

WORLD METEOROLOGICAL ORGANIZATION

**COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMME AREA GROUP ON INTEGRATED OBSERVING SYSTEMS
EXPERT TEAM
ON OBSERVATIONAL DATA REQUIREMENTS AND REDESIGN OF THE GLOBAL
OBSERVING SYSTEM**

REDUCED SESSION

OXFORD, UNITED KINGDOM

1 - 5 JULY 2002



FINAL REPORT

WMO General Regulations 42 and 43

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

EXECUTIVE SUMMARY

The Expert Team on Observational Data Requirements and Redesign of the Global Observing System (ET-ODRRGOS) of the CBS Open Programme Area Group (OPAG) on Integrated Observing Systems (IOS) met from 1 to 5 July 2002 at Wadham College in Oxford, United Kingdom.

The ET-ODRRGOS pursued their agenda (a) to discuss potential near term contributions of operational and non-operational (research and development) satellites to the Global Observing System (GOS) with a focus on the potential of microwave remote sensing of precipitation, (b) to hear about progress on non-satellite components of the GOS (esp. AMDAR), (c) to review Statements of Guidance (SOGs) in several applications areas and their implications for the GOS, (d) to review progress on Observing System Experiments and their implications for the GOS, and (e) to develop a draft proposal for the redesign of the GOS.

Review of earlier recommendations to evolve the GOS produced some revisions. The ET-ODRRGOS now has 19 recommendations regarding the space based component of the GOS (8 for operational geostationary and polar orbiting, 11 for R&D satellites) and 22 recommendations for the surface based component of the GOS. A vision of the composite GOS for 2015 and beyond was drafted.

In addition, the Manual for the GOS was reviewed and edits were suggested. Preparations for the upcoming Implementation and Coordination Team meeting were made; the recommendations for evolving the GOS will comprise most of the input for that meeting as well as the ten actions from this meeting. The ET-ODRRGOS concluded by drafting a work plan for the upcoming year.

In order to implement the recommendations for the evolution of the GOS, coordinated and dedicated efforts by WMO Members will be required. The future GOS builds upon the existing components, both surface and space based, and capitalizes on existing observing technologies not presently incorporated or fully exploited into the GOS. The benefits to be derived from the new GOS will be tremendous. All experiments in testing hypotheses towards the redesign have indicated that each incremental addition to the GOS will be reflected in better data, products and services from the National Meteorological and Hydrological Services (NMHSs). Additions to the surface-based component of the GOS include: improved data distribution; enhanced AMDAR ascent/descent as well as flight level data, especially over data sparse areas; optimized radiosonde launches; targeted observations; inclusion of ground based GPS, radars and wind profilers into the GOS; increased oceanic coverage through expanded ASAPs, drifting buoys, and ARGO; and the use of UAVs. The space-based component of the GOS builds upon the known plans of the satellite operators, both operational and research and development (R&D). The addition of R&D satellites into the GOS was a landmark decision and will provide more methodical transitions from research into operations for those data that become operational imperatives. ET-ODRRGOS recommended several enhancements beyond those plans that call for improved spatial, spectral, temporal resolution and improved radiometric accuracies. In particular, two research missions that will be of the utmost importance for the future GOS are wind profiling and global precipitation measurement missions.

GENERAL SUMMARY OF THE WORK OF THE SESSION

1. ORGANIZATION OF THE SESSION (*Agenda item 1*)

1.1. Opening of the meeting (*Agenda item 1.1*)

The session of the Expert Team (ET) on Observational Data Requirements and Redesign of the Global Observing System (ET-ODRRGOS) of the Commission for Basic Systems (CBS) Open Programme Area Group (OPAG) on Integrated Observing Systems (IOS) was opened by its Chairman, Dr. Paul Menzel, at 10 am on Monday 1 July 2002 in Wadham College, Oxford, United Kingdom. The list of participants is attached in Annex I.

On behalf of the Met Office, Dr. Jim Caughey welcomed the participants to Oxford. He noted that recommendations for the evolution of Global Observing System that the ET was drafting and submitting to the CBS could be a catalyst for far reaching improvements and wished the ET a pleasant and productive stay in Oxford. Local host Dr. John Eyre added a welcome to Wadham College and explained the local arrangements in support of the ET meeting.

1.2. Adoption of the agenda (*Agenda item 1.2*)

The agenda adopted by the ET is given in Annex II.

1.3. Working arrangements (*Agenda item 1.3*)

The ET agreed on working arrangements and adopted a tentative work plan for consideration of the various agenda items.

2. REPORT OF THE CHAIRMAN (*Agenda Item 2*)

2.1. The Chairman presented his report. He noted that the ET has two main tasks: (a) to continue the Rolling Review of Requirements (RRR), under which requirements for observations to meet the needs of all WMO programmes are compared with the capabilities of present and planned observing systems to provide them; and (b) to make recommendations to the CBS on the "re-design" of the Global Observing System (GOS). The ET-ODRRGOS is now coming towards the end of its 4-year work programme.

2.2. The January 2002 ET meeting made considerable progress in preparing a set of recommendations for the evolution of both the space-based and surface-based components of the GOS; these will be refined in this July 2002 meeting and then passed on through the OPAG IOS chair to CBS for consideration at their December 2002 meeting. A full report on the January 2002 ET meeting is available via the WMO homepage at <http://www.wmo.ch/web/www/reports.html>. Highlights of the January 2002 meeting included:

- The Team heard about significant progress in AMDAR and in situ marine observing systems;
- The RRR process was extended into other application areas including atmospheric chemistry, ocean weather forecasting, coastal marine services (applications areas covered by the Joint Commission for Oceanography and Marine Meteorology (JCOMM)), and seasonal to inter-annual forecasting (representing just one of several climate-related applications areas);
- The ET reviewed Statements of Guidance in several applications areas and prepared a draft set of recommendations to CBS on how the space-based component and surface-based components of the GOS should evolve;

- The ET discussed preparations for the next Workshop on NWP Impact Studies (following the workshop that took place in Toulouse in 2000). The ET agreed that the organisation of the next meeting should be led by the WMO (i.e. CBS, via members of ET-ODRRGOS) with strong participation representing regional observing system activities (e.g. COSNA, EUCOS, NAOS). A workshop in early 2004 was suggested.

2.3. Overall, the Chairman indicated that he felt that substantial progress had been made on the work programme drafted at the last CBS. His goals for the July 2002 meeting are to:

- consider the implications from the May 2002 Composite Observing System for the North Atlantic (COSNA) Scientific Evaluation Group (SEG) meeting on GOS monitoring activities and NWP impact studies;
- hear progress reports on the eight OSEs suggested at previous ET meetings and consider any other OSEs that could be important;
- consider any appropriate revisions to existing Statements of Guidance in light of new information from OSEs or other sources;
- review and refine the draft recommendations for evolution of the GOS;
- develop input to be submitted to CBS-Ext. 2002 that would summarize the major outcomes of ET-ODRRGOS activities; and prepare for the upcoming ICT meeting in October 2002.

2.4. With the upcoming review of all recommended actions emerging from ET-ODRRGOS by the chairman of the OPAG-IOS, the Chairman indicated that a full review of all actions must be undertaken. At the conclusion of this meeting, he noted that a consolidated paper will define the inputs from ET-ODRRGOS to CBS; this document, along with those prepared by the other Expert Teams within the OPAG-IOS will be consolidated into appropriate OPAG-IOS input for the CBS-EXT (2002).

3. REPORT ON THE COSNA / SEG MEETING (*Agenda item 3*)

3.1. Dr. Horst Böttger reported on the outcome of the COSNA / SEG meeting, which was held at ECMWF, Reading, 21-22 May 2002. He focussed on the review of recent data impact studies and continuation of the SEG activities if the CGC is subsumed by EUCOS in 2003 as expected.

3.2. There was considerable discussion at the SEG regarding continuation of its main activities, including the conduct of Observing System Experiments (OSEs), if the CGC ceases to exist. The CGC on COSNA is likely to be subsumed into EUCOS by August 2003 when the final decision will be taken. EUCOS will have a Scientific Advisory Team to advise on issues related to the observing system over Europe and the North Atlantic and will not be able to support the more general study of observing system impact that has been carried out over the last 10 years by the SEG for COSNA. Although the SEG focussed on the North Atlantic, the impact studies were mainly undertaken with global forecasting systems and produced globally valid results. The SEG also organised two workshops on data impact studies (partially funded by CGC and co-sponsored by the WMO).

3.3. The data impact study work of the SEG and the related workshops are considered to be valuable contributions towards the monitoring and development of the GOS. Environmental monitoring and weather forecasting through global NWP systems require a well-balanced and integrated observing system providing high quality *in situ* and remotely sensed data of land, ocean, and atmosphere. Global NWP centres are best placed to assess the relative contribution and value of various components of the GOS and to provide feedback on data requirement and input for GOS re-design. In particular the evolution of the satellite observing system capabilities and the

utilisation of these data in skilful data assimilation systems should be monitored and supported through a well-organised programme of OSEs involving the major NWP centres of the WMO members from all the Regions.

3.4. Thus it was felt that these important activities of the SEG should be continued. The view of the SEG was that the CBS/OPAG-IOs through the ET ODRRGOS and its Rapporteurs on global and regional NWP appeared to be best placed to organize the OSE work and arrange future NWP impact study workshops. These enable exchange of results from OSE studies and provide feedback to the operators and managers of the GOS on the performance of their systems and future data requirements.

3.5. The ET-ODRRGOS concurred on the importance of the work of the SEG and expressed their willingness to assist the rapporteur on global OSEs/OSSEs (currently Jean Pailleux) in the organisation of the next workshop on NWP impact studies (to follow on from the workshop held in Toulouse in March 2000). The suggestion is for a venue in Europe in the first quarter of 2004. An action was taken to announce the workshop details in the last quarter of 2002. See Action 1.

4. STATUS AND RESULTS OF OSEs (Agenda item 4)

4.1. Summary of COSNA / SEG Impact Studies

4.1.1. Dr. Horst Böttger reviewed the OSE results of the last year from the major European NWP centres, including the HIRLAM consortium, as well as NCEP. Several OSEs addressed issues that had been raised by the ET ODRRGOS at its April 2001 meeting, in particular the impact of hourly SYNOPs and the impact of tropical radiosonde data. Other studies addressed the use of high frequency data, in particular from automated systems, such as AMDAR or wind profilers, in 4D-Var data assimilation systems or by using shortened data assimilation time windows.

4.1.2 The results of the OSEs conducted for the SEG were summarized as follows:

- Positive impact was found from the use of high resolution data in 4D-Var or high frequency assimilation cycles.
- Positive impact was found from a range of newly introduced satellite data, ie scatterometer winds, MODIS winds, ozone data, and radiances.
- Positive impact was found from surface observations. Data denial studies indicated a strong impact from surface pressure measurements; there is evidence of additional beneficial impact from high frequency surface pressure data (e.g. hourly observations).
- A significant positive impact was found from aircraft temperature and wind measurements taken during ascent and descent.
- An impact was found from the tropical radiosonde network, but a more extensive study will be required to consolidate the results.

4.1 Analysis of the Siberian Sondes

4.2.1. Dr. Oleg Pokrovsky presented an evaluation of the Siberian raob network information content based on H500 field analysis and its evolution over the last 50 years. The covariance and Fisher information matrices were analysed to make quantitative estimates of information content; this may serve as a background for suggesting an optimal design for the sonde network. Simulation experiments were conducted by applying spectral analysis of H500 field variability. Large (thousands of km) scale variability patterns were shown to be linked with Asian monsoon

phenomenon occurrences. Medium (hundreds of km) scale variability component analysis revealed that sonde network data information content was increasing from 1955 till 1985 and decreasing thereafter. The small (tens of km) scale analysis indicated that satellite remote sensing data had substantial impact on H500 Siberian field retrievals in the late 1980s and early 1990s. H500 observations from the eastern Siberian regions (Kamchatka peninsula, Far East range, East-Siberian Sea coast, and Yakutia) affect analysis and short term weather forecasting over distant regions (North America (Alaska, Canada and north-western part of USA), Japan, Arctic, and North Pacific, respectively). Temporal dependence of H500 observational data over Siberia on North America region achieved a maximum in 1996. This result is explained by superposition of medium and small scale spatial components provided by sonde and satellite remote sensing data. The number of Siberian upper-air stations was reduced by the end of the 1990s, especially in 1999 because of financial problems. At this time, in the eastern Siberian area the average number of launches was only 1-7 launches per station per month. This area, however, provided the most significant information impact on North America and Arctic H500 analysis. Dr. Pokrovsky suggested further work should be undertaken to compare the relative information content attributed to selected Siberian zones and to substantiate a minimal network configuration that would optimise an observational programme in this area.

4.3 OSEs conducted in the USA (FSL)

4.3.1. Dr. Tom Schlatter reported on two regional impact tests conducted by Dr. Stan Benjamin and colleagues at NOAA's Forecast Systems Laboratory. The experiments relied on the Rapid Update Cycle (RUC), that produces hourly analyses and short-range forecasts (out to twelve hours) of tropospheric and lower stratospheric conditions over the contiguous United States.

4.3.2. The first experiment investigated the impact of vertically Integrated Precipitable Water (IPW) data inferred from the analysis of signals received at the ground from Global Positioning (GPS) satellites. IPW data have an RMS error of about 0.8 mm and a bias of less than 0.1 mm measured relative to ground-based radiometric data and water vapor lidars. The meteorological application of this information in the U.S. began in the mid 1990s using a handful of dual-frequency receivers. The network of receivers has since grown to over 100 sites and will be approximately 200 within a year. Forecast accuracy is verified with reference to rawinsondes in the south central U.S. or, in the case of precipitation, with reference to high-resolution analyses based upon radar and rain gauges. The impact study covered 1998 through 2001; the results indicate a small but consistent positive impact on short-term forecast accuracy for relative humidity, primarily below 500 hPa, and for precipitation. The magnitude of impact has improved as the number of GPS stations has increased. The impact occurs despite the fact that the RUC assimilates each hour more than 1000 each of GOES and SSM/I observations of precipitable water.

4.3.3. The second experiment investigated the effect of variations in the number of automated aircraft reports (ACARS / MDCRS) over the United States on the accuracy of short-term tropospheric wind forecasts. Immediately after the events of 11 September 2001, all commercial air traffic was temporarily grounded. During 36 hours when there was virtually no commercial air traffic, it was noticed that 3-h wind forecast accuracy with the RUC was no better than 12-h accuracy. This rarely occurs; normally, the thousands of aircraft temperature and wind reports per hour over the U.S. ensures that shorter forecasts are more accurate than longer forecasts. Without the numerous aircraft reports to update the model background, this was not the case and the background systematically deteriorated. Degradation in short-term wind forecasts also occurs regularly on Saturday and Sunday nights, when package carriers, responsible for 75% of reports below 25,000 feet, do not fly. This results in a 12-h reduction of nearly 20,000 reports and a 7% reduction in 3-h forecast accuracy for high tropospheric winds.

4.4 EUCOS Programmes

4.4.1. Dr. Jim Caughey, the EUCOS Programme Manager, outlined the main elements of the EUCOS Operational Programmes. He then described in some detail the contents of the EUCOS

Studies Programme. This programme is intended to guide and provide scientific justification for the development of the main EUCOS observational elements from 2002-2006.

Three proposed OSEs were outlined involving:

- targeted observations in February or March 2003 (as a European component of THORpex);
- higher frequency AMDAR data;
- higher density surface marine observations to help identify the requirement for surface pressure/wind measurements in support of satellite observations.

It was expected that EUCOS would conduct these OSEs in collaboration with several European NWP centres.

4.4.2. The EUCOS Studies Programme also contains proposals for demonstrations of new technology. Important topics include assessment of the utility of AMDAR humidity data (when available) and extension of the AMDAR network using TAMDAR (when development is completed). Within EUCOS, it was also considered important to study, in as objective a manner as possible, the optimal evolutionary relationship between the terrestrial and space components of the overall (integrated) system. Major developments are planned in the space segment out to 2015 and there is a need to understand the implications for the in situ networks.

4.4.3. The ET agreed that many aspects of the EUCOS programme were of interest to CBS as examples of regional activities that improve the effectiveness of observing systems. Also, it agreed that the three OSEs listed above were of particular interest in the context of the evolution of the GOS. Concerning targeted observations, studies are needed to demonstrate the use of NWP systems to identify "sensitive areas", in which observations are expected to have most impact on forecast skill. This in turn demonstrates an "interactive observing system", through which a NWP system could be used to guide the most effective deployment of observations. The EUCOS programme offers such an opportunity.

4.5. Mesoscale OSEs conducted at JMA and other NWP centres

4.5.1. Dr. Tadashi Tsuyuki, representing the Rapporteur for regional OSEs, reported on results from mesoscale OSEs at JMA. They showed that over the mountainous island of Japan, low-level wind data from wind profilers and pilot balloons were beneficial for heavy rainfall predictions, and that ground based GPS total column water data had marginally positive impact on precipitation forecasts. These results complement the similar regional OSEs that were conducted over different terrains in the USA and Europe. JMA plans to test impacts of radial wind data from Doppler radars and satellite microwave precipitable water data. NCEP is testing impacts of wind profiler and aircraft ascent / descent data on 0 to 12 hour forecasts; preliminary results from wind profiler denial showed positive impact of these data on wind forecasts. In addition he reported on 15 case studies performed by the Met Office on high-impact weather that found particular benefits from aircraft data, surface observations, and the derived "MOPS" moisture profile data for precipitation forecasts. The Met Office plans are to test impact of ground-based GPS data and AMSU-B data from the NOAA satellites.

4.6. OSEs at the Met Office

4.6.1. Dr. John Eyre presented preliminary results of an OSE at the Met Office (UK) to study the impact of atmospheric profile data in the tropics. Observations were withheld from an area in tropical S.E. Asia and Australasia (20N-20S, 90E-150E). This region is well observed compared with the rest of the tropics; the impact of denying data in this region indicates the potential advantages of improving observational coverage in tropical regions less well observed.

Preliminary results indicated a substantial impact from wind / temperature profile data with a much smaller impact from humidity data.

4.7. OSEs carried out in Canada (MSC) and Australia (BoM)

4.7.1. The Rapporteur on global OSEs reported on a set of OSEs being carried out in Canada, addressing the relative contributions of the satellite and conventional surface based observing systems. One of the Canadian radiosonde experiments investigates the role of raob data above 100 hPa (OSE 2 recommended by the ET in April 2001; see Annex III for a list of the OSEs and a summary of progress to date). Results are expected by autumn 2002.

4.7.2. In Australia, the impact of scatterometer surface winds (from Quikscat) has been studied. A modest positive impact has been found, mainly in the southern hemisphere and these data are expected to be used operationally. This reinforces the earlier results from the ECMWF reported at the Jan 2002 ET-ODRRGOS meeting.

4.8. OSEs carried out in MeteoFrance

4.8.1. In preparing for the operational use of some data sets, several impact studies have been performed with the MeteoFrance 4D-VAR system. A significant impact of profilers has been found over Europe and North America. The use of raw ATOVS radiances has also had a positive impact with respect to the use of processed radiances (which are currently used in operations).

4.8.2. In order to evaluate the impact of tropical radiosondes, an impact study has been carried out for a 3-week period in June 2000 in which all the TEMP and PILOT messages were removed in the tropical belt (20N to 20S). This is the OSE 5 recommended by ET-ODRRGOS. It has been performed with a uniform version of the global model ARPEGE using a 6 hourly 3D-VAR. Analysis differences are generally small, except in the Australia –Indonesia area where they are bigger all the time (half of the removed radiosondes are in this area). 96 hr ARPEGE forecasts have been run for each day from 00 UTC; on one or two occasions, initial differences grew and propagated up to 50 to 60 degrees of latitude in the 72 to 96 hour range. One case of positive impact was found growing from the Australia-Indonesia area up to Japan at 96 hours.

4.8.3. Bogus humidity data produced from the Meteosat images have been assimilated in an experimental 3D-VAR mesoscale system based on the operational ALADIN / France model (10 km resolution). A case study showed that these data are able to improve the details of the ALADIN precipitation forecasts, out to 36 hours.

4.9. Update to conclusions from Toulouse Workshop on NWP Impact Studies

4.9.1. The ET reviewed the conclusions from the Toulouse Workshop on NWP Impact Studies in March 2000. The ET also summarized the results of the eight OSEs suggested at their April 2001 and January 2002 meetings. See Annex III. In light of these and other OSEs conducted since the Toulouse Workshop, the ET updated the recommendations for alleviating the deficiencies of the current in situ observing system. These are listed in Annex IV along with a reference to published impact studies and/or ET suggested OSEs for each recommendation.

4.10 Update to SoG for Global NWP

4.10.1. Dr. John Eyre presented the draft update of the section of the Statement of Guidance covering Global NWP (GNWP). This update had taken advantage of substantial new work performed by the EUMETSAT Applications Expert Group on GNWP in the context on EUMETSAT's Meteosat Second Generation follow-on studies. This activity had taken as its starting point the previous Global NWP SoG.

4.10.2 The ET agreed that an update for all application areas should be initiated. Current versions of the summaries from all ten SoGs and their last date of update are listed in Annex V. An action for the updates was drafted. See Action 2.

5. REVIEW OF RECOMMENDATIONS FOR EVOLUTION OF SURFACE AND SPACE-BASED COMPONENTS OF THE GOS (*Agenda Item 5*)

5.1. Report on the ET-SSUP Activities

5.1.1. A briefing was given by the Secretariat on the results of the fourth session of the Expert Team on Satellite System Utilization and Products (ET-SSUP) held in Geneva, Switzerland, 29 April - 3 May 2002. The primary objectives for the fourth session included the finalization of a new WMO Satellite Activities Technical Document on the Status of the Availability and Use of Satellite Data and Products by WMO Members plus comparable data content from future polar-orbiting satellites and further refinement of the concept for Alternative Dissemination Methods (ADM) for data from meteorological satellites.

5.1.2. The ET-SSUP, in their fourth session, agreed to a set of conclusions and recommendations resulting from analysis of their questionnaire on the availability and use of satellite data and products for 2001. The conclusions and recommendations will serve to assist WMO Members in identifying ways to improve satellite system utilization. It was noted that the analysis of the questionnaire had resulted in recommendations compatible and comparable to those of ET-ODRRGOS in its activities towards the redesign of the GOS. ADM principles, potential benefits, a perspective from the satellite operators of the Coordination Group for Meteorological Satellites (CGMS), data dissemination concept, characteristics and preliminary user requirements were discussed and agreed upon at the fourth session.

5.2 Considerations about Microwave Remote Sensing

5.2.1. Dr. Peter Bauer gave an invited presentation on microwave considerations for low earth orbiting (LEO) and geostationary (GEO) remote sensing of precipitation and cloud properties. He noted that candidate frequency bands for the remote sensing of precipitation are selected from a compromise between information content and affordable antenna size. Possible window frequencies are at 11, 19, 37, 89, 157, 220, 340, 400, 500 GHz. These may be combined with frequencies that are primarily useful for sounding of temperature and moisture profiles. Neighboring O₂ or H₂O frequency band pairs with identical clear-air response carry information on cloud and precipitation by differential scattering. The best suited absorption band combinations are near 57, 118, 425 GHz (O₂) and 183, 325, 380 GHz (H₂O).

5.2.2. Quantitative cloud / precipitation parameter retrievals over oceans are well established using window frequencies (11-90 GHz) on LEO-radiometers with spatial resolutions between 5-50 km. Over land, surface emissivity is high and variable so that only higher frequencies (> 85 GHz) provide indirect information on precipitation. Almost independent of surface type, differential scattering at sounding frequency pairs allows limited retrieval of precipitation (light rain) and good access to cloud water/ice and frozen precipitation quantities. However, depending on the channel selection, the sounding channels may not be sensitive to shallow systems (for example in GEO a 4 m antenna with 15 km resolution requires usage of 220+ GHz channels that have sounding altitudes above ~750 hPa).

5.2.3. First assimilation experiments using LEO-radiometry (10-37 GHz) over precipitation affected areas are promising; however, the use of higher frequency channels will strongly depend on the quality of model cloud parameterisations. Over oceans, polarization information is highly desirable because it is directly related to integrated rain water path (<19 GHz). For ice retrievals, polarization supports the retrieval of particle shapes and sizes (>85 GHz).

5.2.4. The use of sounding channels for cloud / precipitation parameter retrieval is new and requires detailed technical studies that focus on the ideal channel combinations (with different

resolutions if the same antenna is used for all channels) and their sensitivity under various weather conditions. GEO-radiometry (at 220+ GHz) would complement the rather high accuracy of precipitation retrieval from current LEO-radiometers over oceans with cloud / ice / snow information. Over land, GEO-radiometry can also complement LEO-radiometry (all frequencies) due to the high temporal sampling frequency. However, the relation between possible GEO-frequencies and near-surface precipitation is indirect and requires constraints through, e.g., cloud models (NWP) or calibration data (radar).

5.3. Remote Sensing of Volcanic Ash

5.3.1. Ms Sarah Watkin presented an overview of the current method for detecting and tracking volcanic ash using satellite imagery, and reviewed the strengths and weaknesses of this technique, with some examples. She also outlined the method for detecting plumes of volcanic sulphur dioxide and hot spots. She concluded with a summary of the methods that would be available for detecting and tracking volcanic emissions using advanced geostationary image data (e.g. from SEVIRI on Meteosat Second Generation).

5.4. A proposal - Global Universal Profiling System (GUPS)

5.4.1. Dr. Tom Schlatter informed the ET of a proposal for a Global Universal Profiling System (GUPS) intended to provide detailed vertical profiles of meteorological parameters, aerosols, and chemical constituents in the atmosphere and measurements of temperature, salinity, currents, and biological activities within the ocean. Such measurements would be made at regular timed intervals on a coarse but uniform grid covering the world's oceans and polar regions. The profiles would extend from the stratosphere to deep in the ocean. They would calibrate satellite measurements, monitor a number of environmental parameters, especially vertical fluxes, that are difficult to measure or inadequately measured, and, over a period of years, provide information on climate trends. The proposal requests NOAA support for system design beginning in 2004 or 2005. A key component of GUPS is a fleet of unmanned aircraft whose normal flight altitude would be in the stratosphere and carrying payloads approaching 1000 kg. The payload would include expendable sondes for atmospheric measurements, bathythermographs for oceanic measurements, and a variety of onboard instruments for particle sampling and gas chemistry. The aircraft would be capable of descent into the troposphere for *in situ* sampling. When not gathering profile information at assigned locations, the aircraft could drop sondes for targeted observations. Moored buoys and ARGO-like floats could perform the oceanic observations at some locations. It is a goal that a more rigorous scientific basis will exist for informing policy makers on the effects of regulating greenhouse gas emissions after some years of GUPS operations.

5.5 Updates to the Manual on the GOS

5.5.1. The ET noted the updating process for the Manual on the GOS carried out by OPAG/OIS Rapporteur on Regulatory Material and the secretariat in accordance with recommendations of CBS. The revised draft of the Manual was reviewed by the Task Team on Regulatory Material in November 2001 and was posted on the WMO Web site in the middle of April 2002 with an invitation for comments by members of CBS. The ET agreed that regulatory material on the GOS should contain an updated methodology that had been accepted to describe observational data requirements in terms of horizontal, vertical, and temporal resolution in addition to accuracy and timeliness. In this connection, the ET strongly recommended adding to the Manual on the GOS a description of the Rolling Review of Requirements (RRR) process used by the ET to propose future configurations of the GOS and appropriate reference to the list of applications areas' observational requirements being reviewed by the ET on a regular basis. Inclusion of the RRR process should be also made in the Guide on the GOS and should be updated in parallel with the Manual on the GOS. In the view of the above, the ET requested the Rapporteur on Regulatory material to amend accordingly the draft Manual in consultation with the secretariat as a matter of urgency in order to provide appropriate information to the forthcoming session of CBS. The ET further recommended that the CBS be encouraged to undertake routine updates to the Manual in the interests of keeping it current. See Action 3.

5.5.2. The ET noted that Manual for the GOS contains specific observations requirements for environmental emergency response activities but this is not an applications area currently being considered by the RRR process. The ET suggested that CBS be asked if the RRR process should be extended to include this area. See Action 4.

5.6 Monitoring of the GOS

5.6.1. The ET noted the results of the October 2001 Special MTN monitoring provides an objective picture of the data coverage for the current GOS. The availability of SYNOP reports at MTN centres remained unchanged globally, constituting 75% of the reports expected from stations included in the RBSNs. The availability of SYNOP reports received daily at MTN centres is less in Regions I (50%), III and V (63%) than in Regions II (82%), IV (83%) and VI (91%). The low availability level was considered to be marginally satisfactory. The results of Special MTN monitoring also showed that the availability of upper-air reports had a global average of 61% (58% in 1999). The regional breakdown of the availability of TEMP reports by regions was: Region I (29% in 2001, 31% in 2000 and 29% in 1999), Region II (61%, 59% and 52%), Region III (41%, 39% and 35%), Region V (58%, 58% and 57%), Region VI (72%, 73% and 70%) and Region IV (83%, 86% and 84%). These results were reflected in the recommendations concerning the surface based component of the GOS.

5.7 Review of the Recommendations for Evolution of the Space-Based Component of the new GOS

5.7.1. The ET reviewed the recommendations on improvements to the space based component of the GOS that were based on the Rolling Review of Requirements (RRR) for Applications Areas GNWP, RNWP, Synoptic Meteorology, Nowcasting and VSRF, Aeronautical Meteorology, Hydrology, SIA, Atmospheric Chemistry, Ocean Weather Forecasting: A revised version was drafted and a preamble was added. The new version can be found in Annex VI.

5.8 Review of the Recommendations for Evolution of the Surface-Based Component of the new GOS

5.8.1 Deficiencies in the surface based components of the GOS were identified and remedial actions were recommended [citing referenced impact studies that support the recommendation]. These can be found in Annex IV. The ET then revised the recommendations for the evolution of the surface based component of the GOS that were based on the RRR for Applications Areas GNWP, RNWP, Synoptic Meteorology, Nowcasting and VSRF, Aeronautical Meteorology, SIA, Atmospheric Chemistry, and Ocean Weather Forecasting. The new version of these recommendations can be found in Annex VI (along with the recommendations for the space based component).

6. PREPARATION OF THE ET INPUT TO THE CBS-EXT (Agenda Item 6)

6.1.1. The ET agreed that the material in Annex VI containing the recommendations for the evolution of the space based and surface based components of the GOS would comprise the much of the ET-ODRRGOS input to the CBS-EXT. It will be noted that the scope of the changes to the GOS coming in the next decade will be so massive that new revolutionary approaches for science, data handling, product development, training, and utilization will be required. To emphasize this, the ET recommended that the CBS-EXT should be advised of the urgent need to study comprehensive strategies for anticipating and evaluating changes to the GOS and that a focused funded activity needs to be developed to study observing system design. An action to advise the OPAG IOS chair of this was taken. See Action 5.

7. DISCUSSION OF THE UPCOMING ICT

7.1.1. The ET agreed that input to the ICT would be the summary of OSE results contained in Annex III, the summary of SoGs contained in Annex V, the recommendations for the evolution of the GOS and the vision for the GOS in 2015 contained in Annex VI, and the workplan for 2002-2003 contained in Annex VIII.

8. ANY OTHER BUSINESS (*Agenda Item 7*)

8.1.1. The ET reviewed the actions from the January 2002 ET-ODRRGOS meeting. Six of the actions had been closed and five remained open; these were added to the five new actions generated during this meeting. See Actions 6 through 10. The ET also drafted a workplan for 2002-2003. See Annex VIII. A brief summary of ET-ODRRGOS accomplishments to date was discussed. See Annex IX. It was felt that a good start had been made.

9. CLOSURE OF THE SESSION (*Agenda Item 8*)

9.1.1. The Chairman thanked the ET members and invited experts for their excellent contributions to the meeting. He also noted the valuable support from the Met Office and the WMO secretariat in facilitating the meeting. The session closed at 1:00 pm on Friday 5 July 2002.

ANNEX I

Expert Team Meeting on Observational Data Requirements and Redesign of the Global Observing System, Reduced Session, Oxford, UK, 1 - 5 July 2002

List of participants

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ANNEX II

Agenda

1. ORGANIZATION OF THE SESSION
 - 1.1 Opening of the meeting
 - 1.2 Adoption of the agenda
 - 1.3 Working arrangements
 2. REPORT OF THE CHAIRMAN
 3. REPORT ON THE COSNA / SEG MEETING
 4. STATUS AND RESULTS OF OSEs
 5. REVIEW OF RECOMMENDATIONS FOR EVOLUTION OF SURFACE AND SPACE-BASED COMPONENTS OF THE GOS
 5. PREPARATION OF THE ET INPUT TO THE CBS-
 6. DISCUSSION OF THE UPCOMING ICT
 7. ANY OTHER BUSINESS
 8. CLOSURE OF THE SESSION
-

ANNEX III

Summary of OSE Results as of July 2002

The ET ODRRGOS suggested eight OSEs for consideration by NWP centres and asked the OSE/OSSE rapporteurs (Jean Pailleux and Nobuo Sato) to engage as many as possible in this work. Good response was received and results are coming in. The OSEs and the initial results from the contributing NWP centres are listed below:

1. Impact of hourly versus 6-hourly surface pressures (ECMWF), done for May 2001 with 4DVAR positive over north Atlantic and southern oceans.
 2. Impact of denial of radiosonde data globally above the tropopause (Canadian AES), ongoing at AES; report anticipated autumn 2002.
 3. Information content of the Siberian radiosonde network and its changes during last decades (Main Geophysical Observatory in St Petersburg, NCEP), done for last decade information content ascending until 1985, descending thereafter since 1985 decrease in performance of 500 hPa height analysis over NA temporal dependence of info impact of Siberian region over NA highest in 1996.
 4. Impact of AMDAR data over Africa through data denial in a 4D-Var analysis and forecasting system (ECMWF, Meteo France, NCEP), ECMWF shows denial over NH of obs below 350 hPa has large significant impact in summer and winter, African impact pending at MeteoFrance.
 5. Impact of tropical radiosonde data (Met Office, Meteo France, JMA), SE Asia raob density varied showing high impact on winds at all levels occasional propagation of impact to mid latitudes temperature and wind information most important potential of AMDAR in less well observed tropical areas (eg Africa, Central America) suggested.
 6. Impact of three LEO AMSU-like sounders (NOAA 15 and 16 and AQUA), and (Met Office, NCEP, JMA), pending commissioning of Aqua and NOAA -17 results pending second half of 2002.
 7. Impact of AIRS data (ECMWF, Met Office, NCEP, BMRC, JMA). pending commissioning of Aqua.
 8. Impact of better than 3 hourly ascent descent AMDAR data preliminary NH AMDAR ascent/descent impact suggests positive effect of higher frequency data EUCOS is arranging higher frequency observations in 2003 to enable this study by NWP centres.
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ANNEX IV

Recommendations for addressing deficiencies identified in the current in-situ observing system [citing referenced impact studies that support the recommendation]

Based on the conclusions found in the Proceedings of the second CGC/WMO Workshop on the Impact of Various Observing Systems on NWP held 6-8 March 2000 in Toulouse, France (WMO TD-1034) and the OSEs initiated by the ET-ODRRGOS, the following recommendations for improvements in the in situ observing system were made. It was noted that the technologies and methodologies for achieving these targets are either available now or are likely to become available in the near future.

- * Strive for improved performance in the upper air network, especially in Regions I and III and Siberia (as noted in sections 4.2 and 5.6 of this report).
 - * Collect additional AMDAR observations from all major oceanic areas, Africa, west Pacific, Asia, southern America, Canadian arctic, and Siberia (in flight data). [Toulouse report, ECMWF NH AMDAR impact study]
 - * Complement the valuable data from radiosondes and pilot balloons with AMDAR measurements of temperature and wind taken during ascent and descent (profile data). [Toulouse report, ECMWF NH AMDAR impact study, OSE-4 and OSE-5 and OSE-8]
 - * Enhance the temperature, wind and, if possible, the humidity profile measurements (from radiosondes, pilot balloons and aircraft) in the tropical belt, in particular over Africa and tropical America. There is evidence from recent impact studies with the radiosonde/pilot network over the Indonesian/Australian region that such data give a better depiction of winds in the tropics and occasionally influence strongly the adjacent mid-latitude regions. [OSE-5]
 - * Continue with the development and installation of water vapour sensors on aircrafts and make the observations available for NWP. [Toulouse report]
 - * Transfer into operations the proven methodology of observation targeting to improve the observation coverage in data sensitive areas. This concept is in operational use at the US Weather Service in the north-eastern Pacific during the winter storm period. EUCOS is planning on field experiments in the Atlantic, possibly in the context of a THORPEX study. [FASTEX results and Toulouse report]
 - * Ensure the continuation of an adequate surface pressure observing system in the southern oceans, mainly based on measurements from drifting buoys. [Toulouse report, OSE-0]
 - * Distribute all available high frequency observations globally for use in NWP. Recent studies have shown that 4D-Var data assimilation system or analysis system with frequent update cycles can make excellent use of hourly data, e.g. from SYNOPs, buoys, profilers, aircraft (AMDAR). [OSE-1]
 - * Distribute globally the measurements of total column water vapour (TCWV) from available and emerging ground based GPS systems for use in NWP. Such observations are currently made in Europe, North America and Japan. It is expected that the global coverage will expand over the coming years. [COSNA/SEG, NAOS, JMA reports]
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ANNEX V

Summaries of the Statement of Guidance in ten Applications Areas (last update indicated in parentheses)

Summary of Statement of Guidance for Global NWP (July 2002)

Global NWP centres:

- make use of the complementary strengths of *in situ* and satellite-based observations;
- have shown positive impact from enhanced microwave instruments (such as AMSU);
- are advancing in the use 4D data assimilation systems to benefit from more frequent measurements (e.g. from geostationary satellites) and from measurements of cloud, precipitation, ozone, etc.;
- are poised to take advantage of high spectral resolution sounders (such as IASI, AIRS, CrIS) for improved vertical resolution;
- would benefit from increased coverage of aircraft data, particularly from ascent/descent profiles.

The critical atmospheric and surface parameters (in order of priority) that are not adequately measured by the current or planned observing systems are:

- wind profiles at all levels;
- temperature profiles of adequate vertical resolution in cloudy areas;
- precipitation;
- soil moisture;
- surface pressure;
- snow equivalent water content;

Summary of Statement of Guidance for Regional NWP (January 2002)

Regional (mesoscale) NWP is motivated mainly by a desire to provide enhanced weather services to large population centres and is aided by the availability of comprehensive observations. Oceanic areas are included in the geographical domain for regional weather prediction primarily as a buffer zone upstream from populated land areas, where accuracy is most important. Lateral boundary conditions supplied by global models eventually govern the forecast in the interior of the domain except for locally forced events.

Where observational and computational resources support regional prediction, the following is true:

- NWP centres rely rather more on surface-based and *in situ* observing systems than on space-based systems;
- Weather radars supply the highest resolution information, but the coverage is spatially limited, vertically and horizontally;

- Satellites supply information at high horizontal resolution; infrared sounding coverage is limited primarily by clouds;
- Accurate moisture fluxes are critical for good mesoscale forecasts, especially of clouds and precipitation; the forecasts thus rely heavily upon wind and humidity observations;
- Lower boundary conditions can quickly affect a mesoscale forecast; observations of screen-height (2-metre) air temperature, dew point, wind, and pressure are often good to adequate in coverage and frequency whereas observations of surface conditions, for example, soil moisture, are not.
- In many cases, mesoscale observations are not fully exploited in mesoscale prediction, e.g., radar reflectivity, cloud images, and microwave sounders. This is more a problem in data assimilation than in the character or distribution of the observations.

The greatest observational needs for regional prediction are:

- More comprehensive wind and moisture observations, especially in the planetary boundary layer. Enhancement of the AMDAR data collections and the addition of moisture sensors aboard aircraft are recommended. Numerous ground-based GPS receivers need only the addition of simple surface observations to be able to deliver estimates of integrated water vapour. Wind profiles are needed at closer spacing.
- More accurate and frequent measures of surface and soil properties, in that these influence surface fluxes strongly. More accurate estimates of precipitation are sorely needed.
- More comprehensive observations of cloud base, cloud thickness, and other cloud properties.

Summary of Statement of Guidance for Synoptic Meteorology (April 2001)

NWP models are the main tool for synoptic prediction so the most essential data in synoptic meteorology are the data which have the most important impact on NWP. Thus, the SOG for global and regional NWP applies for Synoptic Meteorology as well. Information that best complements the content of data assimilation models (data not entering or not well treated in NWP schemes) are found in satellite images and radar pictures; their usage is reinforced by their good temporal and spatial resolution. Surface data, because of their good representation of the conditions where people are living, are also quite essential. The most obvious concern is coverage of oceanic areas, where significant phenomena such as cyclogenesis occur but data are sparse; here sensible weather parameters are unavailable and satellite data do not offer enough information (precipitation is not measured well and visibility is not measured at all). Another concern is the quality of cloud cover estimates during the night, seen from ground as well as satellites; progress is expected in this area in the next decade.

Summary of Statement of Guidance for Nowcasting and VSRF (April 2001)

Nowcasting consists of analyzing primarily observational data to make essentially extrapolative forecasts from a few minutes to 2 hours. VSRFs are now often generated by regional NWP models and have a validity period up to 12 hours. Nowcasting and VSRF cover scales from hundreds of metres to as large as 2000 km.

Nowcasting and VSRF can be applied to many phenomena including severe weather, but is most frequently used to forecast:

- convective storms with attendant phenomena;
- mesoscale features associated with extratropical and tropical storms;
- fog and low clouds;
- locally forced precipitation events;
- sand and dust storms.

Key nowcasting and VSRF parameters for which observational data are required are:

- clouds and precipitation;
- surface variables: pressure, wind, temperature, humidity, present weather, visibility and precipitation accumulation;
- 3-D wind field;
- 3-D humidity field;
- 3-D temperature field.

Well-defined high spatial and temporal resolution multispectral imagery from space will provide important immediate benefit to nowcasting phenomena such as areas of cloud, fog and severe convective weather.

While few in number, scanning weather radars (especially Doppler) provide excellent information critical to improving nowcasting and VSRF of convective and stratiform precipitation with their potential for localised flash floods, tornadoes, hail, low ceilings and visibilities, and high winds.

In the intermediate term, the most efficient way of improving the analysis of 3-D wind, humidity and temperature fields important for nowcasting and VSRF is the expansion of AMDAR equipped aircraft providing high resolution wind, humidity and temperature data.

Doppler wind profilers have proven valuable for nowcasting and VSRF because they provide high vertical and temporal resolution as a complement to other upper air observing systems.

Rapid imaging (on the order of minutes) is critical for nowcasting, but is not yet provided by all geostationary satellites. With some systems, the rapid scan for small areas competes with broader coverage.

Reliable precipitation estimates still remain elusive; however, they will benefit from continuing enhancements to satellite measurement capabilities.

Summary of Statement of Guidance for Seasonal to Inter-Annual Forecasting (January 2002)

The following key points summarise the SOG for Seasonal to Interannual forecasts:

- The requirements for seasonal-to-interannual modelling and forecasts are now entered in the CEOS/WMO data base (as well as available in several GCOS and WCRP documents; see paragraph 5);
- The WCRP has concluded that models show useful skill in predicting variability of the El Niño-Southern Oscillation but there is less useful predictability beyond the Pacific. The exploitation of skill is dominated by the signal of El Niño;

- Integrated and complementary approaches to the atmospheric and oceanic observing systems is required, exploiting synergies with other areas;
- The continuation of the TOGA Observing System (SST and winds; subsurface temperature; sea level and currents) provides the backbone of the system in place today;
- Enhancements from satellite wind vector and surface topography estimates, from new autonomous instruments such as *Argo*, and from enhanced surface flux reference sites will be a substantial contribution.

The key observational problems affecting improvements in seasonal to inter-annual forecasting are:

- The transition of research networks and outputs to operational status;
- The timely operational acquisition of data from research and non-governmental systems/sources;
- The lack of long-term commitment to:
 - a two-satellite scatterometer system;
 - tropical moored arrays in the Atlantic and Indian Oceans;
 - operational satellite altimetry;
 - a network of surface flux reference sites.

Summary of Statement of Guidance for Aeronautical Meteorology (January 2002)

The following key points summarize the SOG for Aeronautical Meteorology:

- For upper level temperature and wind forecasts the SOG for global NWP applies for operational forecast production as well. Locally higher vertical resolution is required for development and verification of turbulence forecast algorithms;
- For Meteorological Watch purposes, satellite imagery, and higher-level products such as multi-spectral images, provide good guidance for location and intensity of convection, but only scanning radars in networks combined with lightning detection systems have the cycle times of less than 10 min required for air traffic control;
- For turbulence and gravity wave prediction, current *in-situ* instruments have acceptable vertical resolution, but are not available in sufficient density for all areas of the globe. AMDAR is a data source with a high potential to fill existing data gaps in the medium term;
- For forecasts and warnings in the terminal area, in-situ and ground-based remote sensor technology has the potential to meet requirements, but its high cost inhibits global availability;
- For *en route* forecasts for VFR flights, ground based observations are not meeting the required data coverage except for some densely populated areas. Satellite imagery and specialised products have acceptable horizontal resolution, but lack the information on ceiling height for low cloud;
- For the detection of volcanic ash clouds and eruptions, satellite remote sensing has significantly improved the lack of information in this field. Sonic data are being investigated as a data source for immediate detection of volcanic eruptions.

Summary of Statement of Guidance for Atmospheric Chemistry (January 2002)

The major points regarding atmospheric chemistry are:

- To meet the measurement requirements, it will be necessary to exploit the synergy between satellite measurements and ground based and *in situ* data;
- To date there have been many more space-based chemistry observations of the stratosphere and higher than in the troposphere. In the future more tropospheric measurements are planned, but their numbers will still be lower than those planned for the stratosphere and higher;
- In the troposphere, space-based observations of O₃, water vapour, and CO are being made at acceptable levels, but measurements of aerosols, CO₂, long-lived source gases, radicals and reservoirs and sinks do not meet the requirements;
- In the stratosphere and mesosphere, many planned missions (GOMOS, HIRDLS, ILAS, MIPAS, MLS, SCIAMACHY and TES), followed by NPOESS, give promise for acceptable measurements, but adequate resolution within 24 hours appears to be a problem (except for HIRDLS).

Summary of Statement of Guidance for Agricultural Meteorology (Satellite only, June 1999)

Regarding agricultural meteorology needs, it is concluded that:

- leaf area index and land cover measurements with higher spatial resolution are needed;
- the polar orbiting instruments should be enhanced to resolve sub 1 km features; and
- multifrequency synthetic aperture radar systems could offer significant improvements for canopy structure and water content determinations.

Summary Statement of Guidance for JCOMM Program Areas (January 2002)*Ocean Weather Forecasts*

Increasing ocean information from the remote sensing methods enables us to predict high-frequency components of ocean variability, i.e., ocean weather forecasts. On the basis of traditional ocean observation components for NWP and monitoring of the low frequency variability (e.g., *in situ* platform based observing system), new *in situ* and satellite observations will be integrated to realize operational ocean nowcasting and forecasting in the near future. The ocean observation data will be assimilated into the numerical forecast models. Important observation variables and their present global ocean observing systems are listed in the table below.

Observation variables	Observing System
Temperature/salinity profiles	Tropical mooring buoy (TIP) XBTs (SOOP) Profiling floats (Argo)
Sea Surface Height	Satellite Altimeter Tide Gauges (GLOSS)
High-resolution SST	Infrared, Microwave radiometers

In order to generate the forecasting products, the observed data should be delivered to forecasting centres in timely manner.

The boundary conditions driving the ocean forecast model are generated by the atmospheric numerical model using the marine meteorological observation data.

Coastal Marine Services

With respect to Marine Meteorology, nowcasts and forecasts of sea state (wave environment), ocean surface topography, fog, sea ice and coastal circulation are of critical importance to safe and efficient marine operations including shipping, port operations, search and rescue operations, fishing, recreational boating, swimming, and the extraction of natural resources, etc.

Coastline Changes are constantly occurring due to eroding and accreting from routine and episodic events associated with tides, winds, waves, storm surges, sediment re-suspension and transport by rivers, tectonic processes and human modifications of the coastal zone.

Marine Pollution involves monitoring polluted sea areas (i.e., oil spill, red tide, high sediment concentration etc.) that are drifted by surface and wind-driven currents. Detections of the polluted area and current/wind fields are required for mitigation of their influence on the coastal environment.

In order to provide useful information (products) for the society living in/relating to the coastal region, we need various observational data not only the marine meteorological (physical) variables but also geological/biological variables. The following lists some (but not all) of the important marine meteorological parameters: SST, air temperature, air pressure, surface wind, air humidity, surface wave, temperature/salinity profiles, currents, sea ice, river discharge, coast lines, bathymetry, etc.

The coastal variables are traditionally observed by the *in situ* observing systems. The variables and their observing systems are described in the table below:

Observation variables	Observing System
Wind, Wave height/direction/spectrum	Wind/Wave Moored Buoy
Surface meteorological data	Ships and/or marine platforms
Subsurface oceanographic data	Small moored buoy, Ships
(Temperature, salinity currents)	(Thermistor strings), ADCP

Summary of Statement of Guidance for Hydrology (Satellite only, June 1999)

The following key points summarize the SOG for hydrology applications:

- Satellite data (currently from Landsat and AVHRR) are the only means for providing high resolution data in key regions;
- Acceptable data on areal extent of snow cover from AVHRR will become better with the advent of MODIS; passive microwave instruments (i.e. AMSR) will be able to improve estimates of the thickness of dry snow. These snow cover measurements will be acceptable for mesoscale modelling and snowmelt runoff forecasting;

- Addition of future microwave satellites (ADEOS-II and EOS-PM) along with the AMSU instrument should provide enhanced observational capabilities for snow water equivalent and soil moisture, however operational continuity of these systems is not assured;
 - A number of additional satellite-derived variables are, or will be, extremely useful to hydrology, including but not limited to: precipitation rates and totals, latent and sensible heat, surface air temperature and humidity, and surface winds.
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ANNEX VI

Recommendations for the Evolution of the GOS

Preamble to the Recommendations for Evolution of the Space based component of the GOS

The ET-ODRRGOS investigated an appropriate evolution towards the future space based component of the GOS using the Rolling Review of Requirements (RRR) process and observational requirements for the following applications areas: Global NWP, Regional NWP, Synoptic Meteorology, Nowcasting and Very Short Range Forecasting, Aeronautical Meteorology, Hydrology, Seasonal to Inter-Annual (SIA) Forecasting, Coastal Marine Services, Ocean Weather Forecasting, and Atmospheric Chemistry. Since the decision by the WMO Executive Council in 1993 to expand the space based component of the GOS to include appropriate research and development missions, space based contributions fall in three categories: the operational polar orbiting, the operational geostationary, and the R&D (research and development) satellites. This considerably extends the range of user requirements that can be addressed and provides the mechanism for R&D demonstrations to evolve into operational systems. Recommendations were founded upon Observing System Experiments (OSEs), operational NWP experience, and evidence from field experiments with enhanced observations from ground-, aircraft-, and space-borne instruments. Operational satellite system evolution requires more than a decade to proceed from plans to demonstration to implementation; the individual satellite operator plans for change in the near term are already well formed and in place and change is not likely. Thus the ET focussed on comments / suggestions for coordination of these plans in the near term and recommendations for change in global satellite systems for the longer term.

As the space based remote sensing system of the future develops and evolves, four critical areas (all dealing with resolution) will need to be addressed in order to achieve the desired growth in knowledge and advanced applications. They are: (1) spatial resolution – what picture element size is required to identify the feature of interest and to capture its spatial variability; (2) spectral coverage and resolution – what part of the continuous electromagnetic spectrum at each spatial element should be measured, and with what spectral resolution, to analyze an atmospheric or surface parameter; (3) temporal resolution – how often does the feature of interest need to be observed; and (4) radiometric accuracy – what signal to noise is required and how accurate does an observation need to be. Each of these resolution areas should be addressed in the context of the evolving space based observing system wherein the satellite(s) exist, or will exist.

High priority system specific recommendations for additional capabilities in the space based component of GOS (in order of priority for each category) are listed below; they are followed by comments on the planned improvements to space based component of GOS

High Priority System Specific Recommendations for Additional Capabilities in the Space Based Component of GOS (in order of priority for each category)

GEO satellites

- 1 GEO Imagers - Imagers of future geostationary satellites should have improved spatial and temporal resolution (appropriate to the phenomena being observed), in particular for those spectral bands relevant for depiction of rapid developments and retrieval of wind information.
- 2 GEO Sounders - All meteorological geostationary satellites should be equipped with hyper-spectral infrared sensors (to be demonstrated by GIFTS) for frequent temperature/humidity sounding as well as tracer wind profiling with adequately high resolution (horizontal, vertical and time).

- 3 GEO Imagers and Sounders - To maximize the information available from the geostationary satellite systems, they should be placed “nominally” at a 60-degree sub-point separation across the equatorial belt. This will provide global coverage without serious loss of spatial resolution (with the exception of Polar Regions). In addition this provides for a more substantial backup capability should one satellite fail. In particular, continuity of coverage over the Indian Ocean region is of concern.

LEO satellites

- 1 LEO data timeliness - More timely data are needed. Improved communication and processing systems are required to meet the timeliness requirements in some applications areas (e.g. Regional NWP).
- 2 LEO temporal coverage - Coordination of orbits for LEO missions is necessary to optimize temporal coverage while maintaining some orbit redundancy.
- 3 LEO Sea Surface Wind - Sea-surface wind data from R&D satellites should continue to be made available for operational use; 6-hourly coverage is required. In the NPOESS and METOP era, sea surface wind should be observed in a fully operational framework. Therefore it is urgent to assess whether the multi-polarisation passive MW radiometry is competitive with scatterometry.
- 4 LEO Altimeter - Missions for ocean topography should become an integral part of the operational system.
- 5 LEO Earth Radiation Budget - Continuity of ERB type global measurements for climate records requires immediate planning to maintain broad-band radiometers on at least one LEO.

R&D satellites

- 1 LEO Doppler Winds - Wind profiles from Doppler lidar technology demonstration programme (such as Aeolus) should be made available for initial operational testing; a follow-on long-standing technological programme is solicited to achieve improved coverage characteristics and reduced instrument size necessary for operational implementation.
- 2 GPM - The concept of the Global Precipitation Measurement Missions (combining active precipitation measurements with a constellation of passive microwave imagers) should be supported and the data realized should be available for operational use, thereupon, arrangements should be sought to ensure long-term continuity to the system.
- 3 RO-Sounders - To complement the METOP and NPOESS radio-occultation sounders, the opportunities for a larger constellation should be explored and expanded operational implementation planned. International sharing of ground network systems (necessary for accurate positioning in real time) should be achieved to minimise development and running costs.
- 4 GEO Sub-mm - An early demonstration mission on the applicability of sub-mm radiometry for precipitation estimation and cloud property definition from geostationary orbit should be provided, with a view to possible operational follow-on.
- 5 LEO MW - The capability to observe ocean salinity and soil moisture for weather and climate applications (possibly with only limited horizontal resolution) should be demonstrated in a research mode for possible operational follow-on. Note that the

horizontal resolution from this instrument is unlikely to be adequate for salinity in coastal zones and soil moisture on the mesoscale.

- 6 LEO SAR - Data from SAR should be acquired from R&D satellite programmes and made available for operational observation of a range of geophysical parameters such as wave spectra, sea ice, land surface cover.
- 7 LEO Aerosol - Data from process study missions on clouds and radiation as well as from R&D multi-purpose satellites addressing aerosol distribution and properties should be made available for operational use.
- 8 Cloud Lidar - Given the potential of cloud lidar systems to provide accurate measurements of cloud top height and to observe cloud base height in some instances (stratocumulus, for example), data from R&D satellites should be made available for operational use.
- 9 LEO Far IR - An exploratory mission should be implemented, to collect spectral information in the Far IR region, with a view to improve understanding of water vapour spectroscopy (and its effects on the radiation budget) and the radiative properties of ice clouds.
- 10 Limb Sounders - Temperature profiles in the higher stratosphere from already planned missions oriented to atmospheric chemistry exploiting limb sounders should be made operationally available for environmental monitoring.
- 11 Active Water Vapor Sensing - There is need for an exploratory mission demonstrating high-vertical resolution water vapour profiles by active remote sensing (for example by DIAL) for climate monitoring and, in combination with hyper-spectral passive sensing, for operational NWP.

Comments on Planned Improvements to Space Based Component of GOS

GEO satellites

- * GEO Imagers -The GEO imagers will evolve in a synergistic way with the GEO Sounders. Depending on the characteristics of the evolved temperature/humidity sounder, the imager can focus on different channels with an emphasis on monitoring rapidly developing small scale events.
- * GEO Imagers - Future geostationary satellites will have improved capability for observing land surface temperatures and characterising fire size and temperature.
- * GEO Sounders - IR sounding spectrometers from geostationary orbit are unlikely to be able to follow diurnal variations in boundary layer ozone important in air quality and hazard warnings, and thus will not meet the stated requirements of atmospheric chemistry.

LEO satellites

- * LEO Imagers - In the near and mid term future, vegetation and surface albedo data from R&D and operational satellites will be available for operational use. In the NPOESS era, continued access will improve small-scale applications.
- * LEO Sounders - The advent of hyper-spectral IR sounder on Aqua, METOP, NPP, and NPOESS will improve temperature and moisture profiling; plans for making early hyper-spectral IR data available for operational evaluation are being realized.

R&D satellites

- * LEO Imagers - Until the advent of NPOESS, high-quality sea-surface temperature data from R&D satellites (e.g. ATSR, AATSR, MODIS) will be made available for operational use, specifically for climate monitoring. Future geostationary satellites will have improved capability of observing sea surface temperatures and their diurnal variation.
- * LEO Imagers - Imagers on future polar satellites will enable trace motion wind determination in overlapping areas at high latitudes, similar to those from geostationary satellites.
- * LEO Imagers - On orbit channel selection for multi-disciplinary utilization is being demonstrated by ENVISAT's Medium Resolution Imaging Spectrometer (MERIS). The MERIS primary mission is ocean related (colour), however its flexibility allows for definition of spectral bands that can be used to retrieve information on clouds, vegetation, aerosols and total column water vapor.
- * LEO Ocean Colour - In the near and mid term future, ocean colour data from R&D satellites will be available for operational use. Even in the NPOESS era, continued access from R&D satellites will be complementary, especially in coastal zones.

Table linking observed parameters with a given system of the space based component of the GOS (If the space agencies implement their current plans and the recommendations listed above are acted upon, the space based component of the GOS would have the following characteristics)

System	Improved parameters	Instrumentation
GEOs upgraded	Temperature, humidity, ozone profiles, winds at tracer heights Atmospheric instability index, OLR	Frequent-sounding and imaging IR spectrometer
	Cloud pattern, cover, type, top temp and height, low stratus / fog sea-surface temp, land surface temp, fires, volcanic ash	Fast VIS/IR imager
LEOs upgraded (post-METOP)	Temp, humidity, & ozone profiles; total columns of key trace gases	IR/MW sounder
	Sea/land/ice surface temperatures, sea-ice cover, NDVI, fires, Aerosol size, Cloud pattern, cover, type, top height, cloud optical thickness, drop size, low stratus/fog, high lat winds at tracer heights	Improved VIS/NIR/IR imager
	Short- and long-wave outgoing radiation at TOA	Broadband imager
	Sea-surface wind and temp, sea-ice cover and surface temp snow cover, snow water equivalent, precipitation	MW radiometer with multi-polarisation/viewing
	Water and ice cloud properties, aerosol properties Ozone LAI, PAR, FPAR (large scale). Ocean colour	Imagers covering parts of UV, VIS, NIR, IR, FIR, & Sub-mm, with multi-polarisation
	Wave height, sea level, ocean topography, geoid	Altimeter
R&D GEO SubMM	Cloud water / ice, precipitation	Sub-mm radiometer
R&D LEO for ocean topography	Significant wave height, sea level, ocean topography, geoid. Polar ice thickness and sheet topography	Medium-class altimeter (follow-on Jason)
R&D LEO for wind Profiles	Wind profile in clear air. Aerosol profile (large scale), cloud top and base height	Doppler lidar (follow-on Aeolus)
R&D LEO for land & ocean ice	Wave spectra, ocean ice. Land snow & ice	SAR
R&D LEO for salinity & moisture	Ocean salinity (large scale). Soil moisture (large scale)	Low-frequency MW radiometer
R&D Constellation of mini-sats	UT/LS temperature profile, height of tropopause., LT moisture profile (with ground GPS)	Radio-occultation sounders

Vision of the Space-Based Component of the GOS in 2015

The space-based component of the GOS will provide observations crucial to maintaining and improving performance of systems in several application areas - in operational meteorology and in other aspects of WMO programmes. A few examples follow. It will provide multi-spectral images of cloud and water vapour at high spatial and temporal resolution for use in synoptic meteorology, nowcasting, hydrology, and aeronautical meteorology. It will also provide quantitative measurements of key atmospheric variables for assimilation into operational numerical weather prediction systems. Hyperspectral space borne measurements will expand the atmospheric chemistry applications. The space based component of the GOS must also provide long term stable global measurements of radiation for climate applications.

An analysis of user requirements in applications areas within WMO programmes indicates the need for an operational satellite constellation comprising four polar and six geostationary satellites. The geostationary component will provide visible/infra-red imagery of improved quality and also advanced infrared atmospheric sounding capability. The polar-orbiting component will provide many capabilities including advanced microwave and infrared atmospheric sounding, high-resolution multi-spectral visible/infrared imagery, microwave imagery, ultraviolet ozone sounding, GPS radio occultation sounding, and information from scatterometers, altimeters and microwave radiometers. These will provide quantitative information on many atmospheric and surface variables such as atmospheric profiles of temperature, humidity and ozone; surface temperature; clouds and precipitation; ice and snow cover; vegetation; and ocean surface wind and waves.

Beyond this, data from instruments on R&D satellites will make major new contributions to the GOS including:

- wind profiles from Doppler wind lidars;
- precipitation measurements from a constellation of active and passive microwave instruments;
- GPS radio occultation (RO) constellation;
- ocean colour;
- soil moisture;
- air quality.

Expansion of the space-based component of the GOS will require international collaboration. There will be efforts to facilitate contributions of single instruments to larger platforms. Replacement strategies of the current or near future GOS satellites by the next generation satellites will proceed with a phased implementation approach. The role of small satellites in the GOS will be expanded. Coordination of international contributions to the polar orbiting observing system to achieve optimal spacing for a balance of spectral, spatial, temporal and radiometric coverage will be a goal. Operational continuation of research capabilities with proven utility to the GOS will be occur as much as possible without interruption of the data flow.

There must be a commitment for adequate resources to sustain research developments necessary for improved utilization of these measurements. As much as possible, preparation for utilization of any new measurement will begin prior to launch with distribution of simulated data sets that test processing systems; this will increase the fraction of post-launch lifetime during which the data are used effectively in operational systems. (The current post-launch familiarization period of 6-24 months will be reduced). International development of data processing and assimilation methods and systems will assure best use of available talent and effort, and it will enhance uniformity in derived products.

The following table summarises the space-based component of GOS in 2015.

GOS (2015)

6 GEOs

- all with multispectral imager (IR/VIS)
- some with hyperspectral sounder (IR)

4 LEOs

- all with multispectral imager (MW/IR/VIS/UV)
- all with sounder (MW)
- three with hyperspectral sounder (IR)
- all with radio occultation (RO)
- two with altimeter
- two with conical scan MW or scatterometer

Plus:

- Constellation small satellites for radio occultation (RO)
 - R&D LEO with wind lidar
 - R&D LEO with active and passive microwave precipitation instruments
-

It is envisaged after 2015 that many of the imaging and sounding functions will be served by hyperspectral instruments from both LEO and GEO orbit. R&D developments in wind profiling and precipitation monitoring will also be operational. Remote sensing needs for coastal monitoring and boundary layer chemistry will be addressed by R&D missions. Data movement, processing and utilization will be a large challenge; exploration of Alternative Dissemination Methods will be necessary to seek new solutions. The opportunity for instruments in L1 orbit to serve as environmental sentinels will be explored.

Recommendations for Evolution of the Surface-Based Component of the GOS

The recommendations below take into account known upgrades to current satellite systems and entirely new space-based instrumentation to be deployed by 2015. Proposed changes in surface-based and in situ atmospheric and oceanic observing systems include greater utilization of existing systems and the development of a few relatively new systems - all designed to complement, and be fully consistent with, future satellite capabilities. The goal is to maximize the benefits of the composite observing system for a variety of operational weather services.

Ten years from now, two things are virtually certain: observations will increase markedly in volume, and they will be stored and transmitted almost entirely in binary formats. It is hazardous to guess what kind of surface and in situ atmospheric and oceanic observations will be available beyond ten years merely because new technologies may revolutionize how the atmosphere is measured. For example, ten years ago, few could anticipate the evolution of the AMDAR system or the exploitation of the Global Positioning System in meteorology. Therefore, the present strategy is to extrapolate into the future promising trends in observation technology.

The recommendations below address the Rolling Review of Requirements in a number of applications areas: Global NWP, Regional NWP, Nowcasting and very short-range forecasting, Synoptic meteorology, Ocean weather forecasting, Coastal Marine services, Aeronautical meteorology, Season and inter-annual prediction, and Atmospheric chemistry.

The relevant impact studies that support the recommendation are cited in brackets; often the Observing System Experiment is just listed by number (see Annex III for the list).

High-Priority General Recommendations

Data distribution and coding

1. Exchange internationally observational data not yet centrally collected but potentially useful in NWP, e.g., radar measurements to provide information on precipitation and wind, surface observations, including those from local or regional mesonets, wave buoys. Encourage WMO Members in regions where these data are collected to make them available via WMO real time information systems.
2. Data available at high temporal frequency should be distributed at least hourly. Recent studies have shown that 4D-Var data assimilation system or analysis system with frequent update cycles can make excellent use of hourly data, eg from SYNOPs, buoys, profilers, aircraft (AMDAR). [OSE-1]
3. Assure that all sources are accompanied by good documentation, careful QC, and monitoring.
4. Use coding standards that assure that the content (e.g vertical resolution) of the original measurements, sufficient to meet the user requirements, is retained during transmission. Some current coding/formatting standards in the character codes degrade potentially useful information in meteorological reports. (Example: lost information at various levels in a rawinsonde sounding in the TEMP code could be retained in the BUFR code.) [CBS decision to migrate to table driven and binary codes].

Broader use of ground based and in situ observations

5. Calibration of measurements from satellites depends on using ground-based and *in situ* observations, such as ozone profiles from sondes. Near real-time distribution of ozone sonde data is required for calibration and validation of newly launched instruments and for potential use in NWP. [Joint ECMWF / WMO expert team meeting on real time exchange of ground based ozone measurements, ECMWF, 17-18 October 1996]

Moving towards operational use of targeted observations

6. Transfer into operations the proven methodology of observation targeting to improve the observation coverage in data sensitive areas. This concept is in operational use at the US Weather Service in the north-eastern Pacific during the winter storm period. EUCOS is planning on field experiments in the Atlantic, possibly in the context of a THORPEX study. Designated major operational centres should share the responsibility for determining the target areas. [FASTEX results and Toulouse report]

High Priority System Specific Recommendations

Optimisation of rawinsonde launches

7. Optimise the distribution and the launch times of the rawinsonde sub-system (allowing flexible operation while preserving the GUAN network and taking into consideration regional climate requirements). Example: Avoid duplication of Automated Ship-borne Aerological Program (ASAP) soundings whenever ships are near a fixed rawinsonde site in order to free resources for observations at critical times. Example: Optimise rawinsonde launch to local time of day to meet the local forecasting requirements.[EUCOS Studies, OPAG IOS Chairman]

Development of the AMDAR programme

8. AMDAR technology should provide more ascent/descent profiles, with improved vertical resolution. A good way to accomplish this is to extend the AMDAR programme to short-haul commuter flights, business aviation, and air freight. Emphasis should be to expand into areas where vertical profile data from radiosondes and pilot balloons are sparse as well as into times that are currently not well observed such as 11 pm to 5 am local times. [Toulouse report, ECMWF northern hemisphere AMDAR impact study, OSEs 4, 5, 8]
9. AMDAR coverage is both possible and sorely needed in several currently data-sparse regions, especially Africa and South America, Canadian arctic, northern Asia and most of the world's oceans. Moreover, the timing and location of reports, whose number is potentially very large, can be optimised while controlling communications costs. The recommendation is to optimise the transmission of AMDAR reports taking into account, en route coverage in data-sparse regions, vertical resolution of ascent/descent reports, and targeting related to the weather situation. [Toulouse report, ECMWF northern hemisphere AMDAR impact study]
10. Lower-tropospheric water vapour measurements are vital in many forecast applications. To supplement the temperature and wind reports from AMDAR, the further development and testing of water vapour sensing systems is strongly encouraged. Example: WVSS-2 employs a laser diode to measure the absorption by water vapour of energy in the laser beam over a short path length. This is an absolute measurement of water vapour content that is expected to be accurate from the ground to flight altitudes. [Toulouse report]

Tropospheric Aircraft Meteorological Data Reporting (TAMDAR)

11. TAMDAR could potentially supplement AMDAR and radiosonde data by providing lower level en route observations and profiles over additional, regional airports not served by larger AMDAR compatible aircraft. Instrumentation would not necessarily be designed to function in the high troposphere and would therefore be less expensive. The development of the TAMDAR system should be monitored with a view towards operational use. [EUCOS Programme Plans]

Ground based GPS

12. Develop further the capability of ground-based GPS systems for the inference of vertically integrated moisture with an eye toward operational implementation. Distribute globally the measurements of total column water vapour from available and emerging ground based GPS systems for use in NWP. Such observations are currently made in Europe, North America and Japan. It is expected that the global coverage will expand over the coming years. [COSNA/SEG, NAOS, JMA reports]

Improved observations in ocean areas

13. Increase the availability of high vertical resolution temperature, humidity, and wind profiles over the oceans. Consider as options ASAP and dropsondes by designated aircraft. [EUCOS programme plan]
14. Considering the envisaged increase in spatial and temporal resolution of *in situ* marine observing platforms and the need for network management, either increase the bandwidth of existing telecommunication systems (in both directions) or establish new relevant satellite telecommunications facilities for timely collection and distribution. Examples include drifting buoys, profiling floats, XBTs. [JCOMM Operations Plan]
15. For both NWP (wind) and climate variability/climate change (sub-surface temperature profiles), it is recommended to extend the tropical mooring array into the tropical Indian

Ocean at resolution consistent with what is presently achieved in the tropical Pacific and Atlantic Oceans. . [JCOMM Operations Plan]

16. Ensure adequate coverage of wind and surface pressure observations from drifting buoys in the Southern Ocean in areas between 40S and the Antarctic circle based upon adequate mix of SVPB (surface pressure) and WOTAN technology (surface wind). The pressure observations are a valuable complement to the high density surface winds provided by satellite. [Toulouse report, ODRRGOS OSE study]
17. For Ocean Weather Forecasting purposes, improve timely delivery and distribute high vertical resolution data for sub-surface temperature/salinity profile data from XBTs and Argo floats. . [JCOMM Operations Plan]
18. For NWP purposes, increase coverage of ice buoys (500 km horizontal resolution recommended) to provide surface air pressure and surface wind data. . [JCOMM Operations Plan]

Improved observations over tropical land areas

19. Enhance the temperature, wind and if possible the humidity profile measurements (from radiosondes, pilots and aircraft) in the tropical belt, in particular over Africa and tropical America. There is evidence from recent impact studies with the radiosonde/pilot balloon network over the Indonesian/Australian region that such data give a better depiction of winds in the tropics and occasionally strongly influence the adjacent mid-latitude regions. [OSE-5]

New Observing Technologies

20. Demonstrate the feasibility of ground based interferometers and radiometers (e.g. microwave) to be an operational sub-system providing continuous vertical profiles of temperature and humidity in selected areas.
21. Demonstrate the feasibility of Unmanned Aeronautical Vehicles (UAVs) to be an operational sub-system.
22. Demonstrate the feasibility of high altitude balloons to be an operational sub-system

Vision of the Surface Based Component of the GOS in 2015

It is envisaged that by 2015 the technical advances will have led to substantial innovations in the surface based components of the global observing system. Measurements will be provided by automated systems, manual intervention and the role of humans in the observing chain will have been reduced to a minimum, and may not be required at all any more.

Automation will facilitate the targeting of data sensitive areas through an optimal operation of the upper air observing components, such as radiosondes, ASAP systems, data collection from aircraft in flight and vehicles on the road.

Radiosondes

Automated launches with computerized data processing and real-time data transmission at high vertical resolution. The network will have been optimized to provide the measurements for the calibration of satellite data and to provide the baseline observing system for ground based vertical atmospheric profiling.

Aircraft observations

Fully automated observing system providing temperature, wind and humidity measurements of high quality from the majority of the civilian aircrafts, both in-flight and ascent/descent data at high temporal resolution. Tropospheric profile data will be available from most aerodromes around the world, including from the currently data void airports in Asia, Africa and South America.

Surface observations

From land and ocean observing platforms all measurements will be provided by automated systems. It is expected that the land areas will be covered by a network of sensors at a high spatial resolution, supporting local applications such as road weather. Such data will be of benefit to global and local NWP applications alike. Over the oceans an adequate number of platforms (ship, buoys, moorings) will be available to complement the satellite measurements.

Radar observing systems

Multi-parameter scanning Doppler radars will enable hydrometeor identification and perhaps give information on their size distributions. This in turn will improve estimation of precipitation rate and accumulation. It will also assist in the initialization of cloud physics parameters for NWP. Assimilation of high resolution reflectivity and radial velocity data will have reached the point of resolving the basic mass and wind structures of convective storms. Millimeter-wavelength radars will be able to observe multiple cloud layers, including the altitude of their bases and tops.

Data transmission

The fully automated observing system will produce data volumes which will exceed today's volumes by several orders of magnitude. Data communication technology is expected to have developed accordingly. The technical means to provide the appropriate and affordable communication will have become available. All observational data will be transferred by digital means in a highly compressed form. Data processing will be computerized entirely.

In summary

The rapid development of information technology in all areas of life will continue to give opportunities for obtaining and communicating observations as a by-product of systems installed (and paid for) for other purposes. Currently AMDAR and GPS observations fall into this category and other examples will emerge and should be exploited in the future. It is likely that such observations will form an important part of a cost effective future global observing system.

Table linking observed parameters with a given system of the surface based component of the GOS (If the agencies pursue the recommended actions and encourage the indicated developments, the surface based component of the GOS would have the following characteristics)

System	Parameter	Action/Development
AMDAR	Vertical profiles of temperature and wind at airports	Increase coverage, increase vertical resolution Extend programme to short-haul, commuter and freight flights
	Flight level data	Study feasibility of adaptive use, demonstrate the need for high frequency data, in particular over Africa, South America
	Vertical profiles of humidity	Develop capability
TAMDAR	Vertical profiles of temperature and wind at regional airports	Develop the programme (currently undertaken by NASA), suitable for expansion to other regions, such as the arctic, Siberia, etc.
Radiosondes	Vertical profiles of temperature wind and humidity	Optimise horizontal spacing of raobs and vertical resolution of reports and operation of sub-system (launch times, adaptive operation) Increase the availability over the oceans (ASAP, dropsondes, etc.)
Ozone soundings	Vertical profile of ozone	Integrate into GOS
UAVs	Spatial coverage and vertical profile of wind, temperature and humidity	Demonstrate feasibility of an operational sub-system; target areas for operation are the ocean storm tracks (planned in THORPEX)
High-altitude balloons deploying sondes	Vertical profile of temp, wind and humidity	Demonstrate feasibility of an operational sub-system
Drifting buoys	Surface measurements of temp, wind and pressure, SST	Extend coverage especially in SH based on SVPB and WOTAN technology
Moored buoys	Surface wind, pressure, sub-surface temp profiles	Improve timely availability for NWP (monthly & seasonal forecasting) Extend coverage into Indian Ocean
	Wave height	Provide data
Ice buoys	Ice temp, air pressure, temp and wind	Increase coverage
VOS	Surface pressure, SST, wind	Maintain their availability to provide complementary mix of observations
Ships of opportunity (SOOP)	Sub-surface temperature profiles (XBT)	Improve timely delivery and distribute high vertical resolution data

Subsurface profiling floats Argo programme	Sub-surface temperature and salinity	Improve timely delivery and distribute high resolution data
Tide gauges (GLOSS)	Sea level observations	Establish timely delivery
SYNOP and METAR data	Surface observations of pressure, wind, temperature, clouds and 'weather'	Exchange globally for regional and global NWP at high temporal frequency (at least hourly), develop further automation
	Visibility	Ditto
	Precipitation	Ditto
	Snow cover and depth	Distribute daily
	Soil moisture	Distribute daily
Wind profiling radar	Vertical profile of wind	Distribute data
Scanning weather radar	Precipitation amount and intensity	Provide data, demonstrate use in hydrological applications (regional and global NWP)
	Radial winds, Velocity Azimuth Display (VAD)	Demonstrate use in regional NWP Ensure compatibility in calibration and data extraction methods
Ground Based GPS	Column Water Vapour	Demonstrate real-time capability
Ground Based Interferometers and other radiometers (e.g. MW)	Time continuous vertical profile of temp/humidity	Demonstrate capability

ANNEX VII

Actions

1. An ad hoc committee in the ET (J.Pailleux, N Sato, H Boettger, J Eyre, and T. Schlatter) begin to plan the next NWP OSE and Implications for GOS Workshop (Sep 02).

2. WMO secretariat contact PoCs or the appropriate Technical Commission for each application area and request them to coordinate review and revision of the SoGs from appropriate experts (Jul 02)

global NWP	J. Eyre
regional NWP	T. Schlatter
synoptic Met	E. Legrand
nowcasting and VSRF	TBD
atmospheric chem.	J. Gille
aeronautical Met	H. Puempel
SIA forecast	TBD
other climate	V. Vent-Schmidt / M. Manton
ocean	H. Kawamura
hydrology	TBD
agro Met	TBD

3. Secretariat provide to the Rapporteur on Regulatory Material the ET approved amendments to the draft Manual of the GOS in preparation for the forthcoming session of CBS. Recommend to OPAG IOS Chair that CBS be encouraged to maintain the Manual and Guide of the GOS as a dynamic document that is updated routinely (Jul 02)

4. Since the Manual for the GOS contains specific observations requirements for environmental emergency response activities but this is not an applications area currently being considered by the RRR process, the OPAG IOS chair is asked to query CBS whether the RRR process should be extended to include this area. (P. Menzel, Dec 02)

5. Suggest that OPAG DS Chair advise CBS that comprehensive strategies for anticipating and evaluating changes to the GOS need to be studied and a focused funded activity to study observing system design needs to emerge. (P. Menzel, Dec 02)

6. Update WMO/TD 1040 (by Sep 02) through CIMO input (D. Lockett) and broader community (P. Menzel) within an agreed structure. Structural points to be considered include:

- for each technology, use a standard structure that presents (a) what is measured and how, (b) performance: space and time resolution, accuracy, etc., (c) development status and future prospects, (d) costs, if known;
- present in a logical order (e.g. radiosondes before ASAPs);
- avoid technology names (and websites) which are too mission-specific, although these could be added as examples;
- avoid comments on user requirements (out of place here);
- avoid nation-specific points where possible;
- try to be reasonably comprehensive – check for consistency with technologies represented in the database;

- where possible, indicate an expert point of contact on each technology;
- update regularly.

7. Assure that capabilities of Aura and other new developments for making measurements useful to atmospheric chemistry are reflected in the Atmospheric Chemistry SoG (J. Gille; Sep 02).

8. Update Ocean user requirements and the associated SoG after discussion with ocean community (E. Charpentier, H. Kawamura, Sep 02).

9. Request review of CRs and associated SoGs in ocean application areas from selected experts (P. Menzel, Jul 02).

10. Climate representatives draft a short list of application areas within climate that could be addressed by the RRR process (M. Manton, V. Vent-Schmidt, Sep 02).

ANNEX VIII

Work plan for 2002-2003

1. Continue updating data bases of user requirements and observing system capabilities and include user reviewed R&D expected performances.
 2. Continue RRR for ten application areas and expand to new areas as advised by CBS.
 3. Update SoGs.
 4. Organize next Workshop on Impact of Various Observing Systems on NWP.
 5. Follow up on progress in 8 OSEs, especially those now possible with AIRS and 3 AMSUs.
 6. Pursue OSE opportunities offered by EUCOS and other special observing exercises. Use these to gain support for such exercises being an integral part for evaluating possible changes to the GOS.
 7. Continue update of Candidate Observing Systems Technical Document.
 8. Follow up on CBS approved recommendations for the evolution to the GOS (with particular attention to the developing countries).
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ANNEX IX

Summary of ET-ODRRGOS Accomplishments

1. Users Requirements and Observing System Capabilities were charted in ten application areas (after engaging ocean and climate communities), the Rolling Review of Requirements was pursued, and Statements of Guidance were issued in all ten areas (available in several WMO technical documents).
 2. Candidate Observing Systems (space based and ground based) for the coming decade were studied and a WMO Technical Document was published.
 3. Recommendations for evolution of space based and surface based components of GOS were drafted, reviewed, and submitted to CBS. An eleven page document summarizes the most pressing observational needs and recommendations for the most cost-effective actions for meeting them in the near term and 10-15 years from now.
 4. A vision for the GOS of 2015 and beyond was drafted.
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