WORLD METEOROLOGICAL ORGANIZATION

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

GENEVA, SWITZERLAND

29 NOVEMBER – 3 DECEMBER 1999

FINAL REPORT

GENERAL SUMMARY OF THE WORK OF THE SESSION

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

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

1.1.1. The second session of the CBS/OPAG/IOS Expert Team on Observational Data Requirements and Redesign of the Global Observing System (ET-ODRRGOS) was held in the WMO Headquarters from 29 November to 3 December 1999. The session was opened by the chairman of the Expert Team, Paul Menzel, at 10 a.m. on Monday 29 November 1999. The session was attended by 22 members of the Expert Team and representatives of other WMO technical commissions (CAS, CCl, JCOMM), regional associations (RA I, RA VI), and international programmes (GCOS, EUCOS). The full list of participants is given in Appendix I.

1.1.2. On behalf of the Secretary-General, the Deputy Secretary-General, Mr Michel Jarraud, welcomed the participants to Geneva and to the Secretariat. Mr Jarraud noted that the Global Observing System (GOS) had evolved gradually over the past four decades. Currently there is ample evidence of new observing technologies, including satellites, radars, aircraft, and automated systems at sea. These are all providing essential contributions to the World Weather Watch (WWW). However, Mr Jarraud indicated, there is also a slow but gradual erosion of the traditional surface and upper-air networks due to several factors. Recognizing the growing requirements of Numerical Weather Prediction (NWP) and other WMO programmes, Cg-XIII confirmed a need for a co-ordinated approach to achieve a fundamental redesign of the GOS. Mr Jarraud reminded the group that CBS established the ET-ODRRGOS in order to develop criteria for the redesign of the GOS; this would involve review and update of the observational data requirements for WMO and other international programmes as well as evaluation of the capabilities of existing and new observing systems to meet the stated requirements. The Expert Team should also study possible changes to the GOS and suggest mechanisms for testing them with Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSE). Mr Jarraud congratulated the Expert Team on its successful start in these endeavours at their first meeting in Madison, Wisconsin (June 1999); he encouraged them to continue in the same productive manner at this meeting.

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

The agenda shown in Appendix II was adopted.

1.3. Working arrangements *(Agenda item 1.3.)*

Working hours and a tentative timetable for the meeting were agreed upon. In addition it was decided that three small working groups would be formed to facilitate discussion of (a) the Statement of Guidance, (b) OSE/OSSE options, and (c) redesign of the GOS in developing countries. Their reports will be presented under appropriate agenda items.

2. **CHAIRMAN'S REPORT** *(Agenda item 2)*

2.1. The chairman of the Expert Team presented a short report summarizing the activities originated from the CBS Working Group on Satellites and the CEOS Upper Air Measurements Project leading up to formation of the Expert Team in January 1999. He also reminded the team of the progress made at the first meeting in Madison.

2.1.1. Under the auspices of the Integrated Global Observing Strategy (IGOS), CEOS created an Upper Air (UA) Measurements Project to investigate possible degradation in NWP caused by reduction of radiosonde observations and to explore mitigation with satellite data. Initial studies revealed that loss of radiosonde observations (RAOBS) would negatively impact numerical weather forecast models but this could be somewhat offset by utilizing satellite sounding data over land. The UA Project recommended to the Strategic Implementation Team (SIT) in October 1997 that the global weather prediction centres collaborate with satellite data providers to further develop approaches for inclusion of satellite observations over land. In 1998 the UA project worked with global modelers to enhance the use of satellite data over land and to assess satellite capabilities versus NWP user requirements. In January 1999, the SIT felt that the goal of working towards improved utilization of satellite observations had been advanced and the CBS/OPAG/IOS was the appropriate home for fostering further progress.

2.1.2. After the reorganization of the CBS working groups, activities from the CBS Working Groups on Satellites and Observations were placed under the OPAG for IOS and this Expert Team, the ET-ODRRGOS, was charged with continuing the Rolling Requirements Review (RRR), incorporating *in situ* along with space based observations, and considering options for redesign of the Global Observing System towards more comprehensive observations for the World Weather Watch and other WMO programmes.

2.1.3. In the Madison meeting, the Expert Team updated and documented observational data requirements of the World Weather Watch and assessed the capabilities of space-based and some *in situ* systems. It also reviewed the first Statement of Guidance generated by the Working Group on Satellites; these statements were confined to the space-based system capabilities for meeting user requirements. Review of three applications areas (global NWP, synoptic meteorology and nowcasting) found that no major changes were necessary in the statements of guidance related to these areas; review of three remaining application areas (hydrology, agricultural meteorology and atmospheric chemistry) was planned for later.

2.1.4. Upon inspecting *in situ* observing system capabilities, the Expert Team agreed that they appeared to be characterised by a regionalization and categorization process and that further development of parameters describing them should proceed. A sample data set for land surface observations of air pressure and another data set for aircraft ascent and descent profiles of temperature, humidity and winds were developed; a sample table including these *in situ* systems with the satellite systems for the above meteorological parameters was demonstrated to be of sufficient accuracy to be representative of the actual observing performances for the two systems. Finally, guardians for application requirements and user estimates of expected observing system performances were identified.

2.2. Since the Madison meeting, the chairman presented a summary of the Expert Team activities to the 27th meeting Co-ordinating Group for Meteorological Satellites (Beijing, China, October 1999). CGMS noted the importance of the combined evaluation of satellite and *in situ* systems, complimented Expert Team on its good start, and encouraged further efforts toward a Statement of Guidance including both systems.

2.3. In concluding his report, the chairman pointed out that during this meeting the Expert Team should focus on (a) reviewing the combined *in situ* and satellite observing system capabilities, (b) conducting a critical review in several application areas and drafting the associated statements of guidance, (c) investigating gaps and overlaps in existing and planned observing system capabilities, and (d) exploring options for improvements to the GOS.

3. DEVELOPMENT OF THE “CRITICAL REVIEW” *(Agenda item 3)*

3.1. The ET-ODRRGOS was informed by the Secretariat that the CEOS/WMO data base had been updated to reflect some minor changes in the user requirements in several applications areas and to incorporate land surface and radiosonde observing system capabilities.

3.1.1. The need for some minor changes to user requirements had been noted at the Madison review; this required adjustment but did not produce significant changes in the Critical Review for the six applications areas.

3.1.2. The expected performances for some of the *in situ* systems were estimated based on an analysis of the WMO list of observing stations contained in Volume A WMO Publication No.9 for 34 regions (see Appendix F); this included the horizontal resolution and observing cycles for SYNOP and RAOBS. Expected accuracies were obtained from the CIMO Guide. The parameters analyzed include surface wind vectors over land, surface air temperature, surface air humidity, cloud cover, cloud base height, and surface pressure for SYNOP and air temperature, specific humidity, and wind profiles for RAOBS.

3.1.3. To further the process of developing the in-situ component of the critical review, there was a need to obtain more information on the availability of observational data. There was also some concern that Volume A needed to be updated by WMO Members. A record of actual observational data statistics was required. It was recognized that a number of organizations already collected statistics on actual data received including ECMWF. Examination of ECMWF reports on data received suggested that the ET-ODRRGOS could use the ECMWF information to populate the *in situ* database. These data not only contained more accurate figures on upper air and synoptic stations, but also statistics on buoy, ship, and aircraft reports (including quality and timeliness of data).

3.1.4. The ET-ODRRGOS therefore recommended that the following action be pursued. ECMWF was asked to provide the *in situ* observing system statistics in electronic form regarding availability of measurements (pending approval by the ECMWF) to the ET-ODRRGOS in order to further populate the *in situ* database.

3.2. New Critical Review data sets (user requirements and observing capabilities of both space-based and *in situ* systems for some meteorological parameters in given applications areas) were distributed to the ET-ODRRGOS, and the first iteration of a Rolling Requirements Review was started for Nowcasting, Regional NWP, and Global NWP. This was undertaken by a working group that reviewed the observation requirements/capabilities and Statement of Guidance; the results of their efforts are described below.

3.2.1. The capabilities for a limited set of *in situ* observing systems were reviewed and some updates were provided (see Appendix C). It generated a Work Plan through which these capabilities would be reviewed by expert users and updated prior to the next meeting (see Appendix D). It also prepared a Work Plan to obtain assessments of capabilities for those *in situ* observing systems that were not currently in the database (see Appendix D).

3.2.2. During the review of observing capabilities, a number of questions were raised concerning User Requirements (UR) in the current database. These questions were recorded and referred to the UR providers.

3.2.3. A preliminary critical review, including *in situ* systems, was conducted for three application areas (Global and Regional NWP, and Nowcasting). This permitted the drafting of example “Statements of Guidance” for these areas (see Appendix B). A Work Plan to revise the SOG for these areas and to develop SOGs for other application areas was prepared (see Appendix D and Section 5).

3.2.4. The definitions of “maximum” and “minimum” requirements, as currently used in the Rolling Requirements Review process, were discussed. No material changes were made to these definitions, but explanatory notes were added to aid the correct interpretation of these definitions by UR providers and by readers of the SOG. The SOG was augmented to include a section discussing the relationship between URs (expressed in a technology-free, and therefore cost-free manner) and cost-benefit considerations that necessarily surround the implementation of all observing systems.

3.2.5. The meeting noted that Seasonal to Inter-Annual forecasting has observation requirements that go beyond those represented by Global NWP. While climatology was not included in the initial set of WMO Programme applications areas in the draft Statement of Guidance, Seasonal to Inter-Annual (SIA) forecasts, climate change detection and attribution, and climate impact assessments were all application areas highly dependent on the extent, scope and quality of observational data. ET-ODRRGOS agreed that the development of guidance on the adequacy of observational input, related to objective SIA forecasts could be included in its work as part of the critical review procedure. With respect to climate change detection and attribution, the meeting noted that the Report of the Adequacy of the Global Climate Observing Systems (GCOS-48) contains an appraisal of enhancements of the observational systems that were needed. Additionally a detailed requirement for data in support of research on climate processes already existed.

3.2.6. It was planned that the critical review of SIA will follow the assembly of requirements for observational data in support of Global NWP and ocean modelling, which provided the basis for objective SIA forecasts. It was noted that it was necessary to secure advice from centres producing SIA forecasts, on amendments or additions to these requirements for observations, related to optimization of the quality of NWP-based SIA forecasts. The following action resulted from this discussion. CBS in consultation with CCI and CAS should secure advice on amendments or additions to the user requirements in the application area of SIA forecasts. The aim was to create a preliminary set of user requirements that have been subjected to a preliminary expert review. It was noted that this action was compliant with a decision of a recent meeting on the infrastructure needed to support SIA forecasting.

3.2.7. The meeting noted that one of the main strengths of *in situ* profiling systems (e.g. radiosondes) was their high vertical resolution. However, much of the vertical information was lost in the process of generating encoded observations in a WMO format (i.e. TEMP) for transmission to users. NWP systems were becoming increasingly capable of using the information that was observed but not encoded. This prompted the following recommendation: the Chairman of OPAG/IOS should bring this problem to the attention of President CBS and seek to initiate CBS-wide action to address this problem.

4. REVIEW OF CANDIDATE OBSERVING SYSTEMS *(Agenda item 4)*

4.1 The meeting noted with interest the report prepared by a WMO consultant, on the development and implementation of a composite upper-air sub-system within the framework of an Integrated Global Observing Strategy. The report contained a brief description of current upper-air systems, potential candidates for improvement of global upper-air network, some guidelines for design of a composite upper-air observing system, and proposals for assessment of candidate observing system. The report did not go into detail, nor did it put the existing database on WMO programme requirements to use. However, ET-ODRRGOS felt that this paper presented an independent review of approaches for evaluation and redesign of the GOS; the paper supported the approach undertaken by ET-ODRRGOS.

4.2. ET-ODRRGOS recalled that at its first session in Madison, it decided to update the review of Candidate Observing System Technologies and their Use. It produced an action to make an appropriate update by the time of the next meeting (June 2000).

4.3. The meeting was briefed on new observing system, the Global Air-ocean IN-situ System (GAINS), now in early development stages at the NOAA Forecast Systems Laboratory. This observing system will be an aid in monitoring and predicting conditions in the earth's atmosphere (including air chemistry) as well as near the ocean (on and just beneath the surface). Further information was available at http://www-frd.fsl.noaa.gov/mab/sdb/

4.3.1. GAINS will consist of 100 to 400 long-lived, super-pressure balloons floating in the lower stratosphere between 60,000 and 75,000 feet. Each balloon will carry a payload of compact, lightweight sounding devices that can be released on a regular schedule or by command from a control center. It was envisioned that roughly 500 meteorological sondes, 200 air chemistry sondes, and 100 ocean sondes would comprise the payload. Most of the development so far has concentrated on the carrier balloon, whose altitude can be controlled. At the base of the balloon were solar panels that charge batteries for operating the pump and providing power for communications and an instrument package. Housed within a small, insulated enclosure was a GPS receiver, a microcomputer, line-of-sight and over-the-horizon communications, an aircraft transponder, and sensors that measure internal temperature and pressure. Pressure, temperature, and relative humidity are also measured externally. Also at the base of the balloon were pods that carry deployable sondes. As they fell, the sondes communicated with the carrier balloon. Data collected by the balloon were relayed to a low-earth-orbit satellite that sent the information to a control center on the ground. Finally, the control center archived the information but also forwarded it to numerical weather prediction centers for processing.

4.3.2. Because the lower stratosphere was generally a sheared environment, the ability to change balloon altitude was equivalent to exerting control over its movement. Experiments with the "Reanalysis" dataset from the National Centers for Environmental Prediction indicated that it would not be difficult to keep the balloon close to a particular latitude circle equator-ward of 20 degrees. At higher latitudes, significant excursions away from the target latitude circle could be expected, but further control over the balloon's movement may be possible with a "sail" hanging below the balloon on a long tether.

4.3.3. Though many engineering decisions lie ahead for this observing system, particularly with regard to the choice of sondes, no insurmountable technical barriers have yet been encountered. The objectives for 2000 were to demonstrate 48-h flight capability for an 18-m balloon (37 m will be full size with a payload of 350 kg), assess the degree of vertical control, verify the accuracy of trajectory forecasts in the lower stratosphere, and work out strategies for a multiple balloon network and for launching and recovering the balloons.

5. STATEMENT OF GUIDANCE ON FEASIBILITY OF MEETING REQUIREMENTS BY SATELLITE AND *IN SITU* SYSTEMS

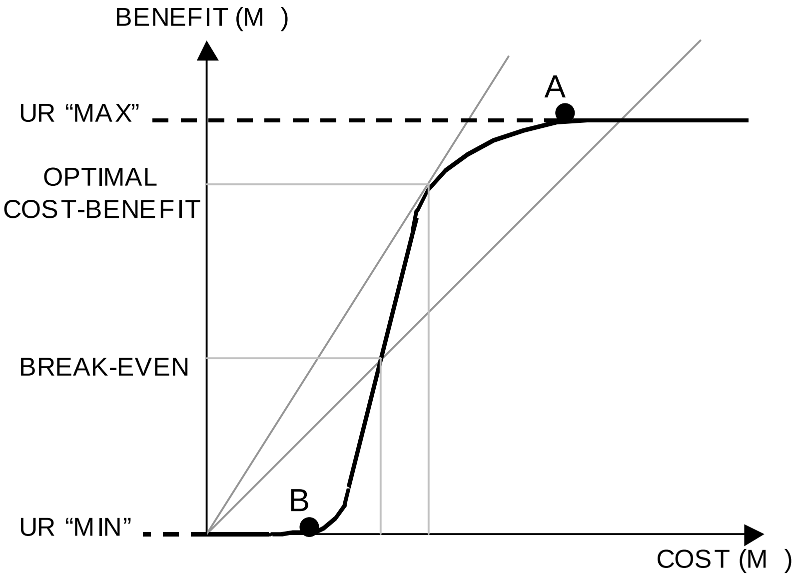
(Agenda item 5)

5.1. Further progress on the Rolling Requirements Review was made by the ET–ODRRGOS for some WMO applications. The review at this meeting utilized the

September 1999 version of the CEOS/WMO data base describing space based satellite capabilities and user requirements. The objective critical review had produced evaluation charts. ET-ODRRGOS provided subjective interpretation of these charts to generate statements of guidance in these applications areas. A second Statement of Guidance for satellite capabilities (without consideration of *in situ* systems) would be issued that reflected these interpretations and included the evaluation charts. This is planned to be the last SOG for satellite only; the next version will include guidance on *in situ* and other ground-based systems. The plan for the structure of new version was prepared and discussed.

5.2. A paper on the relationship between WMO user requirements for observations and cost-effective observing systems was presented. This paper included a cost benefit curve that illustrated the notions that (a) significant cost must be incurred before any significant benefit is derived, (b) the equal cost – benefit slope should be exceeded for cost effective systems, (c) optimum cost – benefit occurred before maximum requirements would be met, and (d) considerable cost could be incurred in moving from optimum – cost benefit to meeting maximum user requirements. ET-ODRRGOS felt that a valuable point was raised; systems should be focussed on achieving optimum and not maximum benefit such that a level representing diminishing returns at the high end of the benefit curve could be avoided (see Fig. 1). It was agreed that portions of this paper would be included in the next Statements of Guidance to assist with their interpretation.

Figure 1. Cost-benefit curve for an observing system.



6. REVIEW OF CURRENT STATUS OF THE GLOBAL OBSERVING SYSTEM *(Agenda item 6)*

6.1. The chairman of the Implementation Co-ordination Team (ICT) on the GOS informed the meeting regarding the operational status of the main parts of the surface-based component of the GOS. Both the networks themselves and the operation of the networks showed weak spots. The implementation of the fixed-station surface networks, including the RBSNs is insufficient in many areas of the Regions I and III, and in some areas in other Regions. In particular, the observing programmes in the Regions I and III were often incomplete. The annual trend in received surface observations, however, was +4% in all Regions. This trend was caused both by an increase of the number of stations and an improvement of the performance per station (+2% each). However, the upper air networks showed relatively larger gaps, and the trends were negative. The annual trend in received upper wind observations was -3%, for radiosondes -1%. The main causes for this decrease seemed to be the ongoing problems in CIS countries, and (in particular for upper wind observations) the cessation of the OMEGA-system in September 1997. The quality of the upper air observations continued to improve, in particular, the data from wind profilers seemed to have improved considerably.

6.2. The meeting also noted the following comments regarding performance of other systems contributing to the GOS.

- The voluntary observing ships were a good basis for surface observations in ocean areas, but limited to the main shipping routes. For the Southern Hemisphere, south of 30 degrees S, it was insufficient. A threat for the system was the problem of sharing the high costs of communication.

- Drifting buoys may form a good contribution in areas where shipping provided not enough data. A drawback was in the limitation of the number of parameters measured.

- Aircraft reports have increased strongly in recent years, and also the quality was now high. The increasing availability of vertical profiles was a very promising feature of this data source. A limitation was the sparse coverage in large parts of the Southern Hemisphere.

- Radiosonde observations from ships form a valuable contribution to the upper air observing system in some areas of the world (especially the North Atlantic and the West Pacific).

6.3. The Technical Coordinator of Data Buoy Cooperation Panel (DBCP)/Ships of Opportunity Programme (SOOP), gave a presentation on activities carried out in ocean areas. ET-ODRRGOS was informed that in August 1999, there were over 800 drifters with various types of sensors (SST, pressure, salinity, etc.). According to ECMWF statistics, the number of reports daily providing a substantial contribution to the surface observational data over the oceans available on the GTS was over 1700. The meeting expressed its concern at the fact that in the near future, a large amount of pressure data from drifters will be lost due to inadequate funding for deployment of atmospheric pressure sensors at drifters. ET-ODRRGOS supported several actions to avoid loss of these data (see Action 5). The meeting also noted the growing activities of Ships of Opportunity Programme (SOOP). It felt that it would be highly desirable if a representative of the newly established joint WMO/IOC Commission for Oceanography and Marine Meteorology (JCOMM) continue to participate in the work of the Expert Team as an invited expert to make appropriate proposals towards the redesign of the marine part of the GOS.

7. REVIEW OF COMPOSITE OBSERVING SYSTEMS THAT ARE BEING DESIGNED UNDER THE G3OS *(Agenda item 7*)

7.1. The meeting was informed by the Secretariat on the status of implementation of the GCOS Upper-Air Network (GUAN). It noted that ECMWF, at the request of CBS, continued to monitor the availability and quality of upper-air data from GUAN stations. The meeting noted with concern that, including the 9 % of stations that provided low quality observations, about 20 % of the GUAN stations did not provide appropriate upper-air data for climatological purposes.

7.2. ET-ODRRGOS recognized that major reason for insufficient availability of data was the lack of consumables; the high cost of radiosondes and general economic constraints experienced by many countries was limiting the number of sondes available for launch. It noted that the recent session Conference of Parties (COP5) was informed on the existing situation and made a recommendation towards achieving and maintaining an appropriate level of GUAN operational stations.

7.3. The meeting was also informed on the establishment of the GCOS Surface Network (GSN), consisting of 989 stations at present. Two climate centres, Offenbach (Germany) and Tokyo (Japan), would monitor GSN operations starting 1 January 2000. ET-ODRRGOS reiterated that GSN and GUAN sites should remain unchanged in the process of redesign of land surface and balloon-borne upper air networks.

7.4. The Expert Team was informed of requirements for an expanding range of observational data in support of WMO supported programmes and international conventions including the UNFCCC and the World Climate Programme (WCP) with its element on Research and Systematic Observation comprising GCOS and WCRP. The shortcomings of existing networks, in meeting present needs, were documented in the Report on the Adequacy of the Global Climate Observing Systems (GCOS-48) and had been the focus of the UNFCCC reporting guidelines adopted at the 5th session of the Conference of the Parties. Other shortcomings were noted at meetings of the CCl/CLIVAR Joint Working Group on Climate Change Detection. Deficiencies in measurement and data exchange were causing serious problems to some areas of climate research. The problems could be generally categorized as follows: a near or complete lack of measurement of some variables at climate reference sites (e.g. troposphere ozone, aerosols and air-sea transfer processes); the lack of mechanisms for transition of observing programmes from the research to the operational domain; the operational acquisition of data gathered by other agencies and organizations, including non-governmental institutions (e.g. glaciology, permafrost); and the application of adequate data management and quality procedures at source in order the make data suitable for climate application (e.g. the Karl principles as extracted from COP.5 document FCCC/CP/1999/L.4/Add.1, see Appendix E). For satellite measurements a list of significant problems which required special processing for their use for climate change research could be found in GCOS-48.

7.5. The Expert Team noted that the concept behind the GOS was an integrated global system to meet the needs of all WMO Programmes and that Congress had urged WMO Members to build on existing infrastructure in addressing their developing needs. The Expert Team recommended that CBS according to its terms of reference gives more emphasis to (i) enhancing observing capabilities and networks to meet growing needs of the WCP and UNFCCC/GCOS/WCRP; (ii) advising on transitional mechanisms including planning activities necessary to secure and convert a research programme of observations for operational management and use; (iii) acquiring observational data useful for climatological purposes from non-NMHS and non-governmental sources; and (iv) promoting operational data management procedures necessary to create homogeneous climate records.

8. REPORTS ON IMPACT ASSESSMENTS CONDUCTED BY NWP CENTRES UNDER COSNA, EUCOS, and NAOS *(Agenda item 8)*

8.1. The chairman of the Scientific Evaluation Group of Coordinating Group for Cosna presented the results of observing system studies carried out for the Composite Observing System for the North Atlantic (COSNA). ET-ODRRGOS was informed that all NWP centres participating in the Ninth session of the SEG presented results from new observing system impact studies that could be summarized as follows:

(i) radiosonde data

- impact studies undertaken by Deutscher Wetterdienst re-iterated the value of radiosonde observations over Canada for NWP;
- a HIRLAM study demonstrated the value of a single radiosonde station (Valentia, Ireland) but it was also noted that it should not be over-interpreted since the denial of a single radiosonde will on average not have any noticeable trace;
- the value of dropsondes and observation targeting was demonstrated for special observing periods over the Pacific, dropsondes were seen as a valuable complement of the in-situ observing system also over the North Atlantic;

(ii) hourly surface observations

- the global exchange of hourly SYNOP data was considered to be increasingly important for NWP. 4-dimensional data assimilation systems (4D-Var) could make optimal use of such data;

(iii) satellite data

- scatterometer data have a noticeable positive impact on depicting and forecasting the positions and intensities of tropical cyclones;

- precipitation estimates based on satellite data (i.e. SSM/I and others) have a positive impact on model spin-up in the Tropics (reported by NCEP and ECMWF);

- the provision of quality control flags with the geostationary satellite data was generally supported and was seen as a beneficial input for the use of such data in NWP;

- centres which carried out such studies <u>all</u> found positive impact from the use of ATOVS radiance data.

(iv) observation targeting

- based on the results from special observing periods in the Atlantic (FASTEX) and Pacific (NORPEX), the use of targeted observations was seen as a valuable complement to the routine observing system. Targeting may be based on the near-realtime analysis of the atmospheric sensitivity pattern and would typically involve the deployment of aircraft in designated geographical regions to collect additional observations from on-board sensors and dropsondes.

8.1.1. The meeting learnt that in the near future, COSNA impact studies would be carried out in conjunction with the studies related to the EUCOS/SOP which took place 20 September to 14 November 1999 (see section 8.3). Several NWP centres plan to evaluate separately the impact of the additional aircraft data which became available over Europe and the Atlantic during the second half of 1999, in particular during the EUCOS/SOP. A special study to evaluate the sensitivity of NWP to observational data to the west of France and the Iberian Peninsula was planned by the UK Meteorological Office. All centres participating in the SEG plan to carry out OSEs and OSSEs with present and future satellite data. A comprehensive list of planned impact studies was given in the Final Report of the Ninth Session of the SEG, 10-11 June 1999, which was available on the WMO server.

8.2. The meeting noted that the second CGC/WMO Workshop on the Impact of Various Observing Systems on NWP would be held in Toulouse, France, 6-8 March 2000. Invited speakers drawn from the SEG membership and other major NWP centres would present results from their recent work which would cover both regional and global aspects of the observing system. There were also plans to invite the participation of observing network managers and system operators. The meeting felt that a representative of the Expert Team should be invited to participate in the Workshop and requested the Secretariat to take appropriate actions (see Action 11).

8.3. The status of the EUCOS programme initiated by EUMETNET was presented. EUCOS is the European initiative similar to NAOS in North America. The objective was to establish a co-operative mechanism for defining, implementing and operating the ground segment of the GOS under the responsibility of EUMETNET Members. The initial task of EUCOS was the definition of the best cost efficient composite system for the measurement of atmospheric profiles. Two scenarios were being tested; the first was the replacement of radiosonde stations by AMDAR units in ascent and descent phase, and the second was the extension of the system over areas surrounding Europe and identified as sensitive for NWP on European territories. Therefore the core of EUCOS was an OSE, starting with a special observation period (20 September 1999 to 14 November 1999) with preparation of an impact study to be performed by ECMWF.

8.3.1. It was reported that the recent observation period had been a success; additional radiosondes were launched and new AMDAR data were collected. The number of AMDAR messages was increased fourfold over Europe during the period and some profiles were generated over near eastern and northern Africa. The impact study has just started and a report on the results will be arranged for the next meeting of the ET-ODRRGOS.

8.4. Recent progress in the North American Atmospheric Observing System (NAOS) programme was summarized. The organization and purpose of NAOS and the hypotheses approved for testing by the NAOS Council were described. Six of these hypotheses invoke Observing System Experiments (OSE) that deny or insert data from existing systems; they were (1) RAOB reduction near sites of ACARS data would have no impact on forecasts, (2) GOES radiances / winds would improve 0-4 day forecasts, (3) targeted observations in sensitive areas (e.g. eastern Pacific Ocean) would help forecasts, (4) targeted observations in tropical cyclones would help, (5) loss of profiler data would degrade forecasts, (6) Doppler radar wind and reflective data would improve 0-2 day forecasts. The remaining hypotheses involved Observing System Simulation Experiments (OSSEs) for future satellite instruments; they included (1) an advanced radiometer or interferometer, (2) wind-finding Doppler lidar, and (3) GPS occultation.

8.4.1. Wintertime tests of Hypothesis 1 have been completed; this hypothesis stated that, for purposes of numerical weather prediction, a limited number of U.S. rawinsondes could be replaced by automated aircraft soundings at nearby airports without noticeable degradation in forecast accuracy. Fourteen U.S. rawinsondes sites were matched with nearby busy airports having the same climatology and at least 20 aircraft soundings per week. Three NWP models, all operational at NCEP, were used to test the hypothesis during January and February 1998: the global spectral model (tested for 45 days), the Eta model (tested for 30 days), and the Rapid Update Cycle model (tested for 11 days). Three experiments were performed. In the Control Run, each model assimilated the full operational complement of observations. In Experiment 1, data from the 14 rawinsonde sites were withheld; in Experiment 2, the same rawinsonde data plus the nearby aircraft soundings (up to 30,000 feet) were withheld. All forecasts were verified against rawinsonde data over North America. For the global and Eta models, there was no degradation in forecasts when data from the 14 rawinsonde sites were withheld and aircraft data were retained. About as many forecasts were improved as were degraded, but always by very small amounts. When both rawinsonde and aircraft data were withheld at the 14 sites, there was a slight trend toward degradation judged to be operationally insignificant. For the Rapid Update Cycle, in a large majority of forecasts, there was measurable degradation when the rawinsonde data were withheld and a further small degradation when the aircraft data were also withheld. The effect was most noticeable at 12 h and decreased at later times (out to 36 h). These findings are preliminary, as more work is planned; a full report of results for all models will be published early in 2000.

8.4.2. It was recognized that NWP tests alone were insufficient for recommending changes in observing systems because observations have uses beyond NWP, most notably for nowcasting and climate monitoring. In the case of Hypothesis 1, forecasters considered the moisture soundings provided by rawinsondes as vital to nowcasting and short term forecasting, and climatologists consider long-term rawinsonde records indispensable for detection of climate change.

8.5. A summary of another OSE conducted at the University of Wisconsin was also presented. Using a workstation version of the Eta Data Assimilation/Forecast System (EDAS), several satellite data types (moisture from from SSM/I, soundings from GOES and TOVS, and winds from GOES and GMS) were individually denied to assess impact on the 00-hr analysis and 24-hr forecast over North America. The case studies included 11-day periods during December 1998, April 1999 and July 1999. Results showed that a modest positive forecast impact could be achieved from all five data types during all three seasons. The cloud motion wind information had the largest positive forecast impact during the winter season, while the precipitable water information had the largest positive forecast impact during the summer and transition seasons. Comparison with the impact from conventional rawinsonde and aircraft observations during the summer season revealed that the satellite data provided as much or slightly more positive forecast impact at 24-hrs.

8.6. Finally, there was a presentation on an OSSE (Observing System Simulation Experiment) regarding the utility of geostationary high spectral resolution measurements. Value of various measurements could be assessed from information content theory. There had been an indication of significant information content in radiance measurements from a geostationary interferometer (GEO-I); investigations suggested that geostationary high spectral resolution soundings were close to providing radiosonde-like information in moist atmospheres available for temperature and moisture profiling every hour every 50 km in clear skies. It was pointed out that an OSSE was the combined measure of the information content of a component of the observing system and the model skill in utilizing that information in assimilation and forecast; if there was no impact it could be either lack of new information or under-developed skill in the model for assimilating new information. Using the Rapid Update Cycle as the vehicle for this OSSE, it was determined that geostationary radiometer sounders (GEO-R) provide moisture information at and above 700 hPa beyond that available from radiosondes, aircraft reports, and profilers, but not below. On the other hand, a geostationary interferometer (GEO-I) could provide twice as much temperature and moisture information as the GEO-R and GEO-I could resolve boundary layer moisture (below 700 hPa) in clear skies. Polar orbiting high spectral resolution IR sounders did not equal GEO-I for moisture performance; hourly high spectral observations were found to make obvious improvements to regional model performance.

9. CONSIDERATION OF PROPOSALS FOR OSES AND OSSES *(Agenda item 9)*

9.1. Several papers were presented concerning OSE and OSSE concepts, feasibility, and mechanisms for testing. These were discussed in depth in the working group on OSE/OSSE and their discussions and conclusions are given below.

9.1.1. The candidates for redesign scenarios of the GOS were summarized at the first meeting of the ET-ODRRGOS. This included some thoughts concerning their status in relation to the redesign of the GOS and on possible scenario testing methods.

9.1.2. A prioritised list of proposals that were both practicable and amenable to testing were suggested as well as mechanisms for testing them. The proposals are meant to follow from a review of observational requirements, GOS performance, emerging observational technologies, and regional observing system studies. This review continued at this meeting, so it is expected that the proposals will evolve.

9.1.3. OSEs/OSSEs are intended to produce a quantitative measure of the (potential) impact of observing systems; they are important part of evaluation and design process. They need to be carefully designed and executed if their results are to be dependable. The group endorsed several comments and guidelines that are presented in Appendix A.

9.1.4. The Expert Team saw the need for those involved in impact experiments to meet regularly, to promulgate the guidelines in Appendix A, and to review and summarise results. This has been happening at informal CGC/WMO workshops on impact studies, the next of which will be in Toulouse 6-8 March 2000. The Expert Team will send a representative to the Toulouse meeting to communicate the scenarios for testing listed in this document and to note progress in impact testing. ET-ODRRGOS will request the forthcoming WMO/CGC Workshop on Impact Studies in Toulouse to (a) review and revise as necessary the guidelines in Appendix A for conducting OSE & OSSE, and to consider how they can best be promulgated, and (b) consider mechanisms for the continuing peer review through a continuing series of meetings like the Toulouse meeting (under appropriate sponsorship) and exchange of results via prompt publication of all experimental results, perhaps in the annual WGNE publication of recent results in numerical experimentation.

9.1.5. It was further noted that observation impact experiments are most effective when they directly affect an actual design decision. The best way to make this happen would be to involve the agency implementing the observing system in the design of the experiment. They could help both in the specification of the scenarios to be tested, and in making the impact assessment measures appropriate for the goals of those funding the observations. The activities of regional groups such as NAOS and EUCOS were good examples of impact studies closely linked to "customers", i.e. those actually funding and implementing observing systems. While funding would remain at a national or regional level, it would be therefore natural that observing system design will take place at this level, and that the global observing system will be the union of these regional systems. OSSEs for future satellite systems are another example of impact experiments where it is possible and desirable to have strong links to those funding or implementing the system. Because of the size of investment decisions for satellite systems, proper impact assessments would be essential. Noting the difficulty of performing realistic OSSEs, it is essential that such experiments are open to careful review by the wider community.

9.1.6. Guided by the changes already being considered by NAOS, and EUCOS, it seemed that the most likely next major change to the global observing system could be the extension of AMDAR reports to all areas with regular airline services. The WMO AMDAR panel is already planning AMDAR demonstration projects in various parts of the world, to demonstrate their impact. Thus it was recommended that (a) the WMO AMDAR panel and CBS, should be encouraged to advertise such AMDAR experiments to the major NWP centres well in advance, so that suitable impact experiments can be organised and (b) the WMO AMDAR panel should be invited to send a representative to the next ET-ODRRGOS meeting to report on progress.

9.1.7. The meeting was informed of the possible cessation of funding for surface pressure observations from drifting buoys in the Southern Hemisphere. Old impact experiments indicated a large impact from these data, so this is a cause for concern. It was suggested that global NWP centres should be asked, as a matter of some urgency, to perform experiments to measure the impact of losing these data in their current systems, and make the results available to possible funders of pressure instruments on these drifting buoys. The WMO/IOC DBCP should be asked to collect and collate the results of these efforts.

9.1.8. At present, NWP centers continue to rely on the radiosonde network; several studies have demonstrated significant degradation in forecasts when they were removed. However, driven by rising running costs, various developments are underway which might change this (for instance AMDAR with humidity sensors, ground based profilers, targeted observations, and improved satellite observations). It is conceivable that, within a decade or so, the radiosonde observing system will receive more emphasis from the climate community. For this reason, ET-ODRRGOS agreed that the GUAN and GSN sites should be preserved in the redesign process (see section 7.4). Just as OSEs are used to validate the stated requirements for NWP, it would be useful to have quantitative validation of these climate requirements. The network redesign projects have a need for quantitative statements on whether the GUAN network is necessary and sufficient for needs such as climate. Thus it was suggested that the CLIVAR working group should be encouraged to organise OSSE type studies, using existing climate change experiments with coupled ocean-atmosphere climate models, in order to see which observations (in particular the GUAN) are important for detecting the "fingerprint" of climate change.

9.1.9. In addition to the "customer" focused impact experiments discussed above, there is an ongoing need for generic impact experiments. Both should be used to check that the impacts of observing systems are in line with those expected from the statement of guidance from the RRR.

9.1.10. The group noted with interest the research activity in targeted observations, and expects such techniques to have an impact on the design of future observing systems. However at this stage it was premature for this group to make any recommendations in this area.

9.1.11. Finally, the group suggested that the following mechanism to be used to get an involvement of advanced NWP centres in the process of the redesign of the GOS by performing proposed OSEs: (a) Chair of OPAG on IOS should submit proposals for OSEs to the forthcoming session of CBS; (b) CBS should invite advanced NWP centres to perform the proposed impact studies;

9.2. While most of the attention on OSEs has centered around data sets available over the European and North American continents, it was noted that China has collected a data set of four daily radiosonde observations for a limited area and period of time. 21 sites evenly distributed cover the Huaihe River Basin (latitude 28 to 40 N, longitude 110 to 122E) during 42 days of the summer 1998 (10 June to July 22). It was noted that the data set (pending approval by China) could be used to test various hypotheses, including some regarding impact of frequency versus density of sonde launches on regional NWP. ET-ODRRGOS expressed interest in these data sets and requested clarification of the data set availability.

10. REDESIGNING THE GOS IN DEVELOPING COUNTRIES (*Agenda item 10*)

10.1. It was noted that redesign of the GOS included several issues that involve developing countries. In some areas, the current GOS system simply does not exist, whereas in other areas it could be improved. When looking at candidate observing systems, consideration must be given not only to NWP but also to human forecasting. These issues were discussed in a working group focussed on redesigning the GOS in developing countries; their deliberations are summarized below.

10.2. Issues that need to be addressed fall under three categories: (a) lack of public infrastructure such as electricity, telecommunication, transport facilities, etc., (b) lack of expertise from people to do the job, training, etc., and (c) funding for equipment, consumables, spare parts, manpower, etc. The lack of infrastructure and expertise may be the result of a lack of funding. This is resulting in deficiencies mainly in certain parts of Regions I, II, and III in particular in tropical areas (between 25N and 25S).

10.3. It was noted that the quality of RAOBS from blocks 42 and 43 in Region II remained a problem. Past efforts to improve their quality have not produced results. It was noted that another approach is being explored and the Secretariat will report on these endeavors.

10.4. In some areas observations have been taken but not disseminated. Attention must therefore be given to improve the current telecommunication facilities in those countries. In addition, in several countries, it is very difficult to get the data from the observing site to the NMS, whereas the communication from there to other centres is less problematic. Sometimes, the data at night were not distributed because it used HF transmission and this did not work at night.

10.5. The redesign may result in upgrading, restoring, substitution and capacity building. Two aspects need to be considered: the use of the data and the production of the data. It is possible that some countries do not and will not be able to produce data and will therefore only be users of data. To help developing countries produce data for international exchange, due consideration must be given to the three issues previously identified i.e. public infrastructure, expertise and funding.

10.6. Possible approaches towards the redesign were discussed. A first step should be to identify observing systems that were less dependent on infrastructure, expertise, and funding. These are satellite and AMDAR. However a minimum set of reliable RAOBs would be required to validate the satellite observations with enough height and accuracy. Where possible these should be located in the vicinity of or in capital city to ensure public infrastructure, and minimize costs. It should be noted that with this approach, some developing countries become users of the data not producers of data.

10.7. It was indicated that there are some disadvantages in organizing new systems outside the scope of National Meteorological Services as it did not stimulate their involvement/contribution and does not stimulate improving the synoptic observing system. It is recommended to find a solution where NMSs are involved and active. It was suggested that sub-regional meteorological arrangements for basic systems needed to be put in place. They would have to work together to find a source of funding and determine priorities for how the funding would be spent.

10.8. There is a need to have a backbone network of RAOBs. However, replacing RAOBs by AMDAR in some places is worth testing. It must be recognised that AMDAR ascent/descent and enroute data will provide little stratospheric information and no humidity data (for the time being).

10.9. It was felt that capacity building in some countries needed further attention. Some countries have satellite receiving stations or receive satellite data through the GTS, but lack the expertise to utilise the information to their benefit. Some countries are acquiring Doppler radar but need training on how to retrieve the information.

10.10. It was noted that good networks were needed to assess rainfall. This requires a much denser network than temperature, the latter being more homogeneous. Also, the weather in Africa is sensitive to position of convergence belt, hence upper air wind.

10.11. A possible funding approach, would be to have an international foundation to which interested participating members including (commercial organizations (aviation, oil/gas/electricity companies, transport companies, insurance companies, vendors of meteorological systems, media) would contribute funding to maintain the core global network. The resources should be distributed in a way that it creates incentives for NMSs to operate and maintain the systems under their responsibility.

10.12. If funding was available, the highest priority should go to (a) maintaining the RBSN, noting that GUAN stations are part of the RBSN, and (b) to rehabilitate observing sites using even distribution.

10.13. Finally, the ET-ODRRGOS suggested that the following recommendations should be taken into account when addressing the issue on redesign of the GOS in developing countries:

- Define geographical areas using advanced technique to help identify where priority should be if additional funding was available;
- Define trial field experiments over data sparse areas, for a limited time, to evaluate how additional data would contribute to improve performance at the regional and global scale. A clearly demonstrated impact might make it easier to agree on some coordinated funding mechanism for areas concerned including funding from GEF (Global Environmental Facilities) for climate stations;
- Encourage neighboring countries to establish sub-regional meteorological arrangements to operate station jointly;
- Examine whether automated stations could become a viable, cost effective alternative to manned stations for the surface network in the future;
- In data-sparse areas of the world, it may be more cost-effective to make full use of aircraft ascent/descent data instead of establishing RAOBs stations (e.g. South America, parts of Africa);
- When changes are made to the climate observing systems, the Karl principles should be followed;
- The telecommunication problem should be referred to the OPAG on ISS and looked at as a priority;
- Prioritise where the needs are most pressing for VCP or other funding.

10.14. ET-ODRRGOS encouraged the chairman of the ICT for IOS to present these recommendations for consideration at their upcoming meeting in March 2000.

11. FUTURE WORK PROGRAMME *(Agenda item 11*)

This is outlined in the Work Plan in APPENDIX D and in the Actions resulting from the meeting (Appendix III). The ET-ODRRGOS tentatively agreed to meet in Europe the week of 19 June 2000.

12. CLOSURE *(Agenda item 12*)

The chairman of the ET-ODRRGOS thanked the participants of the meeting for their excellent cooperation and contributions. He also noted with gratitude the efficient support from the Secretariat. The meeting was closed at 2:00 pm on 3 December 1999.

APPENDIX I

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APPENDIX II

AGENDA

1. ORGANIZATION OF THE MEETING

1.1 Opening of the meeting
1.2 Adoption of the agenda
1.3 Working arrangements

2 CHAIRMAN'S REPORT

3 DEVELOPMENT OF THE "CRITICAL REVIEW"

4 REVIEW OF CANDIDATE OBSERVING SYSTEMS

5 STATEMENT OF GUIDANCE ON FEASIBILITY OF MEETING REQUIREMENTS BY SATELLITE AND IN-SITU SYSTEMS

6 REVIEW OF THE CURRENT STATUS OF THE GLOBAL OBSERVING SYSTEM

7 REVIEW OF COMPOSITE OBSERVING SYSTEMS THAT ARE BEING DESIGNED UNDER THE G3OS

8 REPORTS ON IMPACT ASSESSMENTS CONDUCTED BY NWP CENTRES UNDER COSNA, EUCOS AND NAOS

9 CONSIDERATION OF PROPOSALS FOR OSEs AND OSSEs

10 REDESIGNING THE GOS IN DEVELOPING COUNTRIES

11 FUTURE WORK PROGRAMME

12 CLOSURE OF THE MEETING

Appendix III

ACTIONS RESULTING FROM THE MEETING

1. Provide the *in situ* observing system statistics regarding availability of measurements in electronic form (pending approval by the ECMWF) to Alan Sharp so that the ET-ODRRGOS can further populate the in-situ database. (H. Böttger, Feb 2000)

2. Provide in consultation with CCI and CAS advice on user requirements in the applications area of seasonal to inter-annual forecasts. The aim is to create a preliminary set of user requirements, that have been subjected to a preliminary expert review. Conduct Critical Review of NWP SI forecasts and draft a statement of guidance. (ET-ODRRGOS, at next meeting)

3. Recommend to the CBS that in future more emphasis be given to (i) enhancing observing capabilities and networks to meet growing needs of the WCP and UNFCCC/WCRP; (ii) advising on transitional mechanisms including planning activities necessary to secure and convert a research programme of observations for operational management and use; (iii) acquiring observational data useful for climatological purposes from non-NMHS and non-governmental sources and (iv) promoting operational data management procedures necessary to create homogeneous climate records (ET-ODRRGOS chair, Document to CBS-XII, May 2000).

4a. Request the AMDAR panel advise on AMDAR experiments well in advance, so that NWP centres can organize suitable impact experiments (R. Decker, Feb 2000).

4b. Request OPAG IOS chair to invite AMDAR panel to send a representative to the next ET-ODRRGOS meeting to provide advice on AMDAR-related issues (R. Decker, Feb 2000).

5a. Request that global NWP centres as a matter of urgency, perform experiments to measure the impact of losing southern hemisphere surface pressure observations in drifting buoys in their current systems, and make the results available to possible funders of pressure instruments on these drifting buoys (A. Sharp, A. Lorenc, H. Boettger, F. Rabier, Dec 1999).

5b. Request WMO/IOC DBCP collect and collate the results of the efforts generated by 5a (F. Gerard, when results available).

5c. Request OPAG IOS chair to pursue the issue of pressure sensors on southern hemisphere buoys with responsible agencies (including AOML) as a matter of urgency (ET-ODRRGOS chair, Dec 1999).

5d. Encourage a representative of the newly established Joint WMO/IOC Commission for Oceanography and Marine Meteorology (JCOMM) to continue participating in the work of the ET-ODRRGOS as an invited expert to make appropriate proposals toward the redesign of the marine part of the GOS(Secretariat, Jan 2000).

6. Encourage the CLIVAR working group to organise OSSE type studies, using existing climate change experiments with coupled ocean-atmosphere climate models, in order to see which observations (in particular the GUAN) are important for detecting the "fingerprint" of climate change (D. Parker, Jan 2000).

7. Request that Chair of IOS OPAG pursue a CBS recommendation that advanced NWP centres be involved in the process of redesign of the GOS, including a list of ET-ODRRGOS proposed impact studies (ET-ODRRGOS chair, Dec 1999).

8. Present ET-ODRRGOS recommendations regarding the redesign of the GOS in developing countries to the ICT for consideration at their upcoming meeting in March 2000 (H. Daan, Feb 2000).

9. Request the Chairman of OPAG/IOS to submit proposal to the CBS with a view to rectify the loss of vertical information from RAOBS (R. Decker, Jan 2000).

10. Update the review of Candidate Observing System Technologies and their Use (A. Sharp, before next meeting).

11. Represent ET-ODRRGOS at the second CGC/WMO workshop on the impact of various observing systems on NWP in Toulouse, 6-8 March 2000 to interact with modellers regarding recent work on regional and global aspects of the observing system (F. Rabier, Mar 2000).

APPENDIX A

GUIDELINES FOR OSE / OSSE

A.1. Observing System Experiments (OSEs)

- They are relatively cheap at centres already equipped to do them.

- They are limited to currently available observations (i.e. to operational observations or, at higher cost, to “special observations” which are available with some effort, but not operationally).

- They can be used to test the impact of current observing systems, in isolation or combination.

- They can be made using a random ensemble of cases, or a contiguous set of cases from randomly-selected period(s), or cases chosen because the impact of observations known to be higher than normal (e.g. through study of changes in consecutive forecasts).

- Sample size is important; there is a danger of drawing too general conclusions from a small ensemble of experiments. Ideally experiments should include different seasons, and even different years, as results may depend on a particular weather type. If this is not possible, then at least some statistics of the frequency of weather types, and sensitive areas, in the region of the observations, should be considered. The statistical significance of results should be calculated.

- Experiments can measure the impact of withdrawing an observation type. This demonstrates the current benefit of that observation type. It provides a basis for testing scenarios of withdrawing the system, either to reduce cost or to re-deploy the resource elsewhere.

- Experiments with “special observations” can test certain types of scenarios, e.g. 4 sondes per day but from limited sites, versus 2 sondes per day from all sites.

A.2. Observing System Simulation Experiments (OSSEs)

- They are expensive!

- However, they can be the most convincing way to test impact of planned observing systems for which realistic observations (with realistic coverage) are not available.

- They can also be a “clean” way to test impact (of current or future observations) because you know the “truth”; it is the "nature run" from which observations are simulated.

- However, they are prone to over/under-optimistic specification of observation errors and coverage. Great care is needed in their realism.

- Particular problems arise if the assimilating model is the same as the model used to simulate the observations (identical twin experiment) usually, but not always, leading to over-optimistic results. It is recommended to use different models for the two stages of the process.

- Similarly, if the simulated observation error characteristics are the same as those used in the assimilation, results will tend to be over-optimistic.

- For these reasons it is recommended to calibrate an OSSE against a comparable OSE, if possible.

- For realistic results, it is necessary to simulate not only the observing system of interest but also all other components of the composite observing system expected to be in place at the time of interest. For these future systems, a desirable but impracticable requirement would be to simulate expected improvements in the NWP and data assimilation technology. Because of these unavoidable limitations, OSSEs may not always give an accurate measure of future capabilities. Detecting and allowing for this requires expert judgement.

A.3. Common sense

- For very costly decisions, for instance for future satellite systems, OSSEs play an important role in the decision process, along with OSEs of prototype and surrogate instruments, and stated requirements for observations.

- However, because of their complexity and cost, it is not possible to run experiments for all questions related to observing system design.

- It is often more appropriate to use judgement and experience to extrapolate and adapt results from an existing study. For this to happen efficiently, results of all studies need to be available to all experts concerned.

APPENDIX B

DRAFT STATEMENTS OF GUIDANCE REGARDING *IN SITU* PERFORMANCE FOR NOWCASTING, REGIONAL NWP, AND GLOBAL NWP BASED ON THE CRITICAL REVIEW

B.1. Nowcasting

B.1.1. Nowcasting is carried out in local forecast centres where meteorologists analyze primarily observational data to make extrapolative forecasts from zero to a few hours. It requires frequent, timely, and high spatial resolution data. Specifically, tropospheric profiles of wind, temperature and humidity as well as the location, type and rate or precipitation are required.

B.1.2. Over substantial areas of Regions IV and VI the requirement for wind profiles from 1000 to 100 hPa are met to a good standard by AMDAR and tropospheric wind profilers for vertical resolution, cycle, delay and accuracy. Horizontal resolution generally falls below the minimum standard except over limited areas. The composite rating for these subregions is marginal or less. For most other Regions, radiosondes satisfy the vertical resolution and accuracy requirements to a good standard, but fail to meet minimum standards for horizontal resolution and cycle requirements.

B.1.3. For atmospheric wind profiles between 100 and 10 hPa, over most global sub-regions, radiosondes provide good vertical resolution and marginal to adequate delay and accuracy. However, because the horizontal resolution and cycle time do not meet user requirements, the composite minimum requirement is not met in any sub-region.

B.1.4. Radiosondes provide good vertical resolution and accuracy needed to meet the requirements for humidity profiles from 1000 to 100 hPa in most sub-regions, but do not meet minimum user requirements for horizontal resolution, cycle and delay. In the future, when sufficient numbers of AMDAR aircraft are equipped with humidity sensors, they may partially meet the composite requirement for humidity profiles over limited areas of Regions IV and VI. Currently, the composite requirement for humidity profiles is not satisfied for any sub-region.

B.1.5. For atmospheric temperature profiles between 1000 and 100 hPa, AMDAR meets the requirements for vertical resolution, cycle, delay and accuracy in a few sub-regions of Region IV, but generally not for horizontal resolution. Radiosondes in these sub-regions and many others provide adequate to good vertical resolution, and accuracy. Again the cycle and delay requirements are not met or met only marginally by radiosondes. Except for one or two sub-regions of Region IV, the composite requirement for temperature profiles does not satisfy minimum standards.

B.1.6. Precipitation rate at the ground for Nowcasting is measured principally by networks of automated rain gages. Doppler radar data can also provide information on rainfall rates, as well as the location and movement of cloud and precipitation areas. The accuracy of uncorrected precipitation rates measured using this technique is not high. In a few years, over areas of Region IV, radar data corrected by automated rain gage reports may provide rates that are at least adequate in horizontal resolution, cycle, delay and accuracy. While some sub-regions of Region IV and VI have rain gauge networks that have adequate cycle, delay and accuracy performance, horizontal resolution is marginal or does not meet the minimum standard. The composite requirement is only marginally met in limited areas of these sub-regions. In sub-regions elsewhere, the minimum requirement is not satisfied.

B.1.7. Cloud cover measured by *in situ* observing systems is principally provided by manual and automated surface observing systems. These systems are deployed in limited numbers in sub-regions of Regions IV and VI and over small areas of other Regions. These systems cycle, delay and accuracy performance meets the requirement to a marginal or adequate level, but horizontal resolution does not satisfy minimum requirements.

B.1.8. Atmospheric stability requires profiles of temperature and moisture data. Radiosonde and AMDAR equipped with moisture sensors can provide these data, but even in the intermediate future, their horizontal resolution and cycle frequency will not satisfy minimum requirements over Regions IV and VI. Stability information from these systems will not meet the composite requirement in any subregion.

B.1.9. Summary

* Radiosondes and AMDAR now provide profiles of wind, temperature and humidity (only radiosondes in large numbers for humidity). However the horizontal resolution of these systems and the inadequate cycle frequency of radiosondes result in very limited global coverage. Wind profilers also adequately meet requirements for vertical resolution, cycle delay and accuracy, but their very small numbers limit the global benefit.

* Radiosondes, AMDAR and profilers are very useful diagnostic tools for predicting severe convective storms, winter precipitation type, beginning and cessation of heavy precipitation, high wind events and wind shear at the surface and aloft, turbulence and the validation of numerical prediction forecasts.

* Of the several upper air *in situ* systems, it appears AMDAR is the one most likely to increase in numbers and capabilities. However, even with a large expansion in AMDAR, its profile data will be limited to the vicinity of airports. Over fixed routes, AMDAR can provide large quantities of frequent en route wind, temperature and later moisture and turbulence data.

B.2. Regional Numerical Weather Prediction

B.2.1. Regional NWP models are used to produce more detailed forecasts than are available from global prediction models. The added detail is made possible by a finer computational grid, more detailed specification of terrain, more sophisticated prescription of physical processes, and, ideally, dense and frequent observations to specify appropriately detailed initial conditions. Because regional models depend upon global models for their lateral boundary conditions, the duration of regional forecasts is effectively limited by the size of the computational domain.

B.2.2. Like global models, regional models are initialized through the assimilation of observations. Observing systems that report hourly or more often and at high resolution are relatively more important for regional modeling than for global modeling because of the emphasis on correct prediction of mesoscale events such as thunderstorms, lake-effect snows, fog, or orographically induced windstorms. Proper initialization of physical processes requires detailed observations of the standard variables of temperature, moisture, and wind but also of variables that have a direct bearing on physical processes at the surface and in the atmosphere. For initializing boundary fluxes, observations of vegetative cover, soil moisture, snow or ice cover, and surface albedo are important. For initializing diabatic processes, the presence or absence of clouds and information on hydrometeors, even their size distributions, is important.

B.2.3. Not all of the parameters listed above are observable with current systems, let alone with the required resolution. Nonetheless, a variety of observing systems can contribute to mesoscale numerical prediction, provided that progress continues in the assimilation of the more esoteric data sources. The impetus for regional numerical prediction in a particular area is governed primarily by the observational resources available, and not all countries can justify the expense.

B.2.4. Considering only the frequency of observations but not their spatial distribution, the following ground-based systems are apt for mesoscale prediction: wind profiling radars, dual-frequency GPS receivers for the inference of column water vapor, most automated surface observing systems, automated measurements of cloud base height and cloud coverage, scanning Doppler radars, and fully automated aircraft reports. Future observing systems with special application to regional numerical prediction are water vapor sensors on aircraft (as an adjunct to the temperature and wind information already provided), Doppler radars with multiple polarizations and hourly precipitation estimates from multiple sources.

B.2.5. The following space-based observations are apt for mesoscale prediction: cloud images (visible and infrared), winds determined from the drift of features in satellite images, and radiometric data--all from geosynchronous satellites (frequent views); and scatterometer data for determination of sea-surface winds, so far, available only from polar orbiting satellites. In the future, interferometric data and Doppler lidar data from satellites would contribute toward the prediction of mesoscale events.

B.2.6. Because mesoscale forecasts are perishable, it is important to collect the observations and process them very quickly, usually within one hour or less. The assimilation cycle is likely to be three hours, one hour, or even less.

B.3. Global Numerical Weather Prediction

B.3.1. Global NWP requires data with a broad coverage and at a reasonable resolution for wind, temperature, surface pressure and humidity mainly.

B.3.2. For wind profiles, over populated land areas, the RAOBs and AMDARs can provide high-quality data with a good coverage. Elsewhere, the only information apart from satellite data comes from en-route AMDARs with a relatively poor horizontal and vertical coverage. Above 100 hPa, only RAOBs can provide observations, but useful information can be deduced from satellite temperature information and geostrophy.

B.3.3. For temperature profiles, over populated land areas, the RAOBs and AMDARs can provide high-quality data with a good coverage. Over ocean, we rely on satellite systems.

B.3.4. For surface temperature and pressure, over land, SYNOPs can give a good coverage, but the network is incomplete. Furthermore, there are some assimilation problems in mountainous areas. Over ocean, buoys and ships provide useful information, although sparse.

B.3.5. For humidity profiles, because of a need for higher horizontal resolution for humidity than for temperature for instance, the current radiosonde network is not fully adequate. The situation might improve with various new instruments (humidity sensors from AMDARs, ground-based GPS, radars, etc…) but it will take some time to make proper use of this new information.

APPENDIX C

FUTURE DEVELOPMENT OF THE *IN SITU* DATA BASE

C.1. Since the expert meeting in Madison, an attempt has been made to include some *in situ* information into the comparison database which compares actual observing systems with user requirements. The satellite information contained in the database has been well documented and evaluated, it is now time to include all observations.

C.2. Unlike, satellite data which can be considered on a global scale, the *in situ* data densities vary greatly between regions. For this reason the globe was divided into 34 zones based on geographic and observed data density patterns. These were refined a few times before the final set were accepted.

C.3. So far the *in situ* system information includes :

- Three *in situ* parameters were included in the database during the Madison meeting to assess the broad feasibility of including the insitu information in the same database as the satellite information. The information on the parameters were based on the educated guesses of the participants at the Madison meeting. The resulting output of the comparison database was very promising.

- *In situ* information was compiled to populate the comparison database. Since the information needs to be representative, it was considered that the information within the WMO Vol-A database could be used to estimate the density and frequency of synoptic and upper air sounding observations.

- The number of stations in each zone were summed and the resulting total divided by the geographic area of the zone. It is recognised that the Vol-A database is a list of observing stations and that many stations are not up to the quoted standard. To account for this fact, a scaling factor was introduced. This was derived from the ratio of 'expected' observations to 'actual' observations in each of the WMO Regions. These were obtained from the latest WMO data availability monitoring reports. Horizontal resolution (in km) was derived from the square root of this ratio. The cycle period for these stations was also estimated from the mean number of observations per day at all stations that report this observation.

- Data quality was based on the reports provided by the lead centres. Vertical resolutions were assessed on common practice in radiosonde calculation, based on an assumed 30 second averaging period for PTU data and 60 second averaging period for winds.

- To evaluate the delay time for data, an assumed average delay time was calulated using information on the percentage of data received after fixed times and assumptions on the statisitical spread of incoming data. These values were also obtained from the WMO monitoring reports on data availability.

- It is realised that this information will not be accurate, but should be satisfactory.

C.4. Evaluation of *in situ* information in the comparison database suggested :

The compiled information has the following shortcomings which still needed to be addressed :

- Data that were evaluated as being less than useful, as they fail to meet the lowest criterion in a category, are known to be still useful in actual applications. For example that Arctic radiosondes have a horizontal resolution that does not meet the lowest criteria for NWP, however it is known that this data have a significant affect on NWP in the Northern Atlantic Ocean. This suggests that the user requirements should be reviewed. *Action: It is recommended that the actual meaning of these limits are described properly and that the requirements database then be returned to the users for review noting the above observations.*

- A number of other minimum standards stated by the users seem to be too stringent.

- The mechanism to assign a relative measure of effectiveness for observing systems was reviewed. It was noted that these figures do not represent any significant characteristic of the observing system, but is just designed to provide a relative ranking mechanism to help the user of the database identify systems that are inherently weak or strong. No system of ranking should be expected to be perfect. It was emphasised that the database is only a guidance.

- The validity of the assumptions used in producing the information on *in situ* systems was questioned. It was noted again that these assumptions were made so as to provide enough material at this meeting to make useful assessments on the utility of the comparison database method with *in situ* data. It is recognised that better methods for the evaluation of statistics for the various categories (eg accuracy) need to be pursued. Suggestions are contained within the following section.

- The values for horizontal resolution can be artificially poor for oceanic zones where only one or two observing platforms exist. It was recognised that the actual resolution over the entire water surface would be more realistic if the coastal stations surrounding the ocean area in question were taken into account. A reasonable estimation of the affect of these stations would be obtained by adding one observational platform for each coast adjoining the ocean area based on four sides. That is for the North Pacific Ocean zone there is land to the North, East & West, hence three extra platforms added.

- Further consideration needs to be given on how we handle the fact that many radiosondes do not penetrate into the upper stratosphere (that is above 10hPa).

- Some of the cycle times for polar-orbiting satellites need to be double checked.

- Some *in situ* data developed at Madison meeting are incomplete.

C.5. Future sources for *in situ* data must be sought. There is a need to populate the database with more reliable information on all in-situ systems. This will be done progressively, however as this is a rolling review process so the task will be on-going.

- Meteorological data is most appropriate to our expertise and hence the information we should pursue first. It was recognised that relying solely on WMO Vol-A may provide an unrepresentative viewpoint. A more reliable source of information would be to use statistics on actual observations transmitted over the GTS and received by a global NWP centre. The ECMWF centre releases reports on a regular basis on the amount of data received. Their printed reports present densities of various parameters received over a 5 degree global grid. This includes not only land-surface and radiosonde data, but also ship, aircraft, buoy and other data. If we could tap into their database we may be able to populate some of the database in a fairly easy manner. Some detail cannot be ascertained from this method. For instance, how many synoptic stations report evaporation data or soil temperature? It is hoped that information on quality of certain parameters may also be obtained from the lead centres.

- Regarding non-meteorological information, it is noted that there is a large amount of data which is beyond area of expertise of this meeting. This includes hydrological, agromet and atmospheric chemistry data. These data are mostly transmitted to the relevant agencies by means other than the GTS. In order to obtain the information on these observation systems that is needed to fully populate our database, contacts have to be established with appropriate programmes.

APPENDIX D

ET- ODRRGOS WORK PLAN

D.1. Review of current list of *in situ* capabilities

* Notify reviewers selected by ET (J. Eyre, H. Böttger, R. Decker)	Secretariat	31.Dec.99
* Send reviewers current list of *in situ* capabilities	Secretariat	31.Dec.99
* Send reviews to A. Sharp	Reviewers	31.Jan.00
* Collate and send to Secretariat	Sharp	28.Feb.00
* Update database	Secretariat	31.Mar.00

D.2. Add to the database capabilities of additional observing systems

* List observing systems	Sharp	3.Dec.99
* Add *In situ* Obs System Capabilities		
Aircraft Data (T, W, RH)	Boettger	15.Feb.00
Ship Obs (Synop)	Boettger	15.Feb.00
Buoy Data (P, T, SST, Wave, Current)	Gerard	15.Feb.00
* Populate database	Secretariat	31.Mar.00
* Run "first-pass" CR	Secretariat	30.Apr.00

D.3. Prepare Satellite plus *In situ* SOG for selected applications

* Identify leader for each application	ET	3.Dec.99
global NWP – Eyre		
regional NWP – Schlatter		
nowcasting – Decker		
synoptic meteorology – Legrand		
hydrology – Engman		
atmospheric chemistry – Gille		
interannual/seasonal - Simard		
* Contact leader		
-advise on format of input		
-request input	Secretariat	31.Dec.99
* Generate CR sheets for each application and send CR sheets to leader	Secretariat	15.May.00
* Provide SOG text	Leader	15.June 00

D.4. Arrange for Reviewers of User Requirements in other applications areas

* ATMOSPHERIC CHEMISTRY	Secretariat	before June 00
Numerous parameters		
* AGROMET	Secretariat	before June 00
Vegetation parameters		
Land Cover parameters		
Fire Data (Area/Temp)		
Soil Data (Moisture/Type)		

* HYDROMET	Secretariat	before June 00
Iceberg (ht, extent) Permafrost (cover) Sea Level Snow (cover, depth, melt) Topography		
* AEROMET	Secretariat	before June 00
Cloud Ice Cloud Drop Size (Top) Cloud Water Content OLR OSR Stability Index		

APPENDIX E

GCOS/GOOS/GTOS CLIMATE MONITORING PRINCIPLES (KARL PRINCIPLES)

E.1. Assess the impact of new systems or changes to existing systems prior to implementation.

E.2. Require a suitable period of overlap for new and old observing systems.

E.3. Treat the results of calibration, validation, algorithm changes, and data homogeneity assessments with the same care as data.

E.4. Ensure a capability to routinely assess the quality and homogeneity, including high-resolution data and related descriptive information, of data on extreme events.

E.5. Integrate environmental climate-monitoring products and assessments, such as IPCC assessments, into global observing priorities.

E.6. Maintain uninterrupted stations and observing systems.

E.7. Give a high priority to additional observations in data-poor regions and regions sensitive to change.

E.8. Provide long-term requirements at the outset of new system design and implementation to network operators, designers and instrument engineers.

E.9. Promote the conversion of research observing systems to long-term operations in a carefully planned manner.

E.10. Data management systems that facilitate access, use and interpretation are essential.

APPENDIX F

THIRTY FOUR HOMOGENEOUS SUB-REGIONS FOR *IN SITU* OBSERVING SYSTEMS

F.1. The meeting recalled that the Expert Team Meeting held in Madison, Wisconsin in June 1999 had discussed the incorporation of *in situ* observing systems into the Rolling Review of Requirements process. The Madison meeting also recognized that it was necessary to categorize the surface-based sub-system of the Global Observing System (GOS) into homogeneous regions before it could describe the associated observing system capabilities. In so doing, it would allow the representation of the variability of *in situ* observing systems over the globe. Thus, the meeting defined a set of 34 sub regions. The meeting then reviewed a set of expected performances of *in situ* observing systems expected as regards:

* Balloon based observations,
* Land surface observations,

F.2. The meeting noted that the expected performances had been produced through a systematic analysis of the WMO list of observing stations as contained in Volume A. Based on the 34 regions, figures describing the horizontal resolution and observing cycles for SYNOP and TEMP observations were developed as well as estimates for accuracy for TEMP parameters and delay of availability. Accuracy for SYNOP parameters were taken from the CIMO Guide. The parameters for which performance was compiled were: SYNOP (surface wind vector over land, surface air temperature, surface air humidity, cloud cover, cloud base height and surface air pressure) and TEMP (air temperature, specific humidity and wind profiles).

F.3. All performances were input into the CEOS/WMO database and Critical Review charts were produced for each of the above parameters for the following applications area requirements: Global NWP, Regional NWP and Nowcasting. The Global NWP requirements had been modified slightly based on suggestions made during the Madison meeting.

F.4. The meeting noted that for the time being the following observing systems have not yet been included into the database:

* Aircraft
* Buoys,
* Ships
* Remote sensing (to be further elaborated),
* Ocean sub-surface profilers, and
* Others.

THIRTY FOUR HOMOGENEOUS SUB-REGIONS FOR *IN SITU* OBSERVING SYSTEMS

No	Name	Description
1	North Atlantic Ocean (Coastal)	Atlantic Ocean and seas around UK between 60N and 23.5N within 200 miles of N America, Europe and UK including all of North & Baltic Seas
2	North Atlantic Ocean (Open)	Atlantic Ocean between 60N and 23.5N over 200 miles from N America Europe and UK
3	Tropical Atlantic Ocean (Coastal)	Atlantic Ocean between 23.5N and 23.5S and east of 60W within 200 miles of Africa or S America
4	Tropical Atlantic Ocean (Open)	Atlantic Ocean between 23.5N and 23.5S and east of 60W over 200 miles from Africa and S America
5	South Atlantic Ocean (Coastal)	Oceanic region in box 20S-60S, 70W-20E within 200 miles of Africa or S America
6	South Atlantic Ocean (Open)	Oceanic region in box 20S-60S, 70W-20E over 200 miles from Africa and S America
7	North Pacific Ocean (Coastal)	Pacific Ocean between 60N and 23.5N within 200Miles of Asia, Japan or N America including Sea of Japan
8	North Pacific Ocean (Open)	Pacific Ocean between 60N and 23.5N over 200Miles from Asia, Japan and N America
9	Tropical Pacific Ocean (Coastal)	Pacific Ocean between 23.5N and 23.5S within 200 miles of the Americas
10	Tropical Pacific Ocean (Open)	Pacific Ocean between 23.5N and 23.5S and east of 155E over 200 miles from the Americas
11	South Pacific Ocean (Coastal)	Pacific Ocean between 23.5 S and 60 S within 200 miles of S America
12	South Pacific Ocean (Open)	Pacific Ocean between 23.5 S and 60 S and east of 180W over 200 miles from S America
13	North Indian Ocean (Coastal)	Ocean areas in box 25N-10S, 20E-100E within 200 miles of Africa and the Asian continent
14	North Indian Ocean (Open)	Ocean areas in box 25N-10S, 20E-100E over 200 miles from Africa or the Asian continent
15	South Indian Ocean	Ocean areas in adjoining boxes 10S-60S, 20E-110E and 47S-60S, 110E-180E (excluding Madagascar)
16	Arctic Zone	All north of 60N excluding Norway, Sweden and Finland
17	Antarctic Zone (R-VII)	All south of 60S
18	Mediteranean	Mediteranean Sea (Including Adriatic, Aegean, Ionian & Tyrrhenian seas) and African land areas north of 30N
19	R-I Sahara	African land areas between 30N and 15N
20	R-I Tropical	African land areas between 15N and 23.5S (including Madagasca)
21	R-I South	African land areas south of 23.5S
22	R-II North	Region of Russian Federation and Mongolia in R-II and south of 60N
23	R-II East	China, Korea, Japan, Vietnam, Laos, Cambodia and Thailand
24	R-II South	Pakistan, India, Sri Lanka, Nepal, Bhutan, Bangladesh and Myanmar
25	R-II West	Kazakhstan and remaining R-II countries to the southwest.
26	R-III North	All R-III countries excluding Chile, Argentina and Uruguay
27	R-III South	Chile, Argentina and Uruguay
28	R-IV North	R-IV land areas 60N-52N including Hudson Bay
29	R-IV Central	USA (excluding Alaska & Hawaii) and region of Canada south of 52N
30	R-IV South	R-IV Countries south of USA including West Indies. Also Gulf of Mexico, Caribbean Sea and region of Atlantic ocean west of 60E and south of 23.5N
31	R-V North West	All land and ocean areas in R-V north of 10S and between 100E and 160E
32	R-V South West	All land and ocean areas in R-V in box 10S-47S, 110E-180E
33	R-VI West Europe	Denmark, Germany, Switzerland, Italy, all continental European countries to the west, including UK and Ireland.
34	R-VI East Europe	Norway, Sweden, Poland, Czech Republic, Slovenia, Austria and remainder of R-VI to the east of these countries and the Adriatic Sea (except portion of Russian Federation North of 60N)
Note: Unspecified islands within defined ocean areas are included as part of the ocean area.		