IN SITU OBSERVATIONS FOR THE GLOBAL OBSERVING SYSTEMS

Development of an integrated strategy and identification of priorities for implementation

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PREFACE

In situ observations are crucial to the success of the three global observing systems, specifically the Global Climate Observing System, the Global Ocean Observing System and the Global Terrestrial Observing System. This report summarizes the results of an international meeting co-organized by the three global observing systems held in Geneva, Switzerland, that considered strategic issues relating to the collection of these observations and specifically to the identification of priorities relating to climate requirements.

In addition to recommendations on specific technical issues concerning the collection and management of *in situ* observations, the meeting also considered many aspects of the inter-relationships between the observing systems and other international organizations. It was recommended that the Committee on Earth Observation Satellites enhance the activities of its Calibration and Validation Working Group so that it can be more responsive to the needs of the three global observing systems.

Since this was the first joint meeting of all three observing systems on any topic, several recommendations were made concerning joint approaches to their activities including common approaches in ensuring the collection of long-term consistent observations and in defining priorities.

ORGANIZATION OF REPORT

The meeting was organized around three main systematic sessions on atmospheric (p.11), oceanic (p. 19) and terrestrial observations (p. 23) and a fourth on requirements for calibration and validation of space-based observations (p. 30). Finally, a session was devoted to cross-cutting issues (p. 35). Because many conclusions in the individual sessions overlapped to varying degrees, a section on Integrated Recommendations and Summary of Conclusions (p. 4) was included. Appendices contain the agenda of the programme (p. 40), the organizing committee and session organizers (p. 43), the attendees (p. 44), and acronyms (p. 51).

1. INTRODUCTION

Development of overall strategies for observations of the Earth system has received considerable attention over the last two years. Most attention has been paid to space-based observations, but of comparable importance is the wide variety of *in situ* observations made at the surface of the Earth and in its atmosphere and oceans. By *in situ* observations we refer to those observations made as a result of direct measurement at a site: some observations will be made directly, possibly by automated means, whereas many others may be made in the laboratory on samples taken from a site. A joint meeting co-sponsored by the Global Climate, Ocean and Terrestrial Observing Systems (GCOS, GOOS and GTOS) was convened to examine the extent to which observational capabilities match needs and to determine what are the key actions needed to remedy deficiencies in current systems.

In some fields, the last ten years have seen considerable improvements in the acquisition of *in situ* observations, but other *in situ* observational systems have suffered serious decline. Some global *in situ* observational systems are well organized and function very successfully. But there are important *in situ* observational systems, such as those relating to terrestrial ecology, lacking comprehensive international coordination of global observations.

The meeting concentrated on strategic issues and identification of priorities relating to climate requirements for global *in situ* observations and products, including those for climate prediction services, climate research and assessment of climate change. It was based on requirements as outlined in the existing plans (e.g., GCOS 1995a, Ocean Observing System Development Panel 1995, ICSU/UNEP/FAO/UNESCO/ WMO 1996) of the three observing systems (GCOS, GOOS and GTOS)[1].

The three global observing systems already have a number of mechanisms for ensuring coordination of their strategies. There are the two joint design panels, namely the Ocean Observation Panel for Climate (OOPC) and the Terrestrial Observation Panel for Climate (TOPC), the first of which is developing the ocean component of GCOS and the climate component of GOOS and similarly the TOPC is developing the terrestrial component of GCOS and the climate component of GTOS.

Recently it has been decided to expand the scope of the Space-based Observation Panel of GCOS to include the interests of GCOS, GOOS and GTOS and there are proposals in hand similarly to expand the scope of the GCOS Data and Information Management Panel.

The meeting's objectives were to carry out the following:

- Provide an overview of the principal internationally coordinated *in situ* observing systems, mainly by identifying and reviewing critical deficiencies in current *in situ* observations using the plans of the three global observing systems to identify requirements;
- Assess future *in situ* requirements on the basis of these plans;

[1] Many global observing systems exist apart from GCOS, GOOS and GTOS. For example the World Weather Watch and Global Atmospheric Watch are global observing systems responsible for the international coordination of many key atmospheric observations. Moreover part of the World Weather Watch is itself called the Global Observing System. But to avoid endless repetition of acronyms and avoidance of such clumsy expressions as the "G3OS's" the term global observing systems will be used within this document to refer to GCOS, GTOS and GOOS.

- Review the status of *in situ* observations vital for the support of space observations;
- Develop a strategy to remedy deficiencies, based on existing mechanisms and networks;
- Review the status of data management systems;
- Identify deficiencies in the organizational arrangements for the collection assembly and distribution of observational data sets;
- Consider the position of *in situ* observations in relation to other strategies such as those for space in the "integrated global observation strategy".

In situ observations at a global scale are often inadequate for several reasons including the following:

- Lack of precision and accuracy, arising through factors such as inadequate instrumentation, lack of skilled personnel and inadequate maintenance;
- Inadequate sampling in space and/or time;
- Incompatibility of observations, for example by the use of different instruments, different timing of observations and different methods for recording the data;
- Inadequate assembly of observations globally often due to a lack of data management but also for some observations, because of national sensitivities about the use of observations relating to national resources.

The reasons for such deficiencies apart from the more obvious technical ones are not difficult to identify. They include inadequate data management locally, nationally and internationally, deficiencies of international coordination mechanisms to ensure that collected observations are assembled into global data sets and of course insufficient financial resources.

Given the heterogeneity of *in situ* observational systems it is appropriate to question why a strategic oversight for *in situ* observations is needed. Firstly there is the fact that many *in situ* observations are irreplaceable in that they are not substitutable by remote sensing observations and have to be maintained for an understanding of climate. However some of these *in situ* systems are deteriorating. Also many new techniques for *in situ* observations are becoming available, which may compete with existing systems to the possible detriment of consistent long-term observations. In many areas resources are becoming increasingly constrained, so that choices may have to be made between different observational systems. The latter is one of the main drivers behind the increasing desire of some governments to establish observational priorities with the framework of an overall integrated observational strategy. Finally it is clear, that for globally relevant *in situ* observations to be collected, many different nations and organizations have to be involved in planning and implementation and a coordinated approach has to be developed.

Strategies are needed to establish requirements in a consistent fashion, to assess priorities and to achieve implementation. This poses considerable challenges. For example prioritization is difficult *within* observing systems and setting priorities *between* observing systems may be very difficult indeed. But if the global observing systems do not establish priorities others, outside or peripheral to the global observing systems or charged with implementing systems, certainly will do so.

In some ways it is becoming more difficult to demonstrate the benefits of improving or maintaining observations because of the complex way in which observations are processed to generate the products required by users. For example products are often derived by integration of *in situ* and remote sensing observations. Four dimensional assimilation techniques are increasingly used to create more consistent data sets, but this may make it difficult to track the contribution of any individual observational component. Also there is the fundamental problem that data quality is highly dependent on the specific application of the data: new applications may often reveal new deficiencies and hence quality and data deficiencies are dynamic attributes of data sets.

Achieving implementation of the plans of the global observing systems whether for *in situ* or for space observations will prove a difficult task. For this to be possible it is important to ensure that national governments, who provide funding, have a better understanding of the importance of *in situ* observations through a comprehensive understanding of requirements and capabilities. Of equal importance is that they understand the benefits of these observations and the advantages of international cooperative efforts in their assembly and use. Simply asking for improvements, which demand additional resources, will usually be unsuccessful. There is a need to demonstrate the vital need for improvements, their impacts in terms of use, and their feasibility especially in terms of cost-effectiveness. The latter will be assisted by the strengthening of existing organizational structures and mechanisms, for example through closer collaboration between the global observing systems.

Some mechanisms for implementation already exist. For example, through the World Meteorological Organization (WMO), there exists a process whereby the permanent representatives of member countries can be formally approached seeking their cooperation in collecting new or improved observations following a systematic process of developing, evaluating and vetting proposals from organizations such as GCOS. But for some *in situ* observations there is no existing international agency responsible for such coordination, for example for the global network of ecological test sites proposed by the TOPC. In such cases it will be important that an appropriate international agency takes on an international coordinating responsibility. Sometimes networks with operational responsibilities emerge from prototype research observational systems, such as the Tropical Atmosphere Ocean (TAO) array, but the transfer from research programme to operational programme may be very lengthy.

Improving the quality of *in situ* observations will be a complex and difficult set of tasks. The report of this meeting is intended to provide an initial overview of requirements, capabilities and the steps needed to improve the most important elements.

2. INTEGRATED RECOMMENDATIONS AND SUMMARY OF CONCLUSIONS

The following sections outline the presentations, conclusions and discussions of the meeting as prepared by writing teams during and immediately after the meeting. Inevitably several of the recommendations from the different sessions overlap. Consequently this integrating section is included to draw out the main conclusions of the meeting and to form an executive summary. The source of the recommendations is indicated as follows:

- Atmospheric session's recommendations have the prefix A (see Section 3);
- Oceanic session's recommendations have the prefix O (see Section 4);
- Terrestrial session's recommendations have the prefix T (see Section 5);
- Calibration and validation session's recommendations have the prefix C (see Section 6);
- Cross-cutting session's recommendations have the prefix X (see Section 7).

2.1 Data collection and assembly

Because of the strategic nature of much of the meeting there was less emphasis on recommendations concerning the creation of specific data sets than would be the case in thematic meetings on particular observations. The latter are described in varying degrees of specificity in the reports of the observing systems and their panels. Nevertheless a number of key requirements relating to the improved collection and assembly of data sets were made:

The WMO should consider ways of expanding and improving the aircraft observing scheme to include additional aircraft as well as new parameters such as atmosphere moisture and carbon dioxide (Recommendation A4).

The WMO should make available updates of baseline data sets such as the Comprehensive Ocean Atmosphere Data Set (COADS) on a regular basis (Recommendation A3).

The GCOS Joint Scientific and Technical Committee (JSTC) should facilitate the enhancement and development of a global database on aerosol characteristics appropriate to quantify regional and global climate forcing (Recommendation A10).

Sensors and systems (e.g., acoustics and optics) which can provide key Living Marine Resources (LMR) data should be included on other platforms (e.g., moorings and Volunteer Observing Ships) to provide concurrent, complementary and economical information about LMR (Recommendation O7).

The effective implementation of the LMR *module* depends on the development of a more timely and effective system for gathering and collating fish stock data. It is recommended that opportunities within the global observing system process be sought in order that such a system can be put into place (Recommendation O8).

WMO through the Hydrology and Water Resources Programme (HWRP) should periodically contribute to an assessment of the state of the hydrological networks (Recommendation T1).

Given the lack of availability of many types of hydrological data GCOS and GTOS should immediately contact the FRIEND (Flow Regimes from International Experiments and Network Data) office to take advantage of the offer of this programme office to help make their data available to a wider community. Making such data available on the Internet should encourage others to make their data available as well. In addition GCOS and GTOS should establish Internet links to the vast amount of US Geological Survey data that is already available (Recommendation T2).

In the context of sampling devices for hydrological measurements WMO should continue to support inter-comparison studies and work towards standardization to the maximum extent possible (Recommendation T3).

The TOPC should develop a global demonstration project to test the ability of GTOS to deliver a needed terrestrial product rapidly and cost effectively. Soil carbon and its associated variables might be an appropriate test case (Recommendation T5).

2.2 Calibration and validation

The importance of calibration and validation of both *in situ* and remote sensing observations was a recurrent theme of the meeting. Specifically the importance of *in situ* observations in calibrating and validating remote sensing observations was recognized.

A cross-sectoral approach to calibration and validation of remote sensors with *in situ* data is recommended, because for several sensors, applications cross the boundaries of the global observing systems and their components. Merged satellite-*in situ* products are proving more useful than either of the individual (remote or *in situ*) products (Recommendation O5).

The meeting endorsed the recommendation from Working Group on Calibration and Validation (WGCV) to the Committee on Earth Observation Satellites (CEOS) plenary concerning cross-calibration activities and establishment of test sites (Recommendation C6).

Interactions of the global observing systems with the CEOS Working Group for Calibration and Validation were identified as being of particular importance. Two recommendations are of particular relevance to the new Space Panel serving the needs of all three global observing systems.

Recognizing that all the global observing systems will soon be affiliates of CEOS, the global observing systems should coordinate their participation in CEOS though the Global Observing Systems Space Panel (GOSSP) to optimize input to the Members for their planning of validation (Recommendation C1).

The GOSSP should develop a scheme for identifying priorities for validation issues (Recommendation C2).

The following three recommendations are made to CEOS with respect to the development of the activities of its WGCV.

CEOS should consider enhancing the activities of the WGCV to address international co-ordination and collaboration of satellite product calibration and validation. For validation this should take into account priorities identified by the global observing systems (Recommendation C3).

On the basis of the priorities established above the WGCV should develop a pilot project to address issues such as measurement protocols, test regimes and data management in relation to calibration and validation (Recommendation C4).

CEOS members should maintain electronic bulletin boards providing access to up-to-date consensus calibration information for their sensors and CEOS members should provide access to them (Recommendation C5).

2.3 Data management

Effective data management is central to the success of the global observing systems. Recently the scope of the GCOS Data and Information Management Panel was broadened to include the interests of GOOS and GTOS. The need for a more integrated approach to this topic was recognized in a number of recommendations.

The Sponsors should continue to support inter-programme data management (Recommendation A7).

It is recommended that the global observing systems should seek a set of generic principles and/or guidelines governing the management of data, information and products of the global observing systems. These guidelines should not be restrictive but provide clarification and direction, based on the experiences of existing operational and experimental systems, that will facilitate the development, planning and integrated implementation of global observing system elements (Recommendation O3).

The Sponsor's policies should ensure full and open access of all data required for the global observing systems (Recommendation A8).

The importance of evolving new management concepts to expand the capability of the global observing systems was recognized.

In implementing their plans the global observing systems should take advantage of observations and products being derived through new regional and platform observing management activities such as the North American Atmospheric Observing System (NAOS) and Composite Observing System for the North Atlantic (COSNA) as ways of expanding global observing capabilities (Recommendation A5).

Particular problems were identified in the arena of terrestrial observations where for many observations data management systems are not well developed. Three specific recommendations concerning these types of observations were made.

For cryospheric observations it is recommended that coordinating mechanisms should be improved by focusing initially on two areas namely permafrost and glacier monitoring, that are already relatively well organized (Recommendation T4).

The Data and Information Management Panel (DIMP) and TOPC should develop an on-line meta-database providing details concerning the existing terrestrial networks currently collecting *in situ* terrestrial data of direct

relevance to the prioritized requirements provided by the global observing systems (Recommendation T11).

DIMP in conjunction with TOPC should give high priority to developing an effective data policy and management plan appropriate to the specific problems of terrestrial data exchange that should then be actively tested through pilot projects. As part of this activity DIMP and TOPC should generate an assessment of the development of previous models of data systems for guidance in how terrestrial data could be shared, managed and distributed (Recommendation T10).

In developing improved capability for terrestrial systems especially for biospheric aspects it was regarded as essential to build on existing capabilities rather than create new systems.

In terms of an overall framework for providing international linkages it is recommended that the data and information management system for terrestrial observations work closely with the International Council of Scientific Unions (ICSU) World Data Centre System, International Geosphere-Biosphere Programme Data and Information System (IGBP-DIS) and with United Nations Environment Programme's (UNEP) Global Resource Information Database (GRID) programme. After the initial data centres are established, it is expected that others will be added to the system (Recommendation T7).

2.4 Interactions between the global observing systems

The bringing together of representatives from the three global observing systems led to several recommendations concerning their responsibilities and how they should be interacting.

The Sponsors are urged to encourage a more rapid development of GTOS as an organization in terms of its secretariat and constituent panels, to bring it to a comparable stage of development to the other observing systems (Recommendation X7, see also recommendation T12).

The GCOS JSTC should consider taking the lead responsibility for the cryospheric and hydrologic component of climate but that the subject of climate impacts on terrestrial systems should be carried out jointly with GTOS (Recommendation A9).

It is recommended that an analysis be carried out by GTOS and GCOS working with the World Weather Watch (WWW) to evaluate the extent of the overlap and possible linkages between the *in situ* ecological sites identified by GTOS and the base-line observation system defined by GCOS (Recommendation A11).

The philosophy, design and implementation of coastal zone measurements within GOOS should be coordinated with similar activities within the other global observing systems, particularly GTOS (Recommendation O6).

The global observing systems should work towards the implementation of a proposed regional pilot project aimed at demonstrating the utility of the global observing systems to developing countries (Recommendation T6).

The possibility of further joint scientific meetings between the global observing systems was discussed. The importance of 4-dimensional data assimilation methods and their impact on *in situ* and remote sensing observations was identified as a high priority.

It was recommended that an international meeting should be convened with the focus on data assimilation jointly sponsored by the three global observing systems (Recommendation X6).

Considerable discussion revolved around the role of the global observing systems in providing timely information for the assessment process of the Intergovernmental Panel on Climate Change (IPCC).

The Sponsors should consider a mechanism for the scientific advisory bodies to consult with the IPCC regarding data requirements for future assessments. The global observing systems should seek a multi-disciplinary response to the demands for observations and analysis from the IPCC assessment process, and to state-of-the-environment reporting processes (Recommendations X1, A2 and O4).

It was recommended to the global observing systems that they institute a short case study to examine the improvements in precipitation analyses to use as input for IPCC assessment (Recommendation X2).

Another area where it was recommended that the global observing systems should play a stronger role was in the area of *indicators*.

The scientific and technical bodies of the observing systems should, through their sponsoring agencies, enter into a dialogue with the bodies responsible for the development of the "indicators" strategy to make them aware of the valuable information resource that resides within the developing observing systems, and seek a mechanism for the continuing involvement and support of the observing systems for this strategy (Recommendation X3).

2.5 Common issues for the global observing systems

A joint meeting relating to the three observing systems not only led to identification of specific ways in which they should improve their interactions (section 2.4), but also led to recommendations about common approaches that they should adopt in carrying out their work. One set of principles arose from the "Guidelines and Principles for Climate Monitoring" developed as part of the GCOS Meeting on Long-Term Climate Change held at Asheville, North Carolina, USA in 1995 (Karl 1996). These are regarded as being not only critical for climate observations but also for others relating to long-term observations.

It is recommended that the Sponsors and scientific oversight committees of GCOS, GOOS and GTOS support the following principles and activities relating to the collection of long-term consistent observations (Recommendations A1 and X5).

> **Studies must be carried out to assess impacts of the new technology as they affect the climate record preferably prior to implementation. The sensitivity of objectives, applications and products to the change should be determined. This information should be widely distributed;**
>
> **Periodic information on data quality monitoring and data assessment including random errors and long-term systematic biases from the appropriate monitoring center must be assembled;**

Routine and permanent mechanisms for evaluating and monitoring observing system performance should be put in place;

There must be wide and regular distribution of periodic information regarding calibration and metadata and processing of data;

Baseline reference networks should be established similar to those established for surface and upper air within the WWW for GCOS to ensure the collection of long-term consistent records to reliably characterize the state of the Earth system. Emphasis should be initially based on defining the minimal configurations necessary for this task;

In implementing these principles and activities every effort should be made to build on existing mechanisms, plans and systems as appropriate.

Associated with the principles and activities outlined in the previous recommendation is the continuing role of the global observing systems in ensuring that observing systems evolve on the basis of carefully conducted scientific analyses involving the broader scientific community.

The scientific and steering advisory groups of the global observing systems should continue to conduct scientific evaluation through impact and sensitivity studies so as to influence the design and evolution of the observing systems in cooperation with existing scientific committees (Recommendation A6).

Associated with the need to ensure long-term systematic collection of observations it was concluded that there should be a clearly understood uniform integrated approach for distinguishing the experimental research systems from systematic operational ones allowing for differences in implementation between different types of observations.

The global observing systems should seek a common methodology for drawing the distinction between experimental and *ad hoc* observations on the one hand, and systematic, routine global observing system observations on the other (Recommendation O1).

Preparatory materials for the meeting indicated the enormous range of *in situ* observations currently being collected, whose enhancement is required by various components of the global observing systems. This highlighted the need to develop an accepted procedure for prioritization.

The global observing systems should recognize the fundamental importance of prioritization for the development of operational, long-term observing systems and should encourage the development of common approaches to prioritization (Recommendation O2).

It was agreed the following steps could be included in a common prioritization process (based on Recommendations O2 and X4; also see Recommendations T8 and T9).

Articulate the objectives or clusters of objectives in relation to the phenomena whose understanding has to be improved as a result of the work of the global observing systems;

Explicitly identify the products and benefits attached to the component of the observing system under consideration;

Examine feasibility, difficulty, and practicality of implementing elements;

Discuss the relevance and impact of the element with respect to the objectives and cost;

As appropriate, apply a hierarchical sampling framework.

There was discussion about the development of integrated global observation strategies and how *in situ* observations might relate to these. Presentations were made outlining various proposals that have been made by a number of individual national organizations and by CEOS. As a result of these discussions the following recommendation was made:

It is recommended to the scientific advisory bodies of the global observing systems (GCOS, GOOS, and GTOS) that they continue to explore prospects for involvement in the continuing discussions on the development of integrated strategies for global observations. In particular it is recommended to the scientific advisory bodies (Recommendation X7):

That representatives of the global observing systems engage with CEOS in better defining their roles as affiliates, especially with respect to calibration and validation, associated with the evolving emphases of CEOS activities;

That the work of the global observing systems contribute to an improved understanding of the roles of *in situ* and remote sensing observations through a more explicit emphasis on their requirements based on an end-to-end view of key products, which have been generated;

That the results of this meeting be reported at the CEOS plenary in Canberra, Australia, by the chair of the JSTC of GCOS.

3. ATMOSPHERIC OBSERVATIONS

3.1 Summary of presentations

The papers on atmospheric observations focused on four primary areas namely requirements, programmes with existing *in situ* observation networks, future observing systems, and a regional framework for observations. A brief summary of each paper is given below as well as a summary of the ensuing discussion.

GUIDELINES AND PRINCIPLES FOR CLIMATE MONITORING

Prior to implementing changes to existing systems or introducing new observing systems standard practice should include an assessment of the effects on our ability to monitor climate variations and changes.

Overlapping measurements of both the old and new observing systems should be standard practice for critical climate variables.

Calibration, validation, knowledge of instrument, station and/or platform history is essential for data interpretation and use. Changes in instrument sampling time, local environmental conditions, and any other factors pertinent to the interpretation of the observations and measurements should be recorded as a mandatory part of the observing routine and be archived with original data. The algorithms used to process observations must be well documented. Documentation of changes and improvements in the algorithms should be carried along with the data throughout the data archiving process.

The capability must be established to routinely assess the quality and homogeneity of the historical database for monitoring climate variations and change including long-term high resolution data capable of resolving important extreme environmental events.

Environmental assessments that require knowledge of climate variations and change should be well integrated into a Global Observing Systems strategy.

Observations with a long uninterrupted record should be maintained. Every effort should be applied to protect the data sets that have provided long-term homogeneous observations. Long-term may be a century or more. Each element of the observation system should develop a list of prioritized sites or observations based on their contribution to long-term environmental monitoring.

Data poor regions, variables, regions sensitive to change, and key measurements with inadequate temporal resolution should be given the highest priority in the design and implementation of new environmental observing systems.

Network designers, operators, and instrument engineers must be provided climate monitoring requirements at the outset of network design. This is particularly important because most observing systems have been designed for purposes other than long-term monitoring. Instruments must have adequate accuracy with biases small enough to resolve climate variations and changes of primary interest.

Much of the development of new observation capabilities and much of the evidence supporting the value of these observations stem from research-oriented needs or programmes. Stable, long-term commitments to these observations, a clear transition plan from research to operations, are two requirements in the development of adequate climate monitoring capabilities.

Data management systems that facilitate access, use, and interpretation are essential. Freedom of access, low cost, mechanisms which facilitate use (directories, catalogues, browse capabilities, availability of metadata on station histories, algorithm accessibility and documentation, etc.) and quality control should guide data management. International cooperation is critical for successful management of data used to monitor long-term climate change and variability.

IPCC REQUIREMENTS

"Warmer temperatures will lead to a more vigorous hydrological cycle; ..."

The following questions are raised by this conclusion of the IPCC (1995) report.

Q.1 Because the statement appears to be mostly based upon "medium" to "low" confidence data for the time period of 1950s to early 80s (when the global temperature remained largely flat) should we not be extending the database into the 1990s when the warming seems to have really picked up?

Q.2 Which of the hydrological cycle components will show the most vigour and where? Should we not be strengthening the observing system for those parameters and in those regions with a higher priority?

Q.3 What changes in advection and convection are implied by enhanced spatial gradients predicted in the warmer world? Should we not be monitoring those changes also?

A second monitoring issue which is raised by the latest IPCC Assessment is that although the future climates over the continents appear to be mostly dependent on the aerosol concentrations over these areas, there is currently no reliable observation system to monitor the distribution of optical characteristics of aerosols either for land or ocean.

WORLD WEATHER WATCH *IN SITU* OBSERVATIONS

Most likely any global observing network of the atmosphere will include the WWW either directly or indirectly. It should be noted that a focus on that small portion of the WWW that deals with the *in situ* aspects of the surface-based Global Observation System (GOS) will present a limited capability. The true capability is better reflected in a full understanding of the Basic Systems of the WWW. The surface-based GOS consists of six Regional Basic Synoptic Networks (RBSN) composed of about 4000 surface and 900 upper-air stations. The GOS also includes a further 6000 land surface observing stations, 7300 Volunteer Observing Ships, 600 data buoys, a large portion of the commercial wide body airliners that provide up to 40,000 observations per day, and many other observing technologies that primarily are directed at national and high resolution observations such as Radar and Sferics.

The overall trend of the GOS is to more automation and remote sensing. With respect to the surface-based RBSN, the surface observations are increasing and the quality of observations are improving due to increased automation. The upper air network is declining but at a very slow rate. The basic problems are the pending termination of the Omega navigational system and the increase cost of expendable items. With respect to climatological and agricultural meteorological stations, there is a continuing increase at a fairly moderate rate, that is expected to continue. The number of Volunteer Observing Ships (VOS) is slowly decreasing due to the overall decline of the merchant marine service; however the quality and quantity of ship reports is actually slightly increasing due to automation and more efficient communication through satellites. The major growth in the surface *in situ* system will be in data buoys (drifting and moored) and in aircraft observations, again principally because of automation and more efficient telecommunications.

With respect to factors related to improvements and impediments to improving the surfaced-based observing system, there are several, which in some cases pertain to the overall WWW.

The major impediments include increased costs to developing countries and the ability to link synoptic type observations to national services and priorities. The major factors related to improvements are as follows:

(a) implementation is linked to a requirements process rather than a static set of requirements - the opportunity for technology and scientific upgrades are built in and include complementary research programmes;

(b) there are mechanisms for all countries to participate through contributions to the programme, derivation of benefits from the programme, and a structure for assistance and cooperation activity specifically in support of the WWW;

(c) implementation and coordination groups are composed of the actual "hands-on" people;

(d) exposure of the WWW Programme at the highest level of the UN system (UN General Assembly resolution);

(e) a flexible and creative set of funding mechanisms involving both national and regional mechanisms.

GLOBAL ATMOSPHERE WATCH

The main goal of the WMO Global Atmosphere Watch (GAW) is to coordinate the ground-based long-term monitoring system of the chemical composition of the atmosphere and related parameters such as greenhouse gases, aerosols, pollutants, precipitation chemistry, and ozone. GAW is contributing to the evaluation and the understanding of the influence of the atmospheric composition on the environment as well as to the understanding of the climate variability. GAW is therefore contributing to GCOS. GAW also provides scientific assessments of long-term trends and early warning of changes in composition of the atmosphere.

During the past 4 years, the main effort has been in developing the network coverage and in improving the final scientific quality of the measurements. In this respect, eight new global stations which combine full atmospheric chemistry measurements and scientific activity (six in developing countries supported by the Global Environmental Facility (GEF)) have been implemented bringing the total to 21.

The regional network has also been enhanced, particularly in the southern cone region of South America where 11 new stations for ozone and ultra-violet radiation measurements have been implemented.

Concerning the quality of the data provided by GAW, three Quality Assurance Centres associated with 12 World Calibration Centres have been implemented in order to ensure the scientific quality of the data archived in the six WMO World Data Archiving Centres responsible for providing the data to the users: scientific community, agencies and governments.

For the future, the main priority of the GAW programme is to consolidate the present developments and ensure their long-term continuation:

- Reinforcement of the Quality Assurance/ World Calibration Centres system;
- Continuation of the present good cooperation with international programmes: International Global Atmospheric Chemistry Project (IGAC), World Climate Research Programme (WCRP), GCOS;
- More training, particularly in developing countries that are an essential support to the programme;
- Support of scientific assessment of GAW issues.

AIRCRAFT AND FUTURE OBSERVING SYSTEMS

Global coverage from satellites is crucial for the study of climate change. However, with a few exceptions, the satellite error bars are still too large for some climate applications. The application of Kalman filters to quantify and to extract gradient information from satellite data requires high space/time density of *in situ* (or other remotely sensed) measurements. This can only realistically occur with the addition of new automated *in situ* and/or other remotely sensed information sources.

Four key examples of automated observing systems were provided which would help fill crucial gaps in our understanding of the climate system.

The first example is the use of many Profiling Automatic Lagrangian Circulation Explorer (PALACE) floats to help deduce upper ocean thermal and density structure. This can be achieved with the help of the satellite altimeter.

The second example is the use of ground-based remote sensing systems for water vapour and wind measurements, along with similar measurements from commercial aircraft, to obtain low-level water vapour flux information. These same automated systems for water vapour can be used with the satellite water vapour measurement systems to significantly improve water vapour flux measurements associated with large scale monsoon active and break periods. These combined systems would also be used to better establish the important upper level moisture fields associated with cirrus cloud formation and greenhouse gas warming issues.

The third example comes from the carbon dioxide assessment community, which is calling for more detailed four-dimensional measurements of carbon dioxide. Here, a method of using package-carrying commercial aircraft as a means for increased chemical measurements has been identified. Also possible with these package-carrying aircraft are wind profiles over the ocean using Doppler lidar systems. These wind measurements, while valuable in their own right, would provide an additional means for calibration and validation of future Doppler lidar systems on micro-satellites.

The fourth example is the establishment of several "super sites" at various surface locations. Such sites would measure surface fluxes, provide remotely sensed profiles of temperature and humidity, be equipped with a cloud radar, and also contain a pulsed lidar. These systems would simultaneously measure radiation, clouds and aerosols and provide a means for the calibration and validation of similar simultaneous field of view satellite measurements with similar instruments. Such a satellite mission is being proposed by Global Energy and Water Cycle Experiment (GEWEX).

All of these examples are systems with very low recurring costs. However, initial capital costs are not insignificant, though still extremely small compared to satellite costs. This requires a new concept of shared satellite/non-satellite observing systems for funding and planning.

NORTH AMERICAN ATMOSPHERIC OBSERVING SYSTEM

The NAOS programme, currently being implemented by Canada, Mexico and the USA, is a strategy to define the "best mix" of observing systems, reduce observing systems risks and uncertainty, and improve the government decision-making process in defining the future atmospheric observing system.

During a time when the present data set is inadequate to further meteorological services, the maintenance of existing systems is becoming more costly, changes are being mandated, new observing systems are emerging or are in limited use, and the NAOS strategy is being put in place to assist in making the difficult choices ahead. A mix of scientific evaluation of alternative observing architectures, operating system considerations, and systems design is being called upon to assist in making the difficult decisions for implementing alternative observing system strategies.

A NAOS Council has been established with representation from NOAA, the research community, Canada, Mexico, and other US Federal agencies. Three Council sessions have been held on a quarterly basis, a test and evaluation set of hypotheses have been approved. Studies have been initiated and are focused upon improvements to the Upper Air Sounding System. Early efforts will focus upon radiosondes, automated aircraft data, wind information from profilers and an expanding network of Doppler radars (WSR-88D), but eventually all observing system components will be examined.

Results will be presented at annual sessions of the American Meteorological Society and other venues. An Outreach Plan is in preparation and a programme plan is in press.

The strategy of implementation includes high level scientific and management participation in the Council who can take direct action with existing computational and human resources and have a management mechanism to report to decision-makers in the US, Canada, and Mexico. No major new system implementation decisions will be taken without adequate scientific and technical supporting information because of the considerable funding implications. The impact on climate measurements will be an explicit consideration.

THE COMPOSITE OBSERVING SYSTEM FOR THE NORTH ATLANTIC (COSNA)

The session was informed of the structural and organizational set-up of the COSNA that has been supported for seven years by several national meteorological services (NMSs) on the basis of a non-governmental agreement. The COSNA Agreement aims at the implementation of the WWW components especially with regard to generating atmospheric observational data needed for numerical weather prediction (NWP) on a real-time operational basis.

Maintaining COSNA as an operational system involves:

- A scheme of voluntary contributions in cash and in kind;
- A scientific evaluation group (SEG) supported by the major NWP centres;

- A small trust fund, fed by regular contributions in cash;
- Very small overhead costs.

The operational components of COSNA make use of all available data sources in the COSNA region that are coordinated and integrated in a systematic manner that includes regular performance monitoring and evaluation against data requirements stated by the users. Use is made in particular of the WWW specialized monitoring centres and of input provided by the operators of systems components like ASDAR/AMDAR (aircraft platforms), ASAP (automated shipboard aerological programme), data buoys, voluntary observing ships.

The SEG focuses on studying the relative merits of the COSNA components with a view to optimizing the system design using impact studies and input from various data assimilation schemes. This includes involvement of the major research groups in the NWP area.

COSNA provides a unique example of NMSs taking joint responsibility for operational observing systems operated outside national boundaries in a data-sparse area. It was suggested that COSNA might serve as a model for establishing the global observing system modules by creating joint schemes for funding, planning and operation by Members. The use of existing agreements such as that for COSNA was offered as an opportunity to serve the purpose of GCOS provided the special requirements are made known to the Co-ordination Group for the Composite Observing System for the North Atlantic (CGC). In an environment of competition for funding resources, budget cuts and dominating national interests, the COSNA approach seems to offer a viable solution to the start-up problems and future operation of relevant modules of the GCOS.

It was noted that a group of West European NMSs is now in the process of designing a composite observing system that will include COSNA. The new agreement includes joint funding by assessed contributions and, while assigning joint responsibility for implementing and maintaining the relevant operational structures, will dominate national interests.

3.2 Plenary discussion

A variety of factors are driving observation system changes including limitations on resources, emerging new technologies that offer the possibility of reduced costs and improved observations, new requirements based on increased understanding of natural and anthropogenic climate variability and change, and the general recognition of the need to improve past data as well as present and future observations.

Two views emerged with respect to how well observing systems are integrating these factors into present and proposed networks. Scientists trying to better understand climate variability and change, for example as reported to the IPCC, have identified a variety of observing system inadequacies, whereas network managers and users, focusing on the short-term prediction problem, appear to be more satisfied with the current state of affairs. It was pointed out that the adequacy of observations is dependent upon the questions being addressed. For example, with respect to precipitation measurement, current biases can be of minor significance in short-term analyses of rainfall, but they are very significant for long-term monitoring of rain and snowfall. This led to the point that the most serious inadequacies and perhaps the most difficult requirements to achieve are likely to be related to detecting climate change and variability. In this context it was suggested that the Guidelines and

Principles for Climate Monitoring were applicable to many other areas, and each of the global observing systems should review the Guidelines during their general requirements-setting process.

Several other issues arose during the discussion related to a variety of data-quality strategies. It was pointed out that re-analysis and data assimilation schemes are currently being used to improve data quality and extend data to observation-sparse areas. The importance of near-real-time data access from data distribution centres is crucial for both improved data quality and assessments. As data sets change it is critical to retain previous versions and make them all readily accessible. Although the number of reporting stations for the WWW over the past few decades has been nearly constant, or even increasing (depending on the network), there has been a redistribution of stations such that gaps in coverage have been emerging, e.g., data-poor areas have fewer stations now compared to previous decades.

The discussion concluded with the question "What is currently broken in the observing system and what needs to be fixed?" The answer seems to depend on the scientific question being asked. For example, addressing the question "Which components of the hydrological cycle are expected to increase in intensity?" might lead to a different set of priorities compared to addressing the question, "Which aspects of the hydrological cycle will have the greatest impact on managed and natural ecosystems?" Nonetheless, if some key elements could be recommended for improved measurements and specific characteristics be developed to achieve these measurements, then the JSTC may be able to consolidate and articulate the global observing system's highest priorities to the stake-holders and network operators.

The need was noted to correlate the *in situ* observation sites identified through GTOS and the climate observation sites selected by GCOS, to determine the extent of useful overlap and the potential for linkages between sites.

3.3 Recommendations

Recommendation A1. It is recommended that the Sponsors of GCOS, GOOS and GTOS adopt the "Guidelines and Principles for Climate Monitoring" within those observation and data programmes that support the global observing systems and the studies of the IPCC. In particular, consideration should be given to:

Studies to assess impacts of the new technology as they affect the climate record preferably prior to implementation. This information should be widely distributed;

Wide distribution of periodic information regarding calibration and metadata and processing of data;

Periodic information on data quality monitoring and data assessment including random errors and long-term systematic biases from the appropriate monitoring centre;

Establishment of Reference Networks similar to those established for surface and upper air within the WWW for GCOS .

Recommendation A2. The Sponsors should consider a mechanism for the scientific advisory bodies to consult with the IPCC regarding data requirements for future assessments.

Recommendation A3. The WMO should make available updates of baseline data sets such as COADS on a regular basis.

Recommendation A4. The WMO should consider ways of expanding and improving the aircraft observing scheme to include additional aircraft as well as new parameters such as atmosphere moisture and carbon dioxide.

Recommendation A5. In implementing their plans the global observing systems should take advantage of observations and products being derived through new regional and platform observing management activities such as NAOS and COSNA as ways of expanding global observing capabilities (Recommendation A5).

Recommendation A6. The scientific and steering advisory groups of the global observing systems should continue to conduct scientific evaluation through impact and sensitivity studies so as to influence the design and evolution of the observing systems in cooperation with existing scientific committees.

Recommendation A7. The Sponsors should continue to support inter-programme data management.

Recommendation A8. The Sponsor's policies should ensure full and open access of all data required for the global observing systems.

Recommendation A9. The GCOS JSTC should consider taking the lead responsibility for the cryospheric and hydrologic component of climate but that the subject of climate impacts on terrestrial systems should be carried out jointly with GTOS.

Recommendation A10. The GCOS JSTC should facilitate the enhancement and development of a global database on aerosol characteristics appropriate to quantify regional and global climate forcing.

Recommendation A11. It is recommended that an analysis be carried out to evaluate the extent of the overlap and possible linkages between the *in situ* ecological sites identified by GTOS and the base-line observation system defined by GCOS.

4. OCEAN OBSERVATIONS

A great deal of effort has already been expended establishing the scientific and intergovernmental organizational and planning mechanisms for GOOS. During the last five years many recommendations have been passed, both scientific and at the intergovernmental level, in an attempt to see the concept of GOOS made into a real, effective system. Unfortunately, most of these recommendations have borne little or no fruit, principally because there were not sufficient resources to ensure the recommendations were acted upon. There have been other factors, such as the lack of a permanent GOOS Support Office Director, and, it must be admitted, several of the recommendations were unrealistic. This meeting provides yet another opportunity to assess, evaluate and recommend actions for the implementation of GOOS. It would be pointless to revisit issues that are relevant only to GOOS or, as is more often the case, relevant only to the community and agencies concerned with a particular aspect (module) of GOOS.

What this meeting does provide is an opportunity for GOOS to make others in the global observing system community more aware of its objectives and operating principles, and of its products and database, and in turn for GOOS to become acquainted with planning and implementation activities external to its domain. It follows then that the meeting should concentrate on those GOOS issues which demand, or could benefit from, discussion and debate in the broader, multi-disciplinary community concerned with integrated global observing systems.

A detailed background document concerning ocean observations was prepared for the meeting (Smith *et al.*, 1996), and will be published separately.

4.1 General conclusions and recommendations

First, some general remarks should be made about the relationship between the (integrated) global observing systems and that part which we refer to here as GOOS, the ocean observing system. From the viewpoint of GOOS and its scientific planning, most people involved concede there is a considerable amount of work yet to be done and that an integrated GOOS largely remains in the conceptual phase. Furthermore, at the component (module) level, the various specialist groups are at different stages of development. The Climate and Health Of The Oceans (HOTO) modules are beginning the task of implementation whilst the Living Marine Resources (LMR) and Coastal Zone (CZ) modules are only at a preliminary strategic design stage. Thus there are very few examples of successful integration at the component (or even sub-component level). This is not to be interpreted as implying that the concept of GOOS is flawed, but that GOOS is embarking on a task that is challenging in the extreme, and patience and effort will be required. What experience GOOS does have would suggest that integration and prioritization must be tackled at the sub-component and component levels before attempting it at the GOOS level. What, then, is the prospect of achieving useful outcomes at the next level in this hierarchy, in terms of the overall global observing systems (GCOS, GOOS, GTOS), or "G3OSs" as they are colloquially known? A conclusion we can draw from the experience of GOOS is as follows.

Conclusion 1: *GOOS will benefit from an integrated global observing system through the identification of opportunities for constructive cooperation among the three global observing systems.*

However the development of overall strategies for the three global observing systems should avoid directly or indirectly duplicating the decision-making and prioritization processes that already exist at the observing system (e.g.,the Joint Scientific and Technical Committee for GOOS (J-GOOS)) or observing system component (e.g., the HOTO module) levels. The interaction between GOOS and the atmospheric global observing system is fundamental to many of the applications presented here and must be strengthened and sustained. There is also an issue of cooperation through common (non-global) regional systems.

From the outset it has been realized that ocean observing systems must be supported by science, both at the planning stage and as part of the evolution of the system. The observing elements also need to be effective and efficient if they are to be maintained long-term and be able to withstand the inevitable cost versus effect pressures. It is for this reason that a definition of "operational" is proposed, that underpins the steps toward prioritization. An "operational" data-gathering system for GOOS should be:

> **systematic** - measurement methods should be supported by a sound scientific rationale;
>
> **relevant** - measurements should be taken with purpose and due regard of the GOOS objectives;
>
> **long term and routine** - the methods should not be experimental or *ad hoc*, but should be based on a history of successful testing and should be capable of implementation over extended periods with regular sampling and minimal reliance on direct scientific oversight; and
>
> **cost-effective** - observational methods should be efficient and economical.

If a potential measurement system cannot meet these requirements, then it is unlikely to be regarded as a high priority for GOOS, though it may, however, continue to be regarded as important for experimental programmes. The distinction between "operational" and "research" is even more formal within meteorological agencies with regard to numerical weather prediction.

Recommendation O1. A general recommendation is that the global observing systems should seek a common methodology for drawing the distinction between experimental and *ad hoc* observations on the one hand, and systematic, routine global observing system observations on the other.

Recommendation O2. It follows from conclusion 1 and recommendation O1 that the global observing systems should recognize the fundamental importance of prioritization for the development of operational, long-term observing systems and should encourage the development of common approaches to prioritization.

For the implementation of *in situ* systems, where limited resources and lack of longevity are often the norm, prioritization is critical. The need for prioritization, and clear demonstration of the importance of observing system elements, which are candidates for implementation, is repeatedly emphasized by those charged with implementation. This does not mean that the recommended prioritizations are fixed. They should be revisited as alternate or improved technologies emerge, or as understanding of the sampling requirements change, though this revisiting should be on a frequency commensurate with the long-term, “stable” principles of the observing system.

Data and information management also tends to have generic issues that cross the boundaries of the different observing systems. GCOS and GOOS have recently agreed to adopt a unified approach to data management through the appointment of a single data and information management panel. While this rationalization is laudable, some very difficult problems are bound to arise as the HOTO, LMR and CZ modules develop. Many of the data collection methods, quality assurance processes, communication techniques and archiving procedures are, according to the "operational" definition above, still in an experimental phase. Progress in these cases may depend on allowing further experimentation and refinement rather than the imposition of strict guidelines. Another thorny issue concerns the "free and open exchange of data and products" principle that has been adopted for GOOS. For the data and information pertaining to the exclusive economic zones of different countries, it may prove very difficult to get agreement on just how this principle should be invoked. Perhaps now, before planning has advanced too far, we should be seeking out the principles and guidelines that are generic and seeking general endorsement of those principles.

Recommendation O3. It is recommended that the global observing systems should seek a set of generic principles and/or guidelines governing the management of data, information and products of the global observing systems. These guidelines should not be restrictive but provide clarification and direction, based on the experiences of existing operational and experimental systems, that will facilitate the development, planning and integrated implementation of global observing system elements.

Remote sensing effectively imposes integrated requirements across the modules of GOOS and, in many cases, across the different global observing systems. For example, surface wind and sea surface temperature information is an important requirement for all modules of GOOS, although each module is likely to specify different sampling characteristics. While the *in situ* requirements may be met in different ways, the remote sensing requirements will normally depend on a single platform (or, at most two or three). GCOS has put considerable effort into identifying common requirements for GCOS and in many cases for GOOS (GCOS, 1995c). A similar approach should be taken for the global observing systems. However, we must avoid the "wish list" syndrome, where specifications are added without due regard to the actual priority attached to the data by those planning and coordinating the observing system components and we must maintain as far as possible the connections between the specified requirements and the user community and observing system products. Tables of sampling densities and frequencies lose all meaning if they do not have an attached context and clear purpose.

Conclusion 2: *GOOS seeks a unified and integrated approach to remote sensing ("All for 1 and 1 for all") whereby its requirements are considered as part of the justification for operational sensors, rather than each observing system seeking to justify sensors in their own right. Furthermore, GOOS strongly commends an approach to remote sensor specifications that takes full account of the basis for prioritization and rationalization between GOOS elements, and which maintains a clear linkage between the specifications and the prime user communities and products that ultimately must provide justification for the sensor.*

4.2 Specific recommendations

The discussion of the ocean observing system for climate strongly supports the following:

Recommendation O4. The global observing systems should seek a multi-disciplinary response to the demands for observations and analysis from the IPCC assessment process, and to the state-of-the-environment reporting processes.

GCOS is in part meeting this challenge, but in a more general sense. This recommendation suggests that the IPCC process should be used as a motivation to focus and integrate relevant climate activities. Such a response requires close collaboration, and joint implementation, with research groups. The global observing systems might also assist in coordinating approaches used in assessing the state of the environment.

Recommendation O5. GOOS and the Climate module in particular recommends a cross-sectoral approach to calibration and validation of remote sensors with *in situ* data and notes that the detail of sensor sampling requirements are dependent on the application. For several sensors the applications cross GOOS component and other global observing system's component boundaries. Merged satellite-*in situ* products are proving more useful than either of the individual (remote or *in situ*) products.

Conclusion 3: *Routine forecasts of the El Niño-Southern Oscillation phenomenon are now feasible. Their existence creates many opportunities for inter-disciplinary collaboration. In particular, products now being developed outside the domain of GOOS, such as agricultural outlooks, depend directly on terrestrial data and indirectly on ocean (GOOS) and atmospheric (WWW) data. This observing system inter-dependency demands cooperation and collaboration in evaluating system design and prioritization.*

The discussion from both the climate/coastal physics presentation and that of HOTO identified an opportunity to pursue planning in concert with that being undertaken within GTOS, and to cooperate with and build on the research being undertaken within the IGBP Land Ocean Interactions in the Coastal Zone (LOICZ) programme. This would be facilitated by agreements at the sponsor level that their requirements could be met by a cooperative approach. Therefore it was agreed that:

Recommendation O6. The philosophy, design and implementation of coastal zone measurements within GOOS should be coordinated with similar activities within the other global observing systems, particularly GTOS.

The presentations on health of the oceans living marine resources and biology covered many issues, some of which are common to planning issues faced in GTOS. The following conclusions and recommendations were reached.

Recommendation O7. Sensors and systems (e.g., acoustics and optics) which can provide key LMR data should be included on other platforms (e.g., moorings and VOS) to provide concurrent, complementary and economical information about LMR.

Such an approach not only achieves cost savings but allows immediate access to contextual information such as temperature and circulation fields, which assist interpretation.

Conclusion 4: *The development of the GOOS LMR module must involve consultation and cooperation with many groups outside the LMR community, and groups external to GOOS (e.g., Joint Global Ocean Flux Study (JGOFS), Global Ocean Ecoystem Dynamics (GLOBEC), LOICZ).*

Recommendation O8. The effective implementation of the LMR module depends on the development of a more timely and effective system for gathering and collating fish stock data. It is recommended that opportunities within the global observing system process be sought in order that such a system can be put into place.

Conclusion 5: *The GOOS LMR module, perhaps more so than any of the other modules of GOOS, depends on progress and cooperation with the research community.*

5. LAND OBSERVATIONS

This section is divided into five parts: first a brief description of the terrestrial observation system design, then sections on three components of terrestrial systems, namely the hydrological, cryological, and ecological systems. Within each of those areas this report gives a brief overview of the state of existing observation systems, identifies some issues and contains some specific recommendations. Finally there is a section on issues and recommendations that cut across all three systems.

5.1 An overview of terrestrial observation system design

Emerging global environmental problems with strong terrestrial impacts, drivers or linkages, have created a need for a robust, flexible and cost-effective terrestrial observing system. The requirement to span a wide range of space scales and temporal resolutions led the joint GCOS and GTOS TOPC to a hierarchically based sampling strategy called GHOST (Global Hierarchical Observing Strategy) (GCOS 1994, ICSU/UNEP/FAO/UNESCO/ WMO 1996). The strategy is outlined in the GHOST brochure and described in detail in the GCOS/GTOS Plan for Terrestrial Climate-related Observations (GCOS, 1995b). The proposed system has five tiers, ranging from a small number of locations where highly integrated, detailed data are collected with a high time resolution, to a large number of locations where very simple data are collected less frequently. There are intermediate tiers with specific roles and attributes. The hierarchical structure, in conjunction with the use of models and remote sensing, is believed to be the only affordable approach that allows global coverage with the necessary levels of complexity, spatial and temporal resolution. Although the hierarchical concept arose from the work of a land-based group, the basic idea is applicable with appropriate modifications to freshwater and cryospheric systems as well. It is not intended to be applied as a rigid formula. The variables in GHOST are designed to be a 'minimum package' to achieve given objectives. They therefore fall into question-based clusters, which span the hierarchical tiers.

5.2 The Hydrosphere

The hydrological cycle is intrinsic to the Earth's climate system. The process by which water, in all its phases, moves through the atmosphere and moves to and from the various repositories on the Earth's surface are intermeshed with the earth's energy budget. The availability of water controls the abundance and distribution of vegetation and biological productivity. One of the most significant results of climate change will be the shift of regional hydrological regimes and changes in the availability of water resources. Our ability to characterize the current state of the hydrological cycle, globally and regionally, and to make quantitative predictions as to the nature of potential changes depends on consistent information of appropriate quality and adequate spatial and temporal coverage. Such hydrological data sets are currently lacking for many regions of the earth.

Improvements are occurring for some hydrological observations. New and more sensitive sensors and methods are being developed so that data can now be obtained that were previously impossible to collect. Flow data, water quality data and the measurement of evaporation have benefited in this way. Weather radar data have provided a better depiction of local and regional rainfall distributions. A number of global centers have been established to collect hydrological data and make them available to users, for example, the Global Runoff Data Centre (GRDC), Koblenz, Germany; the GEMS (Global Environmental Monitoring System) Collaborative Centre for Water Quality, Burlington, Canada; the Global Precipitation Climatology Centre (GPCC), Offenbach, Germany; and the Global Lake and Catchment Conservation Database, Dorking, UK. These and similar regional data sets, such as those being developed by the FRIEND project of the International Hydrological Programme/United Nations Educational, Scientific and Cultural Organization (IHP/UNESCO), are being used in hydrological research projects. There are a number of large basin research projects underway such as the GEWEX-GCIP and the Large Scale Biological-Atmosphere Experiment Amazonia (LBA) experiment that will provide, not only a better understanding of hydrological processes, but basic data that can be used by the global observing systems.

Most countries have routine operational observing systems for national purposes, although these data are not always readily available outside the boundaries of the country collecting the data, nor are they necessarily collected or available in a form suitable for a global observing system. Recently, establishment of a World Hydrological Cycle Observing System (WHYCOS) has begun to collect near real time discharge data from major rivers. WHYCOS has started on a regional basis in the Mediterranean region and southern Africa. Eventually it is planned to be a global operational system of over 1000 stations.

While some observations are being improved, there are numerous problems. Due to the difficulty of measuring many components of the hydrological cycle, measurement errors and gaps in networks exist in parts of the world for many critical variables. The data are rarely normally distributed and they contain many unexplained outliers. A lack of standard methods leads to uncertainties and inconsistencies in the data. For example, there are 60 types of precipitation gages in use around the world making it extremely difficult, if not impossible, to detect systematic changes in precipitation. Densities of networks recommended by WMO are not being met in many parts of the world, particularly in Africa. Moreover, the national hydrological services in many parts of the world are degrading. This is expected to continue in both the developing world and the developed world. Also some countries refuse to make their data available outside their own borders. Other data that are available simply do not make their way to data centres where they could be readily accessed.

Many of these problems will not be solved in the short term, but the global observing systems can help by providing overall planning and coordinating mechanisms. Further, it is critical that the WWW take a lead to assure the standardization of measurements, such as those for precipitation.

***Issue:** There are large gaps in the coverage of critical hydrological observations. This situation is likely to become worse in the near future as many systems continue to degrade.*

Recommendation T1. WMO through the HWRP should periodically contribute to an assessment of the state of the hydrological networks.

***Issue:** There are significant problems associated with the availability of hydrological data. Of particular importance is the refusal of countries to share data outside their national boundaries.*

Recommendation T2. Given the lack of availability of many types of hydrological data GCOS and GTOS should immediately contact the FRIEND office to take advantage of the offer of this programme office to help make their data available to a wider community. Making such data available on the Internet should encourage others to make their data available as well. In

addition GCOS and GTOS should establish Internet links to the vast amount of United States Geological Survey (USGS) data that is already available.

Issue: *There is a lack of standardization of sampling devices in use for many hydrological measurements.*

Recommendation T3. In the context of sampling devices for hydrological measurements WMO should continue to support inter-comparison studies and work towards standardization to the maximum extent possible.

5.3 The Cryosphere

The cryosphere as an entity comprises snow cover, lake ice, sea ice, ice sheets, glaciers and ice caps as well as permafrost. The cryosphere is not just a polar issue, and has close links to other components of the global climate system, via precipitation, river runoff, and feedback to climate. Cryospheric components, such as glaciers, ice sheets and sea ice, tend to integrate small climatic shifts and hence may serve as important indicators of climate change. In addition, the cryosphere provides important feedbacks to climate. The nature of cryospheric variables has necessitated that observations be made using a variety of methods involving *in situ* and remote-sensing measurements and a range of sensors. Here we concentrate on only the *in situ* based measurements.

Snow depth, water equivalent and extent

Snow depth is currently measured at first order synoptic weather stations, but with moves towards automation this observation may be lost at many stations. This would mean that snow area or extent may also no longer be derivable from these data. In the future it is expected that satellite observations of extent will be sufficient, but during the transition phase much valuable data may be lost.

Snow water equivalent measurements were introduced mainly for hydrological purposes. Current problems include the facts that the networks are decreasing, data are not always archived in digital form and they are not included in a global archive. These are significant deficiencies since water equivalent or snow mass is one of the most important cryospheric parameters, significant in understanding both feed back to climate from the cryosphere and detection of climate change.

Glaciers

Selected glaciers, especially in terms of their length, could be key indicators of climatic change. The World Glacier Inventory in Zurich maintains a global data set on these glaciers. More limited data on mass balance are also available on over 50 relatively small glaciers and glacier length changes are observed for about 1,000 glaciers. While there may be some gaps in a given climatic region, it is expected that currently sufficient glaciers are being measured for detection of climate change purposes. There is pressure on *in situ* monitoring programmes in many countries, so this is one area where remote sensing may need to play a key role in the future.

Ice sheets

Current observations are not sufficient to adequately describe the mass balance of the Antarctic and Greenland ice sheets to within 20% of their mass turnover. An improvement in mass balance estimates by a factor of five is required to determine the ice sheet contribution to present sea level rise. Major ice drilling programmes in Greenland and in the Antarctic are underway or planned, and the results from recent ice core studies indicating rapid past climate changes means these areas will likely be very important for climate research in the future.

Lake-ice freeze-up and break-up

More than 500 stations in both hemispheres collect data on lake freezing and thawing, but many stations are being closed. Currently the total number of stations available to the climate community would appear to be sufficient. Microwave remote sensing may play A role in assisting the monitoring of this attribute in the future.

Permafrost

The International Permafrost Association helps to coordinate the effort of observing permafrost. There is a need to rescue and activate earlier permafrost data, since these data sets may provide valuable information on detection of climate change.

Issue: *There is a need for improved mechanisms for cryospheric observations so that existing sites and networks can be better coordinated, enhanced and augmented.*

Recommendation T4. For cryospheric observations it is recommended that coordinating mechanisms should be improved by focusing initially on two areas namely permafrost and glacier monitoring, that are already relatively well organized.

During the early development of the plans of GCOS it was convenient to treat all cryospheric aspects comprehensively within a single panel and the Terrestrial Observation Panel for Climate took on this responsibility. It is now believed that it is appropriate for sea ice to be dealt with by the OOPC and for glaciers, ice sheets, snow variables and lake-ice and permafrost to remain the responsibility of TOPC.

5.4 The Biosphere

Over 3,000 sites exist globally, which could form the basis of an *in situ* network for the global observing systems. Significant and critical gaps in coverage already exist and these are expected to increase as funding resources become even more scarce. The majority of gaps are currently in the southern hemisphere, though there are notable exceptions primarily in Australia, Brazil, Chile and New Zealand. Further details will be found in the GCOS/GTOS Plan for Terrestrial Climate-related Observations GCOS (GCOS 1995b) and in Version 2.0 of the Plan due to be published shortly. These sites, along with major on going research efforts, such as the IGBP transect studies, will provide many of the needed sites. Some of these sites are already grouped into networks and are moving towards common procedures for measurements. Few of the existing sites measure all of the TOPC highest priority variables, though most measure at least some of them. Currently there are relatively few unbiasedly placed sites. These have been considered as crucial by the TOPC as they serve two purposes, only the first of which is strictly speaking a monitoring function, but both of which are necessary for an operational system: repeated measurements, for purposes of change detection; and one-time measurements, for assessing the state of the system and model parameterization.

GCOS/GTOS should develop a global demonstration project to show their ability to deliver a needed product, rapidly and cost-effectively. Such a product would have to be one with a wide range of uses and users. As one possibility it is suggested that the cluster of variables surrounding soil carbon be considered in development of a project.

Issue: *The preparation of global data sets involving ecological in situ data is a challenging area with relatively little prior experience. The utility of such data sets* *needs to be clearly demonstrated to the scientific community and policy- and decision-makers.*

Recommendation T5. The TOPC should develop a global demonstration project to test the ability of GTOS to deliver a needed terrestrial product rapidly and cost effectively. Soil carbon and its associated variables might be an appropriate test case.

GCOS/GTOS have so far concentrated on the planning aspects of these programmes. It is critically important that activities be initiated, as soon as possible, to demonstrate the importance and the unique role these global observing systems need to fulfil. This could take the form of demonstration or pilot projects at the regional or global levels. A draft of such a project has been prepared by members of the three global observing systems acting jointly. However it is still waiting final review by the steering committee of GTOS. The project that has been proposed for southeast Asia, has four purposes:

1. Demonstrate the national and regional level application and value of global observing systems (GCOS/GTOS/GOOS) data by:

   - Assisting countries in the development of a data system for exchange of information within the region;
   - Assisting countries in the development of their own seasonal to interannual climate predictions;
   - Modelling and assessing the potential impact of climate change on land use and fisheries production in the coastal zones; and
   - Providing the necessary training to carry out the above functions.

2. Extend existing Advanced Very High Resolution Radiometer (AVHRR) products into the coastal zones and make these products available to all nations in the area.

3. To test, demonstrate and refine the linkages within the proposed 5 tier hierarchy and particularly between *in situ* and space-based observations.

4. To make these data sets accessible via GCOS/GTOS/GOOS approved data access mechanisms, including the Internet, diskettes and paper copy.

Issue: *GCOS and GTOS have so far concentrated on the planning aspects of these programmes. It is critically important that activities be initiated, as soon as possible, to demonstrate the importance and the unique role these global observing systems need to fulfil. This could take the form of demonstration or pilot projects at the regional or global levels.*

Recommendation T6. The global observing systems should work towards the implementation of a regional pilot project aimed at demonstrating the utility of the global observing systems to developing countries.

In the absence of an existing international system, data and information management for the biosphere will have to rely primarily on the efforts of national institutions. Among recent national developments of international significance is the Distributed Active Archive Centre (DAAC) system in the US developed as part of NASA's Earth Observing System.

Recommendation T7. In terms of an overall framework for providing international linkages it is recommended that the data and information management system for terrestrial observations work closely with ICSU's World Data Centre System, IGBP-DIS and with UNEP's Global Resource

Information Database (GRID) programme. After the initial data centres are established, it is expected that others will be added to the system.

5.5 General issues for the hydrosphere, cryosphere and biosphere

The presentations and the discussion that followed identified a number of issues facing all three components, hydrological, cryological and ecological, of the land surface community. There are two issues that relate to coordination of sites, networks and data collection, two that relate to data and information management and one issue that relates to the overall development of the global observing systems.

. ***Coordination of Programmes:***

Many useful coordination efforts have been initiated by the International Long Term Ecological Research (ILTER) programme, the Consultative Group on International Agricultural Research (CGIAR) and others. However, in terms of coverage and the variables measured, the available terrestrial data collected to date are inadequate to meet the needs of global observing systems and their clients in national resource planning agencies and the global change research community.

Issue: *There is a need for mechanisms through which existing sites and networks can be coordinated, enhanced and augmented. The need is to establish a more cohesive global network in terms of methodological procedures and in data collection, geo-referencing, availability and quality control. For example, there is no overall coordinating mechanism for ecological sites and networks. Examples of critical specific variables for which there has been inadequate coordination include soil carbon, river discharge, and snow water equivalent.*

Issue: *Many of the existing stations are under financial constraints. This may be of serious concern because some of the sites critical for a global sampling strategy are likely to be discontinued. In addition, under these constraints there is little chance in filling the obvious gaps in the global distribution of sites or in strengthening the institutional capacity. Notable examples include hydrological networks in Africa and ecological sites in the newly independent states of the former Soviet Union.*

Recommendation T8. TOPC should prioritize the questions to be answered, identify the associated requirements and select critical *in situ* terrestrial sites for achieving the climate-related objectives of GCOS and GTOS. GTOS needs to undertake a similar activity for meeting its other objectives.

Recommendation T9. Based on their prioritized requirements of the TOPC, GCOS and GTOS should work with existing major programmes (e.g. CGIAR, ILTER) to develop implementation plans. This needs to be done for all three terrestrial subject areas since it is unlikely that hydrology, cryology and ecology will be well served by a single integrated plan.

. ***Data and Information Management:***

While GCOS and GTOS should oversee development of a coordinated information system design that identifies the responsibilities of all cooperating agencies and programmes, it should not anticipate new institutions to carry out the tasks required for its implementation. Instead, these tasks should be performed by the existing world and national observing systems, telecommunications networks, and data and processing centres. GCOS and GTOS should act to ensure data are collected, validated, processed and archived to the exacting standards necessary. They should also review, monitor and coordinate activities between groups to ensure proper data are being collected and can be exchanged easily. A related but separate issue is the ability of centres to acquire the data they need for the user communities and to have access to it in appropriate formats.

Issue: *There is a need for a mechanism through which existing sites and networks can be coordinated, enhanced and augmented.*

Issue: *The terrestrial community in terms of data management is not well served for many observations. These data, in general, are poorly managed and poorly accessible to those outside of the project for which the data are collected. Terrestrial in situ data present some real obstacles that need to be overcome for effective data exchange, e.g., data are in inappropriate formats and resources are often not available for conversion, national sensitivities, data ownership and commercial considerations.*

Recommendation T10. DIMP in conjunction with TOPC should give high priority to developing an effective data policy and management plan appropriate to the specific problems of terrestrial data exchange.

Recommendation T11. DIMP and TOPC should develop an on-line meta-database providing details concerning the existing terrestrial networks currently collecting *in situ* terrestrial data of direct relevance to the prioritized requirements provided by the global observing systems.

. *Relative Development of the Global Observing Systems:*

Issue: *There is an overarching concern that the disparity in the maturity of the global observing systems, in particular the relatively slow organizational development of GTOS, is hampering progress in generating an integrated set of terrestrial in situ data requirements, implementation and the development of an integrated data management plan.*

Recommendation T12. The TOPC has made substantial progress in developing its plans in spite of the fact that the GTOS secretariat is not yet fully operational. It is imperative that the GTOS Sponsors assure that the necessary resources (financial and human) are available to staff the GTOS secretariat, and that its activities are started as soon as possible.

6. CALIBRATION AND VALIDATION OF SPACE-BASED OBSERVATIONS

The session focused on the *in situ* data necessary to ensure that satellite remotely sensed data are properly calibrated and validated. Four presentations were made and this was followed by a general discussion.

6.1 Summary of presentations

IN SITU OBSERVATIONS FOR CALIBRATION AND VALIDATION: A CEOS OVERVIEW

The CEOS defines calibration as the process of quantitatively defining the system response to known, controlled signal inputs, and validation as the process of assessing by independent means the quality of the data provided. Only with both elements of calibration and validation present can higher level products be successfully generated from satellite sensor data, and changes in these products identified as either a change in the instrument or a change in the environment.

By the year 2000, atmospheric, land and ocean observations will be possible from around 60 earth observation satellites, which in turn will lead to hundreds of derived products. The calibration of this range of satellite data and products is a major task. The CEOS WGCV was established to provide a forum for international dialogue on calibration and validation issues, to enhance coordination, to promote international cooperation and to focus activities in the field.

Today, calibration and validation activities are sensor, rather than product driven, but there is an increasing need for product validation and this has to be based on *in situ* observations. A further problem is that environmental factors can generate anomalies, even when sensors remain stable, e.g., volcanic gas. Unfortunately, calibration and validation requirements for different parameters are not usually complementary. Furthermore, calibration and validation sites are often mutually exclusive. Calibration calls for spatial and temporal homogeneity and stability, yet validation is often associated with the need for variable sites.

The CEOS WGCV has two tasks: sensor-specific calibration and validation of geophysical parameters and other derived products. Most effort to date has been placed on sensor-specific Calibration/Validation activities, but there are proposals for cross calibration activities and the identification of common test sites.

ADVANCED EARTH OBSERVATION SATELLITE (ADEOS) CALIBRATION

The ADEOS calibration programme will cover all the main 8 instruments on board the satellite. The complete range of activities will take time with some value added products being available after 6 months. The presentation also showed some of the first images of the ADEOS satellite from the Advanced Visible Near-Infrared Radiometer (AVNIR) instrument.

The presentation focused on Ocean Color Temperature Scanner (OCTS). A range of techniques is proposed which involve *in situ* and airborne data sets to be collected. Some of these involve collaboration such as that for the OCTS instrument. Here, test sites in California (and offshore) and Japanese waters are being used. Vicarious calibration techniques will be used for OTCS validation.

Validated OCTS products for the sea around Japan are expected after 6 months with a global product available after 12 months.

THE EARTH OBSERVING SYSTEM (EOS) VALIDATION ACTIVITIES

International coordination is providing a focused international satellite monitoring programme with a common science agenda (e.g., Integrated Global Observing Strategy (IGOS), IGBP, CEOS). A coordination activity needs to be developed associated with the validation of the derived global data products from such a programme. There are common validation needs for different sensors, platforms and agencies. The higher order data products developed by these sensors are intended for use by the international science community and this in itself will provide a level of international validation that will benefit from an appropriate level of coordination. These science users will need data products with known and stated accuracy. It is clear that there are insufficient resources for any one programme to provide validation of global data fields. In addition, there is a limited pool of scientists in any one country to perform validation measurements, especially those that require high technology instrumentation. A large number of *in situ* measurements are already being taken by national and international agencies or organizations with little overall coordination or data management. There is the possibility to augment some of these existing networks to assist in satellite product validation. These reasons and others combine to make international coordination essential for global satellite product validation.

Science users currently need consistent fields of geophysical parameters to drive and validate regional and global models. The demand is for higher order satellite products beyond satellite radiances using community algorithms based on peer reviewed journal articles, tailored for model input (time and space scales). These input data need to be well calibrated which is a prerequisite for product validation. Similarly quality assurance, quality control and systematic product evaluation needs to be performed as part of the product chain prior to product validation.

Product validation needs to be undertaken through independent measurement of geophysical parameters at a spatial scale appropriate for the sensing system to characterize the product accuracy, consistency and uncertainties. Validation is needed with spatial and temporal representativeness over the range of environmental conditions encountered by the product. The level of validation should be tailored to satisfy intended use of the data. In the context of the global observing systems, the satellite validation should be driven by their prioritized science objectives. The existing *in situ* networks can provide a good basis for developing the satellite product validation.

NASA's EOS provides a good case study on product validation issues and demonstrates the overlap between the data needed for satellite product validation and *in situ* data needed to meet the climate objectives of the three global observing systems. EOS involves multiple platforms, multiple instruments, multiple science objectives and multiple products and as such provides a microcosm of the validation issues for the broader international satellite user community.

In the EOS programme, product validation is a contractual obligation of the instrument teams that are supported to undertake scientific research using the data they generate. It is recognized that an important step in the validation is performed by the final data users. EOS has established a Validation Science Office responsible for coordinating instruments and platforms. Validation planning is currently underway; instrument teams are generating coordinated validation plans, workshops have been held and the utility of existing national monitoring networks are being evaluated. There is an urgent need to internationalize the EOS validation coordination for which there is currently no workable mechanism. The EOS Validation Program is being designed based on discipline and product. The validation plan for the Moderate Resolution Imaging Spectroradiometer (MODIS) has three components: field campaigns, ground validation test sites and airborne measurements. The land validation community has adopted and adapted the TOPC GHOST to meet EOS test site validation needs (section 5.1).

The following recommended actions assume that the satellite data products have been prioritized for global change research according to their significance, uncertainty and measurement feasibility. This prioritization is appropriate for joint activities of TOPC and CEOS.

There is a need to establish a validation coordination mechanism to develop a coordinated validation plan(s) to match the coordinated satellite observation programme. This coordination mechanism needs to include a combination of satellite and *in situ* communities. CEOS is the obvious forum for this coordination but the existing WGCV would need to be reconstituted to meet this enhanced commitment.

There is a need to determine the appropriate level of validation needed for the products. This needs to be determined by the science community, e.g., through the IGBP and WCRP. Similarly, timelines for product data availability are needed. This is clearly within the remit of CEOS. It is important to reduce the current list of satellite derived products to a smaller number of high priority products and use these initially to provide a pathfinding activity for international validation coordination. This task should be undertaken by the global observing systems. There is also a need to determine the synergies and efficiencies between existing individual instrument product validation programmes and plans, and engage instruments currently in design-phase in the validation coordination process. This task is more suited to the WGCV. It will be important to involve the *in situ* monitoring communities in this design to ensure that the plans are implementable.

There is a need to evaluate the utility of existing *in situ* monitoring networks to provide the necessary validation data needed by the global observing systems and to work up a short-list of candidate sites and perform an in-depth assessment of capacity. It is also essential to scope the predicted costs and state clearly benefits of the proposed coordinated validation activities. It will then be necessary to seek commitment from agencies to implement validation programmes and to proceed to implement pilot activities to test the measurement and data protocols and demonstrate the benefit of validation coordination.

Finally, it will be important to ensure close involvement of data producers and algorithm developers in this process, to encourage feedback from product validation programmes to algorithm refinement and eventual data reprocessing.

OCEANIC CALIBRATION/VALIDATION ISSUES; COMPUTATION OF SEA SURFACE TEMPERATURE AND SEA SURFACE SALINITY

A global sea surface temperature (SST) analysis is computed at the US National Centre for Environmental Prediction (NCEP). The analysis provides weekly data from November 1981 to the present on a one-degree grid using optimal interpolation (OI). The analysis uses *in situ* and satellite SSTs plus SSTs simulated by sea-ice cover. Because the number of *in situ* observations is relatively small compared to the number of satellite observations, the satellite data dominate the analysis. However, the *in situ* data are critically important in correcting the satellite data for biases before these data are used in the OI. The complete analysis is designed to emphasis the relative strength of each type of date to produce high quality global SST fields. Comparisons with independent data show that *in situ* data are needed for bias correction on five- to ten-degree spatial scales. However, there is no clear preference for the type of the *in situ* data and either ship or buoy data are sufficient.

An analysis of sea surface salinity (SSS) was carried out for the tropical Pacific. This analysis was needed to help eliminate sea level errors in the NCEP Pacific ocean model that were caused by neglect of the interannual signal in salinity. Because salinity data are so sparse, the analysis can only be done using the SSS ship track data. However, these data do not provide a complete field in the tropical Pacific. The surface forcing fields of SSS [evaporation minus precipitation (E-P)] were used to fill in the SSS data. This was done by computing empirical orthogonal functions (EOFs) from the E-P anomalies. The first six spatial EOFs were then selected and used as basis functions for the SSS data. This technique was applied to the SSS data to yield full monthly anomaly fields of SSS for the tropical Pacific from 1979-1995. The SSS fields will be evaluated by comparison with other salinity data and will be tested using the NCEP ocean model. The international variability of SSS in the western Pacific is important and it is critical to continue the SSS observation in this region.

6.2 Plenary discussion

The question of whether calibration and validation should be sensor or product driven was discussed. In general, calibration is sensor driven and should primarily be the responsibility of the space agency concerned. Validation is more complex, because of the need for long-term sensor validation as well as product validation. It was accepted that the data users should be involved in or lead discussions on validation. A further issue is the role of assimilation. In meteorology, it is common to use four dimensional data assimilation techniques involving integration of raw calibrated satellite and *in situ* data in models and providing an output, which is effectively a high-level, validated product. It was accepted that in the future the global observing system programmes may use assimilation techniques more widely, but in any case will require multi-sensor products. These trends will require a greater involvement of the data users.

An important issue was the need for information on the calibration and validation procedures being provided as part of the product and thus providing an 'audit' trial of processing. This is seen by some groups as essential for understanding the quality of the data being used. It also relates to the problem of calibration of equipment. This issue is often underestimated, but is essential for some global products to be accurately developed.

There was a discussion of elimination of systematic bias. For example, a dawn, morning, or afternoon orbit may introduce a systematic bias that needs to be understood, particularly if multi-system products are being generated. One example is SST products, where satellites observe the skin temperature, which has greater daily variability than the bulk temperature, which is the *in situ* observation.

It was agreed that much more could be done with respect to improved collaboration. Satellite calibration and validation can make much better use of the existing *in situ* data measurement programmes. This requires better knowledge of ongoing activities to provide a basis for improved cooperation. It could even be possible to add extra data collection procedures to existing *in situ* programmes to gain greater overall benefit. One issue is the need and realism of having common test sites for calibration. If possible, a 'common core' of measurements should be identified which may then be added to four specific campaigns. Are protocols for data collection and handling possible? The meeting welcomed the CEOS proposal to address this issue.

In the debate on collaboration the role of CEOS was discussed. It was agreed that the WGCV should consider broadening its role. One aim would be to ensure a better and more coordinated input from the affiliates. A second aim could be to provide better information on future calibration and validation activities. A third aim would be to act as a forum for setting out the individual agency priorities as a basis for more effective integrated planning of calibration and validation activities. There is also the possibility of CEOS providing a framework for specific multi-agency validation activities. It was also pointed out that calibration/validation data handling could be an issue for the CEOS Working Group on Information Systems and Services (WGISS) which has responsibility for this subject.

Overall, the group felt that calibration and validation should be seen as an integral part of the mission specification. The WGCV's activities have tended so far to concentrate on calibration activities and there should be more consideration of the validation of satellite geophysical data. This might involve restructuring of the WGCV.

6.3 Recommendations

Recommendation C1. Recognizing that all the global observing systems will soon be affiliates of CEOS, the global observing systems should coordinate their participation in CEOS though the GOSSP to optimize input to the Members for their planning of validation.

Recommendation C2. The GOSSP should develop a scheme for identifying priorities for validation issues.

Recommendation C3. CEOS should consider enhancing the activities of the WGCV to address international co-ordination and collaboration of satellite product calibration and validation. For validation this should take into account priorities identified by the global observing systems.

Recommendation C4. On the basis of the priorities established above the WGCV should develop a pilot project to address issues such as measurement protocols, test regimes and data management in relation to calibration and validation.

Recommendation C5. CEOS members should maintain electronic bulletin boards providing access to up-to-date consensus calibration information for their sensors and CEOS members should provide access to them.

Recommendation C6. The meeting endorsed the recommendation from WGCV to the CEOS plenary concerning cross-calibration activities and establishment of test sites.

7. CROSS-CUTTING ISSUES FOR GCOS, GOOS AND GTOS

7.1 Climate assessment

Presentations on the Land, Ocean and Atmospheric Global Observing Systems identified the process of climate assessment as a principal customer for their products.

Recommendation X1. The Sponsors of the observing systems should seek a mechanism that will allow the scientific advisory bodies to consult with the IPCC regarding data requirements for future assessments.

As a way to illustrate the powerful organizing principle behind the joint exploitation of data from land, ocean and atmosphere it is recommended that a simple pilot project be undertaken. The area in which the goals of all the global observing systems are identical is the one of climate.

In particular, it is believed that many data exist in various networks that have not yet been exploited and, with not too great an effort, could be brought together. One case that appears to offer significant possibilities in this regard is global precipitation.

Recommendation X2. It is therefore recommended that a short case study be instituted to examine the improvements in precipitation analyses to use as input for IPCC assessment.

7.2 Environmental indicators

There are several parallel activities to climate assessment involving non-climate issues for which products of the global observing systems should be relevant and useful. Various intergovernmental and non-governmental organizations are seeking, among other things, indicators for sustainable development, change in the environment and for soil quality. The Commission on Sustainable Development has adopted a work programme on indicators of sustainable development including economic, social, environmental and institutional indicators. The initial pragmatic list of indicators for which methodologies have been developed was based on measures for which adequate global data were available. For many environmental dimensions of interest to the global observing systems, the data presently available are inadequate, which is one reason we need operational observations on the dynamics of the resource base and on key trends that can be projected through indicators. If the global observing systems can generate the data for indicators on critical issues of policy interest such as food security and land-based activities affecting the marine environment, then there are mechanisms to include these indicators among those recommended for international use. The following recommendation was therefore made.

Recommendation X3. The scientific and technical bodies of the observing systems should, through their sponsoring agencies, (1) enter into a dialogue with the bodies responsible for the development of the "indicators" strategy to make them aware of the valuable information resource that resides within the developing observing systems, and (2) seek a mechanism for the continuing involvement and support of the observing systems for this strategy.

7.3 Prioritization

All the observing systems recognized the paramount importance of establishing an explicit methodology for prioritization of observing network elements. It was noted that there are several different approaches:

(a) The NAOS initiative approached prioritization through a loop of combined objective and subjective evaluation. The evaluation parameters included scientific impact, fiscal benefits, cost and risks (fragility) of the observing elements. The objective evaluation included impact and sensitivity studies to evaluate observing system design and production methods (analysis, assimilation, modelling). All were combined with subjective evaluations to guide the evolution of design and to set priorities;

(b) The climate surface and upper air reference networks were designed with specific objectives in mind, such as climate change and assessment and stewardship (preservation) of the network. Prioritization of candidate sites depended on subjective evaluation of the contribution of that site to meeting these objectives;

(c) The ocean observing system used a method that mapped the feasibility and difficulty of taking measurements against the impact on the scientific or user product. For the climate module observing system experiments were possible, but most the judgment was subjective. The prioritization for the modules was driven by phenomenological and/or regional objectives;

(d) The development of priorities within the terrestrial component relied on the GHOST tiers concept. Relevance, practicality and scientific objectives were factored into the prioritization process;

(e) The remote sensing community sought a compromise between extreme targets and the minimum workable configuration for horizontal resolution, accuracy, etc.

It was agreed that a completely uniform approach to prioritization was probably not possible, but that certain key steps in developing prioritization would assist the work of the global observing systems.

Recommendation X4. It was agreed the following steps should be included in a (common) prioritization process.

Articulate the objectives by phenomenon, or by "clusters" of requirements;

Explicitly identify the products and benefits attached to the component of the observing system under consideration;

Examine the feasibility, difficulty, practicality of implementing elements;

Discuss the relevance and impact of the element with respect to the objectives and cost;

Develop as appropriate within a framework of a hierarchical observing system.

7.4 Guidelines and principles for the observing systems

Recommendation X5. The following common set of principles should be adopted for long-term observations based on those proposed by Karl (1996) with reference to long-term climate networks:

Build on existing mechanisms, plans and systems as appropriate;

The impact of changed observing practices and technology should be thoroughly investigated prior to their implementation. The sensitivity of objectives, applications and products to the change should be determined;

Baseline reference networks (minimal configurations) provide strength and a foundation for observing systems' development and evolution;

The global observing systems should exploit a common data and information management practice to ensure appropriate and adequate metadata are available on calibration, modification, etc.;

Routine and permanent mechanisms for evaluating and monitoring observing system performance should be put in place.

It was not possible to reach a common definition of what constitutes an operational network. GOOS uses several criteria including whether the element or method is systematic, routine, long-term, relevant and cost-effective. Meteorology has rather quite precise definitions of operational observing system contributions. The climate and atmospheric composition parts of meteorology have less rigorous distinctions. For remote sensing, continuity and longevity were critical factors. GTOS has yet to adopt a strict definition. It was agreed that the definition should be driven by the nature of the *services* resulting from networks and their elements and that it provides a means for coordinating the development of the observing systems together.

7.5 Data assimilation

The importance of data assimilation techniques for the oceans and the atmosphere and their impact on observational strategies was recognized along with the key need to develop these methods for the land where they are least well developed at present.

Recommendation X6. It was recommended that an international meeting should be convened with the focus on data assimilation jointly sponsored by the three Global Observing Systems.

7.6 Disparities in the development of the global observing systems

There is an overarching concern that the disparity in the maturity of the global observing systems and in particular the slow organizational development of GTOS is presenting a major obstacle to the desired integration of common components of the observing system.

A current manifestation is the difficulty in establishing the common data requirements and their prioritization along with data management planning particularly with respect to the terrestrial *in situ* observations needed by the global observing systems as a whole.

Recommendation X7. The G3OS Sponsors are urged to encourage a more rapid development of GTOS as an organization in terms of its secretariat and constituent panels, to bring it to a comparable stage of development to the other observing systems.

7.7 Considerations of overall global observation strategies

There was discussion about the development of integrated global observation strategies and how *in situ* observations might relate to these. Presentations were made outlining various proposals that have been made by a number of individual national organizations and by CEOS. As a result of these discussions the following recommendation was made:

Recommendation X7. It is recommended to the scientific advisory bodies of the global observing systems (GCOS, GOOS, and GTOS) that they continue to explore prospects for involvement in the continuing discussions on the development of integrated strategies for global observations. In particular it is recommended to the scientific advisory bodies:

That representatives of the global observing systems engage with CEOS in better defining their roles as affiliates, especially with respect to calibration and validation, associated with the evolving emphases of CEOS activities;

That the work of the global observing systems contribute to an improved understanding of the roles of *in situ* and remote sensing observations through a more explicit emphasis on their requirements based on an end-to-end view of key products, which have been generated;

That the results of this meeting be reported at the CEOS plenary in Canberra, Australia, by the chair of the JSTC of GCOS.

8. REFERENCES

GCOS (1994). *Report of the GCOS/GTOS Terrestrial Observation Panel, first session,* Arlington, VA, USA, June 28-30, 1994, GCOS-8 (WMO/TD-No. 642 and UNEP/EAP.MR/94-9).

GCOS (1995a). *Plan for the Global Climate Observing System,* GCOS-14, (WMO/TD-No. 681).

GCOS (1995b). *GCOS/GTOS Plan for Terrestrial Climate-related Observations,* Version 1.0, November 1995, GCOS-21 (WMO/TD-No. 721 and UNEP/EAP.TR/95-07).

GCOS (1995c). *Plan for Space-based Observations,* Version 1.0, June 1995, GCOS-15 (WMO/TD-No. 684).

ICSU/UNEP/FAO/UNESCO/WMO (1996). *Global Terrestrial Observing System (GTOS): Turning a sound concept into a practical reality* - UNEP/EAP.TR.95-08, Division of Environment Information Programme, P.O. Box 30552, Nairobi, Kenya.

IPCC (1995). *Second Assessment Report of the Intergovernmental Panel on Climate Change,* J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell (eds.), Cambridge University Press, Cambridge, UK.

Karl, T. (1996). *Long-term Climate Monitoring by the Global Climate Observing System,* Kluwer Academic Publishers, Dordrecht (also appeared as Volume 31, Nos 2-4 Climatic Change).

Ocean Observing System Development Panel (1995). *Scientific Design for Common module of the Global Ocean Observing System and the Global Climate Observing System: An Ocean Observing System for Climate.* Department of Oceanography, Texas A&M University, College Station, Texas, 265pp.

Smith, N.R., N. Andersen, J.M. Bewers, O. Brown, P. Dexter, and T. Dickey, (1996). *The Global Ocean Observing System: The Role of In Situ Observations* (A background paper for the meeting on *In Situ* Observations for the Global Observing Systems, Geneva, Switzerland, 10-13 September, 1996.)

9. APPENDICES

9.1 Appendix 1 Agenda

Tuesday 10 September

OPENING SESSION		Chairman:	J. Townshend
1400	Welcome and Opening Remarks		M. Jarraud (WMO) A. Dahl (UNEP) J.-P. Rebert (IOC) D. Norse (FAO) O. Brown (ICSU)
1415	Objectives of the Meeting		J. Townshend
1445	Role of *in situ* Observations for GCOS		T. Spence
1515	Role of *in situ* Observations for GTOS		J. Cihlar
1545	*Break*		
1600	Role of *in situ* Observations for GOOS		O. Brown
1630	Discussion	Leader:	J. Townshend
1730	*Adjourn*		

Wednesday 11 September

ATMOSPHERIC SYSTEMS		Chairman:	R. Landis
0900	Guidelines and Principles for Climate Monitoring		T. Karl
0930	IPCC Requirements		I. Rasool
0940	World Weather Watch		R. Landis
1000	Global Atmosphere Watch		F. Delsol
1015	*Break*		
1030	Aircraft and Future Observing Systems		R. Fleming
1050	North American Observing System (NAOS)		F. Zbar
1105	Composite Observing System for the North Atlantic (COSNA)		S. Mildner
1115	Discussion	Leader:	T. Karl
1200	*Lunch*		

TERRESTRIAL SYSTEMS Chairman: C. Magadza

1330	Issues		R. Scholes
1400	Existing Hydrological Networks		J. Rodda
1425	Existing Cryospheric Networks		C. Kottmeier
1450	*Break*		
1505	Existing Terrestrial Systems		D. Norse
1530	Discussion	Leader:	J. Cihlar
1630	Drafting Sessions		

Thursday 12 September

OCEAN SYSTEMS Chairman: G. Needler

0900	GOOS Climate Module		N. Smith
0935	GOOS Health of the Oceans Module		M. Bewers
1005	GOOS Living Marine Resources Module		T. Dickey
1030	*Break*		
1045	Ocean Implementation Issues		P. Dexter
1110	Discussion	Leader:	N. Smith
1200	*Lunch*		

CALIBRATION/VALIDATION OF SATELLITE DATA
Chairman: D. Williams

1330	Introduction		D. Williams
1340	*In situ* Observations Cal/Val CEOS Overview		A. Belward
1405	The Earth Observation System Validation Activities		C. Justice
1425	ADEOS calibration		T. Uesugi
1445	*Break*		
1515	Oceanic Cal/Val Issues		D. Reynolds
1530	Discussion	Leader:	O. Brown
1630	Drafting Sessions		

Friday 13 September

CONCLUSIONS AND RECOMMENDATIONS

Chairman: J. Townshend

Presentation and discussion of atmosphere, land and oceans recommendations and conclusions.

0900	Atmosphere	T. Karl
0930	Land	C. Justice
1000	Oceans	N. Smith
1030	*Break*	
1045	**Cross-cutting issues**	
	Cal/val session	D. Williams
	Data and information management	G. Withee
	Links with other strategic approach	B. Embleton D. Williams D. Hinsman O. Takasawa R. Schiffer
1200	*Lunch*	
1300	**Other linking issues between global observing systems**	N. Smith
1400	**The way forward**	J. Townshend
1530	*Close*	

9.2 Appendix 2 Organizing Committee and Session Organizers

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9.4 Appendix 4 Acronyms

ADEOS	Advanced Earth Observing Satellite
AMDAR	Aircraft Meteorological Data Relay
AMS	American Meteorological Society
ASAP	Automated Shipboard Aerological Programme
ASDAR	Aircraft to Satellite Data Relay
AVHRR	Advanced Very High Resolution Radiometer
AVNIR	Advanced Visible and Near-Infrared Radiometer
Cal/Val	Calibration and Validation
CEOS	Committee on Earth Observation Satellites
CGC	Co-ordination Group for the Composite Observing System for the North Atlantic
CGIAR	Consultative Group on International Agricultural Research
COADS	Comprehensive Ocean Atmosphere Data Set
COSNA	Composite Observing System for the North Atlantic
CZ	Coastal Zone
DAAC	Distributed Active Archive Center
DIMP	Data and Information Management Panel
EOF	Empirical Orthogonal Functions
EOS	Earth Observing System
E-P	Evaporation minus Precipitation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organization
FRIEND	Flow Regimes from International Experiments and Network Data
GAW	Global Atmosphere Watch
GCIP	GEWEX Continental-scale International Project
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GEMS	Global Environmental Monitoring System
GEWEX	Global Energy and Water Cycle Experiment
GHOST	Global Hierarchical Observing Strategy
GLOBEC	Global Ocean Ecosystem Dynamics
GOOS	Global Ocean Observing System
GOS	Global Observation System
GOSSP	Global Observing Systems Space Panel
GPCC	Global Precipitation Climatology Centre
GRDC	Global Runoff Data Centre
GRID	Global Resource Information Database
GTOS	Global Terrestrial Observing System
G3OS	Global Observing Systems of GCOS, GOOS and GTOS
HOTO	Health Of The Oceans
HWRP	Hydrology and Water Resources Programme
ICSU	International Council of Scientific Unions
IGAC	International Global Atmospheric Chemistry Programme
IGBP	International Geosphere-Biosphere Programme
IGBP-DIS	IGBP-Data and Information System
IGOS	Integrated Global Observing Strategy
IHP	International Hydrological Programme
ILTER	International Long Term Ecological Research
IOC	Intergovernmental Oceangraphic Commission

IPCC	Intergovernmental Panel on Climate Change
JGOFS	Joint Global Ocean Flux Study
J-GOOS	Joint Scientific and Technical Committee for GOOS
JSTC	Joint Scientific and Technical Committee
LBA	Large Scale Biological-Atmosphere Experiment Amazonia
LMR	Living Marine Resources
LOICZ	Land Ocean Interactions in the Coastal Zone
MODIS	Moderate Resolution Imaging Spectroradiometer
NAOS	North American Atmospheric Observing System
NASA	National Aeronautics and Space Administration
NCEP	National Centre for Environmental Prediction
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
OCTS	Ocean Color Temperature Scanner
OI	Optimum Interpolation
OOPC	Ocean Observation Panel for Climate
PALACE	Profiling Automatic Lagrangian Circulation Explorer
RBSN	Regional Basic Synoptic Network
SEG	Scientific Evaluation Group
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
TAO	Tropical Atmosphere Ocean
TOPC	Terrestrial Observation Panel for Climate
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
VOS	Volunteer Observing Ship
WCRP	World Climate Research Programme
WGCV	Working Group on Calibration and Validation
WGISS	Working Group on Information Systems and Services
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization
WWW	World Weather Watch

LIST OF GCOS PUBLICATIONS

GCOS-1 (WMO/TD-No. 493)	Report of the first session of the Joint Scientific and Technical Committee for GCOS (Geneva, Switzerland, April 13-15, 1992)
GCOS-2 (WMO/TD-No. 551)	Report of the second session of the Joint Scientific and Technical Committee for GCOS (Washington DC, USA, January 11-14, 1993)
GCOS-3 (WMO/TD-No. 590)	Report of the third session of the Joint Scientific and Technical Committee for GCOS (Abingdon, UK, November 1-3,1993) [ftp://www.wmo.ch/Documents/gcos/jstc-3.txt]
GCOS-4 (WMO/TD-No. 637)	Report of the fourth session of the Joint Scientific and Technical Committee for GCOS (Hamburg, Germany, September 19-22, 1994) [ftp://www.wmo.ch/Documents/gcos/jstc-4.txt or /jstc-4.wp5]
GCOS-5 (WMO/TD-No. 639)	Report of the GCOS Data System Task Group (Offenbach, Germany, March 22-25, 1994) [ftp://www.wmo.ch/Documents/gcos/dstg.txt or /dstg.wp5]
GCOS-6 (WMO/TD-No. 640)	Report of the GCOS Atmospheric Observation Panel, first session (Hamburg, Germany, April 25-28, 1994) [ftp://www.wmo.ch/Documents/gcos/aop-1.txt or /aop-1.wp5]
GCOS-7 (WMO/TD No. 641)	Report of the GCOS Space-based Observation Task Group (Darmstadt, Germany, May 3-6, 1994) [ftp://www.wmo.ch/Documents/gcos/sotg.txt or /sotg.wp5]
GCOS-8 (WMO/TD No. 642) (UNEP/EAP.MR/94-9)	Report of the GCOS/GTOS Terrestrial Observation Panel, first session (Arlington, VA, USA, June 28-30, 1994) [ftp://www.wmo.ch/Documents/gcos/top-1.txt or /top-1.wp5]
GCOS-9 (WMO/TD-No. 643)	Report of the GCOS Working Group on Socio-economic Benefits, first session (Washington DC, USA, August 1-3, 1994) [ftp://www.wmo.ch/Documents/gcos/wgsb-1.txt or /wgsb-1.wp5]
GCOS-10 (WMO/TD-No. 666)	Summary of the GCOS Plan, Version 1.0, April 1995 [ftp://www.wmo.ch/Documents/gcos/gps-ver1.txt or /gps-ver1.wp5]
GCOS-11 (WMO/TD-No. 673)	Report of the GCOS Data and Information Management Panel, first session (Washington DC, USA, February 7-10, 1995) [ftp://www.wmo.ch/Documents/gcos/dimp-1.txt or /dimp-1.wp5]
GCOS-12 (WMO/TD-No. 674)	The Socio-economic Benefits of Climate Forecasts: Literature Review and Recommendations (Report prepared by the GCOS Working Group on Socio-economic Benefits), April 1995 [ftp://www.wmo.ch/Documents/gcos/wgsb-1rr.txt or /wgsb-1rr.wp5]

GCOS-13 (WMO/TD-No. 677)	GCOS Data and Information Management Plan, Version 1.0, April 1995 [ftp://www.wmo.ch/Documents/gcos/dp-ver1.txt or /dp-ver1.wp5]
GCOS-14 (WMO/TD-No. 681)	Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995 [ftp://www.wmo.ch/Documents/gcos/gp-ver1.txt or /gp-ver1.wp5]
GCOS-15 (WMO/TD-No. 684)	GCOS Plan for Space-based Observations, Version 1.0, June 1995 [ftp://www.wmo.ch/Documents/gcos/sp-ver1.wp5] (wp version only)
GCOS-16 (WMO/TD-No. 685)	GCOS Guide to Satellite Instruments for Climate, June 1995 (will not be on FTP Server)
GCOS-17 (WMO/TD-No. 696)	Report of the GCOS Atmospheric Observation Panel, second session (Tokyo, Japan, March 20-23, 1995) [ftp://www.wmo.ch/Documents/gcos/aop-2.txt or /aop-2.wp5]
GCOS-18 (WMO/TD-No. 697) (UNEP/EAP.MR/95-10)	Report of the GCOS/GTOS Terrestrial Observation Panel, second session (London, UK, April 19-21, 1995) [ftp://www.wmo.ch/Documents/gcos/top-2.txt or /top-2.wp5]
GCOS-19 (WMO/TD-No. 709)	Report of the GCOS Data Centre Implementation/Co-ordination Meeting (Offenbach, Germany, June 27-29, 1995) [ftp://www.wmo.ch/Documents/gcos/dcc-1.txt or /dcc-1.wp5]
GCOS-20 (WMO/TD-No. 720)	GCOS Observation Programme for Atmospheric Constituents: Background, Status and Action Plan, September 1995 [ftp://www.wmo.ch/Documents/gcos/atmcons.txt or /atmcons.wp5]
GCOS-21 (WMO/TD-No. 721) (UNEP/EAP.TR/95-07)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 1.0, November 1995 [ftp://www.wmo.ch/Documents/gcos/top-ver1.wp5]
GCOS-22 (WMO/TD-No. 722)	Report of the fifth session of the Joint Scientific and Technical Committee for GCOS (Hakone, Japan, October 16-19, 1995) [ftp://www.wmo.ch/Documents/gcos/jstc-5.wp5]
GCOS-23 (WMO/TD-No. 754) (UNEP/DEIA/MR.96-6) (FAO GTOS-1)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, third session (Cape Town, South Africa, March 19-22, 1996) [ftp://www.wmo.ch/Documents/gcos/top-3.wp5]

GCOS-24 (WMO/TD-No. 768) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, first session (Miami, Florida, USA, March 25-27, 1996) [ftp://www.wmo.ch/Documents/gcos/oopc-1.wp5]
GCOS-25 (WMO/TD-No. 765) (UNEP/DEIA/MR.96-5)	Report of the GCOS Data and Information Management Panel, second session (Ottawa, Ontario, Canada, May 14-17, 1996) [ftp://www.wmo.ch/Documents/gcos/dimp-2.wp5]
GCOS-26 (WMO/TD-No. 766)	Report of the Joint CCl/CBS Expert Meeting on the GCOS Surface Network (Norwich, UK, March 25-27, 1996) [ftp://www.wmo.ch/Documents/gcos/cbs-1.wp5]
GCOS-27 (WMO/TD-No. 772) (UNEP/DEIA/MR.96-7)	Report of the Expert Meeting on Hydrological Data for Global Observing Systems (Geneva, Switzerland, April 29-May 1, 1996) [ftp://www.wmo.ch/Documents/gcos/hwr-1.wp5]
GCOS-28 (WMO/TD-No. 793) (UNEP/DEIA/MR.97-3)	*In Situ* Observations for the Global Observing Systems (Geneva, Switzerland, September 10-13, 1996) [ftp://www.wmo.ch/Documents/gcos/insitu.wp5]