WORLD METEOROLOGICAL ORGANIZATION
GLOBAL ATMOSPHERE WATCH

No. 142

Strategy for the Implementation of the Global Atmosphere Watch Programme (2001 – 2007)

A Contribution to the Implementation of the WMO Long-Term Plan

June 2001

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THE GLOBAL ATMOSPHERE WATCH (GAW) STRATEGIC PLAN 2001-2007

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FOREWORD

Based on a recommendation from the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry and supported by Twelfth Congress, a strategic plan to further develop WMO's Global Atmosphere Watch was prepared covering the period 1997-2000. Important progress was made during that period under guidance from the plan. This progress was acknowledged by Thirteenth Congress in 1999 and by the EC Panel/CAS Working Group at its most recent session in April 2001.

The present document has been prepared as a contribution to the WMO Long-Term Plan and represents a GAW Strategic Implementation Plan for the period 2001-2007 which builds on the successes evident in recent years. It has been developed in a series of interactive steps that has included consultations and advice from the international GAW community, including the GAW Scientific Advisory Groups, directors of the Quality Assurance/Science Activity Centres and World Calibration Centres, Word Data Centre managers and a number of atmospheric chemistry experts.

I wish to thank the numerous individuals who have been involved in the drafting and review stages of the Plan's development, the EC Panel members who provided insightful guidance and especially Messrs Gerhard Müller of the Swiss Meteorological Institute and Joerg Klausen of the Swiss Federal Materials and Research Laboratory, who took lead roles in its preparation.

I hope those readers who actively contribute to the GAW system will carefully review the contents of this report and find it possible to participate in fulfilling the goals and implementation tasks outlined therein.

(G.O.P. Obasi)

Secretary-General

THE GLOBAL ATMOSPHERE WATCH (GAW)

STRATEGIC PLAN 2001-2007

EXECUTIVE SUMMARY

Rationale and Mission of GAW

The depletion of the stratospheric ozone layer, increases in tropospheric ozone, acid deposition, rising greenhouse gas 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-supporting system of planet Earth.

The **rationale** for GAW is driven by the need to

- Understand the complex mechanisms with respect to natural and anthropogenic atmospheric change.
- Improve the understanding of interactions between the atmosphere, ocean and biosphere.
- Provide reliable scientific data and information for national and international policy makers..

Established in 1989 by the Eleventh World Meteorological Congress (Cg-XI) as a major priority programme, GAW is one of WMO's most important contributions to the study of environmental issues in the post-UNCED period (United Nations Conference on Environment and Development, 1992).

The **mission** of the Global Atmosphere Watch is to

1. Make reliable, comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere on global and regional scales.
2. Provide the scientific community with the means to predict future atmospheric states.
3. Organize assessments in support of formulating environmental policy.

GAW is considered the atmospheric chemistry component of the Global Climate Observing System (GCOS).

Programme Status

About **80 WMO Member countries** are currently participating in the measurement programme of GAW, and a quarter of them are establishing or operating Global Stations. About ten countries provide GAW central facilities. As of July 2000, about **300 GAW stations**, mostly concentrated in WMO Regions II, IV and VI were in operation. Of these, 22 were Global Stations (cf. Figure 1) with the remainder Regional stations. The WMO Secretariat maintains a station inventory of operational GAW stations.

Global Stations are usually situated in remote locations, have very low (background) levels of pollutants that are representative of large geographic areas, and continuously measure a broad range of atmospheric parameters over decades. High priority is given to measurements of the vertical distribution of ozone, total ozone, greenhouse gases, precipitation chemistry, aerosol components, reactive gases and UV. **Regional Stations** are representative of smaller geographic regions unaffected by nearby sources of pollution such as vehicular, industrial or agricultural activities. They generally carry out a narrower set of observations. Data are typically applied to regional issues such as acid deposition, transport of trace gases and aerosols, and local UV radiation.

Many World Data Centres receive data from stations that have not formally been designated as either Global or Regional GAW stations. Their contribution to GAW is nevertheless very valuable and they are classified as either **Contributing Stations or Associate Stations**. Contributing station networks include the Network for Detection of Stratospheric Change (NDSC), the Baseline Surface Radiation Network (BSRN), and the European Monitoring and Evaluation Programme (EMEP).

Space-based observations (cf. Table 2) offer a partial solution toward the goal of achieving global coverage of measurements important to the GAW programme. These measurements include ozone (column and profile), solar radiation, aerosol measurements such as aerosol optical depth and measurements of some trace gases in the free troposphere such as carbon monoxide. Ultraviolet radiation, VOCs, nitrogen oxides, and certain aerosol parameters also belong to the new generation of measurements from space that may one day benefit from the ground based GAW network of measurements.

A number of GAW central facilities have been established to ensure high quality data from the network, with guidance provided by the WMO Commission for Atmospheric Sciences (CAS) and its EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (the "Panel"). These comprise six Scientific Advisory Groups (SAGs) to organise and co-ordinate GAW activities by parameter, four Quality Assurance/Science Activity Centres (QA/SACs) to perform network-wide data quality functions, ten World Calibration Centres, assisted by Regional Calibration Centres, to maintain calibration standards, provide instrument calibrations and training to the stations, and six World Data Centres to archive the atmospheric data information. Table 1 gives an overview of these **World Central Facilities**.

The first edition of the Strategic Plan was published in 1997 (GAW Report No. 113). The participants learned a lot by putting this plan in place although not all goals were met. The Congress of WMO recognised that the plan has to be an evolving document and that it should be modified with changing conditions and with operating experience. This **second edition of the strategic plan** is based on the decisions of Cg-XIII in 1999 and covers the years 2001-2007. For the period 2001-2004 detailed implementation steps are given. The Strategic plan primarily addresses GAW specialists, professional GAW bodies such as the Panel, Scientific Advisory Groups or operational GAW institutions, and secondly other interested scientists. It has been reviewed and approved in its entirety by the Panel.

Critical Issues

A number of critical issues and challenges are associated with the proper functioning of GAW. These can be summarised as:

- The need to find realistic approaches and set clear priorities in view of the system's scope and complexity.
- The need to expand the number of countries able to contribute to the operation of the programme.
- The need to strengthen operational thrust of the programme.
- The need to ensure adequate human and financial resources, particularly in developing countries, in order to maintain and enhance GAW's operational infrastructure.

Strategic Goals

Main strategic goals have been identified. They are generally consistent with the critical issues raised above and correspond to the main long-term objectives of GAW in the Fifth WMO Long-term Plan 2000-2009 (WMO-No. 908). The primary difference with respect to the Fourth Long-term Plan (1996-2005) is the introduction of activities in urban atmospheric environments into the GAW programme. The strategic goals are:

- Improve measurements programme for better geographical and temporal coverage and for near real time monitoring capability.
- Complete the quality assurance/quality control (QA/QC) system.

- Improve availability of data and promote their use.
- Improve communication and co-operation between all GAW components and with the scientific community.
- Identify and clarify changing roles of GAW components.
- Maintain present, and solicit new support and collaborations for the GAW programme.
- Intensify capacity building in developing countries.
- Enhance the capabilities of NMHSs in providing urban-environmental air quality services.

Implementation Strategy

The overall implementation strategy focuses on the following activities for 2001-2004:

- Stabilise operations at the present stations and extend measurements in regions with insufficient coverage, especially in the Tropics, the Southern Hemisphere and in continental areas, and continue capacity building efforts.
- Evolve GAW into a three-dimensional global observation network through the integration of surface-based, aircraft, satellite and other remote sensing observations.
- Acquire and distribute only data of high and known quality through establishing data quality objectives and standard operating procedures for all measurements.
- Intensively use the potential of the World Wide Web as a means of communicating GAW information, exchanging data and managing GAW activities.
- Expand the user base by providing easy access to the data and by promoting data applications for modelling and scientific assessments.
- Build analysis capabilities at GAW facilities in co-operation with the scientific research community.
- Expand the support base by enlisting the assistance of the world's best researchers and institutes in GAW leadership and activities, and by working closely with the NMHSs.
- Strengthen GAW leadership by organising regular review meetings with participation of the "key players" in order to control the development of the programme.

The status, goals and implementation steps are specified for all main components of GAW in chapters 3-9.

Development of the Measurement Programme

The future developments of the individual measurement parameters have been specified by the SAGs and can be summarised as follows:

Ozone (O_3) plays a central role in physical, chemical, and radiative processes in the troposphere. In spite of its effects on the biota and human health, our knowledge of trends in the global distribution of **surface ozone** is still incomplete; there is a need for more stations in the middle of continents (e.g. Asia) and in the Southern Hemisphere. The need for high quality **total ozone** observations continues. The recent changes observed in stratospheric ozone and the almost total elimination of releases of chlorofluorocarbons through international agreements require that observations be continued for decades in order to monitor the expected return of the ozone layer to its previous state. Improving our knowledge of the vertical distribution of ozone at the global scale is of high priority. Development of standard operating procedures for **ozone sondes** and expansion of the sounding network over the Tropics and the Southern Hemisphere will be the key issues.

Of the greenhouse gases that are directly affected by anthropogenic activities, **carbon dioxide** (CO_2) has the largest total radiative effect, followed by **chlorofluorocarbons** (CFCs), **methane** (CH_4), **tropospheric ozone** (O_3), and **nitrous oxide** (N_2O). If we are to provide reliable long-term estimates of CO_2 increases appropriate to particular emission management scenarios the target precision of the CO_2 measurement programme is set at 0.1 ppm in the Northern, and 0.05 ppm in the Southern Hemisphere. Continued operation of the CO_2 network will need to be directed towards resolving these issues and acquiring more complete information about sources and sinks. Additional data are needed from continental areas and low latitudes which is also true for other greenhouse gases.

With respect to reactive gases, highest priority will need to be given to complete the operational **carbon monoxide** (CO) programme and to develop monitoring of **volatile organic compounds** (VOCs) and **nitrogen oxides** (NO_x). Regarding CO, the highest priority will be afforded to laboratory inter-comparisons. In order to determine global trends in CO an expansion of measurements in the middle and high latitudes of the Southern Hemisphere is desirable. There is now a wealth of data on VOCs and NO_x from aircraft campaigns in various parts of the world. GAW can benefit from the experience gained in these international projects. Sulphur dioxide (SO_2) has not been routinely monitored at Global Stations; measurements have only low priority over the next several years.

Despite the obvious achievements of GAW acid deposition **precipitation chemistry** activities since the 1960s, some problems remain. In particular, economic development and population growth in countries in Asia, South America and Africa, as well as the climate change issue, have made these regions vulnerable to atmospheric deposition of pollutants. In addition, there is growing global concern with regard to atmospheric deposition of **heavy metals** and **persistent organic pollutants** (POPs). In many areas reductions in emissions of sulfur dioxide have been reflected in precipitation chemistry, but it is increasingly evident that the deposition of nutrients (nitrogen and perhaps phosphorous) in precipitation is contributing to the overenrichment of ecosystems and the eutrophication of coastal waters. Monitoring of precipitation chemistry remains, therefore, an important GAW contribution, worldwide. The addition of these new considerations to what was initially a programme focused on acid rain will result in revisions to the GAW standard operating procedures and improvements in quality assurance/quality control and data management.

The radiation component of GAW is concentrated on **UV radiation**. Other specialised WMO programmes such as the World Weather Watch (WWW) and the BSRN deal with other aspects of solar radiation. With UV radiation linked to several harmful effects on many forms of life, the necessity for monitoring surface UV radiation and quantifying future changes is of great importance. During recent years, instrument intercomparisons, new guidelines, harmonisation of the UV-Index as well as the expansion of the measuring network have greatly helped improve the quality of the UV measurements. The future programme remains very ambitious; it includes further development of the network, standard operating procedures, establishment of calibration centres and promotion of the use of UV data.

Aerosol activities have developed into a core component of GAW because of their importance to a wide range of issues from global climate change to regional and local air quality. The aerosol programme includes **optical depth** measurements and addresses both climate and health issues. Regional aerosol aspects may frequently be equally or more important than global concerns. For the future it will be important to establish the recommended measurement programme by developing a sense of community that results in increased participation in the GAW aerosol programme.

The global distributions of the source-sink terms of the naturally occurring **radionuclides** (^{7}Be, ^{10}Be, ^{210}Pb, and ^{222}Rn) and the anthropogenic radionuclide (^{85}Kr) are reasonably well known. They serve as ideal tools to assess large- and global-scale transport of gases and aerosols.

Over the lifetime of this Strategic Plan human activities will continue to change the composition of the atmosphere. Although efforts will most likely be made to control these changes through international protocols, the earth's atmosphere can be expected to exhibit increasing levels of most trace species. The WMO's Global Atmosphere Watch system, therefore, must continue to monitor these changes and provide crucial scientific information for studies to understand and imately predict future climate and global change.

1. INTRODUCTION

1.1 Mission and Objectives

The depletion of the stratospheric ozone layer, increase in tropospheric ozone, acid deposition, rising greenhouse gas 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-supporting system of planet earth. These issues are likely to be with us for a long time. The causes will persist over the coming decades, and social awareness and demands for remedial and preventive actions will continue to increase.

Recognising the fundamental importance of the atmosphere to the ecological well-being of the planet, the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, pointed out that the ability to monitor and predict both the short- and long-term evolution of the earth's atmospheric environment and the impacts of these changes on the total climate system was an essential precondition for achieving sustainable development. It is the need to achieve this capability and, ultimately, to understand the complex and interlinked mechanisms of both natural and anthropogenic atmospheric change that provides the rationale for GAW. Established by the Eleventh WMO Congress (Cg-XI) in 1991 as a major priority programme, GAW is one of WMO's most important contributions to the study of environmental issues in the post-UNCED period.

Mission

The *mission* of the Global Atmosphere Watch is to make reliable, comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere in order to provide the scientific community with the means to predict future atmospheric states, and to organize assessments in support of formulating environmental policy.

Objectives

The *main long-term objectives* of GAW are described in the Fifth WMO Long-term Plan 2000-2009 (WMO-No. 908). Quoted verbatim, they are,

- "To develop further, whenever feasible, a functional system for real-time or quasi real-time measurement of the atmospheric composition enabling the prediction of future states of the earth system and thus providing an early warning of its changes.
- To improve the understanding of both stratospheric and tropospheric budgets of ozone and relevant compounds in order to develop improved coupled atmospheric chemistry and transport models, and their application in problems associated with the impact of ozone variations on living organisms.
- To further understand the chemistry and physics of the atmosphere and the cycles of greenhouse gases, as well as oxidising species and other atmospheric constituents.
- To promote studies of the interaction of the atmosphere with the marine and terrestrial biosphere.
- To co-ordinate and develop the necessary technology and facilities for use in response to environmental emergencies.
- To meet the responsibilities of WMO in providing leadership and guidance to governments in international efforts directed towards the protection and management of the atmospheric environment.
- To promote and co-ordinate activities in atmospheric urban environment.

- To facilitate the training of monitoring station personnel and the transfer of technology in measurement techniques, data analysis and application."

The main difference with respect to the Fourth Long-term Plan (1996-2005) is the introduction of activities in urban atmospheric environments into the GAW programme.

1.2 Operating Environment

National and international policy decisions affecting the environment in the 21st century will rely heavily on scientific data gathered through GAW. The need for better global atmospheric data is driven both by scientific uncertainties and by policy considerations. In practice, there is no strong societal incentive to resolve scientific uncertainties unless a policy issue is at stake, and it is mostly when scientific uncertainties and policy requirements coincide that the need for new data is strongest.

The success of GAW will depend to a great extent on the involvement of the atmospheric science community. Several large multi-component international scientific programmes in atmospheric chemistry and aerosols exist and interact closely with GAW and its sites. There are, however, important differences in emphasis and approach between GAW and many of these other programmes. While the focus of GAW is on long-term observations through a network of global and regional sites, other international programmes are more process-oriented and hence involve intensive campaign-type measurements in specific geographic regions of the globe.

Through other programmes such as the World Weather Watch and the World Climate Programme, WMO has acquired extensive experience in building up operational observing networks and exchanging data and products within the framework of a worldwide community. However, GAW also presents new challenges. As a contributing part of the Global Climate Observing System (GCOS), GAW deals with a wide variety of global issues that are quite different from those that concern classical meteorology. Moreover, observations of chemical composition require additional sophistication in measuring techniques including awareness of data quality. As a consequence of these challenges, there must be substantial collaboration between WMO and its technical commissions and international organizations and programmes such as the United Nations Environment Programme (UNEP), the International Atomic Energy Agency (IAEA), the World Health Organization (WHO), the International Council for Science (ICSU), the Commission for Atmospheric Chemistry and Global Pollution (CACGP), the International Ozone Commission (IOC), the International Geosphere-Biosphere Programme (IGBP) of ICSU and its International Global Atmospheric Chemistry Programme (IGAC), the Baseline Surface Radiation Network (BSRN), the Network for the Detection of Stratospheric Change (NDSC), and a large number of international activities that focus on atmospheric chemistry and climate. In addition, various continental programmes such as the Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) and the North American Research Strategy for Tropospheric Ozone (NARSTO) have potential for complementary contributions to GAW.

1.3 Status Summary

In 1999 GAW became ten years old. During the past decade, as the Thirteenth WMO Congress noted, "GAW continued to mature [...] under the guidance of the Strategic Plan". With its global station network and recent improvements, GAW has now reached broad acceptance as the baseline global measurement system for the community of atmospheric chemists and physicists.

National Meteorological and Hydrological Services (NMHSs) have the most important role in supporting GAW. WMO has requested all its Members to give the same attention to atmospheric chemistry measurements as to other meteorological parameters and has encouraged the NMHSs to ensure that chemical composition observations become an integral part of atmospheric observations. About 80 Member countries are currently participating in GAW's measurement programme, and a quarter of them are establishing or operating global stations. With respect to services provided by central facilities, GAW depends on relatively few countries.

As of July 2000, there were about 300 GAW stations, mostly concentrated in WMO Regions II, IV, and VI. Of these, 22 were Global stations (cf. Figure 1) with the remainder Regional stations. The most notable recent improvements to the network was the addition of six global monitoring sites under the Global Environment Facility (GEF) and UNDP project "Monitoring of Greenhouse Gases Including Ozone". These are located at Tamanrasset/Assekrem, Algeria; Ushuaia, Argentina; Mount Waliguan, China; Bukit Koto Tabang, Indonesia; Mount Kenya, Kenya; and Arembepe, Brazil. Of these stations, the first four are in operation while the last two are currently completing their start-up phase. Under another WMO/GEF/UNDP project "Monitoring Ozone and UV-B in Southern Cone Countries", Regional stations were established in Argentina, Brazil, Chile, Paraguay and Uruguay.

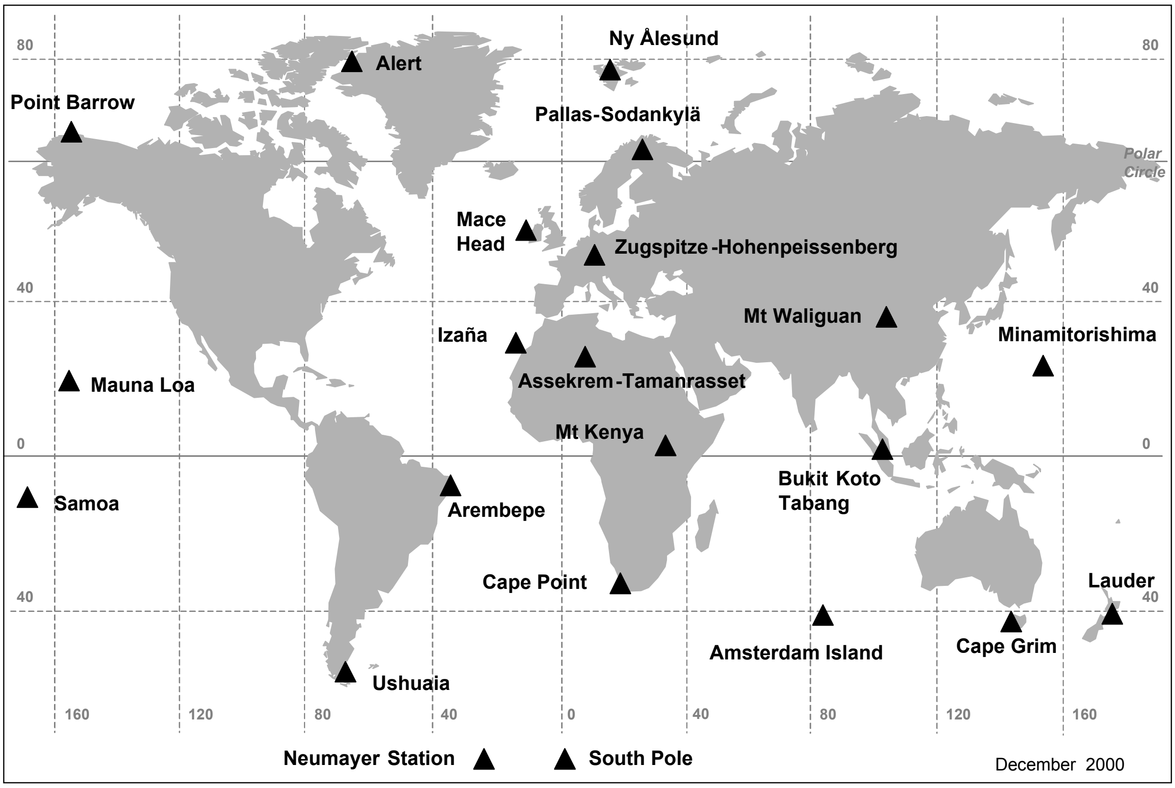

FIGURE 1. Global Station Network of the Global Atmosphere Watch

Global stations measure many of the key variables in order to fulfil their role to serve as standards for other stations in their region. Within the global measuring programme, high priority is given to measurements of the vertical distribution of ozone, total column ozone, greenhouse gases, precipitation chemistry, aerosol components, and UV. Most Regional stations carry out a narrower set of parameters.

The Commission for Atmospheric Sciences (CAS) is the lead WMO technical commission for research activities (including those of the GAW) in the atmospheric sciences and related fields. CAS has formally designated the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (the "Panel") as the overall steering body for the GAW.

Following the recommendations of the previous version of the Strategic Plan, the Panel has established Scientific Advisory Groups (SAGs) to organise and co-ordinate GAW activities for six different parameter types. Each SAG is responsible for establishing and overseeing the observation network, the data quality procedures and scientific work for its assigned parameter type. Within the WMO Secretariat, the Environment Division (referred to as the Secretariat in this document) of the Atmospheric Research and Environment Programme (AREP) Department provides the operational support for GAW and co-ordinates with other WMO programmes. The management and leadership of the operation of GAW is the major activity of the Secretariat.

Quality assurance procedures for GAW are developed and currently implemented by four Quality Assurance/Science Activity Centres (QA/SACs). While the QA/SACs perform a network-wide quality review, the stations have primary responsibility for the quality of the data generated at their sites. The QA/SACs organise and co-ordinate, in co-operation with the Secretariat, QA-related GAW activities. GAW-specific education and training is an integral part of the QA component and generally is regional in character. In recent years, many training sessions at stations and several regional workshops have been organised by the QA/SACs and WMO.

Ten World Calibration Centres, assisted by Regional Calibration Centres, maintain calibration standards, provide instrument calibrations and training to the stations. GAW also operates six World Data Centres for collection of atmospheric data from its network. Table 1 gives an overview of the World Central Facilities.

TABLE 1. Overview of the GAW World Central Facilities (as at December 2000). The World Central Facilities have assumed global responsibilities, unless indicated (Am: Americas; E/A: Europe and Africa; A/O: Asia and the South-West Pacific)

Species	QA/SAC	World Calibration Centre	Reference Standard	World Data Centre
CO_2	JMA (A/O)	CMDL	CMDL	JMA
CH_4	EMPA (Am, E/A) JMA (A/O)	EMPA (Am, E/A) JMA (A/O)		JMA
N_2O	UBA[5]	IFU[5]	CMDL	JMA
CFCs				JMA
Total Ozone	JMA (A/O)	CMDL[1], MSC[2], MGO[3]	CMDL[1], MSC[2]	MSC
Ozone Sondes	FZ-Jülich[5]	FZ-Jülich	FZ-Jülich	MSC
Surface Ozone	EMPA	EMPA	NIST	NILU
Precipitation Chemistry	ASRC-SUNY	ASRC-SUNY	ISWS	ASRC-SUNY
CO	EMPA	EMPA	CMDL	JMA
VOC	UBA[5]	IFU[5]		JMA
SO_2				JMA
NO_x				JMA
Aerosol				JRC
Optical Depth		PMOD/WRC	PMOD/WRC[4]	JRC
UV Radiation	ASRC-SUNY (Am)	SRRB (Am)[5]		MSC
Solar Radiation		PMOD/WRC	PMOD/WRC	MGO
^{85}Kr, ^{222}Rn		EML		JMA
^{7}Be, ^{210}Pb		EML		EML

ASRC-SUNY	Atmospheric Sciences Research Centre, State University of New York (SUNY), Albany NY, USA, hosting the World Data Centre for Precipitation Chemistry (WDCPC)
BSRN	Baseline Surface Radiation Network, Federal Institute of Technology (ETH), Zürich, Switzerland
CMDL	Climate Monitoring and Diagnostic Laboratory, National Oceanic and Atmospheric Administration (NOAA), Boulder CO, USA
EML	Environmental Measurements Laboratory, Department of Energy (DoE), New York City NY, USA
EMPA	Swiss Federal Laboratories for Materials Research and Testing, Dübendorf, Switzerland
FZ-Jülich	Forschungszentrum Jülich, Jülich, Germany
IFU	Fraunhofer Institut für Atmosphärische Umweltforschung, Garmisch-Partenkirchen, Germany
ISWS	Illinois State Water Survey, Champaign IL, USA
JMA	Japan Meteorological Agency, Tokyo, Japan, hosting the World Data Centre for Greenhouse Gases (WDCGG) and the Quality Assurance/Science Activity Centre for Asia and the South-West Pacific
JRC	Environment Institute, Ispra, Italy, hosting the World Data Centre for Aerosols (WDCA)
MGO	A.I. Voeikov Main Geophysical Observatory, Russian Federal Service for Hydrometeorology and Environment, St. Petersburg, Russia, hosting the World Radiation Data Centre (WRDC)
MSC	Meteorological Service of Canada – formerly Atmospheric Environment Services (AES), Environment Canada, Toronto, Canada, hosting the World Ozone and UV Data Centre (WOUDC)
NILU	Norwegian Institute for Air Research (NILU), Kjeller, Norway, hosting the World Data Centre for Surface Ozone (WDCSO)
NIST	National Institute of Standards and Technology, Gaithersburg MD, USA
PMOD/WRC	Physikalisch-Meteorologisches Observatorium Davos/World Radiation Centre, Davos, Switzerland
SRRB	Surface Radiation Research Branch of NOAA's Air Resources Laboratory, Boulder CO, USA
UBA	German Environmental Protection Agency, Berlin, Germany

[1] Dobson only
[2] Brewer only
[3] Filter instruments
[4] Precision Filter Radiometers (PFR)
[5] Being established

1.4 Strategic Goals

The previous GAW Strategic Plan listed core activities which remain as effective guidelines. The strategic goals discussed here fulfil the requirements within those guidelines, and have been used to select the specific goals in each of the sections that follow.

Goal A. Improve measurements programme for better geographical and temporal coverage and for near real time monitoring capability

Review of the status of stations and expansion of some measurement programmes are necessary to provide adequate global coverage for the core measurement parameters of GAW.

Goal B. Complete the quality assurance/quality control (QA/QC) system

Although standard operating procedures (SOPs) and data quality objectives (DQOs) are in place for some measurements, continued efforts to establish them for all measured parameters and to refine those that are presently in place will be necessary. Routine calibration procedures for many of the measurements are not in place but are necessary to maintain a high level of confidence in the quality of the data.

Goal C. Improve availability of data and promote their use

The data centres now contain valuable data which must be made more readily available for modelling, satellite validation, near real-time needs, and for local use.

Goal D. Improve communication and co-operation between all GAW components and with the scientific community

Communication between all of the GAW components needs to be improved, particularly between stations. Communication with NMHSs and within their various national components must be improved. WMO maintains a station directory that lists all GAW component information. Internet can be exploited to help provide the communication links.

Goal E. Identify and clarify changing roles of GAW components

The SAGs will assume a greater role in the implementation of the GAW Strategic Plan, GAW Advisors to the Secretariat will be used more frequently, QA/SACs will assume larger geographic responsibilities than in the past, and Calibration Centres will expand activities to include regional centres.

Goal F. Maintain present and solicit new support and collaborations for the GAW programme

The GAW programme is strongly supported by the Member countries of the WMO. Much of the direct support necessary to co-ordinate this programme is of a voluntary nature. The GAW programme's increased presence in developing countries is necessary to provide the global coverage required to attain its goals. However, maintaining present support and new funding is necessary for the programme to reach its full potential. Various opportunities to obtain these funds exist and must be pursued. Collaborations with other complimentary programmes will be necessary if a three-dimensional global observation network is to be achieved.

Goal G. Intensify capacity building in developing countries

If the stations in developing countries are to fulfil their potential, continued attention to training, twinning and workshops must be given. Although basic training has been provided for many of the station operators, more advanced and longer term training is necessary. To help attain the level of expertise necessary to become scientifically independent, the twinning concept must continue to emphasise one-to-one assistance and collaboration of experienced scientists with GAW scientists in developing countries.

Goal H. Enhance the capabilities of NMHSs in providing urban-environmental air quality services

The WMO GAW Urban Research Meteorology and Environment (GURME) project was developed in response to the requests of the NMHSs as a means to help enhance their capabilities to handle meteorological and related aspects of urban pollution. The NMHSs will be provided with easy access to information on measurement and modelling techniques, a series of pilot projects will be promoted and regional workshops, focused on ways and means of developing urban-environmental forecasting capabilities, will be conducted.

1.5 Implementation Strategy

The overall implementation strategy puts a focus on the following activities for 2001-2004:

- Stabilise operations at the present stations and extend measurements in regions with insufficient coverage, especially in the Tropics, the Southern Hemisphere and in continental areas, and continue capacity building efforts.
- Evolve GAW into a three-dimensional global observation network through the integration of surface-based, aircraft, satellite and other remote sensing observations.
- Acquire and distribute only data of known quality through establishing data quality objectives and standard operating procedures for all measurements.
- Intensively use the potential of the World Wide Web as means of communicating GAW information, exchanging data and managing GAW activities.
- Expand the user base by providing easy access to the data and by promoting data applications especially for modelling and scientific assessments.
- Build analysis capabilities at GAW facilities in co-operation with the scientific research community.
- Expand the support base by enlisting the assistance of the world's top level researchers and institutes in GAW leadership and activities, and by working closely with the NMHSs.
- Strengthen GAW leadership by organising regular review meetings with participation of the "key players" in order to promote the development of the programme.

2. HOW TO USE THIS DOCUMENT

The first edition of the GAW Strategic Plan was published in 1997 and offered broad guidelines to attain the visions and objectives of the Twelfth Congress of WMO. It was recognised that the plan would be an evolving document and that specific elements should be modified with changing conditions and with operating experience. This second edition of the plan is based on the decisions of the Thirteenth WMO Congress in 1999 and covers the years 2001-2007. For the period 2001-2004 detailed implementation steps are given.

The GAW Strategic Plan is based on decisions that have been made by Congress, the WMO Executive Council (EC), CAS, and on the objectives described in the Technical Regulations for GAW (Vol. 1, [B.2.]) and the GAW Measurements Guide. Where possible, it incorporates earlier priorities set forth by the Panel and various other groups of experts. The Strategic Plan also makes use of the GAW Report Series and has been reviewed and approved in its entirety by the Panel.

The Strategic Plan contains a set of strategic goals, with implementation strategies and evaluation criteria identified to help guide GAW towards its objectives. It includes a detailed set of guidelines for establishing working plans and programmes and for developing GAW facilities over the next four years.

This document primarily addresses GAW specialists, professional GAW bodies such as the Panel, SAGs, operational GAW institutions, and other interested scientists. The Strategic Plan has the following structure and contents:

Chapter 1: Introduces the GAW programme, states the mission and objectives of GAW, describes the operating environment, summarises the programme status and main strategic goals.

Chapter 2: Specifies the scope of the document and tells the reader how to use it.

Chapters 3-9: Summarises for each component the current status of GAW activities and provides comments on developments and problems.

Identifies the goals for the years 2001-2004 for all main components of GAW. Some of these goals are extracted as a whole from the Fifth Long-Term Plan because of their high priority. The rest are partial goals and represent the first realistic steps towards the achievement of the long-term goals. The goals include quantitative elements in order to facilitate control of the future progress of the programme.

Specifies the implementation strategy for achieving the stated goals based on specific tasks with responsibilities and completion dates approximated wherever possible.

Chapter 10: Gives an overview of the resources available.

Chapter 11: Describes how the activities of the Strategic Plan may be monitored and how it should be updated on a regular basis.

Work plans for all GAW facilities and expert bodies should be designed to meet the goals and strategies agreed upon in the Strategic Plan.

As is true for all other WMO programmes, GAW is based on voluntary contributions by the Member countries and the scientific community. WMO can only encourage and recommend rather than require participants to make regular contributions to the programme. Consequently the achievement of the objectives of this strategic plan depends entirely on the close and continuous participation of Member countries and active interaction with the international atmospheric science community.

3. THE GAW ORGANIZATIONAL COMPONENTS

3.1 Role of National Meteorological and Hydrological Services (NMHSs)

Current Status

The WMO EC expressed the need to strengthen the role of WMO and the NMHSs of Member countries with respect to atmospheric chemistry monitoring and research activities. In 1990, EC recommended that all Members give the same priority to atmospheric chemistry measurements as to other meteorological parameters and encouraged the NMHSs to ensure that chemical composition observations become an integral part of atmospheric observations. Further incentive for these actions comes from Agenda 21, first stated at UNCED in 1992. Since that time, under the Framework Convention on Climate Change, there has been a call for strong support for the Global Atmosphere Watch under the Global Climate Observing System. The co-ordination of these national activities on behalf of GAW, including those of research institutes and other organizations, is the responsibility of the NMHSs.

About 80 Member countries are participating in GAW's measurement programme. A quarter of them are establishing or operating Global stations, partly with support from other Members or international organizations. The responsibility for operation of the stations lies with the participating countries.

A number of WMO Member countries already provide, or plan to provide, vital central facilities for the GAW. Among those doing so are:

Canada:	Calibration Centre for total ozone (Brewer)
	World Ozone and UV Data Centre (WOUDC)
EU:	World Data Centre for Aerosols (WDCA)
Germany:	Quality Assurance/Science Activity Centre (QA/SAC) for ozonesondes, volatile organic compounds (VOCs), sulphur dioxide, NO_x and aerosols
	World Calibration Centre for ozone sondes, N_2O and VOCs
	Regional Dobson Calibration Centre (RDCC)
	GAW Training and Education Centre (GAWTEC)
Japan:	QA/SAC for carbon dioxide, methane and total ozone (Asia and the South-West Pacific)
	World Data Centre for Greenhouse and Reactive Gases (WDCGG)
Norway:	World Data Centre for Surface Ozone (WDCSO)
Russia:	World Radiation Data Centre (WRDC)
Switzerland:	QA/SAC for surface ozone, carbon monoxide and methane
	World Calibration Centre for surface ozone, carbon monoxide and methane
	World Optical Depth and Radiation Research Centre (WORRC), including the Calibration Centre for optical depth
USA:	QA/SAC for precipitation chemistry and UV (the Americas)
	World Calibration Centres for total ozone (Dobson), carbon dioxide, precipitation chemistry
	World Data Centre for Precipitation Chemistry (WDCPC)

Comment

Most of WMO's participating countries are able to support GAW monitoring stations but not all are able to provide services for central facilities. All countries must be kept aware of the importance of their continued support.

National responsibilities for environmental activities are frequently not entirely within the jurisdiction of the NMHSs. They may even be the responsibility of several national authorities (e.g., between environment and research ministries). In such cases national discussions must take place and the NMHSs may need strong support from WMO and other international organizations to negotiate a successful outcome. Further, Members must decide if they can support, on a long-term basis, GAW Global and Regional stations which require considerable resources and technical skill.

Goals

- To support and encourage the operation of the existing central facilities and GAW stations on the basis of commitments by Member countries.
- To increase the number of participating countries, particularly those that may contribute to central facilities services and expert groups, by inviting Member countries with extensive know-how and development capabilities to expand their support.
- To encourage NMHSs and other interested national organizations to establish internal co-operation between competent laboratories and institutes and to ensure that WMO guidelines and observational practices and recommendations are adhered to throughout the GAW structure.

Implementation Strategy

Task 1. To negotiate and enhance commitments with targeted Member countries that are needed for the success of the GAW programmes. Continued commitments are needed from USA, Germany, Japan, Canada, Switzerland, but also others.
(AREP/WMO - semi-annually)

Task 2. To identify and approach Member countries for their support of GAW tasks of high priority. Commitments are needed at least from additional countries of the European Union.
(AREP/WMO - semi-annually)

Task 3. To encourage Members to strengthen co-operation between various agencies within the country.
(AREP/WMO - Congress XIV, 2003)

3.2 Co-operation with other International Programmes

Current Status

GAW is linked to a larger international scientific community. All GAW activities depend on collaboration, resource sharing, and interaction with many other partner organizations and networks including:

Acid Deposition Monitoring Network in East Asia (EANET)
Arctic Monitoring and Assessment Programme (AMAP)
Baseline Solar Radiation Network (BSRN)
Commission on Atmospheric Chemistry and Global Pollution (CACGP)
Committee on Earth Observation Satellites (CEOS)
European Monitoring and Evaluation Programme (EMEP)
Integrated Global Observing Strategy (IGOS)
Intergovernmental Panel on Climate Change (IPCC)
International Atomic Energy Agency (IAEA)
International Council for Science (ICSU)
International Global Atmospheric Chemistry Project (IGAC)
International Ozone Commission (IOC)
International Union of Pure and Applied Chemistry (IUPAC)
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)
Network for the Detection of Stratospheric Change (NDSC)
North American Research Strategy for Tropospheric Ozone (NARSTO)
Ozone Convention Secretariat
Stratospheric Processes and Their Role in Climate (SPARC)
United Nations Development Programme (UNDP)
United Nations Environment Programme (UNEP)
World Health Organization (WHO)

Comment

GAW is considered the atmospheric chemistry component of GCOS. The role of GAW and its collaboration with other international programmes with complementary and compatible objectives should be encouraged. In co-operation with UNEP and EMEP, for example, efforts should be made to locate ecosystem studies at, or near, GAW Global stations and to involve Members and stations in integrated monitoring activities. Collaboration with IGAC involving the use of and access to geophysical data would also be helpful because both programmes are operating global databases. Within the framework of the Environmental Emergency Response Project, co-operation with IAEA is necessary. It is important, however, to avoid duplication with other programmes and to use GAW's limited resources primarily for the identified GAW core activities.

Within Europe, environmental monitoring is organised under EMEP, to which all nations contribute monitoring information in support of the overall modelling effort guiding the European emission control and regulation activities. Presently, WMO is co-chairing the EMEP Task Force on Measurements and Modelling. Further collaboration is occurring among the acid deposition programmes being conducted in North America and Asia. A number of countries are not yet participating, and many monitoring stations need the assistance of meteorological services in constructing backward trajectories for data interpretation. In the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) the lack of funds is hindering the global assessment of the state of the marine environment.

Goals

- To nurture strong relationships with research and process oriented programmes.
- To seek the active participation of our partners, national and international organizations in the responsibilities of GAW.

Implementation Strategy

Task 1. To invite rapporteurs from other programmes - at least from IGAC, SPARC and UNDP - to participate on a regular basis in future sessions of the Panel and contribute to GAW by preparing surveys and summaries of existing knowledge and recommendations for future technical scientific activities.
(Panel - every two years starting in 2001)

Task 2. To distribute relevant GAW information and publications originating from the Secretariat, the GAW central facilities, and GAW bodies to the officials of other international programmes interested in GAW.
(Secretariat - ongoing)

3.3 Internal Lead Responsibilities

3.3.1 Expert Groups and Central Facilities

Current Status

CAS is the lead WMO technical commission for research activities (including those of GAW) in the atmospheric sciences and related fields. CAS formally established the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (the Panel) as the overall steering body for GAW. Under the Panel, Scientific Advisory Groups (SAGs) have been formally identified for the following topics: greenhouse gases, aerosols, UV, precipitation chemistry, ozone, and GURME. Other informal groups have produced recommendations for observational practices, such as for reactive gases.

Three kinds of central facilities are in operation: Quality Assurance/Science Activity Centres (QA/SACs), Calibration Centres dedicated to different measurement parameters and World Data Centres with responsibility for archiving GAW data. The duties and co-operative arrangements between QA/SACs, Calibration Centres and Data Centres are specified in the GAW Handbook.

Comment

The Panel provides advice to the WMO EC and the Secretary-General of WMO regarding direction for GAW. Individual Panel members also have responsibilities relating to some elements of GAW with a number of them involved in expert groups. The Panel, in its role as an advisory body, does not meet often enough to follow the operation of the central facilities closely and to act as effectively as desirable as a steering body.

Leading scientists have made a considerable effort in the past few years to improve GAW's central facilities and to involve competent researchers and institutions in its activities. Operational functions have now become increasingly important in subsequent phases. Because of the scarcity of resources there is an urgent need to provide the central facilities with further support from experts with operational expertise in specific GAW fields. The Operations Support Group (OSG) which was established under the last Strategic Plan was recently disbanded and in its place GAW Advisors will be asked to do specific tasks. The Network SAG (originally the Observation Group) has been discontinued because the individual SAGs are now responsible for the development of the network. Regular meetings are proposed involving all centre directors, data managers, SAG chairpersons and selected experts in order to discuss and manage the present status of GAW and its future. The first such meeting took place in April 2001.

As a part of the GAW Strategic Plan 1997-2000, ad hoc SAGs, consisting of experts, were established to advise on a number of scientific issues. During this period, the SAGs have made important contributions to the programme and their activities are now well established. Every two years, a review of the SAG activities is made for the Panel. Furthermore, the Panel chairman prepares, in consultation with the Secretariat, a list of proposed chairs. The list is circulated to the Panel for their advice. It is recommended that a SAG chairman usually serves up to two terms (4 years total). The chairman of the Panel, the approved SAG chairmen, and the Secretariat will select/confirm the members of the individual SAGs based upon the current needs and availability of financial resources within the GAW programme.

Goals

- To specify clear scientific leadership responsibility for all activities within the GAW organization, especially for the activities of experts and central facilities and the support activities of WMO.
- To standardise and establish an effective management structure for all programme components of GAW and, in particular, to co-ordinate and connect the functions of the QA/SACs, World Calibration Centres (WCCs) and World Data Centres (WDCs).
- To enlarge the circle of active experts who will share responsibility for the guidance of GAW over the longer term. To increase the number of available experts by increasing the involvement of Members not only in routine operations but also in other activities, such as providing additional stations, including chemical measurements as well as standard meteorological measurements, and hosting central facilities.

Implementation Strategy

Task 1. To maintain and confirm, or establish where necessary, SAGs for at least the following different components of the GAW:

- Radiation (SAG UV)
- Aerosols (SAG Aerosols)
- Ozone (SAG Ozone)
- Precipitation chemistry (SAG Precipitation Chemistry)
- Greenhouse Gases (SAG Greenhouse Gases)
- Reactive Gases (SAG Reactive Gases)
- GURME (SAG GURME)

The SAGs are assigned the following specific tasks:

- To establish scientific priorities on the basis of user requirements and scientific needs.
- To establish Data Quality Objectives (DQOs) and approve Standard Operating Procedures (SOPs).

- To track operations at sites and make recommendations regarding the development of networks, observation methodologies, and techniques.
- To advise the central facilities with regard to scientific matters.
- To organise scientific assessments and give advice about user applications.
- For parameters for which there may be no need to establish a SAG or no possibility of doing so (e.g., radioactivity), alternative scientific leadership responsibilities must be defined.

(Panel – April 2001, review 2003)

Task 2. To request individual scientists to act as "GAW Advisors" for specific tasks over a given time period. Tasks assigned to these individuals should include:

- To assist in the establishment of additional World Calibration Centres as necessary.
- To establish regular planning, reporting, and controlling functions with respect to all central facilities in co-operation with the Secretariat.
- To clarify the operational functions and interfaces between QA/SACs, Calibration Centres, and Data Centres and submit the corresponding proposals to the Panel.
- To advise the QA/SACs in accomplishing their goal of completing all standard operating procedures and review their progress.

(Secretariat, Panel – ongoing)

Task 3. To organise regular meetings of individuals involved in GAW operational and scientific activities to plan for the future.

(Secretariat – every four years)

3.3.2 Secretariat

Current Status

Within the WMO Secretariat, the Environment Division (referred to as the Secretariat in this document) of the Atmospheric Research and Environment Programme (AREP) Department provides the operational support for GAW. It co-ordinates with other WMO programmes such as the World Weather Watch Programme (WWW), the World Climate Programme (WCP), the World Climate Research Programme (WCRP), the GCOS and the Education and Training Programme. The management and leadership of the operation of GAW is the major activity of the Secretariat. To this end, the Secretariat, under the institutional guidance of the appropriate WMO bodies, is in continual contact with the NMHSs in the participating countries, the institutions of WMO's regional associations, the various GAW central facilities, and the relevant international organizations and programmes.

The co-ordination of SAG, WDC, WCC and QA/SAC activities has become a major task of the Secretariat. Arrangement of intercomparisons and calibrations is a part of this. Continuing efforts are being made to acquire funds for the different GAW activities and facilities and to arrange twinning partners and other contacts. The Secretariat prepares special bulletins, such as the Antarctic Ozone Bulletin, and also assists countries in co-ordinating related activities, e.g. in the case of biomass burning in Southeast Asia. The interaction and synchronisation of activities with other UN organizations (especially WHO and UNEP) and other programmes, such as EMEP and IGAC, is ongoing and very active.

The Secretariat issues an unofficial "Information Sheet" every four months on the activities that have taken place in GAW and the Secretariat, including an annual list of meetings. This is distributed to the whole GAW community for information and planning. For training and scientific purposes, about 30-50 conferences, workshops, and sessions of GAW bodies are organised or co-sponsored by the Secretariat annually. The outcomes of these are documented in the form of reports in the GAW Report Series. This report series, which is GAW's backbone documentation, is of great value to "insiders" as well as to external users and is distributed free of charge.

Comment

GAW's organisational and co-ordinating tasks are complex, the workload is considerable and resources available to the Secretariat from WMO sources are limited. These combine to make it difficult to provide optimum operational leadership for the programme.

Goals

- To optimise co-ordination of the individual programme components of GAW
- To implement the priorities set up within this strategic plan through co-ordination and oversight

Implementation Strategy

Task 1. To recommend specific tasks to GAW participants and to manage their activities.
(Secretariat – ongoing)

Task 2. To establish the GAW web site as an interactive tool for the GAW system so that all GAW components have appropriate web pages that are regularly maintained.
(Secretariat, SAGs, WDCs, WCCs, QA/SACs – ongoing)

Task 3. To initiate meetings and sessions based on critical issues of the GAW system.
(Secretariat – ongoing)

Task 4. To formally survey Members' GAW activities and organise the maintenance of this information in a suitable database.
(Secretariat – 2001, 2003)

Task 5. To compile working plans and meeting reports from the central facilities and the expert groups on a routine basis.
(Secretariat –starting 2001)

Task 6. To establish priorities for funding arrangements and to prepare plans for the use of available funds (budgets).
(Secretariat – every three months)

Task 7. To employ GAW Advisors to assist with operational matters.
(Secretariat – as appropriate)

Task 8. To improve the information flow to the GAW community by regular and official distribution of the GAW Information Sheets three times per year and by fast publication of Reports.
(Secretariat – ongoing)

3.4 Communications

Current Status

To ensure timely and efficient communication among all the GAW-related parties is one of the main tasks of the Secretariat and the GAW central facilities. This activity is implemented through conducting various meetings, preparing and disseminating the GAW Information Sheets and publications, providing other GAW-related information over the Internet and maintaining current contacts by e-mail, mail and telecommunication.

About 30-50 GAW-related meetings are organised or co-sponsored by the Secretariat each year. They include biennial meetings of the Panel, meetings of SAGs and GAW World Data Centres' managers, expert meetings on GAW technical subjects and training workshops, co-sponsorship of scientific conferences and workshops and representation at relevant meetings of other organizations and programmes to provide information on GAW and to strengthen co-operation.

The GAW Information Sheets are issued every four months to provide information on current GAW activities and meetings, and are disseminated to more than 350 GAW contacts. The GAW publications include the GAW Measurements Guide, GAW Handbook, GAW Report Series, Fact Sheets and popular-style brochures which are distributed to WMO Members and GAW contact persons, as well as to interested individual scientists. Beginning with the second half of 2000, the GAW publications were also made available on the GAW Web site. Other publications are issued by the GAW Data Centres and contain the data collected by the centres as well as manuals for data submission. Information on all these publications can be found on the appropriate web sites.

As far as the state of the ozone layer is concerned, the near-real-time Antarctic ozone bulletins are prepared by the Secretariat from August to November and issued over the Global Telecommunication System (GTS). In addition, the Aristotle University of Thessaloniki, Greece, collects near-real-time ozone data and transmits daily ozone maps of the Northern Hemisphere during the December-March period. The Meteorological Service of Canada has also begun providing similar products throughout the year.

Inefficiencies in information dissemination and communication currently pose a major challenge to effective GAW operations. The existing GAW web sites need further development and regular updating.

Comment

Close and efficient contacts between all the GAW partners, timely dissemination of GAW publications and data is required for the GAW programme to continue to succeed. Recognition by both environmental scientific and policy-making communities depends on efficient communications.

Modern telecommunication networks will have a positive impact on the operation, management and further development of GAW as well as on the effective use and application of GAW data and products for the protection of the atmospheric environment.

The complex, multinational nature of GAW operations, with its needs for frequent and effective communication, dictate that a web-based facility be employed as a primary and central tool for managing and co-ordinating GAW activities, for disseminating data and other information products and for two-way communications.

Traditional forms of communication used within the GAW system (such as expert meetings, scientific conferences, training workshops, publications, etc.) also need improvement to ensure wider and faster dissemination of GAW-related information and data and to facilitate the wider and fuller use of GAW products both for scientific studies and for development of environment protection measures. Regular GAW review meetings with participation of the GAW Advisors, managers of GAW central facilities, chairmen of SAGs and those responsible for the main individual GAW stations are encouraged.

Improving communication and co-operation among relevant scientific institutions within individual countries should receive particular attention from the GAW management during the period covered by the present Strategic Plan.

Goals

- To ensure efficient use of modern telecommunication facilities, in particular the Internet, for wider and timely dissemination of GAW-related information and data.
- To promote close co-operation and communication between GAW partners, including those within individual countries.
- To maintain and further develop timely communication between the Secretariat, central facilities and the GAW stations, as well as direct contacts between the stations and GAW collaborating institutions.
- To review GAW-related meetings to conform with the priorities set within the GAW programme and to guarantee adequate preparation and efficient management of the meetings.

Implementation Strategy

Task 1. To complete the development of the GAW home page and other related web sites and to ensure their regular updating, interlinks and ease of use.
(Secretariat and GAW central facilities – December 2001)

Task 2. To identify and review, on an annual basis, a prioritised plan for all GAW meetings including proposals for themes and objectives, and allocation of financial resources.
(Secretariat – annually in October)

Task 3. To continue the publication of the GAW Report Series, Information Sheets, Fact Sheets, data reports and other material, and to ensure that these publications are available over the Internet.
(Secretariat and Data Centres – ongoing)

Task 4. To prepare/update the GAW Measurements Guide and GAW Handbook.
(Chairmen of SAGs and the Secretariat – 2001)

Task 5. To include universities and other institutions both within and outside the meteorological services in the GAW communication network and to foster closer collaboration between such institutions within individual countries.
(Secretariat and GAW central facilities – ongoing)

3.5 Capacity Building

Current Status

Education and training for GAW station personnel is an integral part of the GAW programme and is described in GAW Report No. 93. Training and education needs in developing countries will continue to be a high priority for the GAW programme, particularly during the start-up and the first years of operation of newly established stations. Longer-term education and training are also provided to build scientific capacities in atmospheric sciences through workshops, training centres, instrument calibrations, station audits/visits, and twinning. These longer-term capacity building activities are of increased importance as the GAW network of stations in developing countries has begun to mature and many of the newer stations are operational.

Extensive training has taken place within two programmes co-sponsored by GAW and UNDP, one to establish six Global GAW stations under the Global Environment Facility's Monitoring of Greenhouse Including Ozone project and the other to increase the number of stations measuring ozone and UV in the southern cone of South America. It is through this training that measurements of ozone, greenhouse gases and solar radiation including UV are being successfully conducted in these remote areas of the globe where there were no previous measurements.

Some station operators and other scientists in countries hosting GAW stations have also participated in workshops, international and local scientific meetings, and instrument calibration activities. The Dobson inter-comparisons that are organised by WMO have been strongly supported by the Climate Monitoring and Diagnostics Laboratory (CMDL) of the National Oceanic and Atmospheric Administration (NOAA) and have provided many opportunities to teach the operators of Dobson spectrophotometers about ozone measurements and their importance. The Swiss Laboratories for Materials Testing and Research (EMPA), the Institute for Atmospheric Environmental Research (IFU), NOAA (CMDL and Aeronomy Laboratory), MeteoSwiss, and Solar and Ozone Observatory (SOO) of the Czech Hydrometeorological Institute, have all worked directly with capacity building of station personnel, while the National Aeronautics and Space Administration (NASA) and the Inter American Institute for Global Change Research (IAI) have made substantial contributions through workshops.

An example of a station with many years of experience helping to establish an important measurement programme in a developing country is the ozone sonde station in Nairobi, Kenya. In this case, MeteoSwiss has trained and financially supported the local personnel to establish and maintain this equatorial site thus providing important equatorial measurements.

Comment

Atmospheric scientists are in limited supply, and this shortage is particularly acute in developing countries. Training and education are critical to the long-term success of the GAW programme, particularly within the developing countries that have committed to maintain and operate Global or Regional stations (see Section 4, Observing Systems). In addition to the immediate need for training in the operational aspects of the GAW programme, there is an urgent need to enhance the overall scientific capacity and further expand the scientific infrastructure in the host developing countries. Scientific capacity building requires a commitment of the host country to provide university trained scientists who will remain in the GAW programme for many years in order to translate into action the GAW specific training they have received. One of the most challenging problems is to acquire sufficient funding to provide adequate education and training for GAW station personnel in developing countries.

Goals

- To expand the GAW training and education activities in developing countries beyond "start-up" training, to include more advanced workshops, frequent station audits/visits, intensive training at the GAW training centres, and participation in international scientific meetings appropriate for the individual country's GAW scientific programme.
- To promote twinning relationships between station personnel in developing countries and established atmospheric scientists who wish to collaborate in the use of GAW station data for research.

Implementation Strategy

Task 1. Organise and support more training and education workshops related to the GAW core measurement parameters.

(Secretariat, QA/SAC, SAGs – ongoing)

Task 2. Identify and provide training to station personnel who need more advanced education available at international scientific meetings, and workshops.

(All GAW bodies – ongoing)

Task 3. To organise regular meetings of the GAW Global station managers to increase communication and co-ordination between all GAW Global stations.

(Secretariat, QA/SACs – begin 2002)

Task 4. Request the SAGs to identify twinning collaboration possibilities between GAW station personnel in developing countries and countries in transition, and experienced scientists from established laboratories and stations, in order to promote the joint use and publication of the station data.

(Secretariat, SAGs – ongoing)

4. OBSERVING SYSTEMS

4.1 Surface-Based Observations

Current Status

Surface based observations are the backbone of the GAW network, which consists of *Global* and *Regional* measurement stations and co-operates with many *Contributing* and *Associate* stations. The present network of GAW Global stations consists of 22 stations as shown in Figure 1 (Chapter 1.3). Global stations are usually situated in remote locations, have very low (background) levels of pollutants that are representative of large geographic areas, and continuously measure a broad range of atmospheric parameters over decades (cf. WMO Technical Regulations, Vol. 1, [B.2.] 5.1). It is important to note that Global station sites must be entirely free of the effects of local and regional pollution sources during frequent and substantial periods throughout the year. It is much more demanding to make these measurements in pristine than urban areas. Data are typically applied to global issues such as climate change and stratospheric ozone depletion.

GAW Regional stations are representative of smaller geographic regions that are not affected by nearby sources of pollution such as vehicular and industrial combustion or agricultural activities (ibid. [B.2.] 5.3). Data are typically applied to more regional issues such as acid deposition, transport of trace gases and aerosols, and local UV radiation.

Many Data Centres receive data from stations that have not been formally designated as either Global or Regional GAW stations. Their contribution to GAW is nevertheless very valuable and they are classified as either Contributing stations or Associate stations. Contributing station networks include the Network for Detection of Stratospheric Change (NDSC), the Baseline Surface Radiation Network (BSRN), and the European Monitoring and Evaluation Programme (EMEP). Some of the stations within these networks are also Global or Regional GAW stations, while Associate stations include many single measurement stations as well as air and ship platforms.

Not all of the several dozen atmospheric parameters can or even should be measured at each GAW station, and in many cases, a station may measure only a single parameter. There are nine major types of measurement parameters in the GAW programme (ibid. [B.2] 8.2), namely:

- Greenhouse gases (carbon dioxide, CFCs, methane, nitrous oxide, tropospheric ozone, water vapour).
- Ozone (surface, total column and vertical profile).
- Solar radiation including ultraviolet.
- Precipitation chemistry.
- Chemical and physical properties of aerosols including optical depth.
- Reactive gases (carbon monoxide, sulphur dioxide, nitrogen oxides, volatile organic compounds (VOCs)).
- Persistent organic pollutants (POPs) and heavy metals.
- Radionuclides (krypton-85, radon-222, beryllium-7, lead-210).
- Meteorological parameters.

Comment

The GAW network of Global stations should maintain at least one station in every principal climate region. Even though global coverage was markedly improved with the addition of six stations through funding from a GEF/UNDP project (cf. Chapter 1.3), the goal stated in the previous Strategic Plan of having “a minimum of 25 Global stations operating reliably and continuously” has not yet been achieved. Of particular importance is the need for additional mid-continent stations. Member countries must be encouraged to find funding to complete this important network of Global stations.

Like the 22 Global stations, the approximately 300 Regional stations generally require complex instrumentation with well trained operators. Due to limited financial resources, maintaining these facilities and personnel is problematical. Many of the Global stations help Regional stations, and in some situations they help other Global stations that have a more limited measurement capability. Although many of the Regional stations measure only one or two atmospheric parameters, many other Regional stations are as fully instrumented as the Global stations, having provided excellent measurements for decades. The long term success of the GAW programme is dependent upon the financial support of the Global and Regional stations from the host countries, the co-operative programmes between the stations and outside twinning partners, and the dedicated scientific interest of the station personnel.

In general, meteorological data are necessary for interpretation of parameters measured in the other categories. Although meteorological measurements are not usually available in the GAW data centres, they are generally available directly from all GAW stations and will soon be routinely archived in some of the GAW data centres. Upper air data from meteorological radio sondes at nearby stations are also valuable for interpretation of both tropospheric and stratospheric data and should be incorporated into the GAW data sets wherever possible.

As scientific issues of global change evolve, particularly in the area of climate change, it has become increasingly important to strengthen the collaborations between the stratospheric and the tropospheric research communities. There are feedback mechanisms between these layers of the atmosphere that must be better quantified if we are to be able to predict climate change with confidence. To better understand these atmospheric feedback mechanisms at and near the tropopause, measurements from aircraft and using remote sensing instrumentation such as Lidar (ozone and aerosol) and microwave radiometers should be encouraged in some locations where local infrastructure is sufficient for their support. By including the extensive NDSC stratospheric network as a contributing part of GAW, and enhancing the three-dimensional observations through aircraft, ozone sondes and remote sensing, a more comprehensive system of interrelated stations has been realised.

The WMO Secretariat maintains an inventory of operational GAW stations.

Goals

- To increase the number and quality of GAW stations to provide better global coverage focusing particularly in areas where there are significant regional issues.
- To maintain and improve the network of observing stations for near-real-time monitoring of the atmosphere, producing comprehensive, reliable, and timely measurements that cover all regions of the world.
- To provide information on atmospheric composition for global, regional and local scale issues.
- To validate and keep up-to-date a Station Directory on Global and Regional stations and to make the Directory available to interested parties through the Internet.
- To improve collaboration and communication between all station types.

Implementation Strategy

Task 1. To pursue funding opportunities that maintain and expand the GAW system of Global and Regional stations.
(Secretariat, Panel, NMHS's – ongoing)

Task 2. To study the geographical distribution of the Regional and Global stations through measurements and modelling and with interaction between SAGs in order to make recommendations regarding placement of stations.
(SAGs – December 2001)

Task 3. To take action aimed at increasing availability of key instrument spare parts for developing countries to minimise data gaps.
(Secretariat – ongoing)

Task 4. To validate and complete the Station Directory and establish operational procedures for its maintenance, including automatic updates from the World Data Centres.
(Secretariat, WDC's, QA/SACs – December 2001)

Task 5. To promote the establishment of remote sensing and aircraft monitoring programmes.
(Secretariat, QA/SACs – on going)

Task 6. To organise regular meetings of the Global station managers to increase communication and co-ordination between Global stations.
(Secretariat, QA/SACs – on going)

4.2 Satellite-Based Observations

Current Status

Satellite and ground-based observations play complimentary roles, and both are essential to reach the goal of providing global coverage of critical parameters necessary to understand changes occurring in the stratosphere and troposphere. Space-based measurements have low spatial resolution and are of limited use at ground level, but they usually have global scale coverage. On the other hand, ground-based observations have limited geographic coverage but are highly accurate at and near ground level, and stations can be chosen as representative of large homogeneous regions. Ground-based measurements can include a wider variety of species and allow detailed study of interactions. There is also a potential for longer lifetimes for specific measurement programmes. Clearly, a globally integrated system of observations must include highly accurate measurements at and near the ground in all regions of the globe. This cannot be provided by space-based measurements alone.

The multi-agency Integrated Global Observing Strategy (IGOS) has proposed to integrate the major satellite and ground-based systems to provide highly accurate global environmental observations of the atmosphere. The measurement objectives of the various space-based systems are summarised in Table 2. The recommendations of IGOS call for the space agencies to provide sustained support for the independently calibrated ground-based networks (including airborne operations) to ensure the continuity and the quality of data needed by the atmospheric community. The EC Panel met in March 1999 and also recognised this need over the coming decades, recommending that the satellite community share responsibility and resources with the GAW programme in maintaining high quality measurements over the lifetime of the satellite sensors.

Comment

Space-based observations offer a partial solution toward the goal of achieving global coverage of certain measurements important to the GAW programme. These measurements include ozone (column and profile), solar radiation, aerosol measurements such as aerosol optical depth and measurements of some trace gases in the free troposphere such as carbon monoxide (CO). Satellite observations are of benefit to the global community and are of special interest to developing countries where there are gaps in GAW's surface-based monitoring network. For this reason integration of satellite observations into the GAW programme is highly desirable. In turn, satellite systems can only meet their established requirements if they are checked against highly accurate ground based measurements of known quality. As stated in the WMO/CEOS Report on the Integration of Satellite and in-situ Measurements of Ozone, GAW Report No. 140, "…there must be formal recognition and support for the international community who are providing critical data from ground-based systems for the calibration and validation of the space-borne systems."

The GAW network of stations has provided both total column ozone and vertical profile ozone data for satellite validation for the past few decades. A new generation of satellites sensors have begun operation and presently include the capability to make free tropospheric measurements of carbon monoxide and column methane. A few of the high altitude GAW stations measure carbon monoxide and could be of value for checking the accuracy of these relatively new CO satellite remote measurements. Similarly, UV, VOCs, nitrogen oxides, sulphur dioxide and certain aerosol parameters also belong to the new generation of measurements from space that may one day benefit from the ground-based GAW network of measurements.

Goals

- To establish a central archive for satellite data relating to the GAW parameters.
- To provide ground-truth information for satellite validation of ozone, CO, aerosol parameters and other components.

Implementation Strategy

Task 1. To seek support from space agencies for a central data archive for satellite ozone and related measurements for near-real-time evaluation of instrumental and atmospheric changes that may be occurring in either the GAW network of ground-based instruments or in the satellite instrumentation and affecting the integrity of the measurements.

(EC Panel, Secretariat – 2002)

Task 2. To seek support from space agencies for ground truth observations at certain selected GAW station sites.

(EC Panel, Secretariat, SAGs – 2002)

Task 3. To specify the needs for ground-based measurements for existing and new generation satellites and to expand the GAW measurement programme accordingly.

(Secretariat, SAGs – 2003)

Task 4. To identify GAW network stations and GAW measurement parameters that are of value to CEOS as part of the IGOS.

(Secretariat, SAGs, CEOS – 2003)

Task 5. To promote the establishment of remote sensing and aircraft monitoring programmes.

(Secretariat, QA/SACs – on going)

TABLE 2(a): Measurement Objectives of Various Space-Based Systems

INSTRUMENT	Platform	Ozone Column	Ozone Profile	Aerosol Column	Aerosol Profile	Constit. Column	Constit. Profile	Temp. Profile	Winds	Irrad.	Surface UV
TOMS	Earth Probe	X		X		SO_2					
OMI	EOS-Aura	X	X	X		SO_2, BrO, NO_2, CH_2O				UV/Vis	X
OMPS	NPOESS	X	X	X		SO_2, BrO, CH_2O, OclO				UV/Vis /NIR	X
SBUV	Nimbus 7	X	X			SO_2, NO (p< 1 mb)				UV	
SBUV/2	NOAA-11, 14, (POES)	X	X			SO_2, NO (p< 1 mb)				UV	
SSBUV	Shuttle	X	X			SO_2, NO (p< 1 mb)				UV	
GOME	ERS-2	X	X	X		SO_2, BrO, NO_2, CH_2O, OclO, H_2O				UV/Vis	X
SCIAMACHY	ENVISAT	X	X	X		SO_2, BrO, NO_2, CH_2O, CO, CH_4, OclO, H_2O, N_2O				UV/Vis /NIR	X
GOME-2	METOP	X	X	X		SO_2, BrO, NO_2, CH_2O, OclO, H_2O				UV/Vis	X
SAGE I	AEM-2	X	X	X	X	NO_2	NO_2				
SAGE II	ERBS	X	X	X	X	NO_2, H_2O	NO_2, H_2O				
SAGE III	METEOR, ISS & TBD[1]	X	X	X	X	NO_2, H_2O, NO_3, OclO	NO_2, H_2O, NO_3, OclO	X			
UVISI	MSX	X	X			O_3, NO_2	O_3, NO_2				
ACE	SCISAT-1	X	X	X	X	About 30 species	About 30 species	X			
SMILES	ISS	X	X			ClO, H_2O, H_2O_2, HCl, HNO_3, BrO,	ClO, H_2O, H_2O_2, HCl, HNO_3, BrO,	X			
IMG	ADEOS	X	X			H_2O, CH_4, CO	H_2O, CH_4, CO	X		X	

(Note [1]): TBD – to be determined)

TABLE 2 (b): Measurement Objectives of Various Space-Based Systems

Instrument	Platform	Ozone Column	Ozone Profile	Aerosol Column	Aerosol Profile	Constit. Column	Constit. Profile	temp. Profile	winds	Irrad.	Surface UV
ODUS	GCOM-A1	X		X		SO_2, BrO, NO_2, CH_2O, OclO				UV/Vis	
SOFIS	GCOM-1	X	X	X	X	NO_2, CH_4, $CFCl_3$, CF_2Cl_2, HNO_3, $ClONO_2$, CO_2	NO_2, CH_4, $CFCl_3$, CF_2Cl_2, HNO_3, $ClONO_2$, CO_2				
POAM II	SPOT-3	X	X	X	X	NO_2	NO_2				
POAM III	SPOT-4	X	X	X	X	NO_2, H_2O	NO_2, H_2O				
LIMS	Nimbus 7	X	X			NO_2, H_2O, HNO_3	NO_2, H_2O, HNO_3				
SAMS	Nimbus 7					CH_4, N_2O	CH_4, N_2O				
SOLSE/LORE	Shuttle	X	X								
ATMOS	Shuttle	X	X			Close to 30 species	Close to 30 species				
MAS	Shuttle	X	X			ClO, H_2O	ClO, H_2O				
CRISTA	Shuttle/SPAS		X			More than 20 species	More than 20 species				
MAHRSI	Shuttle/SPAS					OH, NO	OH, NO				
CLAES	UARS	X	X	X	X	More than 10 species	More than 10 species				
ISAMS	UARS	X	X	X	X	H_2O, CH_4, NO, NO_2, N_2O, N_2O_5, HNO_3, CO	H_2O, CH_4, NO, NO_2, N_2O, N_2O_5, HNO_3, CO				
HALOE	UARS	X	X	X	X	H_2O, CH_4, NO, NO_2, HCl, HF	H_2O, CH_4, NO, NO_2, HCl, HF				
MLS	UARS	X	X			ClO, H_2O, HNO_3	ClO, H_2O, HNO_3				
HRDI	UARS										
SOLSTICE	UARS									UV	
SUSIM	UARS									UV	

TABLE 2 ©: Measurement Objectives of Various Space-Based Systems

Instrument	Platform	Ozone Column	Ozone Profile	Aerosol Column	Aerosol Profile	Constit. Column	Constit. Profile	Temp. Profile	Winds	Irrad.	Surface UV
ILAS	ADEOS	X	X	X	X	NO_2, CH_4, $CFCl_3$, CF_2Cl_2, HNO_3	NO_2, CH_4, $CFCl_3$, CF_2Cl_2, HNO_3	X			
RIS	ADEOS										
Osiris	Odin	X	X	X	X	NO_2 SO_2, CH_2O, BrO, OclO, H_2O, NO	NO_2 SO_2, CH_2O, BrO, OclO, H_2O, NO				
SMR	Odin	X	X			More than 10 species	More than 10 species				
GOMOS	ENVISAT	X	X	x	x	NO_2, NO_3, H_2O	NO_2, NO_3, H_2O	X			
MIPAS	ENVISAT	X	X	X	X	More than 20 species	More than 20 species	X			
ILAS-2	ADEOS-2	X	X	X	X	NO_2, CH_4, $CFCl_3$, CF_2Cl_2, HNO_3, $ClONO_2$	NO_2, CH_4, $CFCl_3$, CF_2Cl_2, HNO_3, $ClONO_2$				
HIRDLS	EOS-Aura	X	X			CFC11, CFC12, $ClONO_2$, H_2O, N_2O, NO_2, N_2O_5, HNO_3, CH_4	CFC11, CFC12, $ClONO_2$, H_2O, N_2O, NO_2, N_2O_5, HNO_3, CH_4	X			
MLS	EOS-Aura	X	X			ClO, H_2O, N_2O, CO, SO_2	ClO, H_2O, N_2O, CO, SO_2	X			
TES	EOS-Aura	X	X			About 30 species	About 30 species	X			
ACE	SCISAT-1	X	X	X	X	About 30 species	About 30 species	X			
SMILES	ISS	X	X			ClO, H_2O, H_2O_2, HCl, HNO_3, BrO,	ClO, H_2O, H_2O_2, HCl, HNO_3, BrO,	X			

5. MEASUREMENT PARAMETERS

5.1 Ozone

5.1.1 Surface Ozone

Current Status

Lead responsibility	Scientific Advisory Group for Ozone (SAG Ozone)
QA/SAC	Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland.
Calibration Centres	Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland (World Calibration Centre). Czech Hydrometeorological Institute, Prague, Czech Republic (Regional Calibration Centre). Servicio Meteorologico Nacional (SMN), Buenos Aires, Argentina (Regional Calibration Centre).
Reference Standard	National Institute of Science and Technology (NIST), Gaithersburg MD, USA
DQO	Not available.
SOP	WMO Report No. 97, 1995, for surface ozone is complete and available. An update of this report is being prepared.
Data Centres	World Data Centre for Surface Ozone (WDCSO), Norwegian Institute for Air Research (NILU), Kjeller (Norway).

Comment

Ozone plays a central role in physical, chemical, and radiative processes in the troposphere. It has become apparent that: (1) surface (ground-level) ozone significantly influences the formation of photochemical smog; and (2) surface ozone is an irritant with effects both on the biota and human health. Because of these roles, it is imperative that the GAW measurement programme for surface ozone be continued and extended to provide sufficient high quality data to characterise the global background distribution. Regular performance audits at about half of the Global GAW stations show that these stations are providing measurements of the required quality.

Our knowledge of trends in the global distribution of surface ozone is still incomplete. Most surface ozone monitoring stations are located in northern mid-latitudes. There is still a need for more remote stations measuring ozone in the middle of continents (e.g., continental Asia) and in the southern hemisphere.

Goals

- To establish data submission objectives and format.
- To expand activities of the GAW WDCSO to provide routine on-site checks of the calibrations and operations of the GAW stations with surface ozone measurements.
- To establish a routine for calibration of surface ozone instruments at all GAW stations in South America through the Regional Calibration Centre in Buenos Aires.

Implementation Strategy

Task 1. To organise a meeting of experts on surface ozone to:

- Determine how to best achieve the scientific objectives for surface ozone measurements.
- Promote activities to encourage prompt data submission to WDCSO.
- Provide input to update GAW report No. 97 on the standard operating procedures and quality assurance.

(SAG Ozone, QA/SAC – 2001)

Task 2. To establish a data format for surface ozone based upon the results of the data managers meeting in 2001

(Data Managers – 2001)

Task 3. To begin biennial calibrations at SMN in Buenos Aires for South American stations.

(WCC, SMN – 2001)

5.1.2 Column (Total) Ozone

Current status

Lead responsibility: Scientific Advisory Group for Ozone (SAG Ozone)

QA/SAC: Japan Meteorological Agency (JMA), Tokyo, Japan for Asia and the South-West Pacific

Calibration Centres (a) World Dobson Calibration Centre at the Climate Monitoring and Diagnostics Laboratory (CMDL) of the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado, USA for Dobson intercomparisons; Regional Dobson Calibration Centre for Europe (WMO RA VI) at the Meteorological Observatory in Hohenpeissenberg, Germany, in co-operation with Hradec Kralove, for Asia (WMO RA II) in Tsukuba, Japan, and for the Southwest Pacific (RA V) in Melbourne, Australia; Regional Dobson Calibration Centres are anticipated for Villa Ortuzar, Buenos Aires, Argentina (RA III) and Pretoria, South Africa (RA I).

(b) Calibration of Brewer automated spectrophotometers is based upon a triad of instruments maintained by the Meteorological Service of Canada (MSC, formerly Atmospheric Environment Service, AES), Toronto, Canada, and a travelling Brewer (No. 34) used for field calibrations. Occasional participation during Dobson intercomparisons also provides comparisons between the two instrument types.

(c) The model M-124 filter instruments are calibrated against a well-maintained Dobson spectrophotometer in the Main Geophysical Observatory (MGO), St. Petersburg, Russia.

Reference Standard CMDL maintains Dobson No. 83 and MSC maintains an independent triad of Brewers

DQO Not formally established, but a long-standing agreement of the community exists

SOP For Dobson spectrophotometers: WMO Ozone Report No. 6. Procedures for re-evaluation of the historical Dobson data set were established in WMO 1993 Ozone Report No. 29. Generalised software for the reduction of total ozone observations with the Dobson spectrophotometers has been provided by the Czech Hydrometeorological Institute's Solar and Ozone Observatory, Hradec Kralove, Czech Republic.

	For Brewer instruments: not available except as provided by manufacturer's instructions For the filter ozonometers: formal manual for operation plus instruction provided by MGO
Data Centre	WMO World Ozone and Ultraviolet Data Centre (WOUDC) operated by MSC since 1960

Comment

Although total ozone observations were begun in the 1920s, systematic measurements on global scales started in 1957/58 during the International Geophysical Year (IGY). The Dobson-equipped stations that have operated continuously since then have provided the longest duration data set for evaluation of changes in stratospheric ozone distribution. Dobson spectrophotometers are used at about 100 observation sites and are the backbone of the GAW ozone observing network. Filter ozonometers have also provided data over this same period, from more than 40 stations in the former USSR. Automated Brewer ozone spectrophotometers have also contributed substantially to the total column ozone record. Ground-based measurements are complimented with the global coverage provided by satellite-based remote ozone instrumentation.

In the 1970s the release of chlorofluorocarbon compounds (CFCs) into the atmosphere was identified as a possible source of stratospheric ozone loss. This led to a critical analysis of the long-term ozone data set, with the aim to better evaluate the possible effects of the CFCs on the stratospheric ozone. It was not until the mid-1980s, however, that unequivocal evidence of ozone destruction was found, first in the dramatic ozone losses observed during the Antarctic spring and, a few years later, in the substantial ozone losses that seasonally occur in the northern upper and middle latitudes. The losses over Antarctica were first identified by measurements from Dobson spectrophotometers.

The need for high quality total ozone observations continues. The recent changes in stratospheric ozone and the elimination of CFC release through international agreements require that observations be continued in order to monitor the return of the ozone layer to its previous state and to improve our scientific understanding of present and possible future perturbations. This need assures the GAW ozone network an important role in ozone observations for decades.

Goals

- To assure regular calibration of total column instruments.
- To provide the uninterrupted and systematic measurement of total ozone by the GAW ozone network of stations which is essential if we are to provide a reliable long-term data series suitable for trend analysis on global and regional scales, as requested by WMO EC in 1998 and 1999. The GAW network must continue to provide an independent measure of stratospheric ozone on global scales, and thereby better define the ozone changes that occur.
- To encourage the submission of data to the WOUDC. Timely submission is required for the preparation of periodic information bulletins for Antarctica and for the Northern Hemisphere, as requested by EC and Congress as well as for UV warning bulletins.
- To expand and improve the Umkehr observations.
- To encourage intercomparisons between all ground-based total column instrument types.

Implementation Strategy

Task 1a. Continue major quadrennial intercomparisons alternating between WMO RA I, II, III and V and minor annual intercomparisons in RA VI in the established Dobson calibration centres to ensure regular calibration of each field Dobson every four years.
(Secretariat - ongoing)

Task 1b. Performs absolute calibrations and/or intercomparisons of the regional standard Dobsons with the world reference standard Dobson No. 83 from NOAA/Boulder on a two or three years interval.
(Secretariat - ongoing)

Task 2. To update Ozone Report No. 6 on Dobson standard operating procedures.
(SAG Ozone - 2001)

Task 3. To increase participation of Brewer and M124 instruments during Dobson intercomparisons.
(Secretariat, SAG Ozone - ongoing)

Task 4. To increase the number of Umkehr measurement sites through workshops and providing hands on training during intercomparisons and calibration visits.
(Secretariat – ongoing)

Task 5. To improve communication between stations and the WOUDC to maximise data submission.
(WOUDC - ongoing)

Task 6. To update the Dobson SOPs and to make them available to the Dobson community.
(SAG Ozone – 2002)

Task 7. To encourage Brewer calibrations at least every 4 years by travelling standards.
(Secretariat, SAG Ozone - ongoing)

Task 8. Refine the Umkehr data reduction algorithms in collaboration with satellite community.
(Secretariat, SAG Ozone - ongoing)

5.1.3 Ozone Sondes

Current Status

Lead responsibility	Scientific Advisory Group for Ozone (SAG Ozone)
QA/SAC	Forschungszentrum, Jülich, Germany (being established)
Calibration Centre	World Calibration Centre for Ozone Sondes (WCCOS) at Forschungszentrum Jülich, Germany
Reference Standard	UV photometer in environmental chamber maintained by WCCOS
DQO	Not available
SOP	Under development through the Jülich Ozone Sonde Intercomparison Experiments (JOSIE)
Data Centres	World Ozone and Ultraviolet Data Centre (WOUDC), Meteorological Service of Canada (MSC, formerly Atmospheric Environment Service, AES), Toronto, Canada

Comment

Characterising the vertical distribution of ozone both in the troposphere and stratosphere is essential to understand the physical, chemical, and radiative processes in our atmosphere. It has become apparent that the vertical distribution of ozone significantly influences the radiative balance of the atmosphere, plays an important role in climate variability and change, and strongly affects the cleansing capability through oxidation. Because of these roles, it is imperative that the GAW ozonesonde measurement programme be continued and extended to provide sufficient high quality data to characterise the global vertical distribution ozone from the ground to the middle stratosphere.

Our knowledge of the vertical distribution of ozone on global scales is very incomplete, particularly in the free troposphere where trends in the vertical distribution are very uncertain. There are perhaps 15 stations with long-term records (>15 years), and most of these are located in Canada, Europe and Japan, with very few in the USA and Australia. Among these stations the data quality and sampling frequency are not uniform. There is only one station in the tropics having a long record (from 1979), although new stations are now in place under the NASA Southern Hemisphere Additional Ozonesondes (SHADOZ) programme. In general, more frequent sonde measurements at more locations are highly desirable. Lidars are also used to measure vertical profile of ozone up to 50km altitude. This very sophisticated and highly technical method can be used at only a few GAW stations.

Previous intercomparisons, carried out by launching several different kinds of ozone sondes simultaneously, have provided information regarding instrument accuracies, but many questions remain unanswered about differences in instrument performance and optimal operating procedures. The World Calibration Centre for Ozone Sondes at the Forschungszentrum Jülich, Germany, has provided the environmental chamber simulator to resolve a number of the outstanding questions. Their facilities include a specially designed vacuum chamber and a reference ozone photometer for simultaneous intercomparison of up to 4 ozone sondes under conditions that simulate the temperatures and pressures encountered in actual ozone sonde ascents. All JOSIE activities use this facility.

A major expansion of the current number of ozone sonde measurement stations and establishing SOPs for ozone sondes are necessary if we are to provide the data necessary to characterise the vertical distribution of ozone. The SOPs are under development through the JOSIE experiments. The JOSIE 1996 report is available as GAW Report No. 130. Results from JOSIE 1998, 1999 and 2000 will be prepared during 2001 and made available as GAW reports.

Goals

- To complete the development of SOPs for ozone sondes.
- To expand the ozone sonde network to include more tropical and Southern Hemisphere stations with weekly soundings.

Implementation Strategy

Task 1. To complete JOSIE 2000 chamber intercomparison and evaluate results.
(WCCOS, SAG Ozone - 2001)

Task 2. To hold a balloon intercomparison of ozone sondes to verify or further refine the results of JOSIE.
(WCCOS, SAG Ozone - 2002)

Task 3. To finalise standard operating procedures for ozone sondes based upon the JOSIE experiments and balloon intercomparisons.
(SAG Ozone and JOSIE Science Committee - 2003)

Task 4. To seek funding to establish new ozone sonde stations in developing countries within the tropics and Southern Hemisphere.
(Secretariat - ongoing)

Task 5. To hold a workshop on the needs of the modelling community for ozone sonde data from GAW including the location of new stations.
(Secretariat, SAG Ozone - 2002)

5.2 Greenhouse Gases

5.2.1 Carbon Dioxide (CO_2)

Current Status

Lead responsibility	Scientific Advisory Group for Greenhouse Gases (SAG GG)
QA/SAC	Japan Meteorological Agency (JMA), Tokyo, Japan for Asia and the South-West Pacific
Calibration Centre	Climate Monitoring and Diagnostics Laboratory (CMDL), Boulder, Colorado, USA, with the assistance of Regional Calibration Centres
Reference Standard	CMDL
DQO	Established through GAW reports Nos. 121 and 132
SOP	GAW Report No. 134 is complete and available
Data Centre	Japan Meteorological Agency (JMA), Tokyo, Japan

Comments

Carbon dioxide plays a significant role in the earth's radiation balance because of its large atmospheric abundance and its absorption of long-wave radiation. It is continually cycled through the earth system, and its highest natural exchange rates occur between the terrestrial biota and the atmosphere and between the surface water of the oceans and the atmosphere. Human additions to the cycle through fossil fuel combustion and deforestation are much smaller than these natural fluxes, but they are still large enough to perturb the natural carbon cycle.

The target precision of the CO_2 measurement programme is set to 0.1 ppm in the Northern and 0.05 ppm in the Southern Hemisphere. It is necessary to balance the carbon-cycle budget to within at least 10% of anthropogenic emissions if we are to provide reliable long-term estimates of CO_2 increases appropriate to particular emission management scenarios. Continued operation of the CO_2 network should be directed towards resolving these issues.

Atmospheric CO_2 monitoring was started over 40 years ago to establish that the CO_2 concentration was rising and to document its rate of increase. This has led to a new scientific focus, namely the estimation of sources and sinks of CO_2 from measured concentration differences in space and time. The first priority is to find out what is actually happening on the largest spatial scales. Sustained monitoring of CO_2 and its isotopes at the GAW sites can reveal these large-scale patterns and their development over time.

A strong second priority is to collaborate in interdisciplinary process studies of well-defined and representative ecosystem types. Strong cross-linkages must be maintained with the global CO_2 survey of the Joint Global Ocean Flux Study (JGOFS) and the World Ocean Circulation Experiment (WCRP/WOCE) as well as with various programmes of the International Geosphere-Biosphere Programme (IGBP) and the International Global Atmospheric Chemistry Programme (IGAC). An existing co-ordinated research programme on isotope variations of CO_2 and other trace gases in the atmosphere is being conducted by the International Atomic Energy Agency (IAEA). In collaboration with IAEA, common isotope quality assurance procedures should be defined. Further, this GAW activity should contribute to the implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol.

Currently there are nearly 50 measuring stations in various areas of the world, with over a third providing continuous records while the rest collect flask samples of air. In order to use atmospheric transport models for regional scale CO_2 source and sink determination, it is necessary to create an appropriate and more extensive database than that available at present. More data are needed from continental stations and stations at low latitudes. A fundamental requirement for such a programme is careful and continuing calibration for CO_2 as well as its isotopes. Without a solid and precise link to a common calibration scale, most of the measurements would be of limited value.

Goals

- To produce an internally consistent CO_2 data set through regular calibration and intercomparisons of measurements.
- To improve the global network, particularly in continental areas and at low latitudes, in order to acquire more complete information about sources and sinks of CO_2 and to reveal large-scale CO_2 flux and sequestration patterns and their relationship to measured concentrations in space and time. To include measurements throughout the troposphere to determine the attenuation and phase shift of annual cycles with height.
- To co-operate with IAEA with regard to isotopic measurements, to identify those factors necessary for meaningful intercomparison, and to formulate an initial set of guidelines concerning sample collection/site details, laboratory analysis details, and isotopic standards.
- To co-operate with process-oriented research programmes (IGAC, JGOFS/WOCE) in obtaining vertical flux and profile measurements up to the upper troposphere, making oceanic carbon observations, and using special observation systems (towers, aeroplanes, etc.).
- To integrate satellite and surface-based measurements for the purpose of monitoring progress in the reduction of greenhouse gas emissions (implementation of Kyoto Protocol).

Implementation Strategy

Task 1. To review DQOs for data on CO_2 and its isotopes, and to add a section on isotopes to the SOP for CO_2.
(SAG GG - December 2002)

Task 2. To work with the Reference Standard, WCC, and QA/SAC to agree upon tasks and interfaces for carrying out calibration and intercomparison of all Global GAW stations.
(PS, WCC, QA/SACs - December 2002)

Task 3. To co-operate with research programmes involving measurements made from ships and aircrafts, vertical profiles from towers, and the flux measurement network.
(SAG GG - December 2003)

Task 4. To review the internal consistency of CO_2 global data sets archived at the WDCGG with respect to calibration scales.
(SAG GG, in co-operation with QA/SACs, WDCGG - December 2004)

Task 5. To develop a plan for integrated satellite and surface-based measurements for monitoring greenhouse gases.
(SAG GG - 2003)

Task 6. To encourage Member countries to pursue funding opportunities to establish more stations where data are needed.

(Panel, SAG GG - December 2002)

5.2.2 Methane (CH_4)

Current Status

Lead responsibility	Scientific Advisory Group for Greenhouse Gases (SAG GG)
QA/SAC	Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland, for Europe, Africa, and the Americas Japan Meteorological Agency (JMA), Tokyo, Japan, for Asia and the South-West Pacific
Calibration Centre	Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland, for Europe, Africa, and the Americas Japan Meteorological Agency (JMA), Tokyo, Japan, for Asia and the South-West Pacific
Reference Standard	Not yet established
DQO	Not yet established
SOP	Not yet established
Data Centre	World Data Centre for Greenhouse Gases (WDCGG), Japan Meteorological Agency, Tokyo, Japan

Comment

Methane is the second-most important human-influenced greenhouse gas (after CO_2) and contributes about 20% of direct radiative forcing. Changes in the atmospheric abundance of methane also feed back into atmospheric chemistry, affecting climate indirectly by influencing other greenhouse gases such as tropospheric O_3 and stratospheric H_2O. Methane, along with CO, NOx, O_3, and nonmethane hydrocarbons, affects the concentration of OH, and therefore the lifetimes of other reduced greenhouse gases such as HFCs. The indirect effects are estimated to add ~40% to the direct climate effect of methane.

Methane is emitted to the atmosphere by natural (wetlands (predominantly), termites, oceans, and destabilization of clathrates) and anthropogenic (fossil fuel exploitation, rice agriculture, landfills, domestic ruminant animals, landfills, waste treatment, and biomass burning) sources. Although the major sources have been identified, the magnitude of emissions from many sources are still quite uncertain due to the difficulty in assessing global emissions from sources whose strengths are spatially and temporally quite variable. Clearly, reducing methane emissions to the atmosphere would decrease its potential effect on climate. Before reasonable policies can be developed to reduce CH_4 emissions, its budget of sources and sinks must be understood better than it is currently.

Measurements of CH_4 in ice core and firn air indicate that the tropospheric abundance of CH_4 has increased by a factor of 2.5 since the mid-1800s. Modern measurements show that while CH_4 continues to increase, the rate of increase has slowed over the past 2 decades.

Measurements of CH_4 are made either from an in situ sampling and analytical system or from discrete samples collected in flasks that are sent back to a central laboratory for analysis. The most commonly used technique for *in situ* monitoring of these gases is gas chromatography. Methane mole fractions are determined by comparing the instrument response from air samples with the response from standard gases that are precisely calibrated. Development of an internationally accepted standard scale is a critical task.

Currently, there are only about ten stations that monitor CH_4 continuously. Flask samples are collected periodically at many more stations. More data are needed from continental stations and stations at low latitudes.

Goals

- To produce an internally consistent methane data set through regular calibration and auditing of Global GAW stations and intercomparison of measurements.
- To co-ordinate and refine measurements/data management procedures for CH_4 in co-operation with relevant international research programmes, in particular the International Global Atmospheric Chemistry Programme (IGAC).
- To improve the GAW network, particularly in continental areas and at low latitudes, to determine large scale spatial distribution and temporal trends in atmospheric CH_4 abundance in co-operation with IGBP/GAIM Global Atmospheric Methane Synthesis (GAMeS).

Implementation Strategy

Task 1. To establish data quality objectives (DQOs).
(SAG GG - December 2003)

Task 2. To work with the Reference Standard (RS), WCC and QA/SAC to agree upon tasks and interfaces for carrying out calibration and intercomparison in the GAW network.
(RS, WCC, QA/SACs - December 2002)

Task 3. To establish co-operation with active laboratories on CH_4 measurement methods and sites, calibration standards, quality assurance, and standard operating procedures.
(SAG GG, QA/SACs - December 2003)

5.2.3 Nitrous Oxide (N_2O), and Chlorofluorocarbons (CFCs)

Current Status

Lead responsibility	Scientific Advisory Group for Greenhouse Gases (SAG GG)
QA/SAC	Umweltbundesamt Berlin (UBA) (for N_2O) being established
Calibration Centre	Fraunhofer Institut für Atmosphärische Umweltforschung (IFU) in Garmisch Partenkirchen, Germany (for N_2O) being established
Reference Standard	Climate Monitoring and Diagnostics Laboratory (CMDL), National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado, USA (for N_2O)
DQO	Not yet established
SOP	Not yet established
Data Centre	World Data Centre for Greenhouse Gases (WDCGG), Japan Meteorological Agency, Tokyo, Japan

Comment

Nitrous oxide has many natural and anthropogenic sources, including emissions from natural and fertilized agricultural soils, the oceans, fossil fuel burning, and biomass burning. It is inert in the troposphere, and its low abundance means that N_2O has contributed only a small proportion of the recent decadal increase in greenhouse radiative forcing.

CFCs, including CFC-11, -12, -113, -114, and -115, are compounds that do not exist naturally in the environment. First manufactured in the 1930s, they have been used as refrigerant gases, solvents, and propellants. However, as a consequence of actions taken under the Montreal Protocol and its subsequent amendments, tropospheric growth rates of CFCs have slowed significantly.

Measurements of N_2O, and CFCs are made either from an in situ sampling and analytical system or from discrete samples collected in flasks that are sent back to a central laboratory for analysis. The most commonly used technique for in situ monitoring of these gases involves gas chromatography. Concentrations are determined by comparing the measurements with calibration gases of known concentration. Improvement of calibration is a critical task for these gases. No systematic international inter-laboratory calibration scheme for standard reference gases exists. This makes it difficult to compare and combine measurements from different monitoring programmes in order to increase global coverage.

A small number of data reporting stations exists for CFCs and N_2O.

Goals

- To co-operate with active laboratories and relevant research programmes, especially the International Global Atmospheric Chemistry Programme (IGAC), to refine measurements and data management for N_2O, and CFCs.
- To define and establish central facilities for these gases, as needed, in co-operation with IGAC.

Implementation Strategy

Task 1. To work with the Reference Standard (RS), WCC, and QA/SAC to agree upon tasks and interfaces for carrying out calibration and intercomparison in the GAW network.
(RS, WCC, QA/SACs - December 2004)

Task 2. To define and establish, in co-operation with IGAC, central facilities for N_2O, and CFCs measurement methods and sites, calibration standards, quality assurance, and standard operating procedures.
(SAG GG - December 2004)

5.3 Reactive gases

5.3.1 Carbon Monoxide (CO)

Current Status

Lead responsibility	SAG for Reactive Gases is not formally established but needs to be formed. A group of experts on CO instrumentation met in Geneva during September 1999 and made recommendations to the Secretariat regarding the GAW CO measurement programme
QA/SAC	Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland
Calibration Centre	EMPA
Reference Standard	Climate Monitoring and Diagnostics Laboratory (CMDL), Boulder, Colorado, USA. CMDL is also responsible for preparation of secondary standards for flask analysis of CO

DQO	Not yet established
SOP	Under development at EMPA
Data Centre	World Data Centre for Greenhouse Gases (WDCGG), Japan Meteorological Agency, Tokyo, Japan

Comments

The oxidising capacity of the troposphere is strongly influenced by levels of CO. Mixing ratios for CO in the troposphere have been reported by laboratories over the past 25 years, but definitive intercomparisons of CO data from these laboratories are still needed. Laboratories have depended on a variety of methods to maintain their calibrations and standardisation is still lacking.

The CO instrumentation used in GAW consists of two fundamentally different types: continuous (frequent) sampling and measurement, and flask samples (infrequent) for later analysis at centralised laboratories. It was recommended to the WMO by a group of experts on CO instrumentation that more of the remote Global GAW stations begin continuous measurement programmes of CO. It was also recommended that all stations with continuous CO programmes also make weekly flask samples to provide an independent intercomparison to help identify problems that may arise with the long-term accuracy and precision of these measurements.

Despite continuing uncertainties regarding absolute accuracy and calibration, the fundamental qualitative distributions of CO are known. Seasonal cycles, combined with significant inter-annual variation, have been described at many locations. Less well defined are long-term changes in atmospheric CO levels. The CO concentrations vary with time and location, and global trends are impossible to determine on the basis of measurements from only a few stations. It is therefore highly desirable to expand CO measurement activities in GAW. In particular, there are few data available in the middle and high latitudes of the Southern Hemisphere. Measurements above the boundary layer are also needed to define the vertical distribution and temporal variation in the free troposphere, implying that more mountain stations with continuous CO measurement capability are highly desirable.

Recognising that continuous measurements of CO is a difficult task, more help is essential, particularly for new stations in developing countries, if a long-term record of high quality data is to be established.

Goals

- To produce an internally consistent CO data set through regular calibration and intercomparisons of measurements conducted by the Calibration Centre for CO and, in particular, to improve the long-term quality of measurements so inter-annual variations can be reliably detected.
- To increase the number of GAW stations making continuous CO measurements in order to better characterise its spatial and temporal distribution. This expansion should include continuous measurements at the Mount Kenya, Indonesia, and Brazil sites.
- To include flask sampling for CO at all sites that make continuous measurements, in order to better assure the accuracy of the continuous measurements with weekly intercomparisons between the two different methods.
- To provide assistance to the stations in developing countries through twinning, workshops, long-term training, and the calibration gases that are essential if these stations are to maintain a reliable measurements programme.
- To establish a co-operative programme for providing ground-truth of CO measurements for satellites.

Implementation Strategy

Task 1. To establish DQOs for CO and SOPs for continuous CO measurements.
(WCC, QA/SACs - ongoing)

Task 2. To establish continuous measurements of CO at Global GAW stations in developing countries and additionally to collect weekly flask samples at these stations for intercomparison with the continuous measurements. This programme must include a strong training component.
(WCC - ongoing)

5.3.2 Volatile Organic Compounds (VOCs) and Nitrogen Oxides (NO_x)

Current Status

Lead responsibility	SAG for Reactive Gases (is not formally established but needs to be formed)
QA/SAC	Umweltbundesamt Berlin (UBA), for Europe and Africa
Calibration Centre	Fraunhofer Institut für Atmosphärische Umweltforschung (IFU), being established
DQO	Not yet established
SOP	Not yet established
Data Centre	World Data Centre for Greenhouse Gases (WDCGG), Japan Meteorological Agency, Tokyo, Japan

Comment

The growing interest in tropospheric ozone as a climate gas and atmospheric oxidant has heightened GAW's need to document the global distribution of VOCs and NO_x as precursors for ozone and other oxidants in the troposphere. Due to their short lifetime in the atmosphere, their global concentration varies significantly from region to region, making it difficult for GAW to establish a global climatology for these parameters with only a limited number of measurement sites.

The demand for regular VOC monitoring is actually being met by the establishment of a variety of monitoring networks on both a national and a global basis, coupled with local monitoring by urban authorities, environmental bodies, and universities. Although many VOC measurements are routinely performed throughout Europe and the USA, the overall quality of these data sets is still poorly defined and known. Several national and international intercomparisons have shown deviations between measurements by different laboratories of more than 200%. Much of the VOC monitoring in Europe has been done by grab sampling (e.g., in the EMEP network). Grab sampling may also be favoured for GAW. A huge variety of VOCs exist, and some are much more difficult to measure than others. Therefore, any practical sampling programme will produce only a limited subset of the total VOC concentration spectrum. Because the value of any database increases with the number of species measured, an optimum measurement configuration will represent a balance between information content and practical measurement considerations.

Nitrogen oxides have not been routinely measured at Global stations since no acceptable methods have been available to measure the very low concentrations present. The more important compounds are NO, NO_2, HNO_3, aerosol nitrate, and peroxyacetylnitrate (PAN). Conversions between the different compounds are generally rapid, and the only unambiguous data for nitrogen oxides would be the sum of all compounds, which is often denoted as "NO_y". Since anthropogenic activities constitute a large source of nitrogen oxides, any true global signal could be observed only at very remote locations. A dense network would be necessary for any true description of the overall variability of these compounds. Since the concentrations are so low, even at less remote locations, the problem of contamination is a substantial one.

In view of these considerations and the current state of measurement technology, GAW should develop its VOC and NO_x measurements in stages. VOC and NO_x measurements are expected to be applied in conjunction with a variety of interpretative techniques, including comprehensive three-dimensional modelling, to accomplish the goals.

There is now a wealth of data on VOCs and NO_x from aircraft campaigns in various parts of the world. These data may be very useful in the selection of future sites. GAW must also benefit from the experience gained in international projects, most notably in the International Global Atmospheric Chemistry Non-Methane Hydrocarbon Intercomparison Experiment (IGAC-NOMHICE) or the European Experiment on Transport and Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe (EUROTRAC). The network must also be harmonised with the European Monitoring and Evaluation Programme (EMEP) and the North American Research Strategy for Tropospheric Ozone (NARSTO).

Goals

- Over the shorter term, to co-operate with IGAC, EMEP, and NARSTO to redefine measurement methods and sites, calibration standards, and quality assurance and standard operating procedures for VOCs and required co-data.
- Over the longer term, to detect the spatial distributions, as well as the seasonal and long-term changes, of VOCs and NO_x in the remote troposphere. To identify major sources and sinks and to establish the chemical basis for the ozone content and general oxidation capacity of the remote troposphere.

Implementation Strategy

Task 1. To initiate establishment of a World Calibration Centre for VOCs.
(SAG reactive gases, QA/SAC - December 2001)

Task 2. To establish DQOs and begin developing SOPs in co-operation with EMEP for VOCs and NOx.
(SAG reactive gases, QA/SAC - December 2002)

Task 3. To enlarge the VOC measurement programme in stages, proceeding from the easiest measurements to those that are more difficult, by implementing the following measurement activities at least at three stations:

- measurements of C_2-C_9 hydrocarbons, including alkanes, alkenes, alkynes, dienes, and monocyclics
- measurements of C_{10}-C_{14} hydrocarbons, including higher homologues as well as biogenic hydrocarbon compounds
- measurements of oxygenated VOCs, including alcohols, carbonyls, and carboxylic acids.

(SAG RG - October 2001)

5.3.3 Sulphur Dioxide (SO_2)

Current Status

Lead responsibility SAG for Reactive Gases (is not formally established but needs to be formed)

QA/SAC Not yet established

Calibration Centre	Not yet established
DQO	Not yet established
SOP	Not yet established
Data Centre	World Data Centre for Greenhouse Gases (WDCGG), Japan Meteorological Agency, Tokyo, Japan

Comment

Sulphur dioxide has not been monitored at Global stations routinely, except as a part of acid deposition studies. It has a lifetime of hours to days. The sources for SO_2 include the sea, volcanic activity, anthropogenic emissions, and biomass decay processes. Measurements to monitor the background concentration of SO_2 should be made far away from sources. SO_2 is a standard measurement at a large number of Regional stations, and these data can be used to investigate relationships between its atmospheric concentration and regional and national emissions.

Goals

No concrete goals have been specified for this parameter.

Implementation Strategy

No specific tasks.

5.4 Atmospheric Deposition

Current Status

Lead responsibility	SAG for Precipitation Chemistry and Deposition (SAG PC)
QA/SAC	Atmospheric Sciences Research Centre (ASRC), State University of New York (SUNY), Albany NY, USA
Reference Standard	Illinois State Water Survey, Champaign IL, USA (ISWS)
Calibration Centre	ASRC-SUNY
DQOs	Established for precipitation chemistry measurements and will be published in a GAW report in 2001
SOPs	Established for precipitation chemistry measurements in general and will be published in a GAW report in 2001
Data Centre	World Data Centre for Precipitation Chemistry (WDCPC), ASRC-SUNY

Comment

Precipitation chemistry is the simplest way to obtain an indication of pollution in the lower atmosphere. In essence, air pollutants are scavenged by the precipitation process and delivered to the surface in an easily collectable form, permitting straightforward laboratory analysis. In the 1960s, 1970s and 1980s, it was the acidity of precipitation caused by this pollution that was the major concern in Europe and eastern North America. This acidity was known to have adverse effects on the terrestrial and aquatic environments, ranging from the acidification of soils and inland waters (causing vegetation decline and fish kills) to the damage of buildings and monuments. The concern about acidification continues in many regions of the world, especially Asia, but is now accompanied by increasing recognition that the nitrogen nutrients (and perhaps phosphorus) delivered to the surface by precipitation may contribute significantly to the over-enrichment of ecosystems and especially to the eutrophication of coastal waters.

The initial objectives of the WMO precipitation chemistry measurements initiated in the early 1960s to characterize wet deposition were to evaluate global and regional concentrations of selected chemical compounds in precipitation, to determine their spatial and temporal distributions, to assess the influence of human activities on the composition of the atmosphere, and to improve knowledge of physico-chemical processes related to the atmospheric transport and deposition of pollutants. Dry deposition remains an elusive contribution to the total deposition of pollutants from the air to natural surfaces. In the absence of suitable direct dry deposition measurement techniques, dry deposition, which is often of major importance near pollution source areas and in arid regions, is estimated by using measurement data on concentrations of major pollutants in air. Exploratory programmes presently testing possible monitoring methodologies will be evaluated by GAW, and relevant techniques will be introduced once well enough proven. The GAW precipitation chemistry network comprises more than 200 stations, most of which are in Europe and North America. Recent progress has been made in East Asia with the formation of the new Acid Deposition Monitoring Network in East Asia (EANET) which currently involves ten countries, but the number of precipitation measurement sites is insufficient in South America, Africa and in many parts of Asia. Furthermore, there are inconsistencies in the sampling instrumentation and the sampling protocols around the world.

GAW precipitation chemistry data are archived at the GAW World Data Centre for Precipitation Chemistry (WDCPC), located with the QA/SAC at the State University of New York in Albany, New York, USA. Historical GAW data have been quality assured (to the extent possible given the lack of historical quality control information) but the quality of these data has been generally insufficient for broad use by the scientific community and for the development of pollution control measures. New data are being added to the WDCPC continuously and a World Wide Web site has been established to facilitate timely data submission and data access.

Despite obvious achievements of the GAW precipitation chemistry and deposition activities, some problems, as mentioned above, await solutions. In particular, economic development and population growth in developing countries in Asia, South America and Africa, as well as climate change, have made these regions vulnerable to atmospheric deposition of pollutants. Furthermore, there is growing global concern with regard to atmospheric deposition of heavy metals and persistent organic pollutants (POPs). It is anticipated that the methodologies for these components, when adequately well developed, will be assimilated into the GAW precipitation chemistry programme. To address all these problems and, in particular, the need to revise standard operating procedures (SOPs) and to improve quality assurance/quality control (QA/QC) and data management, the GAW Scientific Advisory Group on Precipitation Chemistry (SAG PC) was established in 1998.

Goals

- To improve GAW precipitation chemistry measurements through the implementation of new SOPs, including improved measurement methods and QA/QC and more consistent laboratory performance, and through harmonization of measurements conducted globally by various regional and national programmes.
- To enhance the timely submission and distribution of GAW precipitation chemistry data through use of the World Wide Web and to promote the use of these data both for scientific and pollution control purposes.
- To stimulate and support the establishment of additional precipitation chemistry monitoring sites in data sparse and newly industrialising regions of the world through interested regional and national organizations.

- To carry out quadrennial scientific assessments of global precipitation chemistry (mainly based on data in WDCPC) including patterns and trends of acid deposition as well as available results of modelling of long-range transport from major source areas.
- To provide data for evaluating effects of acid deposition on major ecosystems (in particular coastal and/or sensitive areas), to improve understanding of biogeochemical cycles of major elements and to develop control measures.
- To assess and, if necessary, implement suitable measurement programmes for air/surface exchange including dry deposition as well as for trace metals and POPs in precipitation.

Implementation Strategy

Task 1. To initiate the implementation of the new SOPs for GAW precipitation chemistry measurements through the distribution of a new Guidance Document harmonizing measurement procedures used in various regional and national programmes, and the development of a new data submission/distribution system on the World Wide Web.

(SAG PC - June 2001).

Task 2. To upgrade the Precipitation Chemistry Quality Assurance Programme by:

- implementing a comprehensive set of quality assurance and quality control activities (as specified in the Guidance Document),
- further developing and improving the QA procedures for precipitation chemistry measurements including the development of stringent data acceptance criteria,
- conducting the semi-annual Laboratory Intercomparison Studies and providing training and feedback to countries and laboratories with substandard performances.

(SAG PC - December 2003)

Task 3. To conclude studies on sample preservation and to make recommendations on the most appropriate preservation methods for minimizing sample degradation during collection and shipping.

(SAG PC - July 2001)

Task 4. To assist in developing regional programmes, to identify and attempt to increase the number of precipitation chemistry monitoring sites in data sparse areas of the world, most notably in South America, Asia, and Africa as well as in large and relatively homogeneous ecosystems such as rain forests, savannahs, and Arctic regions. More measurements may also be needed in rapidly industrialising areas to provide information required for political decisions to reduce acidifying emissions.

(SAG PC - June 2002 and afterwards)

Task 5. To carry out an assessment of the quality of GAW precipitation chemistry data and the success of the new SOPs.

(QA/SAC - June 2004)

Task 6. To initiate the preparation of a formal scientific assessment of global precipitation chemistry.

(SAG PC - June 2004)

Task 7. To assess the requirement for measurements of air-surface exchange, including dry deposition of acidifying species. This will require a careful assessment of the scientific needs, appropriate technology, proper measurement systems, suitable QA/QC, and adequate data management methods

(SAG PC - December 2003)

Task 8. To assess the need for trace metal and POPs measurements in the GAW programme. If such needs are identified, to propose a suitable measurement programme.

(SAG PC - December 2004)

5.5 Solar Radiation

Current Status

Lead responsibility	For UV: Scientific Advisory Group on UV radiation (SAG UV); responsible for all types of UV radiation measurements and for co-operation with WWW and WCRP/BSRN
	For other radiation components: Scientific Review Panel for BSRN, various WWW/CIMO and WWW/CBS expert groups
QA/SAC	For UV: ASRC-SUNY for the Americas only
	For other radiation components: not applicable
Calibration Centre	For UV: Surface Radiation Research Branch of NOAA's Air Resources Laboratory, Boulder, CO. USA (SRRB): being established for Americas
	For other radiation components: World Radiation Centre (WRC), Physikalisch-Meteorologisches Observatorium, Davos, Switzerland, for the WWW
DQO	In preparation (parts in WMO reports Nos. 125, 126)
SOP	In preparation (parts in WMO reports Nos. 125, 126)
Data Centre	World Ozone and UV Data Centre (WOUDC), Meteorological Service of Canada (MSC, former AES), Toronto, Canada
	World Radiation Data Centre (WRDC), Main Geophysical Observatory, St. Petersburg, Russia, for GAW, WWW, and WCP
	World Radiation Monitoring Centre (WRMC) for BSRN, Institute for Climate Research ETH, Swiss Federal Institute of Technology, Zurich, Switzerland

Comment

The radiation component of GAW has concentrated its efforts on UV radiation. Other specialised WMO programmes - such as WWW and BSRN - have dealt with other aspects of solar radiation. For example, radiation measurements are part of the WMO Commission on Instruments and Methods of Observation (CIMO) objectives and are described in WMO's Guide to Meteorological Instruments and Methods of Observation. The BSRN has produced the BSRN Operations Manual (1998) for their programme which aims at providing high quality and high sampling rate observations of the short- and long-wave surface radiation fluxes at a number of selected background stations for ground-truthing of satellite measurements. At all BSRN stations, the global, direct, diffuse, and long-wave downward radiation are measured and standard meteorological (including upper air) observations are carried out. Many of the stations also measure direct spectral solar irradiance, aerosol, and water vapour vertical distribution. Some of the BSRN sites correspond very well to the needs specified for the GAW Global station network, and practically all of them coincide with GAW Regional station sites. All of the six GAW Global stations established in the GEF project in the late 1990s take solar radiation measurements and most fulfil the requirements for BSRN stations.

During the time period of the previous GAW Strategic Plan (1997-2000) several UV instrument intercomparisons were carried out. These have helped greatly to improve the quality of the UV measurements. The collaboration of the UV Calibration Centre at NOAA, Boulder with GAW is an important step in setting up UV calibrations in GAW. Guidelines for measuring UV radiation have been issued (WMO Report No. 125). The Guidelines for Site Quality Control (WMO Report No. 126) have been published and distributed to the UV community. Recommendations for harmonisation of the UV Index have been produced. The global UV network information has been posted on the UV Web site and is being updated. In the Southern Cone project, 12 UV measurement stations were set up in South America. The UV data requirements, archiving and distribution system have been established in the WOUDC and data is available. GAW UV activities have been presented at the major UV conferences.

With UV radiation linked to several harmful effects on many forms of life, either directly (biological damages) or indirectly (quality of life), the necessity for monitoring surface UV radiation and quantifying future changes is of great importance. Monitoring UV along with other factors such as clouds, aerosols, albedo and pollutants allows UV irradiation conditions to be defined on regional and worldwide scales, as well as determining, quantitatively, the factors that affect the surface UV dose. During the last decade, UV measurements of all types have continued to expand and the number of sites undertaking UV monitoring increased. To support the global network of UV measurements on an international basis, WMO established, in 1994, the Scientific Advisory Group on UV radiation (SAG UV).

At present, a wide range of instruments is available to measure UV, including spectroradiometers, broadband UV detectors, multi-channel narrow-band radiometers and dosimeters. Nevertheless, it does not seem likely that the available instruments will satisfy all requirements. Furthermore, it is generally agreed that the UV measurements are not yet fully operational at the appropriate level of accuracy and in terms of quality control for long-term studies.

Besides measurement activities, modelling of the radiative transfer of UV radiation has become an important part of the activities. Radiative transfer models have been applied in the development of satellite-based methodologies for estimating the UV irradiance on the earth's surface. UV monitoring from space offers the opportunity to achieve a global coverage of the UV radiation field. It is a promising tool in support of environmental assessments and environmental information for the public, e.g., in the form of a UV index related to UV forecasting.

Goals

- To further the development and co-ordination of the GAW UV radiation monitoring network.
- To establish a UV climatology, i.e. a knowledge of average levels of UV doses and UV variations on a world-wide basis.
- To develop a reliable database of UV observations for use in UV effect studies.
- To increase public awareness of UV changes and potential effects of UV exposure.
- To define and promote the implementation of operational structures for quality control, quality assurance, data archiving, and the ancillary measurements needed for data analysis.
- To establish relationships with other agencies, user communities, and scientific programmes dealing with UV radiation.
- To refine statements of the need within GAW for solar radiation data relating to the infrared and visible spectrum and, in particular, to identify the interfaces with the BSRN and WWW programmes.

Implementation Strategy

Task 1. To update as required the procedures for UV data archiving at and distribution through the World Ozone and UV Data Centre, in collaboration with the other WMO World Data Centres; to promote data submission.
(SAG UV – continuous effort, next milestone December 2001)

Task 2. To update the UV network status and establish their GAW station status as part of SOPs.
(SAG UV - December 2001)

Task 3. To define QA guidelines as part of SOPs.
(SAG UV - July 2002)

Task 4. To continue defining instrument specifications in relation to monitoring objectives with the required ancillary measurements, specifically by producing guidelines for broad- and narrow-band instruments as part of SOPs.
(SAG UV - July 2002)

Task 5. To establish a UV World Calibration Centre and Regional Calibration Centres in order to initiate regular instrument calibrations and intercomparison campaigns.
(SAG UV - July 2003)

Task 6. To design the GAW UV radiation monitoring network and produce DQOs and a SOP for UV measurements.
(SAG UV, QA/SAC, WOUDC - October 2003)

Task 7. To implement the SOP in the GAW UV radiation monitoring network.
(Secretariat - October 2004)

Task 8. To promote the data to the user community with appropriate documentation.
(SAG UV - continuous effort, next milestone December 2001)

Task 9. To contribute to the revision of the definition of the international UV Index and promote its use.
(SAG UV - October 2001)

Task 10. To specify the needs and use of UV modelling in GAW and relationship of satellite measurements in GAW.
(SAG UV - December 2002)

Task 11. To establish procedures for co-operation with BSRN and WWW.
(SAG UV - July 2001)

5.6 Aerosols

Current Status

Lead Responsibility Scientific Advisory Group on Aerosols (SAG Aerosol)

QA/SAC Not yet established

Calibration Centre For PFR instruments: World Optical Depth Research and Calibration Centre (WORCC), Physikalisch-Meteorologisches Observatorium, Davos, Switzerland

For other aerosol measurements: not yet established. The Institute for Tropospheric Research (IFT), Leipzig, Germany, has offered to act as the Calibration Centre for aerosol physical parameters subject to funding.

DQO Not yet established

SOP Currently being established for selected parameters

Data Centre World Data Centre for Aerosols (WDCA), Joint Research Centre (JRC), European Commission, Ispra, Italy

Comment

The GAW aerosol programme comprises the programmes previously described as “Aerosols” and “Optical Depth”.

Atmospheric aerosols are important for a diverse range of issues from global climate change to regional and local scale air quality. The climate impact of aerosols is a result of both direct radiative effects and indirect effects on cloud properties. Regional problems include potential impacts on human health and mortality. Major sources include both urban/industrial emissions and smoke from biomass burning.

The GAW aerosol programme objective is “to determine the spatio-temporal distribution of aerosol properties related to climate forcing and air quality up to multidecadal time scales” (SAG Aerosol, Wengen, Switzerland, 1998). Multidecadal is considered a key word, because of GAW's mission to provide long-term measurements globally.

The GAW aerosol programme has been set up with the philosophy that it should address not only climate-related, but also air-quality issues. For developing countries in particular, regional aerosol issues may frequently be equally or more important than global concerns. The SAG Aerosol also recognises that climate related and regional environmental measurements can frequently employ common methods.

GAW measurement sites are required to represent the major geographical regions, and to address mainly global climate issues. These regimes include clean and polluted continental, polar, marine, dust-impacted, biomass burning and free-tropospheric locations. Local and regional air quality questions will require measurement sites in locations relevant to the individual problem.

For the period covered by the previous strategic plan, achievements of the GAW aerosol programme include:

- The setting up of the SAG Aerosol
- The definition of the vision, goals, measurement suite and sampling network for the GAW aerosol programme by the SAG
- The establishment of the WDCA
- Draft operation procedures manual of aerosol parameters
- Aerosol part of the GAW Measurements Guide
- Development and deployment of the precision filter radiometer (PFR) for optical depth measurements by WORCC
- The establishment of connections with related networks such as BSRN.

The SAG Aerosol recommends that the GAW aerosol programme include *for Regional stations any one, or more of the following:*

- optical depth
- mass (preferably in two size fractions)
- major chemical components in two size fractions
- light scattering coefficient

For Global stations as many as possible of the following:

- optical depth
- mass in two size fractions
- major chemical components in two size fractions

- light scattering and hemispheric backscattering coefficient at various wavelengths
- light absorption coefficient
- aerosol number concentration
- cloud condensation nuclei (CCN) number concentration at 0.5% supersaturation
- diffuse, global and direct solar radiation

Intermittently:

- aerosol size distribution
- detailed size fractionated chemical composition
- dependence of aerosol properties on relative humidity
- CCN spectra at various supersaturations
- LIDAR (Light Detection And Ranging) and other altitude profile measurements of aerosol properties.

Goals

- To establish the recommended measurement programme in GAW by developing a sense of community amongst the existing participants, and promote activities that result in increased participation in the GAW aerosol programme.
- To foster activities and contacts that result in greater data submission and utilisation of GAW aerosol data.

Implementation Strategy

Task 1. To establish and maintain a complete register of GAW aerosol activities, responsible officers, associated science programmes, contact details.
(Secretariat and SAG Aerosol - ongoing, next milestone October 2001)

Task 2. To complete a first synthesis study of PFR optical depth data from participating GAW stations.
(SAG Aerosol - December 2002)

Task 3a. To begin a calibration and intercomparison programme for aerosol physical properties as an interim step to the establishment by WMO of the WCC for aerosols.
(SAG Aerosol - July 2001 and continuing)

Task 3b. To carry out a pilot study of aerosol inlet characteristics at GAW stations beginning with Cape Grim.
(SAG Aerosol - December 2001 and continuing)

Task 3c. To initiate the establishment of a WCC for aerosol physical properties.
(Secretariat, EC Panel - April 2003)

Task 3d. To initiate the establishment of a WCC for aerosol chemical properties.
(Secretariat, EC Panel - April 2003)

Task 4. To complete the deployment of the PFR instruments at selected stations.
(SAG Aerosol, WORCC, Secretariat - December 2001)

Task 5. To produce the report "Operating procedures for selected aerosol parameters", including appropriate QA/QC procedures.
(SAG Aerosol - July 2001)

Task 6. To establish data submission from participating sites on a regular and timely basis to WDCA.
(SAG Aerosol, WDCA - April 2002)

Task 7. To promote the use of data in WDCA.
(SAG Aerosol, WDCA - ongoing)

Task 8. To organise special sessions on GAW aerosol studies at major aerosol conferences.
(SAG Aerosol - October 2002 and continuing)

Task 9. To collaborate with other major programmes and organisations, such as IGAC, BSRN, NDSC, WHO, and EMEP, establishing where possible common protocols.
(SAG Aerosol - ongoing)

Task 10. To involve members of the modelling and satellite communities in SAG activities.
(SAG Aerosol - October 2001)

Task 11. To establish and maintain a Web site for the GAW Aerosol programme.
(SAG Aerosol - July 2001 and continuing)

Task 12. To contribute actively to capacity building in developing countries.
(SAG Aerosol - December 2003 and continuing).

Task 13. To assess the need for trace metal and POPs measurements in the GAW programme. If such needs are identified, to propose a suitable measurement programme.
(SAG Aerosol - December 2004)

Task 14. To assess GAW aerosol activities and provide a synthesis of selected global aerosol parameters.
(SAG Aerosol - July 2004)

5.7 Radioactivity

Current Status

Lead responsibility	Environmental Measurements Laboratory (EML), Department of Energy, New York, USA
QA/SAC activity	Not yet established
Calibration Centre	Environmental Measurements Laboratory (EML), Department of Energy, New York, USA.
DQO	In preparation
SOP	Not yet established
Data Centre	For Kr-85 and Rn-222: World Data Centre for Greenhouse Gases (WDCGG), Japan Meteorological Agency (JMA), Tokyo, Japan
	For Be-7 and Pb-210: Environmental Measurements Laboratory (EML), New York, USA

Comment

The global distributions of the source-sink terms of the naturally occurring radionuclides (^{7}Be, ^{10}Be, ^{210}Pb, and ^{222}Rn) and the anthropogenic radionuclides (^{85}Kr) by latitude, longitude, and altitude are reasonably well known. ^{7}Be and ^{10}Be are produced by cosmic-ray interactions in the upper troposphere and the lower stratosphere. ^{222}Rn is exhaled from the earth's land surface as a result of uranium decay in soil. ^{210}Pb is produced in the lower troposphere from the decay of ^{222}Rn in the atmosphere. Most of the ^{85}Kr in the atmosphere is released during nuclear fuel reprocessing. Atoms of ^{7}Be, ^{10}Be and ^{210}Pb attach themselves to submicron-size aerosol particles, and, therefore, act as aerosol-borne tracers in the atmosphere. ^{222}Rn and ^{85}Kr, chemically and physically inert, act as noble gases in the atmosphere.

Because of the well-known global source/sink distributions of these radionuclides, they serve as ideal tools to assess the characteristics of the large- and global-scale transport of gases and aerosols as depicted in General Circulation Models (GCMs). For example, high ^{7}Be concentrations with respect to low ^{210}Pb concentrations could indicate subsidence of air from upper altitudes, which might explain a simultaneous increase in ozone concentrations.

Similarly, enhanced ^{222}Rn concentrations at an ocean front station could announce the arrival of air that had recently passed over land. Other interpretations of these tracers are possible, depending upon specific station characteristics. The concentration ratio, $^{10}Be/^{7}Be$, is an ideal indicator for studying the atmospheric exchange between the stratosphere and the troposphere. ^{222}Rn and its long-lived decay product, ^{210}Pb, can also provide a means to assess the parameterisations of the vertical transport and mixing processes in the troposphere of the GCMs. In addition, the large concentration difference of measured ^{222}Rn between continental and maritime air provides a further means to validate synoptic scale horizontal transport.

Lead-212, a decay product of ^{220}Rn (thoron) complements the air mass tracing capabilities of ^{222}Rn. Due to its shorter half-life (10.6 hours) it is useful at smaller temporal and spatial scales and can be effectively used to establish whether an air sample has had recent contact with local land. Consequently, simultaneous measurements of radon and ^{212}Pb provide an experimental discrimination between samples affected by distant and local interaction with land and may make it possible to estimate the distance of the pollution source from the monitoring station.

Concentrations of these natural and anthropogenic radionuclides should be monitored at those GAW Global stations where they can serve as an aid in the interpretation of meteorological processes occurring at the stations, especially as these processes affect concentrations of other atmospheric pollutants measured at the stations.

There are a number of GAW and non-GAW stations measuring some of the radioactive isotopes mentioned above. The radioactivity measurements of these stations are implemented and co-ordinated by EML, the Institute of Atmospheric Radioactivity (IAR) in Germany, Australian Nuclear Science and Technology Organization (ANSTO) and CNRS, France. These institutions also take actions to install additional measurement stations and to provide them with the required instrumentation and assistance. Some measurements are understood to be also conducted by research institutes in Japan, Russia, Slovak Republic and some other countries.

For the GAW stations the EML has been designated as the World Calibration Centre (WCC) and volunteered to play the leading role in developing DQOs, SOPs and to install sampling systems at some GAW stations.

Goals

- To improve our ability to monitor and measure atmospheric radionuclides with the aim of contributing to the better understanding of the mechanisms responsible for transport, vertical mixing and deposition processes in the atmosphere.
- To gain a better knowledge of the current and future needs of key radionuclide databanks for the development and validation of regional and global atmospheric models.

Implementation Strategy

Task 1. To develop, in consultation and co-operation with the existing radioactivity measuring stations and networks, the DQOs for radioactive elements to be measured at GAW stations.
(WCC - December 2001)

Task 2. To develop SOPs, based on the experience of the existing stations and networks, to meet the DQOs.
(WCC - May 2002)

Task 3. To design an instructional programme for candidate site operators on the techniques, instrumentation and quality assurance issues involved in radioactivity monitoring.
(WCC - May 2002)

Task 4. To install appropriate surface air sampling systems at the selected GAW sites.
(Secretariat, WCC, ANSTO - August 2002)

Task 5. To analyse filter samples collected at the selected GAW site in accordance with SOPs.
(WCC - December 2002)

Task 6. To start collecting radioactivity data at the WDCGG, JMA, Japan (for gaseous Kr-85 and Rn-222) and at EML, DoE, USA (for aerosol-bound Be-7 and Pb-210) and to invite all the stations measuring these radioactive isotopes to contribute.
(Secretariat, WDCGG and EML - January 2002)

Task 7. To provide participating sites/laboratories with filter samples spiked with known quantities of radionuclides twice a year to evaluate their analytical performances.
(WCC - June 2003)

6. DATA MANAGEMENT

6.1 Data Submission, Validation, and Archiving

Current Status

Currently, there are six GAW World Data Centres (WDCs) (cf. Table 1). Several of these have been in operation for many years while others have been established more recently. Consequently, some WDCs are further advanced in their activities than others are.

To date, the WDCs have focused on data archiving and data exchange. Most accommodate data submission via the Internet as well as through the more traditional methods of hardcopy and diskette. A common *meta*data format for submitted data files has been developed and adopted by some of the WDCs. The WDCs are continuing their collaboration on issues such as standardisation, harmonisation, linkage of Web sites, co-ordination, quality assurance, as well as a common site identification system. WDC managers have also been working very closely with their respective SAGs to ensure that data archiving, data quality assurance and data exchange activities are guided by, and in tune with, the needs of the scientific community. A special session of the WDCs was held during the Sixth Scientific International Global Atmospheric Chemistry (IGAC) conference in 1999 in order to promote submission and use of GAW data.

Comment

The purpose of the WDCs is to collect and archive GAW data, to make them available to the scientific community, and to provide support in the quality assurance, analysis and interpretation of these data. Increasingly, the GAW WDCs serve the global scientific community as an important source of data necessary for research on national and international levels. With regard to simplifying and harmonising the central activities of GAW WDCs, initial steps have been taken but more work remains. It is necessary to improve Web-based data submission, access, and information exchange while continuing support for hardcopy and electronic exchange mechanisms. Requested data submission formats and methods still vary among WDCs and hence, they are reasonably flexible at accepting non-standard data files. Nevertheless, in order to increase and accommodate the number of stations that submit their data on a regular basis, data submission must be further harmonised to reduce the work involved in both, submitting data and dealing with submitted data of different types to several data centres following different protocols.

Quality assurance of submitted data is not a central task of GAW WDCs, since meeting stated data quality objectives is mainly the responsibility of the stations. In light of data distribution to and data use by the scientific community, however, there is an obvious need for some data validation by the WDCs. This also involves archiving comprehensive metadata. Most WDCs have developed basic quality assurance procedures to validate incoming data. The WDC managers are currently working closely with their respective SAGs to develop and implement further quality assurance procedures. Wherever possible, these will be standardised and harmonised between WDCs.

Goals

- To ensure the long-term viability of all WDCs, and to adhere to WMO policies and plans for data exchange and data management.
- To enhance data submission to the WDCs and to foster and build upon relationships between data originators and the WDCs.
- To create, implement, and continually update a metadata archive – including detailed siting, measurement and QA information – within each WDC.
- To effect efficient, timely and flexible data and metadata submission protocols – with as much harmonisation between WDCs as possible – primarily making use of the Internet but accepting hardcopy submission where necessary.
- To operate within the WDCs a comprehensive set of data quality assurance and validation checks, incorporating timely feedback on data problems to data submitters.

Implementation Strategy

Task 1. To secure proper resources, develop comprehensive back-up strategies, maintain up-to-date storage devices, and implement appropriate network and data access policies.

(WDCs – ongoing)

Task 2. To implement a common site identification system for all GAW stations including a codified system which characterises the nature of GAW stations, e.g. in terms of location, geographical setting, etc.

(WDCs – 2003)

Task 3. To create a metadata archive suited to updating site information, measurement-related information and quality assurance information. This archive should be co-ordinated with the station directory.

(WDCs, in co-operation with Secretariat and QA/SACs – 2002)

Task 4. To implement Internet-based data submission procedures for data and metadata with provisions for hardcopy submission where necessary. Included will be a Web-based catalogue of available data and up-to-date information on the status of data submission by individual sites, to be co-ordinated with the station directory.

(WDCs, Secretariat – 2002)

Task 5. To work with NDSC and Southern Cone Project data managers to submit GAW core programme data monthly to the WDCs.

(WDCs, Secretariat – 2001)

Task 6. To implement data quality assurance and management procedures developed in co-operation with the SAGs and QA/SACs, with a view to providing timely feedback to data submitters when problems are found.

(WDCs, SAGs, QA/SACs – 2002)

6.2 Data Analysis and Distribution

Current Status

Several WDCs are developing Web-based data access systems and/or produce and distribute annual or semi-annual hardcopy reports and/or compact disks for distribution of data. Those WDCs not yet at the stage of producing annual reports intend to do so in the future. Some WDCs are working actively on data analysis projects while others are not – all are looking to greater participation in data analysis activities in the future.

Comment

Some of the WDCs are quite mature and carry out a full suite of data archiving, quality assurance, reporting and analysis activities; others are just at the beginning and have considerable work to do. Most of the WDCs are planning, or are actively underway, to collect and archive data from non-GAW sites/programmes to supplement the GAW data.

There is a need for all WDCs to co-ordinate their Web-based data access/distribution activities to ensure that data users can obtain data in a consistent manner across different WDCs. Close collaboration between SAGs and WDCs has been extremely fruitful in the past and is expected to result in higher quality data and more participation of the WDCs in the analysis of scientific data. In the long term, it is envisaged that the WDCs will become information centres that will work with the scientific community (including the satellite community) to produce value-added scientific reports and global science assessments for scientists and laymen.

Goals

- To implement and operate an Internet-based access/distribution system for GAW measurement data, metadata, quality assurance information, easy access to related meteorological data, and value-added analysis products at each WDC.
- To work with the scientific community to actively promote and participate in the analysis, assessment and scientific use of GAW data, and to assist data users.
- To provide advice and guidance to the SAGs, QA/SACs and individual sites/scientists regarding possible improvements in their measurement programmes based on problems discovered during the data management and analysis process.

Implementation Strategy

Task 1. To implement WMO policy regarding the international exchange of meteorological and related data and products, including relationships to commercial meteorological activities (Resolution 40, Cg-XII).
(WDCs – continuous, next milestone December 2001)

Task 2. To seek input from the satellite community to ensure that common needs are met.
(WDCs, Secretariat – 2001)

Task 3. To develop strategies for a central Internet site that provides user friendly access to measurement data, metadata, quality assurance information, relevant meteorological information, and value-added products such as reports and assessments.
(WDCs, Secretariat – 2002)

Task 4. To implement the strategies developed under Task 3.
(WDCs – 2003)

Task 5. To produce a set of value-added data analysis products such as statistical summaries, quality assurance information and data visualisation.
(WDCs – ongoing)

Task 6. To assist the SAGs and QA/SACs at improving data quality control and data analysis activities.

(WDCs – ongoing)

7. QUALITY ASSURANCE (QA)

Current Status

Under the previous Strategic Plan, GAW's quality assurance system was designed around Quality Assurance/Science Activity Centres (QA/SACs) that were, among other things, expected to critically review, and either accept and/or flag data submitted by individual stations located in their assigned regions. It was also recognised that the stations themselves have primary responsibility for the quality of the data that they generate: "QA of scientific data is best achieved when the data are examined by those collecting the data and by users and researchers who have a personal, professional interest in the data".

The GAW world central facilities established so far are listed in Table 1. As is apparent from this table, the GAW QA system is still incomplete. Up to now, very few guidelines for QA and SOPs have been produced for the GAW programme, and there are no GAW reports currently available concerning system audits.

Comment

The primary objective of the GAW QA system is to ensure that the data in the WDCs are consistent, meet the GAW data quality objectives (DQOs), and are supported by comprehensive metadata. This will be achieved through adherence to GAW SOPs. The original strategy of establishing facilities with regional responsibility has recently undergone review by the EC Panel. During March 1999 the Panel concluded it "[…] strongly supports a shift from QA/SACs having regional responsibility for all GAW measurement parameters, toward global responsibility for specific parameters" (GAW Report No. 135). GAW QA procedures should not only address the quality of the measurement but also the entire QA process, beginning at the station with training of station personnel and ending with the WDCs containing data of the required quality.

It should be noted that the earlier concept of Quality Assurance Project Plans (QAPjP) has been abandoned in favour of individual documents defining DQOs and SOPs, and is reflected in the current Strategic Plan.

The recommended GAW QA principles to ensure comparability and consistency of measurements involve:

- Adoption and use of internationally accepted methods and vocabulary to deal with uncertainty in measurements as outlined in the 'Guide to the Expression of Uncertainty in Measurement' (International Organization for Standardization (ISO), 1st ed, 1995, ISBN 92-67-10188-9) as well as in the 'International Vocabulary of Basic and General Terms in Metrology' (International Organization for Standardization (ISO), 2nd ed, 1993, ISBN 92-67-01075-1).
- Use of a harmonised measurement techniques based on SOPs at all stations. A SOP is a written document that is officially approved by the relevant SAG and that details the method for performing a certain operation, analysis, or action by thoroughly prescribing techniques and steps involved.
- Regular performance and system audits. In the context of GAW, a *performance audit* is understood as being a voluntary check for conformity of a measurement where the audit criteria are the DQOs for that parameter. In the absence of formal DQOs, an audit will at least involve ensuring the traceability of measurements to the Reference Standard. A *system audit* is more generally defined as a check of the overall conformity of a station with the principles of the GAW QA system. The reference for conformity of a station will evolve as the GAW QA system evolves.

Regarding individual parameters, these principles include:

- Use of quantitative DQOs as derived based on the underlying scientific questions. DQOs define qualitatively and quantitatively the type, quality, and quantity required of primary data and derived parameters to yield information that can be used to support decisions. In particular, DQOs specify tolerable levels of uncertainty in the data, as well as required completeness, comparability and representativeness based on the decisions to be made [adapted from Scientific Steering Committee, QA/QC in Eurotrac-2.
- Network-wide use of only one reference standard or scale, where applicable. In consequence, there is only one institution that is responsible for this standard.
- Full traceability to this standard of all measurements made by Global and Regional GAW stations.
- Establishment of SOPs for these measurements.
- Use of detailed log books for each parameter containing comprehensive meta information related to the measurements, maintenance, and 'internal' calibrations.

The QA-related responsibilities for the various GAW components are:

Scientific Advisory Groups

- Establish DQOs for each assigned parameter.
- Approve the corresponding SOPs.
- Provide guidelines and recommendations for achieving the DQOs and implementing the SOPs.
- Support the harmonisation of measurements by recommending state-of-the-science measurement methods and procedures.
- Promote training and twinning in developing countries.

Quality Assurance Science Activity Centres

- Provide support for the local QA system at individual GAW sites.
- Follow the SAGs' guidelines and recommendations.
- Co-ordinate instrument calibrations and intercomparisons and other measurement activities related to SOPs.
- Provide training, long-term technical help, and general GAW workshops for station scientists and technicians.

World Calibration Centres

- Develop relevant quality control procedures following the recommendations by the SAGs and support the QA of specific measurement parameters, including SOPs and the traceability of these measurements to the corresponding reference standards.
- Maintain laboratory and transfer standards that are traceable to the reference standards.
- Perform regular calibrations and performance audits at GAW sites using transfer standards in co-operation with the established regional calibration centres.
- Provide, in co-operation with the QA/SACs, training and long-term technical help for stations.

World Data Centres

- Establish harmonized guidelines and data formats for data submission and retrieval for each parameter.
- Check submitted data for necessary format elements, flag data problems, and provide feedback to the stations, when necessary.

GAW Stations

- Adopt and follow the GAW SOPs.
- Establish quality control procedures by following the guidelines of the responsible QA/SAC and WCC.
- Practice quality control of all parameters and identify questionable data submitted to the WDCs.

Goals

- To establish DQOs and SOPs for all parameters as recommended by the SAGs.
- To identify and establish QA/SACs, WCCs and reference standards where needed (cf. Table 1).
- To harmonise the GAW QA procedures.
- To increase the frequency of instrument calibrations and intercomparisons.
- To build alliances between and among Global and Regional stations (scientific and technical co-operation, twinning), as well as twinning between individuals (scientists, station personnel).

Implementation Strategy

Task 1. To establish a prioritised list of parameters urgently needing DQOs.

(Panel, SAGs, QA/SACs, Secretariat - 2001)

Task. 2. To identify and establish QA/SACs for N_2O and CFCs.

(SAG GG, Panel, Secretariat - 2001)

Task 3. To identify and, where feasible, establish WCCs and reference standards for the remaining parameters.

(QA/SACs, Secretariat - ongoing)

Task 4. To develop SOPs for the remaining parameters.

(QA/SACs, WCC's - ongoing)

Task 5. To develop guidelines for GAW station system audits.

(QA/SACs - 2002)

Task 6. To identify and establish regional calibration centres, where necessary, that provide calibration and instrument intercomparison for GAW stations in the region.

(Secretariat, QA/SACs, SAGs - ongoing)

Task 7. To provide training and workshops for developing countries with a goal of improving the quality of data provided by their GAW stations.

(Secretariat, QA/SACs, WCCs - ongoing)

8. ASSESSMENTS AND DATA APPLICATION

Current Status

GAW is not only a system for monitoring but also for assessment of the chemical composition and related physical characteristics of the global atmosphere. Over the years, WMO has initiated and co-ordinated a number of scientific assessments on specific atmospheric parameters and processes based on data collected by GAW and by collaborating networks. For example, the most recent assessment of ozone depletion in 1998 was only the latest in a series since 1982 and was accomplished in close co-operation of WMO with UNEP, the European Union (EU), the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). One of its primary purposes was to serve the Parties of the Montreal Protocol as a basis for their future decisions regarding protection of the stratospheric ozone layer. GAW ozone data are also used in the preparation of regular bulletins on the state of the ozone layer over Antarctica and for the total ozone maps for the Northern Hemisphere. An assessment of the atmospheric input of trace species to the world's oceans was prepared by WMO within GESAMP in 1989 and a global assessment for acid deposition was published in 1996.

Another essential task of GAW is to encourage and support modelling activities for assessing long-range atmospheric transport and deposition of pollutants as well as air pollution in urban and other areas affected by natural or anthropogenic air pollution. Those activities are mainly implemented in co-operation with various regional programmes, e.g. in South East Asia, in Europe (European Monitoring and Evaluation Programme - EMEP, European Tracer Experiment - ETEX), in the Mediterranean (Mediterranean Pollution Monitoring and Research Programme - MEDPOL) and in North America (North American Research Strategy for Tropospheric Ozone - NARSTO).

Within EMEP, established in 1977 with active participation of WMO, the modelling activities were originally focused on long-range transport and deposition of acidifying compounds (sulphur and nitrogen), with volatile organic compounds (VOCs) and photo-oxidants being added later. In the last few years EMEP modelling has also focused on heavy metals, persistent organic pollutants (POPs) and fine particles. The results of modelling, model intercomparison and validation, recommendations for further model development and data needs were regularly considered at expert meetings and workshops organised by WMO in co-operation with EMEP.

For the MEDPOL programme the main results of modelling include the assessment of long-range transport and deposition of sulphur and nitrogen compounds, heavy metals (Pb, Cd, Zn, As and Hg), some POPs (lindane and PCB) both for the Mediterranean Sea and its sub-regions.

In addition, GAW data was used and applied to assess atmospheric processes during and after the Chernobyl reactor accident, the Kuwait oil fires and biomass burning in South East Asia and to provide information on health and environmental effects of such accidents.

The wide and efficient use of GAW data depends largely on the ability of potential users to analyse the data. To improve that ability, a number of workshops with training components were organised by WMO in co-operation with EMEP, e.g., as on advanced statistical methods and their application to air quality data sets (Helsinki, September 1998), and on data analysis and interpretation (Dubrovnik, October 1999).

The integration of GAW data with satellite observations significantly improves our knowledge of the global distribution of selected gases and aerosols that yield better data products for assessing the state of the atmosphere. A report jointly prepared by the Committee on Earth Observation Satellites (CEOS) and WMO (A strategy for integrating satellite and ground-based observations of ozone, GAW Report No. 140) aims at increasing future co-operation and integration of the two major global observing systems.

Comment

An important task for GAW is to establish closer contacts with potential data users and to identify their needs for solving concrete tasks (health and environmental effects, model validation, pollution forecast and control measures, chemical and physical processes in the atmosphere, air-surface exchange, budget and mass balance in different environmental compartments, trend analysis, etc.). Better and wider use of data collected by GAW and its recognition as a major global provider of atmospheric data depends not only on their use in dealing with global issues but also in addressing regional and national atmospheric environment problems. To this end users need to be better informed about available GAW data that in turn must be easily accessible through modern information transfer technologies. Training aimed at strengthening the ability of data users to analyse and to fully use the GAW data, development of data analysis guides, and exchange of experience among data users are of paramount importance.

Future modelling activities are mainly stipulated by newly emerging environmental problems related to POPs, heavy metals (especially mercury), fine particles and urban air pollution. This will require improvement of models to deal with different scales (from local to regional and hemispheric/global), better parameterisation of such processes as physico-chemical transformation in and removal from the atmosphere, exchange between and cycling in various environmental compartments, coupling of box and three-dimensional models, more detailed meteorological information (including observational data interpolated in space and time, and forecast data from numerical weather prediction models), as well as source-receptor modelling, validation of models on the basis of expanded measurements and more precise emission estimates, and regular model intercomparisons.

Atmospheric chemistry research could also benefit from GAW data and should help to formulate requirements for additional data and thus, for further development of GAW. Closer co-operation with relevant international programmes is needed for wider dissemination and application of not only GAW data but also the research results of other programmes. To this end, considerable educational and training efforts and the preparation of guides for data analysis, tutorials and educational programmes and training workshops are indispensable.

Goals

- To build up an analysis and prediction capability at GAW facilities in co-operation with the scientific research community.
- To promote the use of GAW data for global, regional and national studies and for development of environment protection measures, and to attract international and national research projects to GAW stations.
- To stimulate and support development and improvement of models dealing with different scales (from local to global) to address persistent and emerging atmospheric environment problems in close co-operation with other international programmes.
- To promote and co-ordinate scientific assessments of urgent atmospheric environment issues.
- To use satellite observations and data from ground-based measurements in assessments.

Implementation Strategy

Task 1. To establish closer contacts with potential data users, to inform them about availability of and access to GAW data through the station directory, to identify their needs for data that may be provided by GAW, to outline proposals for joint research work and scientific assessments and to promote the use of GAW data for dealing with specific national and regional environmental problems.
(SAGs, WDCs, Secretariat - ongoing)

Task 2. To organise and oversee the scientific assessments of the following GAW components:

- Stratospheric ozone
  (Secretariat in co-operation with UNEP, EU, NOAA and NASA - 2002)
- Carbon dioxide and other greenhouse gases
  (SAG GG, WDCGG in co-operation with IPCC - 2004)

Task 3. To co-operate with data centres of other programmes in promoting data exchange through the Internet and other media and the use of data for regional and national environmental problems
(WDCs and SAGs - ongoing)

Task 4. To support relevant modelling activities in close co-operation with other collaborating programmes through organization of joint expert meetings, research projects and model intercomparisons.
(Secretariat - ongoing)

Task 5. To conduct and/or co-sponsor training workshops on data analysis, interpretation and assessment and to ensure preparation of relevant guidance materials, training aids and software.
(Secretariat in co-operation with QA/SACs - ongoing)

9. GAW URBAN RESEARCH METEOROLOGY AND ENVIRONMENT (GURME) PROJECT

Current Status

The WMO GAW Urban Research Meteorology and Environment (GURME) project was developed in response to the requests from NMHSs. The lead responsibility for the programme rests with the Scientific Advisory Group (SAG GURME). NMHSs have an important role to play in the study and management of urban environments because they collect information and possess capabilities essential to the urban air pollution forecasting and evaluating the effects of different emission control strategies. While the NMHSs will extend their role in various directions in the future, they will remain centred on the traditional activities related to meteorological monitoring, forecasting, and modelling (both meteorological and chemical) and their applications to air quality problems. GURME also collaborates with environmental agencies responsible for air quality measurements in urban settings. WMO established GURME as a means to help enhance the capabilities of NMHSs to handle meteorological and related aspects of urban pollution. GURME is designed to do this through co-ordination and focussing of present activities, as well as initiation of selected new endeavours.

Comment

While the focal point of GURME will be the NMHSs, the programme will - through the NMHSs - collaborate intensively with environmental agencies. Initial activities of the SAG GURME have focused on developing a clear understanding of what aspects of urban environments should be emphasised and how this programme can best support NMHSs in their activities. A questionnaire and a dedicated Workshop resulted in a programme framework and opportunities as follows:

(a) GURME will assist NMHSs with a breadth of activities related to urban environments including meteorological and air quality measurements, as well as modelling and forecasting activities ranging from meteorological to chemical, and from statistical to dynamic. Some NMHSs are at a very early stage of developing these activities. Results from the GURME survey of NMHSs indicate substantial interest in urban environmental issues within many of them.

(b) GURME offers significant opportunities to assist NMHSs in their pursuit of urban initiatives but also faces important challenges. These challenges are largely related to the fact that often several agencies share responsibility for urban environments, making it more difficult to effectively co-ordinate activities. In addition, NMHSs urban activities need to be conducted in the context of national socio-economic priorities. There is a clear need for capacity building in the areas of problem definition, optimisation of monitoring programmes to balance measurements and modelling, and quantification of the economic benefits of improved air quality for all relevant compounds.

(c) GURME needs to consider the regional context of urban influences in its planning. For example, the impacts of urban activities are not limited to air quality but also affect water resources (through deposition). In addition, regional influences can profoundly influence urban environments (e.g., smoke in Southeast Asia and dust in East Asia).

(d) GURME will assist NMHSs in providing services of high quality, e.g., by enhancing their capabilities to provide meteorological and air quality forecasts for urban environments. The latter is an important focus since it builds upon the traditional strength of the NMHSs in meteorological forecasting and helps to define GURME programme boundaries and to concentrate efforts. This assistance also entails measurement aspects that will support operational forecasting and verification, and should be performed in co-operation with appropriate agencies.

(e) GURME promotes the use of passive samplers. Passive samplers have a variety of applications in urban environments. These include enhancing the suite of species measured, providing or enhancing spatial resolution of the measurements, and in selecting and evaluating appropriate locations for monitoring sites.

(f) GURME offers an excellent opportunity to strengthen co-operation with important activities of the World Health Organization (WHO) such as its Air Management Information System (AMIS).

Goals

- To enhance the capabilities of NMHSs in providing urban-environmental forecasting and in providing air quality services of high quality, illustrating the linkages between meteorology and air quality
- In collaboration with other WMO programmes, WHO and environmental agencies, to better define meteorological and air quality measurements focusing specifically on those that support urban forecasting.
- To provide NMHSs with easy access to information on measurement and modelling techniques.
- To promote a series of pilot projects to demonstrate how NMHSs can successfully expand their activities into urban environment issues, showcase new technologies at appropriate conferences, and develop illustrative examples.

Implementation Strategy

Task 1. To produce GURME Guidelines to enable NMHSs to take full advantage of GURME.
(SAG GURME - 2001)

Task 2. To establish a GURME Web site to be used as the main communication vehicle for GURME activities.
(SAG GURME - 2001)

Task 3. To conduct regional workshops focused on ways and means of developing urban-environmental forecasting capabilities.
(SAG GURME and Secretariat - 2002)

Task 4. To develop new and promote established GURME pilot projects to illustrate the spectrum of NMHSs urban-related activities and opportunities for co-operation with environmental agencies.
(SAG GURME and Secretariat - 2004)

Task 5. To tie into related/complementary activities within WMO (e.g., World Climate Programme - WCP, Commission for Instruments and Methods of Observation - CIMO) by collaborating on a common topic and/or by collocating a project.
(SAG GURME and Secretariat - 2002)

Task 6. To foster and continue close co-operation with the WHO on the meteorological, measurement and health aspects of urban environments.
(SAG GURME and Secretariat - 2002)

Task 7. To develop a strategy for addressing advice and guidance to NMHSs on measurements.
(SAG GURME and Secretariat - 2001)

Task 8. To continue evaluation of the passive sampler method, expand the number of sites and publish the observational data.
(SAG GURME and Secretariat - 2001)

10. RESOURCES

Current Status

Resources for GAW are currently available as follows:

- Regular budget of WMO for GAW, covering costs for the Secretariat staff, external consultants/experts working for GAW, selected calibrations, meetings, travelling costs, general services (reports, computer and transmission facilities, etc.).
- Regular budget of WMO for Voluntary Co-operation Programme (VCP), specially used for training and education funding.
- Special WMO Fund for Climate and Atmospheric Environment Studies, available for single actions, e.g. establishment of the ozone sounding station Kenya.
- External financial funding of specific GAW projects or operations by Member countries or international organizations where execution of work is delegated to specialised persons or institutions providing services as experts or central facilities. Examples include practically all Calibration Centres, and QA/SACs.
- Members or institutions taking over directly tasks for GAW by their own staff which they pay themselves, e.g., the QA/SAC run by the Japan Meteorological Agency, or the Data Centres run by the Meteorological Service of Canada and the National Oceanic and Atmospheric Administration.

An overview on resources available for 2000-2003 is presented in WMO document Cg-XIII/Doc 8(1).

Comment

GAW is implemented in accordance with the principle that all activities in the territories of individual countries are within the responsibility of the countries themselves and should be borne by national resources. When a Member agrees to participate in GAW, full responsibility of any activity stays with the Member. WMO cannot, for example, cover the costs of long-term maintenance of GAW stations and facilities. Nevertheless, many countries, mostly in datasparse areas, require outside support to start, sustain or improve participation in GAW. It is important to provide the support for such sites if the network is to be truly global. In recognition of this, WMO has over the years tried to provide funds for instruments, spare parts, maintenance, consultant services, and training, partially covered under its regular budget. WMO has encouraged Members to include GAW projects in their UNDP national programmes, and to enter "twinning" arrangements wherein, on a bilateral basis, a laboratory, institute or individual scientist in an industrialised country undertakes to sponsor a station or measurement parameter in a participating developing country. The Secretary-General has been authorised by the EC to seek extra-budgetary funding for implementation of GAW projects.

Unfortunately, funding needs continue to grow much faster than the required funds can be made available. Especially for capacity building, the level of support required by Members still far exceeds the resources available under the regular WMO and VCP budget. Substantial additional funds required to provide instruments, spare parts, and expert services, central calibration and fellowship for training are essential to the future development of GAW.

Goals

- To provide regular overviews of costs and available resources and to introduce financial feasibility in the priority setting and planning procedures of GAW.
- To make additional funds available as soon as possible. To assist NMHSs in obtaining financial support from national funds by providing, when requested, the relevant national governments with information on the importance of the GAW programmes both for the national and international communities.

Implementation Strategy

Task 1. To review annually GAW's costs, for:
- the establishment and operation of the central facilities of GAW including QA/SACs, Calibration Centres and World Data Centres;
- expert advisory, training and education purposes;
- purchase of equipment;
- operational services and maintenance of GAW .

(Secretariat - beginning of each calendar year)

Task 2. To continually review the funding needs of the programme and identify:
- how much is needed to achieve specific GAW goals;
- how WMO Member countries can help meet these needs.

(Secretariat - ongoing)

Task 3. To publicize a list of programme needs for which resources are required and to use all avenues to recruit sponsors, as NMHSs, or commercial institutions, etc.

(AREP and Panel - annually)

Task 4. To seek contributions through the Committee on Earth Observation Satellites (CEOS) to support dedicated permanent ground-truth facilities within GAW.

(Secretariat - ongoing)

11. OUTLOOK

The goals specified in this Strategic Plan provide guidelines for establishing working plans and programmes and for developing GAW facilities over the next seven years.

Implementation steps are given only for 2001-2004. For the remainder of the planning period, they will be developed in 2004 after assessing progress made.

The long-term plan requires WMO CAS to review developments in the Atmospheric Research and Environment Programme (AREP) and to co-ordinate the operation and further development of GAW. Therefore, the Panel is responsible for the development and approval of GAW's Strategic Plan. In order to increase the efficiency of the GAW programme, it is recommended that a regular external review procedure be instituted. This could be carried out, for example, by an ad hoc group with the participation of members of the Global Climate Observing System (GCOS) and/or members of the International Geosphere-Biosphere Programme (IGBP/IGAC).

As with all other WMO programmes, GAW is based on voluntary contributions by the Member countries. In such circumstances, top-down management is not possible, and WMO can only encourage rather than require participants to make regular contributions to the programme. The achievement of the objectives of this Strategic Plan therefore depends entirely on the close and continuous participation of member countries and the continued support of the WMO.

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ACRONYMS

AMAP	Arctic Monitoring and Assessment Programme
AMIS	Air Management Information System
AREP	Atmospheric Research and Environment Programme
ASRC-SUNY	Atmospheric Sciences Research Centre, State University of New York (SUNY), Albany NY, USA
BSRN	Baseline Surface Radiation Network, Zurich, Switzerland
CACGP	Commission for Atmospheric Chemistry and Global Pollution
CAS	Commission for Atmospheric Sciences
CCN	Cloud condensation nuclei
CEOS	Committee on Earth Observation Satellites
CFC	Chlorofluorocarbon
CIMO	Commission for Instruments and Methods of Observation
CMDL	Climate Monitoring and Diagnostic Laboratory, NOAA, Boulder, USA
DQO	Data Quality Objective
EANET	Acid Deposition Monitoring Network in East Asia
EC	Executive Council
EMEP	European Monitoring and Evaluation Programme
EML	Environmental Measurements Laboratory, New York, USA
EMPA	Swiss Federal Laboratory for Materials Research and Testing, Dübendorf, Switzerland
ETEX	European Tracer Experiment
EU	European Union
EUROTRAC	European Experiment on Transport and Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe
FZ-Jülich	Forschungszentrum Jülich, Germany
GAMeS	Global Atmospheric Methane Synthesis
GAW	Global Atmosphere Watch
GAWTEC	GAW Training and Education Centre
GCMs	General Circulation Models
GEF	Global Environment Facility
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GCOS	Global Climate Observing System
GTS	Global Telecommunication System
GURME	GAW Urban Research Meteorology and Environment project
IAEA	International Atomic Energy Agency
IAI	Inter American Institute for Global Change Research
ICSU	International Council for Science
IFT	Institute for Tropospheric Research, Leipzig, Germany
IFU	Fraunhofer Institut für Atmosphärische Umweltforschung, Garmisch-Partenkirchen, Germany
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere-Biosphere Programme
IGOS	Integrated Global Observing Strategy
IGY	International Geophysical Year
IOC	International Ozone Commission
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ISWS	Illinois State Water Survey, Champaign IL, USA
IUPAC	International Union of Pure and Applied Chemistry
JGOFS	Joint Global Ocean Flux Study
JMA	Japan Meteorological Agency, Tokyo, Japan
JOSIE	Julich Ozone Sonde Intercomparison Experiments
JRC	Joint Research Centre, Ispra, Italy

LIDAR	Light Detection And Ranging
MEDPOL	Mediterranean Pollution Monitoring and Research Programme
MGO	Main Geophysical Observatory, St Petersburg, Russia
MSC	Meteorological Service of Canada – formerly Atmospheric Environment Services (AES), Toronto, Canada
NARSTO	North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautics and Space Administration
NDSC	Network for the Detection of Stratospheric Change
NILU	Norwegian Institute for Air Research (NILU), Kjeller, Norway
NIST	National Institute of Standards and Technology, Gaithersburg MD, USA
NMHS	National Meteorological and Hydrological Service
NOAA	National Oceanic and Atmospheric Administration
NOMHICE	Non-Methane Hydrocarbon Intercomparison Experiment
OSG	Operations Support Group
PFR	Precision filter radiometer
PMOD/WRC	Physikalisch-Meteorologisches Observatorium Davos/World Radiation Centre, Davos, Switzerland
POPs	Persistent organic pollutants
QA/QC	Quality Assurance/Quality Control
QAPjP	Quality Assurance Project Plan
QA/SAC	Quality Assurance/Science Activity Centre
RDCC	Regional Dobson Calibration Centre
SAG	Scientific Advisory Group
SHADOZ	Southern Hemisphere Additional Ozonesondes programme
SMN	Servicio Meteorologico Nacional, Buenos Aires, Argentina
SOO	Solar and Ozone Observatory, Czech Hydrometeorological Institute
SOPs	Standard Operating Procedures
SPARC	Stratospheric Processes and Their Role in Climate
SRRB	Surface Radiation Research Branch of NOAA's Air Resources Laboratory, Boulder, Colorado, USA
UBA	Umweltbundesamt Berlin, Germany
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VCP	Voluntary Co-operation Programme
VOCs	Volatile Organic Compounds
WCC	World Calibration Centre
WCCOS	World Calibration Centre for Ozone Sondes, Forschungs-zentrum Julich, Germany
WCP	World Climate Programme
WCRP	World Climate Research Programme
WOCE	World Ocean Circulation Experiment
WDC	World Data Centre
WDCA	World Data Centre for Aerosols
WDCGG	World Data Centre for Greenhouse Gases, Tokyo, Japan
WDCPC	World Data Centre for Precipitation Chemistry
WDCSO	World Data Centre for Surface Ozone
WHO	World Health Organization
WORCC	World Optical Depth Research and Calibration Centre, Davos, Switzerland
WOUDC	World Ozone and UV Data Centre, AES, Toronto, Canada
WRC	World Radiation Centre, Davos, Switzerland
WRDC	World Radiation Data Centre, St Petersburg, Russia
WRMC	World Radiation Monitoring Centre, Zurich, Switzerland
WWW	World Weather Watch