real-time analyses of ozone in the Southern Hemisphere winter (WMO Antarctic Ozone Bulletins; see http://www.wmo.ch/pages/prog/arep/gaw/ozone/index.html)
• Satellite and instrument validation (e.g. Dupuy et al., 2008).

Existing UVR measurements have had difficulties in detecting any increase in UVR due to the natural variability in solar UVR at the earths surface (Peter Gies et al., 2004).

ODS data collected at Cape Grim have been used in recent international assessments of climate change (IPCC 2007) and ozone depletion (WMO 2011), and are reported biennially in Baseline (Krummel et al., 2007). The data have been used in the Commonwealth Government State of the Environment Report (Beer et al., 2006).

3. THEORY, MODELLING, AND OTHER RESEARCH

Using the UK Chemistry and Aerosols (UKCA) model within the Australian Community Climate and Earth-Simulation System (ACCESS) framework, researchers at the University of Melbourne and CSIRO, along with collaborators at the New Zealand National Institute of Water and Atmospheric Research (NIWA) are developing the capability of a fully coupled atmosphere-chemistry (and eventually ocean) model. The model will be used to simulate the stratospheric ozone layer chemistry and dynamics with the goal of a better understanding of the impacts of the development and recovery of the Antarctic Ozone Hole on the climate of the southern hemisphere.

Recently Arblaster, Meehl and Karoly (Arblaster et al. 2011) have studied the impact of ozone depletion and recovery on southern hemisphere climate.

With the implementation of the ACCESS modelling system, an Ozone and UV forecast (ACCESS-O3+UV) system has been developed to predict the ozone field within the ACCESS framework. The assimilation and forecast system provides extended ozone forecast from 3d variational (3dVAR) assimilation of ATOVS radiances and a modified version of the ACCESS-NWP unified model (UM) (Lemus-Deschamps et al. 2008). The UV and ozone forecast system http://www.bom.gov.au/uv/index.shtml is under continuous development.

Satellite and surface measurements have been used to investigate ozone and UV changes over Australia and skin cancer incidence (Lemus-Deschamps and Makin, 2011; Makin and Lemus-Deschamps, 2011).

Studies of the Antarctic Ozone Hole in recent years have been made in Tully et al. (2008, 2011). Recent analysis by Salby et al. (2011) reports the strong control of inter-annual variability in the size of the Antarctic Ozone Hole by stratospheric dynamics, and the recent unambiguous sign of ozone recovery.

Work by Innis and Klekociuk (2006) and Alexander et al. (2011) has quantified the effects of planetary waves and orographic gravity waves, respectively, on the formation of Polar Stratospheric Clouds.
4. DISSEMINATION OF RESULTS

4.1 Data reporting

Ozonesonde and Dobson data from all Bureau of Meteorology stations are archived at the World Ozone and UV Data Centre (WOUDC).

Measurements of column amounts from the FTIR system at Wollongong are reported via the Network for Detection of Atmospheric Composition Change (NDACC) database (see http://www.ndsc.ncep.noaa.gov/data/), as are spectral UV data from Alice Springs.

4.2 Information to the public

A UV forecast is issued daily by the Bureau of Meteorology. The UV forecast is important because approximately 380,000 Australians still get skin cancer every year. The UV forecast is released to the public by the Bureau of Meteorology regional office in each state and it is provided to the media as part of the weather report (Deschamps et al., 2006). It is also available at http://www.bom.gov.au/uv/index.shtml, and it is extensively used in Australia’s SunSmart promotional and educational campaigns.

ARPANSA provide measured real-time UV levels which are updated every minute. A plot of the UV levels for Australian sites is available on the ARPANSA web site at http://www.arpansa.gov.au/uvindex/realtime/index.cfm. Historical UV index data since 2004 is also available on the ARPANSA web site at http://www.arpansa.gov.au/uvindex/monthly/ausmonthlyindex.htm.

The Queensland University of Technology’s Aus Sun Research Lab maintains a website giving five-minute updates of the UV Index in Brisbane: http://www.uv.hlth.qut.edu.au/community/uvindex.jsp

Ozone analyses and forecasts are used by a number of groups to issue statements on the development of the ozone hole each year.

4.3 Relevant scientific papers


E. Dupuy, K. A. Walker, J. Kar, et. Al, 2008: Validation of ozone measurements from the 

Peter Gies, Colin Roy, John Javorniczky, Stuart Henderson, Lilia Lemus-Deschamps and 
Colin Driscoli, 2004. Global Solar UV Index: Australian Measurements, Forecasts and 

Structure and long-term change in the zonal asymmetry in Antarctic total ozone during spring. 

Innis, J.L., Klekociuk, A.R., 2006: Planetary wave and gravity wave influence on the 
occurrence of polar stratospheric clouds over Davis Station, Antarctica, seen in lidar and 

Klekociuk, A.R.,and Tully, M.B., 2007: Seasonal variation of ozone above Macquarie Island 
and Davis BMRC Research Letters 6. 12-16.

Lemus-Deschamps, L. and J. Making. 2011: Fifty years of changes in UV Index and skin 
cancer in Australia: Submitted to Int.J. Biometeorol, 23 March, 2011

Lemus-Deschamps L., 2007: The Ozone and UV Forecasting System, Presented at the 

Lemus-Deschamps L., J. Easson and P. Shinkfield, 2007: Changes in Ozone and UV Index of 
2007.

Lemus-Deschamps L., B. Tacal, L.Huntington, J. Easson and P. Shinkfield, 2007: Ozone and 
UV Index over Australia (1958-2004). Presented at the AMOS Conference, Adelaide, 
Australia, February 2007.

and Media Weather Reports. UV Radiation and its Effects, Report of the NIWA Workshop, 

Lemus-Deschamps L., L.Rikus, S.Grainger, P.Gies, J.Sisson and Z.Li, 2004: UV index and 

Lemus-Deschamps Lilia, Lawrie Rikus and Peter Gies, 1999: The operational Australian 

and climate change for skin cancer prevention in Australia: submitted to Australian New 
Zealand Journal of Public Health, 23 March 2011)


Black Saturday bushfire smoke in the lower stratosphere observed by OSIRIS on Odin, J. 

Tully, M.B., Klekociuk, A.R., Deschamps, L.L., Henderson, S.I., Krummel, P.B., Fraser, P.J., 


5. PROJECTS AND COLLABORATION

Information on Australian activities related to ozone and UV is shared through the *Australian Ozone Science Group*, co-ordinated by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), which has led to increased co-operation between agencies and institutions.

The Bureau of Meteorology has ongoing collaboration projects with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on UV Index validation against surface measurements and with SunSmart (Cancer Council Australia) on the use of the UV Index to promote sun protection; and

The BoM/AAD ozonesonde and AAD lidar measurements at Davis station in Antarctica have contributed to the International Polar Year cluster project ORACLE-O3, and the CONCORDIASI and MATCH campaigns.

A number of Australian scientists contributed as lead-authors, co-authors, contributors or reviewers of the 2010 Scientific Assessment of Ozone Depletion, supported by DSEWPC.

6. FUTURE PLANS

- Total column FTIR measurements of ozone and related trace gases at Davis station are currently being validated by the AAD.
- A low-cost UV spectroradiometer is also being developed by the BoM and is currently being field-tested.

7. NEEDS AND RECOMMENDATIONS

Continued provision and development of international data archival facilities (e.g. WOUDC) and instrument calibration standards and inter-comparisons (e.g. through NDACC and WMO).
AZERBAIJAN

Azerbaijan Republic ratified Vienna Convention on Protection of Ozone Layer, Montreal Protocol; London, Montreal and Copenhagen amendments to Montreal Protocol. The Project of “Implementation of National Program to recover and recycle refrigerating agents” was prepared with direct support of UNEP and UNDP. GEF ratified the project in 1998 in order to give a support. As a result of its implementation ozone depleting substances were reduced by 307.4 tones (32% of consumption in 1996 year). Realization of these project finished in 2002. Project consist of a few components like investments into exploitation and using of refrigeration equipment sector, fire safety activities, after realization of this project reconstructions works have been made in the companies producing home and industrial refrigeration installations. The Ministry of Agriculture reported to the Climate change and Ozone Center of National Hydrometeorological department that methyl bromide is not being imported into Azerbaijan since 1997. As a result of project import of CFC and halons was suspended in January 2006. Besides, legal documents were formulated concerning taxes on imports of ODS and licensing systems to monitor and control of ODS import and the ban on imports of equipment which uses ODS.

Systematic observations of general ozone concentrations in upper layers of atmosphere in Azerbaijan began in January of 1995, where ozonometer (of Russian production) was used in meteorological station of Baku (the capital of Azerbaijan). The results of observations were monthly reported to Main Geophysical Observatory of Russian Federation.

In 1997 the equipment broke and needed fixing. Because of absence of financing it was not possible to send the equipment to Russia for repair. At this moment the observations of ozone layer are not conducted in Azerbaijan.

Unfortunately the absence of financial resources of Government doesn’t let to conduct these works fully. We need financial support to restart continuous observations of ozone layer in Azerbaijan.
BELARUS

Following Belarus' accession to the Customs union, all legislative acts (laws, decisions, instructions) regarding ODS circulation, certification and custom charges have been unified with those of Russian Federation and Kazakhstan since January 1st, 2010. As a result of the government reorganization, the Ministry of Education is now in charge of ozone monitoring procedures, whereas the international cooperation is assigned to the Ministry of Environmental Protection and Natural Resources. In December, 2008 instruction on ODS treatment has been approved in Belarus.

1. OBSERVATIONAL ACTIVITIES

Belarus continues to design instrumentation as well as develop monitoring, calibration procedures and the archiving of stratospheric & tropospheric ozone, nitrogen dioxide, aerosols, surface UV radiation data and vertical lidar profiles of stratospheric & tropospheric ozone and aerosoles.

Within the framework of the National Antarctic program the ozonometer PION and the spectroradiometer PION-UV have been specifically modified to be used in polar areas of the Earth. We have also engineered a small-sized surface ozone concentration analyzer on the basis of a semiconductor sensor, a small-sized model of a tropospheric lidar and the mobile monitoring system of ice and snow cover condition.

1.1.1 Column measurements of ozone

In 2007-2010 the monitoring of total ozone column was carried out at the Minsk Ozone Station (Minsk, 27.469E, 53.833N).

Column ozone values were retrieved using the Stamnes’ procedure from spectral irradiance measurements made with the spectroradiometer PION-UV and a new filter radiometer PION-F, the direct-sun and zenith-sky radiance measurement procedures realized with modified filter ozonometers M124-M.

The construction of the PION-F has no moving elements. PION-F is designed for all-weather application in a completely automated mode. Systems of the photometer spectral selection are similar to the M124 filter systems, but radiation registration is realized from a hemisphere in two measuring channels simultaneously. To enhance sensitivity of the system and reduce a stray exposure, a solar-blind PMT has been used in the device (see Section 3).

1.1.2 Total nitrogen dioxide measurements

Monitoring of nitrogen dioxide has been performed at the Minsk Ozone Station since 2007. In 2009-2010 the nitrogen dioxide column values were measured with a new DOAS zenith-sky system constructed on the base of the Oriel-260 spectrometer. The measurement procedure included the nitrogen dioxide column retrieval technique elaborated at the Obuchov’s Institute of the Atmosphere Physics (Russia).

A new MAX-DOAS system has been designed for measuring vertical nitrogen dioxide concentration profiles.

1.1.3 Surface ozone monitoring

Measurements of surface ozone concentration have been carried out at the Minsk Ozone Station and Berezina National Park EMEP station employing DOAS instrument TRIO-1 which has passed standard certifications in the Belarus State Institute of Metrology. The absolute error did not exceed ±1.45 ppb in the ozone concentration range of 0-200 ppb.

For surface ozone monitoring a TEI 49C ozone analyser has also been employed particularly for calibration. A compact device to measure the surface ozone concentration is originated at NOMREC and based on a new type of semiconductor nickel oxide sensor.
Falls in surface ozone concentrations

At the location of the Minsk ozone station one has observed the effect of non-periodic short-term deep surface ozone falls (for a few minutes time). The phenomenon has been detected by instruments of the various types. The fall depth depends on the instrument time constant. The problem needs further analysis and discussion.

1.2 Profile measurements of ozone and aerosols

The atmosphere monitoring has been conducted at the Institute of Physics, National Academy of Sciences of Belarus since 1985.

In 2007-2010 two wavelength (355 and 532 nm) lidar measurements of stratospheric aerosol parameters were performed as well as ozone concentration profiles (266 nm).

A type of lidar system was developed using the transmitter at the wavelength 281.7 nm on the base of solid-state stimulated Raman scattering converter. The system provides measurements of ozone concentration in the layer of 1 – 10 km (see Figure 3).
1.3 UV Radiation Measurements

Regular measurements of UV radiation surface level with a portable spectroradiometer PION-UV have started at the Minsk Ozone Station since September, 2001. PION-UV is an automated double grating spectrometer having a spectral range of 280-450 nm and a slit function of 0.9 nm. It can register more than a hundred of total UV irradiance spectra per day.

To expand the ongoing activities a new UV-B monitoring site was set up in 2008 at the Naroch National Park (the north-western part of Belarus). The new designed automated double-channel narrow-band photometer PION-F is operated at the site.

1.4 Calibration Activity

PION-UV calibrations in the spectral range of 285-450 nm were regularly carried out with a 300 W tungsten band-lamp certified by the Russian National Standard Agency.

M-124M instruments were calibrated using a WMO regional standard (Dobson N108 spectrophotometer) in St. Petersburg, Russia.

We conduct also on a regular basis a parallel data comparison with satellite measurements.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

As a result of the time series analysis for total ozone a shift of the ozone annual course maximum over the territory of Belarus for earlier terms is revealed. In 80’s the maximum monthly average values were observed in April, but since the middle 90’s the annual maximum has been shifted to March.

The analysis of repeatability and fluctuations of macroscale circular processes over the European sector of the Northern hemisphere (classification of circular processes and calendars of circulating epochs according to B.L. Dzerdzevsky) has been conducted. We have discovered that through the Aprils, 1979-1997, a number of days with a meridional northern circulation showed a significant negative trend, whereas increase of a meridional northern circulation is observed in March. Comparison of days number with a certain type of circulation to monthly average TO values of the same periods shows that shift in the annual ozone maximum to earlier terms are connected with fluctuations of macroscale circular processes in the Northern hemisphere (Figures 4, 5)

Figure 4. Trends of the TO monthly average values and the number of days with a meridional northern circulation for April, 1979-1992.

Figure 5. Trends of the TO monthly average values and the number of days with a meridional northern circulation for March, 1997-2009.
3. THEORY AND MODELLING

Some developments have been made advancing the measurement procedure as well as the Stamnes' ozone retrieval technique.

Following the analysis of possibilities for various techniques of TO measurement, one has defined that the errors of direct-sun measurements are comparable to those of zenith measurements in the order of magnitude at large solar zenith angles. Meanwhile, stability of zenith measurements if considering the atmospheric variations is essentially higher. Moreover, the best ratio between signal levels and stability of the TO retrieval algorithm is achieved while registering a signal by a cosine input device in the specially selected spectral intervals.

4. DISSEMINATION OF RESULTS

The data derived by the NOMREC along with the data collected at the Institute of Physics are submitted to and archived in the National database (NEMS). For now we are ready to submit the data in online regime to WOUDC.

4.2 Information to the Public

Mapping and UV Index forecast generated specifically for different regions have been realized since 2006. The UV Index short-term forecast made for the Belarus territory is submitted to the National news agency BelTA on a daily basis. These data are also available on the NOMREC site at http://ozone.bsu.by and on the official site of the NHMA at http://www.pogoda.by.

4. PROJECTS AND COLLABORATION

Monitoring of atmosphere is maintained within the framework of lidar net in CIS countries CIS-LiNet and European lidar network EARLINET.

Natural tests of the modernized M-124 model were performed during the seasonal Antarctic expedition (2006-2007). The model differs from the initial one by the combine interference-absorption filters and the solar-blind phototube. Three years of the seasonal observations at Molodezhnaja station have been thoroughly analyzed and prepared for a publication. Collaboration in this field continues with the MGO (St. Petersburg, Russia).

Further development of the MAX-DOAS procedures will be realized within the framework of the joint project of NFFII with Russian Federation aiming at the following inclusion of both sides into NDACC.

A compact device to measure concentration of surface ozone has been constructed on the basis of the nickel oxide sensor in NOMREC BSU. Tests of an experimental model of the device and parallel ozone measurements with the TEI 49C optical analyzer have yielded a good result. A conclusion has been drawn on a possibility for the further tests of the device in polar conditions resulting in producing the experimental sample of the device.

The analysis of surface ozone measurements is conducted in cooperation with the Institute of Physics (Vilnius, Lithuania).

5. FUTURE PLANS

Four more UV monitoring stations in different Belarus regions will be brought into operation within next 3 years equipped with the automated double-channel filter photometer PION-F. The device is also modified towards measuring TOA at large solar zenith angles and is currently undergoing through testing procedures aiming to be used at polar stations. From now on all three instruments PION, PION-UV, PION-F are commercially available.

The instrument for zenith observation of total nitrogen dioxide is planned to be compared to the regional standard in Zvenigorod (Russia).

The lidar system for sounding ozone in troposphere shall be brought into operation regime at the IP lidar station. A complex technical project on PION and PION-UV modernization is adopted aiming at providing regular measurements of ozone and UV radiation in Antarctica.
Instruments devised within the Antarctic program are ready for natural tests in the conditions of Antarctica. Unfortunately, there are some problems in a practical implementation of the program. A certain collaboration and support on this issue is much needed.

References

BELGIUM

1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss.

1.1.1 The Royal Meteorological Institute (RMI)

The RMI performs Daily Ozone column measurements with two automated Brewer spectrophotometers. One (nr 16) is a single monochromator, in use since 1983 and the other one (nr 178) is a double monochromator installed in 2001. Both instruments are operational in Uccle (Belgium).

Measurements with a Dobson spectrophotometer (nr 40) which started in 1971, continued until end of May 2009. As RMI has two Brewer instruments and a long overlap period with the Dobson instrument, the Dobson measurements were stopped. In agreement with WMO-GAW the instrument is now loaned to the University of Kiev (Ukraine) and is operational there.

The observations mentioned above take place at Uccle (50°48'N, 4°21'E, 100 m asl, complementary NDACC station (see http://www.ndacc.org) and station 053 in the WOUDC list).

In addition RMI started in January 2011 observations at the Belgian Antarctic station Princess Elisabeth with Brewer instrument 100, which was put at our disposal by KNMI in the Netherlands. The new Antarctic station is located at 71 deg south, 23 deg East, 1397m asl. It obtained nr 499 in the WOUDC list, and will be operational during the manned periods in the austral summer.

1.1.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

BIRA-IASB performs ground-based monitoring of the total column of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, processes and long-term trend studies, at:

- the International Scientific Station of the Jungfraujoch, Switzerland (46.5°N, 8.0°E, 3580 m asl): FTIR and SAOZ instruments. SAOZ measures O₃ and NO₂ columns in the UV-Vis spectral range, since 1990. The time series of FTIR data starts in the early eighties. The FTIR observations at Jungfraujoch are lead by ULg. In the second half of 2010, an additional MAXDOAS Instrument has been installed at the Jungfraujoch and provides stratospheric profiles of BrO, NO₂ and ozone as well as tropospheric abundances of NO₂, H₂O, O₃, H₂CO and aerosols.

- Harestua, Norway (60°N, 11°E): UV-VIS DOAS instruments, since 1994 (O₃, NO₂, OCIO, BrO)

- the Observatoire de Haute Provence (OHP), France (44°N, 8°E): UV-VIS DOAS instrument (O₃, NO₂, BrO columns), since summer 1998. The UV-VIS DOAS instrument has been upgraded with an off-axis capability (MAXDOAS) in 2000 and since then provides also tropospheric abundances of NO₂ and H₂CO.

- Ile de la Réunion (22°S, 55°E): FTIR observations (total column abundances and vertical distributions of O₃, halogenated and nitrogenated source and reservoir gases, and more) starting in summer 2002. Initially FTIR observations were made on a campaign basis, in Sept-Oct. 2002, August to November 2004, and May to November 2007. Since May 2009, the instrument is operated on a continuous basis. During the first FTIR campaign in 2002, simultaneous measurements at sea level and at high altitude (2200 m asl) were performed, allowing to infer columns in the boundary layer/low troposphere, via a differential approach. From August 2004 to July 2005, a UV-Vis MAXDOAS instrument (O₃, NO₂, BrO, H₂CO columns and tropospheric abundances) was operated at the same site as the FTIR instrument.

- Ile de la Réunion (22°S, 55°E): in September 2010, BIRA-IASB has installed a new more performant FTIR instrument for high-precision measurements of greenhouse gases (CO₂ and CH₄). The instrument will become operational in summer 2011. As the evolution of the stratospheric ozone layer is influenced by climate changes, these measurements are relevant indirectly for understanding ozone in the future.

BIRA-IASB is involved in several satellite missions measuring the total column of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, process and long-term trend studies, by:
Global Ozone Monitoring Experiment (GOME), measuring aboard ESA’s ERS-2 platform since 1995 the column of O₃, NO₂, BrO and OCIO. BIRA-IASB is a co-proposer of the instrument, plays a key role in scientific developments and geophysical validation of the operational GOME Data Processor for total ozone and NO₂ run at DLR (Germany) on behalf of ESA (Lambert et al. 1999, 2000; Spurr et al. 2004; Van Roozendael et al. 2007; Balis et al. 2007; Loyola et al. 2009; Lerot et al. 2010). OIP in Belgium has built the GOME Polarization Devices (PMDs).

Scanning Imaging Absorption spectrometer for Atmospheric Chartography (SCIAMACHY), a tri-national contribution to ESA’s Envisat by Belgium, Germany and The Netherlands, measuring since 2002 O₃, NO₂, BrO, OCIO columns. BIRA-IASB is a Co-PI of the instrument, has followed the technical development of the instrument, is involved in the development of retrieval algorithms, plays a coordinating role in the geophysical validation of SCIAMACHY data. OIP in Belgium has built the SCIAMACHY Polarization Devices (PMDs).

Ozone Monitoring Instrument (OMI) measuring aboard NASA’s EOS-Aura platform since 2004 the column of O₃, NO₂, BrO and OCIO. BIRA-IASB has been active in the development and validation of ozone, NO₂ and BrO data products from OMI.

Global Ozone Monitoring Experiment-2 (EUMETSAT GOME-2 aboard MetOp-A), measuring aboard EUMETSAT METOP platform since 2006 the column of O₃, NO₂, BrO, SO₂, OCIO, etc. BIRA-IASB plays a key role in scientific developments and geophysical validation of the operational GOME-2 Data Processor for total ozone, NO₂, BrO, H₂CO and SO₂ run at DLR (Germany) as part of the O3M-SAF (Loyola et al. 2011; Lerot et al. 2010b).

IASI, Infrared Atmospheric Sounding Interferometer, on board METOP. BIRA-IASB is developing an N₂O product. N₂O releases NOx in the stratosphere, which is an Ozone Depleting Substance (ODS), the steady growth of N₂O makes it a threat to the stratospheric ozone layer in the future. In addition, BIRA-IASB is developing a methane product from IASI.

The work on GOME/SCIAMACHY/OMI/GOME-2 is a response to the requirement resulting from the 7th ORM Meeting in 2008 (WMO TD No. 51): Continuation of the solar backscatter UV observations must be ensured as they constitute a key baseline set of measurements...

1.1.3 Université Libre de Bruxelles (ULB)

The Atmospheric Spectroscopy group (Service de Chimie Quantique et Photophysique) at ULB is heavily involved in the IASI/MetOp satellite mission, being directly involved in its Science Working Group (ISSWG-2), under auspice of CNES and EUMETSAT. IASI is a sounder that measures the thermal infrared radiation of the Earth/atmosphere in nadir geometry, at fairly high spatial (12 km diameter circular pixel on-ground) and spectral (0.5 cm⁻¹) resolutions (Clerbaux et al 2009). IASI is part of the EPS system, and is scheduled to operate up to 2020 at least. The first IASI instrument onboard the European MetOp-A was launched platform in late 2006 and declared operational in July 2007. As compared to UV sounders but also precursor infrared sounders (IMG and TES), IASI has the advantage of high spatial and temporal sampling, providing global measurements twice daily, once in the morning and once in the evening. The measurements at night are especially of added value for monitoring the composition of the stratosphere in the polar night, prior to the appearance of the ozone hole. Also the small pixel allows capturing fine concentration variations in and out the polar vortex.

The ULB group has set-up, in collaboration with the French LATMOS, a near-real time processing chain for IASI. Of particular relevance here are

- Ozone total columns distributions, which are retrieved global twice a day, in near-real time. The product has already undergone partial validation against ground-based measurements and GOME-2 (Boynard et al. 2009, Keim et al., 2009, Antón et al., 2011).
- Nitric acid total columns distributions, which have an important role in regulating the ozone hole, and a sensitive species to monitor its development (Wesples et al. 2009)
- Methane total columns (Razavi et al. 2009)
In addition a series of column measurements for tropospheric species, strongly involved in the ozone budget by being ozone precursors, are provided. These include CO (George et al. 2009) and volatile organic compounds (Razavi et al. 2011).

- In addition to IASI, the ULB has also derived total column measurements of HNO$_3$ and O$_3$ from IMG instrument, for the year 1997 (Clerbaux et al. 2003, Coheur et al. 2005, Wespès et al. 2007).

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

1.2.1 The Royal Meteorological Institute (RMI)

The vertical distribution of ozone at Uccle is measured three times per week by the means of balloon soundings with ECC ozone sensors, since 1997. Ozone profile data in the period 1969-1997 were obtained with Brewer-Mast sensors.

1.2.2 University of Liège (ULg)

Fourier Transform Infrared (FTIR) spectrometers are operated on a regular basis since the mid-1980s at the Jungfraujoch station (an NDACC site in the Swiss Alps, 46.5°N, 8.0°E, 3580 m asl, see http://www.ndacc.org) to record high-resolution IR solar absorption spectra. Analysis of these observations with dedicated algorithms allows studying and characterizing the state and evolution of the stratosphere and troposphere at northern mid-latitudes. Geophysical parameters consist in total and partial column abundances above the site, including related uncertainty evaluations. Table 1 provides the current list of atmospheric gases routinely studied at the Jungfraujoch. Ozone is among the target gases as well as halogenated or nitrogenated species (sources and reservoirs) involved in ozone depletion. In addition, numerous greenhouse gases are also monitored.

Table 1. Molecules currently studied in FTIR solar spectra recorded at the Jungfraujoch

<table>
<thead>
<tr>
<th>Reference gas:</th>
<th>N$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor constituents:</td>
<td>CO$_2$, N$_2$O, CH$_4$, CO, O$_3$</td>
</tr>
<tr>
<td>Trace constituents:</td>
<td></td>
</tr>
<tr>
<td>Halogenated species:</td>
<td>HCl, ClONO$_2$, HF, COF$_2$,</td>
</tr>
<tr>
<td></td>
<td>CCl$_2$F$_2$, CHClF$_2$, CCl$_3$F, CCl$_4$, CF$_4$, SF$_6$</td>
</tr>
<tr>
<td>Nitrogenated species:</td>
<td>NO, NO$_2$, HNO$_3$</td>
</tr>
<tr>
<td>Others:</td>
<td>H$_2$O, C$_2$H$_6$, C$_2$H$_2$, C$_2$H$_4$, HCN, OCS, H$_2$CO, H$_2$CO$_2$, Isotopologues of CO, CH$_4$, H$_2$O, O$_3$</td>
</tr>
</tbody>
</table>

1.2.3 The Belgian Institute for Space Aeronomy (BIRA-IASB)

BIRA-IASB performs ground-based monitoring of the vertical distribution of ozone and interacting species (halogens, NOy, BrO, HCFC, CFC…) for budget, processes and long-term trend studies, at:

- the International Scientific Station of the Jungfraujoch, Switzerland (46.5°N, 8.0°E, 3580 m asl): the time series of FTIR data starts in the early eighties. The FTIR observations at Jungfraujoch are lead by ULg.
- Harestua, Norway (60°N, 11°E): UV-VIS DOAS instruments, since 1994, from which profiles of stratospheric NO$_2$ and BrO are retrieved.

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1 Species typed in italic are primarily present in the stratosphere, while the others are tropospheric source gases.
• the Observatoire de Haute Provence (OHP), France (44°N, 8°E): UV-VIS DOAS instrument since summer 1998, from which profiles of stratospheric NO$_2$ and BrO are retrieved.

• Ile de la Réunion (22°S, 55°E): From the FTIR observations, at high spectral resolution, one can derive some limited information about the vertical distribution of the observed species. In particular, for Ozone, one can derive 5 independent partial columns between the ground and the upper stratosphere.

BIRA-IASB is involved in several satellite missions measuring the vertical distribution of ozone and interacting species (halogens, NO$_y$, BrO, HCFC, CFC…) for budget, process and long-term trend studies, by:

• Scanning Imaging Absorption spectrometer for Atmospheric Chartography (SCIAMACHY), a tri-national contribution to ESA’s Envisat by Belgium, Germany and The Netherlands, measuring since 2002 O$_3$, NO$_2$, BrO and OCIO columns. BIRA-IASB is a Co-PI of the instrument, has followed the technical development of the instrument, is involved in the development of retrieval algorithms, plays a coordinating role in the geophysical validation of SCIAMACHY data. OPI in Belgium has built the SCIAMACHY Polarization Devices (PMDs).

• Envisat GOMOS (launched in 2002). BIRA-IASB is a co-proposer of the instrument and has been active in the development and validation of ozone, temperature and nitrogen dioxide data products.

• Envisat MIPAS (launched in 2002). BIRA-IASB has been active in the geophysical validation of ozone, temperature, NO$_y$, HCFC and CFC data products.

• SCISAT-1 ACE-FTS (launched in 2003). Belgium has provided the imagers. BIRA-IASB has been active in the development and validation of ozone, NO$_y$, HCl, HCFC and CFC data products.

• National development of ALTIUS, a limb viewing satellite instrument responding to the requirements resulting from the 7th ORM Meeting in 2008 (WMO TD No. 51): “Satellite observations of high vertical resolution profiles using limb viewing for O$_3$ and key molecules are required in order to more accurately understand the changes in O$_3$ as CFCs decline and climate change occurs.”

1.2.4 Université Libre de Bruxelles (ULB)

Contribution to satellite missions:

• The Atmospheric Spectroscopy group (Service de Chimie Quantique et Photophysique) at ULB is at the forefront of the chemistry-related activities around the IASI/MetOp satellite mission. The researchers take active part in the IASI Sounder Science Working Group (ISSWG-2), under auspice of CNES and EUMETSAT. In addition to providing information on total columns (see above), IASI has also profiling capabilities at least equal if not superior to most instrument currently in operation. With the FORLI processing chain set-up at ULB, the following products are available in near-real-time
  
  o Ozone vertical profiles, which are retrieved in 40 layers of 1km thickness starting from the ground, with 3-4 independent pieces of information. Stratospheric and tropospheric contributions are well decorrelated. The maximum sensitivity of IASI to the ozone profile is in the upper troposphere and the lower stratosphere (UTLS), and thus of high relevance for monitoring the vertical structure of the ozone hole.
  
  o Nitric acid vertical profiles. The vertical information is almost inexistent but the retrieval of vertical profiles improves on the columns measurements by accounting for changes in tropopause height. Vertical profiles are available in NRT.
  
  o In addition, vertical profiles of methane are retrieved locally or for restricted periods of time. The sensitivity is highest in the UTLS.

• The ULB researchers are involved SCISAT-1 ACE-FTS Science Team. They have contributed to several studies, including on quantifying the stratospheric chlorine budget.
The ULB have PI contribution for TANSO-FTS GOSAT.
The ULB have demonstrated the potential to retrieve vertical information from nadir infrared radiances by analysing the measurements of the IMG/ADEOS instrument. First vertical profiles of CO, O₃ and HNO₃ were provided (Barret et al. 2005, Coheur et al 2005, Wespes et al 2007)

1.3 UV measurements

1.3.1 Broadband measurements
Nihil

1.3.2 Narrowband filter instruments
Nihil

1.3.3 Spectroradiometers

1.3.3.1 The Royal Meteorological Institute (RMI)

UV spectral irradiance measurements at Uccle: both Brewer spectrophotometers are also used to monitor the UV-B radiation intensities. They perform several scans per day (number depending on the time the sun is above the horizon).

Since January 2011, also the Brewer in Antarctica performs UV spectral measurements during its operational period the austral summer.

1.3.3.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

BIRA-IASB exploits a UV-monitoring network in Belgium (see http://www.aeronomie.be/uv/globaluv/index.php

1.4 Calibration activities

1.4.1 The Royal Meteorological Institute (RMI)

Before the transfer to Ukraine, the Dobson instrument nr 40 was refurbished and calibrated at the Regional Calibration Centre of WMO in Hohenpeißenberg in 2009-2010. It turned out that the instrument has been very stable since the last calibration. Therefore no reprocessing of the data set at Uccle was necessary.

The Brewer instruments 016 and 178 were compared with the travelling reference instrument nr 017 in 2006 and 2008. In 2010 the instruments were calibrated in Uccle together with Brewer #100 (before it was sent to Antarctica) against Brewer reference instrument 158. The results of these calibrations were taken into account for the new ozone observations and also the older data were recalculated.

The ozone sondes are carefully prepared and a correction procedure is applied to minimise the inhomogeneity that could have been introduced at the change of the sonde type in 1997.

The UV-B calibration of the Brewer instruments was checked with 1000W lamps in 2006, 2008 and 2010 during the calibration visits. In 2004 the special comparative observations were performed with a travelling reference UV instrument of the Joint Research Centre (JRC in Ispra) in the frame of the Qasume project (Gröbner et al, 2004). All the 1000W calibrations were consistent with the calibrations based on the monthly tests with 50W lamps within the expected errors.

1.4.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

The ground-based FTIR and MAXDOAS observations are all contributing to the NDACC and are being certified in this framework.

The MAXDOAS instruments have participated to several calibration campaigns, e.g., the recent CINDI campaign in Cabau (NL) in summer 2009 (Roscoe et al., 2010).
The calibration of the FTIR instrument at La Réunion is verified on a daily basis by doing HBr cell measurements. We also participate in the data processing standardisation procedures that are ongoing in the frame of the NDACC Infrared Working Group.

BIRA-IASB coordinates cal/val activities for GOME, GOMOS, MIPAS, SCIAMACHY, ACE-FTS, OMI and GOME-2. BIRA-IASB contributes to the international development of a global data quality strategy for the GEOSS, an effort led by CEOS WGCV in response to GEO Tasks DA-06-02 and DA-09-01. It is involved in the group establishing the Quality Assurance framework for Earth Observation (QA4EO, http://qa4eo.org). At European level it is active in the system engineering for the GMES Atmospheric Service (GAS) and ensures coordination and harmonisation of the data quality strategy for the GMES pioneering project PROMOTE and the EC FP7 projects establishing the GMES atmospheric core service (MACC), the GMES air quality service (PASODOBLE) and the GMES volcanic observatory (EVOSS).

### 1.4.3. University of Liège (ULg)

Calibration of the Jungfraujoch FTIRs is performed according to NDACC recommendations, in order to characterize the instrument performance and stability. This is done by regularly recording HBr cell measurements. Also, N₂ (whose vertical distribution and concentration are well known) absorption features are further used to check the instrumental consistency, in particular for time periods for which regular cell measurements are unavailable.

## 2. RESULTS FROM OBSERVATIONS AND ANALYSIS

### 2.1. The Royal Meteorological Institute (RMI)

Research evolution of total atmospheric ozone and its distribution versus altitude at northern mid-latitudes, in particular above Belgium revealed a mean temporal decrease in ‘good’ ozone in the stratosphere and an increase in ‘bad’ ozone in the troposphere. With the help of model calculations it was shown that both changes are primarily of anthropogenic origin. Further observations in Uccle (Brussels) showed that observed levels of harmful UV-B irradiance at ground level anti-correlate with levels of stratospheric ozone. Initiatives have been taken to warn the general public about health risks resulting from excessive exposure to the sun in summertime.

The figure below shows the time evolution of the ozone column over Uccle based on the combined data of the Dobson (1971-1989) and the Brewer Instruments (1990-now). The ozone column decreased with 3% per decade in the period 1980-1997 and then there is possible sign of recovery afterwards, although the period is too short to draw firm conclusions. The ozone soundings have shown us that the decrease occurs in the lower stratosphere, especially during winter and early spring. In the troposphere, on the contrary, the ozone concentrations tend to increase due to photochemical reactions in polluted air.

The first ozone measurements at the Antarctic Station princess Elisabeth (January and February 2011) are reported to the WOUDC.
2.2 University of Liège (ULg)

The Jungfraujoch FTIR observational data set from ULg now covers more than 25 years. It is the longest available worldwide and hence is particularly appropriate for trend determination investigations. We summarize here below a selection of relevant and recent results.

- Since the mid-1980s, ULg has maintained the consistent monitoring of the vertical column abundances of HCl and ClONO$_2$, which are the main inorganic Cl$_y$ reservoirs in the stratosphere. Their sum shows that the rate of increase of Cl$_y$ has progressively slowed down during the early-1990s, and stabilised in 1996-1997, in response to the amended production regulations on O$_3$-depleting substances by the Montreal Protocol. Since then, the Cl$_y$ loading has shown a slow but statistically significant decrease (-0.93 ± 0.14 %/yr; 2σ) over the 1996-2009 time period, which is commensurate with the organic chlorine decrease in the troposphere when accounting for a mixing time of about 4 years.

- The check of the evolution of anthropogenic chlorine-bearing source gases such as CFC-11, CFC-12 and CCl$_4$ demonstrates the efficiency of the amended Montreal Protocol. Significant rates of decrease are determined for these three first source gases. In contrast, HCFC-22 whose (partial) regulation started later on is still on the rise (+4.22 ± 0.07 %/yr. over 2001-2010; 2σ).

- Recent trend values computed over the 1995-2010 time interval indicate a small but significant (at 2-σ) recovery of stratospheric ozone. This is true for the three stratospheric partial column time series accessible to the FTIR technique (altitude ranges from 10.6 to 17.8 km, 17.8 to 27.4 and 27.4 to 42.4 km). Trend derived from the total column data set amounts to (+0.12 ± 0.06) %/yr.

- A slowing down in the accumulation of the inorganic fluorine concentration in the stratosphere has been detected and characterized. At present, the observed evolution –in particular the
partitioning among the two major reservoirs, HF and COF₂⁻ is not well simulated by model calculations.

- Measured rates of increase of the major radiatively active gases that are to be controlled under the Kyoto Protocol are: for CO₂, an average of 0.49 %/year over the 1984-2010 period; for CH₄, a series of contrasted changes, with in particular a trend of 0.36 %/yr in 1995-1999, 0%/yr in 2000-2004 and a re-increase since then (0.28 %/yr in 2005-2009); for N₂O, an average of 0.28%/year from 1984 to 2009; for SF₆, a substantial increase of still more than 6 %/yr over the last decade.

### 2.3 Université Libre de Bruxelles (ULB)

In the last years The ULB has been heavily involved in the monitoring of global ozone distributions using IASI, both in terms of columns and vertical profiles. Time series are available from 2008 onwards. The ozone products – columns and profiles – have first been analyzed and compared to other available means, showing good overall agreement, although some biases with UV measurement techniques remain (Anton et al. 2011, Boynard et al. 2009, Keim et al. 2009).

The O₃ have been supported by measurements of nitric acid, and the temporal evolution of both species in and outside vortex during Antarctic winter and spring have been carefully analyzed for the first time (Wespès et al., 2009). The results show HNO₃ to be a sensitive probe for the chemistry of the stratosphere. The ability of IASI to probe the polar stratosphere during night, combined to its excellent spatial resolution and sampling were shown to be of added value for future research.

The first trends of the Antarctic ozone hole have been obtained and the ability of IASI to capture the vertical structure of the ozone hole has been looked at (Scannell et al., 2011).

The ULB has contributed to quantifying the chlorine budget in the stratosphere in 2004 and through this to the WMO Scientific assessment on stratospheric ozone.

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**Figure 2**: Time evolution of the total ozone concentration (in DU) measured by IASI on a daily basis at 5 degree latitude increments from 50°S to 90°S. The daily trend is shown as the black line; the shaded grey represents the standard deviation about the average. From (Scannell et al., 2011)

### 3. THEORY, MODELLING, AND OTHER RESEARCH

#### 3.1. The Royal Meteorological Institute (RMI)

The Brewer data have been analysed for aerosol information in the UV. These AOD data at 320 nm are available now (Cheymol and De Backer, 2003). Special measurements with Brewer 178 (and
later also with Brewer 100 in Antarctica) were started to measure also the AOD at 340 nm (De Bock et al, 2010).

RMI is also partner in the BACCHUS project. The aim of the RMI contribution is to run the Canadian regional model for Chemical composition (including ozone) over Europe.

3.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

3.2.1 Modelling

- Complete 3D modelling of the stratosphere, including transport, chemistry, aerosol microphysics and a heterogeneous chemistry module
- Chemical 4D variational data assimilation, in particular of O₃
- 1D box model for process studies, and for interpretation of UV-Vis DOAS observations
- Studies based on 3D model IMAGES for the troposphere and UT/LS boundary region
- Development of inverse tropospheric modelling methods, to identify emissions (e.g., for CO)

3.2.2 Laboratory experiments

- Spectroscopic studies in support of remote sensing experiments (optical spectroscopy, ion chemistry for mass spectrometry applications…)
- Spectroscopic studies in support of investigations concerning global warming issues
- Radiometric calibration for UV monitoring instruments
- Studies of reaction pathways and kinetics of atmospheric species, using mass spectrometry.

3.2.3 Instrument developments

- MAXDOAS instruments and associated data analysis algorithms; The MAXDOAS technique has the capability of determining vertical distributions in the troposphere and low stratosphere.
- Optimisation of the FTIR observations for achieving higher-quality measurements.

3.2.4 Retrieval algorithm developments

- Development of inversion algorithms (using the Optimal Estimation Method) for ground-based DOAS and FTIR remote sensing spectral data, for the retrieval of vertical distributions of the absorbing atmospheric constituents

Recently developed algorithms have implemented the Optimal Estimation Method, and therefore allow the retrieval of vertical profile information from the ground-based DOAS and FTIR spectra, at low vertical resolution (worse than 5 km), for e.g., NO₂, O₃, HNO₃, HCl, ... For the FTIR data this approach has been optimised for some target species in the EC project UFTIR coordinated by BIRA-IASB. Recently Tikhonov regularisation and Information Operator Approach have been implemented as alternative inversion algorithms for FTIR measurements; in some cases, these approaches improve the robustness of the retrievals.

3.2.5 Satellite data retrievals

- Development, validation and implementation of satellite data retrieval algorithms (e.g., for GOME, SCIAMACHY and GOME-2 total O₃, NO₂, BrO, SO₂….; e.g., aerosol and trace gases from GOMOS); data processing and dissemination
• Development of retrieval algorithms for IASI/Metop for aerosol and gases.

3.2.6 Satellite data validation and characterisation

• Continued contributions to the validation of satellite data for O₃, NOy, CH₄, CO, N₂O… (GOME, SCIAMACHY, GOMOS, MIPAS, ACE/SciSat …) using independent ground-based data, mostly NDACC affiliated. This activity will be continued for OMI, GOME-2, IASI, …

• Characterisation of the 4D information content of various satellite data, on the purpose of (1) integrating time series form successive satellite sensors (e.g., for O₃ total column and profile), remote sensing and in situ data from various platforms (ground, balloon, aircraft, satellite,…) and, (2), developing observation operators for correct integration/comparison of satellite data with models.

• Development of climatologies of some stratospheric species like BrO and NO₂

3.2.7 Trend studies

• BIRA-IASB studied trends of stratospheric BrO at several NDACC stations and verified the consistency with the observed trends from SCIAMACHY. BrO is decreasing since 2001 at a rate of about -1%/year (Hendrick et al., 2008 and 2009)

• BIRA-IASB studies trends of O₃ above Europe in various layers in the atmosphere, based on FTIR observations (Vigouroux, C. et al., 2008). An updated trend analysis up to end of 2009 will be published in the upcoming WMO Scientific Assessment of Ozone Depletion: 2010.

• BIRA-IASB has contributed with HCl and HF measurements at La Réunion to a study of the inorganic chlorine and fluorine trends on a global scale, involving all NDACC Infrared Working Group members. This study has been led by the Karlsruhe Institute of Technology (KIT), in the frame of the EU project GEOmon. It compares observed trends with model simulations, and will be published in the course of 2011. Its major findings are also included in the WMO Scientific Assessment of Ozone Depletion 2010.

• In support to the SPARC/IO3C/WMO-IGACO initiative on long-term trend studies of the vertical distribution of ozone, BIRA-IASB investigates the multi-mission consistency and potential drifts of about ten satellite ozone profilers having provided, all together, ozone profile data records from 1984 to 2010. The study is based on the integrated use of GAW-contributing (WOUDC, NDACC, SHADOZ) ground-based network data as a reference.

3.3 University of Liège (ULg)

Most of the research activities reported in the previous Ozone Research Managers Report (2002, 2005) are continuing.

3.3.1 Satellite data validation and characterisation

ULg has been involved in numerous satellite validation studies over recent years (e.g. SCIAMACHY, MIPAS, and MOPITT). In particular, ULg has been strongly involved in the calibration/validation of ACE data products (O₃, N₂O…), leading the validation for HCl, HF, CCl₂F₂ and CCl₃F.

3.3.2 Instrument developments

Since more than two years, a remote control system has been in control of the Jungfraujoch Bruker instrument, allowing to complement the observations performed locally and to maximize the observation time. The system is perfectly working despite the challenging harsh meteorological
conditions encountered at the Jungfraujoch; it has already undergone numerous evolutions to improve reliability and determination of the instrument status.

In parallel, we have been developing a new acquisition system that, along with total integration inside the remote control system, will provide improved signal to noise ratio and instrument throughput as well as the capacity to implement new digital processing methods, leading to enhanced spectrum quality, improved line shape and therefore better vertical distribution determinations.

3.3.3 Trend studies

Numerous relevant long-term trend studies have been performed over the period under review here, on the basis of Jungfraujoch ground-based data (see e.g. section 2.2) or using satellite products (inorganic chlorine and fluorine, organic chlorine and fluorine, source gases relevant to ozone (N₂O, CH₄)...

3.4 Université Libre de Bruxelles (ULB)

3.4.1 Laboratory experiments

The “Service de Chimie Quantique et Photophysique” has a worldwide established expertise in the measurement of accurate absorption line parameters (positions, intensities and widths) for atmospheric trace gases in the infrared (far-, mid- and near-) and visible ranges, using high-resolution Fourier transform spectroscopy. Analysis of spectra is carried out using software written in the laboratory. As highlighted by the list of relevant scientific publications, species as diverse as C₂H₂, C₂H₆, HCOOH, ¹³C¹⁶O₂, N₂O, OCS and several isotopologues of water vapor have been studied since 2005. Most of these activities support investigations of the terrestrial atmosphere. In particular, we showed that absorption line intensities available for HCOOH in HITRAN before 2008 were a factor of about 2 too low (Perrin and Vander Auwera, 2007, and Zander et al, 2010).

3.4.2 Retrieval algorithm developments

Building on their expertise in fundamental spectroscopy, the group has acquired a leading position for the atmospheric radiative transfer modelling in the thermal infrared and also for the development of atmospheric trace gases retrieval methods. It owns and maintains sophisticated algorithms, for research and operational applications in atmospheric chemistry and physics. They include

- The Atmosphit line-by-line radiative transfer model, which allows simulation of spectra recorded under various geometries and/or with different instruments. Accurate and versatile, it has been used in most studies prior to IASI launch, and for IASI local analyses. Recently the group has started modelling the radiative transfer for atmospheric aerosols, with an advanced doubling-adding method to account for multiple scattering. The module was coupled to Atmosphit, allowing simultaneous retrieval of gas and aerosol properties (Clarisse et al. 2010a, 2010b).

- The FORLI series of software specific to IASI. These rely on fast radiative transfer calculations using look-up-table (LUT) approaches. The LUT compile absorbance spectra, pre-calculated on a given spectral range and on well-defined temperature/pressure/humidity grids. FORLI versions are currently in place for O₃, HNO₃ of particular for stratospheric sounding, and in addition NH₃ and CO. The FORLI series allow NRT processing of the huge IASI data flow to provide global distribution of concentrations twice daily.

- Radiance indexing schemes for IASI, which are used to track a reactive species, among which SO₂, CH₃OH, HCOOH, and aerosols, including volcanic ash
3.4.3 Satellite data retrievals

- Development, upgrade and maintenance of a NRT IASI processing chain. Processing starts with the receiving of the calibrated L1C radiances from Eumetcast, which are transformed in suitable format and quality-flagged using available ancillary information (e.g. cloud coverage). The retrievals are performed on a cluster of PCs, which currently has 190 CPU's and 24TB of storage capabilities. Retrieved products from FORLI include O3, HNO3, CO and NH3 profiles on the global scale (cloud-free data).
- Local retrievals of trace gases and aerosols using the line-by-line Atmosphit software.

3.4.4 Satellite data validation and characterisation

- Contribution to the validation activities of IASI and ACE-FTS chemistry products, in particular CO and O3 but also (ongoing) NH3, HNO3, CH3OH.
- Continued cross-comparisons between satellites, in particular CO and O3

3.4.5 Trend studies

- First time series from IASI have been obtained for polar ozone (Scannel et al. 2011). Seasonnal and interannual variabilities of the HNO3/O3 ratio have been analyzed (Wespes at al. 2009). Trends of CO are monitored.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

4.1.1 The Royal Meteorological Institute (RMI)

The ozone data (columns and profiles) are regularly deposited in the WOUDC of WMO. Uccle is also affiliated to NDACC. Therefore the data are also made available in that network. In near real time the data are also distributed via NILU, where the data can be used for campaigns (e.g. Match campaigns to determine ozone losses in the polar and sub polar winter atmosphere, see Streibel et al, 2005). The data are also stored and used in databases for the validation of satellite data (ENVISAT and EUMETSAT). Total ozone values are exchanged daily with the WMO ozone mapping centres in Canada and Greece for the production of daily ozone maps.

4.1.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

Data are submitted on a regular basis to the NDACC database hosted at NOAA. Major results are included in the WMO Scientific Assessment of Ozone Depletion: 2010.

4.1.3 University of Liège (ULg)

Time series of NDACC-relevant molecules (e.g., HCl, ClONO2, HF, COF2, HNO3, NO2, NO, O3, CFC-12, HCFC-22) from 1989 onwards are being archived routinely at the NOAA Data Host Facility (Washington, DC, USA), with the ozone data mirrored to the WOUDC archive in Toronto. Pre-1989 data are available upon request. Transition to hdf file archives is in progress.

In addition, important results deduced from Jungfraujoch observations have been included in successive editions of the scientific assessment of ozone depletion (UNEP/WMO), with ULg scientists involved as co-author or contributors in all recent volumes.

4.1.4 Université Libre de Bruxelles (ULB)

IASI CO distributions of profiles are distributed in NRT to ECMWF in the frame of GMES atmosphere service MACC (http://www.gmes-atmosphere.eu/). The data are also archived at the
French ETHER datacenter ([http://ether.ipsl.jussieu.fr](http://ether.ipsl.jussieu.fr)) and available upon request. O₃ distributions have been distributed for preliminary validation to a series of research groups. They are now similarly available upon request. Future operational dissemination of the IASI CO, O₃, HNO₃ and SO₂ products from IASI will occur within the O3SAF, in the 2012-2015 timeframe (data to be processed at EUMETSAT-CAF and disseminated through EUMETCAST system).

Spectroscopic information obtained by the “Service de Chimie Quantique et Photophysique” is disseminated through various channels:

- the HITRAN ([HIgh-resolution TRANsmission molecular absorption, [http://www.cfa.harvard.edu/HITRAN/](http://www.cfa.harvard.edu/HITRAN/)] and GEISA ([Gestion et Etude des Informations Spectroscopiques Atmosphériques, [http://ether.ipsl.jussieu.fr](http://ether.ipsl.jussieu.fr)] databases. The laboratory is a significant contributor to these databases.
- as supplementary data of publications, maintained by the editors of journals.
- the web site of the laboratory ([http://www.ulb.ac.be/cpm/](http://www.ulb.ac.be/cpm/)).
- laboratory data obtained for water vapour and its isotopologues are included in the MARVEL database ([International Union of Pure and Applied Chemistry IUPAC project; [http://chaos.chem.elte.hu/marvel/](http://chaos.chem.elte.hu/marvel/)]).

4.2 Information to the public

4.2.1. The Royal Meteorological Institute (RMI)

Daily UV forecasts are produced and disseminated with the weather forecasts. They are also available at the internet ([www.meteo.be](http://www.meteo.be)).

Ozone and UV data of Uccle were also used in yearly reports on the environment (successive MIRA reports).

4.2.2. The Belgian Institute for Space Aeronomy (BIRA-IASB)


4.3 Relevant scientific papers

4.3.1 The Royal Meteorological Institute (RMI)

Papers since 2005 (after those included in the previous report) are mentioned. Authors affiliated to RMI are in bold.

Peer reviewed:


[http://www.copernicus.org/EGU/acp/acp/5/131/acp-5-131.pdf](http://www.copernicus.org/EGU/acp/acp/5/131/acp-5-131.pdf)


[http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6VH3-4GNTG12-1-8N&_cdi=6055&user=832113&orig=browse&coverDate=09%2F30%2F2005&sk=999609971&view=c&wchp=dGLbVtz-zSkWb&md5=a70de6d3f2016a3b023a8603833fab9f&ie=/sdarticle.pdf](http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6VH3-4GNTG12-1-8N&_cdi=6055&user=832113&orig=browse&coverDate=09%2F30%2F2005&sk=999609971&view=c&wchp=dGLbVtz-zSkWb&md5=a70de6d3f2016a3b023a8603833fab9f&ie=/sdarticle.pdf)

http://www.copernicus.org/EGU/acp/acp/6/2783/acp-6-2783.pdf


Doi:10.1029/2007JD009098


http://dx.doi.org/10.1080/01431160902825032


http://www.atmos-chem-phys.net/10/5759/2010/acp-10-5759-2010.html


http://www.atmos-chem-phys.net/10/6345/2010/acp-10-6345-2010.html


http://www.atmos-meas-tech.net/3/1577/2010/amt-3-1577-2010.html


Proceedings:


Other publications of RMI:


4.3.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)

Peer-reviewed papers and books (Ordered alphabetically, publications from 2005 to 2011, authors from BIRA-IASB in bold):


Hendrick, F., Rozanov, A., Johnston, P.V., Bovensmann, H., De Maziere, M., Fayt, C., Hermans,


Lambert, J.-C., MACC Validation Protocol, Peer-reviewed Technical Note, EC FP7 Monitoring Atmospheric Composition and Climate (MACC), FP7-MACC-MAN-3-4, Version 1, 47 p., 11 October 2010.


4.3.3 University of Liège (ULg)

(Peer review publications from 2005 to 2010, ordered alphabetically. A list including all types of publication is available upon request (see also http://orbi.ulg.ac.be), authors from ULg in bold)


4.3.4 Université Libre de Bruxelles (ULB)

Relevant peer-reviewed papers (Ordered alphabetically, publications from 2005 to 2011), authors from ULB in bold


Wespes, C., D. Hurtmans, H. Herbin, B. Barret, S. Turquet, J. Hadji-Lazaro, C. Clerbaux, and P. F. Coheur: First global distributions of nitric acid in the troposphere and the stratosphere derived from


**WMO scientific assessment on ozone depletion 2006**

P. Coheur is contributing author to “Scientific Assessment of Ozone Depletion: 2006; Chapter 1: Long-lived compounds” (Lead authors D. Cunnold and C. Clerbaux), World Meteorological Organization (WMO).

**Conference Proceedings**


5. **PROJECTS AND COLLABORATION**

5.1 Participation in national and international other collaborations projects

5.1.1 **The Royal Meteorological Institute (RMI)**


- COST Action ES0604 on Water Vapor and climate (WAVACS)


- Satellite validation projects of ESA and Eumetsat.

- Prodex Project Bacchus (2010-2013)

- Belgian federal science policy: Belatmos project for monitoring of atmospheric composition at the Belgian Antarctic Base (2008-2012)

- Solar Terrestrial centre of Excellence (recurrent support of the ozone research programme)

- Participation in the validation team of the Ozone monitoring SAF of EUMETSAT
5.1.2. The Belgian Institute for Space Aeronomy (BIRA-IASB)

- IPCC assessments, WMO Stratospheric Ozone assessments and SPARC Vertical Ozone Trend assessments
- 6th Framework Programme of the European Commission: GEOmon, ACCENT (and its subproject AT2)
- 7th Framework Programme of the European Commission MACC, PASODOBLE, SHIVA
- ‘Chemistry and climate related studies using the IASI remote sensor’ for preparing the scientific research aspects of the IASI mission onboard METOP-1
- ESA GMES Service Element project PROMOTE (http://www.gse-promote.org)
- ESA CHEOPS-GOME, CHEOPS-SCIA, Multi-TASTE, CEOS Campaigns
- ESA Climate Change Initiative Ozone_cci (http://www.esa-ozone-cci.org/)
- ESA study ‘Capacity’ (http://www.knmi.nl/capacity/) and CAMELOT
- ESA’s Envisat Atmospheric Chemistry Validation Team, ESA’s Quality Working Groups
- Involved in a dozen science and processing teams of satellite missions, e.g. SCIAMACHY SSAG, SCIIVALIG, and SADDU
- Atmospheric Composition, Chemistry and Climate (A3C), PRODEX contract (2011-2013).

5.1.3 University of Liège (ULg)

- Atmospheric Composition, Chemistry and Climate (A3C), PRODEX contract.
- Projet ESA-Multi-TASTE (Technical assistance to Multi-mission Validation by Sounders, Spectrometers and Radiometers)
- Contract FNRS FRFC (Observations and study of the variability and evolution of the free atmosphere from the Jungfraujoch International Scientific Station)
- Project: GAW-CH (FTIR measurements at the Jungfraujoch 2010-2013)
- Project: EC- GEOMON (Global Earth Observation and Monitoring)

5.1.4. Université Libre de Bruxelles (ULB)

- Atmospheric Composition, Chemistry and Climate (A3C), PRODEX contract (2011-2013).
- ESA CAMELOT study for preparation of Sentinel4 and Sentinel5
• Programme Hubert Curien (Belgium-France collaboration): Precise modeling of the low energy infrared spectrum of ethylene for applications to planetary atmospheres (2009-2010).

5.2 Representation in international organisations

5.2.1 The Royal Meteorological Institute (RMI)
• EUMETSAT Scientific and Technical Group, Policy Advisory Committee and Council
• Domain Committee ESSEM van COST (http://w3.cost.esf.org/index.php?id=269).
• Brewer sub-committee of WMO-GAW
• EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (Steering Group member)

5.2.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)
• International Ozone Commission (IO3C) of the IAMAS-IUGG
• WMO GAW NDACC Steering Committee (co-chairman of UV-VIs, IR and Satellite Working Groups)
• WMO GAW UV-SAG
• SPARC/WCRP
• Committee on Earth Observation Satellites (CEOS)
• SAG of GOME and GOME-2, GOMOS, SCIAMACHY, OMI
• Atmospheric Science Panel (European Commission)
• ESA Council, EUMETSAT Council
• International Committee on Space Research (COSPAR)
• Member of the Science Team of the Canadian ACE/SciSAT mission, of the EOS-Aura OMI International Science Team...
• EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring

5.2.3 University of Liège (ULg)
• ACE science team
• ISSJG (International Scientific Station Jungfraujoch and Gornergrat) Astronomic Commission
• NDACC steering committee
• NDAC-Infrared working group
• PI contribution to Task Group 3 of ACCENT-TROPOSAT 2 (strategies for the validation of tropospheric products from satellites)

5.2.4 Université Libre de Bruxelles (ULB)
• Member of the Scientific committee of the “IASI Conference” series
• Member of the IASI Sounder Science Working Group–II
• Member of the ACE Science Team
• Member of ACCENT and coordinator of AT2 activities (2009-)
• International Advisory Committee of the HITRAN (HHigh-resolution TRANsmission molecular absorption, http://www.cfa.harvard.edu/HITRAN/) database.

6. FUTURE PLANS

6.1 The Royal Meteorological Institute (RMI)
• Continuation of the observations at Uccle (ozone column, ozone profile, Spectral UVB, aerosol) and at the Antarctic station (Ozone column, Spectral UVB and aerosol).
• Installation of a Ceilometer LIDAR in Uccle to monitor the aerosol backscatter in the troposphere.
• Analysis of the data obtained at the Belgian Antarctic station.
• Participation in the validation and quality assurance of satellite observations (O₃MSAF CDOP-2 of EUMETSAT and Ozone CCI of ESA).
• A thorough re-evaluation of ozone trends from the balloon ozone profile measurements, using several statistical techniques, is planned in the near future.

6.2 The Belgian Institute for Space Aeronomy (BIRA-IASB)
There are firm plans to install a MAXDOAS instrument and a CIMEL instrument in Bujumbura, Africa, in 2012, for the measurement of ozone-related species, pollutants and aerosol optical depth.

6.3 University of Liège (ULg)
The ULg group has accumulated a solid experience in the high resolution FTIR spectroscopy under high altitude harsh climatic conditions, including remote control operation. Based on this experience, in agreement with our long term development plans and fully in accordance the recommendations in the 7th Ozone Research Managers Meeting, ULg has initiated the necessary contacts, authorization requests and technical preparation to apply a funding proposal to install a remote controlled FTIR facility on the Atacama plateau (about 5100m alt), probably on the ESO APEX or ALMA premises. This location is ideal to characterize the composition of tropical air masses above South America, being a very dry site, free of air and electromagnetic pollution and providing abundant clear sky conditions. The local topology of the site is also ideal for satellite data validation and calibration of an otherwise FTIR uncovered area. It is also accessible for heavy equipment transportation. Of course, our plans include the continuation of the NDACC observations at the Jungfraujoch station and the application of the new acquisition system to all of our instruments.

6.4 Université Libre de Bruxelles (ULB)
The ULB group will maintain its research activities around laboratory rotation-vibration spectroscopy and atmospheric remote sensing. On the remote sensing side, IASI-related activities will be strengthened. The NRT FORLI processing chain will be upgraded and is planned to be implemented shortly at the EUMETSAT CAF (Central Application Facility) for wider dissemination of the L2 products to the community. This should be done within the O3M-SAF. Dedicated researches in relation to polar stratospheric chemistry are ongoing. ACE-FTS measurements will be exploited whenever relevant. On the medium term, the group will also be involved in MTG.
At the occasion of the International Polar Year 2007, the Belgian government decided to build a new scientific summer station at Utsteinen, East Antarctica and committed the International Polar Foundation to design and build this new base.

A Brewer ozone spectrophotometer was installed mid-January 2011 and was able to measure until 14 February 2011. It measured the total column amount of ozone and the UV radiation in the UV-A and UV-B bands. It was successfully set up for the first time. It was mounted on the northern roof of the station. It needs sun and regular maintenance for operation and was therefore de-installed at the end of the season. First analyses of the data show that it made very good and interesting measurements of total ozone and the UV index at Utsteinen.

7. NEEDS AND RECOMMENDATIONS

Needs to secure financial support for laboratory spectroscopic activities supporting investigations of the terrestrial atmosphere.


8.1 Research Needs

8.1.1 The Royal Meteorological Institute (RMI)

In response to “Further research is needed on the response of ground-level UV to changes in ozone and other atmospheric parameters in response to changes in ODSs, air quality, and climate-forcings.” (p 27, WMO TD No. 51):

- RMI participated in the COST action 726 which prepared a UV reconstructed data set (starting from 1950) over Europe.
- At RMI a study on the different contributions to the variations in UV intensities reaching the ground was made (see De Backer, 2009)

In response to “Coupled chemistry-climate models (CCMs) are becoming more mature, but it is clear that more effort must be devoted to model development and validation, including through international programmes” (p 27, WMO TD No. 51):

- At RMI a coupling between the chemical transport model CHIMERE and the numerical weather prediction model (Alladin) was performed.
- Within the BACCHUS project RMI works on the adaptation of the Canadian coupled transport/chemical GEMBACH model to Europe.

8.2 Systematic Observations

8.2.1 The Royal Meteorological Institute (RMI)

In response to “Balloon sonde networks provide critical observations which give vital high resolution vertical profiles of ozone and water vapour that are needed for multiple scientific activities in ozone research and therefore need to be maintained and increased.” (p 27, WMO TD No. 51):

- The observing program of total ozone (with two Brewers at Uccle) and ozone profiles (3 times a week ozone soundings) at Uccle is continued.
- A Brewer instrument was installed in Antarctica
- The water vapour profiles from the radio sondes at Uccle (RMI) were corrected for known errors with algorithms found in literature.
To maintain the data quality the Brewer instruments were calibrated several times at RMI.

8.2.2. The Belgian Institute for Space Aeronomy (BIRA-IASB)

- The work on GOME/SCIAMACHY/OMI/GOME-2 mentioned under 1.1.2 is a response to the requirement resulting from the 7th ORM Meeting in 2008 (p.30 WMO TD No. 51): Continuation of the solar backscatter UV observations must be ensured as they constitute a key baseline set of measurements.

- National development of ALTIUS, a limb viewing satellite instrument responding to the requirements resulting from the 7th ORM Meeting in 2008 (p.30, WMO TD No. 51): “Satellite observations of high vertical resolution profiles using limb viewing for O₃ and key molecules are required in order to more accurately understand the changes in O₃ as CFCs decline and climate change occurs.”

8.2.3 University of Liège (ULg)

In accordance with the specific recommendation “Priority to be given to the tropics, Central Asia, and southern mid-latitudes for filling data gaps in geographic coverage. We should consider the redistribution of observation sites from areas highly populated with instruments to those areas that are poorly populated. This requires infrastructure support in these areas.” (p. 29 WMO TD No. 51), ULg has initiated the necessary contacts, authorization requests and technical preparation to apply a funding proposal to install a remote controlled FTIR facility on the Atacama plateau (about 5100m alt), probably on the ESO APEX or ALMA premises.

8.3 Spectroscopic standards

8.3.1 Université Libre de Bruxelles (ULB)

In response to “Data archives should include documentation of the spectroscopic parameters used for the analysis of the data” (p. 30, WMO TD No. 51):

- The HITRAN and GEISA databases provided spectroscopic information documented in a standardized way.

- One of the tasks of the “International Advisory Committee” of the HITRAN database is to assess the quality of spectroscopic information reported in the literature, and to evaluate its possible inclusion into the database.

8.4 Data Archiving

8.4.1 The Royal Meteorological Institute (RMI)

In response to “Urge all data centres to develop procedures for the prompt submission of their ozone, UV, and ancillary ozone- and climate-related data to the World Ozone and Ultraviolet Data Centre (WOUDC). Data archiving must include detailed metadata that describe the quality of the measurement and the instrument history.” (p. 29, WMO TD No. 51):

- Besides the local archiving of the data at RMI the data are also stored in WOUDC and NDACC databases.

8.5 Capacity Building

8.5.1 The Royal Meteorological Institute (RMI)

In response to “Unused Dobson instruments are a more economical way to expand these networks and to introduce observations into new sites or programmes.” (p 29, WMO TD No. 51): and “Support and encourage regional and bilateral cooperation and collaboration (twinning) among developed and developing countries and to extend global expertise in ozone and UV measurements and research. Several twinning collaborations are already on-going through in-kind contributions. Successful existing twinning collaborations should be identified and expanded with additional funds:

- The unused Dobson instrument is loaned to Ukraine.
• The instrument was refurbished with the support of the regional Dobson Calibration centre in Germany and the operators were trained through collaboration with the Czech Hydro Meteorological Institute.

9. CO-ORDINATES OF BELGIAN INSTITUTES AND LEADING SCIENTISTS INVOLVED IN O3 RELATED RESEARCH AND OBSERVATIONS

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Ph. Demoulin (Remote sensing of the Earth composition and change using ground-based infrared instruments, data analysis and observations)

Dr. C. Servais (FTIR Instrumentation development and improvement (electronic, optic, remote control…), maintenance and observations)

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Dr. Alexander Mangold (Measurements on the Princess Elisabeth Station Antarctica)

Dr. Roeland Van Malderen (Analysis of ozone time series)

Dr. ir. Andy Delcloo (Validation of satellite ozone data, Member of project team of O3M SAF of EUMETSAT)

Ms. Veerle De Bock (Retrieval of aerosol optical parameters from Brewer observations)

Dr. Joris Van Bever (Modelling of chemical composition of the atmosphere within Bacchus)

Dr. Steven Dewitte (Head of department, member of Council of EUMETSAT)
Dr. M. De Mazière (Satellite and ground-based remote sensing measurements of the composition of the atmosphere, especially with infrared spectrometric techniques, implementation and testing of retrieval algorithms to invert observations into geophysical data, remote-sensing instrument developments, data validation)

Dr. J.-C. Lambert (Member of the International Ozone Commission, satellite and ground-based remote sensing of the composition of the atmosphere, synergistic exploitation of atmospheric composition data, data quality strategy, multi-mission satellite validation)

Dr. M. Van Roozendael (Satellite and ground-based remote sensing measurements of the composition of the atmosphere, implementation and testing of retrieval algorithms to invert observations into geophysical data, remote-sensing instrument developments, data validation)

Dr. Q. Errera (stratospheric modeling, chemical data assimilation, reanalysis of long-term data records)

Dr. S. Chabrillat (stratospheric modeling, chemical data assimilation, chemical weather)

Dr. J.-F. Muller (Global tropospheric ozone modelling, inverse source/sink modelling)

Dr. D. Gillotay (Ground- and space-based measurements of solar radiation: UV-B)

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* * *
BURKINA FASO

1 BACKGROUND

Burkina Faso is a landlocked country of 105,869 square miles, located in the heart of Western Africa, approximately 600 miles from the Atlantic Ocean. Ouagadougou, the capital city, has about one million inhabitants. The country borders Benin, Côte d’Ivoire, Ghana, Mali, Niger and Togo. With 13.4 million inhabitants and a density of 13.1 inhabitants per mile², Burkina Faso is one of the most populated states in western Africa. Per capita income is about $US 1000. Industry is mainly agricultural. Burkina Faso exports cotton, cattle and out-of-season vegetables to Europe. Weather is dry for much of the year with summer temperatures often reaching 45 degC. Principal cities are Bobo Dioulasso, Koudougou and Fado Ngourma.

2 Status of Ratification


3 INSTITUTIONAL AND REGULATORY FRAMEWORK

General legislative framework

Burkina Faso ratified the Convention of Vienna and the Montreal Protocol on 20th July 1989. The legal basis for subsequent legislation controlling the import and use of ODS goes back to a ministerial edict (no. 91-069/PRES) promulgated on 25th November 1991 and the corresponding decree through which it was enforced (no. 91-0434/MICM) issued on 27th November 1991. The legal basis for ODS legislation was subsequently strengthened by the Law no. 005/97/ADP promulgated on 30th January 1997. This document defined atmospheric pollution as the presence in the air of substances or particles that prejudice health, public safety or the environment, or by the presence in the atmosphere of substances which (among other things) contribute to Global Warming or Ozone Depletion.

Establishment and Role of National Ozone Unit (Bureau National Ozone (BNO))

The BNO was established in 1994 as an entity within the Department of Anti-pollution and Health which answers to the General department for the Preservation of the Environment within the Ministry of Environment. The objective of the BNO is to reduce ODS consumption according to the limits set in the Montreal Protocol for substances listed in Annexes A and C. To achieve this goal, the following specific tasks have been assigned to the BNO:

- To study the import and consumption of ODS
- To communicate data on the import and consumption of ODS to the MP Secretariat
- To organise training, information and awareness-raising programmes to sensitise the general public to the problem of ozone depletion.
- To create a refrigerant recovery and recycling centre.
ODS legislation

Legislation specific to ODS was enacted via a ministerial decree issued on 11th March 1997. This required that a Prior Approval for Import be obtained for the import of any ODS or piece of equipment containing ODS. A Notice to Importers was issued on the same day (97-005/MCIA/SG) by the Ministry of Commerce covering the import of any substance appearing in Annex A of the Montreal Protocol and its amendments or any equipment containing these substances.

The control of ODS import and export on a day-to-day basis is achieved through close cooperation between the Bureau National Ozone (BNO), the Individual Client Centre, and the Customs Service.

The legislation from 1997 required that importers wishing to import shipments of ODS submit an application to the “Centre des guichets uniques” who then established the bona fides of the importer and referred the application to the BNO, who would decide if and how much ODS the importer could bring into Burkina Faso. A positive response from the BNO would result in the issuing of the Prior Approval for Import (API - referred to above). The BNO issued permits in accordance with a phased reduction in ODS imports which succeeded in meeting the 50% cut in base consumption required for 2005.

The mechanism described above no longer applies as import of most ODS became illegal in January 2006 (see below). Further documentation is required under normal customs rules for any shipment of goods valued at over 500,000 CFA (769 euros). Any shipment of goods valued at 3 million CFA or more (4,614 euros) must be inspected by an accredited goods inspection company. The following describes the current legislative framework governing trade in ODS and ODS-containing equipment.

ODS Legislation via the Union Economique et Monetaire Ouest Africaine (UEMOA)

The UEMOA comprises Togo, Cote d’Ivoire, Benin, Senegal, Mali, Gambia in addition to Burkina Faso. The ODS control mechanism described above became redundant from January 1st 2006 when the UEMOA member states jointly agreed to ban the import and export of all Annexes A, B and E ODS (CFCs, halons, Carbon Tetrachloride, Methyl Chloroform and Methyl Bromide) and equipment containing these ODS apart from equipment required for urgent medical purposes. This was enacted via Regulation No. 04/2005/CM/UEMOA “Harmonisation of regulations concerning the import, trade and re-export of ODS and ODS containing equipment”. This was agreed by the Council of Ministers of the member states in July 2005. It prescribes a tight regime of control which is aimed at preventing the movement of ODS between member states. Some of the relevant articles of the legislation are:

Art 3: Import of ODS and equipment containing ODS will become illegal when this regulation comes into force.

Art 4: Production of ODS and export from the territory of member states is forbidden

Art 5: Application of the provisions of the MP and its amendments in respect of the import from non-member state of ODS or equipment containing ODS is the responsibility of the Ministry in charge of Commerce of the State to which the shipment is destined. Prior authorisation must be provided by the Ministry of Commerce of this state.
Art 7: The BNO of each member state is charged with registering the importers and distributors of ODS and equipment containing it.

Art 8: A Community Ozone Committee (CCO) is created within UEMOA and charged with putting into effect the provisions of the MP relating to ODS.

Art 9: A list of ODS and the equipment containing them can be modified through regulations issued by the UEMOA council of ministers following notification by the CCO.

Art 10: All contravention of the provisions of the present regulation exposes those carrying out the contravention to the legal sanctions provided by the relevant member state.

Art 12: The present regulation enters into force on 1st January 2006 and will be published in the official bulletin of the UEMOA.

4 RESEARCH

For small scale research issue a retrofit center as been put in place in Ouagadougou at premises supplied by the government for this purpose. The role of this centre is to:

- Provide technical support for retrofit activities
- Carry out demonstration projects that will identify the preferred retrofit technologies for different types of system in Burkina Faso
- Provide storage for illegal ODS seized by the Customs Authorities

Demonstration of Retrofit technologies

In principle there are two options for retrofitting small to medium sized refrigeration systems and MACs, namely HFC-134a based blends which can be “dropped in” to CFC-12 systems, and hydrocarbon based blends. Both are mixtures of different fluids which mimic the thermodynamic characteristics of CFC-12 and are compatible with mineral or synthetic lubricants used in CFC-12 systems. Strict procedures have to be observed with both technologies in order that a reliable system with acceptable energy efficiency characteristics results from retrofit. Technicians will be taught both types of retrofit and the criteria for selecting which to use in a given situation.

The objectives of the demonstration project to be carried out at the Retrofit Centre are to:

- Establish which retrofit options should be recommended for different classes of system
- Determine whether there are significant differences in energy efficiency between the two options and how energy consumption compares with that of the original CFC-12 system
- Establish whether there are likely to be reliability problems with different types of retrofit

The activities that will be carried out to determine these issues are:

Purchase of systems for retrofitting
Three identical CFC-12 systems of the classes that are to be compared will be purchased in Burkina Faso. These might be domestic refrigerator (probably two types), and a small commercial display case. MACs will also be compared. Standard government limousines will be provided as test vehicles for retrofit comparisons.

Performance testing of retrofitted systems

Testing will require that the Retrofit Centre be equipped with a protected mains power supply to prevent damage to the systems being tested. Two of the three domestic and commercial systems will be retrofitted respectively to hydrocarbon and HFC based blends and their thermostats set to the same level. Prior to this they will be the subject of simple tests (e.g. motor insulation resistance) to determine that the refrigeration equipment is in good condition.

Each group of systems will be located in the same secure area such that each group experiences the same ambient heat load and cannot be casually interfered with. The refrigeration systems will be connected to the mains supply via standard domestic kWh meters.

Initially pull down times will be measured for each system. They will then be run for a period of at least 6 months. At the end of this period:

- The aggregate energy consumption of each system for the period will be compared with others in the same class
- The compressors will be cut open and checked for damage to motor windings and components such as the valve plate.

This testing will give a good practical indication of:

- The cooling capacity (kW) of the retrofitted systems compared to the original CFC-12 model (from the pull down tests) and
- The energy consumption over time (kWh) when handling an identical load

As these tests are carried out any unusual practical issues that are unique to Burkina Faso will be identified and incorporated in the overall recommendations (below).

It is intended that the retrofitting of the systems used for the demonstration project should take place during the Train-the-Trainers course in consultation with the International Expert who can advise on the exact form the tests should take. The two staff technicians employed by the Retrofit Centre will be participants in the Train-the-Trainers course and will subsequently be responsible for supervising the tests along with carrying out retrofit work.

Identification of retrofit options

Appendix 1 gives the breakdown of estimated costs for retrofitting typical domestic, small commercial and MAC systems using hydrocarbon and HFC based techniques. In addition to cost, there are safety, energy efficiency and reliability issues that will indicate the best choice. From a technical point of view, hydrocarbons are more robust and likely to lead to retrofit which is more reliable and is slightly more energy efficient. Their use, however, raises safety concerns that have to be addressed. Cost levels are similar for domestic refrigerators and small commercial systems, whereas hydrocarbon retrofit is by far the cheapest option for MACs.

These costs are quite sensitive to the fairly high labour costs charged by workshops in Burkina for a skilled technician’s time. The demonstration project will enable the time element involved in each option to be refined and better cost estimates made.

The demonstration project will be carried out in collaboration with the Refrigeration Association, some of whose members will participate in the Train-the-Trainers course. Local experts and the
Bureau National Ozone (BNO) will produce a joint set of recommendations that will address the following:

- The preferred retrofit option for each class of system (with reasons)
- The procedures to be adopted when carrying out retrofit of each class of system

Provision of retrofit toolkits to a selected group of workshops

Appendix 2 provides a list of tools that will be included in each retrofit kit to be purchased for servicing workshops, to be selected by Burkina Faso on the basis of the relatively high amount of repairs they carry out. It is estimated that the budget available will allow the supply of kits to about 45 to 50 workshops.

When CFC-12 systems are retrofitted to other refrigerants, the existing CFC-12 in the system must first be removed. The most common fault on small refrigeration systems is a motor burnout, and the most common fault on MACs systems is a leak. This influences the condition and amount of refrigerant that is likely to be recovered.

- Small refrigeration systems: the burning motor windings create decomposition products that cannot be removed by simple recycling machines. 100% of the charge of this contaminated refrigerant is likely to be recovered.

- MACs: as these are mechanical, open drive systems burnout does not apply. The refrigerant will likely be of acceptable quality slightly contaminated with moisture and acids that can be reliably cleaned by a simple recycling machine. Less than half the charge is likely to be recovered.

Small hand operated recovery pumps will be included in the retrofit kits to enable the refrigerant charge from small refrigeration systems to be recovered. Where this is highly contaminated, it will be stored indefinitely.

In addition to the kits, two MAC dedicated recovery and recycling machines will be purchased in Phase I, one for the Retrofit Centre and the other for a selected servicing workshop. The use of these machines will be closely monitored. Should these enable significant amounts of CFC-12 to be recovered by the retrofit centre and re-used, consideration will be given in Phase 2 to purchasing more for distribution to MACs service workshops. Using the flexibility permitted under TPMP, Burkina Faso and the agency concerned may then decide to alter the budget allocated for the equipment accordingly.

Public awareness raising campaign (PARC)

The general public and businesses in Burkina Faso need to be sensitised to the fact that the price of CFC-12 will rise steeply before 2010 when it will become unavailable. Owners of refrigerant equipment and MACs that still use CFC-12 should therefore have their equipment retrofitted to non-ODS alternative refrigerants the next time their equipment suffers a breakdown that involves opening the refrigerant circuit.

Therefore, a few awareness-raising activities will be implemented to:

- Sensitise the population to the impending scarcity and rising cost of CFC-12
− Present the option of having their equipment retrofitted by workshops whose technicians have been trained and licensed to carry out this activity
− Publicise the officially recommended retrofit options for different types of equipment

The PARC will be implemented through TV and radio news and current affairs slots and newspaper articles following the same pattern as previous PARCs which have been used to promote environmental issues

Expected results and criteria for success

The expected results from this technical assistance programme include:

• Provision of positive recommendations regarding the retrofit technologies to be promoted in Burkina Faso
• Contribution to the phase-out of the remaining CFC consumption consumption before 2010 in a way which minimises the economic impact to the country
• Creation a permanent technology and information resource that will support the refrigeration and MACs industries in Burkina Faso after funding ceases.

The criteria used to measure the success of this programme will be:

• Quality of results acquired from the retrofit demonstration projects
• Numbers of retrofits carried out

Target Audience

All refrigeration and MACs technicians working in legitimate service business throughout Burkina Faso.

Approach

The project will be divided in two phases:

• **Phase I** (during 12 months following implementation):
  − Establish and equip retrofit Centre
  − Carry out demonstration projects
  − Implement first phase of PARC
  − Procure about half of retrofit kits required for distribution to workshops
  − Review results of demonstration projects
  − Consider privatisation of Retrofit Centre

• **Phase II** (after completion of Phase I, for a duration of up to 12 months): Equipment will be procured and distributed to selected workshops.
  − Implement second phase of PARC and publish retrofit recommendations
  − Procure and distribute remaining retrofit kits
  − Monitor and report on equipment use and retrofit projects
Co-operating partners and their role

**Bureau National Ozone (BNO):**

The BNO will be responsible for organising and over-seeing the Retrofit Centre. This will include fitting out the premises provided for the Centre by the government and hiring the technicians and support staff.

The BNO will be responsible for the final selection of workshops that will receive the retrofit toolkits. Returns from the workshops regarding the number of retrofit operations carried out and amounts of refrigerant recovered will initially be sent to the Centre where the support staff will synthesise these into a monthly report. The BNO will be responsible for providing this report to interested parties. It will also make spot checks on workshops that have received the toolkits to verify the returns and to ensure that retrofit techniques taught on the Training Course are being competently carried out.

The BNO will oversee the Retrofit Demonstration activities and ensure that these are being carried in the fashion agreed with the International Expert and that the technicians are monitoring the systems being tested. As the tests are terminated, the BNO will organise meetings with the Refrigeration Association to determine what conclusions can be drawn from the tests in respect of the most suitable retrofit technologies for Burkina Faso.

The BNO will also be responsible for the Centre’s commercial operations. It will ensure that the secretarial support staff maintain proper records of payments and work carried out. The BNO will ensure that the Centre’s accounts are prepared and certified in an appropriate fashion at the end of the financial year.

**Refrigeration Association:**

The Refrigeration Association will provide technical support for the BNO in all the activities described above and any others as required. Its input will be particularly important in drawing conclusions from the Retrofit Demonstration activities, ensuring that the retrofit tests themselves are being properly carried out and that workshops are performing retrofits competently.

**Servicing workshops:**

The workshops receiving retrofit toolkits will retrofit refrigeration systems and/or MACs and provide details of systems retrofitted and amounts of refrigerant recovered. They will also provide feedback to the BNO on any aspect of the implementation of retrofit in the field that requires comment/

**The Retrofit Centre**

The Retrofit Centre will be responsible for:

- Carrying out the Retrofit Demonstration Project
- Processing the returns from workshops and providing a monthly report to the BNO
- Providing technical support to all service workshops on Retrofit.

**Supporting and follow up actions**

As described above, all registered workshops in Burkina Faso will provide monthly returns to the Retrofit Centre, which will then synthesize this information and report to the BNO regarding the amount of ODS refrigerant phased out by retrofitting and amounts of refrigerant recovered
through these and other activities. The BNO will responsible for organising spot checks by competent bodies on workshops to ensure conformity with best retrofit practice as taught on the training programme.

The Refrigeration Associations and the BNO will co-operate in synthesising the experience gained from the Project and contribute to the production of a Completion Report.

**Appendix 1**

<table>
<thead>
<tr>
<th>Retrofit</th>
<th>cost</th>
<th>estimation</th>
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## Domestic Refrigerators

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<th>Hydrocarbon retrofit</th>
<th>HFC-134a blend retrofit</th>
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<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td>$21.02</td>
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<tr>
<td><strong>Labour</strong></td>
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<td><strong>Total retrofit cost</strong></td>
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## Small commercial systems

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<th>Hydrocarbon retrofit</th>
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<tr>
<td><strong>Equipment</strong></td>
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<td><strong>Total retrofit cost</strong></td>
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<td>$33.63</td>
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## MACs

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<th>Hydrocarbon retrofit</th>
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<tr>
<td><strong>Equipment</strong></td>
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<td><strong>Labour</strong></td>
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<td><strong>Total retrofit cost</strong></td>
<td>$40.63</td>
<td>$110.33</td>
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Appendix 2  
Tool kit for Burkina Faso Workshop

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<th>Domestic &amp; Comm Package</th>
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<tbody>
<tr>
<td>Gauge manifold</td>
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<td>Gauge manifold</td>
</tr>
<tr>
<td>Set 3 hoses</td>
<td>25</td>
<td>Set 3 hoses</td>
</tr>
<tr>
<td>Electronic Leak detector</td>
<td>210</td>
<td>Electronic Leak detector</td>
</tr>
<tr>
<td>Small pipe bender</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Swaging/Flaring kit</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Multimeter</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>Recovery unit and cylinder</td>
<td>350</td>
<td>Recovery unit and cylinder</td>
</tr>
<tr>
<td>Charging unit with vacuum pump</td>
<td>733</td>
<td>Charging unit with vacuum pump</td>
</tr>
<tr>
<td>Oil acidity tester</td>
<td>10</td>
<td>Oil acidity tester</td>
</tr>
<tr>
<td>Aluminium soldering kit</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Heat seal stick</td>
<td>12</td>
<td>Hydraulic hose crimping m/c</td>
</tr>
<tr>
<td>Inspection mirror</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Heat shield</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Deburring tool</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Piercing valve</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Crimping pliers</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>1 Litre Charging Still</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Brazing/welding kit with oxygen</td>
<td></td>
<td>Probably owned by all workshops</td>
</tr>
<tr>
<td>Tube cutter</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Small tube cutter</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Capillary cutter</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Dry powder extinguisher</td>
<td>50</td>
<td>Dry powder extinguisher</td>
</tr>
<tr>
<td>Nitrogen cylinder and gauges</td>
<td>150</td>
<td>Nitrogen cylinder and gauges</td>
</tr>
<tr>
<td>HC Gas alarms</td>
<td>100</td>
<td>selected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2237</td>
<td></td>
</tr>
<tr>
<td>Selection for non flammable retrofit</td>
<td>2087</td>
<td></td>
</tr>
<tr>
<td></td>
<td>allow $ 2,500</td>
<td>$ 2,500</td>
</tr>
</tbody>
</table>

129
### Appendix 3

**Equipment for Retrofit Centre**

<table>
<thead>
<tr>
<th>Description</th>
<th>USD Approx Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of general handtools engineering and workshop equipment</td>
<td>4000</td>
</tr>
<tr>
<td>Selection of specialised refrigeration tools and instruments</td>
<td>4000</td>
</tr>
<tr>
<td>Selection of consumable materials</td>
<td>800</td>
</tr>
<tr>
<td>Power protection system for Retrofit Testing</td>
<td>2000</td>
</tr>
<tr>
<td>2 x MACs Recovery and Recycling machines</td>
<td>6000</td>
</tr>
<tr>
<td>Computer and printer for secretarial support staff</td>
<td>1200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18,000</strong></td>
</tr>
</tbody>
</table>
Appendix 4  
Financial Model of Retrofit Centre

<table>
<thead>
<tr>
<th>Financial Model of Retrofit Centre</th>
<th>Based on HFC-134a based MACs Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of Return</td>
<td>42%</td>
</tr>
<tr>
<td>Costs in USD</td>
<td></td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
</tr>
<tr>
<td>Working Days in year</td>
<td>220</td>
</tr>
<tr>
<td>Hours per working day</td>
<td>8</td>
</tr>
<tr>
<td>Average energy consumed per day</td>
<td>0.75 kW</td>
</tr>
<tr>
<td><strong>Variable Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Costs Electricity/kWh</td>
<td>$0.12</td>
</tr>
<tr>
<td>Electricity cost per year</td>
<td>$158</td>
</tr>
<tr>
<td>Wages per man month</td>
<td>$208 (incl social costs)</td>
</tr>
<tr>
<td><strong>Fixed Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Premises: rent</td>
<td>$30 per month</td>
</tr>
<tr>
<td>Building maintenance</td>
<td>$10 per month</td>
</tr>
<tr>
<td><strong>Material costs</strong></td>
<td></td>
</tr>
<tr>
<td>Parts and materials per retrofit</td>
<td>$94</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
<tr>
<td>Number of technicians</td>
<td>2</td>
</tr>
<tr>
<td>Retrofits per day</td>
<td>2.30 max 5 retrofits</td>
</tr>
<tr>
<td>Price paid per retrofit</td>
<td>$120</td>
</tr>
<tr>
<td>Gross Profit per day</td>
<td>$1.30</td>
</tr>
<tr>
<td>Gross Profit per year</td>
<td>$1,555</td>
</tr>
</tbody>
</table>
### Cash Flow

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<tbody>
<tr>
<td>Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Investment</td>
<td>750</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premises</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Delivery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Civs Work</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elec.</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>158</td>
</tr>
<tr>
<td>Filters</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Wages</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
</tr>
<tr>
<td>Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sale Ref.</td>
<td>1555</td>
<td>1555</td>
<td>1555</td>
<td>1555</td>
<td>1555</td>
<td>1555</td>
<td>1555</td>
<td>1555</td>
</tr>
<tr>
<td>Handling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidic Ref.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit</td>
<td>-489</td>
<td>261</td>
<td>261</td>
<td>261</td>
<td>261</td>
<td>261</td>
<td>261</td>
<td>261</td>
</tr>
<tr>
<td>% costs</td>
<td>-24%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Cumulative</td>
<td>-489</td>
<td>-228</td>
<td>32</td>
<td>293</td>
<td>554</td>
<td>815</td>
<td>1076</td>
<td>1336</td>
</tr>
</tbody>
</table>

There is no observing station relating ozone matters in Burkina Faso.

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CAMBODIA

Introduction
Cambodia is a Party to the Montreal Protocol having acceded to the Vienna Convention and the Montreal Protocol in June 2001. Cambodia is a developing country and has been classified as an Article 5(1) country.

This ODS Phase-out Management Plan including Country Program, Terminal Phase out Management Plan and HCFC Management Plan have been prepared and implemented by Cambodia National Ozone Unit of the Ministry of Environment on behalf of the Royal Government of Cambodia. It is a consensus approved by the National Steering Committee and by the Senior Minister, Minister of Environment on behalf of the Royal Government of Cambodia. The plans; especially, HCFC Phase-out Management Plan explains the policies and programs that the Royal Government of Cambodia has both adopted and intends to adopt to ensure Cambodia’s compliance with the Montreal Protocol on ODS phase-out schedule. Many of these activities presume that financial and technical assistance for Cambodia’s efforts will be provided from the Multilateral Fund.

Recently Cambodia’s Hydro-Chlorofluorocarbon Phase-out Management Plan (HPMP) of Ozone Depleting Substances was prepared and submitted for consideration at the 61st Meeting of the Executive Committee of the Multilateral Fund and was approved at the same meeting in November 2010. Cambodia’s consumption of HCF Cs in 2008 was 165 metric tonnes. Thus, Cambodia was faced with a challenge to freeze this consumption by 2013 and phase-down this consumption by new control schedule of Montreal Protocol 10% by 2015 and 35% by 2020 and 67.5% by 2025, and finally the 100% reduction from the base line by 2030 for Annex-C Group-I substances (HCFCs).

Use of CFC and HCFC in sectors
Cambodia uses CFC and HCFCs only in the installation and servicing of refrigeration and air conditioning equipment.

Based on data survey for end-users in 2008, Cambodia used about 164 MT of HCFC-22 and 1.2 MT of HCFC-123. The HCFCs were used in sub-sectors such as air conditioning, chiller, commercial refrigeration and transportation refrigeration. There are also HFC-blended refrigerants (R-404A, R-407C, and R410A) being used. The survey in 2009 did not find any use of HCFC in foam-blowing, fire-fighting, or solvent applications.

Based on data of importation in 2009; there are about 10 companies were registered (included old and new companies) and applied for imported permission from NOU/MoE; and there also the importation of HFCs refrigerant, Air Conditioning equipment contained HCFC-22. Air Conditioning equipment contained HFC-410a as blend refrigerant and others RAC equipment were imported by those companies into Cambodia by the year of 2009 and the estimation trend for the few year ahead as show in the table below:

Forecast number of air conditioner installations and its servicing needs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of new AC import (1,000 units)</td>
<td>42.4</td>
<td>46.7</td>
<td>51.1</td>
<td>55.4</td>
<td>59.8</td>
<td>64.1</td>
<td>68.5</td>
</tr>
<tr>
<td>Number of second-hand AC (1,000 units)</td>
<td>5.0</td>
<td>5.3</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
</tr>
<tr>
<td>Number of scrapped AC (1,000 units)</td>
<td>15.5</td>
<td>16.2</td>
<td>17.0</td>
<td>17.9</td>
<td>18.8</td>
<td>19.7</td>
<td>20.7</td>
</tr>
<tr>
<td>Total installations (1,000 units)</td>
<td>405.3</td>
<td>440.2</td>
<td>478.9</td>
<td>521.4</td>
<td>567.5</td>
<td>617.3</td>
<td>670.8</td>
</tr>
<tr>
<td>Total installed capacity (MT)</td>
<td>405.3</td>
<td>440.2</td>
<td>478.9</td>
<td>521.4</td>
<td>567.5</td>
<td>617.3</td>
<td>670.8</td>
</tr>
</tbody>
</table>
There are ten companies that have previously registered with Ministry of Environment as importers of ozone depleting substances in Cambodia plus four new importers that registered in 2009 (i.e. a total of 14 importers). All except one are in Phnom Penh. The source of imported HCFCs in 2009 was mainly from China, India, and Singapore. There was some amount that was supplied through cross-border trade with Thailand and Vietnam.

Table below shows the Article 7 data for HCFCs that Cambodia had reported to the Ozone Secretariat during 2003-9.

### Cambodia HCFC Article 7 Data from 2003-9 (ODP Tons)

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex C-I</td>
<td>2.8</td>
<td>4.2</td>
<td>6.2</td>
<td>6.0</td>
<td>8.0</td>
<td>7.9</td>
<td>17.1</td>
</tr>
</tbody>
</table>

Error! Reference source not found. 1 shows the import of HCFC-22 from 2003-9 as compiled by the Cambodian NOU. Besides HCFC-22, there is no record of other HCFCs being imported into Cambodia though the survey indicated that 1.2 MT of HCFC-123 had been used in 2008. The import of HCFC-22 has steadily increased in line with the country economic development. HCFC-22 import in 2008 was at 143.27 MT which is almost three times the 2003 import.

Cambodia NOU has also reported 2009 Article 7 consumption data which amounted to 311.17 MT of HCFC-22. This is a dramatic increase of more than twice the 2008 import. The reasons for such high import in 2009 appear to be market penetration and possible stockpiling by new importers.

**Production**

Cambodia does not produce any ODS and all ODS must be imported. The total amount of ODS imported to Cambodia is used only to meet its local demand. There is no known branch/subsidiary of foreign fluorochemical manufacturers in the country.
For the HFCF consumption, there is no known manufacturing of HCFC-dependent RAC equipment such as air conditioners in Cambodia. All RAC equipment is imported into Cambodia.

**Exports**
Export of ODS including HCFCs is controlled under the Sub-Decree. There is no record of export of HCFCs from Cambodia to other countries.

**Levels of HCFCs in blends and as feedstock, as applicable**;
There is no HCFC used as feedstock in Cambodia nor is there any record of import of HCFC in blends. The data survey did not find any use of HCFC blends by the servicing workshops. The NOU also has not issued any import license for HCFC blends.

**HCFC use and consumption**
Cambodia uses HCFCs only in the installation and servicing of refrigeration and air conditioning equipment. The 2009 survey did not find any use of HCFC in foam-blowing, fire-fighting, or solvent applications.

**Levels of HCFC consumption**
Based on the end-user data survey, Cambodia used about 164 MT of HCFC-22 and 1.2 MT of HCFC-123 in 2008. There are also HFC-blended refrigerants (R-404A, R-407C, and R410A) being used. The survey revealed that HCFCs were used in the following sub-sectors: air conditioning, chiller, commercial refrigeration and transportation refrigeration as shown in Table below:

<table>
<thead>
<tr>
<th>Sub-sectors</th>
<th>HCFC-22</th>
<th>HCFC-123</th>
<th>Total</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioning</td>
<td>143.0</td>
<td>143.0</td>
<td>165.2</td>
<td>100%</td>
</tr>
<tr>
<td>Chiller</td>
<td>15.0</td>
<td>1.2</td>
<td>16.2</td>
<td>10%</td>
</tr>
<tr>
<td>Commercial refrigeration</td>
<td>4.0</td>
<td>4.0</td>
<td>2.0</td>
<td>2%</td>
</tr>
<tr>
<td>Transportation refrigeration</td>
<td>2.0</td>
<td>2.0</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>164.0</td>
<td>1.2</td>
<td>165.2</td>
<td>100%</td>
</tr>
</tbody>
</table>

As shown in Figure 2, most of HCFC are used in Phnom Penh (66%), followed by Siem Reap (14%) and Batteay Mean Chey (7%). These 3 provinces are the major cities where most hotels, casinos, restaurants, apartments, office buildings, and other establishments are located. The remaining consumption (13%) is used in other provinces.

Figure 2 Distribution of HCFC use by provinces
**Information on Ozone issues to the public**
The National Ozone Unit under the Institutional Strengthening Program being assisted by UNEP. The NOU has raised awareness on ozone related issues, published awareness materials for distributing to the public, relevant institutions and stakeholders. In addition, the National Ozone Unit conducted the Inter-ministerial Meeting, awareness workshops for the participants from relevant institutions and stakeholders attended these workshops.

**Market study on the cost of Refrigerants**
There some study and survey on the cost of the refrigerants in the market in Cambodia that study are focusing on ODS and alternative refrigerant (non-ODS) and looking ahead for the implementation of the HPMP in Cambodia. The cost of the refrigerant are enclose here bellow:

**Prices of refrigerants in Cambodia in 2010**
- USD 120 for HFC-134a /cylinder of 13.6 kg,
- USD 90-160 for R-410a /cylinder of 11.3 kg,
- USD 85-135 for R-404 /cylinder of 10.9 kg,
- USD 85-135 for R-407 /cylinder of 11.3 kg,
- USD 35-42 for HCFC-22 /cylinder of 13.6 kg,

**Prices of refrigerants in Cambodia in February 2011**
- USD 130 for HFC-134a /cylinder of 13.6 kg,
- USD 80-140 for R-410a /cylinder of 11.3 kg,
- USD 80-130 for R-404 /cylinder of 10.9 kg,
- USD 75-135 for R-407 /cylinder of 11.3 kg,
- USD 35-43 for HCFC-22 /cylinder of 13.6 kg,

**Future plan**
Since Cambodia is the one of the developing countries; therefore, Cambodia are very keen to participate in the research program in the other countries as well as to set up the instrument to monitor the ozone level that can effect to human health, crop, etc.,. In this regard, Cambodia would like to take any project that related to ground ozone Monitoring in Cambodia.

**Need and recommendation**
- There is the need to install the equipment to monitor the ground ozone monitoring in place
- Training on the scientific and technical training and more international collaboration
- Need the financial support for exchange visit among the countries in the region at the monitoring station to improve the knowledge and experiences

Finally, we would like to express our sincere thanks to WMO/UNEP give me the opportunity for me to participate in the meeting and the national report on the implementation of the Montreal Protocol related issues in Cambodia and we hope that we will get more other support on this activities in the near future.

References
- HCFC Phase Out Management Plan for Cambodia
- Terminal Phase out Management Plan for Cambodia
- Country Program for Montreal Protocol Implementation
1 OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone

The Canadian Brewer Ozone Spectrophotometer network consists of 8 real-time reporting stations that provide data directly to the Canadian Meteorological Centre in support of operational requirements. Each of the southern network stations operates two Brewer Spectrophotometers and the Arctic stations have three instruments on site. The additional instruments provide redundancy to reduce overall travel costs, especially in the Arctic, should an instrument fail; provides a means of optimizing the observation of both columnar ozone and UV spectral irradiance; and provides extra data for quality assurance purposes. The Arctic instruments are scheduled to perform moon observations during the Arctic night. Over the last several years Environment Canada has embarked upon an aggressive Life Cycle Management program as part of their ISO 9001 certification. The Brewer network has benefited from this program so that MK III Brewers (double Brewers) are installed at each of the network sites.

The Richmond, BC (Vancouver) site was established in 2010 and following an appropriate overlap period will probably replace the present Saturna Island location. Two reasons for this change are the overall increase in efficiencies associated with travel and maintenance costs, and the improved location of the instrument to provide real-time UV Index information to a major Canadian population area.

Besides the operational network, efforts are underway to establish Brewer Spectrophotometers at each ozonesonde location where the networks are not presently collocated. This will improve the overall quality of the ozonesonde profiles through corrections of the integrated ozonesonde column to the Brewer ozone column observations. Presently, Kelowna, BC and Egbert, ON have collocated Brewers for this purpose and installation at the last station, Yarmouth, NS, is underway.

Canada, in collaboration with the U.S. National Oceanic and Atmospheric Administration (NOAA), maintains a Breuer instruments at the Mauna Loa Observatory, Hawaii and at South Pole Station, Antarctica. There are a number of other Brewers operated by Canadian universities for research purposes that do not report data on a regular basis.
Table 1. Locations of the Canadian Operational Brewer Network. The date the site was established represents the when column ozone observations commenced.

<table>
<thead>
<tr>
<th>NAME</th>
<th>LATITUDE (NORTH)</th>
<th>LONGITUDE (WEST)</th>
<th>ESTABLISHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert</td>
<td>82.50</td>
<td>62.30</td>
<td>1989</td>
</tr>
<tr>
<td>Churchill</td>
<td>58.75</td>
<td>94.00</td>
<td>1964</td>
</tr>
<tr>
<td>Edmonton (Stony Plain)</td>
<td>53.55</td>
<td>114.10</td>
<td>1957</td>
</tr>
<tr>
<td>Eureka</td>
<td>80.05</td>
<td>86.43</td>
<td>1992</td>
</tr>
<tr>
<td>Goose Bay</td>
<td>53.32</td>
<td>60.30</td>
<td>1962</td>
</tr>
<tr>
<td>Regina (Bratt’s Lake)</td>
<td>50.21</td>
<td>104.67</td>
<td>1994</td>
</tr>
<tr>
<td>Resolute Bay</td>
<td>74.72</td>
<td>94.98</td>
<td>1957</td>
</tr>
<tr>
<td>Saturna Island</td>
<td>48.78</td>
<td>123.13</td>
<td>1990</td>
</tr>
<tr>
<td>Toronto (Downsview)</td>
<td>43.78</td>
<td>79.47</td>
<td>1960</td>
</tr>
<tr>
<td>Richmond (Vancouver)</td>
<td>49.182</td>
<td>123.078</td>
<td>2010</td>
</tr>
</tbody>
</table>

1.2 Profile measurements of ozone

Environment Canada launches ozonesondes at 10 locations across Canada once per week using Ensci Inc. sondes. Eight of these stations are operated using the facilities of the Meteorological Service of Canada, while 2 are located at Science and Technology Branch facilities. Sondes are launched from appropriate stations with higher frequency during campaigns such as Match (Alfred Wagner Institute, Bremerhaven, Germany) and for short-term process studies within North America (e.g., BORTAS (see below).

Table 2. Locations of the Canadian Ozonesonde Network.

<table>
<thead>
<tr>
<th>NAME</th>
<th>LATITUDE (NORTH)</th>
<th>LONGITUDE (WEST)</th>
<th>ESTABLISHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert</td>
<td>82.50</td>
<td>62.30</td>
<td>1987</td>
</tr>
<tr>
<td>Churchill</td>
<td>58.75</td>
<td>94.00</td>
<td>1973</td>
</tr>
<tr>
<td>Edmonton (Stony Plain)</td>
<td>53.55</td>
<td>114.10</td>
<td>1970</td>
</tr>
<tr>
<td>Egbert (Centre for Atmospheric Research)</td>
<td>44.23</td>
<td>79.78</td>
<td>2003</td>
</tr>
</tbody>
</table>

1 Environment Canada completed a reorganization of functions in 2007 whereby a new Science and Technology (S&T) Branch was created and atmospheric science research was separated from the more operational aspects of weather and environmental monitoring which remained as the Meteorological Service of Canada (MSC). The ozone monitoring program straddles these two branches.
<table>
<thead>
<tr>
<th>Experiments</th>
<th>80.05</th>
<th>86.43</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eureka</td>
<td>53.32</td>
<td>60.30</td>
<td>1969</td>
</tr>
<tr>
<td>Goose Bay</td>
<td>49.94</td>
<td>119.40</td>
<td>2003</td>
</tr>
<tr>
<td>Kelowna</td>
<td>50.21</td>
<td>104.67</td>
<td>2003</td>
</tr>
<tr>
<td>Regina (Bratt’s Lake)</td>
<td>74.72</td>
<td>94.98</td>
<td>1966</td>
</tr>
<tr>
<td>Resolute Bay</td>
<td>43.87</td>
<td>66.11</td>
<td>2003</td>
</tr>
<tr>
<td>Yarmouth</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Environment Canada operated a stratospheric ozone LIDAR at Eureka, NU until 2009, when its laser failed. In summer 2009 a new laser was installed, but because of electronics problems the LIDAR could not be returned to functionality. Because of the obsolescence of the electronics and operating system of this LIDAR, this instrument has yet to be returned to operation. A second stratospheric LIDAR is being developed approximately 80 km north of Toronto at the Centre for Atmospheric Research Experiments (CARE) using the same laser system as the arctic instrument. Once this second system is completed and tested, the expectation is to have a duplicate set of pre-tested electronics installed at Eureka.

1.3 UV Measurements

1.3.1 Broadband measurements

Broadband observations are not made by Environment Canada, however commercial forecasting companies such as the Weather Network have developed their own broadband UV network for observing erythemal-weighted UV at major Canadian cities.

The United States Department of Agriculture (USDA) UV-B Monitoring and Research Program network is collocated with two Canadian Brewer Spectrophotometer sites in Canada – Bratt’s Lake Observatory and Toronto. As part of their measurement program they obtain erythemal-weighted UV-B irradiance using a Yankee Environmental Systems UVB-1 Pyranometer. Further information can be found at: [http://uvb.nrel.colostate.edu/UVB/index.jsf](http://uvb.nrel.colostate.edu/UVB/index.jsf)

1.3.2 Narrowband filter instruments

Similarly, narrowband filter instruments are not used in Canada other than at the two stations operated in conjunction with the USDA UV-B Monitoring and Research Program.

1.3.3 Spectroradiometers
Observations of spectral UV-irradiance are made using Brewer Spectrophotometers. Because of the dual purpose of these instruments, the number of observations of ozone and spectral UV irradiance are optimized by location and time-of-year. Approximately 5 UV spectra are obtained each hour. A single spectrum, consisting of a forward and backward scan across the grating is obtained in about 8 minutes.

1.4 Calibration Activities

Canada continues to host the World Brewer Ozone Triad and supports the European Brewer (MK III) Ozone Triad located at El Arenosillo Atmospheric Sounding Station, Spain. To date, Environment Canada has sent a double Brewer and two scientists to participate in the bi-annual calibration event and to ensure that the reference maintained in Spain remains in concert with the reference Triad in Toronto.

The World Brewer Ozone Triad is maintained through regular calibration trips to Mauna Loa, Hawaii where Environment Canada maintains a Mark III Brewer Spectrophotometer. Through the maintenance of this single instrument and the calibration of multiple Brewer instruments brought, including one from the Triad, the overall reference Triad is continuously evaluated and maintained. With the overall up-grading of the Canadian network, a number of Mk III Brewers are being evaluated to eventually upgrade the Triad to the Mk III instruments.

The standard and UV lamps of network instruments are monitored constantly to ensure proper operation of each instrument. Should information being reported from the lamp tests or other instrument diagnostics fall outside acceptable levels the instruments are either serviced on site or sent to Toronto for servicing, or removed from network operations (for Arctic stations). Following any servicing of an instrument that might impact the quality of the observations, calibrations are completed as part of the servicing operation. Should an instrument not require servicing sooner, it undergoes a complete on-site service once every two years by Environment Canada technicians. As part of this overhaul, both ozone and UV calibrations are undertaken before and after any work is undertaken on the instrument. Information calibration and servicing methods can be found at:

2 RESULTS FROM OBSERVATIONS AND ANALYSIS

- **Ozone trend studies.** Fioletov was nominated as one of the two Lead authors of the WMO/UNEP 2006 Ozone Assessment, Chapter 3, “Global Ozone: Past and Present” and as one of two Coordinating Lead Authors of the WMO/UNEP 2010 Ozone Assessment, Chapter 2, “Stratospheric Ozone and Surface Ultraviolet Radiation.” This was largely in recognition of his contribution to estimating and understanding long-term ozone trends. Ozone Assessments are
prepared every 4 years and provide the scientific basis for political decisions made by the Parties to the United Nations Montreal Protocol.

- **“Ozone memory” studies.** Fioletov and Shepherd, 2003, GRL paper, demonstrated that summertime total ozone anomalies are strongly linked to springtime anomalies. This and the subsequent papers give a way to predict summertime ozone (and therefore summertime UV) from springtime ozone levels. Subsequent studies by S. Tegtmeier, a PDF under Fioletov’s supervision, found a similar link between winter and summer concentrations of ozone and other trace gases in the lower and upper stratosphere over low and middle latitudes that can be used for long-range forecasts of the stratospheric composition.

- **Ozone network performance study.** One of the outcomes of the Ozone Assessment-2006 was the identification of the need to improve the quality of ground-based total ozone observations. The world ground-based network is comprised of stations from more than 100 different agencies. Operational procedures, calibration histories, etc., are somewhat different among them resulting in a difference in the quality of the data. Fioletov et al., 2008, evaluated the performance of all individual station instruments. This study represents the common view of the WMO SAG-Ozone technical panel comprised of experts in ground-based and satellite total ozone observations.

- **UV Climatology over the US and Canada, erythemal and vitamin D action spectra-weighted UV study.** The UV Index is based on the erythemal action spectrum which expresses the dependence on wavelength of the effectiveness with which radiation produces sunburn. Solar UV radiation is also the main natural source of vitamin D, which is essential for bone and musculoskeletal health, etc. Canadian and US Brewer spectral UV irradiance measurements were used to study the relationship between erythemal and vitamin D action spectra-weighted UV and to estimate Ultraviolet exposure levels for a sufficient vitamin D status in North America.

- **ARC-IONS (2008) Ozonesonde campaign: ~380 profiles.** Cooperation with NASA project Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS), April and July 2008 over northern Canada. Objectives: (1) evaluation of the role of stratosphere/troposphere exchange (STE) in the spring buildup of tropospheric ozone; (2) studies of boundary layer ozone depletions resulting from halogens released from sea salt deposited on Arctic sea ice; (3) the contribution to the tropospheric ozone budget from boreal forest fires and the extent of fire emission influence on a trans-continental scale and beyond; (4) validation of Aura (TES, OMI) at high latitudes; of GEM-MACH, for ozone & STE, and forest fire models.

- **BORTAS-A (2010) Ozonesonde Campaign: ~210 profiles.** Cooperation between Universities of Edinburgh, York and Leeds, Environment Canada,
Dalhousie University, NASA, several other European, Canadian and US universities. Objectives: Study ozone production from boreal fires; quantify the impact of boreal biomass burning on the global tropospheric composition using data from satellite sensors. Rationale: tropical biomass burning is well known, and observed from satellites; the potential atmospheric impact of boreal fires is larger, as both fuel consumption and intensity of boreal fires are typically an order of magnitude larger than for savanna fires; emissions are carried higher, making long-range transport an important consideration. However, previous measurements in smoke plumes show highly variable ozone amounts.

BORTAS-A involved an ozonesonde intensive field study, along with aerosol optical depth and aerosol lidar network intensives, surface measurements at Halifax, and NO2 and CO (plume-tracking) data from AIRS, TES, MOPITT, IASI. Extensive modeling using GEOS-Chem, GEM-FLEXPART, HYSPLIT.

BORTAS-B (2011) will add sampling of the biomass burning outflow of boreal fires from North America toward Europe with the FAAM146 aircraft, in order to quantity the impact of boreal forest fires on oxidant chemistry over the Atlantic with a 3-D chemistry transport model, constrained by field measurements.

3 THEORY, MODELLING AND OTHER RESEARCH

- **New Brewer ZS algorithm.** This new algorithm was developed to improve the quality of Brewer observation under cloudy conditions. Unlike the present algorithm that is based on an empirical relationship, the new algorithm is based on radiative transfer calculations with just a small adjustment that accounts for properties of individual Brewer instruments. (Fioletov, V.E., C. A. McLinden, C. T. McEloy, and V. Savastiouk, New method for deriving total ozone from Brewer zenith sky observations, J. Geophys. Res., 2011.)

- **Research into Ozone and temperature trends.** When ozone trends are computed using profiles measured in different units, differences should be expected due to simultaneous trends in background air number density and layer thicknesses brought about by climate change. The long-standing difference between SAGEI+II and SBUV ozone trends in the upper stratosphere can be largely reconciled when this is taken into account. When SAGE profiles (originally number density on a constant altitude grid) are converted to SBUV-like units (partial column on a pressure grid) differences of 4-6%/decade are reduced to <5%/decade. Any such unit conversion requires that the long-term temperature trend be captures by the temperature profiles used in the conversion. Temperatures from reanalysis are generally not suitable as due to differing data densities and instrumental biases being fed into the assimilation system lead to incorrect trends.
This result has implications for ozone turnaround as instruments measuring in different units/co-ordinates will identify the onset of turnaround at different times – perhaps by as much as ten years difference.

**OSIRIS BrO and Bry.** OSIRIS (Optical spectrograph and Infrared Imager System) UV limb scattered sunlight measurements (345-365 nm) have been inverted to yield vertical profiles of BrO between 16-36 km at 3-4 km resolution. To reduce noise radiances are averaged daily with a given latitude band. Profile precision is estimated at 30%. Ten years of data are averaged to create a monthly-mean climatology, the first such vertically resolved climatology of BrO. Photochemical was modeling used to derive monthly values of total inorganic bromine, Bry. For each month and latitude band a photochemical model, constrained with observed values ozone, temperature, and total reactive nitrogen was used to calculate the fraction of Bry present as BrO at the local mean time of the OSIRIS measurement. By scaling OSIRIS BrO by the inverse of this fraction, a measure of Bry is obtained. OSIRIS find 21 pptv of Bry, implying about 5 pptv originating from very short lived bromine-bearing substances (VSLS).

The correlation between OSIRIS Bry and monthly-mean N₂O measured by the SMR (Submillimetre and Millimetre Radiometer) is similar to correlations obtained by insitu measurements of Bry source gases (that do not account VSLS) except it is shift by 5-6 pptv across the range of N₂O. This suggests that whatever is source is missing from the in situ-derived correlation is, in fact short-lived, or there would be more variation with N₂O.

**Stratospheric Ozone Data Assimilation.** Data assimilation consists of incorporating information from observations into a model state to produce improved estimates of the state variables. Three research projects have been undertaken over the last several years; two projects make use of the Global Environmental Multiscale (GEM) NWP model with addition of a simplified on-line stratospheric photochemical module (LINOZ), while the third utilizes the Canadian Middle Atmosphere Model Data Assimilation System (CMAM-DAS).

The first project is on the implementation and evaluation of dynamically varying ozone and aerosols in the EC global forecast model. Assimilations of MLS-Aura ozone profiles, SBU V/2 partial column ozone profiles with use of averaging kernels, and GOM E-2 total column ozone were conducted for two periods, the Summer of 2008 and the Winter of 2008/09. MLS-Aura data expectedly yielded the most beneficial impact on the quality of the ozone field. The evaluation of the impact from radiative coupling is in progress.

The second project is a subtask of the PREMIER (PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation) Impact Study led by Forschungszentrum Jülich, Germany, and funded by the European Space Agency (ESA/ESTEC). PREMIE R is a candidate of the ESA Earth
Explorer Core Mission. The EC contribution was to assess the possible impact of PREMIER ozone, water vapour and temperature observations on NWP using observation system simulation experiments (OSSEs). The assimilation and medium range forecasting products are being assessed with a final subtask report being prepared for submission this Spring. It was demonstrated, as example, that the PREMIER IRLS (InfraRed Limb Sounder) instrument should very notably improve the troposphere to lower stratosphere ozone analyses and forecasts as compared to MLS in addition to SBUV/2.

The third project was to conduct ozone assimilation with the Canadian Middle Atmosphere Model Data Assimilation System (CMAM-DAS) using OSIRIS and MLS ozone profiles as part of the Canadian SPARC \(^2\) (C-SPARC; 2006-11) project. Phase one focussed on determining ozone zonal mean biases between OSIRIS, MLS and ozonesondes through direct comparisons and through the intermediate use of ozone analyses obtained through MLS ozone assimilation. These results were used to correct for biases between the two satellite instruments and ozonesondes in the lower stratosphere and for OSIRIS in the middle stratosphere and lower mesosphere. The second phase of the project is to use the de-biased data in assimilation.

The Atmospheric Chemistry Experiment. The Atmospheric Chemistry Experiment (ACE) is a small satellite developed by the Canadian Space Agency containing a Fourier Transform Spectrometer (ACE FTS) and a UV-Vis spectrometer (MAESTRO, Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation) for the observation of stratospheric ozone and its associated chemistry. Details can be found at: http://www.ace.uwaterloo.ca/index.html including links to data products and publications. The satellite was launched in 2003 and continues to provide information on polar stratospheric chemistry. Approximately 70,000 profile measurements have been made to date and the satellite health remains excellent.

4 DISSEMINATION OF RESULTS

4.1 Data Reporting

Column ozone and UV-spectral observations are reported to the Canadian Meteorological Centre of the Meteorological Service of Canada in real-time and are used in the Canadian UV-Index forecast and for validation purposes.

\(^2\) Stratospheric Processes And their Role in Climate, a project of the World Climate Research Programme
Data from both the Canadian Ozonesonde and Brewer Spectrophotometer networks is directed to the World Ozone and UV Data Centre following quality assurance procedures. Following the implementation of ISO 9001 protocols and assessments of data from multiple Brewer instruments at each location, data quality control has become significantly more complicated and the overall uncertainty of the Brewer data greater than originally calculated. Multiple Brewer instruments have also led to the discovery that very small changes in wavelength can have significant impacts on the spectral irradiance curves, although not significant enough to alter UV-Index calculations. Because of these issues, which continue to be assessed, co-located Brewers can show single wavelength spectral differences in the order of 5%. As Canadian ozone and spectral UV irradiance data is processed together for inclusion in the WOUDC, several years have passed since data of what is deemed an appropriate quality have been submitted to the WOUDC. Data from the Canadian Ozonesonde network is approximately one year behind schedule in its submission to the WOUDC.

4.2 Information to the public

Near real-time observations are also provided to the public through the web at: http://exp-studies.tor.ec.gc.ca and then http://exp-studies.tor.ec.gc.ca/clf2/main.html. These include both ozone and UV-Index based on Brewer observations.

This website also displays maps of ozone concentrations and deviations of these concentrations from mid-1980 levels.

Each year, based on springtime Arctic ozone levels, a summer seasonal forecast is provided to the public through the Meteorological Service of Canada website: http://www.ec.gc.ca/uv/default.asp?lang=En&n=C28590EA-1. The forecast normally comes out before Canada’s May 24 (Victoria Day) long weekend as this is the ‘first’ long weekend of summer in Canada and many individuals are prone to extended hours outdoors for the first time since winter.

Canada provides daily UV-Index forecasts for values greater that 2 through the Meteorological Service of Canada regular forecasts: http://www.weatheroffice.gc.ca/canada_e.html. Private sector forecasts of the UV-Index are also provided by such organizations as the Weather Network: http://www.theweathernetwork.com/uvreport/canuv_en/?ref=topnav_homepage_uvreport

**World Ozone and UV Data Centre.** Data continues to be submitted to the WOUDC, although budget constraints in many nations are being reflected in lower frequencies of submission. Regular data contributors are reported each week on the WOUDC web site at: http://woudc.org/currentcontributors_e.html.

There are **131 Agencies from 75 Countries representing 500 platforms** (stations) that have in the past or continue to contribute data to the WOUDC.
<table>
<thead>
<tr>
<th>Data Category</th>
<th>Platforms</th>
<th>Number of Files</th>
<th>Temporal Range</th>
<th>Number of New Platforms</th>
<th>Data Increase Since Last Report (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidar</td>
<td>2</td>
<td>~700</td>
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<td>0</td>
<td>No Change</td>
</tr>
<tr>
<td>Ozonesonde</td>
<td>139</td>
<td>~65,000</td>
<td>1962-2011</td>
<td>15</td>
<td>16%</td>
</tr>
<tr>
<td>Total Column ozone (Daily)</td>
<td>287</td>
<td>~64,000 (monthly)</td>
<td>1924-2011</td>
<td>7</td>
<td>9%</td>
</tr>
<tr>
<td>Total Column Ozone (Hourly)</td>
<td>22</td>
<td>~43,000</td>
<td>1984-2011</td>
<td>12</td>
<td>46%</td>
</tr>
<tr>
<td>Umkehr</td>
<td>64</td>
<td>~10,000 monthly records, &gt;50,000 retrievals</td>
<td>1951-2011</td>
<td>0</td>
<td>No Change</td>
</tr>
</tbody>
</table>

Personnel from Environment Canada/WOUDC participated in the following WMO related meetings and activities which have a direct connection to the role and activities of the WOUDC in its capacity to serve the ozone scientific community as well as support the capacity building initiative of the WMO-GAW Programme.

- **Science Advisory Group for Ozone** - Three meetings (2008, 2009 & 2010) with participation from Environment Canada/WOUDC staff. Critical discussion of ozone cross-sections, data citation and new, expanded data formats were the focus.
- **Quadrennial Ozone Symposium** - 2008, Tromso, Norway
- **Biennial Brewer Workshop** – 2009, Aosta, Italy - Was coordinated and chaired by EC/WOUDC staff
- **ET-WDC meeting** – 2009, Geneva, Switzerland - Part of the WMO-GAW 20th anniversary celebration where the data centre is seen as the longest serving centre in the WMO-WDC “family”
- **ET-WDC meeting** – 2010, Toronto, Canada - Environment Canada hosted the 2010 ET-WDC meeting where other world data centre experts attended and progress was made in better collaboration efforts between the ground-based centres and those centres hosting satellite data.
- **Dobson Data Workshop** - Feb 2011 – Hradec Kralove, Czech Republic - Environment Canada scientists participated and lead discussion on issues of data quality and long-term data archiving

The WOUDC continues to produce daily (NRT) ozone and UV maps as well as time series of totals column ozone, ozone sonde and UV index graphs. Ozone information is also made available to the WMO for the Antarctic ozone bulletins and the data archive provides enhanced web tools for searching for data and mapping the results of these searches.

The WOUDC continues to release the *Ozone Data for the World* “red-books” on DVD. The latest DVD will be released later in 2011. The WOUDC Data Archive
continues to be the leading source of total column and profile ozone data as used in large international research projects, modelling efforts, satellite data validation and was used extensively in the 2010 UNEP Ozone Assessment), and remains a key source of metadata for the WMO-GAWSIS.

The WOUDC quality-assurance procedures continue to assist ozone and UV data providers to improve the measurement and dissemination of their data.

Environment Canada will celebrate 50 years of operations and management of the WOUDC in 2012.

5 RELEVANT SCIENTIFIC PAPERS (from last meeting)


6 FUTURE PLANS

In 2010, Canada renewed its commitment to the sponsorship of the WMO Brewer Trust Fund for a further 5 years. This fund provides $30,000 U.S. per year to support the development of Brewer observations through instrument calibrations and capacity building.

Under an agreement between Canada and the WMO, and a Memorandum of Understanding between China and Canada, the 13th Biennial Brewer Users Group Meeting is tentatively planned for 12 – 16 September 2011 in Beijing, China. A link to the 12th meeting at Aosta, Italy, 2009 can be found on the WOUDC website. Further information on the 13th meeting will be found on the website as plans are finalized.

The 2012 Quadrennial Ozone Symposium will be held in Toronto, Canada with sponsorship from Environment Canada, the Canadian Space Agency and several Canadian universities.

7 NEEDS AND RECOMMENDATIONS

There is a continued need to emphasize the importance of monitoring the health of the stratospheric ozone layer. While the recent Arctic spring time depletion was the largest ever recorded, many governments continue to reduce monitoring efforts as indicated by the frequency of data being submitted to the WOUDC.

The number of satellites now observing vertical distributions of ozone are dwindling and, at present, there appears to be no new satellites ready to replace those that are aging. The information provided by such satellites is critical, and nations with the capability to build and/or launch such space-borne instruments should be encouraged to cooperate to ensure a continuous space-based monitoring program of the vertical ozone distribution of the upper atmosphere.

A number of weather centres are exploring the use of assimilating surface, space-based and ozonesonde data for improved weather forecasts. Such on-
going use of this data should be encouraged as a means of aiding in the long-term stability of the global ozone monitoring programme.

The two-way link between ozone and climate change must continue to be emphasized.
OBSERVATIONAL ACTIVITIES

Continuous monitoring of UV radiation in major cities is mainly operated and maintained by the Meteorological National Service of Chile (DMC). Observations of total column ozone are carried out only in one station, in southern Chile (Punta Arenas), operated and maintained by the University of Magallanes (Umag). Ozone profile measurements, two stations are operating: in Isla de Pascua (Eastern Island) since 1995 and recently in Punta Arenas (2009) started continuous observations with ECC ozonesonde.

Ozone Column measurements

<table>
<thead>
<tr>
<th>Station</th>
<th>Instruments</th>
<th>Institution</th>
<th>LAT.</th>
<th>LONG.</th>
<th>Period of observations</th>
<th>Calibrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punta Arenas</td>
<td>Brewer MKIV 068</td>
<td>University of Magallanes</td>
<td>53°18′S</td>
<td>70°54′W</td>
<td>1992-2000</td>
<td></td>
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<tr>
<td>Punta Arenas</td>
<td>Brewer MKIV 124</td>
<td>University of Magallanes (Chile)- INPE (Brazil)</td>
<td>53°18′S</td>
<td>70°54′W</td>
<td>Aug.2007- Nov.2007</td>
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<tr>
<td>Punta Arenas</td>
<td>Brewer MKIII 180</td>
<td>University of Magallanes</td>
<td>53°18′S</td>
<td>70°54′W</td>
<td>Nov.2007-today</td>
<td>2007-2009</td>
</tr>
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</table>
## Ozone Profile measurements

<table>
<thead>
<tr>
<th>Station</th>
<th>Type</th>
<th>Institution</th>
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<th>LONG.</th>
<th>Period of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punta Arenas</td>
<td>Umkehr</td>
<td>University of Magallanes</td>
<td>53°18’S</td>
<td>70°54’W</td>
<td>2002 – today</td>
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<tr>
<td>Punta Arenas</td>
<td>Ozone sondes -ECC-Z</td>
<td>University of Magallanes</td>
<td>53°18’S</td>
<td>70°54’W</td>
<td>2009 – today</td>
</tr>
<tr>
<td>Eastern Island</td>
<td>Ozone sondes ECC</td>
<td>DMC</td>
<td>27°09’S</td>
<td>109°27’W</td>
<td>1994 – today</td>
</tr>
</tbody>
</table>

DMC: Dirección Meteorológica de Chile (National Meteorological Service)

## UV measurements

### Broadband measurements

## Instruments of the groups of research

<table>
<thead>
<tr>
<th>Station</th>
<th>Instruments</th>
<th>Institution</th>
<th>LAT.</th>
<th>LONG.</th>
<th>Period of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arica</td>
<td>Solar Light 501</td>
<td>University of Atacama</td>
<td>13° 28’S</td>
<td>70° 20’W</td>
<td>1998 - 2005</td>
</tr>
<tr>
<td>Santiago</td>
<td>Solar Light 501</td>
<td>University of Santiago</td>
<td>33°26’S</td>
<td>70°40’W</td>
<td>1999 – today</td>
</tr>
<tr>
<td>Puerto Natales</td>
<td>Solar Light 501</td>
<td>University of Magallanes</td>
<td>51° 43’S</td>
<td>72°31’W</td>
<td>1997 - today</td>
</tr>
<tr>
<td>Punta Arenas</td>
<td>Solar Light 501</td>
<td>University of Magallanes</td>
<td>53°18’S</td>
<td>70°54’W</td>
<td>1997 - today</td>
</tr>
<tr>
<td>Puerto Porvenir</td>
<td>Solar Light 501</td>
<td>University of Magallanes</td>
<td>53° 17’S</td>
<td>70°22’W</td>
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</tr>
<tr>
<td>Puerto Williams</td>
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<td>University of Magallanes</td>
<td>54° 55’S</td>
<td>67° 37’W</td>
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</tr>
<tr>
<td>Bernardo O’Higgins</td>
<td>Solar Light 501</td>
<td>University of Magallanes</td>
<td>63°19’S</td>
<td>56°54’W</td>
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</table>
# Network of DMC

<table>
<thead>
<tr>
<th>STATION</th>
<th>TYPE</th>
<th>LAT</th>
<th>LONG</th>
<th>ELEV</th>
<th>PERIOD OF OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arica</td>
<td>Pyranometer YES UV-B</td>
<td>18° 28' S</td>
<td>70° 19' W</td>
<td>23m</td>
<td>2006 – today</td>
</tr>
<tr>
<td>Iquique</td>
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<td>20° 33' S</td>
<td>70° 07' W</td>
<td>60m</td>
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</tr>
<tr>
<td>María Elena</td>
<td>Pyranometer YES UV-B</td>
<td>22° 21' S</td>
<td>69° 40' W</td>
<td>1241m</td>
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</tr>
<tr>
<td>San Pedro de Atacama</td>
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<td>22° 55' S</td>
<td>68° 12' W</td>
<td>2450m</td>
<td>2007 – today</td>
</tr>
<tr>
<td>Antofagasta</td>
<td>Pyranometer YES UV-B</td>
<td>23° 27' S</td>
<td>70° 26' W</td>
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<td>2006 – today</td>
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<tr>
<td>Isla de Pascua</td>
<td>Biometer Solar Light</td>
<td>27° 09' S</td>
<td>109° 26' W</td>
<td>47m</td>
<td>2009 – today</td>
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<tr>
<td>La Serena</td>
<td>Pyranometer YES UV-B</td>
<td>29° 54' S</td>
<td>71° 12' W</td>
<td>25m</td>
<td>2003 – today</td>
</tr>
<tr>
<td>El Tololo</td>
<td>Pyranometer YES UV-B</td>
<td>30° 10' S</td>
<td>70° 48' W</td>
<td>2030m</td>
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<tr>
<td>Valparaiso</td>
<td>Biometer Solar Light</td>
<td>32° 56' S</td>
<td>71° 28' W</td>
<td>131m</td>
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<tr>
<td>Farellones</td>
<td>Pyranometer YES UV-B</td>
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<td>70° 17' W</td>
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<tr>
<td>Valle Nevado</td>
<td>Pyranometer YES UV-B</td>
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<td>70° 15' W</td>
<td>3015m</td>
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<tr>
<td>Santiago- Pudahuel</td>
<td>Pyranometer YES UV-B</td>
<td>33° 23' S</td>
<td>70° 47' W</td>
<td>475m</td>
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<td>Santiago- Quinta Normal</td>
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<td>70° 40' W</td>
<td>520m</td>
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<tr>
<td>Rancagua</td>
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<td>70° 46' W</td>
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<tr>
<td>Talca</td>
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<td>35° 25' S</td>
<td>71° 40' W</td>
<td>100m</td>
<td>2010 – today</td>
</tr>
<tr>
<td>Concepción</td>
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<td>73° 03' W</td>
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<td>Spectroradiometer SUV 100</td>
<td>39° 48' S</td>
<td>73° 14' W</td>
<td>9m</td>
<td>1998 – 2007</td>
</tr>
<tr>
<td>Valdivia – Cecs</td>
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<td>39° 49' S</td>
<td>73° 15' W</td>
<td>18m</td>
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<td>Puerto Montt</td>
<td>Pyranometer YES UV-B</td>
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<tr>
<td>Coyhaique</td>
<td>Pyranometer YES UV-B</td>
<td>45° 35' S</td>
<td>72° 07' W</td>
<td>310m</td>
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</tr>
<tr>
<td>Punta Arenas</td>
<td>Pyranometer YES UV-B</td>
<td>53° 00' S</td>
<td>70° 51' W</td>
<td>37m</td>
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<tr>
<td>Centro Meteorológico Antártico Presidente Eduardo Frei</td>
<td>Pyranometer YES UV-B</td>
<td>62° 25' S</td>
<td>58° 53' W</td>
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### Narrowband filter instruments

<table>
<thead>
<tr>
<th>Station</th>
<th>Instruments</th>
<th>Institution</th>
<th>LAT.</th>
<th>LON.</th>
<th>Period of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santiago</td>
<td>GUV 511</td>
<td>University of Chile</td>
<td>33°26'S</td>
<td>70°40'W</td>
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<tr>
<td>Valdivia</td>
<td>GUV 511</td>
<td>University Austral</td>
<td>39°48'S</td>
<td>73°14'W</td>
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</tr>
<tr>
<td>Punta Arenas</td>
<td>GUV 511</td>
<td>University Magallanes</td>
<td>53°18'S</td>
<td>70°54'W</td>
<td>1993 – today</td>
</tr>
<tr>
<td>Punta Arenas</td>
<td>NILU UV</td>
<td>University Magallanes</td>
<td>53°18'S</td>
<td>70°54'W</td>
<td>2010 – today</td>
</tr>
<tr>
<td>Base Prof. Julio Escudero</td>
<td>NILU UV</td>
<td>University Magallanes</td>
<td>62°12'S</td>
<td>58°57'W</td>
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### Spectroradiometers

<table>
<thead>
<tr>
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<th>Institution</th>
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<th>LON.</th>
<th>Period of observations</th>
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<tr>
<td>Valdivia</td>
<td>SUV 100</td>
<td>DMC-University Austral</td>
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<td>73°14’W</td>
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<td>Station</td>
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<td>University of Magallanes</td>
<td>53°18’S</td>
<td>70°54’W</td>
<td>2002–today</td>
</tr>
</tbody>
</table>

### Calibration activities

a) **DMC-network**: The instruments of the DMC were compared and calibrated in Antofagasta, 2010. It is expected during next years to establish Antofagasta as a national calibration point, especially the geographical location and facilities available there.

b) **BREWER 180 (Punta Arenas)**: International Ozone Services Inc. (IOS) did the ozone and UV calibration and service of Chilean Brewer Spectrophotometer #180 during period Nov. 09 – 12, 2009 at Punta Arenas, Chile. The World Meteorological Organization (WMO) supported this calibrations activities. The Brewer #180 produced lower (~6%) ozone results initially with existing constants, when compared to the traveling Brewer #017.
c) **Biometers network (University of Magallanes):** The Solar Light instruments of the group of the University of Magallanes are calibrated each two year using the Brewer 180 located in Punta Arenas.

d) **Narrowband GUV:** A second Inter-comparasion activity was carried out during 11-15 of January, 2011 with the instruments GUV of Río Gallegos and Punta Arenas. This activity form part of the objectives of the binational project “PROJECT FOR STRENGTHENING THE CAPACITY TO MEASURE THE OZONE LAYER AND UV RADIATION IN THE SOUTHERN PATAGONIA, AND THE PROJECTION TOWARDS THE COMMUNITY (UVO3Patagonia)” supported by the Japan International Cooperation Agency (JICA).

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**RESULTS FROM OBSERVATIONS AND ANALYSIS**

**Results of Studies at Punta Arenas Chile (Lat. 53S, Long. 70W).**

The Brewer observations has been operational at Punta Arenas from May 1992 until today. Brewer #068 (1992-2000) and Brewer #180 (since year 2002). The Figure 2 shows the variation of the ozone column measured by Brewer from 1992 until 2010. A simple linear fit shows a slight increase in the total ozone column at Punta Arenas.
The number of days in which the Antarctic Ozone Hole (AOH) has been over the South cone region varies year to year. Figure 3 shows the number of events of low ozone to Punta Arenas. The criteria for defining an event of low ozone is that ozone column (daily average) must be lower than the reference (mean monthly climatological values for Punta Arenas from TOMS overpass data for the period 1978-1987), minus twice the standard deviation of the mean (mean monthly - 2σ). The number of days per year is shown in part (a), these data show a cyclical variability of about 10 years. Last three years show significant minimum, if these values remain low during next years it would be a sign of recovery of total column ozone to pre-80 values.
Fig. 3.- Number of days per year under the climatological (1978-1987) average minus two standard deviations, period 1992-2010.

DISSEMINATION OF RESULTS

Data reporting
- Data from Brewer 180 being sent to the WOUDC.
- Data of ozone profiles obtained in Punt a Arenas being prepared and sent to the WOUDC.

Information to the public
- The National Meteorological Service (DMC) gives UV-Index forecast for all stations show in DMC network.
- Since 1999 the Ozone Laboratory and RUV of the University of Magallanes provides a UV-Index daily forecast during spring and summer time (TEMIS).

Relevant scientific papers


Munakata, N (Munakata, Nobuo); Kazadzis, S (Kazadzis, Stelios); Bolsee, D (Bolsee, David); Schuch, N (Schuch, Nelson); Koskela, T (Koskela, Tapani); Karpetchko, A (Karpetchko, Alex); Meleti, C (Meleti, Charoula); Casiccia, C (Casiccia, Claudio); et al; Variations and trends of biologically effective doses of solar ultraviolet radiation in Asia, Europe and South America from 1999 to 2007; Photochemical & Photobiological Sciences, 8 (8): 1117-1124 2009.

Vernet, Maria, Susana Diaz, Humberto Fuenzalida, Carolina Camilion, Charles R. Booth, Sergio Cabrera, Claudio Casiccia, Guillermo Deferrari, Charlotte Lovengreen, Alejandro Paladini, Jorge Pedroni, Alejandro Rosales and Horacio Zagarese; Quality of UVR exposure for different biological systems along a latitudinal gradient; Photochemical & Photobiological Sciences, 2009, DOI: 10.1039/B904540F.


PROJECTS AND COLLABORATIONS

UVO₃PATAGONIA: PROJECT DESIGNED TO STRENGTHEN THE CAPACITY TO MEASURE THE OZONE LAYER AND UV RADIATION IN CHILEAN-ARGENTINE SOUTHERN PATAGONIA, AND THE PROJECTION TOWARDS THE COMMUNITY, supported by the Japan International Colaboration Agency (JICA), (2007-2011).

The Ozone and Ultraviolet Radiation Laboratory, (Laboratorio de Ozono y Radiación Ultravioleta) LabO₃RUV of the University of Magallanes, and the Center for Research into Lasers and Applications (Centro de Investigaciones en Láseres y Aplicaciones), CEILAP (CITEFA-CONICET), in Villa Martelli, in the Province of Buenos Aires, propose to carry out joint research and socially-oriented activities aimed at the communities of Southern Patagonia, in relation to this important issue. These institutions have laboratories located 200 Km from one another: in Punta Arenas (Lat. 53ºS; Lon. 70º54´W) and in Rio Gallegos where CEILAP has set up a mobile laboratory (Lat. 51º55´S; Lon.69º14´W), both situated in the extreme south of the American continent where the AOH passes over.

FUTURE PLANS

The research group of the University of Magallanes will continue ozone observations. Collaboration with other groups will be intensified, especially with the CEILAP group in Rio Gallegos and the GAW station located at Ushuaia (Argentina).
NEEDS AND RECOMMENDATIONS

- Since already it was mentioned, due to the disaster happened in Valdivia the Meteorological National Service suffered the loss, among others, of the spectroradiometer SUV 100, instrument that was in use as patron instrument of calibration who was acquired across the project GEF. In view of the cost of the spectroradiometer, reinstatement becomes difficult in the short term; the Meteorological National Service is looking for the financial support in the acquisition of a new instrument, any help is welcome.

- Financial support for supplies for ozonesonde of Punta Arenas is a priority, because the UVO3Patagonia project, funded by the International Agency of Japan will end in September 2011.

- The experience of the intercomparasion and calibration activities (Brewer and GUV) in Punta Arenas was very successful, it would be important to replicate with more instruments.

Recommendations 7ORM

1) Brewers are the preferred instrument for all expansion efforts around the globe where a new Ozone and UV monitoring programme is to be established. Unused Dobson instruments are a more economical way to expand these networks and to introduce observations into new sites or programmes.

In Chile, there is one Brewer (Lat.53S). Geographical characteristics of this country could build up a network of Brewer instruments to assess the evolution of ozone column and UVR from latitude 18°S to latitude 54°S. any financial support for this project is welcome.

2) There is a need to continue and further expand Umkehr sites to maintain this time series in the upper stratosphere. Umkehr observations represent the primary ground technique to observe the upper stratosphere since sondes cannot reach these altitudes.

For Punta Arenas station, there is Umkehr observations records since 2002. Shortly these data will be able at WOUDC.
3) Balloon sonde networks provide critical observations which give vital high resolution vertical profiles of ozone and water vapour that are needed for multiple scientific activities in ozone research and therefore need to be maintained and increased. In 2009, an ongoing program of ozone profile observations began, using ECC sonde, supported by the Japan International Cooperation Agency (JICA), this project ends in September 2011, so far not found financing to obtain the inputs that allow continuity of the measurements.

4) Intercomparison missions are desirable because they assist in defining and reducing the systematic differences in both identical and different measurement techniques. Two ozone profile intercomparison campaigns (2010-2011) were held in Rio Gallegos (Argentina). The OZITOS (OZone profile at RiO GallegoS) campaigns, this campaigns was planned to validate ozone profiles obtained from LIDAR (DIAL) instrument in Rio Gallegos operated by CEILAP (Argentina).
5) Provide resources for sustainable, long-term operation of regional centers for research, calibration, and validation in developed and, especially, in developing countries. Several regional centers for Dobson and Brewer instrument calibration have been established. It is of vital importance that these centers receive sufficient support to arrange regular calibration exercises for the instruments in their respective regions.

In Chile there is no center calibration of ozone and ultraviolet instruments, closest activities are carried out in Buenos Aires (Argentina), to calibrate instruments of the DMC network an instrument is sent, last calibration in Buenos Aires was in 2010.

The latest calibration of the Brewer spectrophotometer #180 were made by International Ozone Service Inc. in 2009, it was supported by WMO.
1. OBSERVATIONAL ACTIVITIES

Two Dobson Spectrophotometers have been setup in Kunming, Yunnan province and in Xianghe, Beijing, by the Institute of Atmospheric Physics (IAP), the Chinese Academy of Sciences since 1938 and 1958 respectively. Four MK II Brewer Spectrophotometers have been set up by Chinese Meteorological Administration (CMA) in Waliguan, Lin’an, Longfengshan WMO GAW station, and Chinese Zhongshan South Pole station in 1990s. The Brewer was used in Taiwan and Hongkang to observe ozone and UVB as part of the current total ozone and UVB observation net in China. Their data are reported to WOUDC routinely. Another Brewer Spectrophotometer has been set up in Lhasa, Tibet in 2008. Total ozone observation from space have been implemented since May 2008 via FY-3 satellite. The orbit altitude of FY-3A is 831 km, inclination is 98.81°, quasi-repeat time is 5 days, local time of the descending node is 10:30. The FY-3 satellite is a second-generation Chinese polar-orbit meteorological satellite. The Solar Backscatter Ultraviolet Sounder (SBUS), one of the main payloads on the FY-3 satellite, is the first Chinese ozone-monitoring instrument on a meteorological satellite. The retrieval FY-3 data are comparable with NOAA data.

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss.

<table>
<thead>
<tr>
<th>Station</th>
<th>Institution</th>
<th>Instruments</th>
<th>Location</th>
<th>Start of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xianghe</td>
<td>Institute of Atmospheric Physics, Chinese Academy of Science</td>
<td>Dobson</td>
<td>116°E, 39°N</td>
<td>1979</td>
</tr>
<tr>
<td>Kunming</td>
<td>Institute of Atmospheric Physics, Chinese Academy of Science</td>
<td>Dobson</td>
<td>102°E, 25°N</td>
<td>1980</td>
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<tr>
<td>MT. Waliguan</td>
<td>China Meteorological Administration</td>
<td>Brewer#54 MKII</td>
<td>100°E, 36°N</td>
<td>1991-</td>
</tr>
<tr>
<td>Longfengshan</td>
<td>China Meteorological Administration</td>
<td>Brewer#76 MKII</td>
<td>127°E, 44°N</td>
<td>1993 -</td>
</tr>
<tr>
<td>Lin’an</td>
<td>China Meteorological Administration</td>
<td>Brewer#77 MKII</td>
<td>119°E, 30°N</td>
<td>1993-</td>
</tr>
<tr>
<td>Zhongshan</td>
<td>China Meteorological Administration</td>
<td>Brewer#74 MKIV</td>
<td>South Pole</td>
<td>1993-</td>
</tr>
<tr>
<td>Hongkong</td>
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<td>Brewer#115</td>
<td>114°E, 22°N</td>
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</tr>
<tr>
<td>Taiwan</td>
<td></td>
<td>Brewer</td>
<td>121°E, 24°N</td>
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<tr>
<td>Lhasa</td>
<td>China Meteorological Administration</td>
<td>Brewer#177</td>
<td>91°E, 23°N</td>
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</tbody>
</table>

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

There are two stations for ozone profile observation which are in constructing by CMA. One is in Lhasa, another is in Beijing. Ozone sondes have been routinely released in Shanghai by Shanghai Meteorological Bureau since 2007.

Since 2008, the FY-3 also provides vertical ozone profiles which is deduced from measurements of SBUS on the satellite.
1.3 UV measurements

<table>
<thead>
<tr>
<th>Station</th>
<th>Institution</th>
<th>Instruments</th>
<th>Location</th>
<th>Start of observations</th>
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</thead>
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<td>China Meteorological Administration</td>
<td>Brewer/UVB-1</td>
<td>100°E, 36°N</td>
<td>1991</td>
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<td>Longfengshan</td>
<td>China Meteorological Administration</td>
<td>Brewer</td>
<td>127°E, 44°N</td>
<td>2003</td>
</tr>
<tr>
<td>Lin'an</td>
<td>China Meteorological Administration</td>
<td>Brewer</td>
<td>119°E, 30°N</td>
<td>2003</td>
</tr>
<tr>
<td>Zhongshan</td>
<td>China Meteorological Administration</td>
<td>Brewer</td>
<td>South Pole</td>
<td>1993</td>
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<td>Hongkong</td>
<td>Brewer</td>
<td></td>
<td>114°E, 22°N</td>
<td></td>
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<td>Taiwan</td>
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<td>121°E, 24°N</td>
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<tr>
<td>Lhasa</td>
<td>China Meteorological Administration</td>
<td>Brewer</td>
<td>91°E, 29°N</td>
<td>1998; 2007-</td>
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<td>Shangdianzi</td>
<td>China Meteorological Administration /Institute of Urban Meteorology, CMA, Beijing</td>
<td>KIPP&amp;ZONEN</td>
<td>117°E, 40°N</td>
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<tr>
<td>Dangxiong</td>
<td>Chinese Academy of Meteorological Sciences</td>
<td>UVB-1</td>
<td>30.2°N, 91.1°E</td>
<td>2009.10-2011.9</td>
</tr>
</tbody>
</table>

1.3.1 Broadband measurements

1.3.2 Narrowband filter instruments

1.3.3 Spectroradiometers

1.4 Calibration activities

The Brewers are calibrated by WMO/GAW Brewer Spectrophotometer Ozone Calibration Centre about every two year. A calibration lab in CMA was setup in 2009.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

The published and unpublished results all shows the total ozone concentration was changing during last 20 years.
Fig. 1  The total ozone trends since 1978 from 3 kinds data sets: ground based, TOMS and integrated of ground based and TOMS observation

Fig. 2  Global total column ozone distribution of March 21, 2009, monitored by S FY-3A/TOU
3. THEORY, MODELLING, AND OTHER RESEARCH

School of Earth and Space Science, University of Science and Technology of China and other research organizations, have done some research on the vertical distributions and variation characters of ozone over the Iranian Plateau and Tibetan Plateau by using the FY-3, TOMS, HALOE and SAGE II data.\textsuperscript{iv}

4. DISSEMINATION OF RESULTS

4.1 Data reporting

The data from the current ozone and UVB observation net in China are reported to WOUDC routinely.

4.2 Information to the public

- The National Meteorological Service has included UV-Index in the public weather forecasts and reports.
- Relevant information can be seen on the China Meteorological Data Sharing Service System, http://cdc.cma.gov.cn/.

4.3 Relevant scientific papers


5. PROJECTS AND COLLABORATION

<table>
<thead>
<tr>
<th>No.</th>
<th>Project</th>
<th>Institution</th>
<th>Period of the project</th>
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<tbody>
<tr>
<td>GYHY(QX)200706038</td>
<td>Travelling standards of the calibration system of Brewer ozone spectrophotometers in CMA</td>
<td>Chinese Academy of Meteorological Sciences</td>
<td>2008-2010</td>
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</tbody>
</table>
6. **FUTURE PLANS**

   The current monitoring networks are to be maintained in operation. However, there is no special plan or project for building new capacities to conduct ozone or UV radiation, some projects, such as projects focusing on climate change, may include instruments installation and research related to ozone and UV.

7. **NEEDS AND RECOMMENDATIONS**

   Much work needs to be carried out to understand many aspects of the ozone evolution and change, including impact of HCFCs, ozone-climate relationships, UV relationships, etc.. The international cooperation and assists for improvement the research level and quality are appreciated.

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COLOMBIA - PROGRAMA NACIONAL DE MEDICIÓN DE LA _COLUMNA DE OZONO_

A. MEDICIÓN DEL PERFIL VERTICAL DEL OZONO

El IDEAM comenzó a realizar mediciones de la columna vertical de ozono, desde el mes de febrero de 1998, en la estación meteorológica ELDORADO en Bogotá, la cual se localizada en:

<table>
<thead>
<tr>
<th>Estación</th>
<th>Latitud</th>
<th>Longitud</th>
<th>Altura</th>
</tr>
</thead>
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<td>04°43´N</td>
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<td>2.546 m</td>
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</tbody>
</table>

Las observaciones de ozono en superficie y al tura se efectúan mediante la ozonosonda, la cual es un analizador de ozono acoplado a una radiosonda que permite medir la concentración del ozono en función de la altura, mediante el muestreo del aire mientras asciende el globo (ver figura 1), el cual, puede llegar hasta altitudes de 30 a 35 kilómetros. La señal del analizador de ozono es enviada a la radiosonda y transmitida telemétricamente por esta a la estación terrena. Los valores en altura de otras variables meteorológicas, como la temperatura, humedad y presión (cuyos sensores están incorporados en la radiosonda), también son transmitidos a la estación terrena.

Figura 1. Equipos empleados en la medición del perfil de ozono. (Fuente: IDEAM).
El ozono es muestreado continuamente durante el ascenso del globo y perfiles de ozono son obtenidos a partir de la superficie de la tierra. La ozonosonda usada en el programa de mediciones en Colombia corresponde a la categoría de Celdas de Concentración Electroquímicas (ECC) producido por Vaisala (denominada ozonosonda OES - Model 6ª ECC), las cuales, son analizadores que utilizan yoduro de potasio, el cual al reaccionar con el O$_3$ produce yodo libre. En efecto, cada molécula de ozono introducida dentro de la celda produce dos electrones. El aire tomado como muestra es bombeado a través de la solución en la celda de reacción y la señal de salida es proporcional al número de moléculas de ozono (definida por la cantidad de electrones producida) presentes en la muestra de aire. Con una conversión apropiada, la medida de ozono es determinada en unidades de presión parcial de ozono. Si la ozonosonda supera los 28 Km de altura (aproximadamente), se puede determinar el ozono total en unidades Dobson, calculado como la suma del ozono residual más el ozono medido. El ozono residual es una estimación del ozono que no fue alcanzado a medir por la ozonosonda y que se encuentra en la capa de la atmósfera superior a donde el equipo dejo de enviar información, mientras que, el ozono medido es el correspondiente al ozono agregado en la columna de la atmósfera que fue analizada.

Los ozonosondeos (ver figura 2) se realizan en Bogotá una vez al mes, entre las diez y las doce de la mañana y sus valores, hasta el momento, se han presentado dentro de lo normal (alrededor de 250 U.D.).

**Figura 2.** Ozonosondeos de Bogotá que han alcanzado mayor altura: el realizado el 22 de diciembre de 2005 con 35424 m (azul) y el del 8 de mayo de 2001 con 34247 m (rojo). (Fuente: IDEAM).

B. SEGUIMIENTO DEL OZONO TOTAL EN COLOMBIA

De igual manera, el IDEAM realiza el seguimiento del ozono total para todo el territorio nacional a través de medidas satelitales (ver satélite Earth Probe), las cuales no muestran ningún adelgazamiento de la capa de ozono en esta zona tropical.

Las mediciones de ozono a partir de espectrómetros portados por satélites, como las mostradas en la figura 3, son usuales hoy en día, ya que permiten una visión global
de la distribución de la columna de ozono. Estas mediciones fueron posibles desde finales del año 1978, fecha en la cual entró en operación el satélite Nimbus-7, cuya misión fue observar la Tierra. Este satélite estaba dotado de un instrumento para la medida del ozono: el Espectrómetro Cartográfico Total de Ozono (Total Ozone Mapping Spectrometer - TOMS), el cual mide la distribución global del ozono total. La misión del Nimbus-7 ha sido permanente hasta la fecha mediante la prolongación de sus programas con el lanzamiento de otros satélites, como el Meteor-3, lanzado en 1991, el Earth Probe en 1996 (con datos disponibles desde el 22 de julio de 1996 hasta el 14 de diciembre de 2005) y el AURA que porta el Instrumento para el Monitoreo del Ozono (OMI - Ozone Monitoring Instrument), el cual se encuentra en operación. La misión AURA investigará la composición, química y dinámica de la atmósfera de la Tierra, así como el ozono, la calidad del aire y el clima.

![Satélite Earth Probe portador del sensor TOMS](image1)
![Satélite AURA portador del sensor OMI](image2)

**Figura 3.** Equipos empleados en la medición del perfil de ozono y del ozono total

C. ANÁLISIS DE LOS OZONOSONDEOS

En la siguiente tabla se muestra la relación de los ozonosondeos **exitosos** (73) que se han realizado en Bogotá.

<table>
<thead>
<tr>
<th>Tabla 1. Inventario de ozonosondeos realizados en Bogotá</th>
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<tr>
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<tr>
<td>16-Feb</td>
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<tr>
<td>06-Nov</td>
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<td>02-Sep</td>
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Nota: **para todos estos ozonosondeos se tienen los archivos temporales y para niveles mandatorios. Hasta el momento no se han enviado al Centro Mundial de Datos y necesitamos que nos informen como se pueden enviar.**
A partir de estos ozonosondeos se realizaron los análisis que se presentan a continuación y que fueron plasmados en una nota técnica que se encuentra en la siguiente dirección:

Los análisis que se realizaron a partir de estos ozonosondeos son los siguientes:

- Temperatura de la tropopausa (°C)
- Altura de la tropopausa (metros)
- Presión de la tropopausa (hPa)
- Nivel de congelamiento (altura y presión donde se alcanzan los cero grados)
- Altura base de la capa de ozono (metros)
- Altura de la máxima concentración de ozono y su valor (metros y milipascales)
- Ozono superficial (promedio y máxima)
- Distribución vertical del ozono en Bogotá
- Gradientes de Temperatura

En la mayoría de los análisis se trató de determinar el promedio mensual de la variable para poder definir su comportamiento durante el año.

D. ACTIVIDADES DE MONITOREO PLANEADAS

En el momento se requiere con urgencia asesoría para volver a realizar los ozonosondeos en Bogotá, ya que desde mediados del año 2008, se han tenido problemas por el cambio (actualización por parte de la empresa Vaisala) del software y del radiosonda de análogo a digital.
I. GENERAL INFORMATION

1. Country presentation

The Union of Comoros is constituted of an archipelago of four islands: Grande Comoro (Ngazidja: 1148 sq), Anjouan (Ndzuani: 374 sq), Moheli (Mwalé: 290 sq) and Mayotte (Maore: 424 sq); the four islands, situated in the Mozambique Channel half way of Madagascar and the African coast, cover a surface of 2236 km². Mayotte is always under French administration in spite of the independence of Comoros in 1975. The relief is damaged and volcanic and the soil and basement are deprived of the mining and energizing resources, but have a lot of agricultural potentialities.

The tropical climate but moderated by the altitude and by the oceanic influence is characterized by two seasons: hot and humid season marked by strong rains and violent winds (kashikasi) and a dry and cool season characterized by winds (kussi) with temperatures oscillating between 24 and 30°C, from where the utility and the consumption of the cold air-conditioning, refrigeration, congealment, cold house etc…)

This document is only about the three independent islands which form the Union of the Comoros.

The general census on the population and housing (RGPH) conducted in 2003 indicated 576,000 inhabitants with a growth rate of 2.1% and an average density of 309 inhabitants per sq, which varies significantly depending on the island; 72.0% of the population lives in rural areas while 28.0% lives in urban areas. The population is mainly concentrated on the coastal zone (65%). So the environment undergoes a set of aggressions because of the ignorance of the population or simply for the despair of survival.

The Growth and Poverty Reduction Strategy Paper (GPRSP) adopted in 2005 constitutes the global framework for the economic development of the country. This document gives a core priority to the promotion of agricultural development, which is identified as an engine for economic growth.

The government has already produced a report on the Millennium Development Goals which reinforces the actions of the GPRSP in the agricultural sector through the reduction by half, between 1990 and 2015, of those in the population suffering from hunger and the reversal of the current trend of loss of environmental resources.

2. Institutional and legal setting

a) Institutional

The Comoros ozone office (BOC), created within the National Direction of Environment in the Ministry of Agriculture, Fishing and Environment (MAPE), has for mission to assure the coordination and to impulse the whole national politics for the protection of the layer ozone. People resources are affected there for the daily management of the program.

A Committee Ozone implying all concerned actors should be put in place to reinforce the efficiency of the Comoros Ozone Office.
b) legal
Since 1993, Comoros are endowed with a National Politics of the environment:
- The setting law relative n° 94-018 to the environment stipulates in its article 3 8b: "a structural decree carrying the measures to limit and to reduce the import, the production, the consumption and the exploitation of the substances likely to destroy the ozone layer and to encourage the recourse to substances and techniques of substitution,
- The law n° 94-011 allows the President of Repub lic to ratify the Convention of Vienna, the Protocol of Montreal and its amendments
Comoros, like the international community anxious to preserve a healthy environment for the present and future generations, adhered to the dynamics to sit an international legal setting in ratifying:

in 1994, and in 2002,
- The Vienna convention, - The Copenhagen Amendment,
- The Montreal Protocol, - The Montreal Amendment,
- The London Amendment; - The Beijing Amendment.

3. Sector using HCFC
The refrigeration sector in the Comoros is mainly composed of home and industrial refrigeration and air-conditioning as well as commercial refrigeration.

All these sub-sectors mainly use HCFC and most of them depend on repair and servicing workshops the owners of which are privileged partners in the process of eliminating ozone depleting substances.

These actors constitute the main targets for sensitisation and training with a view to implementing the measures for the elimination of ODS

4. Targeted regulated substances
The conclusions of the national surveys on the consumption of HCFC as illustrated in the chart below in the sub-sectors relating to the use and the corresponding equipment stock shows the exclusivity of R22 in the maintenance sector

Chart 1: National refrigerating equipment stock using HCFC 22

<table>
<thead>
<tr>
<th>Installation</th>
<th>Air-conditionners</th>
<th>Cool house</th>
<th>Water cooler</th>
<th>Ice making</th>
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<tr>
<td>9000 BTU</td>
<td>3330</td>
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<td>12 000 BTU</td>
<td>8650</td>
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<td>18 000 BTU</td>
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<td>48000 BTU</td>
<td>153</td>
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5. Released project for the elimination of HCFC
In the setting of the implementation of the Montreal Protocol, Comoros benefited from a technical and financial support characterized by a set of projects for the Protection of the ozone layer. This set of projects that aim like objective, the elimination of the Substances Impoverishing the ozone layer (SAO) before 2010, present himself as follows
a) Projects objectives

- Preparation of the program country: to achieve a diagnosis of the consumption of the ODS and to project measures appropriated for a rational management of these substances,
- Institutional capacity-building program: to reinforce the national institutional capacities in order to protect the destruction of the ozone layer by through the gradual elimination of ODS and by the promotion of substitution products,
- Management Plan of refrigerants (PGFF): to plan and to manage in a digressive manner the existing harmful refrigerants into the country for their definitive elimination by 2010,
- Regional methyl bromide project: setting up of a national strategy for the prevention of the introduction and the popularisation of the uses of the methyl bromide,
- CFC Terminal Phase out Management Plan (TPMP): realization of an assessment of the actions led in the centres of the PGFF and the level of perennisation of the innovations dispensed in order to elaborate a proposition of project guaranteeing the final elimination of the refrigerants by 2010.

b) Impact of the different projects

The set of projects and programmes is the result of Comoros’ membership the Montreal Protocol. The achieved activities have contributed to institutional capacity-building, to the improvement of the know-how of the concerned actors and their logistic means, an awareness of a large part of the population on the ozone issue as well as an understanding and an effective involvement of political authorities.

Thus, the impact of the achieved projects can be translated today through:

- An awareness of the population and the actors (custom officers and refrigeration engineers) of the stakes related to the destruction of the ozone;
- An awareness of the authorities and an integration of the ozone issue in the national environmental policy;
- A control by refrigeration engineers of techniques on the manipulation of prohibited gases and the use of alternative gases;
- A control by the customs officers of the techniques for the control of ODS;
- Availability of appropriate equipment and tools to the different types of gases (old and new);
- An operationalisation of the Comoros ozone office and recognition at international level;
- The establishment of an operational consultation framework between the institutions and national partners (administrations, associations of refrigeration engineers and customs officers, technical training schools and media...);
- The establishment of an operational regulatory framework accepted by all;
- Country’s compliance with the requirements of the Montreal Protocol in 2010 (total elimination of CFC);
- The launch of a national system to secure future respect for the commitments related to the ongoing process of eliminating HCFC.

Chart 2: Consumption of CFCs

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<th>Year</th>
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This period coincided with the reconversion of CFC equipment into HCFC equipment

6. Lessons learn from ODS phase-out

All the mechanisms put in place in the process for the elimination of CFC and the collaboration established between the Ozone bureau and its national and international partners have proven to be efficient, and this efficiency has enabled the actors to better understand the ozone issue, a participative adoption and an acceptance of the strategy on the elimination of ODS. This has led to the compliance of the country prior to the fixed date. This strategy which has proven to be successful deserves to be capitalised through its integration in the projects that are being prepared and particularly HMEP.

II. The Hydrofluorocarbons management and elimination plan (HMEP)

The Union of the Comoros is a party to the Montreal Protocol. As such, it must, in accordance with the decision XIX/6 adopted during the 19th COP and with the article 5, put in place the appropriate regulatory framework and take the necessary measures for the rational management of the import and use of HCFC as well as the equipment containing these substances.

The goal of the HCFC management and elimination plan (HMEP) is to realize HCFC reduction targets until their total elimination in accordance with the calendar set by decision XIX/6:

- Freezing from 2013 of the HCFC quantity followed by a 15% reduction in 2015.
- Gradual reduction of HCFC in relation to the 2013 value, then total elimination between 2016 and 2030.

The overall objective of the management plan is the gradual elimination of HCFC by 2030, in liaison with the national development strategies. The Comoros must continue to speed up the elimination of HCFC by managing the import and use of these gas and equipment containing them while respecting the conventional dates of 2015, 2020, 2025 and 2030 provided for by decision XIX/6.

Chart 4: HCFC consumption predictions without and with the Montreal protocol:

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Graph 1: Estimated evolution of HCFC consumption from 2009 to 2040, With protocol and without protocol.
HCFC consumption prediction keeps on increasing if the protocol on the gradual elimination of HCFC is not applied as indicated in graph 8. Very high levels of consumption would be reached by 2050 unlike the recommendations from the HCFC elimination protocol.

III. ACTIVITES ON THE OBSERVATION AND RESEARCH IN OZONE

In spite of the weakness of the industry of cold in Comoros, research constitutes an essential link for the accompaniment of the program Ozone in Comoros. Important efforts were expanded for the reduction of the consumption of the SAO and the meaningful results have been gotten. These efforts deserve to be sustained by the setting up of an Unit of observation and research on the ozone, having to act as basis of orientation in the setting in implementation of the program ozone in Comoros.

In the worry of making operational the unit of observation and Research in ozone, there is place therefore to associate the local appraisal in the activities of research at the international level and to sustain our country for:

- identification or the implantation of a station of control of the air pollution in order to determine the main pollutants,
- the equipment of the aforesaid station in instruments for the measures (UV-B),
- the backing of the capacities of the settings implied in the activities of observation and research,
- the storage of the data coming from various sources of observation.

CONCLUSION

Our country participates in best of its means to the world effort of setting in implementation of the global arrangements on the protection of the ozone layer on the political, and legal plan. The technical and material plan merit being reinforced and sustained financially.
COOK ISLANDS

Report on the Existing and Planned Ozone Research and Monitoring Activities in the Cook Islands.

Introduction

The Cook Islands does not have an existing ozone research. What is has though is a monitoring activity that contributes to the scientific community via the basic meteorological parameters that contributes to the forecasting and climate database of the globe that can used for decision makers in implementing policies.

Status Quo

The Cook Islands operate 7 RBSN and GSN stations that monitors wind speed, wind direction, ambient temperature, dew point, relative humidity, barometric pressure and rainfall. These are collected every synoptic hour (3 hourly) and are disseminated to appropriate meteorological centres that use the data for research and forecasting purposes.

The Cook Islands also operate a GUAN Station that releases a radiosonde flight every day to monitor the temperature, humidity and atmospheric pressure at different altitudes.

Planned Ozone Research

Although the Cook Islands does not have plans in place to monitor ozone, the closeness of the country to Australia and New Zealand, where the ozone layer is a hazard, could be an incentive for the committee to consider the Cook Islands to be a monitoring station. Passed experiments have included the Cook Islands in the monitoring of ozone but nothing has been established permanently to cater for that need.

The report of the 7th session highlights the importance of the upper troposphere and lower stratosphere and I feel that this is well we could be contributing to the task facing the committee and also in enhancing the capability to monitor this phenomenon in this part of the world.

Monitoring Activities

Considering that a close-by nation of the Independent State of Samoa is a Member of this committee and is monitoring ozone, what are the chances that this can be extended to the Cook Islands. A good example of this would be to piggy-back on the current GUAN station that releases a flight every day and maybe with some assistance from the committee, this can complement the work of the committee in monitoring ozone in this part of the world.

I look forward in taking part in this upcoming workshop and to contribute effectively to the goals and objectives of the committee.
La Côte d’Ivoire

La gestion de l’environnement relève de la compétence de plusieurs structures étatiques et non gouvernementales, en particulier le Ministère de l’Environnement, des Eaux et Forêts, le Ministère de la Santé et de la lutte contre le sida, et le Ministère de l’Industrie et du Secteur Privé.


Substances appauvrissant la couche d’ozone (ODS)

La Côte d’Ivoire a adhéré à la Convention de Vienne pour la protection de la couche d’ozone et au Protocole de Montréal relatif à des substances qui appauvrissent la couche d’ozone le 4 juillet 1993.

Aujourd’hui, la Côte d’Ivoire est en conformité avec les exigences du Protocole de Montréal. Cependant, quelques incertitudes subsistent car nous n’avons pas une maîtrise globale de la consommation des substances appauvrissant la couche d’ozone, eu égard à la situation sociopolitique de notre pays.

Communication des données

Le Bureau National Ozone (BNO) a fourni les données de consommation annuelle SAO au Secrétariat de l’Ozone et au Secrétariat du Fonds (voir tableau suivant) :

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L'information au public

Pour réduire le niveau de consommation des substances qui appauvrissent la couche d'ozone, le Bureau National Ozone a initié les activités suivantes :
- Formation des Techniciens du froid aux nouvelles techniques de la réfrigération et de la climatisation,
- Formation des Agents des Douanes et des Agents du Ministère du Commerce aux techniques d'identification des substances qui appauvrissent la couche d'ozone,
- Equipement des Techniciens du froid, des Douanes et des Agents du Ministère du Commerce
- Célébration chaque année le 16 septembre, de la journée internationale de la Protection de la Couche d'Ozone,
- L'organisation de conférences et de campagnes de sensibilisation adressées à l'ensemble des consommateurs et particulièrement aux décideurs, aux investisseurs, aux Organisations Non Gouvernementales, aux élèves et étudiants.

Mesures de l'ozone stratosphérique, distribution verticale de l'ozone et l'ozone extérieur.

La Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique (SODEXAM) est chargée de mener et coordonner les activités d'observations, d'études et de prévisions en météorologie et dans les secteurs spécialisés de la météorologie. À cet effet, la SODEXAM est responsable des mesures de quantité de l'ozone et actionne tout le réseau principal d'ozone-surveillance. Des observations quotidiennes de long terme de l'ozone sont effectuées dans les stations de la SODEXAM à d'Abidjan, Adiaké et Bouaké.

MESURES UV

La SODEXAM prélève les mesures du rayonnement solaire UV à bande large et à bande étroite de filtre de façon périodique.

DIFFUSION DES RÉSULTATS

Communication de données et information au public
Les données de l'ozone se sont rassemblées dans des revues à publication périodique de la SODEXAM (voir sur le site http://www.sodexam.com/nosproduits.htm.).
LES BESOINS ET RECOMMANDATIONS

Nous sommes dans le grand besoin de programme de recherche scientifique dans l'ozone et le modèle de changement climatique.
Nous apprécierons une aide financière afin de renforcer et améliorer les mesures de l'ozone et des UV par l'unité ozone en collaboration avec la SODEXAM.
CUBA

Introduction

The Institute of Meteorology of the Ministry of Science, Technology and Environment of Cuba is the institution responsible for the activities directed to the study of the behavior of the Ozone Layer and ultraviolet Solar Radiation.

OBSERVATIONAL ACTIVITIES

Program of measurements of the total amount of atmospheric ozone and ultraviolet solar radiation (UV-B)

The program of measurements of the total amount of ozone and ultraviolet solar radiation (UV-B) is in charge of the group of Solar Radiation and Atmospheric Ozone of the Center of Physics of the Atmosphere of the Institute of Meteorology and is carried out at the station of Havana (23º 10' N, 82º 21' W, 50 m) - site of the Institute of Meteorology of Cuba.

Measurements of total amount of atmospheric ozone started being carried out in a regular way in Cuba by mid 1981, using for these purposes filter ozonometers type M-83 and M-124 of Soviet origin. The program was carried through, with intervals without measurements during 1984 and from December 1992 until November 1998 being finally interrupted on July 2000, due to the lack of ozonometers in the required technical condition.

This monitoring program, from 1985 on, was framed as the investigation topic; “Study of the variations of the total amount of atmospheric ozone in the presence of tropical hurricanes”, in the Cuban-Soviet collaboration program for the study of the tropical atmosphere and hurricanes, what allowed, in first place, to establish a regular regime of measurements of the ozone layer in our territory, and the development of investigations about the variability of the atmospheric ozone in the presence of tropical hurricanes for our region. The results of this investigations were materialized with the presentation of contributions to the International Symposia on Tropical Meteorology, that were held in Havana (April, 1987) and Obninsk (1991) and the publication of several papers (Gushchin et al, 1987), (Gushchin. G.P, Peláez. J.C et al, 1991).

In late 2003, after the incorporation of the Dobson Spectrophotometer #67, in the II Regional Dobson Intercomparison for WMO Regions III and IV held in Buenos Aires, Argentina (Nov-Dec 2003), Total Ozone monitoring resumed at Havana station (STN 311).

Regrettably, the monitoring program has been often interrupted by remodelation and constructive activities under way at the Institute of Meteorology, as the Dobson instrument could not be taken to another location. More in detail, measurements have been carried between the months of June to October 2006, June to October 2007,
March to October 2009 and April to October 2010. Currently regular measurements are under way since February 2011, after participating in the IV Regional Intercomparison, held at Buenos Aires in Nov-Dec 2010

We expect that, counting on greater support from meteorological authorities, the measurements program with Dobson #67 can be carried out without interruptions. All data obtained so far has been sent to WODC, an can be consulted on http://eesee.tor.ec.gc.ca/cgi-bin/total ozone/

UV Measurements

The program of surveillance of the ultraviolet radiation had its origin in a program of measurements that was carried out in the station of Havana (23 10 N, 82 21 W, 50 m) from 1984 to 1985 with the use of a filters instrument developed at the Main Meteorological Observatory in Postdam. Starting on March 2011, a program of measurements of the solar ultraviolet erythemal radiation has begun as part of the project “Study of the behavior of the Ozone Layer on Cuba” in collaboration with the Observatory of Solar Radiation of the Institute of Geophysics of the Autonomous University of Mexico and the National Meteorological Service of Argentina, the instrument used is a Biometer 501 #2853 manufactured by the firm Solar Light.

Together with the measurements of the total amount of ozone and ultraviolet solar radiation the Group of Solar Radiation and Atmospheric Ozone of the Center of Physics of the Atmosphere of the Institute of Meteorology of Cuba in the Havana Station is in charge of a research program for the solar ultraviolet radiation and other related magnitudes in the country.

Calibration activities

Participation has taken place at the 2006 and 2010 intercomparisons. It was concluded at both events that measurements made in the periods previous to each one, didn't need to be re-evaluated, as the instrument's constants remained with no change. At the IV Intercomparison, between Nov and Dec 2010 the instrument was subjected to a deep revision where some mechanic and electric defects found were corrected.

We would like to highlight the support from Dr. Robert Evans from NOAA/ESRL/GMD, thanks to whom these Intercomparisons have turned so much useful for the good functioning of these instruments. We also thank Argentina's authorities and specialists from the Meteorological Service for their excellent hospitality, their welcome and assistance, that made the IV Regional Intercomparison of Dobson spectrophotometers and UV radiometers a successful event.
RESULTS FROM OBSERVATIONS AND ANALYSIS

With regard to the series of observations, an analysis of measured data has been made jointly with data from TOMS and OMI instruments on board of satellites Nimbus7, Earth Probe and Aura, both, the Over Pass and satellite cover for our territory and near by region. http://toms.gsfc.nasa.gov/overpass/city.html, http://toms.gsfc.nasa.gov/ozone/ozoneother.html

Results

• The total ozone distribution over the National Territory is well defined by an annual cycle with maxima in the summer months and minima in the winter months. The amplitude of this cycle is of about 40 Dobson Units and its mean value is 275 Dobson Units.

• Regarding the spatial distribution over the National Territory, the total ozone content shows a small latitudinal gradient of about 2 DU between the Eastern and the Western regions in the winter season. In the summer this gradient turns bigger reaching 10 DU in May. The small values in latitude are explained by the disposition of our territory, which practically spans over a single latitude (rigorously just a range no larger than 3.5 degrees). As previously pointed out, the most relevant feature is the wide annual cycle of the TOC.

• In addition to the annual cycle, TOC also shows two other seasonal cycles. It is known the variation of ozone following the quasi-biannual oscillation of stratospheric wind, with its greater value precisely over the Equatorial region. At our territory's location, this signal is less visible, but still existent (Bojkov and Fioletov, 1996).

With the purpose of detailing periodicities along this series, the Fourier transform was applied so the power of different harmonics could be displayed.

Figure 1 shows this power spectrum of TOMS/OMI measurements, where a considerable maximum is observed harmonic # 11, which has a period of 372 days, the next harmonic also shows a high value, and corresponds to a period of 341 days. As it is logical to assume, these maxima correspond to the relevant annual cycle of TOC) which lays closest to harmonic 11.

Total ozone variation associated to the quasi-biannual oscillation can also be seen in the smaller maximum between harmonics 6 and 7 which corresponds to a period between 585 and 682 days, which is close, but doesn't reach the 2 years.
Main lines of research

The main lines of investigation embraced in the project “Study of the behavior of the Ozone Layer in Cuba” are directed to the investigation of possible variations of the total amount of ozone in the presence of tropical hurricanes for our region. Equally it is objective of the project to characterize the behavior of the total content of ozone in our region.

With regard to the characterization of regime of ultraviolet solar radiation and in the specific case of the ultraviolet solar radiation of erythemal effect, it is necessary to point out that due to the location of the Havana station (urban type), the program of measurements is directed to the study of the behavior of this component of the radiation flux only for the City of Havana. A no less important objective of the project is the forecast of the index of UV radiation in several locations of the country that require of this type of information for its socioeconomic importance.
DISSEMINATION OF RESULTS

Data reporting

Monthly resumes of the TOC measurements made at Havana station (STN 311) up to March 2011 have been sent to WOUDC, and can be consulted at http://es-ee.tor.ec.gc.ca/cgi-bin/totalzone/

Information to the public

We have plans to start in this year an UV forecast for the whole National Territory

Relevant scientific papers

There are two papers under way

FUTURE PLANS

Following one of the recommendations included in the issue related to Surface Networks at the 7th ORM where the priority of establishing new stations for the monitoring of UV radiation on tropical regions, this year (2011) we expect to establish the UV stations network based on UVA and UVB solar radiation instruments. The stations are located at the same places of the already installed automatic meteorological stations, which measure, in addition, the global component of solar irradiance. It's important to state that most of the instruments that we are using use termopiles as sensor devices, therefore in the topic related to needs, we request some international collaboration to allow us replacing these instruments by others of higher quality and known performance (Broad band radiometers specifically).
NEEDS AND RECOMMENDATIONS

- It's important to state that skin cancer is the fastest growing cancer type in Cuba, so health authorities pay great attention to all factors that might influence the behavior of this pathology, amongst them, the levels of UV radiation. In addition, the greatest number of medical consults given to visiting tourists is related to skin injuries due to extensive exposition to solar radiation. An increased knowledge of UV solar radiation levels would improve not only the general health of our population, but also that of visiting foreigners, mostly from Europe and Canada.

- We wish to highlight that for the tropical region where we stand, UV levels are high. On the other hand “SPARC Report on the Evaluation of Chemistry Climate Model”, (Final Review Meeting in Toledo, Spain, November 9-11, 2009). Models consistently predict a partial recovery of tropical ozone followed by a decrease in the second half of the 21st century, such that the tropical column ozone is predicted not even to return to 1980s values within this century; the long-term decrease is mainly found in the lower stratosphere. It is important that calibration of UV monitoring instruments be made with a periodicity of at least two years, and that in the same manner in which Dobson spectrophotometers are thoroughly analyzed, UV radiometers are fully investigated. In other words, not only a comparison with some reference instrument, but an analysis of the spectral response and other characteristics of the instruments. According to all of this, we consider that it is necessary the onset of a Regional Reference and Calibration Laboratory of UV instrument for WMO Regions III and IV.

- It's also important that through the Vienna Convention Trust Fund for Research and Systematic Observations, the UNEP’s Compliance Assistance Programme (CAP) or other funding sources, the participation of personnel from our region to the excellent training course that specialists from SOO Hradec Kralove at the Czech Republic offer be enabled.

- We would like to propose also that developing countries could count on international funds that allow them to participate at workshops and Symposia.
Report of Ongoing and Planned Ozone Research and Monitoring Activities in the Czech Republic

for the 8th WMO/UNEP Ozone Research Managers Meeting, 02 – 04 May 2011, Geneva, Switzerland

By: Karel Vanicek,
Czech Hydrometeorological Institute

1. OBSERVATIONAL ACTIVITIES

Systematic monitoring of atmospheric ozone and UV solar radiation is performed in the Czech Republic (CR) by the Czech Hydrometeorological Institute (CHMI). The observations contribute to the regular and complex monitoring of the atmosphere and climate in CR and to international activities and projects, mainly to the GAW Programme. All the observations are performed and regularly audited under the rules of the ISO-9001 standards and the data are deposited in the central climate data base of CHMI.

1.1 Column measurements of ozone

Routine daily observations of total ozone (TOZ) have been performed with the Dobson and Brewer (single and double) spectrophotometers operated at the Solar and Ozone Observatory (SOO-HK) of the Czech Hydrometeorological Institute (CHMI) in Hradec Kralove since 1961. In 2010 the SOO-HK reached 50-year period of regular observations of and thus belongs to the GAW stations with the longest continuous data series of TOZ worldwide.

In February 2010 the double MKIII Brewer spectrophotometer B199 was installed at the Marambio Base - Argentina, Antarctica. The activity is part of the project supported by the Ministry of the Environment of the Czech Republic - SPIII 9/23/07 that is realized under the bilateral governmental agreement between CR and Argentina on cooperation in the environmental research in Antarctica. The instrument is controlled and all the primary data and calibration metadata are saved from SOO-HK operationally via the satellite telecommunication system. The TOZ data are currently evaluated and used for the scientific purposes. The data are supposed to be deposited into the WOUDC in 2011.

1.2 Profile measurements of ozone

Since 1978 the balloon-borne ozone profiles monitoring programme using the electrochemical ozone sondes has been performed at the Upper Air Department (UAD) of CHMI in Prague. Currently the ECC sondes monitored by the VAISALA DigiCORA facility are launched three times a week from January to April. The vertical profiles of ozone from the ground to about 30 km, with a vertical resolution of approx.150 m are submitted to the WOUDC and NDACC data bases, as well.

Vertical distribution of ozone is also measured by the Umkehr inverse technique with the Brewer spectrophotometers at the SOO-HK and at Marambio. The observations are processed by the NOAA/NASA UMK-2004 algorithm. Currently the Umkehr profiles are being compared with the simultaneous ozone sonde observations from UAD Prague to evaluate differences in the particular pressure levels.
1.3 UV measurements

1.3.1 Broadband measurements

The UV-Biometers are operated at 4 CHMI stations (Hradec Králové, Košetice, Kuchařovice and Labská Bouda) that are located in typical climate and geographical regions (lowlands, rural land and mountains). The 10-minute erythemal irradiances (EUV) are collected in the near-real-time at SOO-HK. The actual TOZ and UV-Index values are presented to the public at the Portal of CHMI:

1.3.2 Narrowband filter instruments

Narrowband filter instruments are not operated in the Czech Republic presently.

1.3.3 Spectroradiometers

Spectral measurements of UV solar radiation (298-325 nm) are performed with single (MKIV) and double (MKIII) Brewer spectrophotometers at SOO-HK and at the Marambio station. The high-quality and evaluated scans are submitted also to the European UV Data Base (EUVDB) at FMI, Helsinki. The Brewer MKIII operated at SOO-HK is used as the national reference for calibration of the operational UV-Biometers.

1.4 Calibration activities

All ozone and UV instruments operated by CHMI are regularly calibrated towards the international etalons and operated according to proper SOPs. In this way their long-term calibration stability can be checked and evaluated. Because of years of experience in the GAW calibration campaigns the experts from SOO-HK frequently perform on-request calibrations of ozone spectrophotometers at individual stations or they assist to the GAW intercomparisons of the instruments. These activities are mainly anchored in the bilateral cooperation of SOO-HK with the GAW Regional Dobson Calibration Centre - Europe (RDCC-E), the Meteorological Observatory, Hohenpeissenberg, Germany – see Projects and Collaborations.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

The recent analyses of the Dobson and Brewer observations of TOZ from SOO-HK show that both data series should be analyzed separately. While the Dobson record represents mostly a historical memory of the condition of the ozone layer including very important pre-ozone hole period, the Brewer observations have become the dominant source of the current and future information on TOZ in the recent decades. Because of the well known annual differences between Dobson and Brewer observations a simple combination of both data series could introduce unreal signal on the recovery of ozone, mostly in the winter-spring period. Therefore, the trend analyses of TOZ during the last 50 years should go from the assimilated Dobson/Brewer data set. The method of assimilation is now being tested at SOO-HK and will be published in a per-review paper.

Evaluation of the assimilated TOZ data set from SOO-HK shows that in the winter-spring season the amount of ozone is rising up towards the pre-ozone hole values during the recent 15 years. This can be attributed to the reduction of emissions of ODS due to the Montreal Protocol. But in the summer months the ozone layer remains significantly depleted, Fig 1. This could be explained by persistent changes in stratospheric circulation and dynamics at least over Central Europe. Further research on this phenomenon is underway in CHMI.

Changes of vertical distribution of ozone over Central Europe during the past three decades are evident also from ozone sonde observations taken at UAD of CHMI in Praha. While the most significant decrease of ozone concentrations appeare in mid and lower stratosphere.
(~10% at 22 km) comparing prior and post Pinatubo periods (1978-1991 and 1992-2009) in troposphere the amount of ozone has increased by about 50%, Fig. 2.

To expand information about vertical ozone profiles an extensive programme of the Brewer Umkehr observations was implemented at SOO-HK in 2005. The pilot comparison of 77 simultaneous Umkehr and ozone sonde profiles from the winter-spring months, 2005-2009 show that the new UMK-2004 algorithm gives a good fit of the shape of profiles including location of the maximum of ozone concentration. The best fit (less than 2% difference) of concentrations has been found in the Layers 2 (~13 km) and 4 (~23 km). Higher but still acceptable differences (~8%) are at the Layers 3 and 5, Fig 3.

The newly established ozone and UV observations performed with the Brewer instrument at the Marambio station in Antarctica are focused on three main goals – implementation of regular measurements of total ozone and UV-spectral radiation with on-line transmission of data to SOO-HK, the use of measurements of Umkehr vertical profiles of ozone for the operational assessment of the state of the ozone layer including validation of satellite measurements and the use of spectral measurements of UV radiation for operational evaluation of the field UV-index in the Antarctic. The ground Brewer observations of TOZ from Marambio of 2010-2011 have been compared with the overpass OMI-DOAS satellite measurements from the summer periods of 2010-2011. The preliminary results show a fairly good agreement between both data sets, Fig 4. This is a good message which confirms quality of ground and satellite observation systems in this very important location.

![Fig 1: Differences between seasonal averages of assimilated total ozone, Hradec Králové of 1962-2010 towards 1962-1980](image1)

![Fig 2: Comparison of average ECC sonde ozone profiles of different periods, UAD Praha 1983-2009](image2)

![Fig 3: Differences between the ECC sonde and Umkehr ozone profiles from Hradec Králové and Praha](image3)

![Fig 4: Correlation between OMI and Brewer (direct sun) measurements at Marambio, (November 2010–February 2011 2011)](image4)
3. THEORY, MODELLING, AND OTHER RESEARCH

Evaluation of the long-term changes of the ozone layer over CR during the last 50 years is the most actual research project for 2010-2012. The realization requires development, tests and application of specific models and techniques that are tied with the geographic and climate condition of the country. But some of them have possibility for a wider application outside the region. So far the Dobson-to-Brewer TOZ assimilation model has been developed and tested at SOO-HK using the multi-regression transfer function with ozone effective temperature (TOef) and slant-path ozone as the proxies. The TOef values derived from the ozone sonde observations at UAD Praha were correlated with the stratospheric temperatures. Finally temperature at the 20 hPa standard level (T20) has been taken as the most representative parameter of the TOef. Comparison of the assimilated Dobson and measured Brewer daily averages of TOZ confirm the accuracy of the model well below 1%.

A special technique has been developed for reconstruction of the T20 data set representative for the area of CR of the period 1961-2010. The method assimilates T20 values measured by meteorological sondes at UAD Praha and approximation of T20 values from the ERA-40 and ERA-INTERIM data bases for the days with low-quality or missing measurements.

In the next steps the long-term changes of the assimilated daily averages of TOZ from SOO-HK will be investigated mainly with the aim to the circulation patterns and stratospheric dynamics. The extreme-values theory and the neural-network models will be used to evaluate influence and fingerprints of the main contributors (ENSO, NAO, ODS, QBO, polar vortex and volcano).

4. DISSEMINATION OF RESULTS

4.1 Data reporting

The CHMMI facilities continue deposition of the ozone observations mainly to the WOUDC Toronto and the high quality UV spectral irradiances into the European UV Data Base (EUVDB) at FMI, Helsinki. The daily representative values of TOZ are submitted to the World Ozone Mapping Centre of the Environment Canada daily via the GTS/VIS telecommunication system using the CREX-BUFFER codes. The ozone sonde observations are submitted to WOUDC via the NDSC data base and to the partners in the MATCH campaigns.

4.2 Information to the public

The actual values of total ozone and the UV-Index in the territory of CR and their comparison with the long-term averages are is presented daily in mass media and at the Portal of CHMII: 
http://portal.chmi.cz/files/portal/docs/meteo/ozon/UV_online.html. In this way the public have the full access to the fresh pieces of information related to the condition of the ozone layer and harmful UV irradiances. Actual data of total ozone from the Marambio station are presented at the web page of the project.

4.3 Relevant scientific papers


5. PROJECTS AND COLLABORATION

Currently the experts from Czech institutions participate in the following research and development projects, international programmes and co-operations.

- Long-term Changes of the Ozone Layer over the Territory of the Czech Republic. Research project supported by the Czech Grant Agency No.P209/10/0058, 2010-2012. Assimilation of the Dobson and Brewer total ozone data series of 1961-2010. Investigation of contributions of ODS and stratospheric dynamics to changes of the ozone layer during the last 50 years. CHMI, SOO-HK.


- MATCH: International ozone sonde campaigns for the quantification of polar chemical ozone loss since 1998. Participation in yearly campaigns by alert ozone sonde flights. Multinational funding. CHMI, UAD


- WMO-GAW-VIAGOS: Pilot project: Improvement of Dissemination of Ozone (total column, profiles and surface) and Aerosol observations through the WIS” Preparation of the Guidance for Reporting Total Ozone Data in Near Real Time by experts from CHMI. SOO-HK.

- WMO-GAW-RDCCE: The Regional Dobson Calibration Centre – Europe. Bilateral cooperation between the German Weather Service, Meteorological Observatory Hohenpeissenberg, and the CHMI, SOO-HK on activities of RDCC-E, since 1999. Calibration campaigns, Dobson web information site, re-location of instruments, training of operators, software for the GAW Dobson network.
The most recent campaigns co-organized by the Czech experts:

- **Sub-regional calibration of the Brewer spectrophotometers** from Central Europe (CR, Hungary, Poland, Slovakia) towards the travel reference of the IOS, Hradec Kralove, 2009
- **Calibration of Dobson spectrophotometers and training of operators** for two newly established stations Kampala (Uganda) and Kiev (Ukraine) at SOO-HK. Joint action contributed by the experts from WDCC (Boulder, CO) and RDCC-E, 2010
- **Dobson Data Quality Workshop.** The UNEP/WMO action initiated by the 7-ORMM. Update of the knowledge on operation of Dobson instruments, instructions of Dobson data managers on methods of the data quality control, evaluation of data series and collection of the primary (0-level) data and metadata from stations into the WOUDC. Hradec Kralove, 2011, [www.dobsonworkshop.cz](http://www.dobsonworkshop.cz)

### 6. FUTURE PLANS

- The ozone and UV monitoring programme performed by CHMI including the international data transfer will continue in its current structure and scope.
- The quality of total ozone and UV radiation observations taken with the Brewer instrument at the Marambio station will be evaluated and compared with the satellite overpass measurements. Then the data of TOZ will be deposited into the WOUDC.
- The research project on assimilation and analyses of 50-year total ozone data series is to be completed as specified above in 2012 and results published in per-reviewed papers.
- SOO-HK will continue assistance to the ozone segment of the GAW programme mainly through the activities and actions organized by the Regional Dobson Calibration Centre-Europe and by participation in the SAG-Ozone.

### 7. RECOMMENDATIONS addressed to the 8-th ORMM

- Though several new stations have been established by re-location of the Dobson instruments in developing countries and in the former USSR territory in the recent years a significant gap in the ground network still persist mainly in central Asia. The capacity building should be focused primarily on this region
- To reach the highest possible quality of processing the ozone observations and to implement a wider data exchange via the GTS/VIS the unified software tools developed by the GAW central facilities and approved by the SAG-Ozone should be primarily used at the stations.
- The Dobson Data Quality Workshop held in 2011 has encouraged the Dobson station managers to pay more attention to routine assessment of quality total ozone observations and to evaluate the historical records. Such meetings of the experts with station representatives should be organized regularly under the auspices and assistance of the UNEP MP Secretariat and the WMO SAG-Ozone.
- The process of collection historical primary (0-level) data and calibration metadata from the Dobson stations in the WOUDC data base that started at the above Workshop should be continued. The stations that did not participated at the action should be invited to join this very important activity as the Dobson records are bearers of the historical knowledge about condition of the ozone layer of the pre-ozone hole period. The primary data sets are highly important for a complex re-processing of the reference data series if new sets of ozone cross section are to be implemented in the future, among others.
CZECH REPUBLIC

The Contribution of the Czech Republic to the Detection of the State of the Earth’s Ozone Layer and Solar UV-radiation in Antarctica

OBSERVATIONAL ACTIVITIES

Measurements of ozone and UV-radiation
In February of 2010 The Solar and Ozone Observatory of the Czech Hydrometeorological Institute in cooperation with the Argentine Antarctic Institute installed the Brewer ozone spectrophotometer (double MKIII) No. 199 at the Marambio Base - Argentina, Antarctica. The Brewer spectrophotometer (the Brewer) is a fully automated instrument (Fig.1).

![Fig.1: The Brewer spectrophotometer No. 199 - Marambio Base](image)

This activity is part of the VAV project - Ministry of the Environment of the Czech Republic - SPIII 9/23/07 "Contribution of the Czech Republic to detection of the stage of the Ozone layer of the Earth and solar UV radiation in Antarctica, paleoclimate and paleogeographic reconstruction of the selected area of Antarctica and the related geological research studies and mapping."

Cooperation with Argentina is the result of close cooperation in matters relating to the Antarctic between the Government of the Czech Republic and the Government of the Argentina.

The aim of the present work is to improve scientific knowledge for global assessments on ozone depletion and climate change for the Montreal Protocol and the Vienna Convention, better understanding of processes in the upper troposphere and lower stratosphere through modelling and data analysis and studies of the long-term variability in extratropical large scale transport are also being performed to improve long-term predictions of mid and high latitude ozone and UV radiation.
Calibration activities
The Brewer No.199 has been independently calibrated before its deployment at the Marambio Base and the internal tests from the instrument show that the instrument has been stable for the past year (Fig. 2, 3). In the future instrument will be regularly calibrated towards GAW etalons.

Fig 2: Mercury lamp test (February 2010 – January 2011)

Fig 3: Mercury lamp test (February 2010 – January 2011)

RESULTS FROM OBSERVATIONS AND ANALYSIS

The project consist of three parts.

Part A: The introduction of regular measurements of total ozone and UV-spectral radiation in the area in the north-eastern part of the Antarctic Peninsula (Marambio Base –
Argentina) and on-line transmission of data.

Part B: The use of measurements of total ozone and vertical profile of ozone - Umkehr for the operational assessment of the state of the ozone layer and validation of satellite measurements.

Part C: The use of spectral measurements of UV radiation for operational evaluation of the field UV-index in the Antarctic for validation of satellite measurements.

The result of the correlation between OMI and Brewer total ozone measurements is presented in Figure 4.

![Correlation graph between OMI and Brewer total ozone measurements](image)

Fig 4: Correlation between OMI and Brewer (direct sun) measurements (November 2010 – February 2011)

**THEORY, MODELLING, AND OTHER RESEARCH DISSEMINATION OF RESULTS**

**Data reporting**
Ozone observation will be in 2011 regularly submitted to the World Ozone and Ultraviolet Data Centre (WOUDC), Toronto and also to other partner institutions within projects - e.g. Argentine Antarctic Institute and Argentine National Weather Service.

**Information to the public**
In turn, over 6 conferences open to the public were given in the different disciplines in the period 2008-2010. Actual data of total ozone are presented NRT at the web page of the project: [http://www.antarktida-ozon.cz](http://www.antarktida-ozon.cz).

**Relevant scientific papers**


PROJECTS AND COLLABORATION

- With the Argentine Antarctic Institute
- With the Argentine National Weather Service
- With the WOUDC

FUTURE PLANS

- Continuing of measurement at the Marambio Base and publishing of the results (2011-2014).
- Calibration of the spectrophotometer and international comparison

NEEDS AND RECOMMENDATIONS

- Real-time ground base data and validation with the satellite from Antarctica – GTS/WIS

This report was prepared by Michal Janouch.
1. GENERALITÉS

1.1. Présentation de la RDC

La République Démocratique du Congo est le plus vaste pays d’Afrique centrale ayant une superficie de 2.345.000 km² et une population de 60.000.000 d’habitants.

La République Démocratique du Congo s’étend de l’océan atlantique au plateau de l’est et correspond à la majeure part du bassin du fleuve Congo. Le nord du pays est un des plus grand domaine de la forêt équatoriale au monde; l’est du pays est le domaine des montagnes, des collines, des grands lacs mais aussi des volcans. Le sud et le centre, riches en savanes arborées, forment un haut plateau en minerais divers. Le climat général du pays est chaud et humide mais cette situation varie selon les provinces.

La différence est due au fait que l’équateur traverse la totalité du territoire congolais. L’existence d’un tel climat produit une végétation dense et régit les activités agricoles de la population congolaise.

La R.D. Congo partage ses frontières avec l’enclave du Cabinda (Angola) et la République du Congo à l'Ouest, la République Centrafricaine et le Soudan au Nord, l'Ouganda, le Rwanda, le Burundi et la Tanzanie à l'Est, la Zambie et l'Angola au Sud.

La R.D.Congo compte actuellement 11 provinces y compris Kinshasa, la capitale du pays, considérée comme la ville province.

<table>
<thead>
<tr>
<th>N°</th>
<th>NOMS</th>
<th>CHEF LIEU</th>
<th>SUPERFICIE en Km²</th>
<th>DENSITE en hab/Km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BANDUNDU</td>
<td>BANDUNDU</td>
<td>295.658</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>BAS CONGO</td>
<td>MATADI</td>
<td>53.920</td>
<td>52,58</td>
</tr>
<tr>
<td>3</td>
<td>EQUATEUR</td>
<td>MBANDAKA</td>
<td>403.292</td>
<td>18,33</td>
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<tr>
<td>4</td>
<td>KASAI OCCIDENTAL</td>
<td>KANANGA</td>
<td>154.742</td>
<td>21,56</td>
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<tr>
<td>5</td>
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<td>MBUJI MAYI</td>
<td>170.302</td>
<td>45,00</td>
</tr>
<tr>
<td>6</td>
<td>KATANGA</td>
<td>LUBUMBASHI</td>
<td>496.877</td>
<td>16,44</td>
</tr>
<tr>
<td>7</td>
<td>KINSHASA</td>
<td>KINSHASA</td>
<td>9.965</td>
<td>752,63</td>
</tr>
<tr>
<td>8</td>
<td>MANIEMA</td>
<td>KINDU</td>
<td>132.250</td>
<td>14,00</td>
</tr>
<tr>
<td>9</td>
<td>NORD KIVU</td>
<td>GOMA</td>
<td>59.483</td>
<td>71,79</td>
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<tr>
<td>10</td>
<td>ORIENTALE</td>
<td>KISANGANI</td>
<td>503.239</td>
<td>1.777,91</td>
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<tr>
<td>11</td>
<td>SUD KIVU</td>
<td>BUKAVU</td>
<td>65.970</td>
<td>58,24</td>
</tr>
</tbody>
</table>

8 Provinces sur 11 ont été choisies comme cibles lors des enquêtes sur la consommation de HCFCs en raison de :
• L'existence de la fourniture en énergie électrique
• Fortes activités économiques (commerciales et industrielles)
• L'existence d'infrastructures permettant le déplacement et la mobilité des enquêteurs
• L'existence ou la présence d'une représentation locale de l'ACOPROF
• La hauteur du budget alloué aux enquêteurs.

1.2. La RDC et Le Protocole de Montréal

La 19ème conférence des Parties au Protocole de Montréal sur des substances appauvrissant la couche d'ozone (SAO), tenue à Montréal en septembre 2007, a pris la décision XIX/6 visant à accélérer l'élimination progressive des hydrochlorofluorocarbones (HCFC).

Il est demandé aux pays en développement visés à l'article 5 du Protocole de Montréal de se doter d'un plan gestion des HCFC en deux phases. La première comporte le gel en 2013 de la production et de la consommation puis leur réduction de 10% en 2015. La seconde, de 2016 à 2030, concerne la poursuite de la réduction progressive jusqu'à l'élimination finale. La République Démocratique du Congo n'est pas producteur de HCFC mais les importe.

L'inventaire estime à 1.014,984 tonnes les quantités de HCFC consommées annuellement en RDC entre Août 2008 et Août 2009. Cette consommation se répartie essentiellement dans les secteurs ci après:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>53%</td>
</tr>
<tr>
<td>Résidentiel</td>
<td>35%</td>
</tr>
<tr>
<td>Autres</td>
<td>12%</td>
</tr>
</tbody>
</table>

L’application de la méthodologie recommandée par le Protocole pour le calcul de la valeur plafond de 2013 (demi- somme de la consommation des années 2009 et 2010) permet d’estimer à 1.117.393 tonnes en 2013.

Partie aux Protocoles de Montréal et de Kyoto, la RDC se doit de prendre des mesures idoines pour gérer, comme convenu en vertu de la décision XIX/6 de la COP au Protocole de Montréal, l’importation et l’utilisation des HCFC et des équipements les contenant afin d’honorer ses engagements et d’éviter de se retrouver en situation de non-respect aux échéances conventionnelles de 2015, 2020, 2025 et 2030.

Le présent plan est élaboré pour servir de cadre national de référence pour la politique du gouvernement en matière de gestion des HCFC et des équipements les contenant jusqu’à leur élimination finale conformément au calendrier.
préconisé par la décision XIX/6 de la 19ème conférence des Parties au Protocole de Montréal.

Stratégie globale des HCFCs et plan d’élimination

1. Identification et recensement de tous les importateurs de HCFC en collaboration avec la direction générale des douanes et acsises
2. Vulgarisation et sensibilisation des actions à mener pour la mise en conformité de la RDC aux objectifs du Protocole de Montréal.
3. Formation des douaniers, agents de l'Office Congolais de Contrôle ainsi que des techniciens frigoristes.
4. Création par le ministère de l'environnement conservation de la nature et tourisme d'une police environnementale spéciale outillée dans la mise en œuvre de PM et autres conventions similaires.
5. Collaboration avec le FEC, l' ANAPI et les universités et autres forces vives de la nation pour la mise en place effective du Comité National Ozone

1.3. Dispositifs réglementaire et institutionnel

Ils ont pour fondement :

- Le Décret du 29 Janvier 1949 ordonnant et révisant le régime douanier de la République Démocratique du Congo, tel que modifié et complété à ce jour;
- L'ordonnance n°33/9 du 06 Janvier 1950 portant règlement d'exécution du Décret du 29 Janvier 1949 ordonnant et révisant le régime douanier de la République Démocratique du Congo, telle que modifiée et complétée à ce jour;

La RDC a ratifié plusieurs dispositifs et amendements internationaux relatifs à la protection de la couche d'ozone et de l'environnement en général comme illustrés dans le tableau ci-dessous.
Table 1: Status of ratification/accession of the Ozone Agreements

<table>
<thead>
<tr>
<th>Agreement</th>
<th>Entry into force</th>
<th>Date of ratification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vienna Convention</td>
<td>22/09/88</td>
<td>30/11/1994</td>
</tr>
<tr>
<td>Montreal Protocol</td>
<td>01/01/89</td>
<td>30/11/1994</td>
</tr>
<tr>
<td>London Amendment</td>
<td>10/08/92</td>
<td>30/11/1994</td>
</tr>
<tr>
<td>Copenhagen Amendment</td>
<td>14/06/94</td>
<td>30/11/1994</td>
</tr>
<tr>
<td>Montreal Amendment</td>
<td>10/11/99</td>
<td>09/02/2005</td>
</tr>
<tr>
<td>Beijing Amendment</td>
<td>25/02/02</td>
<td>09/02/2005</td>
</tr>
</tbody>
</table>

Note: R: Ratification Ac: Accession

2. Country Programme and Institutional Strengthening Project for the Implementation of the MP in DRC.

<table>
<thead>
<tr>
<th>Project name</th>
<th>Approved Excom Meeting</th>
<th>Status</th>
<th>Résultats acquis (Achevemen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country Program</td>
<td>The Country Programme was prepared and approved at 30th Meeting of the Ex-Com in March 1999. The D.R.Congo is neither a producer nor exporter of ODS. In 1996, ODS consumption by the country was 551.6 tones of ODS, or 0.015 kg of ODP per capita. Imported ozone depleting substances (ODS) are CFC11, CFC12, CFC113, CFC115 (as a mixture in R502), carbon tetrachloride, and 1, 1, 1 trichloroethane. Analysis by substance shows that CFC 12 accounts for 92% of total consumption. Analysis by sector shows that the refrigeration and air conditioning account for about 70% of the total consumption. By manufacturing industry for the following purposes: Inflating foams, and solvent cleaning of metals. Preparation of the country programme began in 1994 and was completed in 1998. Owing to the country difficult circumstances, the enquires were fragmentary and discontinuous, and as a result sometimes give a variable view of the situation of the country as regards ODS consumption. Accordingly the data used are sometimes fragmented. No amendment of CP has initiated.</td>
<td>Mise en place du Bureau National Ozone terminée composé d’un Coordonnateur National, d’un Adjoint et d’un Secrétaire. Le Comité National est composé d’un représentant de la Fédération des Entreprises de la R.D.Congo, des Ministères de l’Agriculture, de l’Industrie et Petites et moyennes Entreprises, de l’Economie, des Finances, du Commerce Extérieur, des Affaires Étrangères, de la Présidence, de l’Office de Contrôle du Congo (OCC), de l’Environnement et des ONGs-Environnement, etc….</td>
<td></td>
</tr>
<tr>
<td>Fist ISP</td>
<td>To develop and deliver public awareness programmes; to implement the activity proposed in the country programme including assistance to users of controlled substances in preparation and implementation of projects to covert to non-ODS alternatives. The National Ozone Office (BNO) began operating from early 2000. 1). Coordonnateur M. Lungili Damien, Directeur des Etablissement Humains et Protection de l’Environnement. 2). Coordonnateur Adjoint, M. Justin Tshikudi, Chef de Division Surveillance Continue de l’Environnement. 3). Secrétaire, M. Lufingu Nkosa Le Bureau assure la coordination et le suivi des activités liées au Protocole de Montréal</td>
<td>Appui du BNO par un matériel informatique et toutes les fournitures de Bureau. • Facilité de déplacement par l’achat du Carburant automobile des cadres œuvrant au sein du BNO. • Population sensibilisée grâce à des réunions techniques se déroulant dans les Universités et Écoles supérieures</td>
<td></td>
</tr>
<tr>
<td>Second ISP</td>
<td>Appui au Bureau National Ozone dans les activités inscrites dans le programme du pays, notamment l’organisation des ateliers de sensibilisation, l’achat du matériel informatique et autres fournitures de bureau.</td>
<td>• Population sensibilisée. • Les industriels intéressés. • Fournitures de bureau achetées. • Nette constatation de la diminution des SAO sur le plan consommation dans les 45 %</td>
<td></td>
</tr>
</tbody>
</table>
| Third ISP | Assurance par le Bureau National Ozone compose de M. Justin Tshikudi, Coordonnateur du projet et Point focal, M. Mudosa Pierre, Point focal Assistant, et M. | La Population atteinte par les média suite à ces formations a été sensibilisée dans presque ¾ du pays. Les dépliants qui ont été
**Fourth ISP**


- Réunions techniques de sensibilisation,
- Entretien du matériel de BNO,
- Déplacements pour la collecte des données et informations sur l’utilisation des SAO en provinces et quelques milieux proches de Kinshasa,
- Paiement de la prime d’encouragement des membres du BNO.

**Fifth ISP**

58è ExCom | On going


- Accroître la sensibilisation sur les questions relatives à l’appauvrissement de la couche d’ozone;
- Sensibiliser au bénéfice à tirer sur l’utilisation de bonnes pratiques ;
- Faire connaissance des différents types des SAO, de leurs utilisations ainsi que de leurs secteurs d’application ;
- Acquérir des méthodes de maintenance permettant d’éliminer des fuites ;
- Faire connaître des technologies alternatives sans impact sur l’Ozone ;
- Informer du calendrier d’élimination établi dans le cadre du programme mondial ;
- Établir un agenda et un calendrier de formations des autres techniciens du pays

Le BNO avait pour tâche :
- D’achever le projet dont le but était l’élimination totale du reste des CFC’s dans le pays, la R.D.Congo.
- Eliminer toutes les autres SAO à l’exception des HCFCs et consolider les avantages de réussite d’autres programmes.

**Refrigent management**

2.7.1.1. “Train the trainer program for servicing technicians” UNEP

Le programme de formation des techniciens de froid visait :
- À renforcer les compétences des techniciens à introduire les bonnes pratiques d’entretien et de réparation avec les nouveaux frigorigènes sans CFCs et
- Assister les associations de la réfrigération existant en R.D.Congo.
- Établissement de Quatre Centres de récupération et de recyclage de CFCs.
- Population, Industriels, et ONGs sensibilisés,
- Incitation,
- surveillance des activités

Du 13 au 16 sept 2005 :
- Centre Orgatec de Kinshasa : 37 frigoristes formateurs formés.

Du 23 au 24 Mars 2006 :
- Institut de Préparation Professionnelle de Kinshasa /Limete : 40 frigoristes formés.
- Institut Industriel de Kinshasa /Ngalia : 42 frigoristes formés.
- Institut Technique Kimbangwiste Bonpolo de Kinshasa : 37 frigoristes formés.
- Paroisse St Alphonse de Kinshasa /Matete : 41 frigoristes formés.
Institut Technique et Industriel de Kin/Ndjili : 41 frigoristes formés.
Du 13 au 14 Avril 2006 :
• Institut Technique de Kin/Bongolo : 70 frigoristes formés.
• Paroisse St Alphonse Kin/Mateete : 41 frigoristes formés.
• Institut Technique Kimbanguiste de Kin/Kalamu : 40 frigoristes formés.
• Institut Technique de Ndjili : 79 techniciens formés.
Du 11 au 13 mai 2008 :
• Ville de Matadi Province du Bas-Congo : 53 frigoristes formés
Du 30 au 31 juillet 2008
• 40 frigoristes de l’Institut technique industriel de Kin/Ngaliema formés,
• 40 frigoristes de l’Institut Technique de Kin/Kalamu formés ;
• 40 frigoristes de l’Institut St Alphonse de Kin/Mateete formés ;
• 40 frigoristes de l’Institut Technique Industriel de Kin/ Ndjili formés.
Du 31 au 02 Juillet 2008
• 22 frigoristes de Kinshasa formés
• 32 frigoristes de la Province du Katanga formés ;
• 32 frigoristes de la Province Orientale formés ;
• 33 frigoristes de la Province du Nord et Sud-Kivu formés.

2.8.1.1. Training of Customs Officials and NOU staff UNEP

Le but principal de la formation des Douaniers, Contrôleurs de l’OCC et Inspecteurs de l’Environnement, est :
• de parvenir à mieux connaître le but de la Convention de Vienne et son Protocole de Montréal relatif à des SAO.
• Assurer les frontières de la RD Congo par le contrôle des importations et exportations.
• Identifications des SAO ainsi que leurs conteneurs.
• Découragement des importations illégales et vulgarisation des textes réglementaires y relatifs y compris ceux régissant le fonctionnement de la douane à des frontières.
• Travaux pratiques.

Du 12 au 14 avril 2005
• 62 Douaniers Formateurs formés en 2004 au Centre Lassalien de Ngaliema à Kinshasa comprenant les cadre de douane, de l’OCC et de l’Environnement.
Du 13 au 16 décembre 2005 :
Deux sessions de formation de :
• 72 cadres de l’OFIDA (douane)
• 15 de l’OCC et
• 20 de l’Environnement.
Du 16 au 22 juin 2006
Deux sessions de Matadi, Province du Bas-Congo
• 105 douaniers, inspecteurs de l’OCC et de l’environnement formés
Du 22 au 24 Juin 2006
Formation de
• 64 douaniers des sites de Boma et Moanda,
frontière avec l’Angola et à l’embouchure du fleuve Congo vers l’océan Atlantique.

Du 19 au 29 juin 2006 :
Site de Matadi :
- 77 douaniers et cadre de l’OCC formés
Site de Boma :
- 34 cadres de douane, OCC et Environnement formés

Du 10 au 14 janvier 2008 :
- 77 cadres de Douane, de et de l’Environnement formés dans les villes de Muanda, Boma et Banana, dans le Bas-Congo

Du 18 au 20 Mars 2008 :
- 41 Cadre de l’OCC de Matadi et Mbaraka-Ngungu Formés

Du 10 au 14 January 2008 :
- 77 cadres de Douane, de et de l’Environnement formés dans les villes de Muanda, Boma et Banana, dans le Bas-Congo

Du 15 au 17 avril 2008 :
- 54 Cadres de douanes formés à Lubumbashi, Province du Katanga

Du 12 au 17 mai 2008 :
- 75 Cadres de Douane, de l’OCC et de l’Environnement formés à Mbuji-Mayi, Province du Kasai Oriental

Du 16 au 18 Février 2010 :
Formation de
- 25 Cadres de Douane de Lubumbashi et Kasumbalesa, Province du Katanga

2.9.1. CFC Terminal Phase-out Management Plan (TPMP) 57è ExCom

Acquisition des instruments de démonstration pour la formation et l’identification des réfrigérants. Coordination des déplacements de formateurs et des techniciens à former et logistique.

2.10. “End-user awareness and Incentive Programme” Implemented by UNDP


Par décision 41/100, le Comité Exécutif du Fonds Multilatéral a donné une flexibilité de mise en œuvre de ces projets

Mise en place de 4 centres de Récupération et de Réçyclage

- Centre de l’Institut technique Industriel de Ndjili (ITI), à Kinshasa
- Centre de l’Institut National de Préparation Professionnelle (INPP), Limete à Kinshasa
- Société ISOCCOOL, Kinshasa/Gombe
- Société Electromax à Matadi dans le Bas-Congo.
Formation supplémentaire appuyée par le PNUD
Du 08 au 18 déc. 2008,
• 50 techniciens formés à Lubumbashi, Province du Katanga sur la bonne pratique, la récupération et le recyclage.
• 52 techniciens formés à Likasi, Katanga sur la même technique.
Du 18 au 22 nov. 2008
Kisangani
• 45 Techniciens frigoristes formés.
Du 21 au 31 déc. 2008
• 130 techniciens formés

Utilisateurs Finaux recensés
• 31 en Province du Katanga,
• 12 au Kasai Oriental, et
• 5 au Nord Kivu
• 12 dans l’ensemble utilisent encore le CFC12

3. Tableau Equipements

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CODE</th>
<th>DESCRIPTION</th>
<th>QTE FOURNIE</th>
<th>OFIDA</th>
<th>OCC</th>
<th>ACOPROF</th>
<th>BNO</th>
<th>ETAT</th>
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<td>R &amp; R Unit</td>
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<td>1</td>
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<td>10</td>
<td>0</td>
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<td>10</td>
<td>0</td>
<td>BON</td>
</tr>
</tbody>
</table>

Matériels livrés aux 4 Centres de récupération et recyclage

<table>
<thead>
<tr>
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<th>DESCRIPTION</th>
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<td>360 80727 03 - 360 81264 00</td>
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<td>465-80052-00</td>
<td>Filtres + Séparateurs</td>
<td>16 + 16</td>
<td>BON</td>
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<tr>
<td>360-81985-00</td>
<td>Compresseurs</td>
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</tr>
<tr>
<td>Tx 200</td>
<td>Filtres (déshydrateur) + Flexibles</td>
<td>36 + 36</td>
<td>BON</td>
</tr>
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<td>Pompe à vide</td>
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<td>465-800533-00</td>
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<tr>
<td>-</td>
<td>Bouteilles petit format</td>
<td>108</td>
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</tr>
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</table>
4. Plan d'actions pour la mise en œuvre de la stratégie gouvernementale

Cette mise en œuvre dépend du plan d'actions et de la structure d'exécution mise en place; ainsi a-t-on prévu les grandes actions ci-après constituant ce plan:

La création d'un cadre institutionnel se traduisant par la mise en place du bureau National Ozone, sous la coordination du Ministère de l'Environnement, Conservation de la Nature et Tourisme;

L'élaboration d'un cadre de réglementation sur l'importation et l'utilisation des SAO et des appareils les conteneurs;

L'évaluation périodique des rapports d'activités mises en œuvre dans le cadre de l'élimination des SAO;

L'exécution des actions de sensibilisation et de formation des techniciens frigoristes, des importateurs et des utilisateurs des SAO;

L'information et la sensibilisation des populations par les médias nationaux.

Les réalisations d'actions de mise en œuvre du Protocole

Elles sont notables sur le plan institutionnel et réglementaire d'une part et d'autre part sur le plan des actions de terrain.

Les réalisations sur le plan institutionnel et réglementaire :

Outre plusieurs actions menées telles que la participation aux réunions internationales relatives à la mise en œuvre du Protocole de Montréal, la RDC a déployé une série d'activités institutionnelles et réglementaires remarquables:

- Elaboration en collaboration avec l'administration douanière d'une instruction relative aux modalités d'application de l'arrêté interministériel n°021/2004 du 06 mai 2004 portant réglementation relative aux importations, réimportations, exportations et réexportations des substances qui appauvrissent la couche d'ozone, produits et/ou équipements contenant de telles substances.

- Obligation faite aux importateurs de l'obtention préalable d'une autorisation spéciale délivrée par le Ministre ayant l'environnement dans ses attributions. Le Ministre peut déléguer sa compétence au Secrétaire Général à l'Environnement, Conservation de la Nature et Tourisme.

- Toute obtention d'une autorisation spéciale d'importation est soumise aux conditions suivantes :
1. avoir acquis un Quota individuel d'importation ou d'exportation des SAO, produits et/ou équipements les contenant délivré par le BNO;

2. justifier de la qualité de commerçant conformément à la législation en vigueur sauf dérogation spéciale du Ministre ayant l'Environnement dans ses attributions notamment pour des raisons scientifiques et de formation.

- Le Quota individuel est annuel et non cessible. Le report à l'année suivante du Quota résiduel non apuré pendant l'année civile considérée et sa cession à un tiers ne sont pas autorisés.

- Le Quota individuel étant un instrument de contrôle et d'élimination progressive de la consommation des SAO du pays alloué au seuls importateurs, ne sera pas exigé lors de l'exportation ou de la réexportation des SAO, produits et/ou équipements.

- Toute importation ou exportation des SAO, produits et/ou équipements les contenant doit faire l'objet d'une déclaration en détail leur assignant un régime douanier déterminé conformément à l'article 5 et du Décret du 29 janvier 1949 ordonnant et révisant le régime douanier de la République Démocratique du Congo, tel que modifié et complété à ce jour.....

4. OBJECTIFS

Objectifs 1: Connaître l'évolution des quantités de HCFC consommées annuellement de 2009 à 2030

L'objectif du présent projet est de permettre à la RDC de disposer en 2013 d'une valeur plafond de référence pour la consommation des HCFC, fiable et conforme aux tendances nationales sur la consommation de HCFC. Pour cela, il faudra :

- Calculer la valeur de référence de 2013 sur la base de la moyenne arithmétique des consommations annuelles des années 2009 et 2010 ;
- Connaître la quantité de HCFC consommée en RDC en 2011 et 2012 afin de corriger la moyenne arithmétique des consommations estimées de 2009 et 2010 pour avoir une valeur plafond de référence pour 2013 plus fiable.
- Connaître chaque année la quantité de HCFC consommées dans le pays de 2013 à 2030 inclus.

Objectifs 2: Adapter le cadre juridique pour la prise en compte de l'élimination des HCFC

L'objectif 2 vise à :
Compléter le cadre juridique existant, relatif à la gestion de l'élimination des SAO en général, de manière à y inclure spécifiquement les dispositions de la décision XIX/6 de la 19ème conférence des Parties au Protocole de Montréal et les mécanismes législatifs et réglementaires de leur mise en œuvre effective
visant à geler, réduire et éliminer quasi-totalement (97,5%) la consommation des HCFC dans la climatisation et la réfrigération entre en 2013 et 2030.

Objectifs 3: Adapter le cadre institutionnel pour la prise en compte de l’élimination des HCFC

Cet objectif vise à outiller convenablement en moyens techniques et matériels ainsi qu’en ressources humaines qualifiées le Bureau National Ozone (BNO) et le Comité National Ozone. Le BNO pourra disposer par exemple de moyens de déplacement appropriés pour les descentes sur le terrain et de d’équipement analytiques pour le dépistage des fluides frigorigènes mis à la disposition de la clientèle afin d’en évaluer la qualité et de détecter les produits fralatés ou contrefaits.

Objectifs 4: Sensibiliser les intervenants sur la stratégie d’élimination progressive et des alternatives

- Informer les décideurs de haut rang, les professionnels du domaine du froid, les journalistes spécialisés dans les questions environnementales, les associations de consommateurs, les ONG, les autres acteurs et le public en général des effets néfastes des HCFC sur la santé humaines et l’environnement à travers l’appauvrissement de couche d’ozone et le réchauffement climatique.
- Mettre un accent particulier sur l’information relative aux alternatives disponibles et accessibles économiquement. Mieux les faire connaître surtout des importateurs et des professionnels. Éclairer les importateurs sur les restrictions prévues par la loi et leurs modalités d’application pour l’importation, etc.

Objectifs 5: Renforcer les capacités des techniciens frigoristes

Cet objectif vise à donner aux frigoristes les informations et les outils techniques nécessaires à leur adaptation aux nouvelles contraintes de leur métier.

En plus des aspects théoriques sur le fonctionnement des équipements et l’identité et les spécificités techniques des alternatives aux HCFC, ils apprendront durant la formation à :
- Récupérer le HCFC d’un appareil et l’y remettre après entretien ou réparation ;
- Remplacer le HCFC d’un appareil par un HFC ;
- Remplacer le HCFC par un hydrocarbure (R404a, R600, R600a, etc.)
- Remplacer le HFC (R134a) d’un équipement par un hydrocarbure ;
- Détecter un frigorigène fralaté et donc impropre à l’emploi ; Etc..
Objectifs 6: Renforcer les capacités des acteurs du service des douanes et de la police de l’environnementale
Le gel de la consommation des HCFC en 2013
Le Contrôle efficace de l’importation de nouveaux HCFC à partir du 01/01/2013

Cet objectif vise la formation des douaniers, des agents de la police environnementale et autres agents des forces de sécurité aux postes de douanes au dépistage des frigorigènes HCFC ou relâchés. Les activités seront quasiment les mêmes que celles réalisées dans le cadre de l’élimination des CFC.

Objectifs 7: Équiper les ateliers de froid et appliquer des mesures d’incitations financières
Cet objectif est l’un des plus importants du plan de gestion de l’élimination des HCFC en RDC comme dans les autres pays en développement. 
Le projet visé est fondamentalement un projet de développement pour un transfert de technologie à travers l’équipement d’un centre national de formation existant en installations de récupération de recyclage des frigorigènes, y compris les HCFC.

Un appui financier de la part des bailleurs bilatéraux ou multilatéraux permettrait au gouvernement de subventionner significativement l’importation des frigorigènes de substitution et d’équipements ne fonctionnant pas aux HCFC.

5. Lessons learned from ODS phase-out

Le renforcement des capacités doit être accompagné obligatoirement des outils permettant aux services ou administrations formées d’être opérationnel sur le terrain; ce qui implique l’élaboration en amont de tous les dispositifs juridiques et autres mesures d’encadrement pour éviter toute léthargie dans la mise en application des contrôles.

Une collaboration étroite entre tous les intervenants dans les circuits des importations, des réimportations, des exportations et des réexportations des SAO est indispensable afin d’assurer une meilleure surveillance du commerce légal et de prévenir le commerce illicite des SAO, produits et/ou équipements les contenant.

Ces différents services collaboreront au sujet :

- de la collecte, de la transmission et de la gestion des données relatives aux Quotas individuels et aux autorisations spéciales octroyées;
• des bénéficiaires, des quantités et des natures des marchandises importées et exportées; et
• des infractions et saisies.

Le Bureau National Ozone en collaboration avec l'Association Congolaise des Professionnels du Froid et de la climatisation doit mettre en place un système de traçabilité des fluides frigorigènes en général et des HCFCs en particulier pour faciliter la gestion et la manipulation de ces derniers.

Le Comité national ozone est appelé à se réunir régulièrement tenant compte des impératifs liés à l'évolution de la réglementation en matière de protection de l'environnement organise des séances de sensibilisation et de vulgarisation au travers des médias nationaux sur la problématique de la protection de la couche d'ozone et du réchauffement climatique.

Créer une police environnementale qui aura plusieurs missions entre autre la surveillance de la mise en œuvre et le respect des conventions ratifiées par le gouvernement.

Créer des check-point aux frontières pour maîtriser et contrôler le flux des SAO et autres substances réglementées.

Subventionner les associations des frigoristes pour assurer la formation permanent des techniciens frigoristes en matière de gestion et de manipulation des fluides frigorigènes et sur le respect de l'environnement.

6. HCFCs CONSUMPTION

La République Démocratique du Congo n'étant pas un pays industriel ou encore producteur des HCFCs comme énoncé ci haut, plusieurs types de réfrigérants ne se retrouvent pas sur notre territoire, si bien que le plus utilisés demeurent R22 pur rare sont les mélanges. Ce qui s'illustre dans les tableaux ci dessous :

6.1. Les Importations :

**Tableau : Pure HCFCs (R22)**

<table>
<thead>
<tr>
<th>Refrigerants</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFCs</td>
<td>509 757</td>
<td>566 397</td>
<td>707 996</td>
</tr>
<tr>
<td>R-22</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R-123</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R141b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub Total</td>
<td>509 757</td>
<td>566 397</td>
<td>707 996</td>
</tr>
</tbody>
</table>
**Tableau HCFCs Blend: Autres**

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-402B</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R-406A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R408A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R-409A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R-502</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Serie de R-400</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Serie des R-500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**HCFCs in Blends**

<table>
<thead>
<tr>
<th>Mélanges</th>
<th>Composants</th>
<th>Quantité de HCFC importé</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-408A</td>
<td>HCFC-22</td>
<td>0Kg</td>
</tr>
<tr>
<td>R-409</td>
<td>HCFC-22</td>
<td>0Kg</td>
</tr>
<tr>
<td></td>
<td>HCFC-124</td>
<td>0Kg</td>
</tr>
<tr>
<td></td>
<td>HCFC-124b</td>
<td>0Kg</td>
</tr>
<tr>
<td></td>
<td>Sub total</td>
<td>0Kg</td>
</tr>
</tbody>
</table>

**6.2. Summary HCFCs import (Pure + in Blend)**

La mise en œuvre du PM a permis une progression sensible de l'utilisation du R22 dans le secteur du froid commercial en remplacement du R12 et R502.

La reconversion des installations frigorifiques a aussi permis cette progression car le prix des fluides alternatifs étant trop élevé et les habitudes aidant nombreux sont les frigoristes qui ont préféré continuer avec le R22 pour des raisons de maitrise de la connaissance des caractéristiques de ce dernier (rapport avec le lubrifiant).

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFC in MT</td>
<td>439,05</td>
<td>585,40</td>
<td>780,53</td>
</tr>
</tbody>
</table>

**6.2.1. Répartition sectorielle ou distribution** : Résidentiel ; Commercial et autres!

<table>
<thead>
<tr>
<th></th>
<th>Domestic servicing</th>
<th>Fisheries</th>
<th>Tourism</th>
<th>Food processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFCs</td>
<td>2 925</td>
<td>3 900</td>
<td>5 200</td>
<td>6 933</td>
</tr>
<tr>
<td>Blends</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>975</td>
<td>1 300</td>
<td>1 733</td>
<td>2 311</td>
</tr>
<tr>
<td>Total</td>
<td>3 900</td>
<td>5 200</td>
<td>6 933</td>
<td>9 244</td>
</tr>
</tbody>
</table>

**6.2.2. Alternatives**
### 6.2.3. Prix des HCFCs et Alternatives

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Price (US$)/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
</tr>
<tr>
<td>CFC-12</td>
<td>10</td>
</tr>
<tr>
<td>R-134a</td>
<td>10</td>
</tr>
<tr>
<td>R-22</td>
<td>8</td>
</tr>
<tr>
<td>R-23</td>
<td>-</td>
</tr>
<tr>
<td>R-123</td>
<td>-</td>
</tr>
<tr>
<td>R-141B</td>
<td>15</td>
</tr>
<tr>
<td>R-402B</td>
<td>-</td>
</tr>
<tr>
<td>R-404A</td>
<td>-</td>
</tr>
<tr>
<td>R-406A</td>
<td>-</td>
</tr>
<tr>
<td>R-407</td>
<td>-</td>
</tr>
<tr>
<td>R-407A</td>
<td>-</td>
</tr>
<tr>
<td>R-407C</td>
<td>-</td>
</tr>
<tr>
<td>R-408A</td>
<td>15</td>
</tr>
<tr>
<td>R-409A</td>
<td>15</td>
</tr>
<tr>
<td>R-410A</td>
<td>-</td>
</tr>
<tr>
<td>R-413</td>
<td>-</td>
</tr>
<tr>
<td>R-417A</td>
<td>-</td>
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<tr>
<td>R-418</td>
<td>-</td>
</tr>
<tr>
<td>R-502</td>
<td>-</td>
</tr>
<tr>
<td>R-507</td>
<td>-</td>
</tr>
<tr>
<td>R-717</td>
<td>-</td>
</tr>
<tr>
<td>HC</td>
<td>-</td>
</tr>
</tbody>
</table>

### 6.3. Tendance de la consommation en HCFCs

#### Demande ou besoin en HCFCs

1. Recensement de tous les équipements fonctionnant aux HCFCs purs avec leur charge

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator (Commercial)</td>
<td>354 434</td>
<td>393 816</td>
<td>492 270</td>
</tr>
<tr>
<td>Air Conditioning (Self-Contained)</td>
<td>1 500 952</td>
<td>1 667 725</td>
<td>2 084 656</td>
</tr>
<tr>
<td>Freezers</td>
<td>7 828</td>
<td>8 698</td>
<td>10 873</td>
</tr>
<tr>
<td>Chiller (Electric) Household</td>
<td>10 650</td>
<td>11 834</td>
<td>14 792</td>
</tr>
<tr>
<td>Equipment type</td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
</tr>
<tr>
<td>----------------------------------------------------------------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Air Conditioning (Self-Contained)</td>
<td>207 217</td>
<td>230 011</td>
<td>287 514</td>
</tr>
<tr>
<td>Freezers</td>
<td>120 171</td>
<td>133 390</td>
<td>166 738</td>
</tr>
<tr>
<td>Refrigerator (commercial)</td>
<td>59 394</td>
<td>65 927</td>
<td>13 047</td>
</tr>
<tr>
<td>Chiller (Electric) Household</td>
<td>9 520</td>
<td>10 567</td>
<td>13 209</td>
</tr>
<tr>
<td>Refrigerating Counter &amp; Refrigerating Table</td>
<td>10 523</td>
<td>11 681</td>
<td>14 601</td>
</tr>
<tr>
<td>Chiller (Industrial)</td>
<td>37 036</td>
<td>41 110</td>
<td>51 388</td>
</tr>
<tr>
<td>Cold Room</td>
<td>25 051</td>
<td>27 807</td>
<td>34 756</td>
</tr>
<tr>
<td>Water Cooler, Electric</td>
<td>1 280</td>
<td>1 422</td>
<td>1 778</td>
</tr>
<tr>
<td>Ice Cube Machine</td>
<td>25 488</td>
<td>28 320</td>
<td>35 400</td>
</tr>
<tr>
<td>Floor standing AC/Split system</td>
<td>10 702</td>
<td>11 891</td>
<td>14 864</td>
</tr>
<tr>
<td>Ice Flaker</td>
<td>56</td>
<td>62</td>
<td>78</td>
</tr>
<tr>
<td>Vending Machines</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Freezer Container</td>
<td>3 313</td>
<td>3 682</td>
<td>4 602</td>
</tr>
<tr>
<td>Total (units)</td>
<td>509 757</td>
<td>565 830</td>
<td>707 288</td>
</tr>
</tbody>
</table>

3 . Évaluation du besoin total en HCFCs pour régler toutes les fuites

<table>
<thead>
<tr>
<th>Sector</th>
<th>Nombre d'équipements</th>
<th>stock installé</th>
<th>Fuites</th>
<th>Besoin annuel</th>
<th>% de HCFC - 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioning (unitary/split systems)</td>
<td></td>
<td>HCFC-22</td>
<td>Leakage % in kGS</td>
<td>Annual needs for servicing in Kg</td>
<td>% of the HCFC -22</td>
</tr>
<tr>
<td>Households</td>
<td>2 154 223</td>
<td>487 942</td>
<td>34 156</td>
<td>522 097</td>
<td>62.00</td>
</tr>
</tbody>
</table>

213
<table>
<thead>
<tr>
<th>Services</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resorts</td>
<td>34 777</td>
<td>7 881</td>
<td>552</td>
</tr>
<tr>
<td>Hotels guest houses</td>
<td>34 777</td>
<td>7 927</td>
<td>551</td>
</tr>
<tr>
<td>Safari vessels</td>
<td>34 777</td>
<td>7 877</td>
<td>1 653</td>
</tr>
<tr>
<td>Fisheries and Agriculture</td>
<td>104 264</td>
<td>23 616</td>
<td>11 018</td>
</tr>
<tr>
<td>Public &amp; business Administration</td>
<td>694 935</td>
<td>157 406</td>
<td>2 755</td>
</tr>
<tr>
<td>Health and social work</td>
<td>173 751</td>
<td>39 355</td>
<td>3 850</td>
</tr>
<tr>
<td>Others - municipal, cultural</td>
<td>243 237</td>
<td>54 994</td>
<td>3 850</td>
</tr>
<tr>
<td>Sub total</td>
<td>3 474 742</td>
<td>786 999</td>
<td>55 090</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food processing and Commercial refrigeration (Display cases, Freezers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial equipments, display cabinets</td>
</tr>
<tr>
<td>Condensing units, ice cream freezers, etc.</td>
</tr>
<tr>
<td>3 139</td>
</tr>
<tr>
<td>523</td>
</tr>
<tr>
<td>Wholesale and retail trade</td>
</tr>
<tr>
<td>136</td>
</tr>
<tr>
<td>1. Freezer</td>
</tr>
<tr>
<td>3 558</td>
</tr>
<tr>
<td>2. Display cases</td>
</tr>
<tr>
<td>314</td>
</tr>
<tr>
<td>3. Ice flakers, ice cube machines blast freezers</td>
</tr>
<tr>
<td>machines blast freezers</td>
</tr>
<tr>
<td>1 256</td>
</tr>
<tr>
<td>1 570</td>
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<tr>
<td>Sub Total</td>
</tr>
<tr>
<td>10 495</td>
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</table>

<table>
<thead>
<tr>
<th>Fisheries/transport and commercial refrigeration (cold rooms, freezer containers)</th>
<th>AUTRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Rooms</td>
<td></td>
</tr>
<tr>
<td>7 848</td>
<td>24 410</td>
</tr>
<tr>
<td>Freezer Containers</td>
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</tr>
<tr>
<td>1 570</td>
<td>5 082</td>
</tr>
<tr>
<td>Fisheries ships</td>
<td></td>
</tr>
<tr>
<td>837</td>
<td>2 710</td>
</tr>
<tr>
<td>Other equipment</td>
<td></td>
</tr>
<tr>
<td>209</td>
<td>1 678</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
</tr>
<tr>
<td>22 529</td>
<td>33 880</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
</tr>
<tr>
<td>3 507 767</td>
<td>943 995</td>
</tr>
</tbody>
</table>

4. Estimation du taux de croissance des équipements de 2009 et 2010

<table>
<thead>
<tr>
<th>Nombre équipements</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 507 767</td>
<td>4 384 709</td>
</tr>
</tbody>
</table>

Estimation des importations de 2009 à 2011

<table>
<thead>
<tr>
<th>HCFC in MT</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.014,984</td>
<td>1.217,981</td>
<td>1.339,779</td>
</tr>
</tbody>
</table>
Prévisions de la consommation en HCFCs, sans et avec le PM:

<table>
<thead>
<tr>
<th>PHASE</th>
<th>PHASE 1 en Tonnes métriques</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREVISIONS SANS PM</td>
<td>1 014,984</td>
</tr>
<tr>
<td>PREVISIONS AVEC PM</td>
<td>1 014,984</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PHASE</th>
<th>PHASE 2 en Tonnes métriques</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANNEE 2021</td>
</tr>
<tr>
<td>PREVISIONS SANS PM</td>
<td>3 159,129</td>
</tr>
<tr>
<td>PREVISIONS AVEC PM</td>
<td>573,381</td>
</tr>
</tbody>
</table>

Graphe 1 et 2

Estimation du Base line

HCFC : 1 117,913 Tonnes métriques (moyenne 2009/2010)

7. Potential Impact on Climat

<table>
<thead>
<tr>
<th>Parameters</th>
<th>HCFC-22</th>
<th>R-410a</th>
<th>R-407a</th>
<th>R-404</th>
<th>HCFc-142b</th>
<th>HFC-134a</th>
<th>Hydrocarbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant charge( tonne)</td>
<td>1014.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GWP</td>
<td>1.780</td>
<td>1.890</td>
<td>1.600</td>
<td>3.800</td>
<td>2.270</td>
<td>1.300</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantité utilisée en cas de reconversion ( tonne)</th>
</tr>
</thead>
</table>
8. HCFCs phase out strategy

Les lignes directrices de la stratégie globale de l'élimination des HCFCs en RD Congo sont représentées par les activités ci-après:

**Activité 1 : Collecte et actualisation des données sur la consommation annuelle des HCFCs**

La connaissance de l'évolution des quantités de HCFC consommées annuellement de 2009 à 2030 inclus.

Ceci permettra à la RD Congo de disposer en 2013 d'une valeur plafond de référence pour la consommation des HCFC, fiable et conforme aux tendances nationales sur la consommation de HCFC.

Pour cela, il faudra:

- Calculer la valeur de référence de 2013 sur la base de la moyenne arithmétique des consommations annuelles des années 2009 et 2010;

- Connaître la quantité de HCFC consommée en 2011 et 2012 afin de corriger la moyenne arithmétique des consommations estimées de 2009 et 2010 pour avoir une valeur plafond de référence pour 2013 plus fiable.

**Activité 2 : Renforcement du cadre juridique pour la mise en œuvre du plan de gestion de l’élimination des HCFC**

Compléter le cadre juridique existant, relatif à la gestion de l’élimination des SAO en général, de manière à y inclure spécifiquement les dispositions de la décision XIX/6 de la 19ème conférence des Parties au Protocole de Montréal et les mécanismes législatifs et réglementaires de leur mise en œuvre effective visant à geler, réduire et éliminer quasi-totalement (97,5%) la consommation des HCFC dans la climatisation et la réfrigération entre en 2013 et 2030.

Réunir tous les éléments techniques pertinents sur les modalités de restriction de l’importation et de l’utilisation des HCFC, les alternatives économiquement et techniquement accessibles à utiliser dans les différents secteurs, la responsabilité des importateurs relativement au principe « pollueur-payeur », le dépistage des frigorigènes et des équipements importés, les contrôles d’étanchéité des gros équipements, les possibilités d’incitation douanières et fiscales pour les équipements sans HCFC, etc.
Activité 3 : Renforcement du cadre institutionnel pour la mise en œuvre du PGEH ;

Equiper convenablement en moyens techniques et matériels ainsi qu’en ressources humaines qualifiées le Bureau National Ozone (BNO) et le Comité National Ozone.

Le BNO pourra disposer par exemple de moyens de déplacement appropriés pour les descentes sur le terrain et de d’équipement analytiques pour le dépistage des fluides frigorigènes mis à la disposition de la clientèle afin d’en évaluer la qualité et de détecter les produits relâchés ou contrefaits.

Activité 4 : Sensibilisation des divers intervenants sur la stratégie de l’élimination progressive et des alternatives ;

Informier les décideurs de haut rang, les professionnels du domaine du froid, les journalistes spécialisés dans les questions environnementales, les associations de consommateurs, les ONG, les autres acteurs et le public en général des effets néfastes des HCFC sur la santé humaines et l’environnement à travers l’appauvrissement de couche d’ozone et le réchauffement climatique.

réduire et abandonner in fine l’importation et l’utilisation des HCFC et des équipements et autres articles les contenant.

Mettre un accent particulier sur l’information relative aux alternatives disponibles et accessibles économiquement. Mieux les faire connaître surtout des importateurs et des professionnels.

éclairer les importateurs sur les restrictions prévues par la loi et leurs modalités d’application pour l’importation, etc.

Activité 5 : Renforcement des capacités des techniciens frigoristes à la gestion et à la manipulation des HCFC ;

Donner aux frigoristes les informations et les outils techniques nécessaires à leur adaptation aux nouvelles contraintes de leur métier.

En plus des aspects théoriques sur le fonctionnement des équipements et l’identité et les spécificités techniques des alternatives aux HCFC, ils apprendront durant la formation à :

Récupérer le HCFC d’un appareil et l’y remettre après entretien ou réparation ;
Remplacer le HCFC d’un appareil par un HFC ;

Remplacer le HCFC par un hydrocarbure (R404a, R600, R600a, etc.)

Remplacer le HFC (R134a) d’un équipement par un hydrocarbure ;

Détecter un frigorigène frelaté et donc impropre à l’emploi ;

Etc.

**Activité 6: Renforcement des capacités des douaniers, des agents de l'OCC;**

Former et équiper des douaniers, des agents de l'OCC et autres agents des forces de sécurité aux postes de douanes au dépistage des frigorigènes HCFC ou frelatés.

Les activités seront quasiment les mêmes que celles réalisées dans le cadre de l’élimination des CFC en respectant le calendrier y afférent.

**Activité 7 : Incitations financières pour l'acquisition des équipements de récupération, recyclage des centres de récupération ;**

Le projet visé est fondamentalement un projet de développement pour un transfert de technologie à travers la création et l’équipement des centres de récupérations existant en matériels de récupération et de recyclage des frigorigènes, y compris les HCFC.

Un appui financier de la part des bailleurs bilatéraux ou multilatéraux permettrait au gouvernement de subventionner significativement l’importation des frigorigènes de substitution et d’équipements ne fonctionnant pas aux HCFC.

**Activité 8 : Appui à l'association des professionnels du froid et de la climatisation ;**

Les bailleurs bilatéraux ou multilatéraux soutiendront l’émergence d’esprit associative des frigoristes afin de contrôler aisément la traçabilité des fluides frigorigènes.

Un appui financier sera nécessaire pour donner aux frigoristes une motivation
réelle dans la mise en œuvre du PM et de ses amendements. Par exemple faciliter le déploiement de l'association à travers le pays afin d'encadrer les techniciens qui sont dans l'imformel.

La mise en œuvre de cette stratégie permettra à la R D Congo d'être en conformité avec le calendrier préconisé par la décision XIX/6 de la 19ème conférence des Parties au Protocole de Montréal.

**Activité 9 : Coordination et suivi du PGEH ;**

Le mécanisme en place inclus le Comité national ozone qui est un comité multisectoriel et pluridisciplinaire et le Bureau national ozone qui est la cheville ouvrière pour la coordination, la planification des activités de mise en œuvre du plan;

ce mécanisme de coordination et de gestion des plan antérieur demeure opérationnel

Moyennant un renforcement adéquat de ses ressources humaines et de ses capacités matérielles, ce mécanisme est à même d’assurer la coordination et la gestion de ce plan d’élimination des HCFC

**Le suivi interne :** Il sera assuré par l’organe d’audit du Ministère en charge de l’environnement.

**Le suivi externe :** Il sera réalisé conformément aux procédures des bailleurs de fonds.

**Autre suivi :** Toute partie prenante, à son initiative et selon ses modalités peu

**9. PROJECTION DE L’EVOLUTION DU CALENDRIER D’ELIMINATION**

Selon la figure ci-dessous les quantités résiduelles des HCFC se présentent comme suit :  1,117,913 tonnes (100%) en 2013; 1,006,121 tonnes (90%) en 2015; 653,979 tonnes (65%) en 2020; 228,893 tonnes (35%) en 2025 et 57,223 tonnes (2,5%) en 2030.
## 10 . Cout de la stratégie globale

<table>
<thead>
<tr>
<th>N° de projet</th>
<th>Intitule</th>
<th>Montant bailleurs de fonds (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projet 1</td>
<td>Collecte et actualisation des données sur la consommation annuelle des HCFC en RDC</td>
<td>20 000</td>
</tr>
<tr>
<td>Projet 2</td>
<td>Renforcement du cadre juridique pour la mise en œuvre du plan de gestion de l’élimination des HCFC</td>
<td>30 000</td>
</tr>
<tr>
<td>Projet 3</td>
<td>Renforcement du cadre institutionnel pour la mise en œuvre du plan de gestion de l’élimination des HCFC en RDC</td>
<td>20 000</td>
</tr>
<tr>
<td>Projet 4</td>
<td>Vulgarisation, Éducation et Sensibilisation</td>
<td>20 000</td>
</tr>
<tr>
<td>Projet 5</td>
<td>Renforcement des capacités des techniciens frigoristes à la gestion et à la manipulation des HCFC</td>
<td>200 000</td>
</tr>
<tr>
<td>Projet 6</td>
<td>Renforcement des capacités des douaniers, des agents de l’Office Congolais de Contrôle</td>
<td>80 000</td>
</tr>
<tr>
<td>Projet 7</td>
<td>Incitation financière pour l’acquisition des équipements aux ateliers de froid et entreprises de froid pour la récupération, le recyclage et la reconversion des installations</td>
<td>800 000</td>
</tr>
<tr>
<td>Projet 8</td>
<td>Appui matériel à l’association des frigoristes pour un meilleur encadrement</td>
<td>130 000</td>
</tr>
<tr>
<td>Projet 9</td>
<td>Monitoring</td>
<td>250 000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>1 520 000</strong></td>
</tr>
</tbody>
</table>
DENMARK

1. OBSERVATIONAL ACTIVITIES

The Danish Meteorological Institute (DMI), in collaboration with the Danish Environmental Protection Agency, conducts permanent measurements of the stratospheric ozone layer. Daily ground-based measurements of the ozone layer thickness as well as weekly balloon based measurements of the vertical ozone profiles are performed in Denmark and Greenland. The measurements are reported to international databases. In addition the measurements are incorporated in validation of satellite measurements. Balloon-based measurements of the ozone layer are often conducted as part of larger international projects such as Match-campaigns.

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss.

Daily observations of total ozone are performed by the DMI in Denmark and Greenland:

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Start of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copenhagen</td>
<td>56°N, 12°E</td>
<td>Brewer Mark IV</td>
<td>May 1992</td>
</tr>
<tr>
<td>Sondre Stromfjord</td>
<td>67°N, 51°W</td>
<td>Brewer Mark II</td>
<td>September 1990</td>
</tr>
<tr>
<td>(Kangerlussuaq)</td>
<td></td>
<td>Brewer Mark III</td>
<td>February 2010</td>
</tr>
<tr>
<td>Thule Air Base</td>
<td>77°, 69°W</td>
<td>SAOZ 1024 diode array</td>
<td>September 1990</td>
</tr>
</tbody>
</table>

On non-regular basis, total ozone has also been measured from Qaanaaq (78°N, 69°W) in Greenland, using the DMI Dobson #92 instrument since early 2000.

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

Weekly ozone soundings have been performed using balloon-borne EEC sensors from Scoresbysund (Illoqqortoormiut, 71°N, 22°W) since January 1993. Ozone soundings have also been performed on campaign basis from Thule Air Base each winter since January 1992 and occasionally from Copenhagen.

1.3 UV measurements

1.3.1 Broadband measurements

A Yankee Environmental Systems model UVB-1 radiometer has been operated by DMI in Copenhagen since 1996. A custom UV radiometer (erythemally weighted UV and total UV-A) has been in operation in Thule (Pituffik) since 1993. The latter instrument is owned by the Health Protection Agency in the U.K. (former National Radiological Protection Board) and the UV-B part of the instrument is similar to the Solar Light model 500.

1.3.2 Narrowband filter instruments

A narrowband filter instrument – Biospherical Inc., model GUV2511 – has been operated on the east coast of Greenland at Scoresbysund (Illotoorqortoormiut) by DMI since 2008.

1.3.3 Spectroradiometers

Daily measurements of the surface UV radiation are performed by DMI at Thule (Pituffik), using a high resolution spectroradiometer, since summer 1994. At Sondre Stromfjord (Kangerlussuaq) the Brewer MkII instrument has measured spectral UV-B (290-325nm) since late 1990 and the Brewer MkIII instrument since February 2010.
1.4 Calibration activities

DMI has contributed with ozone measurements from Greenland to the international projects CINAMON (AO-ID 158), OMI cal/val, GOME-2 and ACE validation as proposed in connection with ESA/NASA/EUMETSATS’s “announcement of opportunities” concerning the ENVISAT, AURA METOP and ACE satellite missions.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Summer (June, July, August) average column ozone measurements, based on NASA TOMS Nimbus 7 version 8 (years 1979-1991) and DMI Brewer (years 1992-2010) from Kangerlussuaq, Greenland, are shown in left-hand side in the figure below. The whole data series shows a significant trend of -2.0±1.1% per decade (2σ) while there is no significant trend during the past 15 years.

Likewise summer (June, July, August) average column ozone measurements, based on NASA TOMS Nimbus 7 version 8 (years 1979-1991) and DMI Brewer (years 1992-2010) from Copenhagen, Denmark, are shown in the right-hand side of the figure. The whole data series shows a significant trend of -2.3±1.2% per decade (2σ) while there is no significant trend during the past 15 years.
3. THEORY, MODELLING, AND OTHER RESEARCH

DMI has participated in major European Arctic and tropic campaigns since the beginning of the 1990’s including EASOE, SESAME, THESEO, THESEO-2000-SOLVE, VINTERSOL, HIBISCUS, and Scout-AMMA, as well as a long series of EU-projects. The research is based on a broad spectrum of accessible observations, including data from the European environmental satellite ENVI SAT and analyses of meteorological conditions in the stratosphere. The research includes analysis of transport of ozone depleted air masses from Arctic areas to mid-latitudes and experimental and theoretical studies of polar stratospheric clouds. In addition research is carried out on cirrus clouds from airplane condensation trails, and on cirrus clouds in the tropics, which is important for transport of water vapour to the stratosphere. DMI participates in the EC-Earth climate model development, in particular regarding an improved representation of the stratosphere, and studies are performed on the downward influence from the stratosphere on tropospheric climate. Using the personal exposure data combined with satellite and ground station data DMI participates in the development of more accurate models to assess the impact of climate change on future UVR exposure to European populations.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

The measurements are reported to databases under Network for the Detection of Atmospheric Composition Change (NDACC) and World Ozone and UV-radiation Data Center (WOUDC) under the WMO-programme Global Atmosphere Watch (GAW).

4.2 Information to the public

UV-index forecasts, based on Danish total ozone measurements, were initiated at DMI in summer 1992. This public service runs permanently, made public on the Internet and in several media. DMI is responsible for the Near Real Time UV-index processing as part of the EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring and provides daily global maps of clear sky UV-indices. DMI has initiated a UV service for Greenland in collaboration with the Greenland Department for Health. DMI’s ozone measurements are made available on the Internet (www.dmi.dk) together with a yearly updated status report (in Danish language).

4.3 Relevant scientific papers


Christiansen, B.: Stratospheric bimodality: Can the equatorial QBO explain the regime behavior of the NH winter vortex? J. Climate, 23(14), 3953-3966, 2010.


5. PROJECTS AND COLLABORATION

Thule, Sondre Stromfjord, and Scoresbysund are Arctic stations within the Network for the Detection of Atmospheric Composition Change. In addition to the DMI instrumentation, aerosol lidars are operated at these stations by the University of Rome (Italy) and SRI International (USA), respectively, together with an FTIR spectrometer at Thule, operated by National Center for Atmospheric Research (USA). DMI also collaborates with Service d’Aeronomie du CNRS (France) for daily total ozone measurements by a SAOZ instrument at Scoresbysund. DMI participates in the EU-project Global Earth Observation and Monitoring (Geomon) providing SAOZ total ozone data from Greenland. DMI participates from Thule and Scoresbysund in the yearly Match-campaigns, coordinated by the Alfred Wegener Institute in Germany, with ozone soundings in the Arctic to quantify the chemical ozone depletion. In March 2007 an aerosol robot (Aeronet) from NASA was installed in Pituffik, in February 2008 a similar instrument was installed in Kangerlussuaq and in October 2009 yet another instrument was installed in Ittoqortoormiit.

Within the EU-project COMBINE, DMI is involved in modelling aspects of the stratosphere-troposphere coupling, investigating the importance of a well-resolved stratospheric representation for modelling the tropospheric climate. In the Scout-O3-project, DMI was involved in tropical balloon-
borne investigations of transport of water vapour to the stratosphere. DMI participates in the EU-project ICEPURE investigating the adverse and beneficial health effects of ultraviolet radiation (UVR) exposure.

The DMI participates in EUMETSAT’s Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring, developing operational UV-index products, based on satellite measurements of the ozone layer.

6. FUTURE PLANS

National funding for ozone and UV monitoring in Denmark and Greenland is secured until the end of 2011. After this period the funding situation will be renegotiated.

Research efforts will be directed towards improved understanding of the role of stratospheric changes for tropospheric climate including the dynamical coupling between the troposphere and the stratosphere. It is intended to include a stratospheric representation in new developments of the EC-Earth model complex. In addition research efforts will be directed towards cirrus cloud formation in the tropical tropopause layer and transport of water vapour to the stratosphere, based on improved microphysical modelling and combining experimental balloon-borne experiments with radio occultation satellite measurements.

7. NEEDS AND RECOMMENDATIONS

It is considered important to monitor the recovery of the ozone layer at high latitudes during changing stratospheric climatic conditions (decreasing temperatures, perhaps increased water vapour concentrations and other changes in chemical composition, changes in stratospheric dynamics). Maintaining and running stratospheric monitoring stations in the Arctic and elsewhere is becoming an increasingly heavy burden on national funding sources and possibilities for direct funding of ground-based monitoring activities and data provision should be considered to be included in major international programmes such as the European Global Monitoring for Environment and Security (GMES).
EGYPT

Montreal Projects in Egypt

Egypt lies in the northern corner of Africa. It is bounded by the international frontiers of the Mediterranean Sea in the North, the Red Sea in the East, Libya in the west and Sudan in the south. Figure 1, presents the map of Egypt.

Figure 1, Egypt Map

Area and Capital:
The total area of Egypt is about 1.02 million Km² and the Capital is: Cairo.

**Geography**

**Topography:**

Egypt is geographically divided into four main divisions:

- The Nile Valley and Delta (approx. 33,000 Km²) - It extends from the North Valley to the Mediterranean Sea and is divided into Upper Egypt and Lower Egypt, extending from Wadi Halfa to the south of Cairo and from North Cairo to the Mediterranean Sea. The River Nile in the north is divided into two branches, Damietta and Rachid embracing the highly fertile agricultural lands of the Delta.

- The Western Desert (approx. 680,000 Km²) - Extends from the Nile Valley in the East to the Libyan borders in the west, and from the Mediterranean in the north to the Egyptian southern borders. It is divided into: The Northern Section, it includes the coastal plain, the northern plateau and the Great Depression, the Natroun Valley and Baharia Oasis. The Southern Section, it includes Farafra, Kharga, Dakhla, and El-Owainat in the far south.

- The Eastern Desert (approx. 325,000 Km²): It extends from the Nile Valley in the West to the Red Sea, Suez gulf, and Suez Canal in the East, and from Lake Manzala on the Mediterranean in the North to Egypt's southern borders with Sudan in the south. The Eastern Desert is marked with the Eastern Mountains that range along the Red Sea with peaks that rise to about 3000 feet above the sea level. This desert is a store of Egyptian natural resources including various ores such as gold, coal, and oil.

- Sinai Peninsula (approx. 61,000 Km²): Sinai has a triangular shape having its base at the Mediterranean in the North and its apex in the South at Ras Mohammed, the Gulf of Aqaba to the East and the Gulf of Suez and Suez Canal to the west. It is topographically divided into three main sections. The southern section, it involves extremely tough terrain that is composed of high-rise granite mountains. Mount Catherine rises about 2640 meters above sea level, thus making it the highest mountaintop in Egypt. The Central section, it comprises the area bounded by the Mediterranean to the North. At-Teeh plateau to the south, it is a plain area having abundant water resources derived from rainwater flowing from southern heights to the central plateau.

**Climate:**

The Egyptian climate is influenced by the factors of location, topography, and general system for pressure and water surfaces. These aspects affect Egypt's climate dividing it into several regions. Egypt lies in the dry equatorial region except its northern areas located within the moderate warm region with a climate similar to that of the Mediterranean region. It is warm and dry in the summer and moderate with limited rainfall increasing at the coast in winter. The annual average day and nighttime temperatures in Lower and Upper Egypt is 20 and 25, and 7 and 17 respectively.²

Table 1, summarizes monthly-average meteorological parameters for GC over the past 30 years. Through most of the year, wind speed is fairly consistent from the north (ENE to NNW) sector. However, during winter and spring (Nov. – Mar.), somewhat higher average winds are seen in the WSW sector. These often represent desert wind storms (Khamaseen winds) which transport dust

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from the deserts to the west and produce elevated PM concentrations in GC. Table 1, presents a quick and approximate data for the meteorological elements of the GC area.

**Table 1**, Monthly-average meteorological data in the greater Cairo (GC) area for the past 30 years

<table>
<thead>
<tr>
<th>Month</th>
<th>Relative Humidity (%)</th>
<th>Visual Distance (Km)</th>
<th>Cloud Cover %</th>
<th>Max Temperature (°C)</th>
<th>Min Temperature (°C)</th>
<th>Wind Speed (Knots) and Direction a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cloud Base (m)</td>
<td></td>
<td></td>
<td>E-NE</td>
</tr>
<tr>
<td>January</td>
<td>58</td>
<td>9</td>
<td>50</td>
<td>1845</td>
<td>18.1</td>
<td>8.6</td>
</tr>
<tr>
<td>February</td>
<td>56</td>
<td>9</td>
<td>50</td>
<td>1756</td>
<td>19.5</td>
<td>9.4</td>
</tr>
<tr>
<td>March</td>
<td>51</td>
<td>9</td>
<td>50</td>
<td>2164</td>
<td>23.4</td>
<td>11.2</td>
</tr>
<tr>
<td>April</td>
<td>45</td>
<td>9</td>
<td>50</td>
<td>3068</td>
<td>28.1</td>
<td>14.5</td>
</tr>
<tr>
<td>May</td>
<td>45</td>
<td>9</td>
<td>50</td>
<td>3677</td>
<td>31.8</td>
<td>17.2</td>
</tr>
<tr>
<td>June</td>
<td>49</td>
<td>9</td>
<td>50</td>
<td>1454</td>
<td>34.3</td>
<td>19.9</td>
</tr>
<tr>
<td>July</td>
<td>57</td>
<td>9</td>
<td>50</td>
<td>875</td>
<td>34.2</td>
<td>21.5</td>
</tr>
<tr>
<td>August</td>
<td>61</td>
<td>9</td>
<td>50</td>
<td>731</td>
<td>33.6</td>
<td>21.8</td>
</tr>
<tr>
<td>September</td>
<td>61</td>
<td>9</td>
<td>38</td>
<td>827</td>
<td>32.3</td>
<td>20.2</td>
</tr>
<tr>
<td>October</td>
<td>60</td>
<td>9</td>
<td>38</td>
<td>1628</td>
<td>30.0</td>
<td>18.0</td>
</tr>
<tr>
<td>November</td>
<td>58</td>
<td>8</td>
<td>38</td>
<td>1663</td>
<td>24.4</td>
<td>14.0</td>
</tr>
<tr>
<td>December</td>
<td>59</td>
<td>8</td>
<td>38</td>
<td>2472</td>
<td>20.3</td>
<td>9.9</td>
</tr>
</tbody>
</table>

a A double asterisk (**) indicates a “most probable” value while a single asterisk indicates a less probable value.

Meteorological data (temperature, relative humidity, and wind speed and direction) from Cairo International Airport are available on an hourly basis from the U.S. NOAA National Climatic Data Center. Data from other locations may be obtained upon request to Egyptian agencies. Studies conducted by Lowenthal et al. (2001) and Abu-Allaban et al. (2007) showed that PM$_{10}$ concentrations in GC were higher in fall than in winter, 1999 or during summer, 2002. Surface meteorological data were examined to try to explain differences between fall and winter of 1999. Seasonal-average temperature and vector-averaged wind speed and direction were calculated for four sites in GC. The average winter temperature ranged from 13.7 to 15.4 °C while the average fall temperature ranged from 19.4 to 20.6 °C. Thus, the seasonal variation was approximately 5 °C. The vector-averaged wind direction ranged from 312 to 6 degrees, i.e., from the north, in both seasons at the four measurement locations. The seasonal variation in concentration was thus unrelated to wind direction. The seasonal vector-averaged wind speed ranged from 1.2 to 2.8 mph in winter and from 0.72 to 1.86 mph in fall. The average ratio of winter to fall wind speed was 1.8±0.8. The lower wind speeds during fall along with increased emissions from agricultural burning may explain the higher PM concentrations during that season because lower ventilation associated with low wind speeds may allow for buildup of pollutants in the vicinity of the sources in Cairo.

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**Montreal Protocol (MP)**

**Background**

The *Montreal Protocol on Substances That Deplete the Ozone Layer* (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion.

Due to its widespread adoption and implementation it has been hailed as an example of exceptional international co-operation with Kofi Annan quoted as saying that "perhaps the single most successful international agreement to date has been the Montreal Protocol". It has been ratified by 196 states.

**Terms and purposes**

The treaty is structured around several groups of halogenated hydrocarbons that have been shown to play a role in ozone depletion. All of these ozone depleting substances contain either chlorine or bromine (substances containing only fluorine do not harm the ozone layer). For a table of ozone-depleting substances see:

For each group, the treaty provides a timetable on which the production of those substances must be phased out and eventually eliminated.

**Multilateral Fund (MLF)**

The *Multilateral Fund for the Implementation of the Montreal Protocol* provides funds to help developing countries to phase out the use of ozone-depleting substances.

The Multilateral Fund was the first financial mechanism to be created under an international treaty. It embodies the principle agreed at the United Nations Conference on Environment and Development in 1992 that countries have a common but differentiated responsibility to protect and manage the global commons.

The Fund is managed by an executive committee with an equal representation of seven industrialized and seven Article 5 countries, which are elected annually by a Meeting of the Parties. The Committee reports annually to the Meeting of the Parties on its operations.

Up to 20 percent of the contributions of contributing parties can also be delivered through their bilateral agencies in the form of eligible projects and activities.

The fund is replenished on a three-year basis by the donors. Pledges amount to US$ 2.1 billion over the period 1991 to 2005. Funds are used, for example, to finance the conversion of existing manufacturing processes, train personnel, pay royalties and patent rights on new technologies, and establish national ozone offices.

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5 [The Ozone Hole-The Montreal Protocol on Substances that Deplete the Ozone Layer](http://ozone.uneo.org/Ratification_status/)
6 [http://ozone.unep.org/Publications/MP_Handbook/Section_1.1_The_Montreal_Protocol](http://www.multilateralfund.org/about_the_multilateral_fund.htm)
**Ozone Depleting Substances (ODS’s)**

Ozone layer is a natural filter and a shield that surround the Earth to protect all creatures from the harmful part of Ultra Violet – B rays that threaten man’s health and safety. The source of threat is the result of actions and technology developed by man with the development of civil life and the development of new chemical substances. This led to the emission of gases from substances that cause the depletion to the ozone layer.

Since the Montreal Protocol came into effect, the atmospheric concentrations of the most important chlorofluorocarbons and related chlorinated hydrocarbons have either leveled off or decreased. Halon concentrations have continued to increase, as the halons presently stored in fire extinguishers are released, but their rate of increase has slowed and their abundances are expected to begin to decline by about 2020. Also, the concentration of the HCFCs increased drastically at least partly because for many uses CFCs (e.g. used as solvents or refrigerating agents) were substituted with HCFCs. While there have been reports of attempts by individuals to circumvent the ban, e.g. by smuggling CFCs from undeveloped to developed nations, the overall level of compliance has been high. In consequence, the Montreal Protocol has often been called the most successful international environmental agreement to date. In a 2001 report, NASA found the ozone thinning over Antarctica had remained the same thickness for the previous three years, however in 2003 the ozone hole grew to its second largest size. The most recent (2006) scientific evaluation of the effects of the Montreal Protocol states, "The Montreal Protocol is working: There is clear evidence of a decrease in the atmospheric burden of ozone-depleting substances and some early signs of stratospheric ozone recovery."

Unfortunately, the hydrochlorofluorocarbons, or HCFCs, and hydrofluorocarbons, or HFCs, are now thought to contribute to anthropogenic global warming. On a molecule-for-molecule basis, these compounds are up to 10,000 times more potent greenhouse gases than carbon dioxide. The Montreal Protocol currently calls for a complete phase-out of HCFCs by 2030, but does not place any restriction on HFCs. Since the CFCs themselves are equally powerful as greenhouse gases, the mere substitution of HFCs for CFCs does not significantly increase the rate of anthropogenic global warming, but over time a steady increase in their use could increase the danger that human activity will change the climate.

Policy experts have advocated for increased efforts to link ozone protection efforts to climate protection efforts. Policy decisions in one arena affect the costs and effectiveness of environmental improvements in the other.

**Global Warming Potentials (GWP) of ODS’s**

The global warming potential (GWP) represents how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide. Carbon dioxide's GWP is defined as 1.0. A GWP is calculated over a specific time interval and the value of this must be stated whenever a GWP is quoted or else the value is meaningless.

---


Why are there three values given for the GWP and atmospheric lifetime?

All GWP values represent global warming potential over a 100-year time horizon. Dashes indicate that the source did not include a GWP value for the given compound. The first value in each of the second and third columns is from the Scientific Assessment of Ozone Depletion, 2002. The second and third values in each of these columns are from the Intergovernmental Panel on Climate Change (IPCC) Second, Third & Fourth Assessment Reports.

For more specific information on how many of these chemicals are used as substitutes for ozone-depleting substances, the Significant New Alternatives Policy (SNAP) Program's web site presents useful information about it.

The substances subject to restrictions in the Kyoto protocol either are rapidly increasing their concentrations in Earth's atmosphere or have a large GWP.

The GWP depends on the following factors:

- the absorption of infrared radiation by a given species
- the spectral location of its absorbing wavelengths
- the atmospheric lifetime of the species

Thus, a high GWP correlates with a large infrared absorption and a long atmospheric lifetime. The dependence of GWP on the wavelength of absorption is more complicated. Even if a gas absorbs radiation efficiently at a certain wavelength, this may not affect its GWP much if the atmosphere already absorbs most radiation at that wavelength. A gas has the most effect if it absorbs in a "window" of wavelengths where the atmosphere is fairly transparent.

Because the GWP of a greenhouse gas depends directly on its infrared spectrum, the use of infrared spectroscopy to study greenhouse gases is centrally important in the effort to understand the impact of human activities on global climate change.

**Calculating the global warming potential**

Just as radioactive forcing provides a simplified means of comparing the various factors that are believed to influence the climate system to one another, Global Warming Potentials (GWPs) are one type of simplified index based upon radioactive properties that can be used to estimate the potential future impacts of emissions of different gases upon the climate system in a relative sense.

GWP is based on a number of factors, including the radioactive efficiency (infrared-absorbing ability) of each gas relative to that of carbon dioxide, as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years) relative to that of carbon dioxide.

The radioactive forcing capacity (RF) is the amount of energy per unit area, per unit time, absorbed by the greenhouse gas that would otherwise be lost to space.

The Intergovernmental Panel on Climate Change (IPCC) provides the generally accepted values for GWP, which changed slightly between 1996 and 2001 Third Assessment Report (TAR). The GWP

is defined as the ratio of the time-integrated radioactive forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas.

Since all GWP calculations are a comparison to CO$_2$ which is non-linear, all GWP values are affected.

**Montreal Protocol Projects in Egypt**

Montreal Protocol projects in Egypt can be summarized in different sectors. Different projects were conducted to minimize and stop using of these ODS, these projects can be summarized in the following:

1- Foam Projects in Egypt:

Table 1, presents all projects conducted in Egypt in the foam sector, including the Ozone Depleting Potential ODP (Tons) and the Global Warming Potential (GWP) in CO$_{2e}$ metric tons.

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Project Title</th>
<th>ODS</th>
<th>ODP (Tons)</th>
<th>GWP (CO$_{2e}$ MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGY/FOA/08/INV/05</td>
<td>Phase-out of CFC-11 in manufacture of flexible polyurethane foam at Misr Foam Co.</td>
<td>CFC-11</td>
<td>121.0</td>
<td>566,280.0</td>
</tr>
<tr>
<td>EGY/FOA/08/INV/06</td>
<td>Phase-out of CFC-11 in the manufacturing of molded, flexible, semi-rigid and rigid polyurethane foam at Taki-Vita factory</td>
<td>CFC-11</td>
<td>50.0</td>
<td>234,000.0</td>
</tr>
<tr>
<td>EGY/FOA/08/INV/07</td>
<td>Phase-out of CFC-11 in the manufacture of molded polyurethane foams at Technopol Egypt SAE</td>
<td>CFC-11</td>
<td>55.0</td>
<td>257,400.0</td>
</tr>
<tr>
<td>EGY/FOA/09/INV/10</td>
<td>Elimination of CFC-12 in the manufacture of extruded polystyrene foam at Al-Sharif Plastic Factories</td>
<td>CFC-12</td>
<td>75.0</td>
<td>804,000.0</td>
</tr>
<tr>
<td>EGY/FOA/09/INV/12</td>
<td>Phase-out of CFC-11 in manufacture of molded foam at Misr Foam Co.</td>
<td>CFC-11</td>
<td>28.0</td>
<td>131,040.0</td>
</tr>
<tr>
<td>EGY/FOA/10/INV/15</td>
<td>Elimination of CFC-11 in the manufacture of molded flexible polyurethane foam at Modern Building Carpentry Co. (Mobica)</td>
<td>CFC-11</td>
<td>20.0</td>
<td>93,600.0</td>
</tr>
<tr>
<td>EGY/FOA/10/INV/17</td>
<td>Elimination of CFC-11 in the manufacture of molded rigid polyurethane foam at Cairo Light Industries Co. (Olympic Electric)</td>
<td>CFC-11</td>
<td>75.0</td>
<td>351,000.0</td>
</tr>
<tr>
<td>EGY/FOA/11/INV/18</td>
<td>Conversion to CFC-11 free technology in the manufacture of rigid polyurethane foam (PUF) at Specialized Engineering Contracting Co.</td>
<td>CFC-11</td>
<td>15.0</td>
<td>70,200.0</td>
</tr>
<tr>
<td>EGY/FOA/11/INV/19</td>
<td>Conversion to CFC-11 free technology in the manufacture of flexible polyurethane foam at Alex Foam (formerly Dekheila Chemical Industries Co.)</td>
<td>CFC-11</td>
<td>130.0</td>
<td>608,400.0</td>
</tr>
<tr>
<td>EGY/FOA/11/INV/20</td>
<td>Conversion to CFC-11 free technology in the manufacture of flexible polyurethane foam (PUF) at Horse Foam Co.</td>
<td>CFC-11</td>
<td>120.0</td>
<td>561,600.0</td>
</tr>
</tbody>
</table>
Table 2, presents all projects conducted in Egypt in the refrigeration sector, including the Ozone Depleting Potential ODP (Tons) and the Global Warming Potential (GWP) in CO2e metric tons.

### Refrigeration Projects in Egypt:

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Project Title</th>
<th>ODS</th>
<th>ODP (Tons)</th>
<th>GWP (CO2e MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGY/REF/08/INV/09</td>
<td>Phase-out of CFC in refrigeration at Koldair Company</td>
<td>CFC-12</td>
<td>18.0</td>
<td>192,960.0</td>
</tr>
<tr>
<td>EGY/REF/12/INV/30</td>
<td>Conversion to CFC free-technology Reftruck Company</td>
<td>CFC-11</td>
<td>25.0</td>
<td>117,000.0</td>
</tr>
<tr>
<td>EGY/REF/12/INV/31</td>
<td>Conversion to CFC free-technology at Misr Panel (Egyptian Company for Cold Storage Industries)</td>
<td>CFC-11</td>
<td>74.4</td>
<td>348,192.0</td>
</tr>
<tr>
<td>EGY/REF/15/INV/44</td>
<td>Elimination of CFC in the manufacture of commercial refrigeration equipment at Royal Engineering, Co.</td>
<td>CFC-11</td>
<td>20.3</td>
<td>95,004.0</td>
</tr>
<tr>
<td>EGY/REF/15/INV/45</td>
<td>Elimination of CFC in the manufacture of commercial refrigeration equipment at Port Said Metal Work, Co. (MOG)</td>
<td>CFC-11</td>
<td>11.8</td>
<td>55,224.0</td>
</tr>
<tr>
<td>EGY/REF/18/INV/49</td>
<td>Elimination of CFC-11 and CFC-12 in the manufacture of commercial refrigeration equipment at United Investment Corporation Inc.</td>
<td>CFC-11</td>
<td>48.7</td>
<td>227,916.0</td>
</tr>
</tbody>
</table>
Elimination of CFC-11 and CFC-12 in the manufacture of commercial refrigeration equipment at Refcat Company Inc.

Elimination of CFC-11 and CFC-12 in the manufacture of commercial refrigeration equipment at El-Mohandes

Implementation of the RMP: establishing a national recovery and recycling network

ODS phase-out at Delta Industrial Co.

Phasing out ODS at Societe Mondiale pour Refroidissement (Alaska) domestic refrigeration plant

ODS phase-out at Electrostar for Refrigeration Co.

ODS phase-out at Kiriazi Refrigeration Manufacturing Co.

Phasing out ODS at Helwan Company for Metallic Appliances domestic refrigeration plant

Phasing out ODS at Islamic Company for Industrialization (Siltal) domestic refrigeration plant

Phasing out ODS at International Co. for Refrigeration and Appliances (Iberna) domestic refrigeration plant

Phasing out ODS at El Nasr Company for Electric and Electronic Apparatus (Philips) domestic refrigeration plant

Phasing out ODS at Super Bosh Factory domestic refrigeration plant

3- Halon Management Bank in Egypt:

Table 3, presents the Halon Management Bank in Egypt, including the Ozone Depleting Potential ODP (Tons) and the Global Warming Potential (GWP) in CO2e metric tons.

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Project Title</th>
<th>ODS</th>
<th>ODP (Tons)</th>
<th>GWP (CO2e MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGY/HAL/32/TAS/81</td>
<td>Halon management bank programme</td>
<td>Halon-1211</td>
<td>251.3</td>
<td>467,480.0</td>
</tr>
</tbody>
</table>

4- Methyl Bromide Project in Egypt:

Table 4, presents the Methyl Bromide project in Egypt, including the Ozone Depleting Potential ODP (Tons) and the Global Warming Potential (GWP) in CO2e metric tons.

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Project Title</th>
<th>ODS</th>
<th>ODP (Tons)</th>
<th>GWP (CO2e MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGY/FUM/38/INV/86</td>
<td>National phase-out of methyl bromide in horticulture and commodities fumigation</td>
<td>MB - CH3Br</td>
<td>309.3</td>
<td>1,546.7</td>
</tr>
</tbody>
</table>
5- Medical aerosol Project in Egypt:

Table 5, presents the Meter Dose Inhaler (MDI) project in Egypt, including the Ozone Depleting Potential ODP (Tons) and the Global Warming Potential (GWP) in CO$_2$e metric tons.

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Project Title</th>
<th>ODS</th>
<th>ODP (Tons)</th>
<th>GWP (CO$_2$e MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGY/PHA/46/INV/91</td>
<td>National CFC phase-out plan (first tranche)</td>
<td>CFC</td>
<td>237.5</td>
<td>2,088,100.0</td>
</tr>
</tbody>
</table>

6- Overall Montreal Project in Egypt:

Table 6, presents the overall Montreal Projects in Egypt, including the Ozone Depleting Potential ODP (Tons) and the Global Warming Potential (GWP) in CO$_2$e metric tons.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total ODP (Ton)</th>
<th>Total GWP (CO$_2$e Metric Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOAM</td>
<td>1,612.9</td>
<td>9,108,504.0</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>786.0</td>
<td>5,390,820.0</td>
</tr>
<tr>
<td>Halons</td>
<td>251.3</td>
<td>467,480.0</td>
</tr>
<tr>
<td>Methyl Bromide</td>
<td>309.3</td>
<td>1,546.7</td>
</tr>
<tr>
<td>MDI</td>
<td>237.5</td>
<td>2,088,100.0</td>
</tr>
</tbody>
</table>
**Figure 2**, ODP Tons of all Montreal Projects in Egypt

![Graph showing ODP Tons for different categories]

**Figure 3**, GWP of all Montreal Projects in Egypt (CO$_2e$ metric tons)

![Graph showing GWP for different categories]
Egypt Consumption of ODS’s from 1992 - 2009 comparison with Base Line

Figure 4, Consumption of CFCs

Figure 5, Consumption of Halons
Figure 6, Consumption of Carbon Tetra Chloride

Figure 7, Consumption of Methyl Chloroform
**Figure 8**, Consumption of HCFCs

**Figure 9**, Consumption of Methyl Bromide
**Measurements of Ozone and UV radiation**

Egyptian Meteorological Authority (EMA) is responsible for measurements of column ozone amount and operates the main total ozone-monitoring network. Long-term daily observations of total ozone have been performed at the regional ozone center of EMA at Cairo (30.08°N, 31.28°E) with the Dobson Spectrophotometer (D096) since 1967. Since 1984; second Dobson instrument (D069) has been maintained at Aswan (23.97°N, 32.87°E) to measure the amount of ozone over tropical area.

As early as October 1967 EMA introduced regular monitoring of ozone at Cairo using the Dobson Spectrophotometer No. 96. At 1973 Cairo became Regional Ozone Center (ROC) for ozone stations at North Africa and Middle East. The part of ROC studies the variation of ozone over Egypt. Therefore, EMA started to measure ozone over Aswan (Upper Egypt), Matrouh (coastal station) and Hurghada (GAW station). Table 7, presents the Egyptian Ozone stations.

At the late of 1998 Brewer Spectrophotometer mark II (B143) has been maintained at Matrouh (31.33°N, 27.22°E) to measure the total ozone and SO2 over northwest coast area of Egypt. With the end of 1999 third Dobson Spectrophotometer (D059) has been maintained at Hurghada (27.28°N, 33.75°E) to measure the amount of ozone over Red sea area.

**Table 7, The Egyptian Ozone Stations.**

<table>
<thead>
<tr>
<th>Matrouh</th>
<th>Cairo</th>
<th>Hurghada</th>
<th>Aswan</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WMO No.</td>
<td>376</td>
<td>62 367</td>
<td>62 464</td>
<td>62 414</td>
<td>Brew II #143</td>
<td>Dobson #096</td>
<td>Dobson #059</td>
</tr>
<tr>
<td>Ozone ID.</td>
<td>152</td>
<td>037</td>
<td>007</td>
<td>245</td>
<td>Brewer II #143</td>
<td>Dobson #096</td>
<td>Dobson #059</td>
</tr>
<tr>
<td>Latitude</td>
<td>31.33°N</td>
<td>30.08°N</td>
<td>27.28°N</td>
<td>23.97°N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitude</td>
<td>27.22°E</td>
<td>31.28°E</td>
<td>33.75°E</td>
<td>32.87°E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>035</td>
<td>037</td>
<td>007</td>
<td>195</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Measurements of Stratospheric Ozone

Dobson observations:

Measurements of total ozone amount and its vertical distribution by Umkehr Method (whenever sky conditions permit) are taken by Dobson at three observatories: Cairo, Aswan and Hurghada. Direct sun (DS) and zenith sky (ZB) or cloud sky (ZC) observations will be taken more than 7–time at different zenith angles (airmasses) daily, using BP-scale. Regular tests by Mercury and standard lamps and Adjustments of ETC, R-N tables and Q-table. (DOBSON/DOBSTOOL software package used for processing of the observations of the all stations by ROC).

Brewer observations:

Measurements of O3 and SO2 and UVB, 9-times daily by Brewer instrument at Matrouh observatory. Whenever sky conditions permit, Umkehr observations are made. Routine daily HG and SL and weekly external UV-lamps tests. Routine processing of observations by the SCI-TEC software.

Surface ozone:

EMA measure surface ozone outside urban regions, at Hurghada which is an official WMO Global Atmospheric Watch (GAW) station. Also EMA measure surface ozone at Sidi Branni (31.37°N, 25.53°E). South Valley University (SVU) in cooperation EMA has been measured surface ozone at Qena.

UV measurements:

EMA take the measurements of broadband UV solar radiation and the biologically effective solar UV-B at different sites. Also EMA in cooperation with University of South valley have been measured the broadband UV radiation at Qena since 2000. The present network of measurements of UV and UVB radiation at Aswan, Qena, Cairo, Rafah (31.22°N, 34.20°E), shown in Table 8.

Table 8, The Egyptian UV and UV-B radiation Stations

<table>
<thead>
<tr>
<th></th>
<th>Aswan</th>
<th>Qena</th>
<th>Cairo</th>
<th>Rafah</th>
<th>Matrouh</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV Instrument</td>
<td>Eppley</td>
<td>Eppley</td>
<td>Eppley</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UV-B Instrument</td>
<td>UVB-1</td>
<td>UVB-1</td>
<td>UVB-1</td>
<td>UVB-1</td>
<td>Brewer MII</td>
</tr>
</tbody>
</table>

National Cooperation's:

Scientists of ozone from EMA taking into consideration the maintenance and calibration of the ozone instruments regularly. The ozone data collected from the network at ROC. Data files of ozone are transmitted regularly with SO2 to World Ozone Data Center (WOUDC) in Toronto, Canada.

- Ozone EMA cooperates with National Ozone Centers at Germany, Czech Rep., Greece, Canada and Japan and USA.

241
• ROC researchers promote the main activities in ozone research.
• EMA in co-operation with WMO carries out a training program for operators of ozone Arab countries.
• WMO and EMA in close cooperation and assistance of Canada International Ozone Services Inc. organized the International comparison of the Brewer No. 143 operated in Matrouh observatory with standard Brewer No. 17 at 2005 and 2008. WMO and EMA and assistance of NOAA organized the Intercomparison of the Dobson ozone instruments operated in the Africa region at Dahab, Egypt at 2004.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Monthly variation and trend of ozone for last five years over Egyptian ozone observatories are represent by Figure 10. The figure shows that the linear trend is negative at all station.

Figure 10, Monthly variation and trend of ozone at Egyptian stations from 01/2006-12/2010

![Graph showing monthly variation and trend at Egyptian ozone observatories from 01/2006-12/2010](image)

Variation of ozone damage UV at northwest of Egyptian:

Monthly variation of total ozone amount and the total integral effect of the UV (weighted Erythema UV) radiation coming to the ground level during the day (dose) at Matrouh shown in Figure 11. It shows that ozone varies seasonally with a maximum in spring and DUV varies seasonally with a maximum in summer.
UV index at northwest of Egyptian:

UV-index forecasts, based on Brewer total ozone measurements at Matrouh (northwestern coast), were initiated at EMA summer 1999. Figure 12, shows the hourly variation of dangerous UV with its Index over northwestern coast of Egypt at summer. UVB protection is critical during summer and especially so in the hours around solar noon. A person being out in the sun during midday hours more than ten minutes if you are without protection.

Ozone and Solar Radiation variation during the Solar Eclipse of 29 March 2009

Northwestern Egypt is likely to be the primary destination for eclipse observers. Matrouh as Salloum has a high frequency of sunshine, with 75% of the maximum possible recorded in March. The instant of greatest eclipse occurs at 10:40UT. Sharp drop in the global solar radiation and UVB irradiances were observed during eclipse of 29 March 2009. The total ozone reduction of more than 30 DU can
be artificially introduced in routine total ozone measurements with Brewer spectrophotometer, see figures. Figures 13, presents the hourly variation of UVB at eclips day (29 March) and normal day (30 March) while Figure 14, presents the hourly variation of ozone at eclips day (29 March) and normal day (30 March).

**Figure 13,** Hourly variation of UVB at eclips day (29 March) and normal day (30 March)

**Figure 14,** Hourly variation of ozone at eclips day (29 March) and normal day (30 March)

**CONCLUSIONS and RECOMMENDATIONS**

**Montreal Protocol** is important for the ozone layer (and implicitly for climate change) but does not address emissions.
The **Kyoto Protocol** is important for climate change, and this addresses emissions and emission reductions. Replacement strategies under both Montreal (CFC, HCFC) and Kyoto (HFC) are important for the atmosphere.

**Multi Lateral Fund** (MLF) provided financial & technical assistance to Egypt, 40 investment projects has been carried out by UN implementing agencies namely UNDP, GTZ and UNIDO during the period of 1992 through 2009.

Egypt is in compliance with the ODS phase-out targets, and with those targets achieved, the time was ripe to look into the future and work to phase out the hydrochlorofluorocarbons (HCFCs), drawing on lessons learned in phasing out other ozone-depleting substances.

Calculations of ODP & GWP of these 40 projects implemented in Egypt from 1992 – 2009 indicated that the ODP of all projects is 3197 Tons while the GWP is 17,056,450.7 CO$_{2e}$ metric tons.

One of the main problems faced by the Egyptian ozone Unit is the lack of adequate funding to maintain such activities over time. This is particularly relevant since at this stage the ozone layer seems to have reached the peak state of its depletion and sensitive monitoring and important research is necessary to determine the future evolution and the start of the possible recovery ozone layer and ozone hole. Also, it is needed to fund cooperative programs between Ozone Unit in Egypt (funded by Montreal Protocol) and the Central Department of Climate Change (CCCD) in Egypt which had some fund through Kyoto Protocol to conduct research programs and fund building database (DB) for both programs. This database aim to involve:

- This DB will involve all related data and information from the different sites managing the work from abroad (as UNDP-UNIDO- GEF-UNFCCC-IPCC- Montréal Protocol- …). It will take care of all activities inside Egypt which deals with related activities as Line Ministries, Custom Authority, NGOs, Universities, Research Institutes, Associations, Factories and other stockholders who are dealing with phasing out ODS, and related activities.
- The DB intends to include inputs from engineering facilities and energy contracting providers, investors, financial institutions, and government and private sector stakeholders in the region. Hence, the approach proposed taking actions related to the two multilateral environmental agreements, namely, the Kyoto Protocol on Climate Change and the Montreal Protocol.
- Exchange electronic data & information between Egyptian Meteorological Authority (EMA) of Egypt and Ozone Unit in EEAA.
- Egypt needs the fund for having this DB including servers, terminals, system software and other relevant equipments.
- We will appreciate assistance to start measurements of vertical ozone distribution advice to elaborate a by ozonesonde especially at Aswan station (tropical area).

It is strongly recommended to conduct Clean Development Mechanism (CDM) for the upcoming Chillers project in Egypt and inform UNFCCC through the Designated National Authority (DNA) of Egypt before start implementing the project.

Much work needs to be carried out to understand many aspects of the ozone evolution and change, including impact of HCFCs, ozone-climate relationships, UV relationships, etc. The international cooperation and assists for improvement the research level and quality are appreciated especially for African countries.

It is recommended to support awareness programs to increase the use of ODS alternative substances with low or negligible global warming potential.
Implementation of ISO standards for data quality assurance is needed for all instruments and observation technologies used for monitoring of ozone and UV in the global networks. This includes mainly definition and implementation of traceable calibration systems/chains, Standard Operating Procedures (SOPs) and maintenance of relevant metadata files.

It is recommended to take care of problems on operation of instruments and stability of data quality persist at some strategic ozone stations located mainly in developing countries in the tropics and in the Southern Hemisphere. To solve the situation the WMO/GAW and the UNEP Programs should reinforce their key role in the capacity building and in maintenance of the global ozone and UV monitoring infrastructure.

It is recommended to study on atmospheric chemistry in relation to ozone layer depletion and climate change, and to develop climatic models to predict the climatic change over Egypt.

It is strongly recommended to support dissemination program for the data and information related to Ozone to the public (newspapers, reports, workshops, radio & TV programs and other resources).

The data shows that the total amount of ozone measured in Egyptian ozone measurement stations network until 2009 tended to increase slightly. This indicates that the ozone layer above Egypt is not very much affective by the reduction occurring in the north and south polar airs.

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1. OBSERVATIONAL ACTIVITIES

Most of systematic monitoring of atmospheric ozone and UV solar radiation in Estonia is performed at Tõravere (58° 15’ N, 26° 28’ E, 70 m a. s. l.), where the research institute Tartu Observatory and the Tartu-Tõravere Meteorological Station of the Estonian Meteorological and Hydrological Institute (EMHI) are located. Research areas of the Tartu Observatory are astrophysics and atmospheric physics. The meteorological station belongs to the Baseline Surface Radiation Network (BSRN) and is specialized on solar radiation measurements. Scientific work on ozone and UV radiation is performed since early 1990s at the department of atmospheric physics of Tartu Observatory. Different auxiliary regular measurements like aerosol and cloud data collection are also performed at the same location. Since 2002 sun photometer of NASA AERONET measuring column aerosol optical depth (AOD) operates there and the group of aerosol studies of University of Tartu performs atmospheric aerosol size distribution measurements. The landscape pattern around consists of arable fields, grassland areas and patches of coniferous forest. It may be considered typical to Estonia.

1.1 Measurements of column ozone

Most of research work using column ozone is based on satellite data. Local column ozone measurements at Tõravere have been rather episodic. Regular direct sun column ozone measurements have been carried out in 1994-1999 using specially suited laboratory spectrometer SDL-1 supplied with a mirror system and Dobson retrieval algorithm. Since 2003 direct sun column ozone measurements are performed using MICROTOPS-II instrument. The average ratio of MICROTOPS-II to OMI values has been 1.002 with SD ± 2.3 %. In summer season SD is approximately ± 8 DU.

1.2 Profile measurements of ozone

No profile measurements of ozone have been performed in Estonia.

1.3 UV measurements

1.3.1 Broadband instruments

All the solar radiation measurements with filter instruments are performed at the Tartu-Tõravere Meteorological Station under scientific supervising by research scientists of Tartu Observatory. The first broadband instrument erythemally weighted sensor UV-SET operates since January 1998. The locally developed, manufactured
and tested broadband UV-A and erythemal sensors on the basis of the solar blind phototube with caesium telluride photocathode were installed in 2002. Kipp & Zonen broadband UV-A sensor as well as YES broadband UV-B sensor were operate since 2005. An handheld erytheme UV meter Solar Light PMA 2200 is used as a transfer instrument.

1.3.2 Narrowband filter instruments

Kipp & Zonen narrowband filter instrument CUVB 1 with effective wavelength 306±0.2 nm and bandwith 2±0.5 nm operates at Tartu-Tõravere meteorological Station since 2002. Similar UV-B instruments are installed at two other meteorological stations Tallinn-Harku (59°26' N, 24°45' E) and Pärnu (58°23' N, 24°38' E).

1.3.3 Spectroradiometers

Spectral measurements of solar UV radiation are performed by Tartu Observatory at the same location with filter instruments. Since 2004 UV spectra are collected by Avantes Inc. simple array minispectrometer AvaSpec-256. A quartz fiber of 4 m length and 100 μm diameter connects the optical input diffuser to the spectrometer inserted to special refrigerator weather box and kept at the temperature +7°C. An UFS-5 glass optical filter was installed between the diffuser and fiber to reduce the stray light inside the spectrometer and to guarantee a reliable recording of signal in the whole UV range. For the reliable recording of noise level the optical interface is periodically covered by a shutter before and after each measurement cycle. Control of the sensitivity for the uniform recording of spectra is realized through the change of integrating time within the interval 1 to 60 s.

In 2008 purchasing of spectrometric system based on Bentham Instruments Ltd. DMC150F-U double monochromator was realized by funding of the EC REGPOT project EstSpacE. The system was installed by early 2009 and is used for recording of the solar UV spectra range 280-400 nm. By both systems the spectra are recorded regularly with a period of 15 minutes.

1.4 Calibration activities

The broadband instruments operated by EMHI need regular recalibration and intercomparison. Problems with funding restrict these activities. For the classical broadband solar radiation sensors the problem is solved. During the period of UV measurements the Eppley Labor Inc. pyrheliometers and Kipp & Zonen pyranometers were used as the broadband solar radiation sensors. The intercalibration of sensors is regularly performed in the World Radiation Center (Davos, Switzerland). Between the campaigns, the absolute radiometer PMO-6 nr. R850405 is used as a secondary standard for regular assurance of the calibration.

Calibration of optical instruments has been performed at Tartu Observatory during several decades. The calibration is based on the tungsten-halogen standard lamp FEL calibrated by Oriel traceable to NIST. An absolute radiometer PMO-6, previously established as the reference instrument for solar radiometry, was used for comparison of FEL lamps in the laboratory.
A program for compensatory calculation of the stray light influence of the array spectrometer AvaSpec-256 was applied. The slit-scattering function of the spectrometer was measured directly using a 450 W xenon arc source and monochromator at the Metrology Research Institute, University of Helsinki (Finland). The stray-light level of the AvaSpec-256 spectrometer is rather high (0.1-1 %), but the slit-scattering function is symmetrical and without noticeable artefacts. The uncertainty estimation of the stray-light correction is based on empirical comparison of the simplified algorithm and deconvolution over the set of measured spectra. For the Bentham spectrometer the calibrator CL 6 is regularly used for checking the sensitivity. The source is checked in laboratory of Tartu Observatory.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Most of recent work in Estonia has been pointed to the studies of spectral composition of the UV doses. Different environmental, biospheric, and health effects as well as influences on atmospheric photochemistry depend on UV spectral composition. The net effect of UV radiation on biological systems is a result of balance between damage and repair which depends on the intensity and duration of irradiance and is modulated by its variability. UV radiation in the lower atmosphere is closely associated with stratospheric ozone, while air pollution and atmospheric composition are strongly influenced by UV radiation. Environmental effects of the UV-B irradiance at any site depend strongly on the availability of direct sunshine and on solar elevation. In quantifying the effects of UV radiation and possible biospheric responses, adequate estimation of doses weighted by action spectra is a necessary precondition. At the site of Tartu Observatory the necessary auxiliary data extend back to 1955 and allows to reconstruct action spectra weighted UV doses.

Despite the fact that the most widely met low and medium level overcast cloudiness is seemingly the most stable attenuating medium for the UV radiation, its cloud modification factor (CMF) for most frequently met cloud types varies in wide ranges. In the most UV radiation rich season when local noon SZA remains in range between 35° and 45°, the average CMF for overcast days appeared to be around 0.33 in the UVB range and 0.35 in the UVA range, manifesting a relatively large contribution of optically thick frontal clouds. No clear difference in the influence of SZA on CMF between low level (St, Ns) and medium level (As, Ac) overcast cloudiness has been found. The aerosol attenuation during large AOD episodes was found comparable to that of medium level clouds. The major difference is that the aerosol attenuation decreases with wavelength in the whole UV range and in the UVA range has wavelength dependency opposite to that of attenuation by clouds.

The work was addressed to potential collaboration with the researchers of UV effects. The health effects depend more on the human behaviour than on the availability of UV radiation. According to the medical study of random selection of 367 individuals performed in the Department of Internal Medicine University of Tartu in winter 73 % in summer 29 % of them had serum 25(OH)D insufficiency. The study of influence of UV-B radiation on the antioxidant anthocyanines content in blueberries and strawberries performed in the Department of Horticulture of the Estonian University of Life Sciences is in initial stage but the effect of UV-B radiation on the antioxidant content is evident. In the Estonian Environmental Research Institute the monitoring of air pollution and stone material corrosion manifested obvious effect on UV-B radiation.
3. THEORY, MODELLING, AND OTHER RESEARCH

Most of the analysis of UV data has been based on statistical methods. In particular cases the radiative transfer calculations using LibRadtran codes have been performed. In statistical trend analyses the conventional mean is widely used as a central tendency measure. The analysis performed at the Tartu Observatory has shown that in the case of monthly distributions of the ratio daily relative global irradiance to its normal clear value the distributions are asymmetric and the central tendency will be underestimated in summer months and overestimated in winter months. Trimean or median are more robust measures of central tendency. Also the AOD measured by the NASA AERONET sun photometer is distributed asymmetrically and the conventional mean overestimates its typical value by about 25%.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

The local database of AvaSpec-256 UV spectra has been built in compliance with the EDUCE standard. Raw spectrometer output data as well as the calibration coefficients are recorded in the MySQL database. Calibration coefficients are regularly updated. For inspecting and analyzing the spectra, a web-based interface was created using the PHP programming language. During database query, all the necessary calculations are performed, e.g. correcting for the dark signal and stray-light and applying of the radiometric calibration. Calibration coefficients are interpolated linearly for any given time. The recording of spectra measured by Bentham spectrometer is performed using the software Benwin+. During the first year of measurements there have been some problems with jumping of scale. For that reason the recorded spectra still have been not transformed from the local databases to the European UV Data Base.

4.2 Information to the public

Short texts (about one page each) containing necessary information about atmospheric ozone, UV radiation and recommendations on the optimal behaviour for safe sunshine are available on homepage of Tartu Observatory (http://sputnik.aai.ee/koduleht/). A graph showing the advance of UV-index during current day is also available. The value of UV index is automatically integrated from the recorded spectra. The EMHI homepage presented a daily maximum value of UV-index from UV-CET and now is going to display current value in real time. During the period May to August the press often displays materials on the UV index, on the quality of sun-glasses, on the sun protection factor and on other sunbath related problems.

4.3 Relevant scientific papers


5. PROJECTS AND COLLABORATION

In 2004-2009 Estonia has participated in COST 726 action. At present interest has been expressed to participate in one submitted COST proposal.

6. FUTURE PLANS

Development of methods for backward estimation of UV doses corresponding different action spectra in all weather conditions.

Searching and developing Estonian internal cooperation in quantitative studies of environmental and biospheric effects of UV radiation.

7. RECOMMENDATIONS addressed to the 8-th ORMM

It should be useful if WMO/UNEP distributes some official recommendations to the governments on the necessity to participate in intercomparisons of UV instruments like it is done in the case of pyranometers. Otherwise the UV part of solar radiation can be considered as something exotic and less important.

To emphasize the necessity of closer collaboration between the UV radiation measuring community and process biologists community to produce synergy on the influence of environmental factors on biospheric species and ecosystems.
EUROPEAN UNION

European research on stratospheric ozone depletion and UV radiation

I. Introduction – past research actions

Stratospheric research has been a priority of the European Framework Programmes for Research and Technological Development (FPs) from the very beginning and has been coordinated at European level since the late 1980s. The early European Stratospheric Research Programmes (FP1-FP3, 1982-1994), focused on the investigation of potential severe Arctic ozone losses and increased UV radiation across Europe and the populated northern mid-latitudes. Research was implemented through a series of national and international programmes including the European Arctic Stratospheric Ozone Experiment (EASOE, 1991-92) and the Second European Stratospheric Arctic and Mid-Latitude Experiment (SESAME, 1994-95).

Under the 4th Framework Programme for Research and Technological Development (FP4, 1994-1998) the focus was on basic processes affecting ozone depletion, in particular over Northern Europe. The Third European Stratospheric Experiment on Ozone (THESEO, 1998-2000) was a major component of this coordinated programme. Moreover, research addressed the mid-latitude lower stratosphere, the interaction with other layers of the atmosphere, the Arctic vortex, and exchanges processes between the Troposphere and the Stratosphere in the tropics and sub-tropics.

The intention of the 5th Framework Programme for Research and Technological Development (FP5, 1998-2002), Programme Energy, Environment and Sustainable Development (EESD) was to establish a solid basis of information on which European environmental legislation could be build on and to support international commitments such as the Montreal Protocol. FP5 was promoting interdisciplinary research and focused on understanding, quantification and prediction of stratospheric changes and changing of UV-radiation levels. The programme has been implemented through numerous projects organised via a number of research clusters addressing similar topics: UV radiation (ATUV), impact of aircraft emissions (CORSAIRE), ozone–climate interactions (OCLI), stratospheric ozone loss (SOLO).

The 6th Framework Programme for Research and Technological Development (FP6, 2002-2006) was designed to promote interdisciplinary research in a more integrated way. The Integrated Project (IP), a newly defined funding instrument, became a very effective implementation tool for stratospheric research at European level. Research focused on future stratospheric ozone levels and physical and chemical processes affecting ozone depletion, ozone-climate interaction and exchange processes between the Troposphere and the Stratosphere. FP6 research projects are listed in Table 1. In addition, the GMES (Global Monitoring for Environment and Security) initiative, also addressed stratospheric research aspects (related to pre-operational services).
In the 7th Framework Programme for Research and Technological Development (FP7, 2007-2013) integrated and interdisciplinary UV and stratospheric research continues under Theme 6 Environment and Theme 9 Space. Priorities are in line with those of FP6. On going FP7 research projects are listed in Table 2.

In the past effective links have been maintained with existing international atmospheric observational programmes such as the Network for the Detection of Atmospheric Composition Change (NDACC) and the Global Atmosphere Watch programme of the World Meteorological Organisation (WMO-GAW).

Overall, stratospheric research has greatly benefited from European Framework Programmes. They also provided effective co-ordination mechanisms to jointly use European research facilities, promote integrated interdisciplinary research thereby addressing the scientific problems in a more holistic way. As a result, European research has significantly contributed to the international Scientific Assessment of Ozone Depletion: 2010.

II. Stratospheric Research in FP6 (2002-2006)

The following section gives a more detailed overview of the FP6 stratospheric research projects and their activities:

Under FP6 European Commission supported 3 IPs focusing on ozone-climate interactions and UV radiation (SCOUT-O3, Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere), on quantifying the impact of emissions from the transport sector on climate and ozone depletion (QUANTIFY, Quantifying the Climate Impact of Global and European Transport Systems) and on atmospheric observations (GEOMON, Global Earth Observation and Monitoring of the atmosphere), respectively. In addition, research priorities of IP GEMS (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data) among others, included a component on the assimilation of gas-phase chemical species in the stratosphere and troposphere.

Furthermore, the European Commission funded a number of Specific Support Actions (SSAs) to underpin stratospheric research and relevant policies. ATTICA (European Assessment of Transport Impacts on Climate Change and Ozone Depletion) was designed to assess the impact of the transport sector (aviation, land traffic, shipping) on climate change and ozone depletion, and the HCFC-Works hop (5-6 April 2008, Montreal) was designed to help developing countries to path ways to reduce and early phase out HCFCs consumptions and emissions, respectively.

2.1 Core objectives of SCOUT-O3

The aim of SCOUT-O3 (Finalised May 2010) was to study and predict the evolution of the coupled chemistry/climate system with emphasis on reliable prediction of the future evolution of the ozone layer and surface UV. Forecasts were built on refined and improved models by exploiting existing data for model testing and validation and by provision of new data on fundamental processes. In order to meet these goals, 10 project activities were defined:

- Determination of air residence time (with major field campaign);
- The influence of clouds on the tropical UTLS (with major field campaign);
- Understanding the stratospheric water vapour trend and its consequences;
- The stratospheric aerosol layer – role of TTL and possible changes;
- Past UV changes, variability and trends;
- Ozone variability and past changes at mid-latitudes;
- Inter-annual variability in polar processes and likely changes in a changing atmosphere;
Improved understanding of the Brewer-Dobson and general stratospheric circulation;
Stratosphere/troposphere coupling – past and future;
Predictions of ozone recovery, effect on climate change on recovery and the impact of the ozone changes on surface UV.

Campaigns

- Tropical aircraft campaign has been carried out November-December 2005, Darwin, Australia (Russian stratospheric research aircraft M55 Geophysica was contributing);
- Atmospheric research campaign with M55 Geophysica from July 31 to August 18, 2006 in Ouagadougou, Capital of Burkina Faso, West Africa;
- SCOUT-O3/AMMA tropical balloon campaign, Niger, July-August 2006;
- SCOUT-O3 UV radiation and aerosol campaign, Thessaloniki (Greece) July 2006 in Southern Europe;
- Balloon campaigns 2008.

2.2 Core objectives of QUANTIFY

The main goal of QUANTIFY (finalised in end of 2010) was to quantify the impact of global and European transport systems on climate and ozone depletion for the present situation and for several scenarios of future development. The climate impact of various transport modes (land transport, shipping, and aviation) has been assessed, including those of long-lived greenhouse gases like CO₂ and N₂O, and in particular the effects of emissions of ozone precursors and particles, as well as of contrails and ship tracks.

Several transport scenarios and potential mitigation options have been assessed to identify the most effective combination of short and long-term measures as input for policy- and industrial decisions. The project aimed to provide such guidance by focused field measurements, exploitation of existing data, a range of numerical models, and new policy-relevant metrics of climate change. The project focused on the following activities:

- Establishment of transport Scenarios and emission inventories;
- Regional dilution and processing (with emphasis on chemical conversion of ship emissions);
- Large-scale chemistry effects (impact of transport emissions on chemical composition for past and present day conditions);
- Long-term measurements of UTLS compounds;
- Aviation, shipping and clouds (generation and modification of clouds by emissions of different traffic modes, with emphasis on cirrus clouds);
- Radiative forcing and climate change (contribution from different modes of transport);
- Development of improved metrics of climate change;
- Synthesis of the results.
2.3 Core objectives of GEOMON

The goal of GEOMON is to sustain and analyze European ground-based observations of atmospheric composition complimentary with satellite measurements. It is a first step to build a future integrated European atmospheric observing system dealing with observations of long-lived greenhouse gases, reactive gases, aerosols, and stratospheric ozone. GEOMON is a European contribution to GEOSS (Global Earth Observation System of Systems) helping to optimize the European strategy of environmental monitoring in the field of atmospheric composition observations. Furthermore, the project is also relevant for the European GMES (Global Monitoring for Environment and Security) initiative integrating in-situ and satellite measurements. Main activities:

- Unify and harmonise the main European networks of surface and aircraft-based atmospheric measurements;
- Support data gathering at existing networks;
- Co-ordinate and access to data and data-products at a common data centre;
- Integrate surface measurements with those of satellites with emphasis on data gathered by NDACC stations;
- Develop new methodologies to use these data for satellite validation;
- Enable new ground based measurements complementary to satellites;
- Deduce biases and random errors in satellite observations, to identify long-term trends in tropospheric and stratospheric composition related to climate change.

2.4 Core objectives of GEMS

The GEMS project (Finalised end of 2009) has created the first-ever system for operational global monitoring and medium & short range forecasts of atmospheric chemistry and dynamics. An improved exploitation of the best available satellite and in-situ data has been achieved through assimilation into numerical models. By 2008, GEMS has produced near-real-time & retrospective analyses of greenhouse gases, reactive gases and aerosols in the troposphere and in the stratosphere on the regional and on the global scale. GEMS covered the atmospheric theme within the GMES initiative of the EC, and GEMS data products provide valuable new analysis & forecast products for the GMES Service Element. Focus was on:

- Global Greenhouse Gases;
- Global Reactive Gases;
- Data on depletion of stratospheric ozone and long-range transport of atmospheric pollution;
- Regional air quality;
- Data assimilation and production;
- Data validation.

2.5 Core objectives of ATTICA

The SSP ATTICA (finalized end of 2010) has provided a coherent series of assessments of the impact of transport emissions on climate change and ozone depletion. Three assessments cover the emissions of single transport sectors (aviation, shipping, land traffic) and the fourth assessment deals with metrics that describe, quantify, and compare in an objective way the effects of the transport emissions in the atmosphere. Finally, the synthesis summarises the key results of the individual reports in a coherent way, and is considered as a reference document for stakeholders and environmental policy makers.
2.6 Core objectives of the HCFC technical workshop

The European Commission has organised an international technical HCFC workshop, 5-6 April 2008, Montreal, Canada, which foc used on the options for reduction of consumption and early and phase-out of HCFC in developing countries between now and 2015. Furthermore, it helped to identify ways to further reduce consumption and dependence on HCFCs between 2016 and 2040. Specifically, the workshop has provided developing country stakeholders with the technical tools and information needed to phase-out HCFCs (e.g., information on viable alternatives, technology transfer, funding opportunities) and to build consensus among stakeholders on next steps for this important issue that faces all of the Parties to the Montreal Protocol.

III. Stratospheric and UV Research in the 7th Framework Programme (FP7, 2007-2013)

Under Theme 6: Environment (including Climate) UV and stratospheric research remains a priority in FP7. More general speaking, research under the Environment theme is supporting the implementation of relevant international environmental commitments, protocols, and initiatives concluded by the European Union and its Member States, such as the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto and Montreal Protocols, respectively. Research is considered as an essential component in the increasing efforts of the European Commission to combat climate change and stratospheric ozone depletion. Research includes health risks associated with changing UV radiation levels.

In addition, Programme 9. Space under the GMES initiative also supports a topic on 'pilot services atmosphere in new application fields' which also includes stratospheric aspects.

The FP7 2008 call (Programme Environment) included two topics on UV and stratospheric research, headline:

ENV.2008.1.1.2.1. Climate-chemistry interactions in the stratosphere related to ozone depletion
Projects funded: RECONCILE and SHIVA

ENV.2008.1.2.1.5. Quantification of changing surface UV radiation levels and its impact on human health
Project funded: ICEPURE

3.1 Core objectives of RECONCILE

RECONCILE (Reconciliation of essential process parameters for an enhanced predictability of Arctic stratospheric ozone loss and its climate interactions) addresses the effects of climate change on stratospheric ozone and its related feedback mechanisms. Furthermore, the project will make reliable forecasts of future ozone loss and recovery.

Work tasks include:

- Chemical kinetic parameter and alternative ozone destruction;
- PSC microphysics and heterogeneous chlorine activation;
- Atmospheric dynamics, mixing, vortex break-up;
- Climate-Chemistry modelling.
Campaigns, experiments

- Match Campaign Winter 2009/2010 launching ozone sondes;
- Laboratory experiments on ClO dimer absorption cross section.

3.2 Core objectives of SHIVA

SHIVA (Stratospheric ozone: Halogen impacts in a varying Atmosphere) aims to reduce uncertainties in present and future halogen loading and ozone depletion resulting from climate feedbacks between emissions and transport of ozone depleting substances (ODS). The focus is on the impact of short and very short-lived substances (VSLS) in the tropical regions and its climate–sensitive natural emissions.

Work tasks comprise:

- The oceanic emission strength of halogenated gases;
- Their atmospheric transport/transformation from the surface to the lower Stratosphere;
- The past, present and future trend of the total halogen burden;
- Its impact on the past, present and future ozone in the Stratosphere Campaigns;
- Tropical campaign (Research Vessel Sonne, Falcon aircraft) will take place in late 2011.

3.3 Core objectives of ICEPURE

ICEPURE (The impact of climatic and environmental factors on personal ultraviolet radiation exposure and human health) will determine the adverse and beneficial health effects of UVR exposure and their relationship with climatic and environmental factors that modify the UVR spectrum.

- Measurement of personal UVR exposure;
- Development of new radiative transfer models;
- Determination of the beneficial and harmful biological effects of UVR;
- Review of the current health risks of UVR.

3.4 Core objectives of MACC

MACC (Monitoring Atmospheric Composition and Climate) is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. MACC combines state-of-the-art atmospheric modelling with Earth observation data to provide information services covering European Air Quality, Global Atmospheric Composition, Climate, and UV and Solar Energy.

Core objectives among others are:

- Monitoring and Forecasting of Ultraviolet Radiation;
- Total Ozone Record;
- Near-real-time Ozone Monitoring;
- Near-real-time Ozone Forecasts;
- Monitoring of surface solar irradiance.
These projects build the back bone of European Commission stratospheric research, thereby maintaining a critical mass essential for future contributions to international ozone and UV assessments.

IV. Future activities

The complexity of the atmospheric processes, the scale of the scientific problems and the potential devastating impact on humans and the ecosystems caused by climate change, stratospheric ozone depletion and changing UV radiation require real interdisciplinary research collaboration. This has already started under the 5th and 6th Framework Programmes and, as indicated above, continues in the 7th Framework Programme, where research will be conducted in the coming years focusing on the climate-stratospheric interaction.

Open scientific questions to be considered in coming calls concern the exchange between the Troposphere and Stratosphere under changing climatic conditions; changes, interactions and feedback between atmospheric composition, the climate system, variations in the solar spectrum and its consequences for the Stratosphere.
Table 1: Relevant research projects supported under FP6

SCOUT-O3 (Stratosphere-Climate Links With Emphasis On The UTLS)
Co-ordinator: Prof. John Pyle, University of Cambridge, UK
Budget: 15.000.000 €
Starting date: 1 May 2005
Duration: 5 years
Web-link: http://www.ozone-sec.ch.cam.ac.uk/scout_o3/index.html

QUANTIFY (Quantifying the Climate impact of Global and European Transport Systems)
Co-ordinator: Prof. Robert Sausen, DLR, DE
Budget: 8.388.172 €
Starting date: 1 March 2006
Duration: 5 years
Web-link: http://www.pa.op.dlr.de/quantify/

GEOMON (Global Earth observation and monitoring of the Atmosphere)
Co-ordinator: Prof. Philippe Ciais, CEA, FR
Budget: 6.621.740 €
Starting date: 1 February 2007
Duration: 4 years
Web-link: http://geomon.ipsl.jussieu.fr/

GEMS (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data)
Co-ordinator: Dr. Adrian Simmons, ECMWF, UK
Budget: 12.450.000 €
Starting date: 1 March 2005
Duration: 4 years
http://www.ecmwf.int/research/EU_projects/GEMS/

ATTICA (European Assessment of the Transport impacts on Climate and Ozone Depletion)
Co-ordinator: Prof. Robert Sausen, DLR, DE
Budget: 680.000 €
Starting date: 1 June 2006
Duration: 3 years 6 months
Web-link: http://www.pa.op.dlr.de/attica/

HCFC workshop
Co-ordinator: ICF international
Budget: 300.000 €
Starting date: 1 January 2007
Duration: 1 year 6 months
The HCFC workshop, 5-6 April 2008, Montreal, Canada
Table 2: Relevant research projects supported under FP7

RECONCILE (Reconciliation of essential process parameters for an enhanced predictability of Arctic stratospheric ozone loss and its climate interactions)
Co-ordinator: Dr. Marc von Hobe, Forschungszentrum Jülich, DE
Budget: 3.500.000 €
Starting date: 1 March 2009
Duration: 48 months
Web-link: https://www.fp7-reconcile.eu/

SHIVA (Stratospheric ozone: halogen impacts in a varying atmosphere)
Co-ordinator: Prof. Klaus Pfeilsticker, University of Heidelberg, DE
Budget: 3.500.000 €
Starting date: 1 July 2009
Duration: 36 months
Web-link: http://shiva.iup.uni-heidelberg.de/

ICEPURE (The impact of climatic and environmental factors on personal ultraviolet radiation exposure and human health)
Co-ordinator: Prof. Antony Young, King's College London, GB
Budget: 3.500.000 €
Starting date: 1 February 2009
Duration: 36 months
Web-link: http://www.icepure.eu/

MACC (Monitoring Atmospheric Composition and Climate)
Co-ordinator: Dr. Adrian Simmons, ECMWF, UK
Budget: 11.700.000 €
Starting date: 1 June 2009
Duration: 29 months
Web-link: http://www.gmes-atmosphere.eu/

Prepared by: Dr. Claus Brüning
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1. **GROUND BASED OBSERVATIONS**

1.1 **Column measurements of ozone and other gases/variables relevant to ozone loss**

The discovery of the Antarctic "ozone hole" in the mid 1980s initiated several ozone monitoring activities also at northern high latitudes. In Finland, ozone column monitoring has been carried out by the Finnish Meteorological Institute at Sodankylä (67.4°N, 26.6°E) since 1988 and at Jokioinen (60.5°N, 23.3°E) since 1994. At both stations an automated system based on Brewer spectrophotometer is continuously operated.

At Sodankylä Arctic research centre (FMI-ARC) wintertime ozone columns are also monitored with a SAOZ spectrophotometer which is operated in cooperation with CNRS-Paris already since 1990. The SAOZ measurements also provide NO₂ and OClO column amounts. This instrument works at large solar zenith angles and is thus capable of measurements during the wintertime at high latitudes. Multiyear ozone measurements from both stations have shown large inter-annual variations, in addition significant ozone loss has been observed in the Arctic stratospheric vortex during several years since early 1990s.

1.2 **Profile measurements of ozone and other gases/variables relevant to ozone loss**

Ozone soundings have been carried out since 1989 at Sodankylä where balloon ozone sensor measurements are carried out regularly throughout the year, while in Jokioinen these measurements are conducted during winter and spring when chemical ozone depletion is expected.

Another long-term initiative at FMI-ARC related to stratospheric ozone is the measurements of polar stratospheric cloud (PSC) properties. PSCs play an essential role in chlorine activation and subsequent ozone depletion. PSCs are generally divided in two types based on their optical parameters, type II are large particles of primarily water ice, type I are typically smaller particles of nitric acid trihydrate or supercooled ternary solution droplets. At Sodankylä these stratospheric cloud particles have been observed during stratospheric campaigns since 1991/1992 by lidar and since 1994 by aerosol backscatter sondes. Recently cooperation with ETH Zurich has started in the framework of development of a new backscatter sonde.

At Sodankylä, since December 2002, stratospheric humidity is monitored in winter months using Cryogenically cooled Frost point Hygrometer (CFH) and/or hygrometers developed at the Central Aerological Observatory of RosHydromet. Already earlier, in January 1996 an Arctic dehydration event was recorded and investigated at Sodankylä using NOAA/CMDL hygrosonde, a predecessor of CFH.

The national meteorological institutes in Finland (FMI) and Argentina (SMN) started a joint ozone research program in 1987, including total ozone measurements at Marambio (64.1°S, 56.4°W), Antarctica. In 1988 routine ozone soundings were started at Marambio. Recently FMI and SMN have started Aerosol optical depth and radionuclide measurements at Marambio.

1.3 **UV measurements**

1.3.1 **Broadband measurements**

FMI operates SL501 broadband instruments at six sites in Finland. These instruments provide online information on the erythemal irradiance that is published through the internet along with the UV-Index forecast.

1.3.2 **Narrowband filter instruments**

FMI cooperates with Argentina and Spain on Antarctic ozone and UV. In 1999 the collaboration was extended to include UV radiation research. The established UV monitoring network consists of NILU-UV instruments in Marambio, Belgrano and Ushuaia, and a travelling reference.
Sodankylä a NILU-UV radiometer has been used to measure UV radiation of a reference field within a large field experiment of FUVIRC (Finnish Ultraviolet International Research Center). One NILU-UV, in Helsinki, has been acquired for campaign use.

1.3.3 Spectroradiometers
FMI has monitored the spectral UV irradiance with Brewer instruments in Jokioinen (Mark III since 1995) and Sodankylä (Mark II since 1990). Additionally, a Bentham DM150 has been acquired for campaign use, as well as, more recently, one diode array spectroradiometer SP-J1009 for monitoring the spectral irradiance on a vertical surface following the solar azimuth, and another for monitoring the direct spectral irradiance at Jokioinen.

1.4 Calibration activities
FMI has dark room UV calibration facilities both in Jokioinen and Sodankylä. FMI has participated in several UV measurement comparison campaigns, where it has been established that the quality of Finnish Brewer measurements is excellent and steady. The Brewer instrument of Jokioinen served as one of the core instruments of the QUASUME project (Quality Assurance of Spectral Ultraviolet Measurements in Europe). The European reference spectroradiometer developed in the project is invited for auditing visits to both observatories on a regular basis. FMI is also responsible for calibration of the Antarctic NILU-UV travelling reference instrument and data quality assurance. Brewer ozone measurements in Jokioinen and Sodankylä are calibrated by annual visits of a travelling Brewer standard instrument, which in turn is calibrated against the Brewer Triad at Toronto.

1.5 Measurement and validation campaigns
The Arctic research center at FMI has become an important site for ozone validation campaigns. In 2006 and 2007 major ozone campaigns were organised in Sodankylä by NASA, ESA and FMI, aiming to achieve < 1% total ozone measurement accuracy in both ground based and satellite based platforms. Sub-percent accuracy is needed for reliable monitoring of the effects of Montreal protocol. FMI Arctic Research Centre (FMI-ARC) also participated in the EUMETSAT EPS campaign in 2007, which involved ozone soundings and groundbased measurements.

FMI has also hosted international intercomparison campaigns of lightweight hygrosondes in 2004 and 2010. The LAPBIAT Atmospheric Sounding Campaign in January-March 2010 involved a large set of stratospheric measurements by applying various measurement techniques. FMI ARC has participated in ozonesonde Match campaigns during each Arctic winter. In 2011 FMI organised the CEOS Nordic Ozone Intercomparison campaign. The goal of the campaign was to characterize Brewer and Dobson spectrophotometer accuracy.

2. SATELLITE OBSERVATIONS AND DATA PRODUCTS
FMI has a strong participation in four satellite instruments that are targeted for monitoring ozone in the atmosphere (GOMOS/Envisat, OSIRIS/Odin, OMI/EOS-Aura). The GOMOS stellar occultation instrument onboard the ESA’s Envisat satellite has been operating since spring 2002. High vertical resolution ozone profiles that cover the altitude range from upper troposphere to lower thermosphere during years 2002-2011 are already available. FMI participates in ensuring the GOMOS data quality and in improving the data processing as a member of the ESA’s GOMOS quality working group. The full reprocessing of GOMOS data is expected in 2011. Recent research also include developing an algorithm for processing GOMOS bright limb data.

GOMOS data plays an important role in the ESA’s climate change initiative for developing essential climate variable (ECV) of ozone. FMI participates in developing the ECV dataset of high resolution ozone profiles using GOMOS data. In addition, FMI is presently studying whether GOMOS ozone data can be used to continue the satellite based high resolution ozone profile dataset of SAGE solar occultation instruments.
The OSIRIS instrument onboard the Swedish small satellite Odin has measured ozone profiles since 2001. The ozone profiles are processed also at FMI and during the last years the validation and optimization of the algorithms have taken place.

FMI is developing GOMOS and OSIRIS monthly averaged zonal averages and these data are distributed via internet (fmi:limb.fmi.fi/).

The Dutch-Finnish OMI instrument onboard the NASA’s EOS-Aura satellite has measured total ozone columns since 2004. FMI is hosting the OMI UV irradiance processing and archiving facility which includes level 2 data, gridded level 2 data and level 3 data. The improvement and validation of the UV products are continuously ongoing. In addition, local maps of total ozone columns and UV irradiance together with other atmospheric constituents covering Central and Northern Europe are processed at FMI. These Very Fast Delivery (VFD) products exploit the Direct Broadcast antenna at Sodankylä, Northern Finland. These products are available in the Internet (omivfd.fmi.fi) within 15 min after the overpass of the satellite. As a continuation to FMI’s research related to OMI, we have recently studied methods to retrieval ozone profile data using Sentinel-5 precursor/TROPOMI instrument.

FMI is responsible of developing, distributing, archiving of the UV-radiation product of GOME-2. This is done within the EUMETSAT’s Satellite Application Facility project of ozone and atmospheric chemistry, O3M-SAF (o3msaf.fmi.fi).

3. RESULTS FROM OBSERVATIONS AND ANALYSIS

FMI has developed quality control (QC) and quality assurance (QA) practices that are suitable for many kinds of UV instruments. At FMI, at the moment, only Brewer UV measurements are considered to have a sufficient quality for assessment of long-term changes. The QC/QA procedures of the Brewers include daily maintenance, laboratory characterizations, calculation of long-term spectral responsivity, data processing and quality assessment. New methods for the cosine correction, the temperature correction and calculation of long-term changes in spectral responsivity were implemented. The Sodankylä spectral time series is among the longest in Europe. A study on the Sodankylä UV time series 1990-2001 revealed no consistent trend during this 12 year period. An increase in UV radiation was observed in early 1990s and then a decrease towards the end of the period with the largest values occurring in 1993 and after the cold winters of mid 1990s. These observations are consistent with the ozone layer development in the same period. The reanalysis of the entire time period is under work.

FMI has participated to UV albedo measurement campaigns. Measurements of snow albedo are still a big challenge due to the demanding measurement conditions as well as measurement uncertainties. The UV albedo has been quantified over Sodankylä. The results show that the albedo of snow depends on the properties of the snow, and that the grain size of the snow differs between the European Arctic and Antarctic regions, which introduce a different UV albedo in these regions. Other atmospheric parameters, e.g., cloudiness and temperature, can influence the albedo. At Sodankylä, the snow albedo was found to change within a few hours, due to the effect of temperature on snow's properties.

Ozonesonde observations have been conducted in Sodankylä since 1989. This data along with the data from other Arctic stations have been analyzed. It was seen that during the recent decades the largest ozone changes in the stratosphere and troposphere have occurred in the late winter/spring period. The observed negative trend in the stratosphere prior to 1996-1997 can be attributed to the combined effect of chemical and dynamical changes, while the observed increase since then is primarily due to the dynamical changes. In the troposphere, trends have been positive regardless of the chosen time period. This may be related to the long-term changes in Arctic oscillation as it regulates the transport of ozone and its precursors from industrialized regions towards the pole and it may also modulate stratosphere-troposphere exchange.
Water vapour changes in the UTLS have a large impact on the climate system. Yet the accurate measurements of the UTLS water vapour remain a technological challenge. FMI has hosted two major field campaigns of comparison of light-weight instruments capable of water vapour measurements in the upper troposphere and lower stratosphere. The campaigns has led to a better understanding of the accuracy of the in situ instruments and contributed to significant improvement of the technology. In addition, the data provided a unique opportunity to study meteorological processes in the lower stratosphere and upper troposphere including PSCs and dehydration.

4. THEORY, MODELLING, AND OTHER RESEARCH

The modelling activities related to middle atmospheric ozone includes the use of a global 3D chemistry transport model of the stratosphere and mesosphere (FinROSE-ctm), a climate model covering the middle atmosphere (MAECHAM), a coupled atmosphere-ocean model (HadGEM1) and a model of the ionosphere (Sodankylä Ion Chemistry model). The modelling work includes both studies of long term trends of stratospheric ozone and water vapour utilizing reanalyzed meteorological data (ECMWF reanalysis data) as well as process studies (PSC, chlorine activation, ozone loss rates). The studies are also focused on impacts of ozone depletion and recovery on surface climate, which are shown to be significant in the Southern Hemisphere. These results add to increasing number of evidences that the stratosphere plays an important role in climate change and call for a better representation of the stratosphere in models used for climate studies, in particular for a wider use of chemistry-climate models (CCMs) which include stratospheric ozone chemistry. FMI has participated in preparation of the SPARC assessment of CCMs (CMVal-2, http://www.atmosp.physics.utoronto.ca/SPARC/cmmval_final/index.php) in support of WMO ozone assessment 2010 and the upcoming IPCC report. The scientific use of satellite measurements is increasingly important. In addition, the impact of solar proton events on the stratosphere and mesosphere is studied. In this study the unique night time ozone profile measurements of the GOMOS instrument are used. GOMOS data are also used for studying turbulence and gravity waves in the stratosphere.

FMI has developed models for reconstruction of the past UV time series as well as for assessment of the future UV levels. These data are essential for assessment of the long-term changes in surface UV. FMI contributed to the Arctic Climate Impact Assessment (ACIA) with a shared lead authorship of the chapter on ozone and UV. FMI has participated in multidisciplinary research projects that aim at better understanding of the effects of increased UV exposures on human health, terrestrial and aquatic ecosystems, or materials.

FMI coordinates the research project UVEMA exploring the Effects of UV radiation on MAterials. The study focuses on rubber compounds, natural fibre composites and carbon fibres provided by the industrial partners of the project. A program of long-term outdoor material testing has been set up at seven European sites, including Jokioinen Observatory and Arctic Research Centre at Sodankylä. Prevailing UV radiation and weather conditions are being monitored alongside with the program at each station. Exposed material samples will be investigated in respect of various properties: colour, quality/coarseness of the surface and compression/flexural/tensile strength. As an outcome, more reliable estimates for the useful life-time of the materials are to be gained.

FMI Arctic Research Centre at Sodankylä hosts the experimental fields of FUVIRC-experiment (Finland UV International Research Centre) to study biological impacts of UV-B radiation to boreal plants at enhanced UV-radiation condition. There are two experimental sites representing typical landscape types of northern Fennoscandia, a boreal pine forest test field and peat land test field. Enhancement of the ambient UV-exposure can be regulated to desired values through extensive monitoring and control system. The field serves atmospheric chemistry, human health, and biological research initiatives by providing extensive UV monitoring data, guidance (i.e. calibration of instruments, maintenance of field test sites), and research facilities (i.e. laboratories, instruments, equipment and accommodation for visiting researchers).
5. DISSEMINATION OF RESULTS

5.1 Data reporting
FMI has participated in the Global Atmospheric Watch (GAW) programme since 1994. Within the program, FMI maintains the Pallas-Sodankylä GAW station and conducts an extensive research programme related to atmospheric aerosols. Within this twin GAW station surface and boundary layer measurements are done in FMI clean air site of Pallas while upper air measurements, UV and Ozone monitoring takes place at Sodankylä (fmiarc.fmi.fi). In upper air research Sodankylä functions as an auxiliary station in the global Network of Detection of Atmospheric Composition Change (NDACC).

FMI maintains the European UV Database (EUVDB). EUVDB is a regional WMO database containing some two million UV spectra (uvdb.fmi.fi/uvdb/). The UV spectra of the two Finnish Brewer instruments are submitted to EUVDB.

Regular ozone soundings have been performed at Marambio since 1988, the ozone data is sent to two international databases at the World Ozone and Ultraviolet Data Centre (WOUDC, Toronto, www.woudc.org) and the Norsk institutt for luftforskning (NILU, Oslo, www.nilu.no/nadir/). Furthermore, the UV measurements are available at polarvortex.org. Both the ozone and UV measurements are used in scientific publications, and form a significant contribution to the WMO ozone bulletins (www.wmo.ch).

5.2 Information to the public
FMI provides a 2-day global forecast of the UV Index (www.fmi.fi/uvi). The forecast, which is published in the internet, includes contour maps of the local solar noon maximum clear sky maximum UV Index. Additionally, local clear sky UVI forecasts are provided for several sites in Finland and globally. The Finnish broadband UVI measurements are also incorporated in the web page. FMI has actively participated in increasing the awareness of general public on the health effects of UV radiation. In addition, FMI contributed to the Arctic Climate Impact Assessment (ACIA) document with a shared lead authorship of the chapter on ozone and UV.

The major scientific results are published in international refereed journals and are also presented at relevant international conferences. Popularized information is distributed through press releases and interviews. Information about research activities, remote sensing projects as well as measurements and analysis results are available through FMI web pages, www.fmi.fi. FMI-ARC observations and analyses are available at fmiarc.fmi.fi.

Ozone depletion has a large public interest due to related health (UV) and environmental issues. The unprecedented stratospheric conditions and severe ozone loss in the spring of 2011 triggered a wide interest in the Finnish media (Figure 1).

Figure 1. Total ozone (DU) above Scandinavia on March 28, 2011. The exceptional Arctic ozone depletion was noted by media in Finland. Both ground based and satellite measurements as well as model forecasts were referred in the media. Left panel, FinROSE-ctm data. Right panel, OMI total ozone data.
5.3 Recent relevant scientific papers


267


6. PROJECTS AND COLLABORATION
The major national funding organisations are the Academy of Finland and the National Technology Agency of Finland. The ozone and UV related research is partly funded by the Academy of Finland. FMI collaborates with Finnish Universities on atmospheric modelling and developing data retrieval methods and assimilation techniques for the GOMOS and OSIRIS instruments.

- SAARA (Studies of the Changing Antarctic Atmosphere using Soundings, Remote Sensing and Modelling: A Bi-polar Approach)
- MIDAT (Middle atmosphere dynamics and chemistry in climate change)
- ASTREX (Advanced Analyses of Stratosphere-Troposphere Exchange)
- UTLS WaVa (Arctic upper troposphere lower stratosphere water vapour)
- COOL (Aerosol intervention technologies to cool the climate: costs, benefits, side effects, and governance)
- FUVIRC (Finnish Ultraviolet International Research Center, http://fmiarc.fmi.fi/fuvirc/fuvirc_hs)
- UVEMA (Effects of UV radiation on Materials, uveuma.fmi.fi)
- MACC (EU project, FMI participating in task related to UV-radiation)
- O3M-SAF (EUMETSAT's Satellite application facility on ozone and atmospheric chemistry)
- IGACO-O3/UV secretariat (WMO and GAW-ozone)
- ACSO (Absorption cross sections of ozone, IGACO-O3/UV activity)

FMI has participated in several EU funded Arctic and Antarctic research projects including tasks such as stratospheric modelling and measurement campaigns. The modelling activities include cooperation with the Max Planck Institute, Hamburg. Sodankylä has participated in all major European stratospheric ozone campaigns. In 1999, 2003 and 2007 the Marambio activities formed an important part of the international stratospheric ozone research campaigns. In addition, FMI took part in activities organized during the International Polar Year 2007/2008.

FMI is coordinating the EUMETSAT Satellite Application Facility on Ozone Monitoring (O3M SAF, o3saf.fmi.fi). O3M SAF is one of the SAFs in EUMETSAT SAF network. SAFs are specialised
development and processing centres within the EUMETSAT Application Ground Segment (www.eumetsat.int). O3M SAF is developed in co-operation with Koninklijk Nederlands Meteorologisch Instituut (KNMI), Deutsche Zentrum fur Luft- und Raumfahrt (DLR), Deutscher Wetterdienst (DWD), Aristotle University of Thessaloniki (LAP), Hellenic National Meteorological Service (HNMS), Danish Meteorological Institute (DMI), Meteo-France (M-F) and Koninklijk Meteorologisch Instituut (KMI).

The purpose of the O3M SAF is to produce a set of near real-time and offline products and validation services. Near real-time products are GOME-2 total ozone and ozone profiles, \( \text{NO}_2 \) and UV fields. Offline products derived from GOME-2 data are total and/or tropospheric column amounts of ozone, \( \text{NO}_2 \), \( \text{BrO} \), \( \text{SO}_2 \), \( \text{HCHO} \), \( \text{H}_2\text{O} \), \( \text{OCIO} \), ozone profiles, aerosol index and UV fields including cloudiness and albedo. The ozone and UV data is validated against ground-based observations of total ozone and UV as well as balloon borne, microwave and lidar observations of the vertical distribution of ozone. An important part of the O3M SAF activities has been related to scientific work to develop radiative transfer calculation methods and other algorithms used for satellite ozone and related data retrieval.

The Satellite Data Centre of FMI-ARC started in 2002. The activities include a processing facility for the GOMOS/Envisat ozone instrument. The FMI-ARC data centre also process part of the OSIRIS/Odin ozone data. Data reception and processing from the EOS-Aura satellite is also going on for Very Fast Delivery products of the total ozone, \( \text{SO}_2 \), aerosol index and UV irradiance products, available within 15 min after the overpass of the satellite. The Centre is also responsible of reception of OMI data used in near real time \( \text{O}_3 \) and UV-products.

FMI also hosts the WMO IGACO (Integrated Global Atmospheric Chemistry Observations) Ozone secretariat (www.igaco-o3.fi). One of the objectives of IGACO strategy, implemented through the GAW programme of WMO, is to ensure long-term continuity and spatial comprehensiveness of atmospheric composition observations, both in the troposphere and the stratosphere. During 2009-2011 the most active task related to IGACO-O3/UV has been the evaluation of absorption cross sections within the so called ACSO activity.

7. **FUTURE PLANS**

Although the basic processes related to stratospheric ozone are now believed to be fairly well understood, there remain important research topics related to ozone and UV, such as the interaction between ozone depletion/recovery and climate change and the effects of UV-irradiance on nature, agriculture, and on materials. According to the present understanding the recovery of the ozone layer will take several decades, but the scenarios contain many uncertainties, among which man’s behaviour is not the smallest. Therefore it is desirable that the research and monitoring activities will be continued and developed.
GAMBIA

THE OZONE UNIT OF THE GAMBIA WEST AFRICA
BY ALHAGIE SARR

The Ozone Unit under the Technical Services Network of the National Environment Agency is charged with the responsibility of monitoring the activities related to the United Nations Environment Programme funded project on Ozone Depleting Substances. The ultimate aim of the Project is to completely phase-out Ozone Depleting Substances from the Gambia and also tries to fulfill any other requirements as enshrined in the Montreal Protocol on Substances that Deplete the Ozone layer.

Although the Ozone Unit was faced with a lot of challenges in the past, the unit is able to achieve some of its objectives. In a bid to achieving the set goals and objectives of a complete phase out of Ozone Depleting Substances we printed five hundred t-shirts which have already been distributed Nationwide for the common man to read and understand issues related to Ozone depletion. These t-shirts were evenly distributed in all the seven regions of the country.

In observance of world Ozone day on the 16th of September 2010 the Ozone unit organized in kanifing. The programme was graced by students, the police band, and the General public. At the end of the March pass participants were given T Shirts bearing different messages about Ozone Depletion.

As part of the celebrations to mark the world Ozone Day an open day was organized where many dignitaries, students and the general public were introduced to work being carried out by the Ozone Unit. Other units within the Agency were given the opportunity to display their work as well.

In another engagement the unit also organized a quiz for ten lower Basic Schools at the NEA main office grounds. This particular programme was successful for the fact that all the ten schools participated fully. Prizes were given to the best three schools and the remaining seven schools were given consolation prizes. Parents and teachers acknowledged the success of the quiz and some of them even called the office to express their appreciation of how the programme was conducted.

Our refresher trainings also were very successful, because we were able to conduct trainings in three provincial regions of the country for customs and other security officers. With regards refrigeration technicians also we conducted one for Central River Region and one in the Upper River Region.

In a bid to phasing out CFCs an incentive programme was initiated to help end users that are fish processing factory owners to retrofit or replace their equipment running on chlorofluorocarbons.
Four companies were identified and all of the four companies’ were given money to either replace or retrofit their equipment. The final National consultancy report was a testimony to this significant achievement. An inception workshop was organized to kick start the HPM P project preparatory activities.

During the month of April 2010, four Refrigerant Identifiers were distributed to Customs Officials along strategic border posts in the Gambia to strengthen our resolve and commitment in the fight against the smuggling of ODS from other countries.

Our awareness campaign to sensitize the public about matters relating to the depletion of the Ozone Layer is on-going, which includes radio shows in the Community Radio Stations throughout the country. This form of awareness campaign involves panel discussions on the radio during which listeners are given the opportunity to phone-in and ask questions seeking clarifications or even contribute by making suggestions as to the way forward. This particular activity took us to Community Radio Stations in Farafenni, Basse, and Soma.

A draft proposal has been produced for the phase-out of Hydrochlorofluorocarbons from the Gambia. The draft is being finalized for submission to EXCOM for approval.
A number of institutions in Germany are very active in ozone and UV research and monitoring. See Table 1 for a summary. Generally, universities and research centers (MPI, DLR, KIT, FZ-Jülich, ...) are more research oriented, government agencies are more monitoring oriented. Germany is a key player for several satellite instruments (GOME, SCIAMACHY, MIPAS). Ground based long-term observations in Germany are provided primarily by DWD (Hohenpeissenberg and Lindenberg stations) and by AWI in the Arctic and Antarctic (Ny-Ålesund/Koldewey and Neumayer stations). UV-monitoring is carried out by BfS, UBA and DWD. By hosting the World Calibration Centre for Ozone Sondes (WCCOS) and the RA VI regional Dobson Calibration Center (RDCC, in cooperation with the Czech Republic), Germany is supporting important international quality-assurance and quality-control activities. Table 1 gives an overview of institutes and their fields.

<table>
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<tr>
<th>Institute</th>
<th>Location</th>
<th>Fields</th>
<th>Keywords</th>
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<td>Deutscher Wetterdienst (DWD)</td>
<td>Hohenpeissenberg, Lindenberg</td>
<td>MT, R, QA/QC</td>
<td>RDCC, NDACC, GAW</td>
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<td>Neumayer, Ny Ålesund, MATCH</td>
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<td>MT,</td>
<td>Air quality</td>
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<td>R, D, MT</td>
<td>GOME, SCIAMACHY, MICROWAVE</td>
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<td>Karlsruhe, Garmisch-Partenkirchen (IfU)</td>
<td>R, D, MD, MT, QA/QC</td>
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<td>Uni Hannover, Inst. f. Meteorologie <a href="http://www.muk.uni-hannover.de">www.muk.uni-hannover.de</a></td>
<td>Hannover</td>
<td>R</td>
<td>UV</td>
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</table>
1. **OBSERVATIONAL ACTIVITIES**

German agencies are major players in ongoing satellite measurements of ozone and related trace gases. The Institute für Meteorologie und Klimaforschung (IMK) of the Karlsruhe Institute for Technology (KIT) has co-developed the MIPAS instrument onboard ENVISAT, and is routinely deriving atmospheric profiles of ozone, temperature and many chemical compounds from the MIPAS data. IUP Bremen is a lead partner for the SCIAMACHY instrument on ENVISAT, as well as for GOME and GOME-2, both for instrument and algorithm development, as well as advanced data processing. DLR is providing much of the ground-processing for several satellite missions and also hosts the World Data Centre for Remote Sensing of the Atmosphere (WDC-RSAT).

Germany’s Meteorological Service (DWD) is running a comprehensive ground-based measurement program at the Observatories Hohenpeissenberg and Lindenberg, monitoring the ozone vertical distribution and total ozone columns on a regular and long-term basis. Special efforts are put into high quality and long-term consistency. The time series cover more than 40 years for column ozone and ozone profiles (Dobson since 1967 and Brewer since 1981, balloon-sonde since 1967), and more than 20 years for stratospheric LIDAR observations up to 48 km (since 1987). Data are regularly submitted to the data centers at Toronto (WOUDC), NDACC, NILU and Thessaloniki. In addition to the operational UV-network of the BfS, DWD continues to measure UV-B radiation for research and development purposes.

Table 2. Operational ground-based network for long-term measurements of ozone and UV

<table>
<thead>
<tr>
<th>Type of observation</th>
<th>Location</th>
<th>Org.</th>
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<th>Type/No.</th>
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</table>

The Alfred Wegener Institute for Polar and Marine Research (AWI) operates two fully equipped polar stations in the Arctic (Koldewey/Ny-Ålesund), and Antarctic (Neumayer) and temporarily onboard RV POLARSTERN. Regular vertical ozone balloon soundings at Neumayer continue the very long Antarctic sounding record that started at the former Georg Forster station in 1985 (see Fig. 1). The full suite of NDACC measurements is also running at the primary station.
Koldewey/Spitsbergen. This includes ozone-soundings by ECC-sondes, Lidar, microwave, DOAS, FTIR and UV-spectrometers. In addition, the same radiation measurements as at Neumayer-Station are performed as part of the BSRN.

Both IUP Bremen and IMK Karlsruhe are running microwave radiometers for ozone profiles (at Ny-Ålesund and Merida, Venezuela). IMK and IFU (both parts of KIT) operate FTIR spectrometers and routinely measure ozone columns (and many other trace gases) at sites in Germany (Karlsruhe, Zugspitze), as well as Kiruna (Sweden), and Izana (Spain). The stratospheric aerosol content is monitored by IFU-KIT since 1976 with a LIDAR which is part of the NDACC at the Garmisch site.

Measurements of ozone and ozone relevant species by IMK have been performed for many years by ground-based, balloon and airborne observations. Since the successful launch of the ENVISAT satellite in 2002, the retrieval of MIPAS-ENVISAT data beyond ESA standard products at IMK provides high quality data sets on a global scale for ozone, temperature, tropospheric source gases and their decomposition products (e.g. H2O, CH4, N2O, CFC-11, CFC-12, HCFC-22, COCl, SF6), chlorine radicals and reservoirs (ClO, ClONO2, HOCl), nitrogen reactants and reservoirs (NO, NO2, HNO3, N2O5, ClONO2, HNO4, BrONO2), odd hydrogen reservoirs (HOCl, H2O2), pollutants relevant to upper tropospheric ozone chemistry (CO, C2H6, C2H2, HCN, formic acid, acetone, PAN), and cloud particle properties of PSCs relevant for the polar ozone loss.

A new container with many new instruments is deployed from Airbus A340-600 passenger aircraft of Deutsche Lufthansa AG. It regularly measures the distribution of ozone and other trace gases in the tropopause region within the CARIBIC project (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container) since 2005. This project with many European partners is co-ordinated by Max Planck Institute for Chemistry in Mainz. [http://www.caribic-atmospheric.com/](http://www.caribic-atmospheric.com/)

1.1. Calibration activities

The Forschungszentrum Jülich hosts the World Calibration Centre for Ozone Sondes (WCCOS). WCCOS is part of the quality assurance plan for balloon borne ozone sondes that are in routine use in the GAW observation network of the WMO. Since its inception in 1995, WCCOS provides an experimental chamber that simulates conditions in the atmosphere as a balloon ascends from the surface to the stratosphere. The Jülich Ozone Sonde Intercomparison Experiments (JOSIE) have evaluated and improved the performance of the ozone sondes. In 2009 and 2010, JOSIE experiments were conducted to derive transfer functions for different types of sondes to homogenize long term ozone sounding records. The results will be integrated in the new SPARC/IGACO-O3/IOC initiative on “Understanding past changes in the vertical distribution of ozone”.

The Regional Dobson Calibration Centre for WMO RA VI Europe (RDCC-E) at the Meteorological Observatory Hohenpeissenberg (MOHp) is closely co-operating with the Solar and Ozone Observatory at Hradec Kralove (SOO-HK, Czech Republic). It has been responsible for second level calibration and maintenance service of approximately 25 operational Dobson spectropho-

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**Fig. 1: Time and altitude plot of ozone partial pressure from German ozone soundings over Antarctica. Plot by G. König-Langlo, AWI Potsdam.**
tometers in Europe since 1999, including the Antarctic Dobsons at Halley Bay (British Antarctic Survey BAS) and Vernadsky (Ukraine). In October 2009, RDCC further supported the establishment of the Regional Dobson Calibration Centre for WMO RA I Africa, to be run by the South African Weather Service. Increasingly, RDCC has been helping to refurbish RA VI Dobson Instruments and to move them to developing countries outside of RA VI.

1.2. UV-measurements

Apart from the routine UV monitoring activities given in Table 2, the University of Hannover (G. Seckmeyer) has also been involved in WMO activities for the description and standardization of UV measurement systems, most recently filter radiometers and the newly emerging UV array spectrometers. The resulting two WMO-GAW reports No. 190 and 191 are detailed in the reference list under 4.3.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Stratospheric chlorine trend measurements at the IMK and IfU sites (ground-based), as well as balloon-borne measurements from Frankfurt and Heidelberg Universities, indicate declining chlorine since the mid 1990ies. This shows the success of the Montréal protocol. The data from University of Heidelberg and University of Frankfurt show that Bromine has also started to decline in recent years (see Fig. 2).

Ozone trend analyses from IUP Bremen (satellite records, see Fig. 3) and at Hohenpeissenberg (Dobson, see Fig. 4) reveal increasing stratospheric ozone since the late 1990s. Ozone increase in the upper stratosphere (not shown) is a first sign of a beginning ozone recovery, but this is not so clear for the total ozone column and the lower stratosphere. There, dynamical factors like the Arctic Oscillation (AO) contribute majorly to the recently enhanced levels. As Figs. 3 and 4 indicate, 2010 was a year with much higher total ozone than observed in the last 15 to 20 years. This substantial increase in just one year can be attributed to the phase of the QBO in early 2010, and to the extreme negative phase of the AO in much of 2010 (compare Fig. 4).

Fig. 2: Total stratospheric Br from balloon-borne BrO observations (squares) and annual means calculated from ground-based measurements at Harestua (60°N) and Lauder (45°S). The stratospheric data are compared to bromine (ppt) measured at the Earth’s surface, with varying amounts of very short lived Bromine species added (blue lines). Plot by K. Pfeilsticker IUP Heidelberg.
Fig. 3: Evolution of total ozone anomalies since 1979. Plot is based on the merged SBUV/TOMS/OMI MOD V8 data record (1978-1996) and merged GOME1/SCIAMACHY/GOME2 (GSG) record. Anomalies were calculated from area weighted monthly mean zonal mean data in 5° latitude steps, by removing the seasonal mean from the period 1980-2008 (Plot by M. Weber, IUP Bremen).

Fig. 4: Observed annual mean total ozone at Hohenpeissenberg, and multiple linear regression analysis of the magnitude of contributing factors. Top: Black: Observations at Hohenpeissenberg (47.8°N, 11°E). Gray: Multiple linear regression result. Red: Ozone variation attributed to Effective Equivalent Stratospheric Chlorine (EESC). Lower graphs: Ozone variation attributed to the QBO (magenta), to the Arctic Oscillation (AO, blue), to enhanced stratospheric aerosol (green), and to the 11-year solar cycle (orange). Plot by W. Steinbrecht, DWD.
AWI has been instrumental in coordinating MATCH balloon-sonde campaigns for the observation of polar ozone losses. MATCH campaigns have been carried out for over 15 years and are a major component of European and world-wide ozone research. They document the long-term evolution of polar ozone loss over the Arctic. Research and data from both IMK and AWI indicate that the unusually cold Arctic winter vortex of 2010/2011 has resulted in large ozone losses, maybe even exceeding the record losses observed in 2005.

3. THEORY, MODELLING, AND OTHER RESEARCH

State of the art chemistry climate models (CCMs) and chemistry transport models (CTMs) are used in Germany to simulate and understand the past evolution of the ozone layer, and to predict the future. German activities are well interfaced to international programs like the SPARC-CCMVAL activity, which is co-led by DLR staff. ECHAM related model development takes place at MPI-Mainz, MPI-Hamburg, FU Berlin, and at DLR. Models have been used to simulate the decadal trends since the 1960s up to 2100, and have contributed significantly to SPARC CCMVAL and to the WMO Scientific Assessments of Ozone (2006 and 2010). As an example, Fig. 5 shows the evolution of extra-polar total ozone from a model simulation by DLR, which in the past compares very well with observations. ECHAM based state-of-the-art CCMs now give a reasonable reproduction of mean parameters and long-term variability characteristics of the ozone layer.

Scientific studies based on the observations of the Arctic and Antarctic winters 2002 to 2004 and the results of several CTMs and CCMs, e.g. at IMK, showed that downward NOx transport from the mesosphere, from high latitudes, or locally produced NOx due to solar proton events reduces considerably the stratospheric polar winter ozone which can, under certain circumstances, outweigh the impact of heterogeneous chemistry. One of the major results of MIPAS-ENVISAT with respect to polar ozone loss has been the retrieval of a global picture of PSC occurrence in the Antarctic during the last polar winters and comparison with chemistry-climate model simulations. Balloon-borne observations allowed further analysis of the composition of PSC particles, ground based studies analyzed ozone loss in several winters.

At Forschungszentrum Jülich (FZJ) various research activities related to stratospheric ozone are carried out with special emphasis on model simulations. FZJ is using and developing the CLAMS model, and is closely cooperating with AWI, e.g. in the analysis of the MATCH campaigns. All these studies have significantly improved knowledge and understanding of chemi-

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Fig. 5: Extra-polar total ozone anomalies modelled by DLRs E39C model from 1960 to 2050, and observed by various satellite instruments since 1979. Note the chlorine related decline from 1970 to the mid 1990s, the beginning recovery, and the expected super recovery after 2030 due to stratospheric cooling and predicted transport changes (courtesy of M. Dameris, DLR Oberpfaffenhofen).
cal ozone loss processes, especially in the Arctic.

The IUP at the university of Bremen is the PI institute for the SCIAMACHY instrument aboard the ENVISAT satellite. Research is made in the field of ozone and ozone relevant trace gas and aerosol retrievals, but also some modeling and analysis on time-scales ranging from ozone episodes to decadal changes. Scientific support includes validation and for the GOME and SCIAMACHY projects, and the generation of consistent long-term data sets.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

Data are regularly submitted to the data centers at Toronto, Thessaloniki, NILU and NDACC.

4.2 Information to the public

A noteworthy German contribution to WMO’s World Data Centers is the World Data Centre for Remote Sensing of the Atmosphere (WDC-RSAT). WDC-RSAT is hosted by the Cluster for Applied Remote Sensing at the German Aerospace Centre (DLR-CAF). WDC-RSAT offers scientists and the general public free access to a continuously growing collection of atmosphere-related satellite-based data sets and services. WDC-RSAT provides support for many Projects, e.g. the EU-funded MACC project. See http://wdc.dlr.de/ for more information.

BfS and DWD provide the public with UV-information including daily forecasts of the UV-index and warnings. The daily UV-forecasts for clear sky and cloudy conditions are available for free on a global scale: http://orias.dwd.de/promote/index.jsp


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5. PROJECTS AND COLLABORATION

Germany is contributing to the preparation of the WMO ozone assessments. For the last assessments, several lead and co-authors, and many contributing authors came from German institutes.

German institutions also participate in a number of international and EU funded research projects, special measurement campaigns and modeling studies, such as CAWSES, SCOUT-O3, GEMS, MACC, SHIVA and RECONCILE. They play a major role in ESA and EUMETSAT projects.

FZ-Jülich is coordinating RECONCILE and has been carrying out several air-borne campaigns using the HALOX, FISH and CHRISTA-NF instruments. Jülich’s CLAMS – CTM is a key infrastructure for interpreting the measurements, for understanding transport and mixing, the development of PSCs, and for understanding the chemical reactions resulting in ozone loss. Recent key findings are:

- Questions about the photolysis of the ClO Dimer have been resolved. The previous “old” understanding of polar ozone loss has been reconfirmed.
- Even without PSCs, background aerosol at cold temperatures can result in substantial chlorine activation. This has important implications, also for the assessment of geo-engineering schemes.
- Generation and growth of PSC particles must be significantly faster that previously assumed, if we want to explain NOy profiles observed at the end of polar winter.
- Uncertainties in transport and mixing in and around the polar vortex are much larger than is often assumed. This is a key limitation for our ability to precisely determine ozone loss rates in individual winters.

The Institut für Umweltphysik (IUP) at University of Heidelberg coordinates the EU framework 7 project SHIVA (Stratospheric ozone: Halogen Impacts in a Varying Atmosphere), which aims to reduce uncertainties in present and future stratospheric halogen loading and ozone depletion resulting from climate feedbacks between emissions and transport of ozone depleting substances (ODS). In this context, low abundance and very short lived Bromine and Iodine species play an important role. Some key results from IUP Heidelberg are:

- Observations of stratospheric bromine by IUP Heidelberg, in cooperation with the Belgian Institute for Space Aeronomy (BISA) and the National Institute of Water & Atmospheric Research (NIWA), show a positive BrO trend of about +2%/year before 2001, followed by a decline by about -1%/year since 2001.
- Balloon-borne solar occultation spectra of IO and OIO in the tropical UT/LS obtained in 2005 and 2008 yield upper limits for the total gaseous inorganic iodine burden (Iy) of 0.17 to 0.35 ppt in the tropical upper troposphere (16.5 km to 13.5 km) and 0.09 to 0.16 ppt in the tropical lower stratosphere (21.0 km to 16.5 km). These findings complement high and mid-latitude observations indicating upper Iy limits of 0.1 ppt.
- These Bromine and Iodine data have provided valuable input to the recent 2010 WMO/UNEP Scientific Assessment of Ozone Depletion.

The Institut für Meereskunde (IFM-Geomar) at the University of Kiel contributes to several national and EU projects, including TransBrom, SHIVA, HALOCAT, SOPRAN, SOLAS, CCMVal. The Institute measures Bromine species in the Ocean and Marine Boundary layer along large scale ship transects, and models the transport of short lived Bromine into the stratosphere. It also models connections between the solar cycle, the Middle Atmosphere and the Ocean, on decadal and climatic time-scales.

Since 2009, J. Orphal from IMK Karlsruhe has been Chair of the “Absorption Cross Sections of Ozone” International Committee at WMO (WMO/IO3C/IGACO-O3). He has been leading an international initiative to review and recommend improved ozone absorption cross-sections. A new standard has been established and is currently being implemented world-wide (Dobson, Brewer, NDACC, UV-visible satellites ...). This new standard will improve the consistence of all atmospheric ozone measurements in the next decades. A final report will be published in 2011.

MIPAS data from IMK are a very important contribution to many ozone related studies, including monitoring of the ozone content of the polar vortices (compare Fig. 6). MIPAS data are used, for example, in the following international activities:
6. FUTURE PLANS

Generally, German ozone observations and research activities are expected to continue along the indicated lines. Funding is expected to continue from national and European sources and projects, however, with a generally decreasing trend.

FZJ/ICG-1 and IMK together with European partners take the initiative for a new ESA satellite mission PREMIER (PRocess Exploration through Measurements of Infrared and millimeter-wave Emitted Radiation) – to understand processes that link trace gases, radiation, chemistry and climate in the atmosphere.

Future stratospheric ozone related research at IMK, FZJ, and other institutes will be focused on the coupling between changes in stratospheric circulation with ozone chemistry, links between the mesosphere and stratospheric ozone chemistry, e.g. by NOx subsiding from the thermosphere into the mesosphere into the stratospheric polar winter vortex, as well as exploitation of data from new and future instruments (GLORIA, PREMIER) for ozone chemistry.

German modeling activities will continue to focus on the expected evolution of ozone (recovery, super-recovery, tropical decline), but also on the important links with climate change (tropospheric warming, stratospheric cooling, changes in wave driving, possible acceleration of the Brewer Dobson circulation).

Regarding UV, Array instruments (see WMO array document, dosimeters) for UV-Monitoring are becoming more and more useful for UV-Studies in Germany. Especially the Vitamin D question has an increasing new importance.
7. NEEDS AND RECOMMENDATIONS

- Continuing high-quality measurements of total ozone and ozone profiles by satellites on the global scale and by ground-based systems at selected stations have to be insured for the next decades. Without such high-quality data it becomes impossible to follow the expected recovery of the ozone layer from man-made halogens, and to understand the substantial cooling of the stratosphere and warming of the troposphere that are expected over the next decades from man-made climate change.

- The complex coupling of ozone, atmospheric chemistry, transports and climate changes is still not fully understood. Further research is needed to better understand the underlying processes and to improve model predictions of the expected substantial changes in both ozone and temperature distributions of the middle atmosphere.

- In this context, there is a need for better and more consistent long-term temperature data in the stratosphere.

- Quality Assurance/Quality Control activities like calibration centres must be supported to maintain the high quality standards of the ground stations. This is necessary for satellite validation, for ozone monitoring, and for trend analyses.

- Availability of space-borne infrared limb emission instruments after MIPAS (i.e. 2014) is essential for future ozone research.

- In UV research, there is a need not only to concentrate on high UV levels, but also on too low UV levels, e.g. in winter time or a consequence of ozone super-recovery.
INDONESIA

INTRODUCTION
Atmospheric structure of Indonesia is expected very complicated because of it's dynamically effect. Strong convection significantly influences the composition of the atmosphere. This phenomenon is mainly driven by solar insolation. Minor constituents that affect the atmospheric dynamics and thermal distributions are found in abundance. Particularly Indonesian Maritime Continent is the region where trace gas distributions in the troposphere is strongly influenced by deep convection, frequent lightning and biomass burning. Quantitative studies of these processes have been very limited so far in this region because of the lack of simultaneous measurements of key species.

OBSERVATIONAL ACTIVITIES
National Institute of Aeronautics and Space (LAPAN) works in collaboration with other National Institutions: NASA, NOAA, NASDA and Japanese University perform ozone measurements.

Surface ozone measurement
Surface Ozone measurement conducted at 4 Locations, Bandung, Watukosek, Biak and Pontianak. The surface ozone monitor used in this observation is Dylec model 1006-AHJ and model 1150, produced under a license of Dasibi Inc. The air containing the ozone is pumped into sample cell where the measurement is done by using ultraviolet absorption technique. The result is represented in units of ppbv with the resolution of 1 ppbv and recorded on a strip chart or sent directly to PC that is operated as data logger. The cycle time of measurement is about 12 seconds (Anonym, 1985). This instrument was operated automatically 24 hours every day.

The measurements are conducted in Bandung (6.9°S, 107.5°E) West Java, 740 m asl, representing polluted city. Biak (1°S,136°E) Papua, 50 m asl, representing unpolluted area. Pontianak (0.05°N, 109.33°E), West Kalimantan, representing unpolluted area that sometimes influenced by pollution comes from biomass burning / forest fire. Watukosek (7.5°S, 122.6°E), East Java, 50 m asl representing growing urban area.

Column measurements of ozone and other gases/variables relevant to ozone loss

Profile measurements of ozone and other gases/variables relevant to ozone loss
Balloon-borne measurements take place at Watukosek, East Java (7.5°S, 122.6°E, 51 m a.s.l.).

Ozonesondes Since 1998, the Watukosek ozonesonde station was officially accepted into the Southern Hemisphere Additional OZonesondes (SHADOZ) network. Weekly ozonesonde soundings have been conducted on a weekly basis, using ECC ozonesondes. Ozonosondes launches are a collaboration between NASA/NOAA. Kyoto University and the Hokkaido University, Japan.

Vertical ozone measurement is conducted regularly at Watukosek by using balloon borne equipment. The system is set up of an airborne system - ozonesonde payload type RSII-KC79D provided by Meisei Co., ground observation system tracking telemetry signal automatically and data processing system (also data acquisition system) based on personal computer. The important ozonesonde unit is made up of an ozone detector and the dedicated electronics. Ozone data which is converted into audio signal is sent sequentially
with meteorological signals information, i.e. temperature, pressure and references (Anonym, 1979). This payloads were carried aloft using meteorological hydrogen filled rubber balloon (usually 3000 grams) and a protective parachute. Ozone detector is based on Komhyr's carbon iodine ozone-sensor. The operating principle is based on the reaction of ozone to a potassium iodide solution wherein free iodine is liberated. The liberated iodine is measured quantitatively by a coulometrical method (Kobayashi and Toyama, 1966). According to Kobayashi, error of the measurement is estimated to be within ± 2%.

**Water Vapor Measurements**
Since 2001, together with ozone soundings also water vapor soundings have been taken place. Soundings have been conducted annually (usually in December or January) using cryogenic chilled-mirror hygrometers that are flown in combination with ozonesondes. Water vapor soundings are a collaboration between Kyoto University, Hokkaido University and CIERE-University of Colorado/NASA/NOAA.

**UV measurements**
The UV measurements are performed by LAPAN, located at Bandung and Watukosek.

**Broadband measurements**

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**Narrowband filter instruments**
Bandung and Watukosek station is used to measure UV. The UV Sensor measures UV-B irradiances of the UV spectrum (280 nm - 315 nm).

**Spectroradiometers**

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**Calibration activities**
Pre-launch calibration takes place in a regular basis. Vaisala is calibrated at NOAA/CIRESUniversity of Colorado/NASA. Brewer instrument was installed by LAPAN in Bandung (Brewer spectrophotometer MK-IV #116). The instrument was installed in early 1995 and last visited in 2001, but had been out of service for the past 4-5 years. The instrument was found to need a new power supply, micro-board and UV filter in front of photomultiplier tube to get it back into service. This calibration was completed in September 2006 at LAPAN site in Bandung, Indonesia by Ken Lamb, (IOS) with support from the Vienna Convention Trust Fund through the World Meteorological Organization (WMO).

RESULTS FROM OBSERVATIONS AND ANALYSIS

![Fig.1. Typical profiles of ozone concentration observed at Watukosek (Komala, N. et al, 1996)](image)
Fig. 2. Mixing ratio of ozone at Watukosek at three layers (0.2-2 km), (5-10 km) and (12-16 km) which shows peak at 1994, 1997 and also shows peak at 2002.

Fig. 3. The time series of tropospheric column ozone shows an interesting peak in 1994, 1997 and late 2002. The peak value is comparable to those of the 1994 and 1997 events.

Fig. 4. Watukosek Brewer Spectrophotometer #92 data (red dot) compared with TOMS data. Late 1994 and late 1997 show higher total ozone due to the longer dry season and forest fire effect from Sumatra and Kalimantan.
Fig 5. The red circle is total ozone by OMI, and black circle is direct-sun Brewer #116. Simultaneous measurement between direct-sun Brewer #116 and OMI gives different value of total ozone column over Bandung.

Fig 6. Comparison of total ozone between zenith-sky Brewer 116 and OMI data. The zenith-sky total ozone is represented by orange circle, whereas OMI data is represented by brown circle.

Fig 7a. Time series of total ozone (DU) in Indonesia from 1979 to 2010, showing slightly decrease tendency

Fig 7b. Annual variation of total ozone in Indonesia

Fig 7. The trend of long term ozone in Indonesian region derived from SBUV, TOMS and OMI AURA (7a) and annual variation of total ozone in Indonesia (7b).
UV measurements

The UV measurements are performed by LAPAN, located at Bandung and Watukosek. The UV Sensor measures UV-B irradiances of the UV spectrum in the wavelength of 280 nm ~ 315 nm. The UV Index measurement also conducted in Bandung by using AWS (Automatic Weather Station).

Figure 8. Daily UV energy at Watukosek and Bandung in 2007

In Indonesia, UV index levels are normally extreme, as shown in time series of UV Index derived from OMI_AURA data in 2004-2010. Range of UV index in Indonesia usually in between 8 to 15.

Figure 9. Time series of UV index in Indonesian region in the period of 2004-2010 derived from OMI AURA data.

Fig 10. Comparison of the diurnal variation of UV index in Bandung on January and July 2008.
UV index levels in Bandung on January (wet season) show higher compare to July (dry season). Peak of UV index in January show 9 and in July only show 7.

THEORY, MODELLING, AND OTHER RESEARCH
The Ozone Standard Profile was constructed by using the long term observation data of the ozonesonde launchings from Watukosek (surface ~ 20 km). This Watukosek standard profile is used to validate Watukosek ozone profile based on MOZART (Model of Ozone And Related Tracers) output.
There is on-going research on the relationship between ozone, UV radiation and climate with the goal of improving modeling.

DISSEMINATION OF RESULTS
Data reporting
The ozone profile data collected in Watukosek is sent to Hokkaido University, Sapporo, Japan. The data from Hokkaido University is then transferred to the SHADOZ (Southern Hemispheric Additional OZonesondes) archives data: http://croc.gsfc.nasa.gov/shadoz/java.html.
Bandung Brewer Spectrophotometer data is sent to WOUDC, Canada, ftp://ftp.tor.ec.gc.ca

Information to the public
Vertical ozone profile data is made available after every launch on the SHADOZ website for the scientific community.

Relevant scientific papers
- Komala, N., S. Sarasriya, K. Kita, and T. Ogawa, Tropospheric ozone behavior observed in Indonesia, Atmospheric Environment, 30, 1851-1856, 1996.
PROJECTS AND COLLABORATION
The major international collaborations are with Hokkaido University, Kyoto University, CIRES-University of Colorado-NOAA/NASA.
LAPAN has participated in projects:
• Southern Hemisphere ADditional OZonosondes, SHADOZ, financed by NASA, from 01.01.1998 - not yet defined.
• Sounding of Ozone and Water vapor at Equatorial Region (SOWER), financed by Hokkaido University, Kyoto University, CIRES-University of Colorado-NOAA/NASA, from: 01.01.2004 – not yet defined, Through this project we launch regularly ozone and water vapor sondes at Biak (campaign is conducted every January).

FUTURE PLANS
These following activities are planned for the future:
• Continue monitoring vertical ozone profiles under the SHADOZ program,
• Ozone Climatology,
• Continue Monitoring of the water vapor profiles in Biak under SOWER program,
• Continuing and improve the Surface ozone measurements,
• To improve dissemination of the data to the Indonesian community by establishing LAPAN’s own web page.

NEEDS AND RECOMMENDATION
• We need financial support for travelling to attend the meetings, seminars and workshops abroad.
• We recommend to start with an UV network in Indonesia (measurement of UV index). Collaboration research concerning the impact of higher UV-B radiation and depletion of the ozone layer in Indonesia are also needed as a consequence of the equatorial region country.
• Assistance for calibration and maintenance of the instrumentations are needed since they can not be done by Indonesia due to the lack of spare parts and expertise.

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REPUBLIC OF IRAQ
MINISTRY OF NVIRONMENT
IRAQ –NOU

8 / OMR

IRAQ
REPORT

Expert
Tuama Al-helo
Iraqi NOU

MAY 2011
1- Introduction

Over the last 3 decades, Iraq went through several regional and international conflicts as well as political disputes that led to an unprecedentedly political, social and economic situation faced by the country. This led to a situation where Iraq couldn’t be able to cope with many international convention/protocols like Montreal Protocol over the last years. However the government of Iraq started lately, few years ago and in light of the positively developing stability conditions, to consider joining the international community its efforts to combat depletion of the ozone layer and phase-out of ozone depleting substances (ODS). In 25th June 2008; Iraq deposited the accession document for joining the Vienna Convention, the Montreal Protocol and its 4 Amendments where 3 months later it became the 193 party to the Montreal Protocol.

Parties to the Montreal Protocol, at their 20th meeting, recognized the political, economical, security difficulties being faced by Iraq and adopted decision XX/15 urging all parties, secretariats, bilateral and implementing agencies to assist Iraq to meet its challenging obligations toward the protocol.

The Executive Committee (ExCom) of the Multilateral Fund of the Montreal Protocol approved at its 54th and 55th meetings approved preparatory funds to assist Iraq in starting up its institutional setup of establishing a national ozone unit (NOU) and preparing a country programme and national phase-out plan (CP/NPP) addressing the phase out of ODS listed in annexes A & B as well as start preparing an HCFC phase-out management plan (HPMP). UNEP (as LA) & UNIDO (as CA) worked very closely with the government of Iraq, over the period of August 08-April 09 to compile, review, propose and finalize the CP/NPP document in a way that capture all relevant consuming sectors and country’s phase-out requirements.

The CP/NPP of Iraq address as a matter of urgency the CFC, Halon & CTC phase-out requirements as the most urgent forthcoming targets through several policy, training and technical assistance as well as investment activities. Due to the special situation of Iraq, the recent joining to the Montreal Protocol, the absence of historical institutional setup to deal with phase-out activities at the national level and in light of XX/15 decision. The fund requested to the MLF by the government of Iraq for the build up as quick as possible its national capacities, catch with the international phase-out targets and complete tasks described in the NPP is US$ 10,375,698.00 (excluding agencies support costs).

The NPP project will offer a strategic plan, for Iraq; to phase out ODS in both industrial and servicing consuming sectors. The plan introduces comprehensive financial and technical package to the local industries using CFC-11 & CFC-12 in the manufacturing of foam and commercial refrigeration appliances in order
to be able shifting completely to non-CFC options and to, as feasible, low GWP alternative substances/technologies.

The plan will also allow Iraq to build its national regulatory framework in order to control and monitor the trade of ODS, in line with the Montreal Amendment, including the establishment of comprehensive legislation that handle import, export and use of ODS in Iraq.

The project will provide technical support to the refrigeration servicing sector through offering assistance in updating the national technical and vocational curricula, developing codes of practice, upgrade some training facilities with relevant equipment and conduct certified training program on refrigeration good practice and emissions reduction. Recovery & Recycling program is introduced as well to ensure practicing the new good practice acquired skills along with supplementary training on retrofitting existing CFC-based refrigeration & air-conditioning systems particularly MAC units.

Thematic technical assistance components to manage local banks of Halon and to phase-out the use of CTC & CFC -113 in laboratories are other important elements of the NPP of Iraq.

2- Government Action Plan

The Government of Iraq is committed to undertake all necessary steps for achieving the complete phase out in the consumption of ODS by 2010. The scope of the country programme (CP) will address the phase-out of all ODS as per the control measures of the Montreal Protocol. Management Plan (HPMP) which is currently under preparation. The government of Iraq will establish a dedicated Ozone Unit to act as the focal point for monitoring and controlling ODS consumption and managing phase-out activities and projects; implement additional policy measures to control the manufacturing and importing of any ODSs and ODS-based equipment; prohibit the establishment of new enterprises consuming, producing and/or assembling equipment and products using ODSs and implement relevant projects including the National Phase-out Plan (NPP) of Iraq.

3- Difficulties faced by Iraq as a new Party

Over the last 3 decades, Iraq went through several regional and international conflicts as well as political disputes that led to an unprecedentedly political, social and economic situation faced by the country starting with the 8 years conflict between Iran & Iraq followed with the conflict with Kuwait (Gulf War 1991) and going through a 12 years of international comprehensive sanctions ended with the 2003 conflict. Those circumstances offered a unique platform for Iraqis to
manage their day-to-day life and securing basic supplies that is needed for the continuation of basic social/economic activities in a country that 67% of its population live in urban societies.

Therefore, parties to the Montreal Protocol, at their 20th meeting in Doha adopted a supportive decision (XX/15) which notes with appreciation Iraq’s joining the international community in its efforts to preserve the ozone layer, which came into effect with the recent accession of Iraq as a Party to the Vienna Convention, the Montreal Protocol and all its amendments, recognizes also the difficulties faced by Iraq by joining the Vienna Convention and the Montreal Protocol and all its amendments shortly before key phase-out dates, recognizes, as well, the security situation and the political, economic and social difficulties faced by Iraq over the last two decades and understands Iraq’s commitments for phasing out ozone-depleting substances under the Montreal Protocol and its amendments within a limited time frame.

To request the Implementation Committee to report on the compliance situation of Iraq to the Open-ended Working Group preceding the Twenty-Third Meeting of the Parties, during which the present decision will be reconsidered, This decision introduces a good basis for parties, secretariats and implementing agencies to provide timely and sufficiently support to Iraq to enable the country catching with the international efforts to phase-out ODS without negative economic and social consequences on Iraq. CP/NPP proposal is considered to be crucial for Iraq to meet its obligations under the Montreal Protocol particularly 2010 obligations which entail a very difficult task for a party joined MP in 2008.
4- **Historical and Current consumption of ODS in Iraq (in MT)**
*Including data of base years and base-line years as well as country official population*

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<td>28810</td>
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**Annex A- G I**

<table>
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<tr>
<th>CFC-11</th>
<th>939.6</th>
<th>631.2</th>
<th>631.2</th>
<th>631.2</th>
<th>292.3</th>
<th>356.4</th>
<th>342.5</th>
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<tbody>
<tr>
<td>CFC-12</td>
<td>822.9</td>
<td>913.0</td>
<td>867.7</td>
<td>868.4</td>
<td>1,117.1</td>
<td>1,320.2</td>
<td>1,244.6</td>
<td>413.66</td>
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<tr>
<td>CFC-113</td>
<td>0.03</td>
<td>0.02</td>
<td>0.03</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.027</td>
<td>0.0</td>
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<tr>
<td>CFC-115 (R502)</td>
<td>4.61</td>
<td>4.6</td>
<td>4.6</td>
<td></td>
<td>7.9</td>
<td>15.9</td>
<td>16.6</td>
<td>18.10</td>
</tr>
</tbody>
</table>

**Annex A- G II**

| Halon 1211 | 8.0 | 3.3 | 2.0 | 1.8 |       |       | 2.2   | 2.0   | 2.7   | 0.0   |
| Halon 1301 | 14.0| 5.6 | 4.8 | 6.2 |       |       | 3.8   | 2.3   | 3.1   | 0.0   |
| Halon 2402 | 9.0 | 0   | 4.0 | 0   |       |       | 2.0   | 0.0   | 0.0   | 0.0   |

**Annex B- G II**

| CTC    | 20.0 |       | 18.4 | 20.3 | 19.6 | 5.474 | 5.482 | 4.2 | 0.98 |

**Annex B- G III**

| TCA (MCF) | 0.2 |       | 0.2  | 0.2  | 0.2  | 0.1  | 0.2  | 0.2  | 0.05 |

**Annex C- G I**

| HCFC-22 | 830.8 |       | 1,735.8 | 1,989.5 | 1938.2 | 1780.67 |

**Annex E**

| MeBr     | 21.0 | 9.0 | 6.0 | 6.0 | 9.5 | 8.0 | 8.0 | 14.0 | 9.7 | 8.3 | 5.3 |
5- ODS Consumption & Consuming Sectors in Iraq

The majority of ODS consumption in Iraq, as in other Article 5 countries, lies in the refrigeration and air-conditioning sectors with considerable amount of CFC-11 still utilized in the foam manufacturing sector. The refrigeration/air-conditioning servicing sector consumes the majority of CFC-12 where around 5% of CFC-12 consumption is used for the manufacturing of domestic and light commercial refrigeration appliances (domestic refrigerators and water-coolers). No CFC uses for Aerosol manufacturing applications were found. The use HCFC particularly HCFC-22 mostly falls in the servicing of refrigeration and air-conditioning applications. However some amounts are used for the manufacturing of HCFC-22 based air-conditioning appliances. Similarly, the survey couldn’t identify any use of other HCFCs for foam manufacturing applications. The HCFC sector will be resurveyed in depth during the preparation of the HPMP of Iraq. Iraq still imports small amounts of Halon mainly to maintain existing old installations particularly in the Oil sector. Solvents are mainly used for laboratory purposes while MeBr is used with small amounts mostly for the date sector. Below table illustrate these sectoral consumption in Iraq:-
** CTC consumption includes feedstock data; country will correct this figure through official communication with the Ozone Secretariat. Actual consumption is the laboratories uses included in the Technical assistance Project for Solvents.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Foam</th>
<th>Fire Fighting</th>
<th>Refrigeration</th>
<th>Methyl bromide</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex A, Group I</td>
<td></td>
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</tr>
<tr>
<td>CFC-11</td>
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<td></td>
<td>11.10</td>
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<td>67.10</td>
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<tr>
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<td>498.85</td>
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<tr>
<td>Halon 1211</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Halon 1301</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Halon 2402</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Sub-Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Annex B, Group II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td></td>
<td></td>
<td>0.98</td>
<td></td>
<td>0.98</td>
</tr>
<tr>
<td>Sub-Total</td>
<td></td>
<td></td>
<td>0.98</td>
<td></td>
<td>0.98</td>
</tr>
<tr>
<td>Annex B, Group III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl chloroform</td>
<td></td>
<td></td>
<td>0.05</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Sub-Total</td>
<td></td>
<td></td>
<td>0.05</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Annex C, Group I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCFC-22</td>
<td>35.16</td>
<td>1745.51</td>
<td></td>
<td></td>
<td>1780.67</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>35.16</td>
<td>1745.51</td>
<td></td>
<td></td>
<td>1780.67</td>
</tr>
<tr>
<td>Annex E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl bromide</td>
<td></td>
<td></td>
<td></td>
<td>5.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Sub-Total</td>
<td></td>
<td></td>
<td></td>
<td>5.3</td>
<td>5.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>56</td>
<td>0.00</td>
<td>67.82</td>
<td>2155.7</td>
<td>1.03</td>
</tr>
</tbody>
</table>

** **
6- Monitoring and Reporting Arrangements

Monitoring of consumption will be carried out through a licensing system which to be issued as described in the policy/legislation component, obtaining data from importers and crosschecked against Customs import/export database.

The NOC/NOU is responsible for compiling and analysing information from all sources and submitting the following:

- Annual reports on ODS consumption to the Ozone Secretariat, as per the requirements of Article 7 of the Montreal Protocol;
- Annual reports on progress of implementation of Country Programme to the Multilateral Fund Secretariat as per decision of the 10th meeting of the Executive Committee of the Multilateral Fund;
- Project related reporting to respective Implementing Agencies.

7- SUB-PROJECT TITLES

<table>
<thead>
<tr>
<th>No</th>
<th>Project Title</th>
<th>Implementing Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establishing and enforcement ODS legislation &amp; curbing illegal trade</td>
<td>UNEP</td>
</tr>
<tr>
<td>2</td>
<td>Refrigeration Training &amp; Certification</td>
<td>UNEP</td>
</tr>
<tr>
<td>3</td>
<td>Technical Assistance to the Servicing Sector</td>
<td>UNIDO</td>
</tr>
<tr>
<td>4</td>
<td>Halon Management Programme in Iraq</td>
<td>UNIDO</td>
</tr>
<tr>
<td>5</td>
<td>Technical Assistance for the phase-out CTC, TCA &amp; CFC-113 Solvents in the Laboratories Sector in Iraq</td>
<td>UNIDO</td>
</tr>
<tr>
<td>6</td>
<td>Umbrella Project for the phase-out of CFC-11 in the Foam manufacturing sectors</td>
<td>UNIDO</td>
</tr>
<tr>
<td>7</td>
<td>Umbrella Project for the phase-out of CFC-12 in the commercial refrigeration manufacturing sector</td>
<td>UNIDO</td>
</tr>
<tr>
<td>8</td>
<td>Implementation, Management and Monitoring of the Project</td>
<td>UNEP</td>
</tr>
</tbody>
</table>

8- RECOMMENDATIONS AND NEEDS :-

* The exact breakdown of HCFC consumption will be resurveyed and presented in depth during the preparation of HPMP.
Because of Iraq's accession to the Vienna Convention and Montreal Protocol in mid-2008 and the instability of political and security situation, didn't give Iraq the opportunity to work researches in the field of atmospheric ozone. So there are no:

- Stations for measuring the amounts of B-UV radiation reach to the ground
- Stations to monitor changing in the Ozone hole.

These require technical and financial assistance from the developed States Parties in the Vienna Convention and Montreal Protocol to Iraq and help us to develop the capabilities of Iraqi experts and researchers for the purpose of conducting researches and studies in this field.

That means Iraq needs the following:

- Scientific research on environmental impacts of increased UV due to the ozone depletion in different parts of the country covering effects of UV radiation on: (human health, Terrestrial and aquatic ecosystems, Biogeochemical cycle, Air quality and Materials)
- Build a "data networking system" for Iraqi Meteorological Organization as it is an important component and provide ozone/UV monitoring system.
- Atmospheric Modeling is another area of interest that requires professional training and advanced hardware and software facilities.
- Build an atmospheric research center and this requires advanced equipments, and networking systems for research programs on the UV/Ozone analysis and impacts. And national UV Observation and Monitoring Network.
- Organization of regional and national training workshops for officials and experts for relevant UV/Ozone monitoring organizations and public seminars on ozone/UV changes and its effects on terrestrial life.
1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss

The Japan Meteorological Agency (JMA) carries out total column ozone and Umkehr measurements at four sites in Japan (Sapporo, Tsukuba, Naha and Minamitorishima) and at Syowa Station in Antarctica (Table 1). A Brewer spectrophotometer is used for measurements at Minamitorishima, whereas Dobson spectrophotometers are used at the other observation sites.

Table 1. Locations of column ozone and Umkehr measurement sites operated by JMA

<table>
<thead>
<tr>
<th>Observation site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Altitude (m)</th>
<th>WMO station number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapporo</td>
<td>43° 04’ N</td>
<td>141° 20’ E</td>
<td>26</td>
<td>47412</td>
</tr>
<tr>
<td>Tsukuba</td>
<td>36° 03’ N</td>
<td>140° 08’ E</td>
<td>31</td>
<td>47646</td>
</tr>
<tr>
<td>Naha</td>
<td>26° 12’ N</td>
<td>127° 41’ E</td>
<td>28</td>
<td>47936</td>
</tr>
<tr>
<td>Minamitorishima</td>
<td>24° 17’ N</td>
<td>153° 59’ E</td>
<td>9</td>
<td>47991</td>
</tr>
<tr>
<td>Syowa</td>
<td>69° 00’ S</td>
<td>39° 35’ E</td>
<td>22</td>
<td>89532</td>
</tr>
</tbody>
</table>

Concentrations of ozone-depleting substances and other constituents are monitored by the Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES) and by JMA. The monitoring sites are listed in Table 2. CGER/NIES monitors halocarbons (CFCs, CCl4, CH3CCl3 and HCFCs), HFCs, surface ozone, CO2, CH4, CO, N2O, NOx, H2, O2/N2 ratio, and aerosols at remote sites (Hateruma and Ochiishi). JMA measures surface concentrations of ozone-depleting substances (CFCs, CCl4 and CH3CCl3) and other constituents (surface ozone, CO2, N2O, CH4 and CO) at Ryori, a Global Atmosphere Watch (GAW) Regional Station in northern Japan. Monitoring of concentrations of surface ozone, CO2, CH4 and CO is also carried out at Minamitorishima (a GAW Global Station) and Yonagunijima (a GAW Regional Station in the Ryukyu Islands).
The Japanese Ministry of the Environment (MOE) monitors concentrations of halocarbons (CFCs, CCl₄, CH₃CCl₃, halons, HCFCs and CH₃Br) and HFCs at remote sites (around Wakkanai and Nemuro) and at an urban site (Kawasaki).

Table 2. Locations of monitoring sites for ozone-depleting substances and other minor constituents

<table>
<thead>
<tr>
<th>Monitoring site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Altitude (m)</th>
<th>Since</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ochiishi</td>
<td>43° 10’N</td>
<td>145° 30’E</td>
<td>45</td>
<td>Oct 1995</td>
<td>CGER/NIES</td>
</tr>
<tr>
<td>Hateruma</td>
<td>24° 03’N</td>
<td>123° 49’E</td>
<td>10</td>
<td>Oct 1993</td>
<td>CGER/NIES</td>
</tr>
<tr>
<td>Ryori</td>
<td>39° 02’N</td>
<td>141° 49’E</td>
<td>260</td>
<td>Jan 1976</td>
<td>JMA</td>
</tr>
<tr>
<td>Minamitorishima</td>
<td>24° 17’N</td>
<td>153° 59’E</td>
<td>8</td>
<td>Mar 1993</td>
<td>JMA</td>
</tr>
<tr>
<td>Yonagunijima</td>
<td>24° 28’N</td>
<td>123° 01’E</td>
<td>30</td>
<td>Jan 1997</td>
<td>JMA</td>
</tr>
<tr>
<td>Syowa</td>
<td>69° 00’S</td>
<td>39° 35’E</td>
<td>18</td>
<td>Jan 1997</td>
<td>JMA</td>
</tr>
</tbody>
</table>

JMA also monitors CFCs, CO₂, N₂O and CH₄ concentrations in both the atmosphere and seawater of the western Pacific onboard the research vessels Ryofu Maru and Keifu Maru.

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

1.2.1 Ground-based and sonde measurements

Since October 1990, CGER/NIES has measured vertical profiles of stratospheric ozone over NIES in Tsukuba with an ozone laser radar (ozone lidar). After comparison with JMA ozone sonde data and Stratospheric Aerosol and Gas Experiment II (SAGE II) ozone profiles, the ozone lidar data were accepted by the Network for the Detection of Atmospheric Composition Change (NDACC) and registered in the NDACC database. CGER/NIES began measuring vertical profiles of ozone with millimetre-wave radiometers in September 1995 at Tsukuba and in March 1999 at Rikubetsu. JMA has been monitoring the vertical ozone distribution weekly by ozone sonde at three sites in Japan and at Syowa Station in Antarctica. The ECC type ozone sonde succeeded the KC type in October 2008 at Naha, in November 2009 at Sapporo and Tsukuba, and in March 2010 at Syowa. The KC sonde was developed by JMA and has been used in Japan since the 1960s.
1.2.2 **Airborne measurements**

In February 2011, JMA began taking monthly (approx.) airborne in situ measurements of CO$_2$, CH$_4$, CO and N$_2$O concentrations at an altitude of about 6 km along the flight path from Tokyo area to Minamitorishima.

1.2.3 **Satellite measurements**

Ozone-layer depletion in high-latitude regions was monitored with the Improved Limb Atmospheric Spectrometer (ILAS), a satellite-borne solar-occultation sensor, from August 1996 to June 1997. ILAS-II (the successor to ILAS) was used to measure concentrations of minor constituents associated with polar ozone depletion from April to October 2003. These data were processed and analyzed at NIES. Version 6.1 ILAS data, which include O$_3$, HNO$_3$, NO$_2$, N$_2$O, CH$_4$, H$_2$O, ClONO$_2$, CFC-12 and aerosol extinction coefficients, were released in 2005. Version 2 ILAS-II data, including O$_3$, HNO$_3$, N$_2$O, CH$_4$, H$_2$O, ClONO$_2$ and aerosol extinction coefficients, were released in February 2008.

The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) was developed for deployment in the Japanese Experiment Module (JEM) on the International Space Station (ISS) through the cooperation of the Japan Aerospace Exploration Agency (JAXA) and the Japanese National Institute of Information and Communications Technology (NICT). SMILES was successfully launched by an H-IIB rocket with the H-II Transfer Vehicle (HTV) on 11 September 2009 (all dates are JST). It was attached to the JEM on 25 September and began atmospheric observations on 12 October. The mission objectives are (1) to demonstrate the viability in the outer space environment of a 4-K mechanical cooler and superconducting mixers for submillimetre limb-emission sounding in frequency bands 624.32–626.32 GHz and 649.12–650.32 GHz and (2) to take global measurements of atmospheric concentrations of minor constituents (O$_3$, HCl, ClO, HO$_2$, HOCl, BrO, O$_3$ isotopes, HNO$_3$, CH$_3$CN, etc.) in the middle atmosphere to gain a better
understanding of the factors and processes, including climate change, that control the amounts of stratospheric ozone.

Unfortunately, SMILES observations have been suspended since 21 April 2010 owing to the failure of a critical component in the submillimetre local oscillator. Until operations were suspended, SMILES was recording global observations at about 100 locations per ISS orbit, except when other ISS operations took precedence. Processing of SMILES data provides global and vertical distributions of about 10 atmospheric minor constituents related to ozone chemistry, which contribute to resolving a number of current issues in atmospheric science.

1.3 UV measurements

1.3.1 Broadband measurements

CGER/NIES has been monitoring surface UV-A and UV-B radiation using broadband radiometers at four observation sites in Japan since 2000. CGER calculates the UV Index from the observed data and makes it available hourly to the public via the Internet.

1.3.2 Spectroradiometers

JMA monitors surface UV-B radiation with Brewer spectrophotometers at Sapporo, Tsukuba and Naha in Japan and at Syowa Station in Antarctica. Observations commenced in 1990 at Tsukuba and in 1991 at the other sites.

1.4 Calibration activities

JMA has operated the Quality Assurance/Science Activity Centre (QA/SAC) and the Regional Dobson Calibration Centre (RDCC) under the GAW programme of the World Meteorological Organization (WMO) to contribute to improving the quality of ozone observations in WMO Regional Associations II (Asia) and V (South-west Pacific). The Regional Standard Dobson instrument (D116) is calibrated against the World Standard instrument (D083) every three years. The most
recent calibration was in 2010 at Mauna Loa, Hawaii, USA. Through the QA/SAC, a JMA expert visited the ozone observatory in Manila in April 2010 to calibrate the Dobson spectrophotometer there and provide training in measurement and maintenance of the instruments used there to monitor the ozone layer. JMA supported installation of automated observation systems for Dobson instruments at NOAA/ESRL, Boulder (May 2009), at Mauna Loa (June 2010), at the Bureau of Meteorology, Melbourne, Australia (August 2010), and at the National Meteorological Service, Buenos Aires, Argentina (November 2010).

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozone mixing ratios measured with the millimetre-wave radiometer at Rikubetsu Station from November 1999 to June 2002 agreed well with ozone sonde data from Sapporo and satellite data from the Halogen Occultation Experiment (HALOE).

Trend analysis (eliminating solar activity and quasi-biennial oscillation (QBO) components) of ozone concentrations recorded between 30 and 40 km altitude by laser radar at NIES, Tsukuba, show a significant decreasing trend from 1988 to 1997 (−6.0 percent per decade), but no significant trend after 1998.

Trend analyses for total ozone concentrations at three sites (Sapporo, Tsukuba and Naha), eliminating solar activity and QBO, have shown an overall decrease of total ozone during the 1980s but, in spite of large year-to-year variations, either no significant change or slight increasing trends since the mid-1990s. Vertical profiles from Umkehr and ozone sonde measurements show reduced ozone levels at altitudes of about 20 and 40 km from 1979 to 2009 at Sapporo and Tsukuba, but an increasing trend at altitudes of less than 15 km from 1998 to 2009 at Naha.

Significant increasing trends in erythemal UV measurements have been observed at three sites in Japan (Tsukuba, Naha and Sapporo) since JMA started monitoring UV radiation in the early 1990s. The increasing trend diminished in early 2000s at Tsukuba and Naha, but continues at Sapporo. The increase of erythemal UV radiation since 1990 cannot be attributed to a reduction of ozone
levels because they ceased to decline after the mid-1990s.

3. THEORY, MODELLING AND OTHER RESEARCH

The Centre for Climate System Research (CCSR, now the Division of Climate System Research within the Atmosphere and Ocean Research Institute), the University of Tokyo and NIES developed a chemistry–climate model (CCSR/NIES CCM). JMA’s Meteorological Research Institute (MRI) independently developed another chemistry–climate model (MRI-CCM). Both the CCSR/NIES and the MRI groups participated in the second round of the Chemistry–Climate Model Validation Activity (CCMVal-2) of the Stratospheric Processes and their Role in Climate (SPARC) programme, and contribute to comparisons between and improvement of CCMs, leading to a better understanding of the individual strengths of these models. The CCSR/NIES and MRI CCMs were used to simulate the recent past and future evolution and global distribution of the stratospheric ozone layer by using concentrations of greenhouse gases and ozone depletion substances as recommended by CCMVal-2. The results of the simulations were published in the SPARC-CCMVal Report (2010). Scientific papers based on the outcome of the simulations were published in a special issue of the Journal of Geophysical Research, and will be published in the WMO Ozone Assessment Report 2010. The distribution of chemical species of the CCSR/NIES CCM was used as a priori data for processing of SMILES data.

NIES is developing a new version of its CCM with T42 horizontal resolution, constructed on the MIROC 3.2 AGCM, which was used for future projections of climate for the IPCC fourth Assessment Report. This model has a new radiation code that greatly reduces the problem in the previous model of cold bias in the tropical upper troposphere/lower stratosphere. The new CCM incorporates more stratospheric water vapour than the previous version and better represents observed data. The new CCM is also used as a three-dimensional chemical transport model (CTM) in which temperature and wind velocity data are assimilated into the calculated fields in the model using a nudging method. The model simulates the global distribution of chemical species observed
JMA's MRI has developed both a CTM and CCM for study of stratospheric ozone. A prominent feature of the MRI-CCM is that QBO, which plays a crucial role in inter-annual variations in the stratosphere, is spontaneously reproduced for wind and ozone in the tropical stratosphere by a T42L68 version that has about 300 km of horizontal resolution and 500 m of vertical resolution in the stratosphere. The MRI-CCM has been used at JMA to simulate ozone distributions by incorporating total ozone data from Total Ozone Mapping Spectrometers (TOMS) and Ozone Monitoring Instruments (OMI) and has produced ozone forecasts for several days. The ozone distributions calculated are used to monitor variations in total and stratospheric ozone, as well as for a UV forecast service. MRI-CCM is also used for research on the effect of the ozone layer on climate, as well as for predictions of the future state of the ozone layer.

The MRI-CCM has been further developed (MRI-CCM2) by incorporating tropospheric chemistry to provide a seamless chemistry module from the Earth's surface to the top of the model at about 80 km altitude. MRI-CCM2 is an important component of the MRI earth-system model, which includes the ocean, atmosphere, cryosphere and biosphere.

ILAS and ILAS-II data have been used extensively to elucidate in detail the chemical and physical processes related to ozone layer depletion in polar regions, such as polar stratospheric cloud (PSC) formation, denitrification, chemical ozone loss rates and partitioning among chlorine species.

The effects of enhanced UV-B radiation on terrestrial plants are being studied by NIES, which has developed a novel method of detecting plant UV-B stresses by identifying mRNA expression changes by cDNA macroarray analysis. This method illustrates shifts in gene expression in response to stressors such as drought, salinity, UV-B, low temperature, high temperature, acid rain and photochemical oxidants. Changes in gene expression patterns after UV-B stress accord well with those after ozone exposure, suggesting that physiological responses to UV-B in plant cells may include active oxygen species. UV-B directly damages macromolecules such as proteins and...
nucleic acids. DNA damage due to UV-B is thought to not only impede DNA replication and gene expression but also lead to mutations. NIES identified that the repair system for UV damaged DNA is controlled by UVB-driven transcriptional activation of the repair enzyme.

4. **DISSEMINATION OF RESULTS**

4.1 **Data reporting**

NIES and the Solar-Terrestrial Environment Laboratory (STEL) of Nagoya University have established stations at Tsukuba and Rikubetsu with NDACC instruments, including lidars, millimetre-wave radiometers and FTIR spectrometers. Some of the activities of these organizations have been incorporated into NDACC measurements in Japan. Reanalyzed NIES ozone lidar data are registered in the NDACC database every year. Vertical profiles of ozone recorded by the NIES/STEL lidar have been used to validate ENVISAT data such as SCIAMACHY, MIPAS and GOMOS.

Observational data acquired at JMA's stations are submitted monthly to the World Ozone and UV Data Centre (WOUDC) in Toronto, Canada. Provisional total ozone data are also delivered daily on the Character Form for the Representation and Exchange of Data (CREX) through the WMO Global Telecommunication System (GTS), and used at the WMO Ozone Mapping Centre in Thessaloniki, Greece, to map the total ozone distribution over the Northern Hemisphere. In the Antarctic winter and spring seasons, total ozone and ozone sonde data acquired at Syowa Station are submitted weekly to the WMO Secretariat for incorporation in Antarctic Ozone Bulletins.

4.2 **Information to the public**

An annual report on the state of the ozone layer, surface UV-B radiation and atmospheric concentrations of ozone-depleting substances is published by the Japanese MOE.

Data summaries of JMA's total ozone, ozone sonde and UV-B measurements are published monthly on the Internet. An annual report that includes detailed trend analyses of ozone over
Japan and the globe is also published for both government and public use. Since 2005, JMA has been providing an Internet UV forecast service (in the form of an hourly UV-index map) based on UV-B observations and ozone forecast modelling techniques. Analytical UV maps and quasi-real-time UV observations are also posted hourly on the website.

4.3 Relevant scientific papers

The MOE supports research on global environmental changes (including ozone layer depletion) through the GERF, and their results are published in their Annual Summary Reports.

5. PROJECTS AND COLLABORATION

As a GERF-funded activity, a project named *Studies on the Variability of Stratospheric Processes and Uncertainties in the Future Projection of Stratospheric Ozone* is being jointly undertaken by NIES, CCSR, Hokkaido University and Miyagi University of Education. Some highlights of the results of this project are as follows.

(1) Tropical lower stratospheric water vapour at 19–21 km altitude was high and increasing in the 1990s, low between 2000 and 2003, and then increased to the level of late 1990s in the mid-2000s.

(2) Gravitational separation in the stratosphere has been identified for the first time from analyses of O$_2$ and N$_2$ isotopes in individual air samples.

(3) A set of high-quality CO$_2$ and SF$_6$ observations from the middle stratosphere of the Northern Hemisphere mid-latitudes suggest that the age of air in this region has been relatively constant since 1975.

(4) Numerical experiments using the CCSR/NIES CCM showed that ozone recovery to the 1980 level was advanced by at least 10 years in response to future increases of GHGs, but the size of the advance was dependent on latitude.

(5) Analyses of observation data and CCSR/NIES CCM outputs indicate that the ozone hole
influences the timing of the Antarctic polar vortex breakup in austral spring.

JMA's Aerological Observatory has developed an automated Dobson measuring system that reduces the burden on the operator and improves data quality (described on the JMA web site at http://gaw.kishou.go.jp/wcc/dobson/windobson.html). JMA has provided technical support to some foreign organizations interested in introducing this automated Dobson system.

6. FUTURE PLANS

JMA has commenced archiving historical raw ozone records (e.g., R-values and related calibration information) from Dobson spectrophotometers at Sapporo, Tsukuba, Naha and Syowa. Archiving is planned for completion by 2013, which will allow retrospective re-evaluation and reprocessing of historical ozone records in view of changes such as those of ozone absorption cross sections.

Ongoing monitoring of levels of ozone, water vapour and other species near the tropical tropopause will continue to improve our understanding of the role of the tropical transition layer in chemistry–climate interactions. Precise measurements of the concentrations of trace gases in the stratosphere will continue to provide key information on physical, chemical and dynamic processes in the stratosphere. For example, precise monitoring of trace gases in the middle atmosphere enables identification of variability in the mean age of air and evaluation of the ability of current models to reproduce changes in dynamic atmospheric processes.

Development and improvement of CCM and CTM numerical models will continue, which will allow better prediction of future changes to the ozone layer and improve our understanding of the mechanisms of the chemistry–climate interaction. A regular CCM update based on the newest global circulation model would be necessary for research of climate–chemistry interaction.

7. NEEDS AND RECOMMENDATIONS

Processing and reporting to WOUDC of a long record of unprocessed Brewer Umkehr data from Minamitorishima are needed. For Brewer instruments, a selection method for cloud-free “good"
data from unattended observations is needed as are side-by-side comparisons with Dobson instruments.

Systematic observations to evaluate the changing state of the ozone layer, including detection of ozone layer recovery, should be continued in cooperation with international monitoring networks such as NDACC and the WMO/GAW programme.

Integration of stratospheric and climate models is desirable to allow more precise prediction of future changes in the ozone layer. The interactions between climate change and ozone layer depletion and changes in the ozone layer in the post-CFC period due to emissions of CH₄, H₂ and N₂O need to be assessed. Studies on chemical and dynamic processes, including the formation of PSCs and denitrification mechanisms, cross-tropopause transport and the ozone budget near the tropopause region should also be continued. Re-evaluation of chemical reaction data, including photochemical data for stratospheric modelling, is urgently required to resolve discrepancies between observations and model calculations.

A systematic calibration program and well-coordinated monitoring network should be established to detect variations and long-term trends in ground-level UV radiation.

Studies on the effects of increased UV radiation on human health, ecosystems, air quality and biogeochemical cycles are strongly recommended, especially the effects of increased UV radiation under rising temperature conditions.
INTRODUCTION
The International Conference on Tropical Ozone and Atmospheric Change held in Penang, Malaysia in February 1991 underscored the lack of atmospheric ozone measurements and research in the equatorial region. Realizing the importance of developing countries in the tropics to play a more important role in the global initiatives to achieve a better understanding of the atmospheric changes and the effects on the environment linked to ozone changes, Kenya has initiated its active involvement in the World Meteorological Organization (WMO) Global Ozone Observing System (GO3OS) with the launching of its ozone monitoring programme in 1984. The ozone monitoring programme involves monitoring of ozone concentrations at the surface, the vertical profile and total column ozone in the atmosphere.

OZONE MONITORING ACTIVITIES (CURRENT STATUS)
Kenya has three ozone monitoring stations with one dormant station namely:
- Mount Kenya Global GAW station
- Nairobi Regional GAW station
- Chiromo urban air pollution monitoring station.
- San Marco Equatorial Site (SMES) under SHADOZ project.

(A) Mount Kenya GAW station
The Global GAW station Mt. Kenya (MKN), management by Kenya Meteorological Department, is located at high altitude (Altitude: 3678m a.s.l, Longitude: 37.297° East, Latitude: 0.062° South,) in equatorial Africa. This location provides a unique opportunity to monitor background air as well as to conduct research in a data-sparse region of the world.

The stations is equipped with one ozone analyzer (TEI 49C). The instrument was initially calibrated at WCC-Empa. Consistent measurements of surface ozone started in May 2002 at MKN, and time series are available since then. All comparisons were done according to Standard Operating Procedures. Data is regularly checked for consistency with time series plots, and submitted to QA/SAC Switzerland. QA/SAC continues to work with the station operators to transfer the responsibility of data evaluation to Kenya meteorological department staff. Ozone data have been submitted to the World Data Centre for Surface Ozone at JMA (WDCGG). The submitted data sets currently span the period from June 2002 to May 2006.
Mt. Kenya Ozone and Carbon Monoxide Time Series

The station also monitors N₂O (Flask sampling) and CH₄ (Picarro G1301) which are both GHGs and ODSs.

(B) Nairobi Regional GAW station
The Nairobi Regional GAW station is managed by Kenya Meteorological Department. It is located close to the equator (Altitude: 1795m asl, Latitude: 1.30 S, Longitude: 36.75 E) in Eastern Africa, and corresponds to a unique site location for the detection of ozone in tropical region.

Nairobi ozonesonde observatory, that measures the vertical profile of ozone, has been in operation since 1996. It uses a Lightweight, balloon-borne instrument mated to a conventional meteorological radiosonde. It has an electrochemical concentration cell (ECC) that senses ozone as it reacts with a dilute solution of potassium iodide to produce a weak electrical current proportional to the ozone concentration of the sampled air. During its ascent through the atmosphere, the ozonesonde transmits ozone and standard meteorological quantities to the ground receiving station. These measurements are performed ones per week and submitted to Switzerland.

Nairobi regional GAW station also measures the total column of ozone using Dobson spectrophotometer number 18 since 2005. However, these measurements started at the University of Nairobi in 1984 until 2005 when the instrument was transferred to Kenya Meteorological Department.
(C) Chiromo urban air pollution monitoring station

The urban air pollution monitoring station was established at the University of Nairobi in 2009. It measures surface one using TEI 49C instrument. The station was started by Kenya Meteorological Department in realization of one of its core function of monitoring environmental pollution and Greenhouse Gases for air quality assessment & climate change detection and attribution over Kenya.

(D) San Marco Equatorial Site (SMES) in Malindi

San Marco equatorial site in Malindi, Kenya (3S, 40E) was incorporated in the SHADOZ Project in 1999 through the sponsorship/partnership with the CRPSM (Centro Ricerche Progetto San Marco) department at the University of Rome ‘La Sapienza’, along with local Kenyan support staff who generally coordinates weekly sonde launches. Archive data is available from March 2001.

The station has an elevation just below sea-level (-6m) which is ideal for studying the retrieval of lower tropospheric ozone. Nairobi, Kenya which is situated approximately 300 km from Malindi (3S, 40E) has an elevation approximately 1.8 km above sea level and excludes the lowermost part of the troposphere. The Malindi site therefore offers a good ozone comparison with Nairobi profiles.
FUTURE OZONE MONITORING PLAN
Kenya Meteorological Department plans to implement the National Flagship Programmes under Kenya’s Vision 2030 which include establishment of climate monitoring stations for air pollution monitoring and climate change detection. Indeed, one station has been established at the University of Nairobi, Chiromo Campus that measures ozone and carbon monoxide. The Meteorological Department plans to establish expand the station by purchasing new instruments and establishing several more stations in the country that will monitor, among other pollutants, ozone.

There is needs to secure the financial support to continue long-term monitoring activities (including calibration of instruments, necessary equipment for ozone soundings, UV instruments and associated software upgrades) and data archiving and dissemination services.

OZONE EXISTING RESEARCH
Currently, we do not have any major ozone research activities in progress. However, several researches on ozone are being conducted by University students at both under graduate and post graduate level. Several researches based on ozone have been conducted in Kenya.

Since Mount Kenya GAW station is at high attitude, the site experiences thermally induced wind systems that disturb free tropospheric conditions. A study to investigate the suitability of the station showed that throughout the whole year the station is influenced by thermally induced wind systems and the atmospheric boundary layer (Henne et al. 2008).

The filters distinguished between thermally and synoptically influenced days. Thermally influenced days (86%) dominated. However, maxima in specific humidity were also reached in the afternoon on synoptically influenced days and were attributed to mixing in the convective boundary layer. During nighttime, downslope wind dominated that carries undisturbed free tropospheric air masses. Nevertheless, during 24% of all nights the specific humidity was also elevated, possibly indicating the presence of residual layers. It is recommended that nighttime data only (2100–0400 UTC) be used for analysis of long-term trends of the free tropospheric background while the remaining data can be used to characterize composition and trends of the regional atmospheric boundary layer.
Wind distribution at Mount Kenya GAW station: Showing, all data, daytime (0800–1500 UTC), nighttime (2000–0300 UTC), and transitional, or remaining, hours (1600–1900 and 0400–0700 UTC).

Representativeness and climatology of carbon monoxide and ozone at the global GAW station Mt. Kenya in equatorial Africa showed diurnal and seasonal variation of ozone. Henne et al. (2008) observed a frequent development of slope wind circulations at MKN and turbulent vertical transport of boundary layer air towards MKN during daytime. These transport processes manifest themselves in a pronounced diurnal cycle of CO mixing ratios. Shortly after sunrise (04:00 UTC) CO starts to rise as a result of advection of more polluted ABL air and reaches a maximum between 11:00 and 13:00 UTC. The average diurnal amplitude was 15 ppb. This pattern recurs during all months of the year, with increased amplitude (25–30 ppb) during July and September.
O3 showed a weaker annual cycle with a minimum in November and a broad summer maximum. Inter-annual variations were explained with differences in southern African biomass burning and transport towards MKN. Although biomass burning had little direct influence on the measurements at MKN it introduces inter-annual variability in the background concentrations of the southern hemisphere that subsequently reaches Kenya.

A statistical analysis of ozone profiles over Nairobi split into 3 layers reveals strong yearly variation in the free troposphere and the tropopause region, while ozone in the stratosphere appears to be relatively constant throughout the year. Total ozone measurements by Dobson instrument confirm maximum total ozone content during the short-rains season and a minimum in the warm-dry season (Ayoma et al, 2002).
Mean “Seasonally averaged” ozone profile over Nairobi based on 8 years of ozone sounding, for respectively long-rains, short-rains, warm-dry and cold-dry season.

As a first output of this analysis indicate that the relative ozone variability in the “stratosphere” is weak, thus indicative of small changes in the ozone concentration in the stratosphere over Nairobi during the last 8 years. On the contrary in the “free troposphere” and “tropopause” regions we observation showed significant changes: up to 40% of peak to peak variation with a well defined yearly cycle. This tropospheric ozone variability is higher than expected and may partially be attributed to turbulent air motions (Ilyas, 1991).

**OZONE PLANNED RESEARCH**

Currently, we do not have any major ozone research project to determine the status of ozone level in Kenya. This is occasioned by lack of adequate ozone observation stations. Consequently, more stations that will monitor total column of ozone, ozone profile and UV need to be established. This will lead to establishment of ozone mapping that will validate the satellite measured global coverage.
RECOMMENDATIONS OF 7ORM

(A) Research Needs
Implementation of 7ORM
There has been little implementation of the recommendations on research from 7ORM. However, awareness to conduct research on ozone has been enhanced through seminars and workshops. This has led to publication of a few international journals in conjunction with twinning partners (EMPA).

Future Recommendations
Several factors inhibit research activities in Kenya. These include:
- Budgetary constraints. The funds allocated for research is inadequate leading to few being conducted. External sourcing of research fund would be welcomed.
- There is little ozone data in the tropics especially in Equatorial Africa. Governments in this region should be sensitized on the need to establish more ozone monitoring stations.
- There are inadequate computing facilities especially for research that involve Global models. Twinning with more advanced research centers should be encouraged.

(B) Systematic observation
Implementation of 7ORM
In filling data gaps in geographic coverage, the government has established an urban air pollution monitoring station at the University of Nairobi that measures surface ozone. Last year, Kenya commenced measurements of methane (CH₄) at Mount Kenya GAW station which is both GHGs and ODSs. CH4 is measured by a Picarro G1301 instrument.

Archived data reports of ozone sondes include the simultaneous water vapour profiles measured by meteorological radiosondes and the data is available for ozone research and monitoring from the relevant world data center.

Future Recommendations
There is poor spatial distribution of ozone monitoring station in Kenya, one at Mount Kenya and two in Nairobi. Consideration of the redistribution of observation sites from areas highly populated with stations to those areas that are poorly populated should be undertaken. This would require both infrastructure and equipment support in order to establish new stations.

(C) Data Archiving
Implementation of 7ORM
The government provides funding for archiving raw data from ozone observational networks, and also facilitates submission of the data to the WOUDC. It is understood that archiving raw data does not replace the archiving of final data products.

The ozone data is archived in such a manner that they can be made easily accessible to scientists and the general public within a reasonable period of time.
Future Recommendations
Since, before being archived, ozone data must be quality assessed to ensure that it is of the highest possible quality, the staff must be fully trained in data management and quality assurance. This will ensure that data submitters continue to adhere to existing data submission protocols, particularly information on standard operating procedures and calibration histories, in order to maintain the overall quality and therefore the reputation of the entire archive. It is acknowledged that obtaining data of this quality is costly and time-consuming but is nonetheless an essential task and so data providers should be adequately funded and recognized for their efforts in providing this data to global archives for the furtherance of ozone and UV science.

(D) Capacity Building
Implementation of 7ORM
The instruments used in ozone measurement require sophisticated calibration and maintenance, much of which is unavailable in Kenya without international intervention. At present, there are insufficient number of regional centres for research, calibration, and training in developed and, especially, in developing countries. To fill this gap, Kenya has established a regional and bilateral cooperation and collaboration (twinning) with Swiss Federal Laboratories for Material Testing and Research (EMPA).

EMPA provide resources and opportunities for scientific and technical training, at and beyond the instrument-operation level, thereby allowing instrument operators and other scientific personnel in Kenya to use their data, other available data, and models in both regional and international research areas. EMPA conducts a biennial system and performance audit of surface ozone and carbon monoxide at the global GAW station Mount Kenya.

The WMO-GAW Training and Education Centre (GAWTEC) established in Germany has been successful in providing training in measurements and instrument calibration to all our staff involved in ozone measurements.

Future Recommendations
Resources should be provided to support more scientists from Kenya to attend conferences and workshops. This will enhance their skills and gain the necessary experience in ozone related research. Resources for the exchange and visits of personnel from monitoring stations in developed and developing countries should be increased in order to ensure technology and knowledge transfer and sustained measurement programmes. Extra establishment of regional centres for research, calibration, and validation in developing countries should be encouraged.

Conclusion
Procurement of instruments, establishment of necessary infrastructure and securing operational costs along with necessary human resource development are utmost necessary for enhancing the existing ozone stations and establishment of the new ones. When this is realized, it will contribute to the ongoing research to the various institutes on impact of both ozone and UV radiation on human health and environment.
REFERENCES


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KYRGYZSTAN

1. Introduction

For more than 30 years the monitoring of ozone, solar UV radiation, tropospheric aerosol and main greenhouse gases in central part of Eurasian continent has been made only at Issyk-Kul station (42.6°N, 77°E, 1650 m a.s.l.) located on the shore of Issyk-Kul Lake in the mountains of northern Tien-Shan. (Fig. 1)

The station is located in the mountains of Northern Tien Shan, it has very favorable conditions for investigations of the above-mentioned problems due to a high transparency of an atmosphere, a lot of sunny days in a year, and also because of absence of sources of anthropogenic pollution. It is unique in the central part of the Eurasian continent.

2. Monitoring

Investigations of atmospheric ozone in Kyrgyzstan had started at the Kyrgyz National University in 1979. Different versions of spectral multiwave methods of measurement of the total content of ozone (TO) and stratospheric nitrogen dioxide were developed. For realization of these methods the devices were made, and the scientific station Issyk-Kul was created.

For validation of ozone measurements in various years, a comparison of the measurements by the ozonometer at the station with measurements by the national etalon device of Russia (Dobson spectrophotometer #107) and with the data of measurements by the satellite device TOMS was carried out.

Since January 2000, a monitoring of intensity of solar UV radiation at the Earth’s surface in 5 bands of a solar spectrum in width of 2 nm being centralized on wavelengths 305; 312; 320; 340 and 380 nm was carried out by the device MICROTOPS II. The device registers radiation of a solar disk plus scattered radiation within a solid angle of 2.5 degrees.

The global erythemally weighted solar UV-B irradiance (UV-er) is regularly measured since May 2003 with Model 501 UV-Biometer (Solar Light Co).

The measurements of the surface ozone concentration at Issyk-Kul station started in August 2003 carried out with the help of the UV ozone analyzer TEI 49C. The fence of air is carried out at height of 5 m above a surface of the ground.
3. Research

Mean monthly total ozone (TO) values in the atmosphere over the central part of Eurasia for 1980 - 2008 are given in Figure 2. These values are obtained by averaging measured daily TO (curve 1) values. A determination error for mean monthly total ozone TO is less than ±0.5%. The same Figure 2 presents the smoothed total ozone values (curve 2) and linear trend (line 3).

![Figure 2](image-url)

**Fig. 2.** Seasonal (1), annual (2) variation total ozone and linear trend (3) at Issyk-Kul GAW station.

The results of mean daily TO values obtained during ground-based measurements with the values of TO satellite measurements made by the TOMS installed on board of the NIMBUS-7 comparison. For the whole period of comparison the data of both measurements correlated with each other with the correlation coefficients \( r = 0.95 \). The value of \( r \) in separate years changes from 0.92 to 0.98.

As it was shown the results of long-term observations at Issyk-Kul station, the 20 - 30% amplitude of total ozone variations was relative to mean annual values of TO with oscillations from 60 DU (1987) to 110 DU (1980, 1986 and 1991). Maxima in TO seasonal variations are observed in February-April and minima in August-November. Here during the whole observation period the changes of maxima in March were 40% and changes of minima in October were only 6%. For Issyk-Kul mean for the observation period annual TO seasonal variation, with the account to a total ozone decrease in 1990 - 1998, is in good agreement with the mean seasonal variation of total ozone during a year 1973 - 1990 averaged for Central Asia (42 N). During the whole observation period at Issyk-Kul station mean annual ozone content in the atmosphere decreased to about 10.5% (34 DU) with an average rate \(-0.39 \pm 0.03\)% in a year.

During the whole measurement period almost regular quasibiennial oscillations of smoothed TO values with an amplitude of 15 DU were observed. In 1980 - 1983 and 1991 - 1992 a disturbance of these oscillations regularity took place. In 1980 - 1983 and 1991 - 1992 TO decreases were maximal and the TO decrease rates were equal to \(-2.1 \pm 0.1\)% and \(-4.5 \pm 0.1\)% per year, correspondingly. This is considered to be connected with the El Chichon and Pinatubo eruptions.

In different time intervals the real trend of inter-annual ozone change may significantly differ from the linear trend for all period of observations. After a short period (1993-1998) of restoration of ozone layer with the mean rate 0.6% per year, further ozone layer depletion with the rate \(-1.5\)% per year took place during the following period.

It is seen from Figure 2, that during some time periods along with usual seasonal total ozone variations considerable "gaps" - negative anomalies of different duration (from several days to several months) - were observed at the station. Their appearance and, consequently, a possible increase of UV radiation fluxes deserve special attention. In their essence these anomalies are regional, local "micro holes" in ozone layer similar and equal in size to the anomalies observed...
over Europe in 1980s. The data of several ozonometric stations located in the Eurasian centre have shown that during the period of 1980 - 1995 the negative anomalies were observed at all stations. Almost simultaneously the anomalies were observed in the first half of the 1990s at the Issyk-Kul, Alma-Ata and Karaganda stations. The first two stations are distanced from each other by ~70 km, and the latter is almost 800 km away from them. In spring 1993 the ozone negative anomaly in this region was probably about 100 0 km in length and southern boundary was registered in Dushanbe.

A correlation of variations of mean monthly and mean annually total ozone (TO) content over the mountain regions of Central Asia for two observation periods 2009 and 2010 at the station 'Issyk-Kul " is given in Fig. 3. The horizontal lines indicate means for 12 months. As shown in Figure 3, for 2009, the TO content is 0.309 atm-cm, while for the later of the second period (2010) obtained a value equal to the TO content -0.326 at m cm and ozone in the atmosphere over Kyrgyzstan increased by approximately 3.3% in 2010 compared with 2009. From Fig. 3 is seen that the main characteristics of intra-anual variations of TO content preserved - a maximum of TO content occurs in spring, at least - in the autumn, with preservation of phase seasonal variation.

![Fig. 3. Intra-annual fluctuations mean (points) monthly TO content and linear trend. Mean total ozone in the atmosphere above the station "Issyk-Kul " for 12-months (horizontal lines) in 2008 - 2010.](image)

The variations of mean monthly intensities of the ozone surface in the Issyk Kul from May 2003 to 2008 are given in Fig. 4

![Fig. 4. The variations of mean monthly intensities of the ozone surface](image)

The variations of mean monthly intensities of the ozone surface in Issyk Kul from 2009 to 2010 are given in Fig. 5.

From the figure 5 is seen, that in 2010 compared to 2009 mean annual concentration of COS increased from 39,1 ppb (in 2009) to 41.7 ppb (in 2010), i.e. to 6,4%.
The variations of mean monthly intensities of erythemally weighted solar UV-B irradiance (UV-er) in Issyk-Kul are given in Fig. 6.

For the period of 1990 - 2003 values of total intensity of erythematos weighed UV-B radiation (295-315 nm) reaching the ground in area of Issyk-Kul lake are estimate using a three-layered model. In this model the measurements’ results of ozone and aerosol optical depth in UV range were used. For the period June, 2003 - February, 2004 the calculated values of total intensity of UV-B radiation are compared to measurements results of UV-B radiation using the UV-Biometer 501.

The calculations have shown that at decreasing total ozone in the region of the Northern Tien Shan since 1990 to 2003 at a rate of (0.23 ±0.05)%/yr the intensity of the global solar UV-er irradiation increased with a rate of (0.38 ±0.07)%/yr.

When comparing the UV-er current mean monthly values with average long-term values, positive deviations of the UV-er were registered: (15-20)% in Feb.1993, April 1997, Feb. 1999, May 2000, Dec. 2000, Nov. 2001, January and March 2002. On some days in spring-summer positive anomalies reached (40-65)%. The increments in UV-er mentioned were observed when local ozone holes were located over the Northern Tien Shan.

The variations of mean monthly intensities of the direct solar UV radiation on the ground surface at local noon in the Issyk-Kul from January 2001 to December 2003 are given in Figure 7 for 4
wavelengths: 305, 312, 320 and 340 nm. Dotted lines are trends. A growth of total ozone for the past several years over the Northern Tien Shan with a rate of \((2.5 \pm 0.14)\%/yr\) is about 5 times higher than the rate of total ozone growth (observed in 1993-1997) caused by a decrease of the stratospheric aerosol burden induced by the Mt. Pinatubo eruption. This total ozone increase was accompanied by a decrease of the UV radiation intensity for \(\lambda = 305, 312, 320\) and 340 nm on the Earth's surface with rates of 7.8; 4.6; 3.3 and 1.4%/yr, accordingly.

![Fig. 7](image)

**Fig. 7.** Time series of the local noon direct solar UV radiation, from March 01 to December 03; dotted line represents trends - change in the data with the seasonal cycle removed.

The measurements have shown that in 2001-2003 the ozone changes is in a steady correlation with the intensity of the direct solar UV radiation \((\lambda = 305 \text{ nm})\) only. Thus an increase UV-irradiance over the Northern Tien Shan the last years occurred mainly due to the depletion of the ozone layer.

**Fig. 8.** shows a seasonal trend of variations of UV-B radiation and an increase of the mean annually UV-B radiation in 2010 by 2.4% compared with 2009 in Issyk-Kul.

![Fig. 8](image)

**Fig. 8.** Intra-annual fluctuations in the local noon (points) the intensity of solar UV-B radiation in the area of the Issyk-Kul Lake in 2008 and 2010.

Mean monthly values of water vapor total content in the atmospheric column of the Eurasia central part are given in Figure 9 for the period of 1980 – 2006.

![Fig. 9](image)

**Fig. 9.** Seasonal (1), annual (2) variation of water vapor and linear trend (3) at Issyk-Kul GAW station.
A total amplitude of seasonal variations of \( W \) from winter to summer at Issyk-Kul station has changed within wide ranges from 1.53 g.cm\(^{-2}\) in 1985 to 2.39 g.cm\(^{-2}\) in 1988 (Figure 9). The mean amplitude for the whole observation period was \((1.91 \pm 0.23)\) g.cm\(^{-2}\).

The mean monthly of the stratospheric nitrogen dioxide (NO\(_2\)) slant column content from April 1983 to December 2010 is presented on Figure 10. The NO\(_2\) seasonal variations have 35-45% amplitudes.

Between 1983 and 2010, the total content of NO\(_2\) vertical column \((Y \times 10^{15}\) mol/cm\(^2\)), hereinafter referred to as a convenience factor \((10^{15}\) as a rule, falls) was measured during sunrise and sunset: 5121 morning and 5076 evening observing sessions, each of which consisted of approximately 170-200 individual measurements. The results are shown in Fig. 10.

The results of measurements of CO\(_2\) and troposphere aerosol at Issyk-Kul station are presented in Fig.11 and 12.
4. Applications

The results of measurements of ozone obtained at Issyk-Kul station are transferred regularly to the World Data Centers: in Ozone (Toronto, Canada #347-WUDC), in Greenhouse Gases (Tokyo, Japan ISK242N00-WDCGG), in aerosol (USA) and on NDSC network of stations (www.empa.ch/gaw/gawsis).

5. Publications

The basic results of investigations are being published in national and international journals and proceedings:


6. Future plans

In accordance with recommendations of the seventh meeting of the Ozone Research Managers (7 ORM), the priority at the above mentioned stations in Kyrgyzstan for the nearest future will be given to investigations of interaction between ozone and climate, ozone layer and UV radiation, stratospheric aerosol and climate.

7. Need of support

For solution of above mentioned tasks, improvement and expansion of the base monitoring of ozone and stratospheric aerosol in the Central Asian region, Kyrgyzstan as a developing country needs a financial support from international organizations.
RAPPORT RESUME DE RECHERCHE

Le présent rapport résume et récapitule les grandes lignes des réalisations et perspectives au niveau de la recherche sur la protection de la couche d’Ozone et de la mise en œuvre des activités contenues dans le Programme de Pays (PP) à Madagascar.

Il décrit brièvement les étapes réalisées et montre les perspectives d’avenir afin de réduire et éliminer la consommation des Substances qui Appauvrisser la couche d’Ozone et afin d’utiliser les nouvelles technologies respectueuses de la couche d’Ozone ainsi que les substances alternatives aux SAO.

I- DESCRIPTION ET CONTEXTE

Le 11 janvier 1995 Madagascar a ratifié la Convention de Vienne pour la protection de la couche d’Ozone et le Protocole de Montréal relatif à des Substances qui Appauvrisser la couche d’Ozone le 02 mai 1996. Et le 23 Octobre 2001, il a ratifié les Amendements de Londres, de Copenhague, de Montréal et de Beijing.

Comme la plupart des pays de l’article 05, Madagascar étant pays importateur des substances réglementées par le Protocole de Montréal, il ne produit ni de substances ni d’équipements ou appareils contenant des Substances Appauvrissant la couche d’Ozone (SAO) par le Protocole de Montréal. Toutefois, Le pays respecte et adopte le programme d’action élaboré par les Nations Unies concernant la mise en œuvre de ce Protocole dans tous les pays partis.

Madagascar figure parmi les six (6) rares pays africains sur 53 ayant présenté avec succès en 2010 leurs Plans de Gestion et d’Elimination finale des Hydrochlorofluorocarbons (PGEH/HPMP).

II- CADRE ISTITUTIONNEL

La réglementation de l’utilisation des SAO à Madagascar est fondée sur le système d’autorisation préalable d’importation. Elle a fait l’objet d’un Décret gouvernemental publié et distribué gracieusement à toutes les parties prenantes, et concerne à la fois les SAO et les matériels qui les contiennent. La base légale de cet acte est matérialisée par le Décret n° 2003-170 du 04 mars 2003 portant réglementation de l’importation et de l’utilisation des Substances qui Appauvrisser la couche d’Ozone; et réglementant l’importation, la vente, la revente et l’utilisation des fluides frigorigènes, des appareils ou équipements frigorifiques et des halons.


III- APPROCHE ET PERSPECTIVES
La première partie du Programme de Pays (de 1999 à 2010) a été réalisée par Madagascar avec succès à travers les projets d’Appui Institutionnel (PAI), le Plan d e Gestion de Réfrigérants (PGF), le Plan de Gestion des Réfrigérants Actualisé (PGR A) et le Plan de Gestion de l’Élimination Finale des CFCs (PGEF/TPMP).

Par ailleurs, les techniciens du froid de Madagascar son t actuellement capables de fabriquer des Machines de récupération des SAO, suite à des activités de recherche effectuées après les formations de base dispensées par le Bureau National Ozone de Madagascar.

Au niveau de l’application de la législation et de la réglementation nationales sur la protection de la couche d’Ozone, des Gaz interdits qui ont frauduleusement entré dans le territoire national, ont été saisis, confisqués par l’équipe du BNO en collaboration étroite avec l’équipe de la Brigade Mobile de S urveillance (BMS) de la Direction Générale des Douanes (DGD) et stockés dans les centres prévus à cet effet..

Ce tableau récapitule l’évolution de la consommation en SAO de Madagascar de 1986 à 2009:

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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>C I HCFCs</td>
<td>1.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>7.7</td>
<td>0.0</td>
<td>0.0</td>
<td>1.1</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>2.6</td>
<td>2.6</td>
<td>1.7</td>
<td>2.1</td>
<td>2.2</td>
<td>16.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C II HBFCs</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
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<td></td>
</tr>
<tr>
<td>C III Bromochloro methane</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>E I Methyl Bromide</td>
<td>0.8</td>
<td>1.3</td>
<td>3.0</td>
<td>3.1</td>
<td>1.2</td>
<td>0.7</td>
<td>0.8</td>
<td>0.4</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>

La deuxième partie de ce programme a été approuvée lors de la vingt sixième Réunion du Comité exécutif du Fonds Multilatéral en 2 010 à M ontréal au Canada. Cette deuxième partie a pour objectif d’éliminer progressivement les HCFCs qui comporte, entre autres, la mise en œuvre d’un Plan de Gestion d’Élimination des Hydrochlorofluorocarbone (PGEH/HPMP).

Ce tableau montre l’évolution de la consommation en HCFCs de Madagascar de 2009 à 2030 avec au sans La mise en œuvre du Protocole de Montréal relatif à des Substances Appauvrissant la couche d’Ozone:

<table>
<thead>
<tr>
<th>PHASE 1 (2009 – 2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREVISIONS SANS PM</td>
</tr>
<tr>
<td>PREVISIONS AVEC PM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PHASE 2 (2021 – 2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANNEE</strong></td>
</tr>
<tr>
<td>PREVISIONS SANS PM</td>
</tr>
<tr>
<td>PREVISIONS AVEC PM</td>
</tr>
</tbody>
</table>
Le PGEH prévoit la sensibilisation du public (sur le danger causé par les Substances qui Appauvrissent la couche d'Ozone sur la santé humaine et sur l'environnement en général.), la vulgarisation de l'arsenal juridique sur la protection de la couche d'ozone, la formation des agents des douanes sur les produits SAO, la formation des formateurs, la formation des techniciens frigoristes sur les bonnes pratiques en réfrigération, le projet d'investissement sur la reconversion des équipements et sur l'achat des équipements et outils pour les bonnes pratiques en réfrigération, le suivi et évaluation de la mise en œuvre des composantes du PGEH.

Actuellement, suivant la politique d'intégration de la dimension environnementale initiée par le Ministère de l'Environnement et des Forêts pour l'adoption de réflexe environnemental à tous les niveaux et dans tous les secteurs à Madagascar, le Module sur l'Ozone commence à être développé au niveau des Études Supérieures en vue du développement durable sur le secteur technique et industriel du pays.

Par ailleurs, des études et recherches sont menées sur l'Ozone de la partie intérieure de l'atmosphère au niveau des services de la Météorologie malgache, mais celles-ci restent essentiellement au niveau de l'Ozone troposphérique.

Comme tous les pays du monde, à Madagascar, il existe des Centres de recherche en matière d’Environnement qui regroupent différents chercheurs du pays à savoir:

- Le Centre National de Recherche sur l’Environnement (CNRE) sous tutelle du Ministère des Recherches Scientifiques;
- L’Institut Nationale des Sciences et Techniques Nucléaires (INSTN);
- La Direction Générale de la Météorologie (DGM);

IV- SUGGESTIONS

- Afin de promouvoir les recherches, chaque pays devrait intensifier un programme de recherche dans le Programme de Pays.

- Le Secrétariat exécutif de l’Ozone devra élaborer un guide de recherche pour les pays de l’article 5 afin de les canaliser sur la priorisation à faire au niveau des thèmes de recherche et mettre à nos dispositions les résultats exploitables suivant l’évolution de la technologie face à la préservation de l’Environnement en général et particulièrement sur la protection de la Couche d’Ozone.

- Favoriser les recherches sur l’Ozone ou projets de recherche sur la protection de la couche d’ozone à tout public à travers des concours au niveau mondial/régional et national.

- Mettre en place des Centres de Recherche sur l’Ozone au niveau régional notamment pour les pays de l’article 05.

- Développer des outils, revues ou des documents sur les recherches et disséminer largement pour tous les pays membres à travers les Bureaux Nationaux Ozone.

Ce document met en exergue le résumé de l’état des recherches et la mise en œuvre des activités liées à la protection de la couche d’Ozone à Madagascar.

Rapport résumé élaboré par:

-Monsieur Claude RAKOTO;
Collaborateur au sein du Bureau National Ozone
Ministère de l’Environnement et des Forêts
Antananarivo - MADAGASCAR
National Report about the Status of Ozone Monitoring of Nepal

1. Background:

Upon the discovery that CFCs and other human-made substances are leading to a depletion of the ozone layer, the international community agreed upon the Vienna Convention for the Protection of the Ozone Layer in 1985. Following this, the Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in 1987 with the objective of reducing and finally phasing out the production and consumption of ozone-depleting substances. Nepal ratified to the Vienna Convention, Montreal Protocol and London Amendment to the Montreal Protocol on 6 April 1990 and came into force on 4 October 1994.

In response to the Convention, Protocol and London Amendment 1990, the Government of Nepal (GoN) formed National Program Preparation Team (NPPT) on 3 October 1996. The NPPT prepared Nepal Country Program for the Phasing out of the Ozone Depleting Substances and the program was agreed on 19 February 1999. The GoN assigned the Nepal Bureau of Standard and Metrology (NBSM) as an Implementing Agency working with the direction of National Ozone Committee (NOC) which was formed under the joint-secretariat level of the then Ministry of Population and Environment in 28 February 2000.

2. Institutional Mechanism:

Implementation of the Convention, Protocol and London Amendment in Nepal started with the following undertakings:

- The then Ministry of Population and Environment (MoPE) (now it is the Ministry of Environment, MoE) was designated as a focal ministry;

- The then MoPE (now MoE) and the then Ministry of Industries, Commerce and Supplies (now the Ministry of Industry) started working in close coordination;

- The then MoPE established the coordination with the Convention Secretariat and necessary organizations;

- The Nepal Bureau of Standard and Metrology (NBSM) was designated as an implementing agency;

- For the effective implementation of the Vienna Convention, Montreal Protocol and London Amendment, necessary committees were constituted as and when necessary. In this regard the Steering Committee was formed and Secretaries of MoE and Ministry of Industry (MoI) have served as the co-chairs. Similarly the Implementation Committee has formed in the chair of the Director General of the NBSM Implementation Committee under the MoI. Other subject committees were established when necessary with the involvement of
Government organizations, private organizations and experts in the related field was also established by the government decision on 28 April 2000.

- A National Ozone Unit (NOU) was established in NBSM with the responsibility of implementing and monitoring the ODS.

The Government formulated policies and enacted Acts and regulations such as Environment Protection Act, 1996, Environment Protection Rules, 1997 and Ozone Depleting Substances Consumption Rules (ODSCR), 2001 etc. Environment Impact Assessment (EIA) of development works was institutionalized and standards related to the industrial effluents air quality were implemented by MoE. Similarly, NBSM has also implemented activities as the major Implementing Agency of the Convention, Protocol and London Amendment.

3. Activities for Monitoring ODS

As the focal point of Convention, Protocol and London amendment, the then MoPE issued a public notice in the National Gazette on 25 September 2000 releasing the Government decision, on annual consumption, import quantity and phase-out rates of ODS. Similarly, as the Rule 4 of the ODSCR, the government designated the licensing authority to the Department of Commerce to work under the Export, Import Control Act 1957 on the recommendation of MoE. Procedures and conditions of license including specification and quantitative standards and annual phase-out rates of ODS were also made public by publishing a notice on 6 March 2001. NOU was the implementing and monitoring unit in all these matters under the NBSM.

The National Bureau of Standards and Metrology (NBSM) started activities related to controlling and monitoring the ODS for not being imported to Nepal from the very beginning when Nepal ratified the Convention and the Protocol. In this regard the GoN established a Committee for the implementation of the Montreal Protocol, with its secretariat in the NBSM within the Ministry of Industry. The committee initiated its work by conducting a countrywide survey in 1996. The survey established basic profile of Ozone Depleting Substances (ODS) consuming sectors in Nepal.

A 1996 survey on ODS consumption in Nepal found 29 tones of Chlorofluorocarbon 12 (CFC12) and 23 tones of Hydrochlorofluorocarbon 22 (HCFC-22). Approximately 1 tones of CFC was used in new equipment and the balance 28 tones for servicing (15.8 tones for domestic and 12.2 tones in commercial and industrial refrigeration). Refrigeration and Air conditioning sector was the predominant consumer of ODS mainly in the assembly, repair and maintenance of equipment. The survey also indicated the general direction for ODS phase-out efforts.

(a) Refrigeration Management Plan (RMP):

Country Program for the phasing out of the ODS in Nepal was approved in 1998. Due to the predominance of the Refrigeration and Air conditioning sector in terms of ODS...
consumption, the need for formulating a Refrigerant Management Plan (RMP) was identified, taking into account the following factors such as availability of alternate refrigerants, residual economic life of CFC containing equipment, training, and technical assistance for transitioning to non-CFC alternatives.

Nepal RMP was approved in July 1999. Under the RMP, the following key activities such as promulgation of regulations covering registration of importers establishing maximum permissible annual limits on import quantities; prohibition on import of CFC based equipment; national CFC recovery and recycling program which covered establishment of two recovery and recycling centers, provision of recovery units to servicing establishments/end users and additional refrigerant equipment to servicing technicians; training of customs officers related to RMP and training program in good practices in refrigeration servicing through train the trainers program.

(b) CFC Monitoring


CFC Phase-out Plan:

<table>
<thead>
<tr>
<th>Year(AD)</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC-11 &amp; CFC-12 Joint (Metric Ton)</td>
<td>29.058</td>
<td>26</td>
<td>23</td>
<td>20</td>
<td>17</td>
<td>14</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Monitoring through licensing also followed as the plan and now CFC import in the country has been controlled fully. Actually Nepal baseline for CFC was 29 ODP tones. It reported import of 94 ODP tones of CFC12 during the period of 1st July 2000 to 30 June 2001. As a consequence for the July 2000 to June 2001 Nepal was in non-compliance with its obligation under Article 2A of the Montreal Protocol as per decision made at 14th Meeting of the Parties held at Italy.

Further the illegally traded quantities should not be counted against a Party consumption provided the Party does not place the said quantities on its own market and if Nepal decides to release any of the seized quantity of CFC into its domestic market, it would be considered to be in non-compliance as per the decision made at 15th meeting of the Party held at Nairobi.

Nepal informed the seizing of the illegal ODS during MOP 16 at Prague in 2004 and the meeting agreed the removal of previous non-compliance issue by Nepal including a commitment by Nepal to report annually on the quantity of CFCs released on to its market.

Accordingly, in the 20th meeting of the Parties, Nepal requested guidance from Parties on continued use of confiscated CFCs post 2010. Nepal proposes to consider options
for destruction of CF C (around 10 tons ) which was approved by the Executive Committee and we are working on this in close cooperation with the Department of Customs.

4. Present Status

Nepal has addressed non-compliance issues in a very remarkable manner during the last four years to adhere strictly to the plan of action and controlled distribution of the stockpiled CFCs into the domestic market. Nepal has also taken significant steps to control and phase-out its CF C consumption, including improved cross-border coordination with countries also engaged in CFC production, creation of awareness among importers of refrigeration and air conditioning equipment and control of such imports.

The continuity of operation of the Ozone Officer appointed in 1998 and establishment of the NOU in Nepal has worked well which makes Officer one of the longest serving National Ozone Officers of all Article 5 countries,

Nepal Refrigeration and Electro Mechanical Association (NREMA) has been established in 2006; it cooperates very closely with the NOU. The CFCs are provided to the workshops/technicians through this association following the procedure established for this purpose. The association is also responsible for tracking the use of CFCs provided through this arrangement and reporting on the same to NOU.

NREMA started organizing training courses of different levels (basic and advanced) with the cooperation of Lalitpur Valley College in Lalitpur for technician students or other interested persons. The training costs were partly covered by the participants and partly by the funding from UNEP, GTZ and India.

Nepal was awarded with "The Montreal Protocol Implementers Awards" by UNEP (United Nations Environmental Program) for the year 2007. The National Ozone Unit of Nepal was honored by this award in reorganization of its extraordinary contribution to the effective implementation of the Montreal Protocol and the global effort to protect the ozone layer.

At 19th Meeting of the Parties, the Parties agreed to accelerate the phase-out of production and consumption of HCFCs by way of an adjustment in accordance with paragraph 9 of Article 2 of the Montreal Protocol by choosing the baseline the average of 2009 and 2010 levels of respectively and to freeze at that baseline level consumption in 2013 and then 10% reduction by 2015, 35% reduction by 2020 and 67.5% reduction by 2025 and 97.5% reduction by 2030.

Nepal HCFC Phase-out Management Plan (HPMP) was prepared and submitted to the 61st Executive Committee to implement above decision made during the 19th Meeting of the Parties.

However, the Committee deferred consideration of the HPMP for Nepal to 62nd Meeting of Executive Committee in light of any additional information regarding the commitment
of Nepal of ratifying the Copenhagen Amendment and to phase-out HCFC in accordance with the Executive Committee.

It may be pointed out that without ratification of Copenhagen Amendment, Nepal would not be entitled to any Multilateral Fund (MLF) assistance to phase-out HCFCs since they would have no commitment to address these substances or any resultant compliance issue.

Nepal understands and appreciates the decisions of the 62nd Executive Committee which mentions that stage I of HPMP could be implemented if Nepal complies with the following by the time of 23rd MOP (14-18 November 2011):

I. Officially deposit its instrument of ratification of Copenhagen Amendment to the Montreal Protocol with the United Nations Treaty Depository Office in New York;

II. Submit on official request to 23rd MOP to be considered under Article 4, Paragraphs 8 and 9 of the Montreal Protocol, which *inter alia* allows a State not Party to an amendment nevertheless to be found by the MOP to be in full compliance with the control provision of the Montreal Protocol, thereby obviating the trade sanctions that might otherwise apply.

The Executive Committee decided that if one of the condition in i) and ii) above had been met, the Government of Nepal would submit a request to the Executive Committee for the first tranche of the HPMP and present the corresponding Agreement between the Executive Committee.

Taking into consideration the above, the MoI has processed for the ratification of all Amendments including Copenhagen Amendment with the inputs of the Ministry of Environment and Ministry of Law and Justice and the proposal has been put forward for Cabinet approval. After due consideration of the Cabinet, the proposal will be submitted to the Parliament for formal ratification.

5. Observations

Beside the given outcomes of these efforts some issues in the government are unclear. The ODSCR chiefly focuses on the licensing system to the importer to control over the illegal import of the ODS. However, rule has not mentioned anything about the exporter because of the reason that Nepal does not produce any ODS within the country.

In addition to this, ODSCR has given authority to the focal ministry to prescribe necessary procedures and conditions for the import of the substance; prescribe necessary specification, annual import and consumption quantity as well as the phase-out rate of the substance for trade, business needed in refrigeration, air conditioning, agriculture and health including fire extinguishing services and in industrial uses; take actions for gradual phasing-out of the annual import and consumption quantity of the substance up to the zero limits within a scheduled period in accordance with the
provision of the Protocol; and monitor and evaluate the status of the consumption as well as sales and distribution of the substance regularly.

At the beginning, the then MoPE started the implementation process on ODS which was smooth and effective also due to the issuance of the ODS Consumption Rules. However, its effective implementation was not achieved to the desired extent, as the then MoPE was dissolved in 2005 and it took time to integrate the functions of the Environment Division of the then MoPE by renaming the Ministry of Science and Technology into the Ministry of Environment, Science and Technology (MoEST). Once the implementation was re-initiated the Government of Nepal separated MoEST again in 2009 into the Ministry of Science and Technology and the Ministry of Environment (MoE). After this, MoE has initiated working on ODS in the spirit of the Convention and the Protocol and has started the ratification process of the Copenhagen Amendment.

For the effective implementation of the licensing system, the NOU has been designated to make this licensing system operational. As mentioned earlier, NREMA has also attempted several activities regarding the awareness raising on ODS including training to the students and capacity building. International Organizations like UNEP has also conducted three days training to the costume officers regarding the ODS in 2001 aiming to build capacity of the customs officers of Nepal on ODS. However, those efforts are not enough to raise awareness on ODS as well as to build capacity for the ODS monitoring and regulating activities.

Despite of the specific ODS study, Nepal has also prepared the Initial National Communication in 2004 in which greenhouse gas inventory was one of the major components. CFCs inventory was not included under the GHGs at that time because of lack of available data. Now, Nepal is engaged in the preparation of the Second National Communication (SNC). The CFCs are also the target for inventory in SNC.

Bed Prakash LEKHAK
Under Secretary and Chief
Climate Change Council Secretariat Section
National Project Manager
Second National Communication Project
Ministry of Environment
Government of Nepal

10 April 2011, Sunday
The Netherlands

Systematic observations:
Surface networks and capacity building

- Brewer measurements in the Netherlands
  The Brewer measurements at the station “De Bilt” by KNMI have been continued. Brewer #100 has been replaced by Brewer #189. “De Bilt” has the longest record of ozone measured with an MKIII instrument in the WOUDC database. The #100 has been refurbished, and transferred to Antarctica.

- Brewer measurements in Suriname
  Measurements at the station “Paramaribo” with Brewer #159 have been continued. After careful cleaning, the dataset has now been submitted to WOUDC and NDACC. (The variability in de ozone data in this tropical station is low, and interference by clouds is a significant problem at this site.)

- Ozone sondes in the Netherlands
  The ozone sounding program at station “De Bilt” by KNMI has been continued, with at least one launch per week, and more when special events occurred.

- Ozone sondes in Surinam
  The ozone sounding program in Paramaribo has been continued with one launch per week. Paramaribo station is part of the SHADOZ network. Problems with the balloons and batteries at this site are still under investigation. The observations at Paramaribo are performed by staff of the Meteorological Service of Surinam and the bilateral cooperation with KNMI includes capacity building at the Anton de Kom University.

- Lidar measurements in New-Zealand
  RIVM has continued the operation of the stratospheric ozone lidar at the NDACC station in Lauder, New-Zealand where first measurements started in 1994. The ozone and temperature profile observations are currently performed about four times per month. The data are available at the NDACC and ESA calibration/validation databases and have been used in various validation studies and also for trend analyses.

- UV-monitoring in the Netherlands
  RIVM has continued spectral UV-monitoring on the Bilthoven location. A 17 year data-record has been achieved in 2010. Over 20000 spectral UV-readings are performed yearly and QC-checked UV-index data are reported live on the webpage [www.rivm.nl/zonkracht](http://www.rivm.nl/zonkracht) (in Dutch). Yearly sums of the UV-doses are calculated and long term trends and variations are analysed. RIVM data are also used in the WMO/UNEP ozone assessment and RIVM lead-authored a publication on long term changes in the UV-climate at eight European UV-stations.
**Satellite networks**

The Netherlands has been involved in satellite ozone measurements from several instruments: GOME, SCIAMACHY, OMI and GOME-2. These are UV-visible satellite spectrometers, from which ozone and several other trace gases, like NO2, SO2, HCHO, are determined. All four instruments are operational, although the global coverage of GOME is lost since 2003.

SCIAMACHY is contributed by Germany, the Netherlands, and Belgium to ESA’s Envisat satellite. SRON is the Dutch co-PI of SCIAMACHY. OMI is a contribution from the Netherlands and Finland to NASA’s EOS-Aura satellite. KNMI has the PI-role for OMI. TROPOMI is the successor instrument of OMI and SCIAMACHY. TROPOMI is approved by the Netherlands and ESA, and will fly on the ESA Sentinel-5 Precursor mission, to be launched end of 2014. KNMI has the PI-role of TROPOMI.

**Ozone data processing and users**

At KNMI near-real time data processing of satellite ozone columns and ozone profiles is taking place; see Table 1. Also data assimilated products are made. Most of the products are being delivered to users via the web portal www.temis.nl.

The OMI ozone products are being delivered via the GSFC Data and Information Services Center (DISC). GOME-2 data processing at KNMI is performed in the framework of the Ozone and Atmospheric Chemistry Monitoring Satellite Application Facility (O3MSAF) of EUMETSAT. Data delivery of near-real-time ozone profile products is done via EUMETCast broadcasting. Fig. 2 gives an example of GOME-2 profiles derived for the Antarctic in 2008.

There are many users of the satellite ozone data; for example, SCIAMACHY and OMI ozone column data is being delivered in near-real-time to ECMWF for assimilation in the model. The EU MACC project is also a user of KNMI satellite ozone data.

**Table 1: Near-real-time and offline satellite ozone products made by KNMI.**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Product</th>
<th>Period</th>
<th>Data delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCIAMACHY</td>
<td>Ozone column</td>
<td>2002 – now</td>
<td><a href="http://www.temis.nl">http://www.temis.nl</a></td>
</tr>
<tr>
<td>OMI</td>
<td>Ozone column, Ozone profile, Assimilated ozone column</td>
<td>2004 – now</td>
<td><a href="http://www.temis.nl">http://www.temis.nl</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><a href="http://disc.sci.gsfc.nasa.gov/Aura">http://disc.sci.gsfc.nasa.gov/Aura</a></td>
</tr>
<tr>
<td>GOME-2</td>
<td>Ozone profile, Assimilated ozone column</td>
<td>2007 – now</td>
<td><a href="http://www.temis.nl">http://www.temis.nl</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><a href="http://o3msaf.fmi.fi">http://o3msaf.fmi.fi</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EUMETCast</td>
</tr>
</tbody>
</table>
**Consistency and complementarity of data sets**

Recent developments in OMI ozone data retrievals and validation

The quality of the second data collection of the Ozone Monitoring Instrument (OMI) flying aboard the NASA EOS-Aura platform was published in the 2007/2008 JGR Special Issue on Aura Validation. It was reported that both the OMI-TOMS and OMI-DOAS total ozone column data products showed remarkable agreement with ground based Dobson and Brewer reference data for the 2004-2007 data record. The validation results show a globally averaged agreement of better than 1% for OMI-TOMS data and better than -2% for OMI-DOAS data with the ground-based observations. The OMI-TOMS data product is shown to be of high overall quality with no significant dependence on solar zenith angle or latitude. However, the OMI-TOMS data product contains interferences from atmospheric sulfur dioxide originating from strong volcanic eruptions, it reveals cloud structures originating from employing a cirrus contaminated cloud top pressure climatology, and it reveals non-physical jumps originating from retrieval setting changes with solar zenith angle and slant column. The OMI-DOAS data product shows no significant dependence on latitude except for the high latitudes of the Southern Hemisphere where it systematically overestimates the total ozone value. In addition a significant dependence on solar zenith angle is found between OMI-DOAS and ground-based data. In the third data collection the issues with OMI-TOMS have been addressed and solved; sulfur dioxide contaminated pixels are flagged more thoroughly, actual cloud top pressure data from the OMI-Raman cloud algorithm is employed and the jumps no longer occur. For OMI-DOAS the dependence on solar zenith angle has been reduced by half as a result of calibration improvements, however the challenge remains to solve this issue. Current developments on OMI-TOMS focus on the combined retrievals of both total ozone column and sulfur dioxide column. Current developments on OMI-DOAS focus on the use of improved absorption cross sections, an improved wavelength calibration and optimizing the sampling of the various look-up-tables by spline interpolation. In September of 2009 the last operational OMI data product came online; vertical ozone profiles operationally retrieved from the UVVIS nadir observations by OMI. Validation against a multitude of ground based and space based reference data sources reveals that OMI stratospheric ozone profiles agree within 20% with correlative data except for both the polar regions during local spring. For ozone in the troposphere OMI shows a systematic positive bias versus the correlative data sets of order 60% in the tropics and 30% at mid-latitude regions. The largest source of error is identified as the spectral stray light fit in our operational algorithm which is currently updated.
Fig. 1: Thirty-year time series of the Antarctic ozone hole, derived from the multi-sensor reanalysis data set of Van der A et al. (2010).

Fig. 2: Vertical structure of the Antarctic ozone hole in 2008 observed by GOME-2 (from Van Peet et al., 2008).

Use of NDACC lidar profiles for validation

Furthermore, RIVM has performed the ozone and temperature profile validation project VALID for ESA. In this project satellite the quality of the satellite-derived ozone profiles (with a focus on GOMOS, MIPAS, and SCIAMACHY measurements) was assessed with NDACC lidar profiles [van Gijsel et al., 2009, van Gijsel et al., 2010, Keckhut et al., 2010].
Re-evaluation of data-records

A major effort has been the multi-sensor re-analysis of total ozone performed with the TM3-DAM model (Van der A et al, 2010). This effort created a single coherent total ozone dataset from all available ozone column data measured by polar orbiting satellites in the near-ultraviolet Huggins band in the last thirty years. Fourteen total ozone satellite retrieval datasets from the instruments TOMS (on the satellites Nimbus-7 and Earth Probe), SBUV (Nimbus-7, NOAA-9, NOAA-11 and NOAA-16), GOME (ERS-2), SCIAMACHY (Envisat), OMI (EOS-Aura), and GOME-2 (Metop-A) were used. It is used to document the evolution of the Antarctic ozone hole (fig. 1).

Reconstruction of erythemal ultraviolet radiation levels in Europe

RIVM has led a large scale study to reconstruct the past UV-radiation levels in Europe by combining several reconstruction techniques and UV-monitoring data from eight European stations. Data from the RIVM site are included in the analysis. For this site the data-record now covers just over 17 years (period 1994-2011). For the combined European sites an increase in yearly UV-doses of around 4-6 % is found (see fig 3) in the past 25 years. Results from this analysis were also included in the WMO/UNEP Scientific assessment report (chapter 2, co-authored by den Outer).

Fig. 3: The combined result for the 10 year running average of the relative yearly UV-doses for eight European sites. Prior to averaging, each reconstructed time series is normalized with respect to the 1983–2004 average. The gray area depicts the estimated uncertainty in the result.
Other contributions

Netherlands scientists have contributed to several chapters of the 2010 UNEP/WMO Scientific assessment report, e.g. to the coordination of chapter 8 (Daniel and Velders, 2010).

A new assessment study has led to an important update of the projected future contribution to climate warming by HFCs (Velders et al., 2009).

References


Ozone research and monitoring in Norway

Ozone monitoring and related research activities in Norway involve several institutions and there is no distinct separation between research, development, monitoring and quality control. In this report we present the ozone related activities that have been carried out in Norway the last years.

1. OBSERVATIONAL ACTIVITIES

In 1990 The Norwegian Pollution Control Authority established the programme “Monitoring of the atmospheric ozone layer”, which initially only included measurements of total ozone. Some years later, in 1994/95, the network was expanded and The Norwegian UV network was established. It consists of eight 5-channel GUV instruments located at sites between 58°N and 79°N. In addition the network includes ozone lidar and ozone sonde measurements. Table 1 gives an overview of the location of the various stations, the type of measurements, and the institutions responsible for the daily operation of the instruments at the different sites.

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>UV</th>
<th>Total ozone</th>
<th>Ozone profiles</th>
<th>Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grimstad</td>
<td>58°N, 08°E</td>
<td>x</td>
<td>GUV</td>
<td>Lidar</td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Oslo</td>
<td>60°N, 10°E</td>
<td>x</td>
<td>Brewer, GUV</td>
<td></td>
<td>University of Oslo/ Norwegian Institute for Air Research</td>
</tr>
<tr>
<td>Østerås</td>
<td>60°N, 10°E</td>
<td>x</td>
<td>GUV</td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Bergen</td>
<td>60°N, 05°E</td>
<td>x</td>
<td>GUV</td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Finse</td>
<td>60°N, 07°E</td>
<td>x</td>
<td>GUV</td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Kise</td>
<td>60°N, 10°E</td>
<td>x</td>
<td>GUV</td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Trondheim</td>
<td>63°N, 10°E</td>
<td>x</td>
<td>GUV</td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Ørlandet</td>
<td>63°N, 09°E</td>
<td>x</td>
<td></td>
<td></td>
<td>Norwegian Institute for Air Research</td>
</tr>
<tr>
<td>Andøya</td>
<td>69°N, 16°E</td>
<td>x</td>
<td>Brewer, GUV</td>
<td></td>
<td>Norwegian Institute for Air Research /Andøya Rocket Range</td>
</tr>
<tr>
<td>Ny-Ålesund</td>
<td>79°N, 12°E</td>
<td>x</td>
<td>GUV</td>
<td></td>
<td>Norwegian Institute for Air Research</td>
</tr>
<tr>
<td>Antarctica</td>
<td>72°S, 02°E</td>
<td>x**</td>
<td>NILU-UVC</td>
<td></td>
<td>Norwegian Institute for Air Research</td>
</tr>
</tbody>
</table>

*The sondes at Ørlandet and the GUV measurements at Ny-Ålesund were excluded from the national monitoring programme in 2006 due to lack of financial support.

** UV and total ozone column measurements at the Norwegian Troll station in Antarctica started in 2007. They are financed by the Norwegian Research Council.

1.1 Column measurements of ozone and short-lived gases relevant to ozone loss

Total ozone measurements using the Dobson spectrophotometer were performed on a regular basis in Oslo from 1978 to 1998 and in Tromsø from 1985 to 1999. Furthermore, quality-assured Dobson measurements were made at Ny-Ålesund, Svalbard, from 1995 to 2007. In 2007 the measurements were stopped due to a technical failure. Brewer measurements started up in Tromsø in 1994, but after the termination of other ozone-related observations at the Auroral Observatory in Tromsø in 1999 the instrument was moved to Andøya, 130 km southwest of Tromsø. Today daily total ozone values from Oslo and Andøya are based on measurements with Brewer spectrometers. The ozone values are derived from direct sun measurements, when available. On overcast days and days where the solar zenith angle is large the ozone values are calculated from the global irradiance method. As the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR) is located north of the polar circle (69.3°N, 16.0°E, http://alomar.rocketrange.no/), there are about 100 days without total ozone measurements during the winter. At Ny-Ålesund, an Italian Brewer instrument has been operating since 2006, and the data are shared between Italy and Norway.

The Norwegian Institute for Air Research (NILU) is also measuring ozone and ozone relevant traces gases at two sites: At ALOMAR two UV/VIS DOAS instruments (SYMOCs) have been used to measure total columns of ozone, NO₂, BrO and OCIO since 1998. Since 2006 the UV instrument for monitoring BrO/OCIO has been out of operation due to lack of financial support. Additionally, there is a DOAS instrument (type SAOZ) at Ny-Ålesund, measuring total columns of ozone and NO₂, which has been in operation since 1991. Near real time data can be found at http://saoz.obs.uvsq.fr. The NO₂
and ozone measurements at ALOMAR and Ny-Ålesund are a part of the Network for the detection of Atmospheric Composition Change (NDACC).

1.2 Profile measurements of ozone and other parameters relevant to ozone loss
Together with the Andøya Rocket Range, NILU has operated an ozone lidar at ALOMAR (Andøya) since January 1995. Since 1997 the instrument has been approved as a complementary site of the NDACC, and data are submitted to the NDACC database. The ozone lidar has also been used to measure polar stratospheric clouds and stratospheric temperature profiles. The lidar is run on a routine basis during clear sky conditions, providing ozone profiles in the height range 8 to 50 km. The latest measured raw data profiles and the latest analysed ozone data are available at http://alomar.rocketrange.no/alomar-lidar.html.

NILU was also operating an ozone sonde station at Ørlandet (63.4°N, 9.2°E) in the period 1994-2006. Nominally between 1 and 4 sondes were launched per month, depending on the time of the year. These measurements have traditionally been used for national monitoring purposes. In addition, NILU has participated in a number of experimental (match) campaigns where several stations have launched sondes in a coordinated pattern to sample the same air masses at different locations. The campaigns have been used to estimate ozone loss as a function of time and sun-lit hours. Finally, the ozone vertical profile soundings have extensively been used for validation of satellite instruments, especially on the ERS-2 and Envisat platforms. Unfortunately the ozone sonde measurements terminated in 2006 due to lack of financial support.

1.3 UV measurements
1.3.1 Narrowband filter instruments
The instruments in the Norwegian UV network (GUV, from Biospherical Ltd) are designed to measure UV irradiances in 4 channels. Using a technique developed by Dahlback (1996)¹, we are able to derive total ozone abundance, cloud cover information, complete UV spectra from 290 to 400 nm, and biologically weighted UV doses for any action spectrum in the UV.

In January 2007 NILU started measurements with a similar instrument (the NILU-UV radiometer) at the Norwegian research station Troll in Antarctica. The instrument is calibrated every month against relative calibration laps in order to keep track of instrument drift. Near real time (NRT) data are available at http://observatories.nilu.no/Datasets/Radiation/tabid/433/Default.aspx and http://observatories.nilu.no/Datasets/Ozonestratosphere/Totalozone/tabid/765/Default.aspx.

1.3.2 Spectroradiometers
Spectral UV irradiances (global scans) are measured at least twice every hour with the Brewer instruments at the Department of Physics, University of Oslo, and at ALOMAR.

1.4 Calibration activities
1.4.2 The Brewer instruments
The Brewer instrument at the University of Oslo has been in operation since summer 1990, whereas the Brewer measurements in Northern Norway started in 1994. The International Ozone Services, Canada, calibrates the Brewer instruments in Oslo and Andøya on a yearly basis, and the instruments are regularly calibrated against standard lamps in order to check their stability. The calibrations show that the Brewer instruments have been stable during the years of observations. Also, the total ozone measurements from the Oslo Brewer instrument agreed well with the Dobson measurements performed in the 1990s.

1.4.3 The GUV instruments
As a part of the Norwegian FARIN project, described in section 5, a major international UV instrument intercomparison was arranged. Altogether 51 UV radiometers from various nations participated, among them 39 multiband filter radiometers (MBFR’s). The instruments were also characterized on site. In addition to measurements of spectral responses, measurements against QTH

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

2.1 Ozone observations in Oslo

In order to detect possible ozone reductions and trends over Oslo we have investigated total ozone values from 1979 to 2008. For the period 1979 to 1998 data from the Dobson instrument has been applied, whereas for the period 1999 to 2006 the Brewer measurements have been used. The results of the trend analysis are summarized in Table 1. For spring months a significant negative trend of \(-0.16\)% per year is observed.

For the winter, summer and fall months no significant trends are detected. When all months are included a significant negative trend of \(-0.08\)% per year is observed. The analysis shows that the low ozone values in the 1990’s strongly contribute to the observed negative trends in total ozone.

Ozone column variability over Scandinavia and over Oslo in particular, in the summertime has been related to dynamical variability. For example, an intense low-ozone episode in August 2003 was associated to the severe heat wave over Europe that summer. High tropopause and anticyclonic anomalies caused westward-propagating, planetary-scale wave trains, extending as far as eastern Eurasia. These wave trains disturbed even the mid-stratosphere, up to about 30 mb (Orsolini and Nikulin, 2006⁢)

### Table 1: Annual percentage changes in total ozone over Oslo for the period 1.1.1979 to 31.12.2009. The numbers in parenthesis represent uncertainty (1σ).

<table>
<thead>
<tr>
<th>Time period</th>
<th>Trend (% per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter: December – February</td>
<td>-0.05 (0.10)</td>
</tr>
<tr>
<td>Spring: March – May</td>
<td>-0.16 (0.09)</td>
</tr>
<tr>
<td>Summer: June - August</td>
<td>-0.02 (0.05)</td>
</tr>
<tr>
<td>Fall: September - November</td>
<td>-0.05 (0.04)</td>
</tr>
<tr>
<td>Annual</td>
<td>-0.08 (0.04)</td>
</tr>
</tbody>
</table>

2.2 Ozone observations at Andøya

As mentioned above, ozone measurements in Northern Norway were performed in Tromsø until 1999 and at ALOMAR/Andøya from 2000. Correlation studies have shown that the ozone climatology is very similar at the two locations and that the two datasets are considered as equivalent representing one site. For the time period 1979 – 1994 total ozone values from the satellite instrument TOMS (Total ozone Mapping Spectrometer) have been used in trend analysis because of insufficient calibration of the Tromsø Dobson instrument before 1991 and low data coverage. The result of the trend analysis is summarized in Table 2. No significant trends were observed for Andøya for this time period.

In recent years the historical total ozone series from Tromsø (Fery spectrograph: 1935-1939, Dobson #14: 1939-1972, 1985-1999) and Svalbard (1950-1962) have been re-analyzed, homogenized, and evaluated by multi-linear regression methods (Hansen and Svenøe, 2005⁴, Vogler et al., 2006⁵). The analysis revealed a strong influence of the local stratospheric temperature at the 30 mbar level and a composite influence of climate tele-connection patterns.

### Table 2: Annual percentage changes in total ozone over Andøya/Tromsø for the period 1979 to 2009. The numbers in parenthesis represent uncertainty (1σ).

<table>
<thead>
<tr>
<th>Time period</th>
<th>Trend (% per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring: March – May</td>
<td>-0.00 (0.01)</td>
</tr>
<tr>
<td>Summer: June - August</td>
<td>-0.02 (0.04)</td>
</tr>
<tr>
<td>Annual (March-September)</td>
<td>-0.00 (0.05)</td>
</tr>
</tbody>
</table>

---


2.3 UV observations

Table 3: Annual integrated UV doses (kJ/m²) at three stations during the period 1995 - 2009.

<table>
<thead>
<tr>
<th>Year</th>
<th>Oslo</th>
<th>Andøya</th>
<th>Tromsø*</th>
<th>Ny-Ålesund</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>387.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>387.4</td>
<td>253.6</td>
<td>218.5</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>415.0</td>
<td>267.0</td>
<td>206.5</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>321.5</td>
<td>248.4</td>
<td>217.7</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>370.5</td>
<td>228.0</td>
<td>186.1</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>363.0</td>
<td>239.7</td>
<td>231.0</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>371.0</td>
<td>237.0</td>
<td>208.6</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>382.5</td>
<td>260.0</td>
<td>201.8</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>373.2</td>
<td>243.4</td>
<td>No measurements</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>373.2</td>
<td>243.7</td>
<td>190.5</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td>No annual UV doses due to calibration campaign</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>372.4</td>
<td>219.4</td>
<td>No measurements</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>351.8</td>
<td>253.3</td>
<td>No measurements</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>375.3</td>
<td>266.5</td>
<td>No measurements</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>278.6</td>
<td>254.1</td>
<td>No measurements</td>
<td></td>
</tr>
</tbody>
</table>

*The GUV instrument at Andøya was operating at Tromsø in the period 1996 – 1999.

3 THEORY, MODELLING, AND OTHER RESEARCH

3.1 University of Oslo

Department of Geosciences runs two models to study stratospheric ozone, namely Oslo CTM3 (updated version of the CTM2) and WACCM. The Oslo CTM3 model is a global three-dimensional chemical transport model covering the troposphere and stratosphere. The CTM3 is updated to the 2009 version of the University of California, Irvine CTM transport. The model core has been substantially changed in this process, comprising faster transport and an update of the photolytic calculations.

The model can be run in different horizontal and vertical resolution and can be forced by either IFS or ERA-40 data. Two comprehensive and well-tested chemistry schemes are included in the model, one for the troposphere and one for the stratosphere. An extensive heterogeneous chemistry has been included. Photo dissociation coefficients are calculated on-line. Emissions of source gases are also included. The Oslo CTM3 model is used in various experiments to look at the chemical changes in ozone. Past time slice runs have used emissions from the Edgar Hyde database to look at the chemical changes up to present. IPCC SRES scenarios have been used for calculating chemical changes in future ozone. Because of large uncertainties in future emissions in the source gases, several time slice runs with different scenarios have been performed. A specific run to look at changes in stratospheric ozone from 2000 through 2007 has been performed and compared with observations. The Oslo CTM2 will eventually be out of date, but will still be available.

The WACCM model is a general circulation model (Whole Atmosphere Community Climate Model) developed at the National Center of Atmospheric Research (NCAR). It is now running at the University of Oslo. WACCM is a coupled climate chemistry model providing a platform for various predictions about the interaction between chemistry and climate. It has 66 vertical levels from the surface through the troposphere, stratosphere and the mesosphere.

In general, the Department of Geosciences are working substantially on stratospheric modelling in order to better understand how the ozone-layer dynamics work. Comprehensive research on atmospheric ozone modelling has been performed by comparing observations with model results. The results show that it is possible to reconstruct the distribution of the ozone layer. The results are described in several publications.6,7,8,9

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3.2 Norwegian Institute for Air Research (NILU)

At NILU there has been a main research focus to understand the dynamical influence on the variability in column ozone, especially at the northern hemisphere at mid and high latitudes. Satellite validation of ozone profiles and total ozone is also a central activity. Some activities and results are listed below:

- The stratospheric lidar data from ALOMAR have been extensively used for the validation of GOME and ENVISAT's atmospheric instruments (GOMOS, MIPAS and SCIAMACHY). This is described in a series of publications. 10, 11, 12, 13, 14
- Leading modes of climate variability have been shown to induce a strong signature on the trend and year-to-year variability in ozone. These modes include planetary-scale components of the atmospheric circulation (the North Atlantic Oscillation, the Aleutian-Icelandic Seesaw) (Orsolini, 200415) but also more regional patterns, e.g. those associated with blocking phenomena (Orsolini and Doblas-Reyes, 200316).
- The dynamically induced low-ozone episodes (LOE) is studied. Orsolini et al. (200317) explained occurrences of summertime LOEs over the northern high latitudes, and Scandinavia in particular, and looked at their impact on the UV erythemal dose at the ground. An intense LOE occurred over Scandinavia during the European Heat Wave of the summer 2003 (Orsolini and Nikulin, 20067).
- Orsolini et al., (200518) have studied the changes in atmospheric composition (HNO3, NOX), and ozone depletion occurring in the afternoon of the exceptional autumn 2003 solar storms. A highly anomalous layer enriched in nitric acid was observed in the upper stratosphere following the storms, and then slowly descended throughout the winter. Simultaneous observations of NO2, including the nighttime polar stratosphere, revealed strongly enrichment of NOX layers following the storms. The formation mechanism for the nitric acid layer does not seem to involve polar stratospheric clouds or aerosols, but rather, is likely to involve heterogeneous chemistry on water ion clusters, a relatively new and unknown topic.

9 Isaksen, I.S.A. and S.B. Dalsøren, Improving estimates of the major atmospheric cleaning agent OH, (2011) Science, 331, DOI: 10.1126,
Jackson and Orsolini, (2007\textsuperscript{19}) have developed a new technique for the estimate of ozone loss in the stratospheric polar vortex based on the assimilation of EOS MLS and SBUV observations in the Met Office data assimilation system. The method has been used to assess Arctic ozone loss during the winters 2004/05 and 2006/07 (abstract presented at the EGU General assembly, 2008) and is aimed at better accounting for mixing and inhomogeneous descent within the vortex. The results show that data assimilation methods are very promising to potentially lead to more accurate ozone-loss estimates.

The ozone data from Tromsø have been used to establish a multi-decadal UV climatology at a nearby site (Skrova, Lofoten) with meteorological information (Engelsen et al., 2004\textsuperscript{20}). For the same area UV maps have been derived for the period 1984-2002, based on various satellite observation data (Meerkötter et al., 2003\textsuperscript{21}). In the frame of the EU project UVAC it was found that there is a positive correlation between maximum daily doses around 1 May and cod recruitment, in contradiction to the work hypothesis assuming a negative influence of UV on cod eggs and larvae.

The Svalbard ozone data have been used, together with long-term observations of cloud cover at Hopen Island (Svalbard), to calculate high-Arctic UV climatology. A preliminary analysis shows that spring UV doses in fact have decreased due to an increase of cloud coverage which is larger than the simultaneous decrease in ozone (Hansen et al., 2007\textsuperscript{22}).

Department of Community Medicine, University of Tromsø, has in collaboration with NILU conducted two field studies\textsuperscript{23,24} and developed a method\textsuperscript{25} for estimation of UV induced vitamin D status in humans. The studies applied UV simulations based on meteorological modelling data, UV measurements, questionnaire forms from cohort investigations, and blood sample analyses. The field studies and the developed method formed the basis for a larger cohort study on approx 41,000 women on the relation between oral and UV induced vitamin D status and breast cancer risk. No relation was found. NILU is also in charge of health risk assessment for Europe from UV exposure within the EU project INTARESE.

The EU CANDIDOZ project (Chemical and Dynamical Influences on Decadal Ozone Change) investigated the chemical and dynamical influences on decadal ozone trends focusing on the Northern Hemisphere. In this project the long-term ozone series at Tromsø\textsuperscript{26} and Svalbard\textsuperscript{27} was re-evaluated and used to quantify factors contributing to past ozone variability and trends.

3.3 CICERO Centre for International Climate and Research – Oslo
At CICERO changes in the total solar radiation at the surface (Kvalevåg and Myhre, 2007\textsuperscript{28}) and UV (Kvalevåg et al., 2008\textsuperscript{29}) over industrial areas have been calculated. In the calculations changes in gases (ozone, CO\textsubscript{2}, H\textsubscript{2}O, CH\textsubscript{4}, NO\textsubscript{2}, SO\textsubscript{2}), direct as well as indirect aerosol effect of sulphate black and organic carbon, surface albedo changes, and contrails are taken into account. For changes in the total solar radiation at the surface, aerosols is a dominating factor for the dimming over land areas, but increase in tropospheric ozone, H\textsubscript{2}O, CH\textsubscript{4}, NO\textsubscript{2} also give a small contribution. At high latitudes reduced total ozone is causing an increase in the total solar radiation at the surface (Kvalevåg and
4. DISSEMINATION OF RESULTS

4.1 Data reporting: Ozone

The complete set of revised Dobson total ozone values from Oslo is available at The World Ozone Data Centre (WOUDC) http://www.msc-smc.ec.gc.ca/woudc/. There are established daily routines submitting ozone data from the University of Oslo and from Andøya to WOUDC. The averaged ozone profiles (2 hours) from Andøya are reported to NDACC twice a year. Preliminary lidar profiles are reported weekly to GEOMON and quality-controlled data products are submitted yearly.

NILU has collected ozone measurements from Arctic balloon flights through the Nadir database since 1988. Files are transferred and stored in the NASA-AMES 2160 format, and an automatic script has been set up to convert incoming data into the CREX format that is used at ECMWF. This script also performs a series of data quality checks and can do simple corrections on erroneous input files.

4.2 Data reporting: UV

NILU has submitted spectral UV measurements from Norway to the European UV database (EUVDB). In the framework of the EU project EDUCE NILU has developed quality assurance software for spectral UV measurements. The QA software is applied automatically to all UV data submitted to EUVDB. Currently there are Brewer and Bentham UV spectral data from Andøya for the period 1998-2001 in the database.

4.3 Information to the public

4.3.1 Ozone

Daily total ozone values for Oslo are available at http://www.fys.uio.no/plasma/ozone/. The latest measured raw data profiles and the latest analysed ozone data from the ALOMAR Observatory at Andøya are available at http://alomar.rocketrange.no/alomar-lidar.html.

4.3.2 UV and ozone from GUV measurements

NILU has developed a web portal for dissemination of UV-observations and UV forecasts for Norway and common global tourist destinations, http://uv.nilu.no. The content of the UV web pages are:

- UV forecast for three days for user-selected locations in Norway. The UV forecast is given for clear-sky, partly cloudy and cloudy conditions
- Global UV forecast for common tourist destinations
- Measured UV doses and total ozone values measured at the Norwegian stations
- Facts on UV radiation and the ozone layer
- Information about sun protection for different locations and situations

The public may receive UV forecasts at user-selected locations by SMS or e-mail. The web application has been developed by NILU in co-operation with the Norwegian Radiation Protection Authority, Storm Weather Center, and the Norwegian Pollution Control Authority. In 2006 the Norwegian Meteorological Institute developed an additional UV forecast service where the weather forecast is an integrated part of the forecasted UV index.

UV indices and cloud effects measured by a GUV-instrument at the Department of Physics, University of Oslo, are presented and updated every 30 min at: http://www.fys.uio.no/plasma/ozone/.
4.4 Relevant scientific papers

The ozone and UV measurements performed in Norway give rise to research in collaboration with national and international partners. The reference list below gives an impression of the international collaboration and ongoing research in the Norwegian ozone and UV scientific community since 2004.

Bjerke, J.W.; Elvebakk, A.; Dominguez, E.; Dahlback, A. (2005), Seasonal trends in usnic acid concentrations of Arctic, alpine and Patogonic populations of the lichen Flavocetraria nivalis. Phytochemistry; 66:337-344


The observations performed by the Norwegian Radiation Protection Authority are available at http://www.nrpa.no/uvnett/ together with annual doses and information on sun protection.


5. PROJECTS AND COLLABORATION

Norwegian institutions and scientists are participating in numerous international and national projects. The following section gives an overview of the most important projects related to ozone and UV research in Norway.

International projects

**GEOMON Global Earth Observation and Monitoring of the atmosphere (2007-2011)** is a European project contributing to GEOSS. Its mission is to build an integrated pan-European atmospheric observing system of greenhouse gases, reactive gases, aerosols, and stratospheric ozone. Ground-based and air-borne data are sustained and analysed, complementary with satellite observations, in order to quantify and understand the ongoing changes of the atmospheric composition. The key objectives of the ozone activities are to continue the monitoring of O₃, NO₂, BrO, Cl₂/F₂, T, H₂O, aerosol/PSC from ground (NDACC) and space. Further the development of homogenisation and consistency of time series are central and the identification of links between stratospheric ozone and climate changes. Both NILU and the University of Oslo (Dep. of Geosciences) participate in this project. Web-site: [http://geomon.ipsl.jussieu.fr/](http://geomon.ipsl.jussieu.fr/)

**NDACC: The Network for the Detection of Atmospheric Composition Change (1991- present)** is a set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the stratosphere. Ozone and key ozone-related chemical compounds and parameters are targeted for measurement. The NDAAC is a major component of the international middle atmosphere research effort and has been endorsed by national and international scientific agencies, including the International Ozone Commission, the United Nations Environment Programme, and the World Meteorological Organization. Web-site: [http://www.ndsc.ncep.noaa.gov/](http://www.ndsc.ncep.noaa.gov/)

**INTARESE: Integrated assessment of health risks of environmental stressors in Europe (2005-2009)** brings together a team of internationally lead scientists in the areas of epidemiology, environmental science and biosciences to collaborate on developing and applying new, integrated approaches to the assessment of environmental health risks and consequences, in support of European policy on environmental health. NILU is responsible for implementation of the human health risk assessment of ultraviolet radiation. Web-site: [http://www.intarese.org](http://www.intarese.org)

**SHIVA: Stratospheric ozone: Halogen Impacts in a Varying Atmosphere (2009-2012)** aims to reduce uncertainties in present and future stratospheric halogen loading and ozone depletion, resulting from climate feedbacks between emissions and transport of ozone depleting substances
(ODS). Of particular relevance will be studies of short and very short-lived substances (VSLS) with climate-sensitive natural emissions. We will perform field studies of ODS production, emission and transport in understudied, but critical, regions of the tropics using ship, aircraft and ground-based instrumentation. We will parameterise potential climate sensitivities of emissions based on inter-dependencies derived from our own field studies, and surveys of ongoing work in this area. Web-site: http://shiva.iup.uni-heidelberg.de

National projects

ARCTIC_LIS Arctic variability and climate change linked to stratosphere (2007-2011) is a NILU-UiO collaboration funded by the Norwegian Research Council. It aims to investigate the impact of climate change on stratospheric ozone chemistry and transport, especially upon the ozone recovery, using a comprehensive, stratospheric chemistry model. It will also carry out exploratory studies on processes, still poorly represented or missing altogether in current chemistry-climate models, and which will be under scrutiny during the International Polar Year: I) the role of solar cycle and solar-terrestrial coupling from energetic particle precipitation (EPP), on the stratospheric ozone and nitrogen chemistry and budget, II) the role of very-short-lived bromine compounds on polar ozone depletion.

MERFATE Occurrence and fate of springtime atmospheric deposition of mercury in the Arctic (2007-2010), funded by the Norwegian Research Council. Deposition of mercury (Hg) from the atmosphere to the sensitive polar ecosystems is of particular interest in the Arctic. This is because studies have indicated the possibility of large depositional fluxes of Hg occurring during the polar spring (so-called Hg Atmospheric Depletion Events or AMDEs). UV radiation is one of the main driving factors in these processes and NILU and NTNU pursue further knowledge about this role of UVR.

SATLUFT Use of Satellite observations in the national and regional assessment of air quality, the atmospheric ozone layer, ultraviolet radiation, and greenhouse gases (2007-2010). The main objectives of the project are to use Earth Observation data to improve the national and regional monitoring and assessment of the stratospheric ozone layer and surface UV exposure, the air quality in Europe and greenhouse gases. NILU coordinates this project which is funded by the Norwegian Space Centre and the European Space Agency.


Atmo-TROLL: Atmospheric research and monitoring at Troll – a long-term observational program (2007-2010). This program intends to establish new knowledge on annual and short-term variability as well as long-term changes of climate and pollution parameters. The list of parameters comprises physical, optical and chemical properties of aerosols, ozone and UV, organic and inorganic pollution including Hg, CO and NMHC and surface ozone. The project is coordinated by NILU and funded by The Research Council of Norway.


UViversal: Industrial Verification of a Self-calibrating, Accurate and Non-expert ultraviolet (UV) Irradiance Meter (2009-2011). The UViversal verification project will develop a new UV irradiance meter, technology which will allow for better UV and ozone measurements, along with making possible for non-experts to precisely measure and monitor UV irradiance. We will enable UViversal to calibrate itself and alter the internal detectors to a non-silicon based technology which will allow for better ozone measurements at lower solar angles and increase the applicability of the instrument throughout the year in areas further north and south.

6. FUTURE PLANS
A short presentation of future plans are summarised below:

- NILU has deployed a NILU-UV instrument that is installed at the Norwegian Antarctic Troll Station (71° S). Analysis, further development, and applications of the instrument are planned for the
upcoming years. NILU will continue the focus on the ozone and UV monitoring activity, in order to establish a high quality data series which is important both for validation and UV/ozone research

- Re-evaluation of Tromsø (since 1994) and Oslo (since 1990) Brewer ozone data series according to better instrument specifications and ozone absorption spectrum, will be conducted during 2011 and reported to the WOUDC in Canada.
- NILU will continue the cooperation with CNRS, France, regarding the long-term series of measurements of \(O_3\), \(NO_2\) and other trace gases, with the newly upgraded SAOZ instrument in Ny-Ålesund.
- NILU will continue in participating in the NDACC and UV/vis workgroup.
- Ny-Ålesund will continue to be included in the UV monitoring programme as long as the financial situation allows it.
- NILU already are involved in community medicine activities related to ozone/UV and health and will continue to establish cooperation with the community medicine institutions

7. NEEDS AND RECOMMENDATIONS

For the past 6 years ozone and UV monitoring in Norway has been suffering from lack of funding. Since 2005 the ozone sondes at Ørlandet and UV observations in Ny-Ålesund have been excluded from the national monitoring programme, but Ny-Ålesund will be included in the programme from 2010, if future funding allows it. The UV-monitoring programme in Norway is a split cooperation between the Norwegian Radiation Protection Authority (NRPA) and NILU, but is funded from different sources. This situation is untenable, as the funding to NRPA is on a long-term basis, and the funding to NILU relies more on short term decisions. Also the LIDAR measurements for ozone profile observations at Andøya are in danger of being excluded due to lack of funding.

In general there is a need for predictable multi-annual funding schedules in order to free operations from additional funding sources. In order to manage surveillance programmes and run instruments properly and continuously, stable long-term economic support is warranted. The trend over the last decade has been that long-term monitoring programmes have been supported through other channels, like satellite validation or other short-term research projects. This is a concern regarding the stability and quality of long-term data sets needed for trend analyses, in particular.

Monitoring of UV radiation and atmospheric ozone is not only a matter of environmental issues. Recommendation of closer international collaboration on UV health risk assessment, UV effects, quality assurance of measurements, databases and forecasting is thus obvious.
In Poland, ozone and UV monitoring and related research activities are conducted by the Institute of Meteorology and Water Management (IMWM), and Institute of Geophysics of the Polish Academy of Sciences (IGFPAS). The ozone and UV-B monitoring and research, carried on in both Institutes, are supported by: Chief Inspectorate for Environmental Protection; National Fund for Environmental Protection and Water Management; Ministry of the Environment.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

**Institute of Geophysics of the Polish Academy of Sciences**

IGFPAS has been involved in the long-term monitoring of the ozone layer for almost 50 years. Measurements of the total ozone content and ozone vertical profile by the Umkehr method at Belsk (51°50'N, 20°47'E) by means of the Dobson spectrophotometer No.84 started in 1963, long before the depletion of the ozone layer became great challenge for research community and the policy makers. In 1991 a Brewer spectrophotometer No.64 (single monochromator) with a UV-B monitor was installed. The Brewer spectrophotometer No. 207 (double monochromator) has been put into operation in 2010. The column ozone and ozone content in the Umkehr layers are measured simultaneously by 3 instruments that helps to determine precision of the ozone observations by each spectrophotometer. The surface ozone measurements with Monitor Labs, ML8810 meter started in 1991 (replaced by ML9811 in 2004) and since 1992 NOx measurements have been performed with Monitor Labs ML8841 meter (replaced by API200AV in 2004).

The extended duration of the measurements and the high quality of the ozone data were essential for trend detection. Because the high quality of the ozone data is crucial subject in the analysis of the ozone variability the quality control and quality assurance of the ozone measurements is the major concern of the ozone research group. The Belsk ozone data were reevaluated in 1983 and 1987 on a reading-by-reading basis, taking into account the calibration history of the instrument. The performance of the Belsk's ozone instruments has been compared several times with the ground-based reference instruments (during international intercomparisons campaigns) and the satellite spectrophotometers (TOMS, OMI).

**Institute of Meteorology and Water Management**

Surface ozone measurements with Monitor Labs. ML9810 are performed at 3 stations: Leba (54.75N, 17.53E) on the Baltic Coast, Jarczew (51.81N, 21.98E) located in the central Poland, Sniezka (50.73N, 15.73E) in Sudety Mountains.

Profile measurements of ozone

**Institute of Geophysics of the Polish Academy of Sciences**

The ozone content in selected layers in the stratosphere over Belsk (51°50' N, 20°47'E) have been calculated using the Umkehr measurements by the Dobson spectrophotometer (since 1963) and the Brewer spectrophotometers (the Brewer No.64 since 1992 and the Brewer No.207 since 2010). The ozone profiles are derived by UMK92 algorithm applied to the Dobson data. UMK04 algorithm is used both for to the Dobson and Brewer Umkehr data. The Belsk ozone profiles have been used in the validation of ozone profiles derived by Microwave Limb Sounder on board of the Aura satellite.

**Institute of Meteorology and Water Management**

The ozone soundings have been performed at Legionowo (52.40N, 20.97E) upper-air station since 1979. Up to May 1993 the OSE ozone sensor with the METEORIT/MARZ radio
sounding system was used. Later on the ECC ozone sensor and DigiCora/RS80/92 radio sounding system of Vaisala is in use. The ozone soundings are launched regularly on each Wednesday. Additional ozone soundings were performed for the purpose of the MATCH campaign (statistical evaluation of ozone chemical destruction in Polar Vortex). The Legionowo ozone profiles were also used in the validation procedures of ozone profiles derived from satellite projects: MIPAS, SCIAMACHY and OMI. Legionowo is a complimentary station of the global NDACC/NDSC ozone sounding network. Ozone sounding data from Legionowo are submitted to the NDACC database. Since 1993, on the base of the NOAA/TOVS/ATOVS satellite data, total ozone maps over Poland and surroundings have operationally been performed at the Satellite Remote Sensing Center of IMWM in Krakow.

UV measurements

Broadband measurements
Institute of Meteorology and Water Management
Broadband UV Biometers model SL 501 vers. 3 have been used for UV measurements at three IMWM stations in Poland: Leba (54.75N, 17.53E), on the Baltic Coast, Legionowo (52.40N, 20.97E), in central Poland, Zakopane 857m, in Tatra Mountains (49.30N, 19.97E). Since 2006, broadband OPTIX UVEM-6C have been used for nowcasting purposes at six IMWM stations in Poland: Leba (54.75N, 17.53E), Mikolajki (53.78N, 21.58E), in the north-eastern Poland, Legionowo (52.40N, 20.97E), Katowice (50.23N, 19.03E) in the southern Poland, Zakopane 857m, in Tatra Mountains (49.30N, 19.97E), Mount Kasprowy Wierch 1988m (49.23N, 19.98E), in Tatra Mountains.

Institute of Geophysics of the Polish Academy of Sciences
Systematic measurements of ground level ultraviolet solar radiation (UV-B) with the Robertson- Berger meter were carried out at Belsk station in the period May 1975 – December 1993. In 1992 UV Biometer SL501A (replaced by the same type of the instrument in 1996), and in 2005 Kipp and Zonen UVS-AE-T broadband radiometer were installed. The instruments have been operated continuously up to now. The UV monitoring has been conducted at the Polish Polar Station at Hornsund, Svalbard (77°00’N, 15°33’) in the period 1996-1997 by UV Biometer SL501A and since spring 2006 up to now by Kipp and Zonen UVS-AE-T.

Narrowband filter instruments
Two NILU-UV spectral filter instruments, installed at IMWM station Legionowo, measure the UV-B, UV-A, total ozone and cloud transmission.

Spectroradiometers
Spectral distribution of UV radiation has also been monitored with the Brewer spectrophotometers at Belsk since 1992 (Brewer No.64) and in addition since 2010 (Brewer No.207). The spectra with 0.5 nm resolution for the range 290-325 nm and 286-363 nm have been calculated by the Brewer (No.64) and Brewer (No.207), respectively. Several spectra per hour are usually obtained for the solar zenith angles less than 85°.

Calibration activities

Institute of Meteorology and Water Management
The recent calibration of the reference UV Biometer model SL 501 took place in 2008 at PMOD/WRC – EUVC in Davos. The next calibration of the instrument is planned in 2011. The NILU-UV spectral filter instruments are regularly calibrated at NRPA, Norway.

Institute of Geophysics of the Polish Academy of Sciences
The Dobson and Brewer spectrophotometers have been regularly calibrated. The recent calibrations of the Dobson instrument took place at the Hohenpeissenberg Observatory of DWD in 2009 and in 2010. The intercomparisons were carried out against the European substandard Dobson No.64. The Brewer spectrophotometer No.64 was calibrated against the reference instrument Brewer No.17 maintained by the International Ozone Corporation (Canada) at the Arosa observatory (Swiss Meteorological Institute) in 2008 and 2010 and at the Hradec Kralove Observatory (Czech Hydrometeorological Institute) in 2009. During the Brewer intercomparison campaigns both the total ozone and UV spectra were calibrated. The Belsk’s broad band UV meters were calibrated in 2008 and 2009 in Innsbruck (CMS Company, Kirchbichl, Austria). Since 2010 the output of the broadband meters is compared against the Belsk’s Brewer No.207 (double monochromator).

RESULTS FROM OBSERVATIONS AND ANALYSIS

Figure 1.

Figure 1. Annual means (1963-2010) of total ozone at Belsk, Poland.

Figure 2.

Figure 2. Annual means of the erythemal weighted doses (1976-2010) at Belsk, Poland.

Figure 3.
Figure 3. Annual means (1992-2010) of surface ozone concentration at Belsk, Poland.

RESEARCH

Institute of Meteorology and Water Management
Ozone and UV research activities are carried on in the Centre of Aerology in Legionowo in cooperation with the Satellite Remote Sensing Center in Krakow.

- Long term changes in ozone profile at Legionowo, Poland have been studied. A definition of the ozone tropopause was proposed to study the variability in the stratospheric ozone columns. A significant ozone increase in the middle stratosphere has been detected. The observed differences in stratospheric ozone destruction from year to year are the result of changing meteorological conditions in the NH stratosphere.
- Legionowo is often located at the edge of the polar vortex and since 1995 participates in MATCH campaigns (statistical evaluation of ozone chemical destruction in Polar Vortex). Episodes of serious ozone deficiencies, observed during the displacements of the cold polar vortex in the winter/spring seasons have been observed.

Legionowo 17.02.2010 12UT

O3 - 308D
monthly mean O3 (1963-2003) - 378D

Figure 4. Example of ozone depletion recently observed at Legionowo.

- UV reconstruction model, elaborated within COST 726 Action ‘Long term and variability UV radiation over Europe’, was used for reconstruction of UV for Poland. The reconstruction algorithm was adopted for the period of 1985-2008 for 21 stations. Spatial and temporal analyses of monthly mean UVI values over area of Poland were performed. The monthly mean all sky UV index values in Poland decrease with increasing latitude. Deviation from latitudinal pattern of monthly mean UVI distribution has been observed in summer. The UVI isopleths direction changes to more longitudinal one with the maximum values in South Eastern Poland. This effect is especially seen in the multiyear monthly mean UVI map for July.
- Seasonal analysis of temporal variability in the years 1985-2008 shows an increase in monthly mean UVI calculated for all stations and cloud free conditions. When all sky UVI values are considered, the positive tendency was obtained for all seasons except for winter, when no
change can be seen. The increase in monthly mean UVI values is especially pronounced in spring and summer.

- Temporal variability of monthly mean UVI depends on the geographical localization as it can be seen in the analysis performed for maritime and mountainous stations. Nevertheless, for both stations the increase in monthly mean UVI has been obtained for spring and summer, what is especially significant for UV radiation biological effects.

- Biologically effective UV radiation (UVBE) for 3 stations of IMWM: Leba, Warsaw and Zakopane was analyzed. Analyses were performed on the basis of reconstructed data series: 17-years (1985-2001) for Leba and 24-years (1985-2008) for Warsaw and Zakopane. In Poland, there are hazards connected with excesses or deficiencies of UV radiation. Biologically effective UV radiation during the summer months may be harmful for human health without any protection. In winter time the UV radiation is not sufficient for natural synthesis of vitamin D3 by humans.

Institute of Geophysics of the Polish Academy of Sciences

The ozone time series (from the observations taken at Belsk and from the global ozone data bases) are examined by statistical models developed in IGFPAS to determine factors responsible for the ozone changes. The ozone variability and quantification of the impact of human activities on the ozone layer is essential because of the coupling of the ozone layer and the global climate system. The changes in the ozone layer are examined in connection with changes in the dynamic factors characterizing the atmospheric circulation in the stratosphere. Various studies have been carried out in the Institute focusing on the role played by the dynamical factors of the ozone variability. Natural dynamical processes in the Earth’s atmosphere could perturb the recovery of the ozone layer. To get more comprehensive view of ozone long-term changes over Europe the trends have been calculated using the reconstructed daily total ozone data since January, 1, 1950 for the area 30-80°N and 25°W-35°E. Variability of solar UV radiation over Belsk since 1976 up to now, i.e. based on the world longest series of the erythemal observations, has been analyzed after homogenization of the whole series of the broadband UV measurements. Recent studies on the atmospheric aerosols properties (from sunphotometric measurements at Belsk and Hornsund) are triggered by our previous findings (Krzyścin and Puchalski, 1998, J.Geophys.Res., vol.103, No. D13, PP. 16,175-16,181, doi:10.1029/98JD00899, Jarosławski and Krzyścin, 2005, J.Geophys.Res.,110, D16201, 9 PP., doi:10.1029/2005JD005951) suggesting that the variability of the aerosol optical characteristics in summer induces changes in the surface UV radiations comparable to those due to total ozone variability.

The research achievements since the previous Report (2008) could be summarized as follow:

- introducing the wavelet multi-resolution decomposition in calculation of the trend pattern in UV time series. (Borkowski, 2008)
- developing the methodology to reconstruct the total ozone time series for the periods without the ozone observations based on the meteorological data from the global 3-D reanalyses (NCAR/NOAA) database. (Krzyścin, 2008)
- building of the European total ozone data base comprising the grided (1 deg x 1 deg) daily total ozone data over the region (30-80°N, 25°W-35°E) since January 1, 1950. The statistically significant negative trends are found almost over the whole Europe only in the period 1985–1994. Negative trends up to ~3% per decade appeared over small areas in earlier periods when the anthropogenic forcing on the ozone layer was weak. The statistically significant positive trends are found only during warm seasons 1995–2004 over Svalbard archipelago. The reduction of ozone level in 2004 relative to that before the satellite era is not dramatic, i.e., up to ~5% and ~3.5% in the cold and warm subperiod, respectively. Present ozone level is still depleted over many popular resorts in southern Europe and northern Africa. For high latitude regions the statistically significant trend overturning could be inferred in last decade (1995–2004) (Krzyścin and Borkowski, 2008).
• support of high quality of the ozone profiles by the Microwave Limb Sounder (MLS) on board of the Aura satellite since 2004 by comparison with the ground-based data from Umkehr observations at Belsk (Krzyścin et al., 2008).
• finding that the UV radiation measured on a surface vertical to ground (usual position of human face and hands, i.e., parts of body being always irradiated by harmful UV radiations) could be effectively recalculated from the output of instrument placed horizontally (standard configuration of the UV measuring instruments at meteorological stations). The conversion constant (~0.5) is universal and allows to have a first guess of the real irradiation of human body by solar UV. (Sobolewski et al., 2008)
• homogenization of the Umkehr observations at Belsk (52°N, 21°E) for the period 1963 to 2007, taking into account step changes in the R-N tables and re-evaluated total ozone values. The negative trend in total ozone (about 3.5% per decade), found for the period 1980 to 1995, is due to the ozone depletion in the lower- and mid-stratosphere (up to 23.5 km). Afterwards, the trends in total ozone and in lower and mid-stratospheric ozone are not statistically significant. In the upper stratosphere (> 37 km) the trends in the period 1996 to 2007 are positive and of about 3-5% per decade. The occurrence of the positive trend after 1995 is in line with the Montreal Protocol regulations on ozone-depleting substances. (Krzyścin and Rajewska, 2009a)
• building a novel trend models capable of detecting signs of the ozone recovery and finding that ozone over Belsk, in central Europe, and in midlatitudinal Europe reaches at least first stage of recovery as defined by the World Meteorological Organization, i.e., a statistically significant reduction in the rate of decline. Substantial seasonal dependent long-term ozone oscillations by the dynamical drivers are revealed causing estimation of the ozone recovery time even more uncertain. (Krzyścin and Rajewska, 2009b)
• homogenization of the Belsk’s UV data obtained by various broadband UV meters since 1975 and calculation of the UV trends (yearly, seasonal, and monthly) in the erythemaly weighted solar radiation for the period 1976-2008 and quantification sources of these trends (ozone, cloudiness). The UV climatology was established and the UV variability was determined. Positive UV trends were found for the period of 1976-2008 in the annual mean (5.6±0.9% per decade), in the seasonal mean for the warm subperiod of the year (April-October, 5.5±1.0% per decade), and in monthly means (~2-9% per decade). A satisfactory agreement between the trend extracted from the homogenized ground-based data and that found in satellite UV data for Belsk (1979-2008) supports the reliability of satellite trend analyses over wider areas during snowless periods. (Krzyścin et al., 2011)
• determination of optical properties of aerosol in the UV range over Belsk (Pietruczuk and Jarosławski, 2008; Jarosławski and Pietruczuk, 2010) and over the Polish Arctic station – Hornsund (Rozwadowska and Sobolewski, 2010) from the sunphotometric measurements and finding factors influencing the aerosol variability there.

DISSEMINATION OF RESULTS

Data reporting
The ozone data taken at Belsk are regularly submitted to the World Ozone and Ultraviolet Radiation Data Centre in Toronto. The mean daily values of total ozone are also submitted operationally to the Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece.

The ozone sounding data from Legionowo are submitted to the World Ozone and Ultraviolet Radiation Data Centre in Toronto regularly on monthly schedule, and operationally to the Data Base at NILU (Norway).

Information to the public
• Since 2006, an operational monitoring of UV Index from the IMWM network has been published on IMWM web pages.
• Since 2000, the UV Index forecast for Poland has been available from May to September on IMWM web pages.
- An information system of solar UV radiation for outdoor workers was developed in the frame of project ‘Determination of UV radiation on Polish territory for the purposes of risk assessment’. (IMWM)
- since 2001, the daily means of total ozone from the Dobson measurements at Belsk and UV Index from the SL501A measurement are displayed in almost real time on web pages http://ozon.igf.edu.pl and http://uvb.igf.edu.pl, respectively. (IGF PAS)

**Relevant scientific papers**

**Institute of Meteorology and Water Management**


**Institute of Geophysics of the Polish Academy of Sciences**


Jarosławski, J., and Pietruczuk A., (2010), On the origin of seasonal variation of aerosol optical thickness in the UV range over Belsk, Poland, Acta Geophysica, 58, 1134-1146


PROJECTS AND COLLABORATION

• Institute of Meteorology and Water Management have participated in projects:

• Institute of Geophysics of the Polish Academy of Sciences
  - 2004-2009 COST 726 Action ‘Long term and variability UV radiation over Europe’
  - 2006-2008 Ministry of Science and Higher Education grant No. N307 005 31/0495 – “Variability of the biologically active solar UV radiation in the mid- and high–latitudes in different time scales”

FUTURE PLANS

Continuation of the current monitoring and research and:
• An e-atlas containing spatial and temporal distribution of UV radiation over Poland will be prepared using the reconstructed data. (IMWM )
• gaining a more robust picture of the ozone global changes examining output of all available trend models used in recent few years (IGF PAS)
• quantification of the impact the Montreal Protocol on the levels of ozone by a novel trend model that searches for a residual trend component that remains in the ozone series after subtracting the ozone signal related to long-term changes in the concentration of the ozone depleting substances in the stratosphere (IGF PAS)
• construction a retrieval algorithm applicable to the Umkehr profiles for the Dobson and Brewer spectrophotometers that allows statistical analyses of the aggregated time series comprising the Dobson and Brewer ozone profiles (IGF PAS)

NEEDS AND RECOMMENDATIONS

IMWM and IGF PAS recommend closer international collaboration on UV radiation to find a proper balance between the risk (carcinogen effects) and the benefit (synthesis of vitamin D in skin) of the solar exposure.

Ozone dial lidar would make possible the extension of the IGF PAS monitoring of the troposphere and lower stratosphere ozone with a special emphasis on the ozone changes in the tropopause region.
REPUBLIC OF KAZAKHSTAN

THE ABSTRACT

The report 73 with., 38 fig., 7 tab., 74 sources of the literature

Object of research are - a quantitative estimation of direct and indirect emissions (green house and ozone depletion influences) ozone depletion substances (ODS) within the limits of obligations Republic of Kazakhstan (RK) under the Montreal report at a transition stage to alternative substances.

The work purpose – Studying of time dynamics of the general maintenance of ozone over Kazakhstan to estimate taking place tendencies. Whenever possible to specify their origin

• To Reveal aerosynoptic conditions at which extreme concentration of the general ozone take place.
• To state an influence estimation ozone depletion, consumed in Kazakhstan, on an ozone layer and on a climate. To estimate share HFC in total amount consumed, ODSs and CFC substitutes in Republic.
• The Analysis of measures undertaken by the developed countries on reduction of emissions ozone depletion substances in various branches of economic activities.
• The Estimation of the undertaken efforts of directing bodies RK on reduction of emissions in atmosphere ODSs, and an estimation of consequences.

In the course of work researches of influence ODSs, on an ozone layer, communications ODSs with climate change, dynamics of emissions ODSs were conducted, a quantitative estimation of a hotbed effect and ozone depletion influences during 1998-2008, the forecast of consumption for the period till 2015 is given.

As a result of the executed researches level of direct and indirect emissions ODSs, in CO2 – an equivalent and its dynamics to 2008 is estimated., the forecast of consumption ODSs till 2015 in connection with transition to alternative sources is given. It is shown that despite consumption growth hydrofluorocarbons in Republic Kazakhstan direct and indirect influence on atmosphere tends to decrease.

Dynamics of the general maintenance of ozone, tropospheric and ground ozone are studied. aerosynoptic conditions of formation of their extreme concentration.

Results of research promote the decision of following problems:
- To quantitative and qualitative acknowledgement of success of performance of the obligations accepted by Republic Kazakhstan according to the Montreal report;
- To preparation of national reports of Republic Kazakhstan under the Montreal report and the Viennese convention;
- Our knowledge in the field of geoecology of formation and dynamics of ozone is expanded.
THE MAINTENANCE

THE LIST OF REDUCTIONS, SYMBOLS, UNITS AND TERMS

SYMBOLS AND UNITS OF PHYSICAL SIZES

INTRODUCTION

1. OZONE IN ATMOSPHERE
   1.1 Physicists of formation of ozone
   1.2. An annual course of the general maintenance of ozone.
   1.3. Tropospheric ozone
   1.4 Ground ozone
   1.4.1 Annual course of ground ozone
   1.4.2. A daily course of ground ozone
   1.4.3. A daily course of ground ozone in Almaty
   1.5. Long-term fluctuations of ozone.
   1.6. Aerosynoptic conditions at which extreme concentration of ground ozone are formed
   1.7 Dynamics and internal structure of monthly sizes of the general maintenance of ozone over Kazakhstan
   1.7.1. Types of fields of distribution general maintainens of ozone (GMO ) over Kazakhstan
   1.7.2. Synoptic conditions of formation of extreme sizes GMO
   1.8. Tendencies of change GMO over Kazakhstan
   1.9. Half Spheric models for transboundary carrying over of the polluting substances, some results for Kazakhstan on ground ozone.

2. THE ESTIMATION OF CONSUMPTION ODSs, IN KAZAKHSTAN ON ECONOMY SECTORS IN 2009 AND THE SCENARIO FOR THE NEXT YEARS
   2.1 Dynamics of quantity consumed ozone depletion substances in Kazakhstan
   2.1.1 Consumption level ODSs, in 2009
   2.1.2 Consumption ODSs on categories.
   2.1.3. Influence on climate ODSs,
   2.2. Consumption of substances of group HFC on sectors
   2.3.1 Uncertainty

3. THE ANALYSIS OF MEASURES UNDERTAKEN BY THE DEVELOPED COUNTRIES ON REDUCTION OF EMISSIONS OZONE DEPLETION SUBSTANCES IN VARIOUS BRANCHES OF ECONOMIC ACTIVITIES
   3.1. The general condition of a question.
   3.2. The measures undertaken by the developed countries for reduction of emissions and reduction of consumption ODSs,
   3.3. An estimation of the undertaken efforts of directing bodies RK on reduction of emissions in atmosphere ODSs,
   3.3.1. The national legislation, the administrative and legal measures, concerning ozone layer protection.
   3.3.2. Data presentation in Secretary on ozone.
   3.4. Necessary actions for maintenance of the program of the Government.

THE LIST OF THE USED SOURCES

Appendices
THE LIST OF REDUCTIONS, SYMBOLS, UNITS AND TERMS

Reductions

BrM  Bromic methyl Gross national product  The Total internal product
ICLLC  Influence on a climate during life cycle
HCFC  hydrochlorofluorocarbon
HFC  Hydrofluorocarbon
HS  The Harmonized system
GTRЭЕЕ  Group under the technical review and an economic estimation
HCFCГХФУ  Hydrochlorofluorocarbon
GEF  Global ecological fund
HFC  hydrofluorocarbon
Kr  Kilotons
EFFICIENCY  Efficiency
MB  Metilbromid
Mr  Metric tons
MOPE  The Ministry of preservation of the environment
MCF  Metilchloroform
MR  The Montreal report
UN  The United Nations
UP  Usual practice
ODSs  Ozone depletion of substances
ODP  Ozone depletion power
PS  polluting substances
GMO  The General maintenance of ozone
GH  Green house gases
PGW  Potential of global warming
PD UN  The Program of development of the United Nations
RK  Republic Kazakhstan
RI  Radiating influence
SC  The Stationary air conditioning
COEUTEE  The Commission of experts under the technical review and an economic estimation
TCM  Tetrahclormetan
HC  Hydrocarbon
CFC  Chlorforcarbon
FCC  Four-chloride carbon
UNPPE  The United Nations Program on preservation of the environment
SYMBOLS AND UNITS OF PHYSICAL SIZES

T.ODP Tons ODP Ozone depletion power
°C Celsius degree
Thousand tons One thousand tons
B. Tenge Billion tenge

Chemical formulas
About Atom of oxygen
O2 An oxygen molecule
CO carbon oxide
CO2 Carbon dioxide
CH4 Methane
N2O Nitrous oxide
INTRODUCTION

About 40 years ago it was revealed that hydrochlorofluorcarbons, used in the industry, especially intensively – in refrigerating branch, destroy an ozone layer of the Earth. The intensive scientific researches which have begun in those years in the field of atmospheric chemistry have allowed to reveal at once some types of the chemical reactions leading to destruction of an ozone layer. As it is known, the basic quantity of ozone is at heights of 22 km or a little above [9, 31, 34]. Hydrochlorofluorcarbons, having, as a rule, long term of a life, rise in an upper atmosphere and enter reaction with ozone, destroying it. Thus hydrochlorofluorcarbons do not collapse almost that has led to their fast enough accumulation in atmosphere and to acceleration of process of destruction of ozone [15, 16, 22, 23].

Ozone absorbs a considerable part of ultra-violet radiation of the Sun, protecting, thus, all live on the Earth, and simultaneously heating up corresponding layers of a stratosphere, i.e. an atmosphere part. Destruction of atmospheric ozone by hydrochlorofluorcarbons, hence, conducts to cooling influence on atmosphere. However hydrochlorofluorcarbons have own strips of absorption in an infra-red range of a spectrum and are, therefore hotbed gases. The majority of hydrochlorofluorcarbons have on atmosphere double influence: destroying an ozone layer, cool it, but absorbing leaving long-wave radiation of the Earth and atmosphere, heat up it. The second effect – heating of atmosphere is much stronger, than cooling [20, 29].

Ozone layer destruction is extremely serious problem for mankind. Therefore a number of the international agreements on curtailment of production and uses especially aggressive hydrochlorofluorcarbons and to replacement search by other substances (this question has been considered at the first stage of performance of a theme) has been accepted.

In connection with the above-stated in the given work dynamics of the general, tropospheric and ground ozone is comprehensively considered, aero synoptic conditions of formation of extrema of their concentration are studied. Time dynamics of concentration GMO is studied and bases for working out of corresponding methods of forecasting are put. For this purpose mathematical models EMEP of the centres the West and the East have been studied also and the binding of results to the Kazakhstan data is carried out.

The Viennese convention on protection of an ozone layer of 1985 was the first international document putting a problem of preservation of an ozone layer of the Earth. This document, inherently, had declarative character. The states which have signed him did not incur any obligations; contours of a universal problem which followed as soon as possible have been only outlined solve. However has passed hardly more than two years, and in 1987 the international community has accepted much more rigid document which has received the name the Montreal report on substances, destroying an ozone layer. According to its positions, the basic originators of destruction of an ozone layer by atoms of chlorine or bromine which have separated from molecules of the chemical compounds synthesised by the person [15, 16, 19, 22, 23] appeared. The basic fault was taken away by hydrochlorofluorcarbons, used as sprays in aerosols, and to coolants, including well-known R12 by which the overwhelming majority of refrigerators and conditioners in those days has been filled. Despite protests of not numerous groups of the authoritative scientists specifying in insufficient scientific validity of positions of the forthcoming contract, the Montreal report has been accepted, and the group of the chemists which have prepared scientific base under this interdiction, has been awarded the Nobel Prize [29, 32, 33].

Till now some researchers express the big doubts concerning expediency of acceptance of an interdiction hydrochlorofluorcarbons. The most rigid critics declare the report the grandiose swindle initiated by group of chemical concerns, on purpose to monopolise the market and to supersede national manufacturers, more moderate - speak about argumentativeness of some positions and call for updating of the report taking into account time.
Kazakhstan ratified the Viennese convention on protection of an ozone layer and the base Montreal report on the substances destroying an ozone layer [15].

The general obligations of the parties of these international nature protection agreements consist in the following. The parties of the Viennese convention undertake to protect health of the person and environment from the influences connected with an exhaustion of an ozone layer. The Montreal report to the convention contains schedules of stage-by-stage decrease in manufacture and consumption, the most important in the ecological and commercial relation ozone depletion substances (ODSs), measures of regulation of their manufacture, export and import [15, 16, 18, 30].

The Report parties found commissions of experts by scientific, ecological and technical and economic estimations. In process of receipt of the new information from these groups about influences on an ozone layer, the world network of supervision based on the data behind the ozone maintenance in atmosphere and its chemical compound, researches of properties OPB and occurrence of alternative substances and technologies, the Parties included in it new substances and strengthened requirements of the Report by acceptance of additions and amendments (London, 1990, Copenhagen, 1992, Montreal, 1997, Beijing, 1999).

In spite of the fact that after introduction of amendments and toughening of schedules of deducing from the reference of adjustable substances the Montreal report has taken very difficult form, it is recognised by most successful of nature protection international agreements. Thanks to the measures of regulation installed by its parties by 2000 world production ozone depletion substances, already it was reduced more than on 85 % in comparison with level of 1986 almost all countries of the world ratified the Montreal report that speaks about importance of participation in this agreement.

Now 27 countries-parties of the Montreal report including Kazakhstan, are carried to the countries with transitive economy. Process of transition of economy to the market relations, carried out by these countries, causes serious difficulties in performance of their obligations under the Montreal report and ratification of amendments to it. Difficulties consist, basically, in absence in these countries of financing for realisation of projects on reduction of consumption ODSs, a lack of the prepared shots and the information in the field of technical alternatives ODSs институциональных and language barriers.

The control over performance of the Montreal report is in conducting UNPE (United Nations Programs on environment). UNPE supports work of Ozone Secretary which (Kenya) is in Nairobi, is executive agency of the financial mechanism of the Montreal report - Multilateral Fund and Global Ecological Fund [15, 16, 19].

For today the total sum of the financial help on realisation of actions for reduction ODSs, rendered to the countries with transitive economy Global Ecological Fund, comes nearer to 200 million US dollars.

Kazakhstan as the country which has joined the Montreal report and other agreements both on protection of an ozone layer and to the Kioto report on measures directed on reduction of emissions of hotbed gases, keeps account consumption hydrochloroflorcarbons in the country and tries to predict such consumption, and also to estimate size of a hotbed effect at the expense of emissions hydrochloroflorcarbons [16, 35-38].

Particularly at the third stage following problems have been put:

1) Studying of time dynamics of the general maintenance of ozone over Kazakhstan, an estimation of its tendencies and an origin;
2) To Reveal aerosynoptic conditions at which extreme concentration of the general and ground ozone take place;
3) To state an influence estimation хладонов, consumed in Kazakhstan on an ozone layer and on a climate. To estimate длю ГФУ in total amount consumed хладонов in Republic
4) To make the analysis of measures undertaken by the developed countries on reduction of emissions ozone depletion substances in various branches of economic activities.
The decision of the problems set forth above, according to the Technical specification on theme performance (Appendix A) also is the maintenance of the given Report. Tasks in view are completely executed, and results are presented in the given report.

1. OZONE IN ATMOSPHERE

1.2. An annual course of the general maintenance of ozone.

The annual course of the general maintenance of ozone at stations of Kazakhstan where it is measured, is very simple and presented on fig. 1. Mans average sizes GMO for the same stations are resulted in table 1.

Fig. 1 Annual course of the general maintenance of ozone at stations of Kazakhstan from 1973 for 2006

It is possible to see that annual course GMO is very simple and similar at all stations of Kazakhstan. It has one maximum in March and a minimum in September. However, in separate years the maximum can move for February, and a minimum for October.

In an annual course it is well looked through following dependence: the to the south the station, the is less GMO in a maximum and as a whole within almost all year except for the minimum period. On this time site of size GMO are very close also dependence on width it is broken. The station Semipalatinsk though is located a little to the south of Karaganda, but it is considerably shifted to the east where the local maximum of ozone [30] takes place.

In a maximum average sizes GMO change from 395 ODSs for Semipalatinsk to 373 ODSs for Almaty. In a minimum the range of change is less: from 309 ODSs for Atyrau in October to 294 ODSs for Almaty in September. Thus, the amplitude of annual course GMO makes 75-80, i.e. 30-35 % from an average for a year.
Table 1
Long-term average monthly values GMO (ODSs)

<table>
<thead>
<tr>
<th>Months</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alma-Ata</td>
<td>351</td>
<td>372</td>
<td>373</td>
<td>353</td>
<td>343</td>
<td>328</td>
<td>308</td>
<td>297</td>
<td>294</td>
<td>299</td>
<td>310</td>
<td>329</td>
</tr>
<tr>
<td>Atyrau</td>
<td>364</td>
<td>388</td>
<td>388</td>
<td>372</td>
<td>366</td>
<td>349</td>
<td>325</td>
<td>316</td>
<td>311</td>
<td>309</td>
<td>313</td>
<td>330</td>
</tr>
<tr>
<td>Aral sea</td>
<td>357</td>
<td>381</td>
<td>384</td>
<td>364</td>
<td>361</td>
<td>344</td>
<td>322</td>
<td>315</td>
<td>306</td>
<td>305</td>
<td>304</td>
<td>326</td>
</tr>
<tr>
<td>Karaganda</td>
<td>364</td>
<td>390</td>
<td>387</td>
<td>372</td>
<td>370</td>
<td>351</td>
<td>335</td>
<td>321</td>
<td>309</td>
<td>305</td>
<td>309</td>
<td>333</td>
</tr>
<tr>
<td>Semipalatinsk</td>
<td>368</td>
<td>389</td>
<td>395</td>
<td>378</td>
<td>372</td>
<td>356</td>
<td>338</td>
<td>330</td>
<td>315</td>
<td>306</td>
<td>312</td>
<td>331</td>
</tr>
</tbody>
</table>

AVERAGE 361 384 385 368 362 346 325 316 307 305 310 330

Against enough simple as it is told above, annual course GMO, characteristic Kazakhstan for all stations, most poorly this minimum is looked through on a curve of course GMO for Almaty. Thus, an annual course and features of spatial distribution GMO over territory of Kazakhstan as a whole correspond to the theory and results of researches of ozone [37, 39, 40, etc.].

1.3. Tropospheric ozone

As tropospheric ozone appears as a result of "infiltration" of stratospheric ozone through тропопаузу it is natural to expect that its annual course will be definitely caused by a course of stratospheric ozone. And stratospheric ozone, or the general maintenance of ozone (GMO), has the expressed simple annual course with one maximum and one minimum. The maximum takes place in the end of winter or in the beginning of spring. In a zone 45-50n.b. It is necessary on the beginning of April. The maximum at all widths of a moderate strip is distinct. Minimum GMO on the contrary flat also "is smeared". It can come in September-October (about 50 % of stations of Northern hemisphere) either in November-December or in August, i.e. the period from August till November of size GMO are insignificant and can change from a month by a month.

Amplitudes of annual course of GMO in the north exceed of 200 Dobson units, and in moderate widths – 100 ODSs.

In table 2 the annual course of size of tropospheric ozone over Kazakhstan in terms of Dobson u. on the basis of satellite measurements during 2005 [25] is presented. For simplification of the analysis in the table the data about tropospheric ozone in adjacent territories for the same year is cited.

Table 2.
Average sizes of tropospheric ozone at stations of Kazakhstan (D.units).

<table>
<thead>
<tr>
<th>Станции</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>The Sum</th>
<th>Compare stations year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alma-Ata</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>25</td>
<td>35</td>
<td>50</td>
<td>40</td>
<td>33</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>328</td>
<td>27,3</td>
</tr>
<tr>
<td>Atyrau</td>
<td>27</td>
<td>30</td>
<td>28</td>
<td>24</td>
<td>30</td>
<td>28</td>
<td>35</td>
<td>30</td>
<td>23</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>306</td>
<td>27,1</td>
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<tr>
<td>Aral sea</td>
<td>26</td>
<td>35</td>
<td>30</td>
<td>22</td>
<td>25</td>
<td>30</td>
<td>40</td>
<td>36</td>
<td>25</td>
<td>22</td>
<td>25</td>
<td>20</td>
<td>336</td>
<td>28,0</td>
</tr>
<tr>
<td>Karaganda</td>
<td>17</td>
<td>26</td>
<td>25</td>
<td>24</td>
<td>22</td>
<td>32</td>
<td>40</td>
<td>36</td>
<td>23</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>305</td>
<td>25,4</td>
</tr>
<tr>
<td>Semip-sk</td>
<td>15</td>
<td>28</td>
<td>23</td>
<td>20</td>
<td>30</td>
<td>35</td>
<td>43</td>
<td>30</td>
<td>22</td>
<td>20</td>
<td>17</td>
<td>17</td>
<td>300</td>
<td>25,0</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>20</td>
<td>28</td>
<td>25</td>
<td>24</td>
<td>26</td>
<td>32</td>
<td>42</td>
<td>34</td>
<td>25</td>
<td>20</td>
<td>22</td>
<td>20</td>
<td>1595</td>
<td>26,6</td>
</tr>
</tbody>
</table>

It is possible that in general an annual course of tropospheric ozone to see much more difficult, than annual course GMO. The basic maximum of tropospheric ozone in territory of Kazakhstan
is necessary for July. This maximum is well expressed in Republic territory though at some stations of adjoining territory it takes place in August or June (Chardzhou, Dushanbe, etc.). The maximum in a time course there is more stretched in time. However, in an annual course of tropospheric ozone unlike GMO is available two minima and two maxima. The second, or the secondary maximum is observed in February, and at some stations of adjoining territories, in March. Accordingly, the secondary minimum takes place in April-May. Both the secondary maximum, and a secondary minimum are expressed accurately and short in time. It is obvious that the secondary maximum in February-March and the basic minimum in September-November coincides with extrema during stratospheric ozone. As to the basic maximum of tropospheric ozone in July it is caused active thermal конвекцией in this season and destruction of tropopauze over the south of Kazakhstan in summertime [30] that facilitates receipt in troposphere of atmospheric ozone.

The basic minimum of tropospheric ozone is observed simultaneously with minimum GMO in atmosphere and, probably, is its consequence. As to a secondary maximum of tropospheric ozone in February (sometimes in March) it coincides on time in due course approaches of maximum GMO. And this factor explains its existence. The approach explanation, however, a secondary minimum of tropospheric ozone in April-May demands additional researches. Probably it is result of strengthening an meridional exchange in which result on territory of Kazakhstan air of tropical widths arrives, poor ozone, and the mechanisms providing receipt of ozone from a stratosphere, are still insufficiently effective at this time. They amplify only by July.

Thus, in an annual course of tropospheric ozone two maxima and two minima take place. The basic maximum takes place in July, and it is caused intensive turbulent and by convection an exchange on a vertical, and also easing тропопаузы, as detaining layer, by this time. The secondary maximum in February-March coincides on time with minimum GMO and, probably, by it is caused. And maximum of GMO comes in connection with activization of the general circulation of atmosphere and carrying out in system of hollows of the cold air rich with ozone from high widths.

The basic minimum of tropospheric ozone is caused by a minimum of stratospheric ozone which comes during the period from September till November. The secondary minimum in April-May is caused by change of carrying out of the cold air weights rich with ozone, from high widths, on carrying out of warm air weights from the south, poor ozone. The annual course of tropospheric ozone appreciably defines a course of concentration of ground ozone.

1.4 Ground ozone (GO )
1.4.1 Annual course of ground ozone

The basic drain of atmospheric ozone, as it is known, are a ground layer and an earth surface where it filters. Therefore the quantity of ground ozone is defined on the one hand by its infiltration from an upper atmosphere (from a stratosphere), and with another – speed of its destruction in a ground layer and at the earth. The best conditions for ozone receipt in a ground layer are such when are developed convection, turbulence, and also the ordered movings of air on a vertical. Such conditions are created during the spring-and-summer period. In the winter for the majority of regions of Kazakhstan, except absence of conditions for intensive convection and turbulence presence of ground inversions or izostratas, interfering ozone receipt in a ground layer is characteristic. It causes in an annual course of ground ozone a maximum during the summer period and a minimum – during the winter period, May and December-January accordingly. Thus the amplitude of its annual course is great: From 0,01 mkg/m3 in the winter to 0,16 mkg/m3 in the summer, i.e. summer average concentration exceed winter at 10-15 time. On fig. 2 the annual course of ground ozone is presented to Almaty for the three-year period.
As speed of destruction of ground ozone depends on concentration of nitrous oxide on the schedule fig. 2 is put also a course of average concentration of this substance. Besides, on the schedule are put, also the monthly average temperatures of air, characterising conditions thermal convection and turbulence.

It is possible to see that from winter by the summer the curve of change of concentration of ground ozone in general repeats a course of temperature of air. Since August, however, concentration of ozone decrease much faster, than air temperature decreases. It is caused by that in the end of summer and in the autumn for region carrying out of warm air weights from Arabian peninsula and from Afghanistan, poor, as it is known, ozone [30] is characteristic. As a result, despite quite intensive hashing on verticals, ozone receipt in the ground layer decreases faster, than there is a decrease in temperature of air.

Annual course of concentration of dioxide of nitrogen returns to an annual course of concentration of ozone. The minimum of dioxide of nitrogen is observed in August, and a maximum - during the winter period that is quite explainable. The basic sources of emissions nitrogen dioxide are the power enterprises, and also motor transport. Emissions of the power enterprises are maximum during winter time and are minimum in the summer. In August also the quantity of cars in a city in comparison with spring is less and considerably decreases in the autumn. Hence, to see effect of destruction of ozone emissions of dioxide of nitrogen it is not obviously possible, at least at level of monthly average sizes.

The particular interest is represented by low concentration of ozone to the winter period. Over the southeast of Kazakhstan at this time the spure of the Siberian anticyclone promoting to formation enough of powerful ground inversions almost constantly settles down. Repeatability of such inversions in Almaty exceeds 70 % [46, etc.]. As a result receipt of ozone from the top layers from troposphere is complicated, and process of its destruction in a ground layer takes place. Against such general feature, characteristic for winter, in separate days depending on aerosynoptic conditions of concentration of ground ozone can strongly increase.

1.4.2. A daily course of ground ozone

As ground ozone makes direct impact on the person the great attention was always given to its research. The particular interest has presented its daily course. Still in [41] it has been shown that features of a daily course are connected with ozone distribution in a ground layer and processes of carrying over and destruction of ground ozone. The author [41] believes, hence, that daily
changes of ground ozone are a consequence of a vertical exchange in weights of air. And only in the winter at strongly weakened exchange the second factor – «air pollution by a smoke and other, destroying ozone a layer» comes into force. In the same place it has been shown that the absolute and relative amplitude of a daily course of ground ozone increases in the summer about to 20% from an average and decreases in the winter. The amplitude is insignificant in a seaside climate and on heights in the winter. The maximum of density of ozone comes usually soon in the afternoon, and a minimum – in the morning during sunrise. In the summer the maximum often moves on 16-17 h. local time.

The researches executed by different authors the next years, have deepened and have expanded our knowledge of a daily course of ground ozone, but the basic results stated in [30], have been confirmed.

1.4.3. A daily course of ground ozone in Almaty

In table 3 the basic characteristics of a daily course Ozone in Almaty in median months of seasons of year are placed.

Table 3
Sizeds of ground ozone over Alma-Ata (mkg/m3)

<table>
<thead>
<tr>
<th>Months</th>
<th>Characteristics</th>
<th>The Average</th>
<th>Terms</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>01</td>
<td>07</td>
<td>13</td>
</tr>
<tr>
<td>January</td>
<td>An average max min</td>
<td>5</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>74</td>
<td>83</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>April</td>
<td>An average max min</td>
<td>108</td>
<td>10.5</td>
<td>227</td>
</tr>
<tr>
<td></td>
<td></td>
<td>274</td>
<td>301</td>
<td>488</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>July</td>
<td>An average max min</td>
<td>201</td>
<td>168</td>
<td>359</td>
</tr>
<tr>
<td></td>
<td></td>
<td>433</td>
<td>341</td>
<td>677</td>
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<tr>
<td></td>
<td></td>
<td>20</td>
<td>31</td>
<td>55</td>
</tr>
<tr>
<td>October</td>
<td>An average max min</td>
<td>38</td>
<td>37</td>
<td>172</td>
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<tr>
<td></td>
<td></td>
<td>226</td>
<td>173</td>
<td>342</td>
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<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

It is possible to see that the daily course of ozone in Almaty essentially differs from the results containing in [41], etc. for plains. The general is that during all seasons of year the maximum of ground ozone takes place at 13 o'clock local time. Thus average concentration from January (minimum) by July (maximum) increases in 20 times, it is essential more than sizes of annual amplitudes to Europe and the North America. The reason of it are the powerful ground inversions caused by influence of a southwest spur of the Siberian anticyclone, observed during all cold period. Inversions interfere with receipt of ozone from troposphere, therefore in the winter a minimum Ozone especially deep.

The ozone minimum in January-April and October in a daily course takes place not in the morning, and in the evening at 19 o'clock. Only in July its minimum is observed in 7 o'clock in the morning. Almaty it is located in foothills of Zailijsky Ala Tau in a zone it is mountain-valey winds [47]. In [42] it has been shown that at the Antarctic coast local winds essentially deform a daily course Ozone. Influence of such winds also forms a daily course.

From a maximum at 13 o'clock concentration Ozone quickly go down by 19 o'clock at the expense of easing convection, turbulence, and also the beginning of formation of the ground or raised inversion which takes place and at any time year, though also the nature at it another. Even with a sunset and cooling of mountains there is a mountain wind. As it is known [8, 9], in
an interface during the cold period at height about 500-1000 m the ozone maximum in its vertical distribution takes place. Here the mountain wind, promotes lowering of air weights along mountain valleys and slopes and enriches ozone the bottom layers. It absence of a minimum of ozone in 07 o'clock in cold months and its presence – in warm also speaks. Thus in June-August this minimum is especially deep. Small falls of concentration of Ozone in 07 o'clock are observed in April and October. In the end of April and the beginning of October of a condition is closer to summer, than to the winter. Therefore we can observe this weak secondary minimum. The similar explanation of a daily course at coast of Antarctica where are observed local стоковые winds, contains in [30, 42], etc.

How does concentration of ground ozone within days strongly vary? According to [8, 9] daily fluctuations of Ozone are in limits + 20 % from an average. It is possible to see that in Almaty in January the daily course of average sizes of ozone makes 100 % from an average towards a maximum and 300 % towards a minimum, in June – 50 and 30 %, in April – 80 and 40 %, in October – 90 and 450 % accordingly. Hence, speed of change of ground concentration the least in July, in the winter, and during transitive seasons it above.

In table 3 extreme values or extrema of Ozone, observed within months of certain seasons are resulted also. In January and also in April and October the bottom values of Ozone are defined by sensitivity of the device. In January in terms 01, 07, 13 and 19 o'clock 18, 13, 4 and 18 cases when the device showed zero concentration of Ozone have been registered. In April and July of such cases was not, and in October they have made 9, 7, 0 and 11 accordingly on terms. April and October, hence, despite approximate similarity radiation conditions, have very differing average sizes Ozone (132 and 94 mkg/m3 accordingly) and maxima Ozone in October much more low, than in April. The most appreciable distinction, however, is repeatability of zero sizes. In October such 27 cases from 94, and in April – any took place. October is transitive month from summer by the winter [30, etc.] When summer processes are already weakened, and winter have not gained in strength. It causes a weak exchange on a vertical (in comparison with April) and fast decrease in ground ozone.

Apparent from the same table 31, extrema in all terms in July only in 2 times exceed average sizes. In April and in October during a day maximum they too only in 2 times exceed average value. In other terms, however, this excess can be in 5 and more times above, than averages for this term. For January, in view of a great number of zero values, conclusions are less reliable, extrema in a day maximum more than three times exceed an average, and in other terms they differ at 10-15 time. Marked features in sizes of averages and extrema allow to assume the following: there are any limiting sizes of concentration of ozone in atmosphere, whence it arrives in a ground layer. In the summer when the mechanism of a vertical exchange is most active, ground concentration of ozone is great, and they considerably come nearer to greatest possible taking into account possibilities of the mechanism of transfer. Therefore average and maximum sizes of ozone differ minimum in an annual course. During other seasons in the ground layer arrives on the average only a part of ozone from the possible.

Only at active synoptic processes of a condition of a vertical exchange temporarily improve ( or not improve ) there is a maximum (or a minimum), essentially distinguished from average.

Synoptic conditions at which extreme conditions of concentration of ozone take place, demand independent consideration, that by us is made below.

Some words about influence of the polluting substances (PS ), contained in a ground layer, on concentration of ground ozone. As it is fairly marked in [30, etc.], such influence can be noticed in the winter, when natural ground concentration of ozone are small. However there are a lot of difficulties in the winter. In [30] it is underlined, that it is frequently easier to allocate horizontal carry of ground ozone, than influence of polluting substances.

In our case, however, in view of results of the analysis of the aerosynoptic conditions stated below, the certain conclusions to make it is possible. First of all, presence in a daily course of a minimum of ozone in 19 o'clock, i.e. in a rush hour, unequivocally specifies influence PS on destruction of ground ozone. Thus the important role in this process plays except for оксидов
nitrogen and окись carbon. It is known, that at emissions of modern thermal stations окись carbon is present only as traces. The basic contribution to ground concentration WITH brings motor transport. Calms and the weak winds prevailing here, promote that concentration 3B can collect up to significant concentration.

The secondary night maximum of concentration of ozone in 01 o'clock too has an explanation. At night when movement of transport strongly weakens, emissions carbon dioxide and nitrous oxides appreciably decrease, process of destruction of ozone too stops. In city the air mass (unimportantly, from what side) is displaced more richer by ozone. It also promotes formation of a night maximum. To the morning we have a natural reduction in concentration of ground ozone due to easing its receipt from above.

The local conditions promoting on the one hand accumulation PS up to high concentration, and with another - a plenty of automobiles and their emissions in city with the expressed daily course of activity is enough facilitate our analysis.

As a whole, however, the problem of ground ozone is still far from a desirable level of understanding and additional more detailed measurements and the analysis are required.

1.5. Long-term fluctuations of ozone.

Studying long-term fluctuations of ozone is of interest. If these fluctuations are somehow connected to changes of a climate and the general circulation of an atmosphere it will allow to consider such fluctuations of ozone as one of chains of the general circulation of an atmosphere. It was specified connection of acyclic fluctuations GMO with the general circulation still in [30]. There it has been shown, that a maximum of ozone by the similar image, appeared above the Western Europe and the Far East, has coincided with deep negative anomaly of temperature. Authors [43] came to a conclusion, that such anomalies are connected «not so much to separate intrusions of Arctic air, how many with the general gradual reorganization of circulation in Northern hemisphere». Similar conclusions are made in [32] on supervision above Northern America where increase GMO on 7 % has been connected to a steady deepening in the winter of trough in the top troposphere above the east the USA which has caused carrying out of Arctic air, rich ozone, on the south.

Convincing enough results confirming the general reorganization of circulation are resulted in [30]. Authors have constructed twenty mons sliding average GMO for the period with 1961 on 1976 for stations Aroza and Tareno in spite of the fact that points divide 130 degrees of a longitude, curve had the certain similarity. High maximum GMO in Aroza took place in November, 1969, and in Tareno - in February - March 1970y. Attraction of the data of station Arhus located on 10 degrees to the north of Aroza, has allowed to allocate a local component. Curves GMO for these stations were almost parallel, but in Arhus the maximum was higher and was observed later, than in Aroza. After 1969 of size GMO at both stations began to go down gradually. Occurrence satellite given, and also some other means now have allowed to study the given problem more deeply and more widly. So, in [44, 48] on the basis of the data of the National meteorological center of the USA are designed by two year long-term components of anomaly of the tropospheric and stratospheric moments of pulses for 1978-1992 гг. It is shown, that distinctions of interannual variability of circulation of troposphere and a stratosphere can be explained by imposing two year and long-term fluctuations. On the basis of satellite measurements GMO it has been shown, that its interannual fluctuations above Antarctica in October can be explained a two year cycle of fluctuations of a zone wind of the bottom troposphere of equatorial latitudes (Singapore). In result have taken place long-term changes inter latitudes connections of circulation of a stratosphere. Hence, the initial reason of occurrence of an ozone gap above Antarctica is long-term easing of wave activity in average and high latitudes of a southern hemisphere. In the latest years a lot of works in which connection of fluctuations of the general circulation of an atmosphere with fluctuations GMO [30] is shown

377
has appeared. Thus, not denying an opportunity of chemical destruction of stratospheric ozone by HFC, it has been convincingly shown, that long-term changes of ozone are caused by the general gradual reorganization of the general circulation.

Let's look, as fluctuations of the general contents of ozone above Kazakhstan are connected to the general circulation of an atmosphere. As the parameters describing the general circulation, we shall take a long-term course of average annual temperature in Almaty (a product of the general circulation), Tokarev's and Bagrov indexes, and the ZONE index, taken in a ready kind from [16]. In figure 3 the century course of temperature on station Almaty and GMO for the same years is submitted.

It is possible to see, that practically to all extremely low mid-annual temperatures of air there correspond extremely high concentration GMO. Conformity to extremely high temperatures extremely low GMO, though and not so well defined takes place also.

![Graph showing temperature and ozone changes over the years.](image)

*Fig. 3. Indexes of circulation of Tokarev and Bagrov indexes, and the ZONE index, and a time course of temperature and GMO on station Almaty.*

As is known, [46, etc.] during the summer period interannual variability of temperature is insignificant. The basic changes occur in a cold season, so they determine size and a sign on annual anomaly. All cold intrusions are accompanied, as by us is shown above, the increased
concentration of ozone, is especially in a zone of fronts. It is caused by carrying out of air, rich in ozone, from the Arctic latitudes. Arrival of tropical air to systems of subtropical crests is accompanied low GMO since this air is poor ozone. Hence, often and intensive intrusions of Arctic air form negative anomaly of temperature and positive - GMO. And often carrying out of air from subtropical latitudes - positive anomaly of temperature and negative - GMO.

On fig. 3 the joint course of Tokarev and Bagrov indexes and GMO on station Almaty for the same line of years is submitted. Earlier in [16] it has been shown, that a temporary line of average annual temperature for Kazakhstan well correlates with the above-named indexes. The temperature of air in Almaty is formed under influence of lines and other factors, except for analyzed. Nevertheless, we can see, that the basic extrema during the named indexes and in course GMO for Almaty coincide.

All marked above, specifies that the most significant fluctuations GMO are caused by fluctuations of parameters of the general circulation of an atmosphere. Hence, the forecast of changes GMO in Kazakhstan, including in long-term aspect should be based on the forecast of dynamic of the general circulation of an atmosphere in Northern hemisphere.

1.6. Aerosynoptic conditions at which extreme concentration of ground ozone are formed

Represents practical interest research of conditions of formation, both the general contents of ozone, and ground one. Whereas conditions of formation of ground ozone in Almaty practically are not investigated, the greatest attention is given to this question.

Then conditions of formation of the general contents of ozone above Kazakhstan are considered.

Last years it has been shown, that transboundary carry of ground ozone can have significant sizes. The special attention is given to this question too. We shall consider also the general tendencies of change GMO above Kazakhstan last ten years.

So, within day small strengthening of the crest focused to a southwest from the Siberian anticyclone on January, 17 took place. The maximum of its development took place, probably, about 21 o'clock. After that its easing and activation of cyclonic activity, including along foothills began. Within this day warm air in the bottom layer of troposphere acted in area Almaty from a southwest, impoverished by ozone. On separate sites of front, however, its essential displacement to a southwest under influence of a crest of an anticyclone (term 03 o'clock still took place.). In this situation the temperature of air in Almaty was lowered up to minimal (about -9 °C). Further carrying out of warm air has proceeded, and the temperature of air gradually grew.

By the end of day on January, 19, in view of clearing in a afterboundary zone in the second part of day occurred downturn of temperature and some growth of pressure that has led to appreciable downturn of temperature of air and strengthening of ground inversion.

Let's consider now a course of temperature and concentration of ground ozone at station Almaty, involving also the data on concentration NOx. On fig. 4 the temporary course of these parameters within three day on January, 17-19 is submitted. The maximum of concentration of ground ozone took place in all cases at presence of atmospheric front at foothills and displacement of a site of front to the north from foothills, i.e. at presence of a southern component of a wind in the bottom layers of an atmosphere (see maps). It occurs or in system of a wave on its warm site (on January, 17 and 18 if the front lays at foothills) or at active displacement of all site of front to the north on plain on southern Balhash region (on January, 19).

At such synoptic situation there is also a receipt of tropospheric ozone to the ground from its maximum located at some height in a tropospheric layer [8, etc.]. It proves to be true also climatic generalizations of ground ozone. Its maximum in a cold part of year takes place in the morning when the mountain component mountain - valley the circulation reaches a maximum, delivering to the ground enriched with ozone air.
Only in the summer, more precisely, in a warm part of year when thermal convection is very strong, time of receipt of a maximum of ground ozone is displaced on 13-15 o'clock of local time. On fig. 13 the temporary course of concentration of dioxide of nitrogen is resulted also. It is possible to see, that it has the expressed daily course with a maximum in a second half of day, about 13 o'clock and, a minimum in the morning, about 7 o'clock mornings. As is known, the layer, rich ozone, at heights of 500-1000 m during the summer period is absent [8]. Therefore in time 07 o'clock, despite of presence of a mountain wind of increase in concentration of ground ozone it is not observed. The maximum of dioxide of nitrogen and carbon dioxides about 19 o'clock is caused by emissions of motor transport which activity at this time is maximal. After that its concentration gradually goes down, including and due to a mountain component of a wind, the maximum which takes place to the morning. The role of this component and others PS, apparently by the example of dioxide of nitrogen, for Almaty is of great importance. (a Fig. 5).

As if to concentration nitrogen dioxides and carbon dioxides in points of a maximum they depend also on intensity of ground inversions. When they are more strongly expressed, the concentration NOx is higher. It is necessary to remember, however, that fluctuations NOx due to
intensity of movement of transport occur on a background of concentration NO<sub>x</sub> caused by emissions of the power enterprises. These emissions have no daily course, and the ground concentration, caused by these emissions, change within day depending on conditions of dispersion.

Thus, influence of concentration NO<sub>x</sub> despite of their significant sizes during winter time, for ground concentration of ozone us are not found out. Probably, such influence is while within the limits of errors of measurements.

In the summer in a daily course of concentration of ground ozone the expressed basic maximum at 13-15 o'clock, and a minimum in 07 o'clock mornings takes place. As it is marked by us above, the maximum is caused active thermal конвекцией, providing receipt of ozone from troposphere.

The maximum of ground ozone in its time course takes place then when the general maintenance of ozone (GMO) and tropospheric ozone increases also, i.e. in a zone of atmospheric fronts in a southeast part of tropospheric hollows. It corresponds to a site of cold front at the ground, at once behind front. Such situation is considered by us in 1.7.2.

1.7 Dynamics and internal structure of monthly sizes of the general maintenance of ozone above Kazakhstan.

Dynamics of atmospheric ozone above Kazakhstan after the fiftieth years of the last century practically was not studied. However is proved heightened interest to a problem on the part of the world community and of some the International Conventions which Kazakhstan has joined, have made such researches necessary [6, 8]. Dynamics of the general maintenance of ozone (GMO) above Kazakhstan was studied by us for the period with 1998 on 2006 Distribution GMO above Kazakhstan is a result of large-scale general circulation of an atmosphere above a significant part of Northern hemisphere. Therefore the information about GMO on space from Atlantic up to Silent oceans was used. sach data are on a regular basis published in reviews in magazine « Meteorology and the Hydrology », and also contains in works [3, 4, 5], etc.

1.7.2. Synoptic conditions of formation of extreme sizes GMO

Further we had been selected cases of extreme sizes GMO above Kazakhstan. Thus for a case took a situation when even on one of stations of Kazakhstan GMO deviates in any side norm up to 2,5 or more values of an average quadratic deviation{rejection} () [11, 12]. For an example we shall consider aerosynoptic conditions when extreme values GMO took place.

Thus, extremely high concentration of ozone were observed in system of especially deep trough, on its southeast periphery as a result of intrusion of a cold Arctic air, rich by ozone.

Deficiency GMO which has made 2,7 , and the next day and more, took place in system of the crest generated as a result of intensive of longitude carrying out of tropical air through the western areas of Kazakhstan. In the top troposphere on 300 hPa the independent area of a high pressure specifying simultaneously and on intensity of carrying out of heat and was generated that displacement of system will be slow. Actually and was. With breaks, as a result of a pulsation of parameters of aerosynoptic system, deficiency GMO took place within several day both above Karaganda, and above Semipalatinsk. Above Almaty, however, deficiency GMO was not observed, as receipt of cold air on east periphery of system here took place.
The deep analysis of all cases abnormal GMO which we have collected, presumes to find quantitative characteristics between GMO above Kazakhstan and parameters of circulation on the basis of which development of recommendations to the forecast extreme GMO is possible.

1.8. Tendencies of change GMO above Kazakhstan

The contents of ozone in an atmosphere is determined mainly by the general circulation of an atmosphere. Infringements of activity of the mechanism of the general circulation can lead to change GMO above huge territories. So, for example in [14, etc.] it is shown, that the initial reason of occurrence of an ozone gap above Antarctica is long-term easing of wave activity in average and low latitudes of our hemisphere. The similar approach is necessary and at the analysis of features of distribution of ozone above Northern hemisphere and Kazakhstan in particular.

The analysis of time course GMO on stations of Kazakhstan shows, that since 1984 has gradual reduction of deficiency of ozone (fig. 6). The executed comparison of distribution GMO above Kazakhstan and above all Eurasia is shown, that all changes are interconnected (fig. 6).

Fig. 6. A time course of the contents of ozone above Kazakhstan.

So, as a whole for 2008 above Eastern Siberia and Chukotka GMO norms are higher 5-6 %, above Kazakhstan and the European part of Russia it is lower than norm on the average for a year not the same of 5-7 %, above the Western Europe deficiency GMO makes 0-4 %. In separate months, however above Kazakhstan and other regions, GMO it happens above norms (fig. 7). Within 2009 GMO has increased above all Northern hemisphere approximately for 1-2 %. It is necessary to note however thus, that because of inconstancy of circulating conditions interannual fluctuations of ozone which complicate allocation of its time trend take place also.
To allocate a share of increase GMO due to reduction of emissions ozone depletion substances very difficultly, especially a share of increase GMO above Kazakhstan. On an ozone cloud above Northern hemisphere some researchers estimate total positive influence in 1 % one year. [12, 61]. This trend, however in due course should decrease a little. As a result of alignment GMO with norm in Northern hemisphere it is expected through 7 - 9 years, this forecast can be counted comprehensible and for Kazakhstan.

1.9. Hemisphere models for trans boundary carry of polluting substances, some results for Kazakhstan on ground ozone.

In the given section the basic characteristics of two hemispheric models for calculation of polluting substances above Northern hemisphere and results of modelling for Kazakhstan are considered.

Studying trans boundary carry PS is the important problem in questions of change of a climate and for its decision is worked hard. One of perspective directions of the decision of a problem is mathematical modelling processes of carry, creation regional and hemisphere models of carry and sedimentation 3B. The regional models created, for example, for territories of the Western Europe or the USA represent the insignificant information on distribution PS on territory RK. From 26 models which we have considered for comparison of their efficiency/17/, we have chosen only two: hemisphere model EMEP and model CTM2 of faculty of geophysics of university in Oslo (18). The given choice is caused by that these two models well enough describe carry 3B and chemical transformations of ground ozone.

Thus by Hydrometeorological service of Kazakhstan from all PS distant carry it is measured only приземный ozone. It allows to estimate an overall performance of models for territory PK even in general.

Results of modelling on models EMEP and CTM2 have passed good and long verification [18]. We shall be limited to results of modelling of ground ozone and accompanying PS and their adaptation for territory of Kazakhstan.

On rice 8 distribution of ground ozone above Kazakhstan in January on models CTM2 and EMEP accordingly is submitted.
Fig. 8 Distribution of concentration of ground ozone (ppb) above Kazakhstan in January on models CTM2 and EMEP {8},

Model EMEP gives size of ground ozone 20+25 ppb above the central areas of Kazakhstan about a minimum 20 ppb and less above northwest and Kazakhstan to the north Aral see. To the southeast it concentration of ozone grow, exceeding 30 ppb in the east and in a southeast of territory, i.e. in areas of Semipalatinsk - Almaty.

Model CTM2 (fig. 8) an axis of a trough with the minimal sizes of ozone has longitude ways above Northern Kazakhstan and only to the south 50 ° n.l. It turns to a southeast. Accordingly, the lowest concentration of ozone take place above Northern Kazakhstan, 20 ppb and less, and the highest, 30 ppb, as above the east and a southeast of territory.

Comparing results of modelling with the data of supervision over ground ozone in Almaty, we mark, that the concentration received on model CTM2 are closer to observable. Presence of the hills interfering free carry of air weights from the south, rich ozone is possible, provides conditions when the air weights acting from northern component and poor ozone prevail of the south and a southeast of Republic. At the same time the course of ground ozone lines above territory of the Republic, received on both models, is very close. Results of modelling for July are submitted on fig. 9
Fig. 9 Distribution of concentration of ground ozone (ppb) above Kazakhstan in July on models CTM2/a/ and EMEP/6/

Both models give a trough focused from northwest on a southeast. Both models give a range of change of ozone within the limits of territory of Kazakhstan from the south on the north in 20 ppb. However model CTM2 - in a range 45-25 ppb., and EMEP - 35-15 ppb. Comparison of results of modelling with the data behind ground ozone in Almaty allows to draw conclusions, that model EMEP underestimates, and model CTM2 overestimates concentration of ground ozone on 5-6 ppb. Besides model CTM2 gives rather smooth reduction of concentration with increase in breadth. Only to the north 50° n.l. Gradients appreciably decrease. Model EMEP the basic reduction of concentration of ozone gives in a strip to the south of a line of Balkhash - Aktyubinsk. Absence of supervision over ground ozone still somewhere, for example, in Northern Kazakhstan, does not allow to draw with full confidence conclusions for the benefit of one of models. The knowledge, however, a mode of direct solar radiation and summer temperatures of air in Kazakhstan, allows to assume, that model CMT2 displays a course and the general distribution of ground ozone it is better.

One of the main for mankind of problems is reduction in emissions in atmosphere PS of all kinds. In ESC-W conditions as concentration PS changes, have been simulated by trans boundary carry if emissions PS to reduce by 15 % on the basic regions of Northern hemisphere. Not having an opportunity to stop on the simulated results for all PS, we shall stop only on what initiate both formation and destruction of ozone.

In table 4 expected changes of concentration of ground ozone above Kazakhstan if emissions NOx and PM in corresponding areas will decrease for 15 % are submitted. It is possible to see, that against expectation the greatest influence on Kazakhstan is rendered with
emissions PS by the industry of the countries of the Near East. Reduction in emissions PS there on 15 % results in reduction in average annual concentration of ground ozone on 0,15 ppb. Thus both models give approximately identical size.

Middle East, i.e. Iran, Iraq, Turkey and the Mediterranean, give in Kazakhstan an average annual background of ground ozone approximately in 0,1 ppb. Such significant size in comparison with industrially advanced regions is caused by that the most part of year carrying out of air massis occurs from Middle East.

Table 4 Average annual sizes of reduction in concentration of ozone (ppb) in territory of Kazakhstan for the account trans boundary carry at reduction in emissions on 15 % in regions - donors accompanying ЗВ.

<table>
<thead>
<tr>
<th>Regions</th>
<th>ЗВ</th>
<th>Sizes of reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Far East</td>
<td>NOX + PM</td>
<td>- About 0,15 ppb on all territory Kazakhstan</td>
</tr>
<tr>
<td>Middle East</td>
<td>- Less than 0,1 ppb to the south оз. Balkhash and about 0,0-to the north</td>
<td></td>
</tr>
<tr>
<td>Northern America</td>
<td>- About 0,10 ppb on all territory on The extreme south - has less</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>A southwest of Kazakhstan down to оз. Balkhash about0,10 ppb. On other Territories about0,05 ppb.</td>
<td></td>
</tr>
<tr>
<td>The sum</td>
<td>0,45 ppb</td>
<td></td>
</tr>
</tbody>
</table>

Average annual concentration of ozone in territory of Kazakhstan 0,25-0,30 ppb air massis occurs from Middle East. Regions of Europe and Northern America provide on 0,1 ppb ozone. In the sum for the account of trans boundary carry we have concentration of the ozone equal 0,45 ppb in Kazakhstan. How the background if receipt atmospheric ЗВ to Kazakhstan would stop at all will change? Then concentration of ground ozone would decrease on 3,5 ppb, that makes about 10-15 % for the south of Republic and 15-20 % - for itsnorthern areas.

The executed analysis shows on international character and the pollution of an atmosphere and struggle against it.

2. THE ESTIMATION OF CONSUMPTION OPB IN KAZAKHSTAN ON SECTORS OF ECONOMY IN 2009 AND THE SCRIPT THE NEAREST YEARS

2.1 Dynamics of quantity consumed ozone depletion in Kazakhstan

Usually any national strategy bases on the current data. It is necessary and an important point which allows to establish « width of a corridor » in which there can be changes. As a rule, the a line is longer, the estimation of forecasting will be more exact. In our disposal there are data for last fifteen years. However, unfortunately, to speak about uniformity of lines, it is not necessary stability of external factors. During monitoring behind consumption level OPB in Kazakhstan there were essential changes, both in quantity consumed HCFC, and in their quality indicators. The structure of consumed substances has changed, there is a reorganization of the market of the equipment where the mentioned substances are used. Certainly, such cardinal measures should affect a consumption level. Besides it is impossible to forget, that from the moment of occurrence of the Viennese convention has passed not less than 30 years and for this time innovative decisions in the equipment have been realized many. In view of that average term of operation of household refrigerators makes 25-30 years, commercial 12-15 years, and complex systems of cooling of stadiums, skating rolls, warehouse or technological premises can
make more than 30 years during existence of the Convention it was replaced already and park of the equipment.

Certainly, such conditions do not allow to speak unequivocally about stable consumption as the equipment and substances involved in contours. It is not necessary to forget and that realization of scientific decisions, as a rule, is directed on reduction of consumption of capacity that is realized through reduction of volume of HCFC its change and technical characteristics. Accordingly, realization of technical decisions at constant number of park of the equipment will already promote reduction of consumption ODS.

It is not necessary to forget and that new substances have appeared, which to attribute to action of the Montreal report hardly, they already get under action of the Киото report. It, certainly a favorite of the modern period - хладон 134a, however except for it are available set of mixes both азотропных and зеотропных which are successfully applied in contours as in new refrigerating systems and are capable to work in the out-of-date equipment prolonging time of its operation. Unfortunately, inside the country the control over a consumption level of such mixes is not conducted almost, therefore at an estimation of demand on ODS the real parameter can be not always objective as the valid consumption is blocked just by such substances. Accordingly, at an estimation of demand in model it is possible to assume only about real volume of consumption, proceeding from the period when such substances in the country yet were not, and the amount of the population was equaled modern.

2.1.1 Consumption level ODS in 2009

In 2009 in Kazakhstan it has been consumed in the sum of 1067,5 tons ODS. It not much is more than the last year, however if to consider the given figure separately on substances it is possible to find out, that the basic in in клад in the general consumption occurs basically because of transitive substance HCFC 22. For today the level of its consumption is 908 tons that makes 78% from general consumption level ODS. In figure 10 dynamics of consumption ODS in Kazakhstan for last 12 years is submitted.

Fig. 10. Dynamics of consumption ODS in Kazakhstan for last 12 years.

However, by developed tradition as the consumption level in tons is not indicative for an estimation of influence on an ozone cloud, it is necessary to present metric tons to tons ozone depletion to ability (ODS). As a rule, traditionally used substances can possess very much
different effort on influence on an ozone cloud, for this reason usual metric tons are not indicative, as different substances at identical volumes possess different destroying abilities. HCFC represent chemical substances in which one or more atoms of carbon are connected from one or more atoms of halogens (fluorine, chlorine, bromine or iodine). Ozone depletion ability HCFC, containing bromine, as a rule, much above, than at what contain chlorine. Synthetic chemical substances which provide the most part of chlorine and bromine for destruction of ozone, are bromic methyl, Metilchloroform, Tetrahclormetan and family of the chemical substances known as HCFC and an.

To each adjustable substance the factor describing its influence on a stratospheric ozone cloud on a mass unit of gas in comparison with the same weight CFC-11 is appropriated. These factors ODS for each adjustable substance are specified in appendices to the Montreal report []. According to the Management on granting the data within the framework of the Montreal Report factor ODS for bromic methyl 0,6, and for HCFC 22 - 0,055. In this case the real picture will look a little differently. fige 11.

It is possible to see, that the consumption level in tons ODS essentially changes a picture. So the basic substance which renders negative influence on an ozone cloud is bromic methyl though its real consumption is lower almost in 7 times in tons metric.

The second on a level of influence is HCFC- 22, this transitive substance which can be used within the framework of the Montreal report. Except for that this substance is the potential applicant for an interdiction in use and most likely it will be applied only together with other substances - in mixes.

![Fig. 11. Dynamics of consumption ODS in tons ODP Kazakhstan for last 12 years.](image)

It is possible to see, that consumption of agents has appreciably increased last four years. At the present stage the amount used ODS almost three times exceeds a level 2003-2004 гг, and five times a level of 1999.

Besides from the submitted data it is visible, that such appreciable difference was formed basically due to increase in consumption of bromic methyl, with its high enough factor ODS. The amount of used bromic methyl is comparable to the sum of all other substances of all categorys (fig. 12).
Fig. 12. A comparative consumption level of bromic methyl (Appendix Е) and transitive substances (Appendix С) for 10 years, in territory of Kazakhstan.

Fig. 13 comparative consumption level of bromic methyl (Appendix Е) and manufactures grain in Kazakhstan.

From the submitted figure 13 it is visible, that the Increase in consumption of bromic methyl is connected to increase in manufacture and import of grain crops. According to world situations the grain cannot be sold if preliminary it has not been processed in the quarantine purposes. On the other hand as bromic methyl is the substance destroying an ozone cloud its application try to limit, on what the Copenhagen amendment is directed. And, right the question with the status of this substance is in study to performance, and there is a probability, that farms and firms on export have some stock of bromic methyl in the banks to avoid its deficiency in the future as in the country in connection with licensing of the substances getting under the Montreal report, process of purchase of the agent was essentially complicated. Besides there is a probability, that sale of bromic methyl to Kazakhstan will be limited for the lack of ratification of the mentioned amendment.
At the same time from figures 1 and 2 it is possible to see, that consumption of such substances as HCFC 141b and HCFC 142b is at a stable level and varies year by year insignificantly. And appreciable dynamics of growth of demand not these agents it is not observed, that speaks about a constant niche in the market where the mentioned agents are used.

Figure 13 evidently shows, as the situation for last ten years in market ODS varied. Besides figure shows, that has changed from the moment of refusal from ODS Appendix A and In in 2004. It is possible to see, that a role of transitive substances, since 2000 began to grow. However, even after full refusal of application of the mentioned substances of sharp demand for substances of the appendix C does not occur. It can be connected to set of the reasons, first of all with problems of technical character. Today, unfortunately, there is no such substance which could replace completely in all sectors, freons 11 and 12.

First, not knowing technical characteristics of the new substances, many firms were not defined finally with a choice [6-8, 10-13, 24, 25].

Second, during economic reforms in the ninetieth years, many businessmen bought new technical equipment which has been already initially charged by transitive substances, and besides corresponded to the international requirements of manufacturing of that moment. It turns out, that demand has not increased yet because of rather new equipment which is maintained in commercial sector.

The third reason of such position, can be presence in the market and sphere of services of illegal freon which does not get under the control of official statistics, but, nevertheless is present. It still proves to be true also that fact, that after 2004 when Kazakhstan has completely refused to operait of the CFC substances, demand for transitive substances in all sectors, has increased insignificantly.

The fourth reason of such situation can be, the incorrect statistical data for the period of 1998 with which values we carry out comparisons. There is a probability, that these data for any reason have been strongly overestimated, or the methodological mistake in calculations is accomplished. The probability of it is improbable, however completely to exclude it does not follow.

As the fifth reason it is possible to assume, that after introduction of some programs in territory of republic, explanatory work which was conducted among suppliers of the equipment and technicians, the role of the fulfilled freon has increased. It is possible, that the enterprises
intentionally buy up an old refrigerating machinery from which it is possible to take not only copper as nonferrous metal, but also the stayed freon. In fact after clearing of oils and other impurity, probably, it ODS refuse. Unfortunately, we do not possess for today real conditions in the market freons, but if it so we can see action of the State programs in a life.

The consumption level in 1100 tons ODS, grows out uses CFC 11 and CFC 12, factor ODP at which highest. Besides in a reality in metric tons this figure is a little bit lower, nevertheless it reflects potential top volume of substances which is necessary for Republic. In connection with replaceable systems of economic activities it is possible to assume, that from the submitted figure it is possible to take away half, having written off it on railcars - refrigerators which operation for today have refused. One more share can be written off on reduction of supersize automobiles with refrigerators which were used at transportations.

Thus, the top level of real consumption makes about 1500 tons хладона in one year. It is possible to expect, that the top border can change aside increases at successful development of economy and realization of all planned State Programs.

For us important to consider as these substances are distributed on categories of refrigerating sector to find out what of sectors uses HCFC more and it is accordingly potentially vulnerable at refusal of transitive substances or use of substitutes.

2.1.2 Consumption ODS on categories.

In figure 14 distribution of consumption ODS on sectors is submitted. It is possible to see, that the ratio of consumption varies year by year insignificantly, however in the sum amount of the consumed substances can vary appreciably besides that demand in the last some years has a little increased. It is possible to explain it to that in the country already there is enough of the equipment working on transitive substances. As the percent of such equipment year from one year will grow, it is possible to expect increase in demand and at coolants of the appendix C.

![Figure 14 - Distribution of consumption ODS of the Appendix C on sectors in Kazakhstan.](image)

Distribution inside sectors can change essentially. Today, getting household refrigerators, the buyer what coolant a little worries, it uses in the work. The consumer the consumption level of energy, guarantee period and operational qualities first of all can interest. Therefore transitive substances here can be quite used, that actually and occurs.
In other sectors where the equipment is in itself estimated highly, there is a high probability, that buyers already now began to pay attention what coolant is used. In fact not far off prospect of full refusal of use of transitive substances. To appear in a situation when the equipment is, and to fill it there will be nothing, nobody would like. Certainly, there is a variant of a choice of other substances which will meet not absolutely to all operational requirements that will cause losses of efficiency, and, hence, financial losses [6-8, 11-13, 38].

2.1.3. Influence on climate ODS

Calculations are executed on the basis of the data contained in the report on the first stage of researches. Thus as it is accepted in world{global} practice, that banks annually lose 5 %, HCFC contained in them. Transitions coefficients are taken in accordens with recommendations of IG on CC UNEP. [20] and [34]. Estimations of emissions CO2-ecv. are executed on groups галпидоуглеводородов, and then shown together (Figure 15).

Fig. 15 - Total emissions CO2-экв., for the period 2000-2009 гг

Consumption HCFC such as 141b is carried out in small amounts. Sizes of consumption make approximately 5 % in comparison with HCFC such as -22. Emissions CO2-ecv., however, make only 3-4 % in comparison with HCFC -22, that is caused by a parity between factors ПГП 5:2 for these groups. A maximum of consumption HCFC -141b then its consumption began to fall sharply.

HCFC such as -142b are used in the same quantity{amount}, as -141b. Emissions CO2-ecv., however, exceed similar from -141b in eight times. It is caused by that ODP for -142b three times is more, than for -141b.

It is possible to expect, that by 2015 emissions CO2-tecv., on substances -141b and 142b will be small as consumption of these substances tends to reduction.

As against calculations on other substances in this case was accepted, that all got bromic methyl was used within one year. Consumption of bromic methyl has appreciably increased last years, approximately in 4 times in comparison with 2000. At the same time emissions CO2-ecv. (greenhouse effect) from group E are insignificant, since. ODP for this substance makes only 5.

Total emissions CO2-ecv.. from all groups HCFC for the period with 1998 on 2008 are resulted in the table 5. These emissions from a minimum in 2000 (10-20 Kr) have increased by
2009 up to 1650 Kr. Thus the basic contribution is brought with emissions from -22. Emissions CO2-ecv. from group E on a background of emissions from substances of group C as a whole practically are not significant.

2.2. Consumption of substances of group HFU on sectors

For last ten years the market of substances which are used in a refrigerating machinery, has essentially changed. To this promoted ratification of the Montreal Report by a plenty of the countries (for today more than 180). As it was already spoken the Montreal Report forbids use of substances of Appendix A and In where concern фреоны 11 and 12, and also limits use of transitive substances of the Appendix With and Е. Ponjatno, that in the world there is a necessity of development and use of new substances which safety requirements would answer all modern and satisfied to technical needs.

We shall not stop on technical complexities of a task in view, we shall note only, that the decision of the given problem is a task of a world scale and today not one scientific division works in the given direction. Unfortunately, to receive ideal HCFC, which met all requirements of the market (as it was in a case with R-11 and R-12) it does not turn out yet. Developers have gone in other way creation for each sector of the substance which met local requirements. Such approach yields the certain results, and the whole spectrum of substances which are aimed at application in the certain type of the equipment for today is offered.

The developed substances of category HFC have been offered as long-term replacement and both in systems of cooling, and in devices of an air conditioning that became the conventional approach within the framework of the European community.

HCFC differ good thermodynamic properties. It means, that they completely satisfy to specifications and requirements to effect evenes for developed systems, and also for modernized systems in which coolant R502 was earlier used. These systems can be various - from small independent refrigerating machineries up to the equipment for supermarkets and the industrial process equipment. ГФУ - the best, for today, a coolant for the new systems replacing in what it was used R22.

Within the framework of performance of our task it was required to estimate quantity used HFC, as one of the most perspective substitutes ODS in the market, including substances of the Appendix C. The data of Customs committee available in our disposal, questioning of firms on service of a refrigerating machinery allow us to estimate amount in the market of this agent in 30 % from the general consumption of substances of the Appendix of C. The some we have in the given segment of the market is appreciated within the framework of National Inventory of green house gases of republic Kazakhstan, (fig. 15 and table 5).

![Figure 15 - Distribution of consumption HFC on sectors in Kazakhstan.](image-url)
Table 5

<table>
<thead>
<tr>
<th>Years</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>The household refrigerating and freezing equipment</td>
<td>35,37</td>
<td>42,46</td>
<td>34,44</td>
<td>38,09</td>
<td>50,79</td>
<td>51,08</td>
<td>84,02</td>
<td>88,81</td>
<td>89,45</td>
<td>89,67</td>
</tr>
<tr>
<td>Commercial refrigerating machinery</td>
<td>22,74</td>
<td>27,29</td>
<td>22,14</td>
<td>24,49</td>
<td>32,65</td>
<td>32,84</td>
<td>54,01</td>
<td>57,09</td>
<td>57,50</td>
<td>57,64</td>
</tr>
<tr>
<td>Stationary air conditioning</td>
<td>15,16</td>
<td>18,20</td>
<td>14,76</td>
<td>16,33</td>
<td>21,77</td>
<td>21,89</td>
<td>36,01</td>
<td>38,06</td>
<td>38,33</td>
<td>38,43</td>
</tr>
<tr>
<td>Mobile air-conditioning and transport refrigerating machinery</td>
<td>37,90</td>
<td>45,49</td>
<td>36,90</td>
<td>40,81</td>
<td>54,41</td>
<td>54,73</td>
<td>90,02</td>
<td>95,15</td>
<td>95,83</td>
<td>96,07</td>
</tr>
<tr>
<td>Fire business</td>
<td>2,53</td>
<td>3,03</td>
<td>2,46</td>
<td>2,72</td>
<td>3,63</td>
<td>3,65</td>
<td>6,00</td>
<td>6,34</td>
<td>6,39</td>
<td>6,40</td>
</tr>
<tr>
<td>Medicine</td>
<td>12,63</td>
<td>15,16</td>
<td>12,30</td>
<td>13,60</td>
<td>18,14</td>
<td>18,24</td>
<td>30,01</td>
<td>31,72</td>
<td>31,94</td>
<td>32,02</td>
</tr>
<tr>
<td>In total</td>
<td>126,33</td>
<td>151,63</td>
<td>123,00</td>
<td>136,04</td>
<td>181,38</td>
<td>182,44</td>
<td>300,06</td>
<td>317,16</td>
<td>319,45</td>
<td>320,24</td>
</tr>
</tbody>
</table>

To given

Sector 1 « the Household refrigerating and freezing equipment »

Apparently from table 1, consumption of substances of group HFC has increased, however on weight this group does not compensate group ODS which were used earlier. It is caused by that together with change of chemical substance more economical has appeared also new, with smaller volume of "banks {technical equipment}.

Sector 2 « the Commercial refrigerating machinery »

Use of substances of group HFC began since 2000. Consumption of substances of this group in it approximately twice is more than in sector 1, it is connected, partly with often перевозом the equipment пou which there are outflow.

Sector 3 « the Stationary air conditioning »

In this sector use of ammonia takes place instead of and other substances which do not get under Кютський the report for this reason expected quantity of HFC a little bit less than it was expected.

Sector 4 « Mobile air-conditioning and a transport refrigerating machinery »

From table 7 it is visible, that appreciable growth of consumption of substances of group GFU began since 2004. It is caused by heavy export of automobiles those years in which conditioners filled 134 have been established and.

Sector 5 « Fire business »

The last years for this purpose substances of group ODS were used. However according to the answer of the Ministry of Emergency Measures to our inquiry last decade getting under the account Montreal or Кютський the report in banks at fire brigades is not present substance. Nevertheless in this sector we have estimated use ГФУ in 2 % from general consumption level HFC.

3. THE ANALYSIS OF MEASURES UNDERTAKEN BY THE ADVANCED COUNTRIES ON REDUCTION OF EMISSIONS OF OZONE DEPLETION SUBSTANCES IN VARIOUS BRANCHES OF ECONOMIC ACTIVITIES

3.3. An estimation of the undertaken efforts of ruling bodies РК on reduction of emissions in atmosphere ODS
For today the Republic Kazakhstan is the party of the Montreal report, accordingly there is a necessity for performance of obligations taken on. The given section is devoted to an estimation of measures applied in Kazakhstan on reduction of consumption OPB and transitive substances. Besides from the moment of signing the contract has passed enough time to tell on how many the measures are effective, used I in Kazakhstan for promotion in the market ozone safe substances and corresponding technologies, and whether am present necessity to application of other measures and strengthening available.

For performance of a task in view it is necessary to list the basic measures which have been undertaken in Kazakhstan for the decision of this question. It is necessary to note, that the basic positions of the Government of Kazakhstan contain in a question of protection of an ozone cloud and announcement of Strategy of reduction of consumption OPB in a number of acts, the international reports, the Ecological Code, the Concept of the project of the State program « the Effective utilization of energy and renewed resources of Republic Kazakhstan with a view of steady development till 2024 » and other documents, speech about which will go in following subitem [45].

3.3.1. The national legislation, the administrative and legal measures concerning protection of an ozone strata.

The government of Kazakhstan in November, 1999 issues the Decision № 1716 which component are the Regulations about import / export ODS substances and production containing ODS with appendices of Lists ODS and production containing ODS subject to state regulation [45].

According to article 2 point b the Viennese convention Kazakhstan takes necessary legislative or administrative measures under the control, restriction, reduction or prevention of activity of the person if this activity renders or can render adverse influence, changing or creating an opportunity of adverse change of a condition of an ozone cloud [45].

Introduction of system of sanctions of import / export OPB allows to adjust import OPB, the obligations of the country following from the Report and for prevention of illegal trade OPB both assistance to data gathering and representation of reports in Secretary on ozone [45].

In this connection the decision of Government RK³19 from January, 8, 2004 about introduction of system of licensing on import, export ODS and on detail connected with manufacture, repair and installation of equipment where it is used ODS which have been reconsidered and updated by the new Decision of the Government №508 from June, 18, 2007 [] is accepted.

To the sanction are subject:

- Import and export OD substances and production their containing;
- Manufacture of works with use OD substances and production containing them, and also repair, installation, service of the equipment working on OD substances.

To exclude a problem of " a technological waste dumping », in Kazakhstan restriction on import of the equipment, containing ODS is entered, by acceptance of the Decision №617 from June, 22, 2005. The given decision enters an interdiction on import ODS of the List And and the List In on the equipment containing the given substances [45].

Consumption ODS is adjusted by the Ecological code of Republic of Kazakhstan (chapter 45): article 314 gives the general {common} requirements under the order of delivery of sanctions to import, export DS substances and production containing them, manufacture of works with use DS substances, repair, installation, service of the equipment containing DS substances, clause {article} 315-318 regulates requirements to consumption DS substances, including carrying out of annual inventory ODS [45].

395
3.3.2. Data presentation in Secretary on ozone.

Data presentation in Secretary on ozone has great value for maintenance of the control over performance of obligations of the Parties. Within the framework of the Montreal report data presentation is the legal obligation of each Party of the Montreal report Article 7) [1].

The data have crucial importance by way of performance by the Parties of the accepted obligations, and at a national level allow to carry out the control strategy of stage-by-stage reduction OPB. The responsible persons accepting the decisions at a national level, without the authentic data cannot formulate corresponding measures on regulation of these substances, to develop realistic strategy of stage-by-stage reduction of application and to provide the necessary financial and technical help. Gathering and data presentation is one of the key problems arising during performance of the Montreal report. Therefore inventory and the analysis of the data is considered not only as the requirement, but also as the useful instrument in this important business [45].

Each Party {Side} annually submits data on all adjustable substances, including the data on consumption (application) on sectors, import, export and to manufacture OPB [45].

Alongside with annual reports on the data on adjustable substances, secretary of Fund the information on actions on maintenance of administrative and organizational support under Montreal report [45] is represented.

Besides within the framework of actions on preservation of an ozone cloud in our country the certificated rates on training and improvement of professional skill at the personnel of the firms connected to sale or service of a refrigerating machinery are organized. Such rates are the important making internal policy (strategy) as many questions connected to the legal moments, technical subtleties and other questions allow to inform up to the persons involved directly in sector where the infringements are possible{probable}. The important component of a rate is the explanation in necessity of transition on new DS substances, acquaintance with characteristics хладонов and their properties.


Also within the framework of the designated actions at participation of the international organizations in Kazakhstan the complex of the equipment on extraction and clearing of old freon (forbidden 11 and 12), for its repeated use or recycling of a failed refrigerating machinery has been put. Within the framework of the Montreal contract such practice is supposed. It allows to support at a stage of a choice of the future refrigerating systems the available equipment in working order, to reduce internal deficiency of agents thus to lower risks of use of illicit production. It is considered, that at absence of the great demand, many manufacturers in the countries, not joined to the Montreal report, will refuse manufacture forbidden хладонов for the lack of demand for it, and will be compelled to reorient the manufactures on allowed HCFC. In this case reorientation of manufactures will demand from such countries of financial investments which they can receive from the World or International financial organizations, that actually conducts to the introduction of such countries into the Montreal contract.
3.4. Necessary actions for maintenance of the program of the Government.

From the previous chapter it is possible to draw a conclusion, that as a whole in the country it is made much, for successful realization of the internal program on reduction of use ODS and to refusal of use of transitive substances.

The basic result which has been achieved is a full refusal of use фреонов in 2005.

Now for Republic very important question, necessities of connection to other amendments to the basic contract is. In this question it is necessary to realize precise understanding of all consequences of such step for a national economy. There are many weighty arguments to detain, connection to the Copenhagen, Peking and Montreal amendments. But also is it a lot of, reasons for the benefit of such step. First of all it is an opportunity to expect for financial support of solid financial institutions, and to increase the status of the country in opinion of world community. It is necessary to understand, that behind connection or refusal of connection well weighed policy based, on comprehension of the responsibility for concrete action is necessary. Besides it demands much, time for internal study of a question with the big stage of preparation of all legal and technical questions connected to the decision.

The precise control over Customs committee, the internal control over work of corresponding firms through licensing and certification allows to supervise this sector successfully. However, there is open a question of the reporting. Today the basic reporting is carried out on the basis of the information of Customs Committee and it is logical, as inside Republic there are no corresponding manufactures. However with transition to Transitive substances of group With, and use ozone safe agents, some of which, can quite be made on oil refineries, the level of such reporting will be insufficient.

Now speech already goes not only about the Montreal contract, it is known, that such substances have a more potential of global warming here again the clear data in frameworks Киотского of the report are required.

Pains of that, there is a probability, that with refusal of use of transitive substances mixes which contain small amount R22 will be used, and the account of them is required already. At a modern level of the reporting will check volumes of uses of mixes hardly and necessity will come, to take into account the charge such HCFC at a level of separate firms.

Today, for this step it is made much. Questions of domestic trade by emissions in frameworks of the Киото report are considered, the level of the reporting of each enterprise or firm raises. Also there are not few preconditions, that these actions finally will affect not only reduction of all emissions GHG in Republic, but also will lead to improvement of the internal reporting, so to the control over workmanship of legislative guidelines.

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The Russian Federation National Report on Studies of the Earth Ozone Layer

1. Observations

Routine observations of atmospheric ozone comprise observations of total ozone (TO), its vertical distribution, and surface ozone concentrations.

Routine observations of nitrogen dioxide comprise observations of its content in the vertical atmospheric column.

1.1. Observations of total ozone and other gases / constituents responsible for ozone loss.

In the Russian Federation, responsibility for regular total ozone measurements and interaction with the corresponding WMO bodies lies with the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). Daily TO measurements are being performed on the network of 28 ozone measuring stations (with TO observations resumed on Heiss Island in 2008), located in the Russian Federation, Ukraine and Kazakhstan and equipped with M-124 filter ozonometers. Technical and methodological support of the network is provided by A.I. Voeykov Main Geophysical Observatory (MGO). Observational data are transmitted on-line to the Central Aerological Observatory (CAO) and MGO. CAO performs primary data quality control, archives the data and transmits it online to the World Ozone and UV Data Centre (WOUDC) under the Environment Service of Canada. Apart from that, CAO provides operational mapping of TO distribution over the territories of Russia and adjacent countries, revealing anomalies and analyzing the reasons for their occurrence. At MGO, the data undergo more thorough quality control, which enables defining the quality of performance of separate instruments, consecutive data correction, and transmission of final data to WOUDC.

MGO has completed upgrading of M-124 ozonometers that had been in operation on the network for over 25 years, which permitted further TO observations at Roshydromet stations. In the course of modernization, the techniques and programs of processing clear and cloudy sky zenith measurements have been improved, which made zenith TO measurements as accurate as direct solar light ones. The ability to measure in any cloudy conditions (except on precipitation days) in the range of a 5° to 70° sun elevation considerably enlarged the amount of information from the stations and enhanced observations at high-latitude stations.

In 2008-2010, four of the stations tested experimental models of UV ozone spectrometer (UVOS) developed for upgrading the equipment of Roshydromet ozone network. This instrument enables measuring TO, registering total UV and zenith radiation in a 290-400 nm range with resolution less than 1 nm and exposure less than 2 s. The network stations are expected to be reequipped with spectral instruments before 2015.

Besides, TO measurements are made at reference sites by institutions of Roshydromet and the Russian Academy of Sciences (RAS) using M-124 ozonometers, Dobson and Brewer spectrophotometers, and SAOZ instrument. Brewer spectrophotometer measurements of TO are performed in Kislovodsk (Obukhov Institute of Atmospheric Physics, RAS), Tomsk (Zuev Institute of Atmospheric Optics, RAS), Obninsk (SI RPA ‘Typhoon’), and Yakutsk (CAO). Total ozone and NO₂ are measured with
SAOZ instrument at two high-latitude stations, Salekhard (67°N, 67°E) and Zhigansk (66°N, 123°E) (CAO).

Regular measurements of NO₂ content in the vertical atmospheric column have been conducted at Zvenigorod research station of A.M. Obukhov Institute of Atmospheric Physics (IAP), RAS, since 1990. The measurements are made with a spectrophotometer based on a domestic monochromator MDR-23, by an original technique. NO₂ vertical profile is reconstructed from twilight morning and evening measurements, and then, NO₂ content in the vertical atmospheric column and, separately, in the boundary layer is determined. The station is included in the International Network for the Detection of Atmospheric Composition Change (NDACC), its NO₂ measurement data being readily available at the NDACC server, at the address: http://www.ndacc.org/.


Measurements of ozone profiles using ozone sondes in winter and spring seasons are carried out at Salekhard station within the framework of the European International program MATCH (CAO). Ozone profiles in the height range of 20-50 km, using microwave radiometer (142.2 GHz) are measured in Moscow (P.N. Lebedev Physical Institute, RAS). In Tomsk (the Institute of Atmospheric Optics, Siberian Branch of RAS), regular lidar measurements of ozone, NO₂ and aerosol profiles at heights up to 70 km are conducted. Besides, monthly measurements of vertical ozone distribution in the troposphere (0-7 km), using chemiluminescent and UV-photometry (TEI-49) ozone gas analyzers installed on board AN-30 aircraft have been conducted there since 1997. These measurements have made it possible, in particular, to assess the influence of different cloud types on ozone concentration. Also initiated there have been experimental studies of the diurnal variation of vertical ozone distribution in the lower troposphere (up to 2-3 km) from board an aircraft.

1.3. Ground-based ozone concentration measurements

Ozone concentration measurements of many years, conducted at remote high-mountain stations in Russia, aim at detecting its long-term changes in the free troposphere. Routine measurements of ozone concentration have been carried out at Kislovodsk High-Mountain Science Station, 44° N, 43° E, 2070 m a.s.l. (the RAS Institute of Atmospheric Physics), since 1989, Terskol station, 43° N, 43° E, 3100 m a.s.l. (the Ukraine Main Astronomical Observatory and CAO), since 2002, Mondy station, 51° N, 101° E, 1304 m a.s.l. (the RAS Limnology Institute), using UV gas-analyzers. The UV gas-analyzers are regularly calibrated at D.I. Mendeleev All-Russia Research Institute of Metrology or compared with the National Standard of Japan. Measurements of surface ozone concentration and concentrations of other minor atmospheric constituents are also fulfilled at a number of flat-country science stations (Moscow, the RAS Institute of Atmospheric Physics; Dolgoprudny, CAO; Omsk, SI RPA ‘Typhoon’; Tomsk, the Institute of Atmospheric Optics, Siberian Branch of RAS, etc.). In order to study the space and time variability of surface ozone and other minor gaseous atmospheric species, the experiment TROICA (Transcontinental Observations into the Chemistry of the Atmosphere) is being continued, wherein concentrations of the gases are measured annually along the railways, generally, along ‘Moscow-Khabarovsk’ railway. Specialists from Germany, USA, Finland, and Austria are involved in the experiment.
1.4. UV-irradiation measurements

1.4.1. Wide-band measurements

Pilot measurements of UVB-radiation have been carried out at 14 ozone measuring station of Roshydromet since 2006. The UV radiation (UVR) measurements follow the technique developed by MGO and use M-124 ozonometers with correction attachments (Larche sphere). Observational results will be available after calibration of the ozonometers with attachments against an UVR reference sample.

1.4.2. Narrow-band filter measurements

Long-term regular measurements of UV-irradiation in an UV-B spectral range, using an UVB-1YES pyranometer, have been conducted at Lomonosov Moscow State University (MSU) since 1999 and in a 300-380 nm range since 1968.

1.4.3. Spectral measurements

UV-B radiation monitoring using Brewer instruments have been carried out in Kislovodsk since 1989, in Obninsk since 1991, and in Tomsk since 2006.

Besides, at 4 stations of Roshydromet, pilot measurements of the spectral composition of total (global) UV radiation within a 290-400 nm range have been conducted since 2008.

1.5. Calibration procedure

1.5.1 Calibration of ozonometers M-124

MGO fulfils calibration of ozonometers M-124. TO reference is provided by Dobson spectrophotometer No.108, which, in turn, once in 4 years undergoes intercalibration procedure at the WMO European Calibration Center. For the period 1988-2009, Dobson No.108 TO departure from WMO reference values was not more than 1%.

1.5.2 Regular quality control of TO measurements

TO measurement scale stability is maintained through regular calibration of ozonometers M-124 at MGO and monthly ozonometer intercomparisons at the stations. Each station has got 3 instruments – operational, back-up, and reserve. After repair (upgrading) and calibration at MGO, reserve ozonometer is set up at the station and becomes operational. The cycle covers 2 years.

MGO provides continuous control of measurement quality and performance rate of ozonometers to reveal measurement scale changes and, if required, correct measurement results. Ozonometers showing considerable changes in measurement scale are replaced ahead of the schedule time and undergo calibration.

1.5.3 UV calibration

In 2010, an operational, Category 1 reference sample of irradiation spectral density in a 250-800 nm range, based on a quartz-halogen bulb, certified by the Russian Federation State Agency for Standardization, Gosstandard, was introduced to practice. Absolute scale calibration of UV radiation measurements will be performed at MGO beginning from 2011.
1.5.4 Brewer spectrophotometer calibration

All the Brewer spectrophotometers in Russia, operated in Obninsk, Kislovodsk, Yakutsk, and Tomsk, were last calibrated in 2008.

2. Measurement data analysis results

A number of studies conducted are devoted to analyzing long-term ozone layer changes and revealing quantitative relations between TO variability and various geo- and heliophysical factors. It is shown that in mid and high latitudes of the northern hemisphere and, in particular, over the territory of the Russian Federation, following TO However, with the observed rate of recovery, TO level characteristic of the 1970's would only be reached in several decades (Zvyagintsev and Ananiev, 2010; Titova and Karol', 2010). Analysis of the global TO time series for 1964–2006, constructed from the data of the world ground-based ozone measuring network, shows that its drastic decrease in the period between the mid 1070's and mid 1990's cannot be only assigned to anthropogenic influence (Bekoriukov et al., 2009). Using the methods of natural orthogonal functions (Kramarova, 2008), regression analysis (Zvyagintsev and Ananiev, 2010), spectral and discrimination analysis (Titova et al., 2009; Titova and Karol', 2010), quantitative effects of the polar stratospheric temperatures, the arctic oscillation, quasi-biennial oscillation, and El-Nino – southern oscillation on TO changes in different regions of the world have been estimated.

Analysis of stratospheric ozone concentration measurements from satellite-borne instrument SAGE II, obtained during 1984-2005, has yielded estimates of the linear ozone trend for three 10-km layers (15–45 km) over the south of the European territory of Russia. It is shown that the rate of ozone concentration decrease is maximal in the upper stratosphere (a 35–45 km layer), amounting to about 3 % per decade (Ionov, 2009).

Lidar sounding data on ozone, aerosol, and temperature in the stratosphere over Tomsk have promoted clarifying the influence of the world centers of action on the vertical distribution of these parameters through constructing regression models (Kruchenitsky and Marichev, 2008).

From the results of long-term measurements of total NO2, quantitative estimates of the diurnal and annual variations in NO2 content, of the role of Pinatubo eruption in NO2 decrease, NO2 changes during an 11-year cycle of solar activity, and linear trends of NO2 content, depending on latitude, were obtained (Gruzdev, 2009). Analysis of the long-term TO data from the World Ozonometer Network and computations using 2D model SOCRATES demonstrated that changes in short-wavelength solar radiation during an 11-year solar activity cycle affects the intensity of the meridional transport of stratospheric ozone during autumn and winter seasons (Gruzdev, 2008).

The influence of an 11-year cycle of solar activity on quasi-biennial variations of ozone and temperature observed in the Canadian Arctic sector is discussed in (Sitnov, 2009). The variability of phase correlation between long-term TO variations at Arosa station and the number of sun-spots during the period 1932-2009 was investigated (Visheratin et al., 2008; Visheratin, 2011). The correlation between inter-diurnal TO variations from TOMS data and the most intense solar flares during the period 1979-2005, with spatial resolution of about 100 km, was explored (Visheratin and Shilkin, 2009). A study to explore the perturbation action of 20 tropical North Atlantic cyclones upon TO
field, based on TOMS data, for all cyclone evolution phases from depression to hurricane was fulfilled (Nerushev, 2008).

The parameters of short- and long-term variability of aerosol over Siberian lidar station were determined (Zuev et al., 2008a). Quantitative effects of aerosol, including that of volcanic origin, on the ozone layer parameters were revealed (Zuev et al., 2008d, 2010). Lidar soundings of ozone detected quite a rare process of the stratosphere-troposphere transport across the tropopause (Zuev et al., 2008b).

Based on the results of a synoptic analysis of mean monthly and mean diurnal TO fields, differences were found in the directions of the zonal transport of air masses containing different ozone amounts, depending on temperatures in the polar winter stratosphere, and phase of quasi-biennial oscillations (Syrovatkina et al., 2008).

Processes of air-mass exchange through the tropopause in extra-tropical latitudes were studied by analyzing balloon sounding data on ozone and water vapor, obtained during the field campaign LAUTLOS, as well as by using a trajectory model to clarify the origin of air masses and estimate fluxes through the tropopause (Luk’yanov et al., 2009).

Measurement time series of biologically active, erythema-weighted UV irradiation in Moscow for the period 1999-2006 were analyzed and its time variation was retrieved for the period 1968-2006 (Chubarova, 2008). The reconstructed model was used to show a marked growth of the rate of erythema-weighted UV irradiation in 1980-2006 due to changes in TO, effective cloud transparency, and aerosol loading. However, no statistically reliable changes in erythema-weighted UV irradiation were observed during a longer period, from 1968 to 2006, which is primarily due to considerable reduction of effective cloud transparency during that period.

A review comprising the most recent information about the chemical composition of the stratosphere and mesosphere has been compiled. The information had been obtained in different seasons and in both hemispheres, using instruments such as MIPAS (IR limb sounder), SCIAMACHY (UV-visible and near-IR nadir and limb viewer) and GOMOS (Global Ozone Mapping Spectrometer) aboard ENVISAT launched in 2002, as well as high-resolution instruments to measure important gaseous species in the stratosphere and upper troposphere on board the recently launched satellite Aura, i.e., HIRDLS – High Resolution Dynamics Limb Sounder, TES – Tropospheric Emission Spectrometer, OMI – Ozone Monitoring Instrument, and upgraded MLS - Microwave Limb Sounder (Repnev and Krivolutsky, 2010).

The results of ground-based spectrometer measurements of atmospheric column NO2 content from IAP Zvenigirod Research station were used to validate NO2 data from OMI (Ozone Monitoring Instrument) on board the US satellite EOS-Aura (Gruzdev and Elokhov, 2009; Gruzdev and Elokhov, 2010).

3. Theoretical, modeling, and other studies

Using a three-dimensional chemical-climatic model HAMMONIA, the influence of 27-day rotational variations of solar radiation on the chemical composition and temperature of the stratosphere, mesosphere, and lower troposphere were studied (Gruzdev et al., 2009). The model results were compared with observational data on tropical ozone and temperature response to a 27-year solar cycle.

The reasons for the enhancement in the XXI century of Brewer-Dobson meridional circulation, which in turn leads to TO increase in extra-tropical latitudes and its reduction
and lower stratosphere cooling in the tropics, were revealed through the use of a tree-di-

imensional chemical-climatic model SOCOL (Schraner et al., 2008), developed at MGO in cooperation with the Physical and Meteorological Observatory (Davos, Switzerland) and the Higher Polytechnic School (Zurich, Switzerland). It was inferred that the enhancement Brewer-Dobson model circulation in SOCOL resulted from increased wave activity of planetary and gravitational waves in the troposphere (Zubov et al., 2011). Using a 2D model of atmospheric photochemistry, radiation, and dynamics (SOCRATES), it was shown that ozone inflow to mid latitudes is enhanced when solar activity is high compared with its minimal activity period (Груздев, 2008). According to modeling data, this mechanism accounts for up to 30% of the winter increase of ozone content in the layer of ozone maximum (at about около 22 km) in mid latitudes of the southern hemisphere at the peak of an 11-year solar activity cycle, while in mid latitudes of the northern hemisphere, its major input to the 11-year variations of ozone content in this layer is made in the second half of winter. A thermodynamic-microphysical model of the formation and evolution of polar stratospheric clouds was constructed and integrated into the chemical-climatic model of the lower and middle atmosphere. Model experiments were staged to study the evolution of gaseous and aerosol composition of the stratosphere in Antarctica and the Arctic. The results of studying differences in the changes occurring in the amount of gaseous minor species and aerosol in polar regions show that the formation of a full-scale ozone hole in Antarctica and only casual “mini-holes” in the Arctic is mainly due to de-nitrification observed in Antarctica and its absence in the Arctic (Smyshlyaev et al., 2010).

Using an analytical and a 1D numerical photochemical models, stratospheric ozone sensitivity to the linear trends of the amount of NO$_2$ and HCl vapor, leading to changes in ozone destruction rate in nitrogen and chlorine photochemical cycles, was estimated. (Gruzdev, 2009). It was shown that to correctly estimate ozone loss due to halocarbons, whose release to the atmosphere is governed by the Montreal Protocol provisions, long-term trends in NO$_2$ content have to be allowed for.

A lidar to measure ozone concentration distribution in the upper troposphere–lower stratosphere was developed (Zuev et al., 2008c; Burlakov et al., 2010).

A technique to determine TO with high space (3 × 3 km$^2$) and time (15 min.) resolution through measurements of the Earth’s outgoing thermal radiation from geo-stationary METEOSAT platforms was suggested (Polyakov and Timofeev, 2008). The technique employs measurements of SEVIRI instrument (8 IR channels) and supplementary information about a three-dimensional atmospheric temperature field and surface temperature from polar satellites (AIRS instrument). Yuri M. Timofeev and his colleagues suggested several improved algorithms to determine TO and vertical distribution of ozone, using satellite-borne UV and IR instrumentation (Virolainen and Timofeev, 2008, 2010; Polyakov et al., 2008, 2010; Polyakov and Timofeev, 2010).

For the first time ever, the mechanism of halogen activation in the lower stratosphere was completed with a new reaction cycle including a family of peroxide compounds, H$_2$O$_2$, H$_3$O$_2^+$, and HSO$_5^−$. It was shown that reactions of these substances with chloride and bromide anions present in sulphate aerosol particles (Junge layer) can, depending on the conditions, either increase or weaken the influence of halogen activation on the ozone layer in mid latitudes (Larin and Yermakov, 2010). The ozone depleting and greenhouse potentials of C$_3$F$_7$I and C$_2$F$_4$I$_2$, which could be used to extinguish fires, were estimated (Larin et al., 2010a). By using a method of resonance fluorescence, the
constants of the rates of reactions of oxygen atoms with molecular chlorine and iodo-
methane were measured (Larin et al., 2010b); also, the formation of atomic iodine through a heterogenic reaction of atomic chlorine with iodo-methane was studied (Larin et al., 2010). Model data on the impact of galactic cosmic rays (GSRs) on minor atmospheric species, including OH, HO₂, O₃, O(^1D), O(^3P), NO, NO₂, NO₃, N₂O₅, HNO₂, HNO₃, HNO₄, ClO, ClONO₂, HCl, HOCl, Br, BrO, and HOBBr, were obtained. It is shown that relative changes in some of the constituents at a 15-20 km level in mid latitudes due to GSRs can reach or exceed 20%. Also shown is that TO decrease in mid latitudes during the 11-year cycle of solar activity, which determines changes in GSRs flux intensity, can account for one third of the atmospheric ozone loss in the late XX century due to anthropogenic release of chlorofluorocarbons (Larin, 2010).

4. Dissemination of results
4.1. Archiving, storage, and transfer of observational results to national and international data archives

The results of TO observations on the M-124 ozonometer network are transmitted to the Hydrometeorological Center of Russia, CAO, and MGO on a daily basis. CAO performs primary data quality control, archives the data and transmits it on-line to the World Ozone and UV Data Centre (WOUDC). MGO receives initial measurement data from the stations, checks its quality, and prepares it for transmission to WOUDC. The ozonometers M-124 having been in operation for over 25 years, despite the upgrading of the instruments, quite a lot of troubles with the measurement scale occur. Therefore, measurement results require thorough verification, and, occasionally, special ozonometer calibration is needed, which precludes timely transfer of verified data to WOUDC.

TO and UV radiation data obtained at Kislovodsk and Obninsk stations using Brewer spectrophotometer are also transmitted to WOUDC.

SAOZ measurement data from the Russian stations are transmitted on-line to the World Data Center in France (http://gosic.org/gcos/SAOZ-data-access.htm).

IAP Zvenigorod research station measurement data on NO₂ content in a stratospheric column and in the atmospheric boundary layer are regularly transmitted to NDACC (http://www.ndacc.org/).

4.2. Forecasting and public information

Analyses of the current ozone layer state are presented by CAO in the quarterly reviews of the journal “Meteorologia i Gidrologia” (with its English version disseminated by Springer Publishing House). Annually, the reviews include data on long-term changes of the ozone layer over Russia, which are compared with those observed in other regions of the globe. Information about the ozone layer state over Russia is also published in the annual reports on the climate of the Russian Federation and reviews of the state and pollution of the environment in the Russian Federation, presented by Roshydromet.

The technology of TO and UV index forecasting for the Russian territory has been recently developed by CAO in cooperation with the Hydrometeorological Center of Russia. TO forecasting uses current TO observations and predicted weather parameters. To determine the current state and forecast UV-B irradiation fields, observational data and
forecasts of TO, cloudiness, and underlying surface albedo are employed. At the present stage, this technology is just a pilot one.

The following 3 monographs have been published:

4.3. Scientific publications
Below, some basic 2008-2010 scientific publications are listed:

Chubarova N.Ye. UV variability in Moscow according to long-term UV measurements and reconstruction model, Atmos. Chem. Phys., 8, 3025–3031, 2008.
Gruzdev, A.N. Latitudinal dependence of the variations of stratospheric NO2 content. Izvestiya, Atmospheric and Oceanic Physics, 44 (3), c. 345-359, 2008.
Ikonov D.V. Vertical structure of long-term stratospheric ozone trend from the satellite-borne measurements over southern Russia. Issledovanie Zemli iz Kosmosa, 4, 3-11, 2009 (in Russian).


Luk’yanov A. N., Karpechko A. Yu., Yushkov V.A., Korshunov L.I., Khaikin S.M., Gan’shin A.V., Kyri E., Kivi R., Maturilli M., and Voemel H., Estimation of Water-Vapor and Ozone Transport in the Upper Troposphere-Lower Stratosphere and Fluxes through the Tropopause during the Field Campaign at the Sodankyla Station (Finland), Izvestiya, Atmospheric and Oceanic Physics, 45 (3), 294-301, 2009.


Visheratin K.N. Phase relations between quasidecadal total ozone oscillations and solar cyclisity./ Geomagnetizm i Aeronomia, 51 (4), 2011 (in press).


Zuev V.V., Burlakov V.D., Dolgii S.I., Nevzorov A.V., El'nikov A.V. Breakthrough of stratospheric air masses into the upper troposphere retrieved from ozone lidar measurements, Atmospheric and Oceanic Optics Journal (Tomsk), 21 (7), 514-519, 2008b.

Zuev V.V., Burlakov V.D., Dolgii S.I., Nevzorov A.V. Differential absorption lidar for ozone sensing in the upper troposphere - lower stratosphere, Atmospheric and Oceanic Optics Journal (Tomsk), 21 (10), 765-768, 2008 c.

Zuev V.V., Bazhenov O.E., Burlakov V.D., Grishaev M.V., Dolgii S.I., Nevzorov A.V. On the effect of volcanic aerosol on variations of stratospheric ozone and NO2 according to measurements at the Siberian Lidar Station, Atmospheric and Oceanic Optics Journal (Tomsk), 21 (11), 825-831, 2008d.


5. Participation in research projects

Scientists from Russia are involved in the following international projects:

- HEPPA - High Energetic Particle Precipitations in the Atmosphere;
- ISST (International Space Science Institute) - Study of cosmic ray influence upon atmospheric processes;
- MATCH - Determination of Stratospheric Polar Ozone Losses);
- POLARCAT - Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport;
RECONCILE - Reconciliation of Essential Parameters for an Enhanced Predictability of Arctic Stratospheric Ozone Loss and its Climate Interactions;
SCOUT-O3 - Stratospheric Climate Links with Emphasis on the UTLS;
YAK-AEROSIB - Airborne Extensive Regular Observations over Siberia – (Russia-France experiment).

6. Future activities

It is planned to resume TO observations at the station on Dickson Island (73,5°N, 80,5°E) and thereby completely restore the Russian Federation ozonometer network of 29 stations that were in operation prior to 1991.

In 2011, the tests of the UV ozone spectrometer are to be completed. Within the period of 2012-2015, these instruments are to be installed at all the ozonometer stations of Roshydromet, which will permit automating TO measurements and provide regular measurements of the spectral composition of the global UV radiation in a 290-400 nm range.

As concerns measurements using Brewer spectrophotometer, it is planned to adopt night-time measurements by the moon and measurements of the vertical profile of ozone concentration by an inversion method, as well as to improve the accuracy of measuring total SO2 and aerosol optical thickness through upgrading data processing procedure.

It is expected, using three-dimensional models, to estimate the input of solar activity to the global changes in atmospheric chemical composition, the temperature and circulation of the middle atmosphere and troposphere (CAO, MGO).

A model version of the numerical forecast of spatial (3-D) ozone distribution for a month’s and a season’s periods in advance (CAO, HMC).
1.1 Introduction

Samoa acceded to both the VC and the MP on 21 December 2002. As a developing country it has been classified as an Article 5(1) country, eligible to receive technical and financial assistance under from the MLF. The proposed TPMP for HCFCs describes Samoa’s approach and associated activities to guide its efforts to comply with the agreed phase-out schedule for HCFCs, from the baseline determination from 2009 and 2010 consumptions to full phase out in 2040. It was prepared by the NOU of MNRE under the supervision of the NOC.

1.2 Country background

Samoa is a Pacific small island developing state that became an independent country in 1962 after a period as a United Nations Trust Territory under New Zealand administration (see Figure 1). This part looks at the background features of Samoa to understand the local setting where the current ozone activities take place and the proposed will be applied and implemented. The setting in this context is the local environment comprising the physical, political, social and economic conditions and the circumstances that would shape decision-making on project activities.

*Figure 1 – The islands of Samoa*
1.2.1 Geographic features

Samoa is comprised of two relatively large islands, Upolu and Savaii, two smaller inhabited islands, Manono and Apolima, and a number of smaller uninhabited offshore islands, islets and rocks (see Figure 1 above). It is the larger and western part of the Samoan archipelago, located between 13° and 14° south latitude and 171° and 173° west longitude. The islands stretch over a distance of about 200 km covering a total land area of about 2,900 km² (40% in Upolu and 60% in Savaii) and an exclusive marine economic zone of approximately 130,000 km². 80% of total land area is held under customary ownership, 16% is government land and 4% freehold. The capital, Apia, is located about midway on the north coast of Upolu. Salelologa is the main centre on Savaii, located on the southeast coast.

The Samoan islands are composed mainly of volcanic, with areas of recent lava flows still exposed on Savaii. Soils are generally clay in texture, free draining, porous and relatively shallow. About 40 per cent of Upolu and 50 per cent of Savaii are characterised by steep slopes descending from volcanic crests, with the interior of both islands covered by montane forests. Cloud forest is found at the higher altitudes on Savaii. The country is rugged and mountainous with the Upolu crestal ridge rising to 1,100 m, and Savaii’s highest mountain reaching up to about 1,850 m. A coral reef surrounds the islands for nearly half of the coastline except where there are coastal cliffs and headlands, and where young lava flows have filled the lagoon.

The climate is generally hot and wet with distinct dry (April to November) and wet (December to March) seasons. Annual rainfall is about 3,000 mm m (varying from 2,500 mm in the rain shadow areas of Savaii’s northwest to over 6,000 mm in the Savaii highlands), with most of the precipitation occurring in the wet season. The average temperature is 27 degrees Celsius with 80% humidity. Samoa experiences southeast trade winds almost all times of the year with tropical cyclones occurring during the wet season.

2.1 Current activities and implementation programmes carried out by the NOU

There are two Implementation programmes and plans currently in place. This is the Terminal Phase out Management Plan for CFCs and the HCFC Phase out Management Plan.

Majority of the activities under the TPMP for CFCs have been completed with only the incentive programe which is scheduled to be completed before mid 2011. On the other hand the HCFC Phase out Management Plan is already in place for Samoa and has been submitted as a Regional Approach to the Executive Committee Meeting in April 2011.

The following will provide the existing and planned research and monitoring activities currently in place for Samoa.

3.1 ODS legislation

In spite of the strong provisions of the current ODS regulations, observance by importers and RAC companies was extremely poor. There was only limited compliance with annual licensing and quarterly
reporting requirements. As a result, it was extremely to obtain accurate information on the use and consumption of ODS. Data provided by the MfR were also found to be incomplete and inconsistent making it quite difficult to determine actual volumes of imported ODS and the number of ODS-based equipments that were brought into Samoa.

However, review of the ODS legislation is currently taking place and the Legal Consultant from the Ministry of Natural Resources and Environment is assessing this review whether it should become an Act or an Amendment. This review will most likely be completed by the end of 2011.

4.1 ODS Consumption

Samoa is not an ODS producing country with demand only for RAC services. Australia, New Zealand and Fiji are the main exporters of ODS to Samoa, although some ODS or ODS-based equipment may have been brought in illegally by local residents or foreign ships.

5.1 Terminal Phase out Management Plan – Activities

The Terminal Phase-out Management Plan for ODS in Samoa was approved by the Executive Committee in its 53rd Meeting in November 2007. According to the agreement between the Government of Samoa and the Executive Committee of the Multilateral Fund for Phase-Out of Ozone-Depleting Substances, Samoa will provide annual report on the implementation of previous year plan and annual implementation plan for the current year.

The National Ozone Committee (NOC) oversees the implementation of the TPMP. One staff member of Samoa Ministry of Natural Resources, Environment and Meteorology is dedicated to the implementation of TPMP. NOC meetings are conducted to discuss arising issues in the implementation on a monthly basis or by request of National Ozone Unit (NOU) or NOC members depending on arising monitoring issues from time to time.

Samoa TPMP implementation started in mid 2008 after the signing of agreements between the Government of Samoa with UNEP and UNDP. The NOU is dedicated to accelerate the implementation of both UNEP and UNDP TPMP components to ensure achievement of all objectives stated in these Agreements before the end of the Project.

This report therefore will provide a summary of the activities undertaken during the time the TPMP started its implementation programme in Samoa in mid 2008 till 2010.

5.1 Achievement of Targets.

Samoa fully met the 2009 targets which is 0.0 ODP tons for CFC import and 0.0 ODP tons for servicing.

Samoa reported zero consumption in 2008 for CFC and other ODSs (except HCFCs) to the Ozone Secretariat as shown below.
Table 1: ODS Consumption during 2003-2010 (ODP Tons)

<table>
<thead>
<tr>
<th>ODS</th>
<th>2003</th>
<th>2004</th>
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<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tr>
<td>Halons</td>
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<td>0</td>
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<tr>
<td>Other Fully Halogenated CFCs</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>Carbon Tetrachloride</td>
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<td>0.1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Ozone Secretariat

Licensed companies provided the NOU with their annual consumption data before 1 March every year as obligated under the license conditions. These data, as well as data from Customs, are reviewed by the NOU before providing a final report of the ODS consumption.

6.1 IMPLEMENTATION OF 2009 & 2010 ANNUAL IMPLEMENTATION PROGRAMME

6.1 Component 1: Policy, Regulatory and Institutional Support

6.1.1 Review of the Atmospheric Policy:
The Atmospheric Policy has been reviewed and it is now still in its final draft. The Ozone Layer Regulations 2006 has been reviewed and is currently being assessed by the Attorney Generals Office.

A total number of two consultations and two workshops were carried out for the review of the Ozone Layer Regulations 2006, however it is intended that an Amendment of Ozone Regulation will be proceed in the near future.

6.1.2 Training of Enforcement Officers:
Training has been carried out for enforcement officers including Customs, Quarantine and conservation officers that are monitoring of imports and enforcement of the regulations. Technicians were hired to conduct these trainings. The customs officers have improved
awareness and capacity to carry out their duties to control the banned refrigerants and equipments that are under control of the Montreal Protocol.

6.2 Component 2: Training Course for Refrigeration Technicians, Capacity Building and Awareness Activities

6.2.1 Support for Refrigeration Association:
The Samoa Refrigeration Engineering Association (SREA) is functioning well and collaborating with the NOU in conducting trainings and monitoring of the licensing system. A JICA volunteer is now working closely with the NOU and the SREA in reviewing the Samoa Technicians Certification System; this system is regarded very important towards the licensing system in Samoa. It is expected to be in place in July 2011.

6.2.2 Expansion of Technician Training Programme
Refrigeration and Air conditioning technicians’ trainings were conducted and 101 technicians were certified during 2009, with 41 technicians certified in 2010. All in all, there were four Trainings carried out for Good refrigeration practices carried out by authorized technicians from SREA and NUS lectures. As a result of this, a total number of 152 technicians certified. However, some of these technicians attended the trainings twice for refreshment purposes.

6.3 Awareness:
Awareness programs have been carried out for the relevant national stakeholders including workshops to further inform them of the relevant information that they need to be aware of. Also a consultation with the MNRE IT personnel have been conducted for future posting of updated Ozone Issues in the MNRE Website. This is accessed by the public.

Furthermore, a number of Important Ozone Issues pertaining the Phasing out of CFCs have been published in the Samoa Observer Newspaper and the main Television channel for effective awareness of the public towards Ozone issues and results of workshops. Also displays of Ozone boards were carried out at the National University of Samoa’s Open Day and Career Day for two years.

6.4 Component 3: Technical assistance and equipment support for servicing/training establishments
6.4.1 Training / Demonstration Equipment:
The Freeze Dry Systems Ltd, Auckland New Zealand was the selected Company for the supply of equipments and the consultant selected was John Campion from the same company. He has been in the refrigeration and vacuum industry business for thirty years.

A whole week Workshop was carried out at the Australian Pacific Technical College Workshop area for the demonstration and trainings were carried out in July 2010.

Representatives from all the ODS Servicing Companies and Importers attended as well as NOC members and Institutions. A total number of 62 participants attended the training and demonstration of equipments.

6.4.2 Equipment procurement:
Procurement of 3 sets of recovery recycling for Refrigeration Service Shops and 2 sets of MAC Recovery and Recycling and selection of shops and distribution of the equipment is completed.

Ongoing / Planned Activities for 2011.

Component 4: Technical Assistance and Equipment Support

6.4.1 Incentive Programme:
Under the TPMP, training and demonstration equipment to the refrigeration and air conditioning servicing industry association was provided with assistance made available in the first tranche. Funding for the second tranche would be used for assisting the country in reducing its dependence on CFC based air-conditioning equipment in Mobile Air-Conditioning (MAC) applications through retrofit incentive program for conversion to alternatives.

This component will cover the following activities:

− Incentive programme for retrofit of 1,000 CFC-based MAC systems at $30 per car. The NOU would have the flexibility to decide on the focus of their incentive programme on MAC or other RAC equipment depending on prevailing situation. The incentive should not be more than 50% of actual retrofit cost.

− Awareness campaign for popularizing the programme as well as to familiarize the automobile users with the prospective vehicle inspection and registration mechanism and the ban on CFC-based systems after 2009. The awareness activities would be undertaken as a part of the ongoing ODS phase-out initiatives under IS project.
6.5 Component 5: Coordination and Monitoring

National Ozone Committee meetings are held with representatives from Ministry of Commerce, Industry and Labour, Customs Department, Office of the Attorney General, Samoa Refrigeration Engineering Association, Samoa Institute of Technology, Ministry of Finance regularly to discuss any required issues from time to time.

Regular contact with UNEP DTIE, Asia Pacific Regional Network, SPREP, Samoa Refrigeration Engineering Association, the National Ozone Committee, the Private Sector, other government departments/agencies/corporations; and other sections/divisions of the MNRE regarding matters pertaining to the implementation of the Montreal Protocol in Samoa.

7. HCFC Phase out Management Plan

7.1 ODS importation

Primary data on annual imports of HCFCs from 2007 to 2010 was compiled from information from received from importers and cross-checked against Customs Department import data. When the NOU started the implementation of the ODS import licensing system, 11 companies were granted licenses of which six were active (Table 4). Two of these six, BOC Gases and Trade Supplies, were importers/resellers while the rest imported ODS for their own use.

Table 2: Registered RAC companies, 2010

<table>
<thead>
<tr>
<th>Company</th>
<th>Refrigerants</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOC Gases Samoa Ltd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Origin Energy Samoa Ltd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Samatic Refrigeration Ltd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Trade Supplies (Samoa) Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>DJ Grevel Refrigeration</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Kool Line Refrigeration (Samoa) Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>SL Refrigeration Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>West End Co. Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Supercool Refrigeration &amp; Air Conditioning</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: NOU survey
7.2 ODS use and consumption

Samoa consumption of HCFCs is shown in Table 5, with a baseline of 3.88 MT or 2.13 ODP (MT) for Samoa. The survey found that the most common refrigerants were HCFC-22 (HFC-134a and R-404A), R-407C, R-410A and R-507A; there was currently no hydrocarbon-based refrigerant being offered. The importation of CFCs was discontinued in 2003 as a direct outcome of the implementation of the CP and RMP and in response to the TPMP for CFC phase-out. Since the ban on CFC imports, recovered and recycled CFCs and drop-in alternatives were used to meet the servicing and maintenance needs of existing equipment.

Table 2: Estimated HCFC consumption for Samoa, 2005-2010

<table>
<thead>
<tr>
<th>HCFC (MT)</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.2</td>
<td>0.29</td>
<td>2.31</td>
<td>2.97</td>
<td>3.50</td>
<td>4.26</td>
<td>3.88</td>
</tr>
<tr>
<td>ODP (MT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.13</td>
</tr>
</tbody>
</table>

Source: NOU survey

7.3 RAC sector

The RAC sector is the only sector consuming HCFCs in Samoa. Since there is no national manufacturing HCFC or HCFC-based equipment, the entire consumption is in servicing of refrigeration and air conditioning equipment.

7.3.1 Domestic refrigeration

Domestic refrigerators are not manufactured in Samoa and the requirements are set and determined by imports. The importation of new non-ODS refrigerators commenced in late 1990s from Australia, New Zealand and other Asian countries. Second-hand HCFC refrigerators are also being imported from Australia and New Zealand.

It was estimated that there were about 30,000 units of HCFC-based refrigerators operating in 2010. With over 90% of households served by the national electricity grid this will lead to increased use of domestic refrigerators. It is more than likely that most villagers will purchase second hand refrigerators, and these communities will need to be informed about the impending phase-out of HCFCs and the proposed incentives to convert their equipment to non-ODS refrigerants.

7.3.2 Commercial refrigeration

Commercial refrigeration equipment includes chest freezers and visi coolers. Chest freezers are mainly used in supermarkets, grocery shops, food product stores and restaurants.

The population of HCFC-based commercial refrigeration equipment in 2010 is estimated at about 700 units. While a significant percentage of existing commercial refrigeration equipment is reaching the end
of its existing life most units, for economic reasons, will be repaired rather than replaced. Second hand equipment is being imported and retrofitted using HCFCs because the new generation refrigerants are expensive to acquire.

The servicing demand in Samoa is very low for commercial refrigeration equipment due to small numbers of existing equipment. It was assumed that 400 gms per unit was required for recharge consumption of commercial equipment during servicing, with about 50% of equipment needing servicing. It is expected that the majority of new commercial equipment will be serviced with non-ODS alternatives.

7.3.3 Industrial refrigeration

Industrial refrigeration equipment is being used primarily for refrigeration applications in food processing industries such as the ice cream factories (about 20 units). About 7 chillers for centrally air-conditioned applications were installed in public buildings in Apia including the new Justice and Court Administration complex.

7.3.4 Mobile air conditioning (MAC)

The usage of vehicles in Samoa has experienced exceptional growth in recent years. As shown in Table 6, the number of registered vehicles more that doubled during 2002-07. The majority of the vehicles imported into the country were second-hand using ODS-based MACs.

Table 3: Number of registered vehicles in Samoa, 2001-2007

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of registered vehicles</th>
<th>Light vehicles¹</th>
<th>Estimated amount of refrigerants (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>% of total</td>
</tr>
<tr>
<td>2001</td>
<td>7,731</td>
<td>6,359</td>
<td>82</td>
</tr>
<tr>
<td>2002</td>
<td>9,196</td>
<td>7,910</td>
<td>86</td>
</tr>
<tr>
<td>2003</td>
<td>11,288</td>
<td>9,932</td>
<td>88</td>
</tr>
<tr>
<td>2004</td>
<td>13,485</td>
<td>12,120</td>
<td>90</td>
</tr>
<tr>
<td>2005</td>
<td>14,400</td>
<td>13,000</td>
<td>90</td>
</tr>
<tr>
<td>2006</td>
<td>15,012</td>
<td>13,603</td>
<td>91</td>
</tr>
<tr>
<td>2007</td>
<td>16,215</td>
<td>14,794</td>
<td>91</td>
</tr>
</tbody>
</table>

Source: SBS
The amount of 0.9 kg was prescribed by the RAC servicing companies as the average amount of refrigerant contained in each imported vehicles. It was also assumed that 75% of the light vehicle population have MAC units and 30% are serviced annually.

7.3.5 Domestic and commercial air conditioning

There are 3,000 installations of HCFC-based room air-conditioning units (mainly in office and commercial buildings, hotels, restaurants and hospitals) with a few in private homes.

7.3.6 Servicing establishments

There were 21 licensed refrigeration service and repair workshops mainly on Upolu Island. Of these, about 14 catered to the domestic, commercial and industrial refrigeration sub-sectors and 7 dealt with the MAC sub-sector. There are a total of about 120 technicians operating in the RAC servicing sector with varying skill and competency levels.

8. Recommendations:

In regards to the recommendations mentioned in the Ozone Research Managers Meeting, 2008. Samoa does not have any further recommendations at this stage.

Samoa is looking forward to participate in this Ozone Research Managers Meeting in order to become fully aware and understand activities planned to be implemented for research and monitoring activities.
Introduction

The depletion of the stratospheric ozone layer, increases in troposphere ozone, higher levels of acidity in rain, rising carbon dioxide and methane concentrations, and changes in the radiative balance of the earth-atmosphere energy system - all reflect the increasing influence of human activity on the global atmosphere, the life-support system of planet Earth. Environmental issues and policy matters have to play a pivotal role in meeting the developing needs and challenges of the people in a new democratic South African Society. Clauses in protecting and respecting the environment in a sustainable context, is embedded in the South African Constitution.

To underline these facts: - An excerpt by the Minister of Water and Environmental Affairs Me. Bee Molewa, on Wednesday 20 April 2011, in the National Assembly, Parliament.

"We rank among the world's top 20 greenhouse gas emitting countries. As a country, we must strive to maintain a balance between development and environmental conservation. Like many other countries of the world, the number one threat to our long term sustainable development, economic growth and quality of life are related to the impacts of climate change.

Climate change is already a reality! Its early impacts can be seen on declining agricultural production, higher food prices and food insecurity; which are most severely felt in developing countries like ours. Working together we must ensure that our response to climate change seizes the new growth opportunities presented by the global effort to address climate change.

President Jacob Zuma announced prior to the Copenhagen United Nations Climate Change Conference in December 2009 that South Africa will implement nationally appropriate mitigation actions which will result in the reduction of our carbon emissions by 34 % by 2020 and by 42 % in 2025, dependant on availability of finance and technology.

As a department working together with the people of South Africa, we are ready to give practical meaning to this commitment. Consequently, our Climate Change Response Policy is nearing completion and we will present the Climate Change White Paper for Cabinet approval, later this year. This evolving policy outlines our vision for an effective climate change response and our transition to a climate resilient and low-carbon economy and society.

From the 28th of November to the 9th of December this year 2011, our country will host the United Nations Climate Change Conferences in Durban (COP17). “

In light of the above stated commitment the activities following describes the ongoing systematic monitoring efforts in South Africa.

1. **OZONE OBSERVATIONAL ACTIVITIES**

The South African Weather Service (SAWS), an agency of the Government Department of Environmental Affairs and Tourism (DEAT), is the focal point of ozone monitoring and research activities in South Africa. These activities are enhanced by collaboration with a few national research centers and universities.
The ozone monitoring and research activities are conducted within the context of the World Meteorological Organizations (WMO) Global Atmosphere Watch (GAW) program. The Cape Point Global Atmosphere Watch (GAW) station undertakes a regional network of observations.

1.1 Atmospheric Ozone Monitoring

The first South African column ozone measurements were made during 1964 until 1972 with Dobson #089 operating from Pretoria. Reinstating South Africa’s commitment to the Vienna Convention, the Weather Service now operates two Dobson ozone spectrophotometers, #089 at Irene near Pretoria (25.9 S, 28.2 E) since 1989, and #132 at Springbok (29.7 S, 17.9 E) since 1995. Both these instruments have been regularly calibrated with reference to the world standard. Our participation at the recent UNEP/WMO Dobson Data Workshop held in Hradec Kralove, Czech Republic re-affirmed good quality data sets.

During 2009, the 3rd African UNEP/WMO International Comparison of Dobson Spectrophotometers was organized by the World Meteorological Organization and the South African Weather Service in close cooperation with the World Calibrations centre at NOAA and the European calibrations centre hosted by DWD, Germany. This event was conducted during October 2009 at the Irene Weather Service Technical Centre, just south of Pretoria.

After a three year break the Weather Service has been fortunate to reinstate its ECC RSG92-15GE Ozonesonde sounding program, which operated during the period 1990’s until early 2007. Regular ozonesonde soundings are once again scheduled for 2011. This data is shared with the Southern Hemisphere Additional Ozonesondes (SHADOZ- http://croc.gsfc.nasa.gov/shadoz/) program from NASA, USA, which also is submitted to WOUDC.

Figure 1: Dobson #132 Total Ozone Column for Springbok

![Figure 1: Dobson #132 Total Ozone Column for Springbok](image)

Figure 2: Dobson #89 Total Ozone Column for Irene

![Figure 2: Dobson #89 Total Ozone Column for Irene](image)
Surface ozone measurements are continuously undertaken at Cape Point since 1982. Our program has also extended surface ozone measurements to the South African National Antarctic Expedition Base (SANAE IV) in Antarctica since December 2003. Surface ozone monitoring is to be extended to the two Dobson stations, Irene and Springbok during 2011.

1.2 Other relevant Trace Gases and profile measurements

The pristine location of the Cape Point Global Atmosphere Watch GAW station (34.3S, 18.5E) enables measurements to be made in air that has passed over the vast clean Southern Ocean. Such long-term observations are representative of background conditions, making it possible to detect changes in the atmosphere's composition. The Cape Point GAW Laboratory is also scientifically twinned with a research partner, namely the Fraunhofer Institute for Atmospheric Environmental Research (IFU) in Garmisch, Germany, now IMK-IFU (Forschungszentrum Karlsruhe).

Measurements include a wide range of parameters namely: - surface O$_3$, gases which lead to stratospheric ozone depletion such as: CFCl$_3$, CCl$_3$F$_2$, CCl$_2$F-CClF, CH$_3$CCl$_3$, Cl$_4$ and N$_2$O greenhouse gases in the troposphere such as CO$_2$ and CH$_4$ and reactive gases such as CO.

Furthermore, UV-A, UV-B and global radiation (total and diffuse) are also measured as well as the normal surface meteorological parameters. Radon measurements to assist with the classification of air masses arriving at Cape Point have been successfully established over the last five years. Regular scientific audits from EMPA, Switzerland for surface O$_3$, CO and CH$_4$ have been successfully conducted over the past seven years. In 2003 the WCC-N$_2$O (Forschungszentrum Karlsruhe IMK-IFU and Umweltbundesamt) conducted an audit for N$_2$O at Cape Point. During 2006 with German collaborations (GKSS Research Centre Geestacht) the Cape Point gashouse mercury measurement program was also revived.

Since 2005 a project was undertaken for the continuous measurements of aerosols. This is now a well established program at the Cape Point GAW station and includes physical, chemistry and optical properties being measured. This milestone was reached with start-up funding support from WMO, scientific partnering with NOAA ESRL scientists (who designed and constructed the aerosol system) and local SAWS station scientist running and maintaining the system. The latest addition was the establishment of Aerosol Optical Depth (AOD) measurement relevant to global climate change in accordance to detailed guidelines set out in GAW Precision Filter Radiometer Network (GAWNET) http://www.pmodwrc.ch/worcc and Global Atmosphere Watch Program of the World Meteorological Organization (GAW) http://gaw.tropos.de

1.3 Ultraviolet-B measurements

Since January 1994 the Weather Service has maintained a routine program for monitoring erythemally weighted UV-B radiation at Cape Town (34.0S, 18.6E), Durban (30.0S, 31.0E) and Pretoria (25.7S, 28.2E), De Aar (30.7S, 24.0E) and Port Elizabeth (33.9S, 25.5E). The equipment used in this network is the Solar Light Model 501 Robertson-Berger UV-Biometer. The program was motivated by and in collaboration with the School of Pharmacy at the Medical University of Southern Africa (MEDUNSA), near Pretoria.

Since December 2001, the UV-Biometers are directly linked on the Services wide area network, and available in real-time on the SAWS WWW-site http://www.weathersa.co.za/. UV-B forecasts are also issued for the Cape Town, Durban and Pretoria-Johannesburg metropolitan areas since 1 December 1997. The main purpose of the UV-Biometer network is to make the public aware of the hazards of excessive exposure to biologically active UV-B radiation, and it contributes to the school's awareness programs for education. Regular enquiries from scholars are dealt with to satisfy their need to acquire more ozone and ultraviolet radiation knowledge. Celebrations around 16 September, each year, usually focuses
to create public awareness. Once a year on this day it is also dedicated to the hard working ozone observers and technicians gathering the measurements.

Renewed UV research is being undertaken by the Council for Scientific and Industry Research (CSIR). Their research unit for health is conducting research towards UVB exposure amongst scholars.

2. Other Observation/Monitoring Networks

2.1 Research Aircraft

The South African Weather Service’s two research aircraft Aerocommanders are used as Airborne monitoring platforms. Site sampling is conducted at a speed of 100 ms\(^{-1}\), at low atmospheric levels (500 – 3000m above ground level) and the range of the aircraft is around 3.5 hours, over predetermined pollution hotspot areas over the country.

In addition to standard meteorological parameters, instruments mounted in and on the aircraft measure the following trace gases and aerosols:

- Carbon dioxide, Carbon monoxide, Sulphur dioxide, Hydrogen sulphide, Oxides of nitrogen, Ozone, Volatile organic compounds, and the concentration of aerosols between.

There has been a shift in air quality management in South Africa from source control to pollution prevention by focussing on ambient air quality is intended to ensure improved air quality for future generations. The aircraft monitoring capabilities complements other ground-based research and monitoring processes to ensure that information and data associated with air pollution are of the highest quality and are accessible to all South Africans.

The primary airborne monitoring project objectives are:

- To determine the spatial and temporal characteristics of air quality over South Africa through the use of ground-based, airborne and satellite measurements;
- To validate the various measurements and integrate them into a holistic picture of the South African air quality situation with the context of the region;
- To build capacity in the fields of air quality and atmospheric chemistry through hands-on training.

The Aircraft research and monitoring facilities are jointly managed by the South African Weather Service and the Climatology Research Group of the Witwatersrand University (Wits) in Johannesburg. These aircrafts and logistical staff have taken part in field experiments conducted in Australia and India during the last three years.

2.2 LIDAR

During the past three years, the Council for Scientific and Industrial Research - CSIR has developed a new mobile LIDAR. The Light Detection and Ranging (LIDAR) has become an excellent tool for monitoring the atmosphere in a relatively short period of time (within a few seconds to minutes). Currently, LIDAR systems are used for studying the atmospheric structure and dynamics, trace constituents, aerosols, clouds, boundary and mixed layers and other meteorological applications [1]. Although ground based LIDAR systems are deployed for atmosphere studies in many developed countries, it is still a very novel technique for South Africa and African countries. There are currently two different LIDARs available in South Africa, located in Pretoria and Durban respectively. The Durban LIDAR is operated at University of KwaZulu-Natal as part of cooperation between the Reunion University and the Service d’Aéronomie (CNRS, IPSL, and Paris) for climate research studies. It allows for studying the stratosphere-mesosphere (30-80 km) thermal structure and troposphere-stratosphere aerosol
(8-40 km). Future plans include field campaign measurements in and around South Africa, for qualitative industrial pollutant measurements and higher atmosphere characteristic changes in ozone, aerosol and other parameters.

3 CALIBRATION ACTIVITIES AND DATA SUBMISSIONS

All primary GAW data (ozone and trace gas data) are submitted regularly to WMO recognised World Data centers. Dobson column ozone is submitted to WOUDC, Toronto, Canada. Since the inception of the Dobson programs these instruments have been internationally calibrated through inter-comparison campaigns as supported by UNEP and WMO. Various regular international scientific audits remain in place for the Cape Point GAW station.

4. COLLABORATION - NATIONAL AND INTERNATIONAL

Ozone and related research are conducted sporadically within the country, mostly at a few academic institutions such as the CSIR, University of Kwazulu Natal in Durban, the University of Cape Town, and the University of the Witwatersrand in Johannesburg. Typical GAW type of collaborations is ongoing with the University of North West, School of Chemistry in Potchefstroom.

South Africa must also acknowledge its many international collaborators with specific references to international programs and institutions such as:

- The World Meteorological Organization (WMO) and many other NHMS in our region
- SHADOZ/Penn State University
- USA NOAA ESRL, Boulder
- WOUDC and ARQP, Toronto, Canada
- Training assistance from GAWTEC [http://www.schneefernerhaus.de/e-gawtec.htm](http://www.schneefernerhaus.de/e-gawtec.htm), Germany also DWD (European Dobson Calibration facility)
- LSCE, CNRS and DEBITS, Paris and Toulouse, and La Reunion Island - France. (Flask sampling, the SASRIO project and GDRI offices)
- The CZECH SOO-HK, in Hradec Kralove
5. FUTURE PLANS AND RECOMMENDATIONS

Priority research work at the South African continues to include a service rendering UVB Forecast, especially during summer months. South Africa has some of the world’s highest UVB levels. There still remains the need to establish long term continued high-resolution spectro-radiometer UV observations at some suitable sites in southern Africa.

To maintain and enhance our data quality and to gain near real-time access of the data from the monitoring processes to various user-communities.

The SAOZ ozone monitoring instrument from SANAE, Antarctica has been brought back to South Africa and needs to be refurbished before resuming its monitoring capabilities.

The South African Weather Service is now well settled in its role of the custodian of the South African Air Quality Information System (SAAQIS) which has been developed and launched during 2010. The SAAQIS is a web-based interactive air quality information system which seeks to provide state of the air quality information to citizens and it is a research portal for strengthening policy development related to air quality issues. This has a profound advantage in that the country we can begin to assess whether air quality is improving and also identify areas where potential air pollution problems exist.

Various national air-quality monitor stations is linked in real time gathering vital atmospheric data for decision making for improving ambient air quality in especially our industrial areas. Technical staff off the Weather Service is tasked to calibrate and maintain these monitoring stations as part of the normal weather observational system across the country. [http://www.saaqis.org.za/](http://www.saaqis.org.za/).

To continue building our scientific capacity – ozone, atmospheric research and monitoring in general, and related Climate Change Activities). The South African “ozone” community is very small and published peer reviewed articles of research findings remain admittedly very scarce.

CONTACT INFORMATION

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1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone

Total ozone is monitored at two sites in Sweden by SMHI (Swedish Meteorological and Hydrological Institute) on behalf of the Swedish Environmental Protection Agency. Daily measurements started in Norrköping in 1988 using the Brewer #6, which was replaced by Brewer #128 in 1996. In Vindeln manual measurements started in 1991 using the refurbished old Dobson #30 and since 1996 the automatic Brewer #6 is also used.

The instruments are calibrated and served regularly. Efforts have been spent on improving the methods to retrieve good observations at low solar elevations since the 1990-ties, Josefsson (2003) and to improve the algorithms for cloud covered skies Josefsson and Ottosson-Löfvenius (2008). This year one Dobson and one Brewer participated in the CEOS campaign in Sodankylä.

1.2 Profile measurements of ozone and other gases

At the Swedish Institute of Space Physics in Kiruna there are a number of sophisticated instruments in operation. Special radars can track the circulation in the stratosphere. LIDAR gives a profile of the ozone and aerosols in the stratosphere, when there are no interfering clouds. There is also an instrument KIMRA (Kiruna Millimeter wave radiometer) that is used to monitor O₃, ClO, N₂O and HNO₃. The vertical resolution may not be the best, but it is independent of the weather so it can operate continuously.

Forschungszentrum Karlsruhe has located a FTIR (Fourier-Transform Infrared) Spectroradiometer at the same site to record long-term trends, Kohlrepp et al. (2011).

There is also a DOAS-instrument from NIWA and University of Heidelberg recording primarily total ozone and the column amounts of a number of other species.

1.3 Satellite measurements

The satellite Odin (Sweden, France, Canada and Finland) has now been in orbit for more than ten years. On board there are two instruments with connection to stratospheric studies a submillimeter radiometer, SMR, and an optical spectrograph and infrared imaging system, OSIRIS.

1.4 UV measurements

1.4.1 Broadband measurements

Monitoring of broadband UV (CIE-erythema weighted) started relatively early in Sweden. Supported by SSM (the Swedish Radiation Safety Authority) SMHI has been measuring since 1983. Josefsson (2006). There has also been a small network of five stations for a limited period. Presently, SMHI operates one station in Norrköping using a Solar Light Model 501. In the northernmost part of Sweden the Abisko Scientific Research Station is also using a similar instrument.

1.4.2 Narrowband filter instruments

The SSM have operated three stations, Stockholm, Tylösand and Visby, using GUV-instruments.

1.4.3 Spectroradiometers
In the past one UV-spectrum was recorded in between the monitoring of total ozone. Both Brewer instruments operated by SMHI were used. These data have been included in EC-funded projects SUVDAMA, EUDUCE and SCOUT-O3, e.g. Bais et al. (2007), Outer den (2006). In recent years data are still collected despite that funding ceased, but there is no calibration done.

1.5 Calibration activities

The Brewer instruments for total ozone are calibrated and serviced regularly by three year interval by IOS (International Ozone Services Inc.). Thus the output will be traceable to the Brewer Triad, which forms the WMO/GAW calibration centre. The Dobson instrument is recalibrated roughly every fifth year by visits to the WMO regional calibration centre at Hohenpeissenberg, Germany. The last calibrations were in 2007 and in 2010, when the instrument was served, calibrated and the electronics was replaced.

The broadband UV-meter used at Norrköping has participated in a number of international comparisons, see e.g. Gröbner et al (2002), Johnsen et al. (2006) and Josefsson (2006). Also the radiometers used by SSM have participated in comparisons or have been compared to the one of SMHI.

Due to lack of funding the absolute calibration (lamp or intercomparisons) of the spectroradiometers have not been done for recent years.
2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Controlled and processed total ozone and broadband UV-data are available from web-sites of SMHI and/or WOUDC. Below is shown a summary of various observations made at Norrköping, Sweden. Interestingly, the Brewer spectrophotometer data can also be used to compute the aerosol optical depth (AOD), Cheymol et al (2006).

Figure 2.1. Long-term, 1983-2010, CIE-weighted UV, total ozone, global radiation and sunshine duration from Norrköping, Sweden. A linear trend is tested on the level of 95% significance for each variable.
Figure 1.1 HCl and ClONO$_2$ from FTIR-measurements over Kiruna, from Kohlrepp et al. (2011).

Figure 1.2 The ozone change in several atmospheric layers over Kiruna has been studied using the FTIR, from Barthlott et al. (2011).
3. THEORY, MODELLING, AND OTHER RESEARCH

3.1 Modelling

In early 2000 the STRÅNG-model system Landelius, Josefsson and Persson (2001) was launched, see http://strang.smhi.se/ as a co-operation between SMHI, the Swedish Environmental Protection Agency and the Swedish Radiation Safety Authority. Now, there is over 10 years of hourly data available for anyone to download, period 1999- up to yesterday. The modelled variables are CIE-weighted UV, global radiation, direct solar radiation, sunshine duration and photosynthetic photon density (PAR). The geographical area covers a large part of northern Europe with a present spatial resolution of 11 km.

Swedish UV-data has also been used for validation of re-constructed past UV-variation based on ERA-40 data, for validation of models based on satellite input and for validation of various UV-models, see e.g. Feister et al. (2008), Kaurola et al (2007), Kaurola et al (2010), Lindfors et al (2007), Lindfors et al (2009) and den Outer et al. (2010).

3.2 Satellite

Results from the Odin satellite instruments have published see e.g section 1.3 and Rösevall et al.(2007, 2007a, 2007b, 2008), Jones et al. (2009).

The observations have been compared with data from CTMs (Chemical Transport Models) see Khosrawi et al. (2008) and Khosrawi et al. (2009).

\[ \text{Figure 1.2. Here two CTMs (CLaMS and Kasima) and one CCM (E5M1) are compared to the Odin/SMR data at two potential temperatures levels (500 and 650 K) for one month, namely March. Additionally the ILAS/ILAS-II data has been included in this comparison. The 500 K level is the one to look at how well ozone loss during Arctic spring is represented by the models. In general, models tend to underestimate ozone loss as can be seen from the deviation of the curves, they all show higher values than the observations from Odin/SMR or ILAS/ILAS-II, from Koshrawi et al (2009).} \]
4. DISSEMINATION OF RESULTS

4.1 Data reporting

Daily total ozone data are submitted once a month to the WOUDC. These data are also available at the www.smhi.se where also daily UV can be downloaded.

4.2 Information to the public

General information on the stratospheric ozone and UV-radiation can be found at www.smhi.se and at www.naturvardsverket.se/

The SSM (the Swedish Radiation Safety Authority) has more public information on their web-site www.ssm.se. This governmental authority also produce brochures and some of them are possible to download from their web site. They also have had activities with the goal to change the behaviour of people mainly directed towards children. One activity was to publish and distribute “A book about the sun” to all kindergartens (8000) in Sweden, http://www.ssi.se/UVindex/PDFer/EnBokOmSolen.pdf another one was to educate the teachers of preschools and primary schools on the basics of and risks of UV. Collaboration with the Swedish Life Saving Society offers sun protection information to many thousands of children every year.

The distribution of daily UV-index forecasts started in 1993 from SMHI. In 1996 the UV-index forecast was introduced on the web (http://www.smhi.se) as a Table for 15 regions in Sweden and three resorts. Next year, 1997, the graphical layout was improved and since then the daily course of the UV-index is presented for a number of climatological similar regions in Sweden. During the first winters there was no forecasting of UV-index done. The season started in late March and stopped at the end of August. Since the year 2000, it is in operation all the year around. There is also some additional text presenting some specific features of interest regarding UV-radiation in general.

5. RECOMMENDATIONS

Concerning future research and activities regarding the ozone layer monitoring is still needed using both ground and space based instruments. Models needs to be improved, especially the CCMs. Predictions about when and to what extent the ozone layer will recover have still uncertainties and the model results deviate from each other by one or two decades.

Another valuable contribution from long-term measurements of ozone and related species from ground or from satellites are their connection to the climate change issue.

Relevant scientific papers


http://www.atmos-chem-phys.net/8/3107/2008/acp-8-3107-2008.pdf


Josefsson W. and M. Ottosson Löfvenius (2008), Total ozone from zenith radiance measurements - An empirical model approach, Meteorologi Nr.130, ISSN 0283-7730 SMHI Meteorology http://www.smhi.se/content/1/c6/03/36/29/attatchments meteorologi_130.pdf


1 OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone

- Total ozone is measured regularly at Arosa since 1926. Presently, the measurements are performed with two partly computer-controlled Dobson spectrophotometers (D101 & D062) and three Brewer instruments B040, B072 (Mark II) and B156 (Mark III).

1.2 Profile measurements of ozone

- Balloon ozone soundings are measured from the Payerne Aerological Station three times per week since 1968. Until August 2002, Brewer-Mast (BM) ozonesondes were used while since September 2002 ECC (ENSCI – 0.5%) sensors are the operational instruments.
- The Umkehr ozone profiles are recorded at sunrise and sunset at Arosa since 1956 in clear sky conditions. Originally the measurements were performed manually but since 1989, the data acquisition of the Dobson Umkehr (D051) is computer-controlled. In 1988, the Brewer (B040) Umkehr series have started and presently the three Brewer are simultaneously measuring the Umkehr profiles.
- Since 1995, ozone profiles (20 – 70 km) are retrieved from ground based microwave radiometry from Bern (GROMOS) and in addition since 2001 also from Payerne (SOMORA). Both instruments deliver thirty minutes averaged profiles continuously. Data products are provided to the NDACC database. The microwave radiometers have been recently updated by replacing the aging (AOS) Acousto-Optical Spectrometers to digital FFT spectrometers. The SOMORA data processing software has also been changed adapting the widely used ARTS/Qpack package.

1.3 UV measurements

- The Swiss Atmospheric Radiation Monitoring programme (CHARM) consisting of 4 stations covering the altitude range of 366 to 3587m was build up between 1995 and 2000. The measurements programme consists of:
  - Broadband measurements: the direct, diffuse and global components of the broad-band erythemal UV-ERY radiation (Solar Light UV-Biometers) are measured,
  - Narrowband filter instruments: spectral direct irradiances are measured with Precision Filter Radiometers (PFR) at 16 wavelengths in the range 305 nm to 1024 nm.
- Besides the direct measurements, the UV index, the AOD at various wavelengths as well as the Integrated Water Vapor (IW) are calculated from those data.
- Spectral Brewer UV measurements: at Arosa, since 1994 spectral global UVB measurements are recorded with the Brewer instruments 072 on the range 290 nm – 325 nm. Since 1998, the Brewer Mark III 156 is in operation and it measures the range 286.5 - 363 nm.

1.4 Calibration activities

- At Arosa, regular calibrations and maintenances are organised for the Brewer (every 2 years) and for the Dobson instruments (every 4 years) traceable to the world standards.
Each ECC ozonesonde is calibrated prior to the flight against a reference UV photometer traceable to the national standard from METAS.

The CHARM instruments are compared to reference instruments traceable to the world standards.

1.5 **Halocarbon measurements at the global GAW station Jungfraujoch (Empa, Dr. S. Reimann, Dr. M.K. Vollmer)**

The high Alpine site of Jungfraujoch (3580 m asl) is one of a few stations covering the entire measurement programme of the GAW concerning greenhouse gases and reactive gases. The measurements of ozone depleting substances and halogenated greenhouse gases, such as HFCs, CFCs, HCFCs, chlorinated solvents, and bromocarbons are performed continuously at Jungfraujoch since the year 2000 in a joint project of Empa and BAFU (HALCLIM). A thorough description of the project (in German) is available at: http://www.empa.ch/plugin/template/empa/*/101463.

The measurements are part of the world-wide AGAGE network (Advanced Global Atmospheric Gases Experiment). Since February 2008 the identical preconcentration unit (“MEDUSA”) as used within the AGAGE network has been installed at Jungfraujoch for the continuous measurements. Empa has a track record of producing first world-wide measurements of newly produced HFCs (see figure 1).

Figure 1: Comprehensive time series of the new hydrofluorocarbons HFCs--365mfc, -245fa, -227ea and -236fa, measured at several global stations within the AGAGE network (incl. Jungfraujoch) (Vollmer et al., 2011). For HFC-245fa and HFC-365mfc the first measurements worldwide have been performed at Jungfraujoch. In-situ measurements (in blue and black) are extended by air archive measurements (in green and brown).
2 RESULTS FROM OBSERVATIONS AND ANALYSIS

2.1 Ozone at MeteoSwiss / Payerne (P. Jeannet, Dr. R. Stübi)
A detailed analysis of the 35 years long series of BM ozone sounding at Payerne has been published in 2007 (Jeannet et al. 2007) and a trend analysis was presented in this paper. The trend analysis was updated recently to emphasise the change of behaviour of the ozone profiles before and after the mid-nineties. In figure 2, the results of this analysis are illustrated for the period prior to 1995 in the left panel and after 1995 in the right panel. The red broken line is the corresponding trend calculated from the Dobson total ozone series measured at Arosa station.

Figure 2: Trend profiles of the Payerne ozone sounding series. Left panel: trends over the periods 1975-1995 on various pressure levels. On the right panel: similar results for the period 1996-2009. The red dashed vertical line corresponds to the trend of the Dobson total ozone series from Arosa.

These figures show clearly a change of the tendency where the well defined stratospheric ozone decrease for the former period is now mostly on the positive side but with larger uncertainties. The tropospheric ozone shows also a change of tendency but the other way around, from an increase in the former period to decrease tendency for the last decade. This trend analysis was done with the standard model including a bi-linear trend term with a change of slope beginning of 1996.

2.2 University of Bern / IAP (Prof N. Kämpfer, Dr. K. Hocke)
Long-term monitoring of the vertical distribution of stratospheric ozone was continued with a 142-GHz microwave radiometer at Bern. Ozone profiles with a time resolution of 2 hours and a vertical resolution of about 10 km were submitted to the Network for the Detection of Atmospheric Composition Change (NDACC). These ozone data were utilized for satellite validation, atmospheric modeling and ozone trend studies by the scientific community. The impact of sudden stratospheric warming on the ozone distribution was analysed.
2.3 ETH Zurich / IAC (Prof J. Staehelin, Dr. J. Mäder, Dr H. Rieder. Dr. C. Schnad)

Mäder et al. (2010) studied the changes in the ozone layer as response to the effect of the Montreal Protocol by a statistical modeling approach: Long-term ground-based measurements were first fitted by proxies explaining most of the variability of the measurements using backward elimination; subsequently the models of the individual sites were optimized for latitudinal bands. In a further step the long-term changes were described in the models either by fitting the individual time series by a term using EESC (development as expected from the Montreal Protocol, red in Fig. 4) or a linear trend term (as expected without the Montreal Protocol, blue in Fig. 4) and it was determined for which stations a better fit was obtained with the EESC curve (Montreal Protocol) or a linear trend. The results show that the majority of the series follow a time evolution better described by EESC than by a linear (downward) trend (see Fig. 5) (it was also checked that measurements of individual stations contain independent information).

Figure 3: Ozone volume mixing ratio as function of time and pressure level above Bern. Observations were obtained by a 142-GHz microwave radiometer (IAP, Bern). Tick marks are on January 1.

Figure 4: Time series of EESC (in red, Equivalent Effective Stratospheric Chlorine, describing the integral effect of chemical ozone depletion by ozone depleting substances on stratospheric ozone for midlatitude) compared with a linear trend (blue). Grey: Measurements of column HCl measured at Jungfraujoch (Switzerland).
Figure 5: Preference of individual long-term ground based total ozone series for a time evolution following EESC (blue) or a linear (downward) trend (red). On the right side: Results of statistics for individual latitudinal bands (from Mäder et al., 2010).

In northern midlatitude the results are most convincing, whereas in southern midlatitude only few long-term measurements are available probably making the result statistically insignificant. For tropical stations the results are not conclusive probably attributable to the fact that the long-term total ozone trends are much smaller in the tropics than in the extra tropics. The results of Antarctica need to be taken with care since at the South pole ozone chemical ozone depletion is presently saturated by ODS. For more details see Mäder et al., 2010.

Rieder at al. (2010 a,b) applied for the first time extreme value statistics to analyze stratospheric ozone measurements. They fitted daily mean values of the total ozone series of Arosa with the Generalized Pareto Distribution allowing classifying the observation into “extreme high ozone values (EHOs)”, “extreme low ozone values (ELOs) and “normal” values. The time series of the frequency of EHOs and ELOs show characteristic features which can be attributed to different processes such as caused be dynamics (e.g. ElNino, or NAO), volcanic eruptions and chemical ozone depletions including strong Arctic ozone depletion. The same approach was also applied to five other European long total ozone series (Rieder et al., 2011) confirming the results of the Arosa series.

Total ozone reached record low values in the Northern midlatitude in the years following the large volcanic eruption of Mt. Pinatubo in 1991 whereas no similar decrease was found in the Southern midlatitude. Schnadt et al. (2011) found that particular dynamics compensating chemical ozone loss were responsible for the lack of low ozone values in the Southern hemisphere. They found that besides of the phase of QBO and aerosol heating several significant wave events from fall 1991 through 1992 most probably led to significantly enhanced Brewer-Dobson circulation and more ozone transport from the tropics to the Southern hemisphere.

Schnadt et al (2009) studied ozone time evolution at the tropopause region based on regular air craft measurements performed in the second part of the 1970s (Global Atmospheric Sampling Program (GASP)) and the second part of the 1990s MOZAIC (Measurement of Ozone and Water Vapor by Airbus in Service Aircraft Program) showing large increases in ozone mixing ratios in spring and summer at the upper troposphere over Turkey, India and China, most probably attributable to increases in ozone precursor emissions. Ozone changes over Europe in the upper troposphere were small, contradicting results obtained by Brewer Mast ozone sondes used in this period at Uccle (Belgium), Payerne (Switzerland) and Hohenpeissenberg (Southern Germany).
3 DISSEMINATION OF RESULTS

3.1 Data reporting

- The ozone data from Arosa, respectively Payerne are regularly deposited at the WODC and at the NDACC data centers. They are also deposited at NILU data center for validation projects and measurements campaigns (Satellites, ECMWF, MATCH).
- The GROMOS and SOMORA radiometers data are deposited at NDSC and NILU (SOMORA only) data centres.
- The radiation data from the CHARM Payerne station are deposited at the WRM-BSRN data center.
- The data of the continuous halogenated greenhouse gas measurements at Jungfraujoch performed by Empa/BAFU are regularly reported to the WDCGG (World Data center for Greenhouse Gases) of WMO.

3.2 Information to the public

The UV forecasts are issued daily during the summer months in many newspapers, on different web sites (public media, national institutions) and at the TV weather presentations. The alerts for high ozone concentration at surface level are also announced when necessary in the same information channels.

3.3 Relevant scientific papers


4 PROJECTS AND COLLABORATION

Besides of the activities in the framework of the national and international monitoring and research programmes, Switzerland contributes to the international WMO/GAW programme through the following services and collaborations:

- Support to the ozone sounding station Nairobi of the Kenyan Meteorological Institute,
- World Optical Depth Research Centre (WORCC) at Physikalisch-Meteorologisches Observatorium / World Radiation Centre (PMOD /WRC) in Davos
- World Calibration Centre (WCC) and Quality Assurance /Science Activity Centre (QA/SAC) for Surface Ozone, carbon monoxide and methane at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Dübendorf.
- Support to the Jungfraujoch site which recently reached to the status of global GAW station

At the national level, there is an important cooperation between the national Weather and Climate office (MeteoSwiss) and the academic and research institutions. This collaboration organised within a national GAW-CH programme allows to support research projects for the development and improvement of the monitoring programme as well as for the data analysis. The continuous measurements of ozone-depleting substances (CFCs, HCFCs, halones) is part of the SOGE – network (System for Observation of Halogenated Greenhouse Gases in Europe), which is an associate programme to the world-wide AGAGE program (Advanced Global Atmospheric Gases Experiment). Combine information on remaining emissions of ozone-depleting chloro-and bromocarbons (CFCs, HCFCs, halones) by merging measurements and meteorological information from different European background sites within the SOGE network in conjunction with AGAGE will be further developed.
Togo has established regulations for each specific problem in environmental issues. Thus, in the process of Ozone Depleting Substances (ODS) eliminating, several actions are carried out with significant results at the location of the various stakeholders. But ozone research needs huge efforts and financial support to achieve objectives of the laboratories in developing countries.

This report reviews current research and future research on releases of chemicals.

In Togo, the research on chemical releases into the environment are conducted by the Laboratory of Atmospheric Chemistry, the laboratory of waste management, the Water Chemistry Laboratory at the University of Lome and the Laboratory of Sanitation Water Science and Environment at the University of Kara. Unfortunately, these laboratories conduct environmental impact studies of ecosystems through physicochemical characterizations of the samples. They lack the necessary scientific equipment to monitor ozone research.

Furthermore, the observation station Kuma Konda National Service of Meteorology provides only the temperature, pressure, rainfall. It is unable to provide data on the evolution of the ozone layer.

The research laboratories are therefore intended to reduce and eliminate or substitute these substances that deplete the ozone layer. The research is mainly based on evaluation of chemical releases into the environment. To this we can include research of Sabi Kokou and Ajavon on the estimation of ODS from 2000 to 2005 in Togo (Sabi, Déchets – revue francophone d’écologie industrielle, 2008, N° 51). In this article the authors evaluated the amounts of CFC11, CFC 12 and HCFC-22 consumed during the period from 2000 to 2005. In the area of waste can also meet the work Koledzi (Koledzi, Déchets – revue francophone d’écologie industrielle, 2011).

Besides research, they conducted training activities for the different actors involved in the issue of ODS. Several actions are also conducted within the framework of the implementation of the Management Plan for Final Disposal of ODS. This work was carried out by the Ministry of Environment with support from UNEP.

This involved strengthening the capacities building of those who involved in the management and use of ODS. At the Ministry for the Environment the magazine called the "environment " had initiated in 2009 an information campaign for users and importers of ODS and ODS equipment repairers. The information is based on the dangers of these substances on the environment. These awareness are commonly organized by the National Ozone Unit (focal point) at the location of refrigeration technicians, main manipulators of CFCs. They are also educated on best practices in the refrigeration sector.
PROJECTS

- monitoring the evolution of the stratospheric ozone layer;
- looking for new hazardous substances;
- rehabilitation of Kouma Konda meteorological station;
- monitoring the process of reduction and ODS elimination;
- alternative research;
- qualitative and quantitative estimation of discharges of pollutants into atmosphere.

NEEDS AND RECOMMENDATIONS

Needs
- slight scientific equipment for the recovery and recycling of ODS involving research laboratories;
- financial support to the location of the laboratories on the basis of projects submitted to conduct research activities;
- rehabilitation of the station Kouma-Konda station to monitor evolution of stratospheric ozone in the sub-region.

Recommendations
- material and financial support of laboratories in developing countries;
- establishment in Africa of a regional center for research on ozone-climate interactions
- initiation of research projects involving sub-regional researchers from several countries;
- encouragement of research structures in developing countries;
- creation of regional networks and international trade data, information and experiences on ODS;
- industrial involvement in the search for solutions to the ODS;
- more awareness among decision-makers to become more involved in finding solutions to environmental problems.

Conclusion

Despite the availability of researchers to become more involved in research on ozone, the lack of funding slows their activities. For similar reasons, the recommendations of 2008 (7th Meeting) were unsuccessful and no further significant. Unfortunately, when the Ozone Secretariat has launched an appeal to submit projects, we submitted the draft of Togo but no action was taken in our project. So we hope that new opportunities will be offered to submit our research projects.

Kara, 14th march 2011
Prof. Gnon Baba
TURKEY

Turkish State Meteorological Service is responsible for observing and promoting research activities on measurements of ozone and UV radiation.

OBSERVATIONAL ACTIVITIES

Two methods are commonly used for ozone measurements in Ankara. One method is to use the Electrochemical Concentration Cell (ECC) ozonsonde. The second method is using Brewer Spectrophotometer.

UV radiometers are used to measure UV radiation at 10 stations in narrow band and at 1 station in broad band with varied instruments.

Column measurements of ozone and other gases/variables relevant to ozone loss

Brewer Spectrophotometer

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankara</td>
<td>Brewer MKIII-188</td>
<td>TSMS</td>
<td>39° 57’ (N)</td>
<td>32° 53’ (E)</td>
<td>Sep.,2006 to present</td>
</tr>
</tbody>
</table>

Brewer spectrophotometer is deployed on a solar azimuth tracker which allows daily automatic measurements of total ozone, zenith sky and direct sun in Ankara station which is the component of WMO-Global Atmosphere Watch Programme.

All data measured by Brewer MK III Spectrophotometer #188 are stored in the database of Research and Data Processing Section of TSMS and are also sent to be recorded at the World Ozone and UV radiation Data Center (WOUDC) in Toronto, Canada.

Profile measurement of ozone and other gases/variables relevant to ozone loss

Ozonesonde

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
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<td>Ankara</td>
<td>Ozonesonde(ECC)</td>
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<td>39° 57’ (N)</td>
<td>32° 53’(E)</td>
<td>Sep.,2006 to present</td>
</tr>
</tbody>
</table>

Research and Data Processing Section of TSMS has been making ozone vertical profile measurements through the atmosphere using balloon borne ozonesondes since 1994 in Ankara station.

Data obtained from ozonsonde are received from Vaisala ground receiving station located in Ankara.

UV measurements

Broad band measurements

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
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<tr>
<td>Ankara</td>
<td>Solar Light 501</td>
<td>TSMS</td>
<td>39° 57’ (N)</td>
<td>32° 53’ (E)</td>
<td>1997 to present</td>
</tr>
<tr>
<td>Antalya</td>
<td>Solar Light 501</td>
<td>TSMS</td>
<td>36° 42’ (N)</td>
<td>30° 44’ (E)</td>
<td>1997–2003</td>
</tr>
</tbody>
</table>

UV-Biometer Model 501 is used for broad band UV radiation measurements.
Narrow band filter instrument

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
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<tr>
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<td>TSMS</td>
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<td>39° 35’ (E)</td>
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<td>TSMS</td>
<td>38° 23’ (N)</td>
<td>34° 03’ (E)</td>
<td>2009 to present</td>
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<td>2009 to present</td>
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<tr>
<td>Göksun</td>
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<td>TSMS</td>
<td>38° 01’ (N)</td>
<td>36° 30’ (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Mardin</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>37° 30’ (N)</td>
<td>40° 73’ (E)</td>
<td>2009 to present</td>
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<td>Oltu</td>
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<td>TSMS</td>
<td>40° 33’ (N)</td>
<td>41° 59’ (E)</td>
<td>2009 to present</td>
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<tr>
<td>Sivas</td>
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<td>TSMS</td>
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<td>37° 02’ (E)</td>
<td>2009 to present</td>
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<td>TSMS</td>
<td>36° 55’ (N)</td>
<td>34° 54’ (E)</td>
<td>2009 to present</td>
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<td>Tokat</td>
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<td>36° 57’ (E)</td>
<td>2009 to present</td>
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<td>Van</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>38° 45’ (N)</td>
<td>43° 32’ (E)</td>
<td>2009 to present</td>
</tr>
</tbody>
</table>

UVR1-B Global Spectral Radiometers are used for narrow band UV radiation measurements.

Spectroradiometers

Spectral UVB measurements (290-325 nm) by Brewer spectrophotometer #188 MK III have started from 09 Sep., 2006 in Ankara station.

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
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<tbody>
<tr>
<td>Ankara</td>
<td>Brewer MKIII–188</td>
<td>TSMS</td>
<td>39° 57’ (N)</td>
<td>32° 53’(E)</td>
<td>Sep., 2006 to present</td>
</tr>
</tbody>
</table>

Calibration activities

Calibration of Brewer spectrophotometer #188 MK III has been performed biennially. First Brewer S. calibration was carried out by International Ozone Services Inc. (IOS) which provides worldwide ozone and UV calibration services to customers with Brewer Ozone Spectrophotometer instruments. IOS used Brewer Ozone Spectrophotometer #017 as a reference instrument on 07–12 October 2008 in Ankara station.
Second Brewer S. calibration was carried out by Kipp&Zonen on 22–29 September 2010. Kipp&Zonen used Brewer Ozone Spectrophotometer #158 as a reference instrument in Ankara station.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Figure 3. Comparison of OMI_TOMS from satellite with the total ozone measurements of Brewer S.#188 between 11 June 2006 and 31 December 2010.

In figure 3, Relationship between total ozone measurements of Brewer #188 and OMI_TOMS observed total ozone data from satellite indicates high correlation. Correlation coefficient is R=0.97 and $R^2=0.9396$. 
DISSEMINATION OF RESULTS

Data reporting

Products of ozone and UVB radiation measurements are stored at the Research and Data Processing Section of TSMS and can be accessible through intranet to users.

All data measured by Brewer MK III Spectrophotometer #188 and ozonosonde are sent regularly to the World Ozone and UV radiation Data Center (WOUDC). They are archived and published with the station number 348 in Toronto, Canada.

Information to the public

A TUBITAK project, under contract no.105G032 titled “Observing the Variability in the Tropospheric and Stratospheric Ozone and UVB measurements and Analyzing the Results”, was conducted at TSMS under the collaboration with some scientist from Istanbul Technical University and completed in 2008. As a result, a statistical model was developed to forecast daily total ozone and UV index.

The model runs for 125 stations in Turkey and 5 stations in the Turkish Republic of Northern Cyprus and the model results are published through internet web site. http://www.dmi.gov.tr/kurumici/tahmin-ozon-dmi.aspx

Figure 4. The TSMS Model outputs for daily forecasted total ozone and UV index in Turkey.
A joint effort between the TSMS and Deutscher Wetterdienst (DWD) lead to publishing information on daily forecasted total ozone and maximum UV index to the public at the TSMS web page: http://www.dmi.gov.tr/kurumici/tahmin-ozon-dwd.aspx

![Image of DWD model products showing information on daily forecasted total ozone and maximum UV index to the public at the TSMS web page for Turkey.](image)

**Figure 5.** DWD model products showing information on daily forecasted total ozone and maximum UV index to the public at the TSMS web page for Turkey.

**Relevant scientific papers**


**PROJECTS AND COLLABORATIONS**

The ground-based Brewer data #188 and model predicted output data on total ozone and UV index have been compared systematically with satellite observations.
FUTURE PLANS

- to establish a Brewer Spectrophotometer Network to cover and to represent whole Turkey for measuring total ozone and UV index by purchasing more Brewer Spectrophotometer.
- to examine tropospheric ozone profile.
- to examine stratospheric ozone profile.
- to study on interactions between stratospheric ozone and climate change.
- to examine variation in ozone and UV index in time.
- to evaluate interaction between ozone change and climate change.
- to contribute to ozone assessments by sharing information.
- to seek for research at the European level implemented through the Framework Programmes for research and technological development (FPs) of European Commission.
- to participate seminars, conferences and meetings related with global ozone research and international monitoring programme.

NEEDS AND RECOMMENDATIONS

Providing a continued maintenance and calibration of instruments such as Brewer S. and UV sensor with the support of WMO is important.
In Turkmenistan the atmospheric ozone monitoring is carried out by the National Hydrometeorology Committee at the Cabinet of Ministers of Turkmenistan (“Turkmenhydomet”). At present the regular daily monitoring for the total atmospheric ozone content is carried out at 4 stations:

<table>
<thead>
<tr>
<th>#</th>
<th>Stations</th>
<th>Coordinates</th>
<th>Area Height. m</th>
<th>Devices Used</th>
<th>Type</th>
<th>#</th>
<th>Year</th>
<th>Calibration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mary</td>
<td>37.36° N , 53.00° E</td>
<td>221.7</td>
<td>M-124</td>
<td>386</td>
<td>1988</td>
<td>VII-VIII. 1995</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bekreve</td>
<td>37.57° N, 58.21° E</td>
<td>311.6</td>
<td>M-124</td>
<td>290</td>
<td>1987</td>
<td>VIII-IX. 2000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Repetek</td>
<td>38.34° N, 63.11° E</td>
<td>185.0</td>
<td>M-124</td>
<td>269</td>
<td>1983</td>
<td>III-IV. 2001</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Turkmenbashi</td>
<td>40.03° N, 53.00° E</td>
<td>82.5</td>
<td>M-124</td>
<td>287</td>
<td>1987</td>
<td>IX-X. 2002</td>
<td></td>
</tr>
</tbody>
</table>

The first monitoring for atmospheric ozone commenced in 1953 on the basis of the Chardzhou aerologic station (Turkmenabat now). In 1975 the ozone station was transferred to a meteorological site of the Repetek station and the ozone monitoring has been carried out at this station so far.

In 1961 the ozone measurements commenced on a meteorological site of the Keshi station. In 1998 this meteorological station was transferred to Berzengi village and later in Bekreve village in 2001. The ozone measurements have been carried out at this station so far.

In 1994 in Turkmenbashi (Krasnovodsk) the measurements of the total atmospheric ozone content commenced. Within 2000-2002 due to delivery of M-124 ozonometer for calibration the monitoring was not carried out. After calibration of this device the monitoring has commenced since October 2002 and it continues at present.

In 2001 the monitoring of the total atmospheric ozone content was arranged in the Murgab meteorological post. This ozone station was transferred to a meteorological site of the Mary station in 2005 where the ozone monitoring has been carried out so far.

Measurements of the atmospheric ozone content are carried out by means of M-124 ozonometers produced in Russia. The ozonometers used have become physically outdated. Lack of spare and reserve ozonometers for replacement of operating devices during their calibrations (a case in Turkmenbashi) results in a monitoring failure for a long term.
Over the last years due to the absence of possibilities for calibrations and routine maintenance of the devices used a technical state of ozonometers has considerably worsened. Overheat of device’s bodies, essential deviation of the measured values from former data and others are observed. After 2002 the ozonometers have not been calibrated. The situation developed in aggregate impacts negatively on quality of the data obtained. In support it is possible to demonstrate the Monitoring Result Review for OCO over the CIS countries for 2008 carried out by the Central Aerologic Observatory under the guidance of the Main Geophysical Observatory where poor quality of ozone monitoring data at some stations is highlighted including Repetek, Turkmenbashi and Bekreve.

Daily data on the total atmospheric ozone content (Chardzhou), Turkmenbashi (Krasnovodsk) and Bekreve (Ashkhabad) are preliminary processed and sent by telegramme at the address: AVIA Moscow 736 OZONE. Monthly Tables O-3 are sent to the Main Geophysical Observatory named after Voyeykov not later than on the 3rd day of the following month. Then, all information is delivered to the data exchange coordinated international network of the World Meteorological Organization (WMO).

All primary data are stored in “Turkmengidromet” archive in a paper form.

**Director of “Klimat” STC**

G. Muhyyev
UNITED KINGDOM

1. OBSERVATIONAL ACTIVITIES

1.1. Column measurements of ozone and other gases/variables relevant to ozone loss

The UK Government Department for Environment, Food and Rural Affairs (Defra) funds an on-going monitoring programme that records total values of stratospheric ozone at two UK locations. Measurements with a Dobson instrument are taken at the Lerwick Observatory in the Shetland Islands (N of Scotland) and a Brewer spectrophotometer is used at the Reading site in Berkshire (S England). The latter site replaced the Camborne Observatory site in Cornwall at the end of 2003, where a Dobson instrument had been used for ozone measurements. The spectrophotometers sample the ozone column at frequent intervals throughout the day to produce daily mean values, except for when weather conditions prevent values from being recorded and during the winter at Lerwick when the sun is too low in the sky.

Column ozone measurements are also made at the University of Manchester (N England) using a Brewer instrument. These are also made available to the above monitoring programme (but are separately funded) and similarly submitted to the WOUDC. Measurements using a SAOZ instrument are made in Aberystwyth, and are submitted to the NDACC network.

The British Antarctic Survey continues total column ozone measurements at Halley with a Dobson spectrophotometer, and supports those made at Vernadsky (Ukraine). BAS also continues total ozone and NO\textsubscript{2} column measurements at Rothera with a SAOZ spectrometer. A radiosonde programme continues at both Halley and Rothera, supported by the UK Met Office.

The UK Met Office has lent Dobson #35 to the South African Weather Service. It is not yet in active use, but has been intercompared.

1.2. Profile measurements of ozone and other gases/variables relevant to ozone loss

High frequency, real time *in situ* measurements of the principal halocarbons and radiatively active trace gases have been made at Mace Head on the West coast of Ireland since 1987, as part of the Global Atmospheric Gases Experiment (GAGE) there. For about 70% of the time the measurement station, which is situated on the Atlantic coast, monitors clean westerly air that has travelled across the North Atlantic Ocean. For about 30% of the time, Mace Head receives substantial regional scale pollution in air that has travelled from the industrial regions of Europe. The site is therefore ideally situated to record trace gas concentrations associated with both the Northern Hemisphere background levels and with the more polluted air arising from Europe.

Using the Mace Head data with a Lagrangian dispersion model that determines the origin of the air arriving at Mace Head at the time of each observation, estimates of the Northern
hemisphere baseline concentrations are made for each trace gas. By removing the underlying baseline trends from the observations and by modelling where the air originated from on a regional scale, an iterative best-fit technique then searches a set of random emission maps to determine the one that most accurately mimics the Mace Head observations.

The UK Department for Energy and Climate Change is intending to expand the Atmospheric Observation Network to include three additional sites in the UK, to be located at Edinburgh, Tacolneston, and Ridge Hill. These sites will result in significant increases in spatial and temporal resolution for the interpretation work, enabling UK Devolved Administration emission estimates from atmospheric observations as well as decreasing the uncertainties associated with all the analytical outputs of this project.

Analysis of the atmospheric observation data also identifies sources of and trends in ozone formation from different areas, including comparison of observed data with expected trends, to identify any new substances with ozone depleting or radiative forcing properties. The possible use and analysis of any data coming from other sites that could be of policy relevance is currently under consideration.

1.3. UV measurements

1.3.1. Broadband measurements

The solar UV index is measured at six sites at approximately 2 degrees of latitude increments (from 50 to 60° N) across the UK by the Centre for Radiation, Chemical and Environmental Hazards of the Health Protection Agency (HPA). A seventh site on Mount Snowdon in Wales has been temporarily removed while the site is developed. In addition, spectral UV measurements are carried out at the HPA site at Chilton. A portable spectral measurement system is currently under development for temporary deployment during extreme weather or atmospheric events or at locations where large numbers of people gather outside. The Department of Health provides support for this UV monitoring work, which provides information for the Global Solar UV Index in association with WHO, WMO, UNEP and the International Commission on Non-Ionizing Radiation Protection.

1.3.2. Narrowband filter instruments

No instruments of this type are currently being used in the UK.

1.3.3. Spectroradiometers

A spectroradiometer is co-located with the Brewer spectrophotometer in Reading, funded as part of the Defra monitoring programme. The Bentham DM150 UV spectroradiometer has been in place since 1993, and is regularly calibrated in situ. The instrument takes spectra from 290nm to 500nm at 0.5nm resolution at half-hour periods during daylight hours, every day of the year.

A spectroradiometer is also co-located with the Brewer spectrophotometer at the University of Manchester, which provides five minute averages in each of the five narrow wavebands (305, 313, 320, 340, 380nm). Apart from calibration periods, the Manchester instrument has
been in continuous operation since 1997, and provides a southern site in the Nordic network of GUV radiometers. Data are submitted to WOUDC alongside the ozone data series.

The British Antarctic Survey makes spectral measurements of UV using a Bentham spectro-radiometer at Rothera.

### 1.4. Calibration activities

Regular calibrations have been carried out on both Met Office Dobson instruments and the Reading Brewer spectrophotometer. The current recommendation is to re-calibrate every two years.

Dobson #32 and the Brewer #075 were taken to Spain in September 2007 for international inter-comparison at El Arenosillo. The Brewer results were good, but the Dobson calibration identified a problem with the CD measurements, which required re-evaluation of historical data. This was carried out and it was demonstrated that the new calibration provided a much more accurate dataset.

Dobson #41 was taken to Hohenpeissenberg for international inter-comparison in June 2009 and was found to be performing well. A further calibration is scheduled for September 2011.

Brewer instrument #075 was taken to El Arenosillo during September 2009. The change in instrument response for measuring ozone over the two year period was found to be 0.3%, well within the acceptable limits. Following technical problems and subsequent repairs, Brewer #075 was calibrated at the RBCC-E home site at Izana, Tenerife, where a new calibration was determined and verified against the European triad of Brewer instruments. During the intervening period, the instrument was temporarily replaced with Brewer #126 courtesy of the UK Met Office in order to maintain the time series.

### 2. RESULTS FROM OBSERVATIONS AND ANALYSIS

The long-term annual mean trend in ozone for the Lerwick site, and a combined southern England trend from the Camborne (up to 2003) and Reading (2003 onwards) are given below.

A recent trends analysis paper in the International Journal of Climatology (Smedley et al., 2011), analysed the trend data from these sites. This paper demonstrated that the year at which total ozone stopped decreasing over the UK was 1993, by which time statistically significant reductions of 4.8% per decade for Southern England and 5.8% per decade for Lerwick were observed. These rates of decrease are at the upper end of the range in comparison with other European ozone trends before the mid-1990s.

From 1993 to the present the data did not show any significant trend, although small average increases were noted. That there is no trend over this time period is in contrast with Europe as a whole, where a significant increase has been noted.
The data from the monitoring programme have also been analysed seasonally. Table 1 shows that a significant decline at Lerwick since 1978 is seen in the annual mean, Spring and Autumn for both single and multiple regression analysis. There are no significant changes at Reading since 2003. Multiple regression has a large impact on seasonal trends at Reading because of the shorter record.

<table>
<thead>
<tr>
<th></th>
<th>Annual</th>
<th>Winter (DJF)</th>
<th>Spring (MAM)</th>
<th>Summer (JJA)</th>
<th>Autumn (SON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lerwick -SR</td>
<td>-0.62 +/- 0.20</td>
<td>-0.12 +/- 0.58</td>
<td>-0.85 +/- 0.30</td>
<td>-0.24 +/- 0.17</td>
<td>-0.61 +/- 0.21</td>
</tr>
<tr>
<td>Lerwick -MR</td>
<td>-0.50 +/- 0.21</td>
<td>-0.08 +/- 0.60</td>
<td>-0.69 +/- 0.26</td>
<td>-0.22 +/- 0.14</td>
<td>-0.40 +/- 0.18</td>
</tr>
<tr>
<td>Reading -SR</td>
<td>+2.97 +/- 1.19</td>
<td>+2.86 +/- 2.69</td>
<td>+2.18 +/- 1.70</td>
<td>+1.76 +/- 0.74</td>
<td>+2.19 +/- 1.70</td>
</tr>
<tr>
<td>Reading -MR</td>
<td>+2.02 +/- 1.65</td>
<td>+0.07 +/- 1.79</td>
<td>+2.10 +/- 1.87</td>
<td>+1.66 +/- 0.89</td>
<td>+0.49 +/- 1.15</td>
</tr>
</tbody>
</table>

Table 1 Column ozone trend in DU per year with standard errors. Numbers in bold are significant at the 95% confidence level (P<0.05) SR: single regression; MR: multiple regression. Lerwick since 1978 and Reading since 2003 both to December 2010.
Low ozone events observed by the Defra monitoring programme are reported in near real-time. Two events were reported in 2008, two in 2009 and none in 2010. The frequency of these events has been found to exhibit little historical pattern, but there are two features to note. Firstly, an anomalous decade at Lerwick (1977-1987) when there were very few low ozone events reported. Secondly, high ozone events of the southern UK may be increasing – perhaps in line with a northwards displacement of the Atlantic storm track suggested by climate change predictions.

The UV monitoring results from the Defra programme were also assessed in the Smedley et al. paper, which found no significant trend between 1993 and 2008 in the daily totals of UV, but an increase of 6% per decade was seen in the mid-day values of the UV index. This, combined with a lack of correlation between ozone and UV anomalies suggests that changes in cloud cover were the cause.

It should be noted that despite the long-term data produced by the UK total ozone and spectral UV records, in order to clearly observe significant trends since the mid-1990s several more years of high quality data are necessary.

3. THEORY, MODELLING AND OTHER RESEARCH

No activities to report.

4. DISSEMINATION OF RESULTS

4.1. Data reporting

The ozone monitoring data from Lerwick and Reading are processed daily by local operators prior to being quality checked and disseminated. A number of checks are performed to ensure the integrity of these data, including comparison of daily results with OMI satellite measurements and the nearest ground-based measurements.

Results are disseminated by uploading to a dedicated website (http://ozone-uv.defra.gov.uk/) and issuing results to the WOUDC Real-time Mapping Centre. Monthly data are submitted to the WOUDC for inclusion on their archive.

Both total ozone and spectral UV data from the Manchester site are submitted regularly to the WOUDC.

Level 0 and Level 1 ozone data from Halley and Rothera were submitted to the WOUDC by the British Antarctic Survey. Near real-time ozone observations are submitted by BAS to the WMO on a weekly basis. Near real-time reporting using CREX code on the GTS will commence in the near future.

4.2. Information to the public

Ozone monitoring results from the Lerwick, Reading and Camborne sites are publically available on the website (http://ozone-uv.defra.gov.uk/), along with relevant reports.

Broadband UV Index graphs produced by the UK Health Protection Agency are also available on their website at:

http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/UltravioletRadiation/uv_Index/
5. PROJECTS AND COLLABORATION

The UK Met Office

The UK Met Office has applied its ozone data assimilation scheme to infer chemical polar ozone loss and to examine phenomena such as low ozone events in the southern summer stratosphere. Studies on the impact of the representation of stratospheric ozone on extended range tropospheric forecasts are also being carried out. The above work is being carried out in collaboration with Imperial College London and European partners. In addition, a Met Office representative co-leads the WCRP SPARC Data Assimilation Working Group.

The UK Met Office Hadley Centre (MOHC) is working on the modelling of stratospheric and tropospheric ozone and their relationship to climate change, as part of its joint DECC/Defra funded MOHC Programme. The MOHC is represented on the coordinating/planning committees of two of the WCRP’s SPARC modelling initiatives: CCMVal-2 (Chemistry-Climate Model Validation-2) and DynVar (Modelling the Dynamics and Variability of the Stratosphere-Troposphere System).

The MOHC has further developed its whole atmosphere chemistry model UKCA (United Kingdom Chemistry and Aerosols), in collaboration with Cambridge, Leeds and Oxford universities. These developments are making the UKCA model more self-consistent so that, for example, changes to aerosol concentrations change the chemistry through the photolysis rates. The improvements will also ensure that responses to climate change are well modelled.

Further developments of a full Earth-System Model, in which the UKCA is combined with the MOHC’s climate and ecosystem models, have been made. This is enabling the prediction of feedbacks involving tropospheric and stratospheric ozone between climate, chemistry and ecosystems. This links in strongly with the NERC QUEST programme, its earth-system modelling (QUESM), the atmospheric chemistry component (QUAAC) and the land surface component (JULES).

The Natural Environment research Council

The UK Natural Environment Research Council (NERC) funds a number of research programmes relating to stratospheric ozone. The CLEARFOGG (Checking Layers of the Earth’s Atmosphere For halogenated Ozone-depleting and Greenhouse Gases) project, due to complete in 2011, is performing a systematic screening of various layers in the Earth’s atmosphere for unknown halocarbons, and will determine the influence of these halocarbons on stratospheric ozone depletion.

The Southern hemisphere climate change in an era of ozone recovery project, due to complete in 2011, will use state of the art climate modelling to derive a range of predictions of future climate change which take account of our uncertainty in future ozone change, particularly focussing on the southern hemisphere and the Antarctic ozone hole.

The SOLCLI consortium are running a 4-year coordinated study which began in 2007, on the influences of solar variability on atmospheric composition and climate. The consortium is led by Imperial College, with partners at the Universities of Cambridge, Leeds and Reading and the British Antarctic Survey and with collaborators in Germany, Japan, the USA and the UK.
Met Office. Study topics include: variability over the past 150 years in solar spectral irradiance; detection of solar signals throughout the lower and middle atmosphere; response of stratospheric composition, specifically ozone, to varying UV; mechanisms for stratosphere-troposphere dynamical coupling; and better representation of solar effects in climate models.

Further NERC-funded research projects relating to stratospheric ozone include: the impact of the representation of ozone on tropospheric weather forecasts; multi-scale modelling of mesospheric metals, and the impact of the mesosphere on stratospheric ozone and climate; interactions of the lower stratosphere with the tropospheric chemistry/climate system (including recovery scenarios for stratospheric ozone); producing a century-long record of trace gases in the northern hemisphere from the NEEM ice core drilling project in Greenland.

The University of Manchester

The University of Manchester is represented on the WMO Brewer sub-committee, and has been active in discussions on the effective changeover of ozone absorption coefficients and the need for a reliable historical dataset on ozone profiles, required for trend analysis in the presence of climate and circulation changes.

The British Antarctic Survey

An opinion piece by Jonathan Shanklin was published in Nature, and a celebratory meeting held in Cambridge in 2010, to mark the 25th anniversary of the discovery of the ozone hole. Work is in progress on re-evaluating BAS ozone data collected since 1972.

6. FUTURE PLANS

Defra does not have any plans at present to provide direct government funding for any additional ozone, UV or ODS monitoring sites in the UK. The current basic levels of monitoring will, however, be continued.

Defra is keeping future research needs for policy development on stratospheric ozone under review.

NERC is continuing to provide some funding support for new research projects on ozone.

7. NEEDS AND RECOMMENDATIONS

International agreement needs to be reached on the form of zenith polynomial for use in Dobson zenith sky measurements.

Maintenance of long time-series remains essential, especially for trend analysis and ground-truthing of satellite data.

Further work to model emissions of trace gases and ODS will be beneficial for assessing emissions inventories.
UNITED STATES OF AMERICA

OBSERVATIONAL ACTIVITIES

Column Measurements

Ozone
US Satellites
Long-term dataset of total column ozone continues to be produced from the SBUV/2 instruments on the NOAA polar orbiting environmental satellites (NOAA-16, 17, 18 & 19). The SBUV record extends back to April, 1970 with a data gap between 1974 and 1978. The TOMS total ozone series started in October 1978 and ended in December 2006. All TOMS data have been reprocessed by applying an empirical correction based on the SBUV/2 record. Hence the SBUV total ozone record is considered the primary record for trend analysis. (NASA, NOAA)

Total ozone data from the Ozone Monitoring Instrument (OMI) on the EOS Aura satellite is available beginning October, 2004. Two independent algorithms are used to produce OMI total ozone data, one developed by NASA the other by KNMI, NL. NASA now has reprocessed SBUV, TOMS and OMI data using a common (version 9) algorithm. (NASA)

Ozone Estimates from Infrared Sensors
NOAA produces estimates of total ozone by using information in the 9.7 micron channel of HIRS. The retrieval products are combined with SBUV/2 information to generate global maps of column ozone. See http://www.osd.p.noaa.gov/PSB/OZONE/TOAST/. (NOAA)

Total ozone products from thermal emission spectrometers also exist from both the TES instrument on the EOS Aura satellite and the AIRS instrument on the EOS Aqua satellite. These data are available on the NASA GSFC DAAC at http://disc.gsfc.nasa.gov/. (NASA)

Dobson Network
Dobson total column ozone measurements in the U.S. are done through the NOAA Cooperative Network at 16 locations, including 10 national sites in the continental U.S. and Hawaii. Five other sites are collaborative international programmes (South Pole, Perth, Lauder, Samoa, OHP). Data are used for satellite validation and determining ozone trends for the WMO/UNEP Ozone Assessments. NASA also supports Dobson measurements within the U.S. under the auspices of the Network for the Detection of Atmospheric Composition Change (NDACC). (NOAA, NASA)

UVB Monitoring and Research Programme (UVMRP)
Direct-sun column ozone is retrieved by UV Multi-Filter Rotating Shadowband
Radiometers (UV-MFRSRs) at 34 U.S. sites, 2 Canadian sites, and 1 New Zealand site within the U. S. Department of Agriculture (USDA) UV-B Monitoring and Research Programme (UVMRP).

**NOAA-EPA Ultraviolet Brewer (NEUBrew) Network**

NOAA and the EPA have established a network of Brewer Mark IV UV spectrometers that were deployed at six U.S. locations. The six stations have been operating continuously since the fall of 2006 with funding from the EPA and NOAA. The network Brewers [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/) take a daily average of 25 total column ozone measurements. (NOAA, EPA)

The total ozone column and Umkehr profile daily data from the NOAA-EPA Brewer and NOAA Dobson network, as well as ozone-sounding profiles will be used in the validation activities of the total column ozone data collected by the soon-to-be-launched satellite under the NOAA’s National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) and the following Joint Polar Satellite System JPSS program. The NPP launch is scheduled for October 25, 2011. The Ozone Mapping and Profiler Suite (OMPS) on board NPP will monitor the global distribution of ozone on the daily basis. Much of the work in preparation for the validation activities include algorithm development, data quality control, instrument automation, calibration, trending analysis and maintenance, data archiving, and web page and satellite validation updates. (NOAA)

**Ozone-Relevant Gases and Variables**

**Ozone Monitoring Instrument (OMI) on the Aura Satellite**

In addition to its primary focus on column ozone, OMI measures tropospheric columns of aerosols, nitrogen dioxide, and sulphur dioxide. (NASA)

**GOME-2 Instrument on MetOp-A**

NOAA is working to implement additional operational products from the GOME-2 Level 1 data. These include aerosols, nitrogen dioxide, and sulphur dioxide. (EuMetSat/NOAA)

**Network for the Detection of Atmospheric Composition Change (NDACC)**

This international ground-based remote-sensing network was formed to provide a consistent, standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites. While the NDACC maintains its original commitment to monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer its priorities have broadened considerably to encompass the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere, establishing links between climate change and atmospheric composition, calibrating and validating space-based measurements of the atmosphere, supporting process-focused scientific field campaigns, and testing and improving theoretical models of the atmosphere. NDACC instruments that are particularly suited for column measurements include UV/Visible spectrometers for ozone, NO2, BrO, and OCIO; FTIR spectrometers for a wide variety of source and reservoir compounds; and Dobson and Brewer
spectrometers for ozone. Additional information on the NDACC is available at http://www.ndacc.org. (NASA, NOAA)

Profile Measurements

Ozone

BUV Instrument Series (10 Instruments)
The SBUV/2 instruments on NOAA satellites continue to measure ozone vertical profiles in the upper stratosphere (1-30 hPa) with vertical resolution varying from 6 to 8 km. (This technique also provides accurate estimates of the partial column ozone between 30-700 hPa.) This data record extends back to April 1970, with a data gap between 1974 and 1978. Profile datasets are also being produced from the OMI instrument. OMI provides full daily coverage compared to SBUV which provides daily coverage in approximately two weeks. OMI profiles have similar information content as SBUV in the upper stratosphere (1-30hPa) but have higher vertical resolution (~10 km) at lower altitudes. The long-term ozone profile record from the SBUV/2 instrument series has been significantly affected by drifting orbits. Analysis of these effects is currently in progress. NASA has reprocessed data from the entire BUV instrument series, including OMI, using a consistent algorithm (version 9). Current and archived Version 8 ozone profile data are being used in the NOAA/NCEP Climate Forecast System Reanalysis and Reforecast, a successor of the NCEP/DOE Reanalysis 2. (NOAA, NASA)

Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)
The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of ozone in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to 2005. This series will be resumed in 3-4 years from the existing SAGE-III instrument when it is deployed on the International Space Station. (NASA)

Aura Satellite Instruments
Ozone profiles from 0.5- 200 hPa with about 3 km vertical resolution have been produced by the Microwave Limb Sounder (MLS). The high resolution dynamic limb sounder (HIRDLS), which suffers from a partial obscuration of the field of view that occurred during launch, has recently reprocessed the ozone profile data. These data have 1 km or higher vertical resolution in the stratosphere. This data series ended in 2008. Two other instruments on Aura Tropospheric Emission Spectrometer (TES) and OMI produce lower vertical resolution ozone profiles but they measure lower into the troposphere than either HIRDLS or MLS. A new activity to combine the radiances from TES and OMI to obtain better profile information in the troposphere is ongoing. (NASA)

Balloonborne Measurements
NOAA routinely conducts ozonesonde measurements at nine locations (5 domestic, 4 international). NASA, in collaboration with NOAA and numerous international partners, supports the operations of the Southern Hemisphere Additional Ozonesonde (SHADOZ) network of ozonesonde launches from several locations in the tropics and southern
subtropics. NASA also flies ozonesondes and an ozone photometer as components of moderate-scale balloon campaigns that also utilize a submillimeter/millimeter-wave radiometer, an infrared spectrometer, and a far-infrared spectrometer. (NOAA, NASA)

Dobson Umkehr
Profiles are obtained from six automated Dobson instruments using the Umkehr technique (Lauder, Perth, Hawaii, Boulder, OHP, Fairbanks). Through collaboration between NASA and NOAA, a new ozone-profile algorithm has been developed to process Dobson Umkehr data. This algorithm is similar to the SBUV V8 algorithm, and has been optimized for deriving trends. (NOAA, NASA)

Brewer Umkehr
Brewer Mark IV UV spectrometers were deployed at six U.S. locations in the last half of 2006 with funding from the EPA and NOAA. Total column ozone and ozone profiles using the Umkehr technique are regularly derived from these measurements. All raw and processed data are posted on the open access NOAA/NEUBrew web-site: [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/). Dobson Umkehr ozone profile retrieval algorithm has been modified to process Brewer Umkehr data on a selective basis. It is implemented at all NOAA operated sites. It is also made available for the Brewer Umkehr data processing world-wide and has been implemented at several stations (Check republic). However, due to lack of availability of the Brewer raw radiance data at the WOUDC archive, it has not been possible to reprocess all currently operational Brewer Umkehr data using a consistent algorithm. The WMO SAG-O3 and the WOUDC has made an effort to reach out to operators of the Brewer instruments and offered to archive raw data (NOAA)

Network for the Detection of Atmospheric Composition Change (NDACC)
NDACC lidars (whose retrievals are limited primarily to the stratosphere) and microwave radiometers (whose retrievals are limited primarily to the stratosphere) are providing long-term ozone profile measurements. Ozonesondes routinely launched at many NDACC stations also provide ozone-profile data. In addition, several of the high-resolution FTIR spectrometers are beginning to yield ozone-profile information. (NASA, NOAA)

Brewer Umkehr
NOAA-EPA Brewer Spectrophotometer UV and Ozone Network
The NOAA/EPA Brewer Spectrophotometer Network (NEUBrew) consists of six stations located in the western, central and eastern United States. Brewer MKIV instruments provide twice daily ozone vertical profiles based on Umkehr scans. Data is available online with a latency of one day. [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/) (EPA, NOAA)

Ozone-Relevant Gases and Variables
Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)
The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of aerosols in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to 2005. Water vapor profiles are also available. This series will be resumed in 3-4 years from the existing SAGE-III instrument when it is deployed on the International Space Station. (NASA)

Aura Satellite Instruments
The four Aura instruments provide profile measurements of numerous atmospheric constituents and parameters in the stratosphere and troposphere. MLS is delivering profiles of temperature, H2O, ClO, BrO, HCl, OH, HO2, HNO3, HCN, N2O, and CO. HIRDLS retrieved profiles of temperature, O3, HNO3, aerosols, CFC11, and CFC12 at 1.2 km vertical resolution and will soon deliver profiles of H2O, CH4, N2O, and NO2. TES is providing limited profile information for O3, CO, H2O, and HDO from its nadir viewing owing to it’s high spectral resolution. (NASA)

Combined NASA Satellite Data
Past global space-based measurements of atmospheric composition (e.g., from SAGE, SBUV, UARS, and TOMS) are being extended via observations available from the Aura satellite and other A-Train satellites. These new measurements are providing an unprecedented global characterization of atmospheric composition and climate parameters. Efforts are underway to produce merged data sets connecting these recent measurements to past satellite observations of the atmosphere. (NASA)

Balloonborne Water Vapor Measurements
NOAA monitors upper tropospheric and stratospheric water vapor using cryogenic, chilled-mirror hygrometers that are flown with ozonesondes on a biweekly schedule in Boulder, CO, and at Lauder, New Zealand, in collaboration with NIWA, and monthly at Hilo, Hawaii starting in 2010. Water-vapor profiles also are obtained on a campaign basis in Indonesia and the Galapagos. NASA supports the flights of several balloon instruments (primarily on a campaign basis) capable of providing profile information for numerous atmospheric constituents. (NOAA, NASA)

Airborne Measurements
NASA-sponsored airborne campaigns, using both medium- and high-altitude aircraft, have been conducted with NOAA, NSF, and university partnerships, with a focus on satellite validation and scientific study of ozone and climate change. While designed more for process study than for trend determinations, the airborne measurements have provided a unique view of changes in atmospheric composition at various altitudes in response to source forcings. The most recent campaigns are the GLOPAC mission using the new NASA Global Hawk and the MACPEX campaign using the NASA WB57 have concentrated on the processes that control the concentrations source gases in the upper troposphere and stratosphere with a goal of understanding the effects on stratospheric ozone. The international POLARCAT campaign with components from NASA, NOAA, DOE, and NSF was executed looking at atmospheric processes in the Arctic troposphere. (NASA, NOAA, NSF)
Researchers have completed three deployments of the HIAPER Pole-to-Pole Observations of Greenhouse Gases (HIPPO) mission, with two further deployments scheduled for 2011. HIAPER – the High-performance Instrumented Airborne Platform – is the National Science Foundation’s Gulfstream V research aircraft. The HIPPO program is providing unprecedented seasonal pole-to-pole snapshots of greenhouse gases and ozone-depleting gases in the troposphere, data that will permit climate modelers to verify models and improve models projections of future climate change and the future ozone layer. The program will provide the first comprehensive, global survey of atmospheric trace gases, covering the full troposphere in all seasons and multiple years. (NSF; NOAA)

Among the objectives of the Mid-latitude Airborne Cirrus Properties Experiment (MACPEX) airborne field campaign is an extensive intercomparison of instruments for measuring atmospheric water vapor, as well as understanding the properties of cirrus clouds at mid latitudes. The MACPEX campaign took place in March and April 2011 and is focused on central North America. (NASA and NOAA)

New Aircraft Technologies: Unmanned Aircraft Systems (UAS)
NASA Dryden has obtained new resources in Unmanned Aircraft Systems including General Atomics Aeronautical Systems (GAAS) Altair (leased), Predator-B (IKHANA), and three Northrop Grumman Global Hawks. The first civilian scientific use of the Global Hawk UAS was the Global Hawk Pacific Experiment (GloPac) and was completed in May 2010. There were instruments on board that measured ozone and ozone depleting. GloPac completed a series of UAS flights over the Pacific bearing a variety of instruments to measure ozone, aerosols, and other substances. Three successful science flights showed the impressive range (9700nm), hazardous duty over the Arctic, altitude (65,200 ft) and duration (28.6 hours) capability of the UAS, including one flight from Dryden to the North Pole and back. (NASA, NOAA)

Network for the Detection of Atmospheric Composition Change (NDACC)
Several of the NDACC remote sensing instruments provide profile data for a variety of ozone- and climate-relevant gases and variables. These observations continue the long term trends for ozone, water vapor, CFCs, HCl, HF, CH₄, and N₂O. (NASA, NOAA, DoD/NRL)

Special campaigns to validate satellites
NASA recently (March/April 2011) sponsored a ground-based campaign with a number of DOAS instruments from Fairbanks Alaska. The goal was to compare direct and all sky angle DOAS observations with the OMI instrument to understand the high values of BrO retrieved by OMI, in conjunction with Ozone observations. (NASA)

Ground-Based In Situ Measurement Networks
Both NASA and NOAA support in situ sampling of ozone- and climate-related trace gases via networks of flask sampling and real time in situ measurements. These data provide the basis for determining global tropospheric trends and for computation of effective equivalent chlorine (EECl) in the atmosphere. The NASA Advanced Global
Atmospheric Gases Experiment (AGAGE) network has the longest continuous observational record for such species, extending back almost three decades for some CFCs. New NASA and NOAA instrumentation permits the monitoring of many of the CFC replacements, thereby enabling a tracking of such chemicals from their first appearance in the atmosphere. Measurement and standards intercomparisons between the AGAGE and NOAA networks and with other international collaborators are leading to an improved long-term database for many ozone- and climate-related gases. (NOAA, NASA)

UV Irradiance Measurements

Broadband Measurements
SURFRAD Network
Seven Surface Radiation (SURFRAD) sites operate Yankee Environmental Systems, Inc. (YES) UVB-1 broadband radiometers. The ISIS network of solar measurements includes broadband Solar Light 501 UVB biometers at each of seven sites. Other instrumentation (located at the Table Mountain test facility near Boulder, Colorado) includes a triad of calibration-reference YES UVB-1 broadband radiometers, and two calibration reference Solar Light 501 UVB biometers. Several other broadband UV radiometers also are operated at the Table Mountain site. These include a Scintec UV radiometer, two types of Kipp & Zonen broadband UV radiometers, an EKO UV radiometer, and a Solar Light 501 UVA biometer. (NOAA)

NOAA Network
Supplemental measurements of UV-B using YES UVB-1 instruments continue at Boulder, Colorado and Mauna Loa, Hawaii, where high-resolution UV spectroradiometers also are operated and can be used to interpret accurately the broadband measurements. (NOAA)

NEUBrew network
Each NEUBrew station has a Yankee UVB-1 broadband radiometer collocated with the Brewer spectroradiometer. The UVB-1 provides measurements of Erythemal daily dose. The NEUBrew Mountain Research Station also includes a broadband Yankee UV-A instrument. (EPA, NOAA)

USDA UV-B Monitoring and Research Programme (UVMRP)
Thirty-eight YES UVB-1 radiometers are fielded under this programme. (USDA)

Narrowband Filter Measurements
Central Ultraviolet Calibration Facility
Currently instruments that have been operating at the Table Mountain test facility in Colorado are a Biospherical Instruments GUV-511 UV radiometer, a Smithsonian 18-channel UV narrow-band radiometer, and two YES UV-MFRSRs. The Smithsonian instrument was removed from operation in 2010 and the two YES UV-MFRSRs were removed from operation at Table Mountain in 2009. A YES UV-MFRSR is deployed at
the Central Ultraviolet Calibration Facility’s High-Altitude Mountain Research Station at Niwot Ridge, Colorado. (NOAA)

**USDA UVB Monitoring and Research Programme (UVMRP)**
UV-MFRSRs deployed within this network measure total and diffuse horizontal and direct normal irradiance at nominal 300, 305, 311, 317, 325, 332, and 368 nm with a 2.0 nm bandpass. In addition, vis-MFRSRs are deployed with nominal 415, 500, 610, 665, 862 and 940 nm wavelengths with 10.0 nm bandpass. These 13 measurements are used to create a continuous synthetic spectra model which can then be convolved with specific weighting functions to meet researcher’s needs. Access to the synthetic spectra is found on the UVMRP web site at: (http://uvb.nrel.colostate.edu/UVB/uvb_dataaccess.jsf) (USDA)

**NEUBrew Network**
Each NEUBrew station has a Yankee UV-MFRSR and visible MFRSR collocated with the Brewer spectrophotometer. (EPA, NOAA)

**NOAA Antarctic UV Monitoring Network**
NOAA/GMD has assumed operations of the Antarctic portion of the former NSF UV Monitoring Network. There are Biospherical Instruments (BSI) GUV-511 moderate bandwidth multi-channel radiometers deployed at two of the Antarctic stations, McMurdo and Palmer and a GUV-541 radiometer deployed at the South Pole. (NOAA)

**Spectroradiometer Measurements**
**Central Ultraviolet Calibration Facility**
A high-precision UV spectroradiometer and a UV spectrograph are located at the Table Mountain Test Facility in Colorado under the auspices of this programme. The UV spectrograph was removed from operation in August 2009 due to equipment failure. (NOAA)

**Network for the Detection of Atmospheric Composition Change (NDACC)**
State-of-the-art, high-resolution spectroradiometric UV observations are conducted as a part of the NDACC at several primary and complementary sites. In particular, U.S. collaboration with NIWA (New Zealand) enables such measurements at Mauna Loa, HI and Boulder, CO. The measurements at Mauna Loa were started in 1995, those in Boulder began in 1998, and they continue to the present. (NOAA)

**NSF (AON Grant to the University of Chicago) UV Monitoring Network**
BSI SUV-100 high-resolution scanning spectroradiometers are deployed at; San Diego, California; (sub-tropical location) and Barrow, Alaska; A BSI SUV-150B spectroradiometer is deployed at the Summit, Greenland. (NSF)

**NOAA Antarctic UV Monitoring Network**
NOAA has assumed operations of the NSF UV Antarctic Network. BSI SUV-100 scanning spectroradiometers are deployed at the three Antarctic stations, McMurdo, Palmer, and South Pole.
**UV-Net Programme**

Brewer Mark IV spectrometers that measure the spectrum between 290 and 325 nm are deployed at all 21 network sites located in 14 U.S. national parks and 7 urban areas around the U.S. This network ceased operation in 2004 and all 21 Brewers were removed from their network sites. (EPA)

**NEUBrew Network**

The NOAA/EPA Brewer Spectrophotometer Network (NEUBrew) consists of six stations located in the western, central and eastern United States. Brewer MKIV instruments provide UV irradiance over the range 286.5 nm to 363 nm with 0.5 nm resolution up to 20 times per day. Absolute spectral UV irradiance, instantaneous UV index, and daily erythemal dose time series are available online with a latency of one day. [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/). (NOAA, EPA)

**Satellite-based Estimation**

Surface UV radiation can be estimated using satellite-measured total column ozone and top-of-the-atmosphere radiance at a non-ozone absorbing UV wavelength as input to a radiative transfer code. Such methods have been applied to estimate both the spectral irradiance as well as UVB from the TOMS instrument series. Similar data are being produced by the Finnish Meteorological Institute (FMI) using OMI data. Since the cloud effects vary at very short spatial and temporal scales, the satellite derived UVB data are most useful for making estimates of monthly average UVB and spectral irradiance at ~100 km grid scales. An outstanding problem in the estimation of UVB from satellites is the strong UV absorption of most aerosols, most notably dust and secondary organics. An aerosol absorption correction is applied to the TOMS UVB record (but not to the OMI record) using TOMS-derived aerosol index (AI). Though AI can correct for elevated plumes of dust and smoke, it is not sensitive to aerosols near the surface. As a result the satellites can overestimate UVB by up to 30% in polluted areas. However, this error is largely localized to urban areas and shouldn’t significantly affect regional averages. (NASA)

**Calibration Activities**

**Satellite BUV instruments**

The UV instruments have very high susceptibility to degradation in the space environment with unpredictable variability from one instrument to another. In addition, some instruments have had non-linear detector response as well as hysteresis and spectral stray light problems. The EP/TOMS instrument developed a complex cross-track dependent response after several years. NASA has for several decades supported the calibration of NOAA SBUV/2 instruments both before and after launch. The post launch activities include both hard calibration (by monitoring on-board calibration data and the solar irradiance), as well as soft calibration. Soft calibration techniques include analysis of spectral and spatial patterns in measured radiances to separate geophysical effects from instrumental effects. NASA flew the SSBUV instrument 8 times on the Space Shuttle to provide calibration of NOAA SBUV/2 instruments. Other satellite instruments such as SAGE, and currently the MLS instrument on Aura, are also providing useful calibration.
information. However, ground-based data have not been used for satellite calibration, except for the BUV instrument that operated on the Nimbus-4 satellite from 1970 to 1974. However, NASA uses Dobson/Brewer ozone network and ozone soundings to verify SBUV/2 and TOMS data after applying soft and hard calibrations. (NOAA)

**Dobson Network**
World Standard Dobson No. 83 is maintained at NOAA/ESRLGMD as part of the World Dobson Calibration Facility, and regularly participates in international intercomparisons of regional and national standards. Since 2006, intercomparisons have been held in Melbourne, Australia; Tsukuba, Japan; Buenos Aires, Argentina (twice) and Irene, South Africa. Investigations into the correct characterization of the Dobson instruments are continuing.(NOAA)

**Ozone Soundings**
NOAA calibrates balloons according to the developed procedures. It participates in international intercomparisons of ozone sonde measurements (chamber tests) and develops methods to resolve instrument related differences. It is done to homogenize time series of balloon measurements at each NOAA site. WMO Global Atmospheric Watch sponsors the ozonesonde calibrations where various international groups are invited to the World Calibration Centre for Ozone Sondes, Research Centre Juelich Institute for Chemistry and Dynamics of the Geosphere: Troposphere. These chamber calibration tests were held in 1996 and 2000. The last calibration campaign was a field (balloon) project at Laramie Wyoming called BESOS in 2004: [http://croc.gsfc.nasa.gov/besos/](http://croc.gsfc.nasa.gov/besos/) (NASA, NOAA)

**Network for the Detection of Atmospheric Composition Change (NDACC)**
Several operational protocols have been developed to insure that NDACC data is of the highest long-term quality as possible within the constraints of measurement technology and retrieval theory at the time the data are taken and analyzed. Validation is a continuing process through which instruments and their associated data analysis methods must be validated before they are accepted in the NDACC and must be continuously monitored throughout their use. Several mobile intercomparators within the various NDACC instrument types exist to assist in such validation. (NASA, NOAA)

**Ground-Based In Situ Measurement Networks**
Both the NOAA and NASA/AGAGE networks independently develop and maintain highly accurate and precise calibration scales at ppt and ppb levels for the major and minor long-lived ozone-depleting gases. In addition, both networks are developing reliable calibration scales for the short-lived halogen-containing gases that have been introduced as CFC replacements. (NOAA, NASA)

**Central Ultraviolet Calibration Facility**
The Central Ultraviolet Calibration Facility (CUCF) is located in NOAA’s David Skaggs Research Center in Boulder, Colorado. The CUCF calibrates UV instruments for several U.S. Government agencies and other UV research concerns, both national and international. In addition to laboratory calibrations, the CUCF has developed a portable
UV field calibration system that allows laboratory-grade calibrations to be made at spectroradiometer field sites. The CUCF also produces secondary standards of spectral irradiance that are directly traceable to NIST primary transfer standards. The secondary standards can be calibrated for operation in either the vertical or horizontal orientation. (NOAA)

**USDA UVB Monitoring and Research Programme (UVMRP)**

NOAA CUCF lamp calibrations performed in horizontal and vertical position using NIST traceable 1000-W halogen lamps are used to calibrate 51 USDA UV-MFRSRs and 52 UVB-1 broadbands. A U-1000 1.0-m double Jobin Yvon with 0.1-nm resolution and 10° out-of-band rejection is used as a reference spectroradiometer to transfer lamp calibration to a broadband triad. The UV-MFRSR radiometer spectral response and its angular response (critical for direct beam retrieval) are measured. The Langley calibration method is employed to provide additional absolute calibration of UV-MFRSRs and to track radiometric stability *in situ*. (USDA)

**NEUBrew network**

The NOAA/EPA Brewer spectrophotometer network (NEUBrew) consists of six stations located in the western, central, and eastern United States. Each Brewer Mark IV spectrophotometer is calibrated for absolute spectral UV irradiance at least one per calendar year. (EPA, NOAA) All six of the network Brewers were originally calibrated by International Ozone Services by comparing to the WMO Brewer transfer standard #017. Brewer 017 is directly traceable to the WMO Brewer Ozone Triad located at Environment Canada in Toronto, Ontario, Canada. Two methods of tracking any drift from those original calibrations are employed by NEUBrew. The first is to adjust the extra-terrestrial constant (ETC) calibration constant by using the internally generated R6 value and the second is by performing Langley regressions on the ozone data to derive the ETC. (EPA, NOAA)

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

**Ozone**

*Merged Satellite Datasets*

Since there are often biases between different satellite instruments it is necessary to create consistent long-term data sets by cross-calibration of different records when they overlap and by using ground-based data (including NOAA ground based networks) when they do not. Such data sets have been produced using TOMS and SBUV total column ozone and profile records. Several new efforts to provide long term merged data sets of ozone columns and stratospheric profiles of ozone and other trace gases are ongoing. (NASA, NOAA)

**Ozone Depletion & Recovery**

Statistical analysis of the Umkehr ground based data, FTIR and merged SBUV profile ozone data set from 1979 to June 1997 shows the largest negative trends in the upper stratosphere (35-45 km) at middle latitudes at -10 % per decade at both Southern and
Northern Hemispheres. The middle stratosphere (20-25 km) trends are derived from ozonesonde, satellite and FTIR records indicate -7% per decade decline at both Southern and Northern middle latitudes and less negative trends are found at lower stratosphere (12-15 km) at -9% per decade in the Northern Hemisphere (no information for Southern hemisphere). These trends are in general agreement with previous profile trend estimates from satellite and ground-based records. Since 1997, ozone between 12 and 15 km (lower stratosphere) in the Northern middle latitudes has increased at a larger rate than expected based on the decline in the ODS abundances. The middle and upper stratospheric ozone has been increasing at some locations at the Northern middle latitudes since 1997, but it is not observed globally. Ground-based and satellite ozone measurements taken at the upper stratosphere since 1997 also indicate positive trends that are consistent with leveling off of the ODS concentrations. However, the derived trends are not always statistically significant, since the natural ozone variability, stratospheric cooling and measurement uncertainties make analyses less certain.

Total ozone levels have remained relatively constant over the last decade (1998-2007). Northern midlatitude ozone reached a minimum of 5.5% below 1979-1980 mean values in 1993 because of forcings from the Mt. Pinatubo eruption and the solar cycle minimum. From 1992-1998 total ozone levels recovered from the effects of the Mt. Pinatubo eruption to about 3% below the 1979-1980 values. In the years since, the northern midlatitude total ozone has been highly variable, but has increased on average, to about 3.5% below the 1964-1980 values. Southern midlatitude ozone decreased steadily until the late 1990s, and has been nearly constant since at 6% below 1964-1980 average values. There are no significant ozone trends over the tropics. (NASA, NOAA)

**Antarctic Ozone Hole**
Since approximately 1997, the underlying trend of Antarctic ozone (i.e., the trend after removal of the effect of natural variability in vortex temperatures) has been zero. This cessation of the downward trend in ozone is consistently seen at 60ºS to 70ºS in TOMS total ozone columns, SAGE/HALOE stratospheric columns, ozonesonde ozone columns at Syowa (69ºS), and Dobson total column measurements at 65ºS and 69ºS. The cessation of the downward trend is primarily a result of the saturation of the losses, and not due to decreasing levels of stratospheric chlorine. Antarctic ozone depletion is primarily controlled by inorganic chlorine and bromine levels (effective equivalent stratospheric chlorine, EESC), and secondarily controlled by Antarctic stratospheric temperatures. Fits of various ozone hole diagnostics to temperature and chlorine and bromine levels suggest that the ozone hole is very slowly improving. However, detection of this slow improvement is masked by the large natural variability of the Antarctic stratosphere. (NASA)

**Ozone Maps**
Daily maps of total ozone and monthly total ozone anomalies are being produced, as well as routine updates of the SBUV-2 total ozone change utilizing a statistical model that includes the 1979 to 1996 trend, the trend-change in 1996, plus ancillary variables of solar variation (f10.7), QBO, and AO/AAO. In addition, twice-yearly (Northern and...
Southern Hemisphere) winter summaries of selected indicators of stratospheric climate are generated. (NOAA/CPC)

**Ozone-Related Gases and Variables**

**Stratospheric Ozone - Climate Connection**
A recent analysis of observations has been combined with radiative transfer considerations to show that changes in stratospheric water vapor have made significant contributions to recent decadal rates of warming of the Earth’s surface climate. Stratospheric water vapor concentrations decreased by about 10% after the year 2000. The study shows that this acted to slow the rate of increase in global surface temperature over 2000-2009 by about 25% compared to that which would have occurred due only to carbon dioxide and other greenhouse gases. The findings show that stratospheric water vapor represents an important driver of decadal global surface climate change. (NOAA)

**UV**

**Instrumentation**
NOAA/GRAD and NOAA/NWS/NCEP/CPC in collaboration with Klein Buendel, Inc, a health research company developed a prototype for a smart-phone application that utilizes NOAA’s UV forecast. The application is a tool for managing and providing information on sun-burning potential and vitamin D production. The project was funded by the National Institute of Health and is on-going.

**UV Trends**

**SURFRAD Network**
A paper co-authored with Colorado State University (CSU) UVB researchers analyzing trends in solar UV irradiance at eight stations in the CSU-USDA network stations over the period 1995 to 2006 has been published in JGR Atmospheres (2008). Both positive and negative tendencies were detected ranging from –5% to +2% per decade. However, inter-annual variability was between 2 and 5%. (NOAA)

**USDA UVB Monitoring and Research Programme (UVMRP)**
The multidecadal change of ozone from 1979 to 2005 was investigated using four UVMRP ground stations, WA01, CO01, MD01, and AZ01. The UV index has increased at the four stations while total ozone has decreased in continental USA. Spatial distribution of ozone shows substantial variation from coastal zones to the Midwest, yet the tendency toward recovery of the ozone layer in the continental USA cannot be fully confirmed. (Gao et al., 2010)

Scientists analyzing UV-B flux over the continental USA using NASA TOMS data and UVMRP network data found that “ground-based in-situ measurements, like those from the UVMRP network, are indispensable in monitoring atmospheric status and not totally replaceable by space-based remote sensing retrievals”. The incorporation of these ground-based measurements with current satellite algorithms has improved UV retrievals for the latest satellite package (OMI). (Xu et al., 2010) (USDA)
**UV Forecasts and Exposure**

**UV Forecasts and Alert System**
NOAA/CPC is producing UV forecasts and has developed a UV Alert system with the EPA. The UV Index forecasts are on a gridded field covering the entire globe. Forecast fields are generated at one hour frequency out to five days. The UV Index forecasts include the effects of Earth-Sun distance, total ozone, solar zenith angle, surface albedo (inclusive of snow/ice), cloud attenuation, and climatological aerosol conditions. The gridded fields are freely available on the NCEP ftp site. The UV Alert system is designed to advise the public when UV levels are unusually high and represent an elevated risk to human health. The UV Alert system consists of a graphical map displaying the daily UV Alert areas, as well as additional information included in the EPA’s UV Index ZIP Code look-up web page and via the EPA’s AIRNow EnviroFlash e-mail notification system. The criteria for a UV Alert are that the noontime UV Index must be at least a 6 and must be 2 standard deviations above the daily climatology. (NOAA/CPC, EPA)

**Effects of UVB Exposure**
A major limitation in predicting the impacts of UVB irradiance on humans, plant leaves and flowers, and aquatic organisms is the difficulty in estimating exposure. An analysis of the spatial variability in the daily exposure to narrowband 300- and 368-nm and broadband 290- to 315-nm (UVB) solar radiation between 12 paired locations in the USDA UV-B Climatological Network over two summer growing seasons has been completed. The spatial correlation of the UVB, 300- and 368- nm daily exposures between locations was approximately 0.7 to 0.8 for spacing distances of 100 km. The 300-nm daily exposure was typically more highly correlated between locations than the 368-nm daily exposure. (USDA)

**THEORY, MODELING, AND OTHER RESEARCH**

**Ozone:**

**Ozone-Layer Recovery Estimates**
Equivalent effective stratospheric chlorine (EESC) is a convenient parameter to quantify the effects of halogens (chlorine and bromine) on ozone depletion in the stratosphere. EESC has been extensively used to evaluate future scenarios of ozone-depleting substances (ODSs) on the stratosphere. Research has led to a new formulation of EESC that provides revised estimates of ozone layer recovery. The work shows that ozone levels will recover to 1980 levels in the year 2041 in the midlatitudes, and 2067 over Antarctica, assuming adherence to international agreements that regulate the use of ODSs. The researchers assessed the uncertainties in the estimated recovery times. The midlatitude recovery of 2041 has a 95% confidence uncertainty from 2028 to 2049, while the 2067 Antarctic recovery has a 95% confidence uncertainty from 2056 to 2078. (NOAA and NASA) In recent research, hypothetical reductions in future emissions of ODSs and nitrous oxide (N₂O) have been evaluated in terms of effects on EESC, globally-averaged total column ozone, and radiative forcing through 2100. The findings show that due to the established success of the Montreal Protocol, these actions can have
only a fraction of the impact on ozone depletion that regulations already in force have had. If all anthropogenic ODS and N\textsubscript{2}O emissions were halted beginning in 2011, ozone is calculated to be higher by about 1 to 2% during the period 2030–2100 compared to a case of no additional restrictions. (NOAA)

**Antarctic and Arctic Ozone Loss**
Contrasts between ozone depletion at the poles have been investigated in a recent study that used available long balloon-borne records and ground-based records that cover multiple decades. Antarctic ozone observations reveal widespread and massive local depletion in the heart of the ozone “hole” region near 18 km, frequently exceeding 90%. The depth of the ozone losses in the Arctic are considerably smaller, and their occurrence is far less frequent. However, the 2011 Arctic Polar vortex was uncharacteristically stable and cold allowing record stratospheric ozone depletion to occur in the late winter and early spring as reported by the Alfred Wegener Institute for Polar and Marine Research (AWI). This was based on their analysis from an ongoing international network of about 30 cooperative ozone sounding stations in the Arctic and Subarctic. Similar studies are being done with satellite data from the MLS instrument. (NOAA, NASA)

**SPARC Initiative on Halogen Chemistry and Polar Ozone Loss**
NASA and NOAA scientists are working with international colleagues to examine the effects of new laboratory data on the photolysis rate of the ClO dimer (ClOOCl) on the quantification of polar ozone depletion. These efforts were coordinated under a new SPARC initiative on “The Role of Halogen Chemistry in Polar Ozone Loss”. The work resulted in publication of a report that gives a comprehensive review of existing and ongoing laboratory studies, atmospheric observations, and modeling activities. (NASA, NOAA)

**Decadal Analyses and Simulations**
Simulated fields of atmospheric constituents derived using NASA’s Global Modeling Initiative (GMI) Chemical Transport Model (CTM) are being used in comparison with Aura data to evaluate the transport and photochemical processes in the upper troposphere and lower stratosphere. These simulations are being used along with trajectory calculations to interpret aircraft measurements of chlorofluorocarbons and to develop better estimates of their atmospheric lifetimes. In addition, 25-year time-slice simulations have been done in which specific years (in terms of halogen amounts) are repeated in order to get better mean distributions and estimates of variability for ozone and relevant chemical compounds. These simulations have been included in the Chemistry Climate Model Validation (CCMVal) exercise and were part of the 2010 WMO/UNEP Ozone Assessment. (NASA)

**Ozone-Related Gases and Variables**

**Environmental Properties of Atmospheric Gases**

**Chemistry Related to Ozone Depletion**
Laboratory work determined the chlorine monoxide radical (ClO) yields in the reaction of O(1\textsuperscript{D}) with Cl\textsubscript{2}, HCl, chloromethanes, and chlorofluoromethanes. The formation of the
reactive ClO is particularly important in the stratosphere due to its influence on ozone abundance (e.g., the Antarctic ozone hole) through its participation in the ClOx catalytic ozone destruction cycle as well as the ClO dimer (Cl2O2) cycle, which plays an important role in polar stratospheric ozone chemistry. (NOAA)

Laboratory work has been completed on the kinetics of the ClO + ClO reaction over a range of temperatures and pressures. Rate constants obtained are larger than current recommended values, and modeling work will be done to determine the impact of the new results on ozone-related chemistry in the stratosphere. The reaction is a key step in catalytic cycles that destroy stratospheric ozone in both polar and non-polar regions. (NOAA, NASA).

The abundance and atmospheric lifetimes of nitrous oxide (N2O) and carbon tetrachloride (CCl4) are important to understanding stratospheric ozone recovery and climate change as well as the linkage between these issues. Laboratory work has determined updated values for the UV absorption cross sections of these gases, and to determine the temperature dependence of these values, for which there are few previous studies. The information will help reduce the uncertainties in calculations of the atmospheric lifetimes of these species, which are inputs to atmospheric models. The reduced uncertainties in the N2O and CCl4 absorption cross section data, and in photolysis lifetimes, will enable improved model calculations of ozone recovery. (NOAA)

Chemistry of Potential ODS Replacements
Laboratory and theoretical work has provided information about the ozone-layer friendliness and climate friendliness of candidate replacements for ozone-depleting substances used for a variety of societal applications such as refrigeration, air conditioning, electronics manufacture, and fire protections. Early information about the suitability of a proposed substance is needed by industry before costly development investments are made. These results provide important input parameters for model calculations of the future vulnerability of the ozone layer, and are used together with industrial production-and-use information to analyze the growth of such chemicals in the atmosphere. (Recent studies have focused on unsaturated partially fluorinated compounds, as well as methoxy perfluorinated heptenes. A modeling study of the degradation products of a potential substitute for HFC-134a is in progress. A particular focus on the yield of trifluoroacetic acid (TFA), a compound that has possible ecological implications. (NOAA)

The Montreal Protocol with its subsequent amendments and adjustments have led, and will likely continue to lead, to the replacement of chlorofluorocarbons (CFCs), Halons (brominated chemicals) and hydrochlorofluorocarbons (HCFCs) with chemicals that are shorter lived or do not contain either chlorine or bromine. Over the past two decades, potential substitutes with lifetimes as short as a few days have been considered. Researchers have developed a new approach for calculating the fraction of very-short lived substances (VSLS) emitted at the surface (and their degradation products) that reach the stratosphere, and have used those fractions to estimate Ozone Depletion Potentials.
(ODPs) of several short-lived compounds. Calculated values show large regional and seasonal variability. (NOAA)

A recent study has provided the first calculation of the Ozone Depletion Potential (ODP) of nitrous oxide (N₂O), a gas long recognized as the primary source gas for nitrogen oxides in the stratosphere. The concept of the ODP, which is used extensively in characterizing the relative roles of halogen-containing ODSs, had not previously been applied to N₂O. The study’s analysis uses the ODP to show that nitrous oxide has now become the largest ozone-depleting substance emitted through human activities, and is expected to remain the largest throughout the 21st century. (NOAA)

UV

**UV Instrumentation**
The temperature dependence of the Brewer UV spectrometer has been studied in order to improve the quality of data for UV trends. (NOAA)

**UV Effects**
The UVMRP supports research studying UVB effects on plants and ecosystems. Numerous publications document the results of these on-going studies, and are listed on the program’s web site at [http://uvb.nrel.colostate.edu/UVB/uvb_pubs.jsf](http://uvb.nrel.colostate.edu/UVB/uvb_pubs.jsf). (USDA)

**UV Model Comparisons**
The UVMRP’s modeling group, “The Center of Remote Sensing and Modeling for Agricultural Sustainability” has published preliminary results of their coupled climate-crop modeling system. Validation and system refinement is underway and has shown promising results. Corn yields for the 16-state USA corn belt over the 27 year span (1979-2005) agree to within +/-10% of the actual yields. This modeling effort is being expanded to evaluate precipitation, temperature and UV effects on the yields, with the ultimate goal of developing a system that will be capable of both achieving credible and quantitative assessments of key stress factors, and evaluating alternative cultural practices for sustainable agriculture production. (USDA)

DISSEMINATION OF RESULTS

**Data Reporting**

**Ozone**
Ozone data from 3 Aura instruments (OMI, MLS, and HIRDLS), past TOMS instruments, and the AIRS instrument are routinely distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at [http://disc.sci.gsfc.nasa.gov/acdisc](http://disc.sci.gsfc.nasa.gov/acdisc). Both level 2 (measured) data and level 3 (grid averaged) data are distributed in HDF format. OMI level 3 data are distributed in ASCII format via the TOMS web site ([http://toms.gsfc.nasa.gov](http://toms.gsfc.nasa.gov)). Ozone data for the TES instrument on Aura can be found on the NASA Langley DAAC at [http://eosweb.larc.nasa.gov/](http://eosweb.larc.nasa.gov/). (NASA)
Aura Validation Data Center (AVDC)

Preliminary and near real-time total ozone, ozonesondes, ozone profiles from LIDAR and microwave radiometers are archived from US Government Agencies and investigators worldwide. In addition, the AVDC (http://avdc.gsfc.nasa.gov/) also archives and distributes NASA and NOAA total column, profile and tropospheric satellite data subsets. The collected preliminary ozone data are restricted to participants in Aura validation teams, ESA OMI announcement of opportunity participants, and international validation contributors, while the satellite data is freely available (http://avdc.gsfc.nasa.gov/Data/). (NASA)

Umkehr Dobson Data

Dobson Umkehr data processed using UMK04 algorithm are available from the WOUDC archives. Brewer Umkehr data are available for 6 NEUBrew sites at the http://esrl.noaa.gov/gmd/grad/neubrew/. (NOAA, NASA)

World Ozone and Ultraviolet Radiation Data Center (WOUDC)

Total ozone, Umkehr, and ozonesonde data are reported to the WOUDC from U.S. Government agencies and institutions. Ozone data from sites that are part of the NDACC and the SHADOZ network are available from the programme web sites (http://www.ndacc.org/ and http://croc.gsfc.nasa.gov/shadoz/, respectively), and also are imported to WOUDC. (NOAA, NASA).

NEUBrew Data

UV spectra, total column ozone and Umkehr ozone profile data from the NOAA-EPA network are available at the web site http://esrl.noaa.gov/gmd/grad/neubrew/ (NOAA, EPA)

Maps

All daily SBUV/2 total ozone hemispheric analyses generated from NOAA-16, NOAA-17, and NOAA-18 observations are available on the Climate Prediction Center’s stratospheric web pages at http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/. The raw data from the SBUV/2 are available from NESDIS. Additionally, the NCEP/GFS total ozone analysis and forecast fields out to five days are available at http://www.cpc.ncep.noaa.gov/products/stratosphere/strat_a_f/. (NOAA/CPC)

Daily maps from the Version 8 total ozone algorithm processing of GOME-2 data are available from NOAA Operations at http://www.osdpd.noaa.gov/PSB/OZONE/gome.html (NOAA/CPC)

Assessments

NASA and NOAA scientists played key roles as reviewers and authors for various chapters in the 2010 WMO/UNEP Scientific Assessment of Ozone Depletion, mandated under the provisions of the Montreal Protocol. Other scientists from the U.S. and around the world contributed to the report, which was given to the Parties to the Montreal Protocol in late 2010 and is available in print form and on the UNEP and NOAA websites. (NOAA, NASA)
Stratospheric Winter Hemisphere Bulletins
Following each hemisphere’s winter, an assessment of the stratospheric dynamics and chemistry are presented from a NOAA perspective. The southern hemisphere’s winter bulletin focuses upon the ozone hole formation and longevity. Relevant thermal and dynamical attributions are presented. The northern hemisphere’s winter bulletin will discuss ozone loss conditions and stratospheric warmings.

http://www.cpc.ncep.noaa.gov/products/stratosphere/winter_bulletins/ (NOAA/CPC)

Ozone-Related Gases and Variables
Aura Data
Gas and Aerosol constituent data from Aura instruments (OMI, MLS and HIRDLS) are routinely distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at http://disc.sci.gsfc.nasa.gov/acdisc. Both level 2 (measured) data and level 3 (grid averaged) data are distributed in HDF format. OMI level 3 data are distributed in ASCII format via the TOMS web site (http://toms.gsfc.nasa.gov). Data for the TES instrument on Aura can be found on the NASA Langley DAAC at http://eosweb.larc.nasa.gov/ (NASA)

Ozone-Depleting Substance Data
Long-term data from the NOAA network are updated every six months on the website (http://www.esrl.noaa.gov/gmd/) and submitted annually to the World Data Centre and to the World Data Center for Atmospheric Trace Gases at the Carbon Dioxide Information Analysis Data Center (CDIAC). Data from field missions (firn-air studies, ocean flux studies), are posted shortly after mission completion. Data on very short-lived gases from ocean research cruises are posted for use on the NOAA/GMD website. (NOAA)

Long-term data from the NASA/AGAGE network are reviewed on a semi-annual basis by the Science Team, and are archived every six months with Carbon Dioxide Information and Analysis Center (CDIAC) <http://cdiac.esd.ornl.gov/>. Data from the UCI flask sampling network are also archived at CDIAC. (NASA)

UV Data
SURFRAD Network Data
UV data from the SURFRAD Network are available on the NOAA/SRRB website (http://www.srrb.noaa.gov/). (NOAA)

NEUBrew Network UV Data
Spectral UV irradiances are available from the NEUBrew website http://esrl.noaa.gov/gmd/grad/neubrew/ (NOAA)

NOAA Antarctic UV Data
Spectral UV irradiances, derivative UV products, and GUV data will be available from NOAA’s Antarctic UV website. http://esrl/noaa.gov/gmd/grad/antuv (NOAA)
USDA UV-B Monitoring and Research Programme (UVMRP)
UV, visible and ancillary data from the UVMRP network is available next-day on the UVMRP website (http://uvb.nrel.colostate.edu/).

UVB-1 broadband data and UV-MFRSR data from this network are regularly submitted to the WOUDC. (USDA)

Information to the Public

Ozone
TOMS and OMI Data
Near-real-time ozone data from the OMI instrument on Aura is routinely distributed via the NASA web site (http://toms.gsfc.nasa.gov/). Data are usually available within 48 hours, though faster access can be arranged. The site provides online access to both TOMS (1978-2006) and OMI (2004-present) data. While used mostly by scientists, educators and students also use the site extensively. An Ozone Hole Watch web site, http://ozonewatch.gsfc.nasa.gov/ provides information for anyone interested in the Antarctic ozone hole. Near real time Ozone profile data from MLS now exist, and are available at http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/MLS/ml2o3_nrt.002.shtml. (NASA)

Merged TOMS/SBUV Total and Profile Ozone Data
Merged TOMS/SBUV total and profile ozone data sets are available on the Internet (http://hyperion.gsfc.nasa.gov/Data_services/merged/index.html). (NASA)

UV
Forecasts
Noontime UV forecasts are made available to the public via several formats. One is a text bulletin for 58 cities in the U.S. The other is a map displaying the UV Index forecast at each of the 58 cities’ locations. These can be found at http://www.cpc.ncep.noaa.gov/products/stratosphere/uv_index/. Additionally, gridded fields of the noontime forecast for the U.S. and Alaska are made available via the NOAA/CPC and NOAA/NCEP ftp sites. UV Index forecast gridded fields covering the entire globe at one hour increments out to five days are available on the NCEP ftp site: ftp.ncep.noaa.gov/pub/data/nccf/com/hourly/prod. (NOAA/CPC)

Advisories
The primary UVR advisory in the United States is the UV Index, operated jointly by NOAA and EPA. Currently, the UV Index computer model processes total global ozone satellite measurements, a rough cloud correction factor, and elevation to predict daily UVR levels on the ground and the resulting danger to human health. This model assumes zero pollution levels. UV Index reports are available in local newspapers and on television weather reports. The EPA also issues a UV Alert when the UV Index is predicted to have a high sun-exposure level and is unusually intense for the time of year. UV Alert notices can be found at EPA's SunWise web site
Ozone-Depleting Gas Index

An ozone-depleting gas index (ODGI), based on Effective Equivalent Chlorine (EECl) measured globally in the NOAA network, has been implemented. EECl and WMO/UNEP ozone-depleting gas scenarios are used to estimate the progress towards ozone recovery (ODGI = 100 on January 1, 1994 when EECl reached its maximum value and 0 at recovery). The method was published, where the results are updated annually and posted at http://www.esrl.noaa.gov/gmd/odgi. (NOAA)

Relevant Scientific Papers (2008-present)


Biago, C.D., et al. "Evolution of temperature, O₃, CO, and N₂O profiles during the exceptional 2009 Arctic major stratospheric warming as observed by lidar and millimeter-wave spectroscopy at Thule (76.5N, 481


Gilman et al., Ozone variability and halogen oxidation within the Arctic and sub-Arctic springtime boundary layer (2010), *Atmos. Chem. Phys.*, 10, 10223-10236.


Hicke, J. A., J. Slusser, K. Lantz and F. G. Pascual (2008), Trends and interannual variability in surface UV-B radiation over 8-11 years observed across the United States,


Kiedron, P., M. Beauharnois, J. Berndt, P. Disterhoff, L. Harrison, J. Michalsky, G. Scott, J. Schlemmer and J. Slusser (2008), Calibration, data processing, and maintenance of the
United States Department of Agriculture high-resolution ultraviolet spectroradiometers, *Applied Optics*, 47, 6142-6150, 10.1364/AO.47.006142.


Krotkov, N., G. Labow; J. Herman; J. Slusser; R. Tree; G. Janson; B. Durham; T. Eck; B. Holben (2009), Aerosol column absorption measurements using co-located UV-MFRSR and AERONET CIMEL instruments, Proceedings of SPIE Volume: 7462.


Michalsky, J. J. and P. Kiedron (2008), Comparison of UV-RSS spectral measurements and TUV model runs for clear skies for the May 2003 ARM aerosol intensive observation period, Atmospheric Chemistry and Physics, 8, 1813-1821.


Miller, B. R. et al., HFC-23 (CHF₃) emission trend response to HCFC-22 (CHClF₂) production and recent HFC-23 emission abatement measures (2010), Atmos. Chem. Phys., 10, 7875.


PROJECTS AND COLLABORATION

**NOAA**

The Dobson and ozonesonde measurements are included in the WMO Global Atmosphere Watch (GAW) and in the NDACC. Significant collaboration with federal agencies (NASA, DoE) and universities (University of Colorado, Harvard, Princeton, Humboldt State University, etc.) is maintained through both global monitoring and field missions including support for satellite validations. The CUCF is designated by a Memorandum of Understanding to be the national UV calibration facility by agreement among the following organizations: NOAA, USDA, EPA, NASA, National Institute of Standards and Technology (NIST), NSF, National Biological Service, and the Smithsonian Institution. The CUCF compared secondary standards of irradiance with the Joint Research Centre’s European Union UV Calibration Centre’s (ECUV) ultraviolet spectral irradiance scale in Ispra, Italy. The CUCF’s irradiance scale is directly traceable to the NIST spectral irradiance scale, while the ECUV’s irradiance scale is traceable to that of the German national standards laboratory, Physikalisch-Technische Bundesanstalt (PTB).

**NOAA/CPC**

Activities include participation in several initiatives of Stratospheric Processes and their Relation to Climate (SPARC), i.e., stratospheric temperatures, ozone, UV, climate change; collaboration with the EPA on the UV Index and the UV Alert system; collaboration with NASA in ozone monitoring, calibration of the SBUV/2 instruments, dynamical processes influencing ozone changes, and ozone assimilation; collaboration with the surface radiation monitoring efforts of NOAA/OAR and USDA-CSU for the validation of UV forecasts and NCEP/GFS surface radiation products, and the NDACC Data Host Facility.

**NASA:**

NASA collaborates extensively with several NOAA laboratories in all areas of ozone and UV research, including space-based, airborne, balloonborne, and groundbased measurements, as well as in various modeling and analysis activities. NASA often supports research activities within these laboratories, including support for NOAA groundbased measurements for satellite validation. The NDACC, which is championed by NASA and NOAA within the U.S., is a major contributor to WMO’s Global Ozone
Observing System (GO3OS) within the frame of its Global Atmosphere Watch (GAW) Programme. NASA is closely collaborating with KNMI (Netherlands) and FMI (Finland) on processing data from the Aura OMI instrument. NASA is assisting NOAA in the implementation of the OMPS nadir and limb instruments on the NPOESS Preparatory Satellite (NPP) by developing the limb operational algorithms and by performing assessments of the nadir operational products.

**USDA:**
USDA is actively collaborating with the NASA TOMS and AERONET groups on aerosol absorption using UV-MFRSR and Cimel instruments.

**EPA:**
The NOAA/EPA Brewer spectrophotometer network (NEUBrew) consists of six stations located in the western, central, and eastern United States. The NEUBrew network has deployed two Brewer Mark IV spectrophotometers to Brisbane, Australia. The data gathered from this location will be used for atmospheric research and human health effects studies.

**FUTURE PLANS**

**Ozone**

*Column Ozone from Dobson/ Brewer Zenith-Sky Measurements*

The operational zenith-sky total ozone algorithm for Dobson and Brewer instruments is based on empirically derived tables. NASA has developed a TOMS-like algorithm to process these data, which has the potential to substantially improve data quality. There are plans to process all historical zenith-sky data using this algorithm. New algorithms to utilize multi-wavelength Brewer zenith sky measurements for improved ozone profile retrieval are underway. The work on improvement of optical characterization of Dobson and Brewer instruments for stray light minimization and new ozone cross-section implementation is underway. (NOAA, NASA)

According to the ACSO (WMO GAW Ad Hoc Expert team on Absorption Cross-sections of Ozone - ACSO) analysis of the impact of a possible change of ozone absorption cross-sections from Bass and Paur to Brion/ Daumont /Malicet (BDM) on Dobson and Brewer total ozone measurements, SAG-Ozone  (Activity A9 within the ICAGO-O3/UV implementation plan) recommended to develop procedure to apply ozone cross section changes to processed total ozone data from Dobson and Brewer observations. A NOAA group will proceed to convert retrieved total ozone measurements and submit results to the WOUDC. (NOAA)

*Ozone profiles from Dobson/ Brewer Zenith-Sky Measurements*

NOAA GMD will convert retrieved ozone profiles from the NOAA operated stations, and will submit results for Dobson stations to the WOUDC, and will make the amendment to the UMK04 algorithm to replace the look-up tables for the BDM cross-section. Results from the NEUBrew instruments will be posted on the network website.
http://esrl.noaa.gov/gmd/grad/neubrew/, with the follow up submission to the WOUDC Brewer archive. Also, all B-files will be submitted to the WOUDC Brewer archive in accordance with the SAG-Ozone Activity (NOAAESRL/GMD). A new multi-wavelength ozone profile retrieval algorithm for processing Brewer Umkehr measurements (similar to the SBUV retrieval) will be made available for the WOUDC and scientific communities. The algorithm will significantly reduce operational time for the zenith sky measurements as compared to the established “Umkehr” measurements schedule in Brewer operations. It will also allow to process historical data that were not available for standardized processing due to shortness of the solar zenith range coverage. The data processed by the new algorithm will be archived at the WOUDC (NOAA). The Brewer Umkehr data set series from NOAA and other international ground-based stations will be compared to other available co-incident ozone profile data from ozone-sondes, microwave, lidar and Dobson Umkehr profile data. Results will be reported at the next Vertical ozone workshop aimed at understanding of past changes in the vertical distribution of ozone, and will be made available for the next UNEP/WMO Scientific Assessment of Ozone Depletion. (NOAA)

Archiving of the “raw” data at the WOUDC
According to the SAG-Ozone recommendations NOAA will participate in the international effort at the finalization of formats for the storage and reporting of ECC ozonesonde measurements at WOUDC, archiving of R-values of Dobson measurements and related calibration information as well as B-files and relevant information for Brewer measurements. It will provide the updated and modified algorithms used to process these data. NOAA will assist WOUDC with changes of ozone absorption cross sections or other changes that may demand the reprocessing of data records. (NOAA)

Ozone in Climate Forecast Models
NCEP has modified and extended its synoptic forecast model (GFS) to time scales of three weeks to nine months. Ozone forecasts as well as stratospheric temperatures and heights have significant errors in these forecasts. Experiments modifying the model’s physics and structure will need to be conducted in order to improve these forecasts. (NOAA/CPC)

Ozone in the NCEP/Climate Forecast System Reanalysis
NCEP is replacing the NCEP/DOE Reanalysis 2 (R2) with the Climate Forecast System Reanalysis (CFSR). The CFSR improves upon the R2 in many ways. One is by using ozone profile information from the SBUV/2. The CFSR is being rerun from 1979 to present and will continue as the model for NCEP’s Climate Data Assimilation System (CDAS). The CFSR should be the reanalysis of choice to study ozone-dynamics interactions. (NOAA/CPC)

NOAA Antarctic UV Network
Future plans are to deploy two NEUBrew Mark IV spectrophotometers to the McMurdo and Palmer stations to provide daily total column ozone and overlapping spectral UV measurements. The two Brewers will be temperature stabilized and modified for Antarctic operation. Before deployment both Brewers will be converted to “red”
Brewers to facilitate ozone retrievals in the Chappuis band. After conversion and before deploying they will be operated at the CUCF’s Table Mtn Test Facility (Lat 40 N) over the boreal winter to determine the quality of ozone retrievals from this solar spectral region when compared to direct-sun retrievals from the Hartley-Huggins band.

**Ozone-Relevant Gases/Variables:**

*OMPS and CrIS on NPP and NPOESS*

The Ozone Mapping and Profiler Suite will become the operational US ozone monitoring instrument in the NPOESS period. The suite consists of two nadir detectors; one with coverage in the 310 to 380 nm range to provide daily global total column ozone maps, and the other with coverage from 250 to 310 nm to provide nadir ozone profiles to continue the SBUV(2) record. The first OMPS will fly on the NASA NPOESS Preparatory Project Mission in 2010. The OMPS was design to include a third detector, the limb profiler, to provide high-vertical resolution ozone profiles. This instrument was de-manifested due to cost issues. It has been restored on NPP and options for future flights are under consideration. The Cross-track Infrared Sounder is a hyperspectral IR instrument with spectral coverage including the ozone lines around 9.7 microns. NOAA has implemented ozone retrieval algorithms with the AIRS instrument on EOS, and plans to use similar algorithms with the IASI on MetOp-A and the CrIS on NPP and NPOESS. (NOAA, NASA)

*NASA Earth Venture (EV) Investigations and missions*

NASA selected 5 investigations (EV-1) that will last for 5 years to use suborbital platforms for sustained investigations of Earth System processes. 2 of these selected studies have direct relevance to Ozone related science, the Airborne Tropical Tropopause Experiment (ATTREX) and the Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) investigation. These activities started in 2010 and will continue until 2014. Two new competed space mission Announcements of Opportunities (AOs) will be released in 2011. One is for a cost constrained stand alone space mission (EV-2), and one for a cost constrained space based Instrument of Opportunity (EV-Instrument). (NASA)

*NEUBrew Network*

Future plans for the NEUBrew network are to process historical direct-sun measurement data for total column abundance of NO2 and SO2 data products. (NOAA, EPA)

**UV**

*UV Index Forecast*

Aerosols and clouds are the greatest cause of UV Index forecast errors. NCEP and NESDIS are working together to improve the skill of forecasting aerosols. When model generated forecasts of Aerosol Optical Depth and Single Scattering Albedo become available they will be included in the UV Index forecast system. (NOAA/CPC)
NEEDS AND RECOMMENDATIONS

Ozone

Column Ozone
Column ozone observations from ground stations and satellites provide the foundation for trend studies. Future levels of total ozone will be modulated by climate change effects. The current predictions of total ozone from state-of-the-art models suggest polar ozone recovery in the 2060-2070 period, and midlatitude recovery in the 2040-2050 period. It is a primary requirement to continue this data record and to enable retrieval improvements of the observations.

Column ozone data produced by satellite and ground-based instruments agree well in cloud-free conditions and at solar zenith angles less than 70º. However, the data quality of all measuring systems degrade under cloudy conditions and at large solar zenith angles, with differences of 10% or larger. Given the need for accurate ozone trends in the polar regions, it is important to improve the quality of ground-based data in these regions, and to focus future calibration and data intercomparison efforts accordingly. The work on improvement of optical characterization of Dobson and Brewer instruments for stray light minimization, and therefore improved accuracy at low sun and large total ozone conditions, are under development. In addition, the new ozone cross-section implementation in the Dobson and Umkehr data processing is underway. (NASA, NOAA)

Profile Ozone
Ozone profile information has critical importance for both ozone recovery and climate change. The vertical structure of ozone (~ 1 km resolution) near the tropopause is crucial to calculating the radiative forcing of ozone on climate. Furthermore, polar ozone recovery should first manifest itself in the 20-24 km region of the polar stratosphere. Models of ozone suggest that the cooling of the stratosphere will accelerate ozone recovery in the upper stratosphere leading to a “super-recovery”. Hence, observations of the vertical structure of ozone have a bearing on two key scientific issues: ozone recovery and climate change. Some of these profile observations will be obtained by the OMPS Limb instrument on NPP during the next 3-5 years. But these observations will not be continued on the following JPSS platforms. OMPS-Limb will be followed by the SAGE-III on the International Space Station, which may provide useful data to about the end of the lifetime of ISS (~2020). (NASA)

There is a vast amount of unprocessed Brewer Umkehr data residing in the archives. A concerted effort should be made to process these data using a common Dobson/Brewer algorithm, which is necessary for trend studies. The new Brewer Umkehr algorithm to derive ozone profiles under low sun condition is also in works (NASA, NOAA)

The only currently planned U.S. space-based ozone-monitoring instruments in the post-Aura era will be the NPOESS OMPS instrument, a limb scattering measurement with very little heritage, and the SAGE-III experiment on the ISS. In order to provide a
calibration source for OMPS so that the data will be of sufficient quality for scientific studies and trend analysis, consideration should be given to adding a simple solar occultation instrument to NPOESS. (NASA/NOAA/DOD)

NASA has two Earth Science Decadal Survey satellite missions recommended in the future. One (GEO-CAPE) is a geosynchronous orbit and designed to study North American air quality, but should also provide column ozone. The second (GACM) is described as a follow up to Aura with analogous instrumentation using more advanced technology. This will provide profiles for ozone and numerous trace gases in the stratosphere and troposphere. Neither project is planned to be launch until some time after 2020, leaving a large gap between Aura and the next mission. (NASA)

In order for ozone forecasts to improve in the NCEP/GFS, higher quality and greater numbers of ozone profiles need to be available for assimilation than what is available from the current nadir viewing SBUV/2. Ozone profiles from the Aura/MLS and OMI are promising as they provide ozone profiles of greater resolution (MLS) and of greater horizontal coverage (OMI). These products are now available in near-real-time, and are being assimilated into the NCEP/GFS. (NOAA/CPC)

**Ozone-Relevant Gases and Variables**

*Ozone- and Climate-Related Trace-Gas Measurements*

There is a need to maintain and expand the existing *in situ* networks, both geographically and with improved instrumentation. Current workforce limitations prevent the development and propagation of gas standards on as rapid a schedule as required by these networks to keep up with the increasing number of new chemicals of scientific interest. In addition, expanded efforts are needed for data analysis as more and more chemicals are being measured. An intercomparison study, IHALACE, for halocarbon standards between measurement groups that has examined differences in the individual gases was completed and a paper summarizing the results has been submitted for publication. The work found that most independent calibration groups agreed well for most compounds (<5%), but groups using the same calibration standards did not transfer the calibration. (NASA, NOAA)

*Aerosol Absorption Optical Thickness (AAOT)*

There are currently no operational ground-based instruments that provide AAOT in UV. AAOT from the AERONET network is limited to wavelengths longer than 440 nm. NASA has improved a long-standing technique to derive AAOT in UV by combining measurements from AERONET and UV Shadowband radiometers. Efforts to utilize this methodology for deriving AAOT in the UV should be implemented. (NASA)

*NEUBrew Network*

Future plans for the NEUBrew network are for algorithm development for aerosol optical thickness retrievals and direct-sun data processing to provide aerosol optical thickness estimates at the five direct-sun measured UV ozone and five visible NO₂ wavelengths.
**Ozone- and Climate-Related Trace-Gas Measurements**

There is a need to maintain and expand the existing *in situ* networks, both geographically and with improved instrumentation. Current workforce limitations prevent the development and propagation of gas standards on as rapid a schedule as required by these networks to keep up with the increasing number of new chemicals of scientific interest. In addition, expanded efforts are needed for data analysis as more and more chemicals are being measured. (NASA, NOAA)

**Field Campaigns**

Aircraft, balloon, and ground-based measurement campaigns for satellite validation and science are expected to continue, but at a much lower level than in the past since Aura is in its Extended Mission phase now. These campaigns will provide important validation data for ozone and ozone- and climate-related trace gases and parameters for Aura and other satellite sensors. They also will address high-priority science questions associated with atmospheric ozone chemistry and transport. (NASA)

**UV**

*USDA UV-B Monitoring and Research Programme (UVMRP)*

A new site was installed at the University of Texas at El Paso (UTEP) in November 2008. (USDA)

**Geographical Measurement Coverage**

UV monitoring in the tropics is very limited. Relatively inexpensive broadband UV instruments could be set up easily at installations launching ozonesondes (e.g., SHADOZ) in the tropical region. Such efforts should be coordinated with the NDACC. In this way, UV at the surface under aerosols/pollution can be linked with the ozone profiles measured by the ozonesondes and ground-based profiling instruments. (NOAA/CPC)

Only seven of the EPA Brewers are currently deployed in or near densely populated areas. Satellite-derived UVR is less reliable for urban locations, because satellite instruments do not adequately characterize pollutants at ground level. Because of the deficiency of current urban UVR data, health researchers conducting local studies are sometimes making their own UVR measurements as needed, with instruments that are often not easily compared with those from any of the existing UVR networks. Thus, better ground-level measurements collected in locations close to air-quality monitors are required. Finally, many sites have data gaps and inconsistencies. Only a limited number of ground-based sites provide historically continuous UV records. More analyses of available data and improved calibration could fill gaps in coverage. (EPA)

**Calibration and Validation**

It is now well established that the ratio of UVB and UVA can be predicted accurately under clear conditions and to within a few percent in cloudy conditions wherever quality column ozone data exist. Absolute measurements of ozone amounts from satellites are accurate to 2% resulting in a 2% error in UV irradiance at 310 nm and an 8% error at 305 nm. (EPA)
nm with larger errors at higher latitudes. UVA variability is known to correlate with variations in clouds, NO2, and aerosols, some of which are also measured by satellites. Ground based intercomparisons studies are using long time averages to simulate the spatial footprint of satellites. Further studies are required to determine the effectiveness of this approach. (NASA)

**Effects Research**
Although the effects of UV exposure drive UV monitoring activities, only limited resources historically have been targeted towards UVB effects research. Expansion of UVMRP activities in this critical area is needed at a multi-agency level. (USDA)

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**Acronyms and Abbreviations**

- **AAOT** aerosol absorption optical thickness
- **ACIA** Arctic Climate Impacts Assessment
- **AERONET** Aerosol Robotic Network
- **AGAGE** Advanced Global Atmospheric Gases Experiment
- **AIRS** Atmospheric Infrared Sounder
- **AO/AAO** Arctic/Antarctic oscillation
- **BSI** Biospherical Instruments
- **BUV** Backscatter Ultraviolet
- **CAFS CCD** Actinic Flux Spectroradiometer
- **CCD** charge-coupled device
- **CDIAC** Carbon Dioxide Information Analysis Data Center
- **CFC** chlorofluorocarbon
- **COADS** Comprehensive Ocean-Atmosphere Data Set
- **CPC** Climate Prediction Center (NOAA, U.S.)
- **CrIS** Cross-track Infrared Sounder
- **CSD** Chemical Sciences Division (formerly the Aeronomy Lab, NOAA, U.S.)
- **CSD Chemical Sciences Division (NOAA,US)**
- **CSU** Colorado State University (United States)
- **CTMs** chemical transport models
- **CUCF** Central Ultraviolet Calibration Facility
- **DAAC** Distributed Active Archive Center (NASA Langley, U.S.)
- **DISC** Data and Information Services Center (NASA Goddard, U.S.)
- **DoD** Department of Defense (United States)
- **DoE** Department of Energy (United States)
- **DOAS** Differential Optical Absorption Spectroscopy
- **ECD** electron capture detector
- **ECMWF** European Centre for Medium-Range Weather Forecasts (United Kingdom)
- **ECUV** European UV Calibration Center
- **EECl** effective equivalent chlorine
- **EESC** effective equivalent stratospheric chlorine
- **EOS** Earth Observing System
- **E EuMetSat** European Organization for the Exploitation of Meteorological Satellites
- **P** Earth Probe
EPA Environmental Protection Agency (United States)
ESRL Earth System Research Laboratory (NOAA, US)
FMI Finnish Meteorological Institute (Finland)
FTIR Fourier transform infrared
GAW Global Atmosphere Watch
GC Gas Chromatograph
GCM general circulation model
GCMS Gas Chromatography Mass Spectrometry
GES Goddard Earth Sciences
GFS Global Forecast System
GMAO Global Modeling Assimilation Office (NASA Goddard, U.S.)
GMD Global Monitoring Division (formerly CMDL – NOAA, U.S.)
GOES Geostationary Operational Environmental Satellite
GO3OS Global Ozone Observing System (WMO)
GOME Global Ozone Monitoring Experiment
GOMOS Global Ozone Monitoring by Occultation of Stars
GSFC Goddard Space Flight Center (NASA, U.S.)
HALOE Halogen Occultation Experiment
HIRDLS High-Resolution Dynamics Limb Sounder
HIRS High-resolution Infrared Radiation Sounder
IHALACE International Halocarbons in Air Comparison Experiment
IASI Infrared Advanced Sounding Interferometer
JPL Jet Propulsion Laboratory (United States)
KNMI Koninklijk Nederlands Meteorologisch Instituut (The Netherlands)
MetOp Meteorological Operational Satellite
MFRSRs Multi-Filter Rotating Shadowband Radiometers
MIPAS Michelson Interferometer for Passive Atmospheric Sounding
MIRAGE Megacity Impacts on Regional and Global Environments
MLS Microwave Limb Sounder
NASA National Aeronautics and Space Administration (United States)
NAT nitric acid trihydrate
NCAR National Center for Atmospheric Research (United States)
NCEP National Centers for Environmental Prediction (NOAA, U.S.)
NDACC Network for the Detection of Atmospheric Composition Change
NDIR non-dispersive infrared
NESDIS National Environmental Satellite, Data, and Information Service
(NOAA, U.S.)
NIST National Institute of Standards and Technology (United States)
NIWA National Institute of Water and Atmospheric Research (New Zealand)
NOAA National Oceanic and Atmospheric Administration (United States)
NOGAPS Navy Operational Global Atmospheric Prediction System
NPOESS National Polar-Orbiting Operational Environmental Satellite System
NPP NPOESS Preparatory Satellite
NRL Naval Research Laboratory (United States)
NSF National Science Foundation (United States)
NWS National Weather Service (NOAA, U.S.)
ODGI ozone-depleting gas index
ODSs ozone-depleting substances
OHP Observatoire de Haute-Provence (France)
OMI Ozone Monitoring Instrument
OMPS Ozone Mapping and Profiler Suite (NPOESS)
OMS Observations of the Middle Stratosphere
OSIRIS Optical Spectrograph and Infrared Imaging System
PEM Particle Environment Monitor
POAM Polar Ozone and Aerosol Measurement
POES Polar Orbiting Environmental Satellites
PSCs polar stratospheric clouds
PTB Physikalisch-Technische Bundesanstalt (Germany)
QBO quasi-biennial oscillation
SAGE Stratospheric Aerosol and Gas Experiment
SAM Stratospheric Aerosol Measurement
SBUV Solar Backscatter Ultraviolet
SCIAMACHY Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SHADOZ Southern Hemisphere Additional Ozonesonde (Network)
SOLSTICE Solar Stellar Irradiance Comparison Experiment
SPARC Stratospheric Processes and Their Role in Climate
VIETNAM

Introduction
The National Hydro-meteorological Service of Socialist Republic of Vietnam (NHMS) has three ozone and UV-B observing stations, with Hanoi station (21°01’N, 105°51’E) established in 1992, later joined by Sapa station (22°21’N, 103°49’E) and Tan Son Hoa station (10°47’N, 106°42’E) in 1994. In April 2008, Tan Son Hoa station ceased to observe because of instrumental problems. Observation management in NHMS has been operated by the Aero-Meteorological Observatory (AMO).

Observational activities
The total amount of atmospheric ozone (TO3) and UV-B are measured by Russia’s M124 filter instruments. TO3 is measured seven times a day with sun heights between 20° and 70°, while UV-B is observed eleven times per day from 07:00 to 17:00 from May 1st to October 31st, and nine times per day from 08:00 to 16:00 from November 1st to April 30th. In 2006, AMO sent all the instruments to GGO (Petersburg, Russia) for calibration. However, since the M124 type were no longer in production, most of the instruments after calibration have not produced high quality observational data. Nonetheless, all three stations still make observations according to the National Guide for Observation.

Observation results and analysis
According to the satellite-derived Global Distribution of Total Ozone, Vietnam is located in the region with the total ozone amount between 200DU and 300DU (1), with the minimum in winter and the maximum in summer.

As shown on Table 1 and Figure 1 below, the total ozone amount measured at Tan Son Hoa station varied between 120DU and 240DU from January 2006 and December 2007, which is lower than the satellite measurements. Ozone trends were different in 2006 and 2007, with 2007 seeing an irregular trend with a rapid increase from the minimum of 120DU in February to the maximum of 240DU in June. In general, TO3 in 2006 and 2007 was lower than the normal value.

No data update has been made for TO3 observed at Tan Son Hoa station since 2008 due to instrumental problems.
Table 1: Total amount of ozone, Tan Son Hoa station (Unit: DU)

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Figure 1: Total amount of ozone, Tan Son Hoa station (Unit: DU)

In the same period (2006-2007), TO3 measured at Hanoi station was slightly higher (see Table 2 and Figure 2) than at Tan Son Hoa station. Notably, in 2007 and 2010, total ozone amount abnormally peaked in February instead of summer.

From 2008, TO3 sees a more stable and slightly increasing trend in comparison to 2007, with 2010 having the highest TO3 and 2008 the lowest.
Table 2: Total amount of ozone, Hanoi station (Unit: DU)

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Figure 2: Total amount of ozone, Hanoi station (Unit: DU)

TO3 measured at Sapa station ranged from 200DU to 300 DU during 2006-2007 (see Table 3 and Figure 3 below). However, the 2007 trend was not consistent with the Global Distribution of Total Ozone. The total amount of ozone in 2010 was the highest since 2004, emphasizing the overall upward trend since 2008. In general, annual TO3 at Sapa station decreased from January to December, except for February.
Table 3: Total amount of ozone, Sapa station (Unit: DU)

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</table>

Figure 3: Total amount of ozone, Sapa station (Unit: DU)

In addition, column ozone measurements are currently initiated at Hanoi station in collaboration with Japan, with a planned schedule of 1-2 times per month.
Due to the instrumental obsolescence and limited budget for equipment calibration, the ozone data have not been verified, leading to unverified UV-B. Thus UV-B dataset is not presented in this report.

**Future Plan**
Currently, NHMS is in the process of replacing old M124 instruments with Brewer spectrophotometers. The replacement process was planned to complete at the end of 2010. Due to some difficulties, however, it has to be extended into the first half of 2011.

**Recommendations**
In order to improve the observation and measurement of TO3 and UV-B to meet the data quality requirement, there is a strong need for new, modern equipments along with capacity strengthening for NHMS. It is essential that NHMS receive financial and technical support for its instrumental upgrade and staff capacity-building programmes. In particular, NHMS calls for support for the ozonesounding activity in Hanoi, which is planned to take place at least once a week, in parallel to the twice-a-day radiosounding by Finland-manufactured DigiCORA-RS sonde.

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National Report About the Status of Ozone Monitoring

Introduction
Zimbabwe ratified The Vienna Convention for the protection of Ozone layer and the Montreal Protocol on substances that deplete the ozone layer in 1992. The Country Programme has been implemented since 1995 under the Ministry of Environment and Natural Resources Management.

Zimbabwe, like most developing countries has struggled to raise the necessary financial and technical resources to establish National Action Plan for the measurement of Ozone and other stratospheric and tropospheric substances including UV.

Monitoring and Observational Activities of Ozone (current status)
Zimbabwe is yet to undertake observational activities on ozone methodologies including column measurement, profile measurement of ozone and other gases necessary for monitoring the loss of ozone. Although we are very much committed to be among those countries which are on the forefront of monitoring ozone with the zeal to minimize its depletion, our biggest challenge remain the lake of equipment and funding. We do not have anything even the Narrowband filter instruments or Spectro-radiometers and other instruments for the measurement of UV through broadband.

Although we do have our Meteorological Department within the Ministry of Transport and Communication with over 30 stations scattered allover the country their activities have not been anything concerned with ozone. The reason why they have not been doing this comes back to the issue of economic hard times which then cascade to lack of proper equipment and good instruments. The only data available is that of the trend in annual minimum and maximum temperatures up to 2004. Data beyond this date including, 2010 is not available in the national Meteorological Offices suggesting the extend of the desirable need to start equipping the Ozone Project Office with financial resources and equipment for the project to be able to kickoff.

Projects and Collaboration
We have never had and any collaborative activities or projects related to research/monitoring on the status of ozone over Zimbabwe as well as to determine the level of ground UV/Ozone.

Future Plan
Since we have an office for the ozone project in the Ministry of Environment and Natural Resources, we plan to start research activities related to the monitoring of UV/Ozone once the committees are set. We will then have to launch a memorandum of understanding (MOU) between the University of Zimbabwe, Department of Chemistry, Various Ministries Concerned and the department of meteorological services. The Ozone office within the ministry of environment will then do coordination of activities.
**Financial Needs**

We need the instruments like the Dobson Spectrophotometer, ozonesondes observatory to be set in Harare and other minor instruments including UV sensors or digital UV instruments to help in the measurement of UV.

**Conclusion**

We intend to contribute immensely in the data provision of the status of ground UV and OZONE.
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<td>WMO Consultation on Brewer Ozone Spectrophotometer Operation Calibration and Data Reporting (Arosa, Switzerland, August 1990).</td>
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47. Scientific Assessment of Ozone Depletion: 2002 - Twenty Questions and Answers about the Ozone Layer.

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52. Scientific Assessment of Ozone Depletion: 2010