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REPORT OF THE GCOS/WCRP
ATMOSPHERIC OBSERVATION PANEL
FOR CLIMATE

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REPORT OF THE ATMOSPHERIC OBSERVATION PANEL FOR CLIMATE

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REPORT OF THE GCOS/WCRP ATMOSPHERIC OBSERVATION PANEL FOR CLIMATE

1. ORGANISATION OF THE SESSION

1.1 Opening

The GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC)¹ met for the third time at the European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, United Kingdom, 19-22 August 1997. It was the first meeting under joint sponsorship with the World Climate Research Programme (WCRP). The meeting was formally opened by Dr Burridge, Director of the ECMWF. He particularly noted in his introduction the connection between the Global Climate Observing System (GCOS) and the European Re-Analysis (ERA) project and the importance of detecting climate aspects using consistent global observations.

1.2 Welcome and Conduct of the Meeting

On behalf of the Panel, the AOPC Chairman, Dr Manton, thanked the local organiser, Dr Gibson, head of the ERA project, for the hospitality and secretarial support provided by ECMWF. He welcomed all AOPC participants at the Council Chamber of the ECMWF. Dr Richter, member of the GCOS Joint Planning Office (JPO), welcomed the attendees and gave some remarks about the organisation and purposes of the session.

1.3 Approval of the Agenda

The Chairman reviewed the agenda which outlined two days of presentations and discussions and two days of group work to be chaired by lead speakers. He then invited the Panel members and invited participants to introduce themselves (See Annex I). The agenda was adopted by the Panel (See Annex II).

2. TERMS OF REFERENCE

2.1 The AOPC considered its Terms of Reference (See Annex III) and proposed recommendations for modifications to them for the consideration of the GCOS Joint Scientific and Technical Committee (JSTC). The Panel emphasis requires it to determine requirements for data and products in consultation with users; to monitor, understand and predict the dynamical, physical and chemical state of the atmosphere on seasonal and longer climate time scales; and to add value by identifying and promoting actions which would fulfil those requirements. This requires the AOPC to take a comprehensive view of data needs (i.e., forcing functions such as radiative fluxes as well as state variables). The Panel will take on the responsibility to require data of the atmospheric boundaries, e.g., surface climate, air-sea, air-land, and air-snow/ice interfaces.

¹ Formerly the GCOS Atmospheric Observation Panel.

2.2 The AOPC also considered that it was necessary to explicitly state the relationships it expects to have with other research, operational and end-user bodies in addition to the World Weather Watch (WWW) and the Global Atmosphere Watch (GAW). The Panel also **recognised** and expressed appreciation for the joint sponsorship of the WCRP.

3. REPORTS ON GCOS, WCRP AND RE-ANALYSIS PROJECTS

3.1 Global Climate Observing System (GCOS)

3.1.1 Dr Whelpdale, member of the JSTC, gave an overview of GCOS objectives and strategy. He described the GCOS platforms comprising the principal sub-systems "Global", "Oceans", "Atmosphere" and "Land", which led to the proposal of seven "GCOS missions" and the associated observations as outlined in the Space Plan, Version 1.0². The GCOS strategy is to build on existing programmes such as the WWW and GAW by designing and identifying networks of stations. Examples include the Global Upper-Air Network (GUAN) or the Global Surface Network (GSN).

3.1.2 In the following discussion the responsibilities of the National Meteorological and Hydrological Services (NMHS) relative to the AOPC were clarified. The NMHS have agreed to participate in the GCOS networks. In those cases where identified stations do not operate in a fully satisfactory manner, the AOPC is expected to make recommendations for improvements. These would be developed in co-operation with the World Meteorological Organization (WMO) Commission for Basic Systems (CBS), which is actively assisting with the GCOS network implementation. The AOPC is expected to help solve GCOS implementation issues through contacts with CBS, the WMO Secretariat and WMO Members, but also through non-governmental bodies (e.g., universities, space agencies) as appropriate.

3.1.3 In connection with an overview of GCOS activities, Dr Sato provided information on links to other GCOS groups and panels, including a short report on the events at the third session of the Joint Data and Information Management Panel (JDIMP)³ which had just been held in July 1997, in Tokyo, Japan. It was noted that GCOS needs to establish effective institutional arrangements for data collection, quality control, archive and access. The JDIMP will act as the operational group to review and maintain these arrangements. It was agreed that the AOPC Terms of Reference should note the co-ordination expected with the JDIMP. **(Recommendation 1).**

3.1.4 The participants agreed that the GCOS programme should ensure that close links -with CBS, the Commission for Climatology (Ccl), the Commission for Atmospheric Sciences (CAS), and the World Climate Programme (WCP), inter alia, continue to avoid overlaps or gaps. The CC1 link was strengthened with the co-operation in design of the GSN network design and implementation. The link with the CAS link will assist in making progress on implementation of greenhouse gases

² GCOS Plan for Space-based Observations, Version 1.0 (GCOS-15).

³ The JDIMP meeting report has been published as GCOS-39 (GOOS-11 & GTOS- 11).

and aerosol observations through GAW. These issues are not only a high priority for GAW, but also for GCOS and the WCRP Stratospheric Processes and their Role in Climate (SPARC).

3.1.5 Dr Mitchell, representing the Chairman of the Global Observing Systems Space Panel (GOSSP), gave a presentation on the “Comparative Analysis and the Committee on Earth Observation Satellites / Integrated Global Observing Strategy Analysis Group”. He explained how the GCOS and the WMO CBS Working Group on Satellites (WG/SAT) had developed user requirements, and noted that a Committee on Earth Observation Satellites (CEOS) Task Force on Planning and Analysis initiated a similar review of requirements. The assessment of requirements involved the participation of the user communities and resulted in a “stand-alone” database at WMO, and an “on-line” database at the European Space Agency (ESA). The subsequent analysis was intended to address how well existing and planned space systems meet these requirements. Specific analysis tools were developed with the advice and expertise of Mr Morgan, Chairman of the GOSSP⁴ for use by the GOSSP, WG/SAT and the CEOS Analysis Group (AG) to assess the user requirements and the capabilities of the various space agency missions. Dr Mitchell detailed how the analysis tool was intended to work and provided examples of typical output in terms of a summary listing the parameters identified by the user communities, the specific requirements (e.g., accuracy, coverage), and a **timeline** indicating the degree to which the requirements would be satisfied by the relevant missions of the space agencies. Further, Dr Mitchell outlined the concepts of the Integrated Global Observing Strategy (IGOS) and described how it could serve as a framework for users to present their requirements and for providers to express their contributions. The CEOS Strategy Implementation Team (SIT) has initiated six prototype projects’ which are supported by the CEOS AG. These prototypes were developed in consultation with the GOSSP and several CEOS affiliates. (**Recommendation 2; Recommendation 3**) .

3.1.6 The Panel recognised that close collaboration between it and GOSSP is important. Since the CEOS analysis tools are used in management decision-making, they may assume strategic importance. Thus the entries in the database need careful review and updating. The AOPC should review the input for the two atmospheric prototypes of the CEOS/SIT (Upper-Air and Ozone) as well as future projects to be proposed. In addition, CEOS/SIT and AOPC should ensure that processes effectively bring together research and operational communities. This point reinforced the Panel’s viewpoint that its Terms of Reference should specifically note the need for its liaison with appropriate CEOS groups. (**Action 1**).

3.1.7 The Panel also recognised that, while GCOS does not directly support the work of the Intergovernmental Panel on Climate Change (IPCC), it does ensure the provision of data in support of research that is assessed and interpreted by the IPCC.

⁴ Mr Morgan has subsequently resigned as chair of GOSSP.

⁵ (1) Global Ocean **Data** Assimilation Experiment (GODAE), (2) Upper-air measurements, (3) Long-term continuity of ozone measurements, (4) Global Observation of Forest **Cover**, (5) **Long-term** ocean biology measurements, and (6) Disaster management support.

3.2 World Climate Research Programme (WCRP)

3.2.1 Mr Benedict gave an introduction on WCRP projects and noted the primary responsibility of WCRP. The projects reviewed included the Arctic Climate System Study (ACSYS), the Climate Variability and Predictability Programme (CLIVAR), the Global Energy and Water Cycle Experiment (GEWEX), the World Ocean Circulation Experiment (WOCE) and SPARC. WCRP objectives embrace the understanding of significant climate processes and the prediction of climate variations. The operational network like WWW, quasi-operational observing systems like the G3OS⁶, and the WCRP research programmes are the observational data sources. WCRP distinguishes between “fast” climate processes that control the sensitivity of the global climate response to natural or artificial forcing, and “slow” climate processes that determine the timing and geographical patterns of climate variations and change.

3.2.2 Mr Benedict proceeded to outline the various WCRP programmes. The Tropical Ocean Global Atmosphere (TOGA) programme, running from 1985 to 1994, has achieved its major objective of establishing a basis for **skilful** predictions of El Niño. These predictions are based on WWW observations, augmented by the Tropical Atmosphere Ocean (TAO) array in the tropical Pacific. WOCE is providing a **characterisation** of the ocean through observations collected over the past 7 years, and comprehensive modelling which will continue for a few more years. CLIVAR will build on the achievements of TOGA and WOCE. It includes several major programme elements: 1) Global Ocean Atmospheric Land System (GOALS) for prediction of seasonal to interannual climate; 2) the Decadal to Centennial Natural Climate Variability (DEC-CEN); and 3) modelling and detection of anthropogenically-forced climate change. GEWEX is conducting studies of the fast climate processes, and its primary activities are the development of global data sets, process studies, and model development. Several of the elements connecting GEWEX relate to the work of the AOPC. These include the establishment and maintenance of the atmospheric components of calibration and validation networks in support of **dataset** development and application (i.e., surface radiation, water vapour and aerosols); the long-term monitoring for trend analyses; and the support of new satellite missions and in situ networks to provide necessary data records (e.g., 3-d clouds, winds and soil moisture).

3.2.3 Ms Phillips gave a presentation on data requirements necessary to develop the SPARC research. She noted that many SPARC requirements are met by the operational or quasi-operational observing systems implemented under GCOS. The range of parameters required and number of sites are under review taking into consideration recommendations put forward by GAW and the Network for Detection of Stratospheric Change (NDSC). The requirements will be published in the SPARC Implementation Plan, to be available in 1,998. She noted the need to improve observations in the tropics, a particularly high priority region for SPARC to aid understanding of the mechanisms that maintain the distribution of water vapour. Furthermore, she expressed concern about the limited number of upper-air stations in tropics, making it difficult to monitor phenomena like the Quasi-Biennial Oscillation

⁶ G3OS stands for the three global observing systems GCOS, the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS).

(QBO). Ms Phillips pointed out that the altitude levels used by the WMO/CEOS database do not correspond well with SPARC needs. This issue was discussed at an ad hoc AOPC sub-group meeting held in Toronto, in May 1997'. The recommendations that resulted from that meeting were thought to be more appropriate. Finally, it was stressed that there is need to monitor precursor (i.e., controlling) chemical species and to consider requirements for monitoring the atmospheric impact of intermittent volcano eruptions.

3.2.4 On behalf of Dr Trenberth, the Chairman elaborated the interaction of CLIVAR with GCOS. According to Dr Trenberth, the three objectives of CLIVAR are only attainable if GCOS is fully implemented. Additionally, it was pointed out that CLIVAR may be able to deploy pilot observing systems that might lead to GCOS operational observations (e.g., the transition of the TAO Array). The presentation stressed that GCOS will have difficulties being successful unless users for the observations are clearly identified.

3.2.5 The AOPC participants concluded that the Panel must maintain close liaison with WCRP programmes, and in particular should investigate how to cooperate with WCRP to effect a transition of research observation programmes to more operational, long-term programmes of observations.

3.3 Re-Analysis Projects

3.3.1 *ECMWF Re-Analysis (ERA) Project*

Dr Gibson, Head of the European Re-Analysis project (ERA) at ECMWF, provided an overview of the ERA and demonstrated in his presentation how climate data could be used. The ERA project has produced a new, global analysis of atmospheric assimilated data for a 15-year period from 1979 to 1993 (ERA-15). Several reasons have been advanced for a re-analysis of the atmosphere. By selecting a consistent model, data analysis could be performed avoiding major changes in models, analysis techniques, assimilation methods, or other similar problems. Additionally, enhanced observational data sets have become available since the original computations were made. Dr Gibson explained that the principal source of observations for the ERA has been the ECMWF real-time data collection from the Meteorological Archive and Retrieval System (MARS). It has been augmented by the National Oceanic and Atmospheric Administration (NOAA) satellite radiance data for the 15-year period (since 1979), the Comprehensive Ocean-Atmosphere Data Set (COADS) ship and buoy data, the First GARP⁸ Global Experiment (FGGE) data, the Alpine Experiment (ALPEX) data, pseudo-observational data from the Australian Bureau of Meteorology (BoM), Geostationary Meteorological Satellite (GMS) cloud winds, and radiosonde and aircraft data by Japan Meteorological Agency (JMA). The data for sea-surface temperature (SST) have been provided by the United Kingdom Meteorological Office and the National Centres for Environmental Prediction. Sea ice cover has been derived from Scanning Multi-frequency Microwave Radiometer (SMMR) and Special Sensor Microwave/Imager (SSM/I) satellite data. Dr Gibson described the production and monitoring process. He noted that the ability to analyse

⁷ Summary available from the Joint Planning Office.

⁸ Global Atmospheric Research Programme.

long periods rapidly has helped research and will contribute to future research and development.

The success of ERA for large-scale analyses can be seen in the example of the El Niño/Southern Oscillation (ENSO) event in 1982-1983. The original ECMWF analysis described this event only very poorly, whereas in ERA, the pressure oscillation between Papeete and Darwin, droughts in Africa and Brazil, and heavy precipitation over the central Pacific is well captured. Even the Pacific-North American anomaly pattern in the surface pressure is clearly seen and can be connected with the ENSO event in the ERA maps. The ERA found about 70% of all reported tropical cyclones with an error of only one grid point (150 km). Only in areas with few observations, as in the eastern-pacific, the northern-Indian Ocean and the Southern Hemisphere, are the cyclones poorly analysed. Further, the QBO in the stratosphere can be clearly seen in ERA as well as the global temperature anomalies in the stratosphere in 1982 and 1991. This warming was entirely due to Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) and radiosonde data, recorded during the eruption of the volcanoes El Chichon, Mexico and Pinatubo, Philippines. Despite all these positive results, ERA fluxes, which are crucial for the study of the coupled ocean-atmosphere system, suffer from “spin-up” or “spin-down” as do other model-generated fluxes (i.e., they increase or decrease with forecast length). The problem is that direct observations of surface fluxes of energy, momentum and water over land and oceans are not sufficiently accurate or representative, so currently fluxes must be modelled to achieve sufficient accuracy.

Dr Gibson discussed as well the impact of global observing systems on ERA. The global observing systems changed over the ERA period and resulting biases must be taken into account. There have been periods with either one or two polar-orbiting satellites. This fact affects the errors in mean temperatures in the Northern Hemisphere (smaller errors in the two-satellite period). The number of radiosondes, aircraft winds, and drifting buoys have varied considerably. The quality of radiosondes has improved but numbers have decreased since 1990. Additionally, the derivation of observations has changed, e.g., GMS winds have been produced at different altitudes. The application of the correction scheme showed that considerable improvement in cloud motion winds could be achieved from 1979 to 1980 above 250 hPa, and from 1980 onwards, mainly due to the improvement of radiosondes. But these data are biased, and jets and meridional winds are underestimated. Due to the use of the same instruments on satellites during the ERA period (i.e., High Resolution Infrared Sounder (HIRS), Microwave Sounding Unit (MSU) and Stratospheric Sounding Unit (SSU)), the TOVS cloud cleared radiance (CCR) data are relatively unchanged. Nevertheless, the National Environmental Satellite, Data and Information Service (NESDIS) retrievals of temperature and humidity vary considerably due to changes in the statistical retrieval algorithms with the time. Concerning the forecast quality in general, ERA results indicate a clear improvement over the older operational forecasts.

At the moment, the ERA archive contains global analyses and short-range forecasts of all relevant weather parameters which have been generated by a modern, consistent data assimilation system. Each year is being made available once it has been produced and validated. Data may be retrieved by internal ECMWF and Member States using MARS, but the Data Services provide data as well for external

research scientists. Information and brochures describing all services are available from ECMWF upon request.

Dr Gibson finished his presentation with a short description of the 40-year re-analysis (ERA-40) project, which started in the second half of 1997. The lessons learned from ERA-15 will be used to complete this project by the year 2001. Typical applications will be general circulation diagnostics, atmospheric low frequency variability, the global energy and hydrological cycle, studies of predictability, coupled ocean/atmosphere modelling and observing system performance.

Dr Uppala, member of the ERA project group, gave a presentation on the quality of reanalysis and observational validation. Dr **Källberg**, a member of the ERA project, discussed in his presentation some aspects of climate issues related to ERA, e.g., QBO and El Niño as previously already mentioned. He stressed that the observations from island stations should be supported referring to the sensitivity of the analysis to surface observations.

The Panel attendees expressed appreciation to Dr Gibson for his informative presentation, and thanked Drs Uppala and **Källberg** for theirs as well. The Chairman stressed that the Panel should note that reanalysis data are gradually becoming available to the user community. AOPC noted as well that in reanalysis the surface fluxes continue to be affected by spin-up problems and by data distribution. The AOPC recognised the wide range of data (e.g., SATOBS, aircraft, radiosondes, etc.) that will be utilised in a modern climate data analysis system. Reanalysis allows sensitivity studies of impact of data density. It was stressed again that the quality of instruments improved with time, but the bias remains. The AOPC recognised the great importance of reanalysis for climate research and the climate data issue in particular. The attendees noted as well that there is a lack of data particularly in the Indian Ocean. The Panel recognised that quality of radiosondes has improved with time although unfortunately the number of radiosondes has decreased.

3.3.2 *National Centres for Environmental Prediction (NCEP)/ National Centre for Atmospheric Research (NCAR) Re-analysis Project*

Dr **Arkin** gave an overview of the National Centres for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis project. This joint project -was initiated in 1989. The goal is to produce new atmospheric analyses using historical data (from 1957 onward) and to produce analyses of the current atmospheric state through a Climate Data Assimilation System (CDAS). Dr **Arkin** pointed out that these early data have many problems (e.g., very different observing schedules, limited coverage, i.e., only Northern Hemisphere over land). The quality and utility of the reanalyses should be superior to NCEP's original analyses because: 1) a state-of-the-art data assimilation is used; 2) more observations are used; 3) quality control has been improved; 4) the model/data assimilation procedure will remain essentially unchanged during the project; 5) many more fields are being saved (e.g., potential vorticity on isentropic surfaces, **diabatic** heating); 6) global coverage is used (some older analyses were hemispheric); and 7) a better vertical resolution in the stratosphere is used. Preliminary plans for the next few years are to do a regional reanalysis for the USA. Furthermore, a **17-year** Atmospheric Model Intercomparison Project (AMIP) re-analysis (1979-1 995) will be performed,

based on the NCEP reanalysis system but with known errors corrected (e.g., aircraft winds for 1976-1978 with unusually high errors, PAOBS, Southern Hemisphere surface pressure data). NCEP has created special CD-ROMs with the data (e.g., annual data from 1982- 1996 are available from NCAR, 1979-198 1 are being evaluated for release).

3.3.3 *Data Assimilation Office (DAO)/ National Aeronautics and Space Administration (NASA) Re-analysis Project*

Dr Gibson presented, on behalf of Dr Schubert, an overview of the Goddard Earth Observing System (GEOS) Data Assimilation System and reanalyses. As an introduction it was noted that the **DAO** has as its primary mission the development of a global assimilation system suitable for ingesting the Earth Observing System (EOS) and other satellite and in situ observations to produce dynamically, physically, and chemically consistent, gridded high-level data products for studying the Earth system. Version 1 of the GEOS system (GEOS-1) was fixed or "frozen" in March 1993, and a commitment was made to generate a five-year assimilation (March 1985 - February 1990) suitable for climate applications. Version 2 of GEOS (GEOS-2) is an intermediate system to be used primarily for NASA mission support and short-term "experimental" analyses with the focus on improving the cloud forcing, and stratospheric analyses. Version 3 (GEOS-3) will be operational in June 1998, in time for the launch of the EOS Active Microwave (**AM1**) platform. The analysis system will have an improved TOVS temperature and moisture retrievals, satellite surface winds, off-line ozone assimilation, improved error statistics and improved quality control.

3.3.4 The AOPC was informed that the Reanalysis Workshop (Washington DC, October 1997)⁹ would include a discussion of these three reanalysis projects (ERA, NCEPMCAR, and NASA). In 'connection with all given presentations about re-analysis, the AOPC **recognised** the potential value of reanalysis and Observing Systems Simulation Experiments (**OSSEs**) in quantifying data requirements. (**Recommendation 4; Recommendation 5**).

4. REQUIREMENTS FOR CLIMATE OBSERVATIONS

4.1 Dr Richter gave an overview of the requirements that had been developed to date by earlier sessions of the Panel. She observed that existing requirements have been entered in the CEOS affiliate database maintained at WMO. Since the GCOS JPO is planning to incorporate the list of GCOS requirements into a consolidated tabular format, she invited the Panel to undertake the review of four sorts of table entries: 1) the requirements for meteorological variables; 2) the requirements for atmospheric chemistry variables; 3) the requirements shared with the Terrestrial Observation Panel for Climate (TOPC); and 4) those shared with the Ocean Observations Panel for Climate (OOPC). With regard to the third one, she noted that the TOPC had prepared so-called "data fact sheets" for climate variables which gave concise information about users, rationale, resolution, status of research and development, and measurement methods. Such information has found many users, so

⁹ Report and Proceedings available from the **WCRP** Office.

the Panel could provide an important service by providing their review and advice to the JPO. The Panel was urged to review the actual table which takes into account climate data requirements (as listed for example in a Hadley Centre report¹⁰ and to review the available fact sheets (See Annex IV). As a result of the discussion, the AOPC stressed that the requirements should clearly indicate that data needed for climate purposes must have low bias and that the data records be homogeneous and consistent. This is of particular relevance for satellite data. The Panel recommended that the tabulations of data requirements should specify bias limits as well as rms limits. (**Action 2**).

4.2 The Panel discussed the generic data requirements for a global observing system, based on a presentation given by Dr Manton, on behalf of Dr Trenberth. Although in this case the analysis and assimilation systems were held constant, the database was continually changing, especially with regard to satellite data. The analyses were only as good as the input information, and were shown to contain trends associated with changes in rawinsondes types and satellite algorithms. It was concluded that an optimal mix of measurements from various available platforms should be identified. The Panel reiterated that an institution to take responsibility for analysis and quality control of products is required in most cases. The AOPC recognized that some level of redundancy in the observing networks may be desirable and the system would still be cost-effective.

4.3 The Panel discussed requirements needed for seasonal to interannual prediction. It was noted specifically that CLIVAR plans to build on the TOGA observing systems and, where appropriate, extend the observing network to other parts of the global domain. The requirements for ENSO prediction systems need to be assessed and strategies for ameliorating any deficiencies need to be developed. For the ocean, CLIVAR will assess requirements through its Upper Ocean Panel. CLIVAR will soon reassess observational requirements to address global coverage, real-time aspects and accuracy desired. GOALS needs feedback from land surface processes which were not addressed in TOGA. The Pan-American Climate Studies (PACS) programme, for example, is now examining warm season precipitation in the Americas and its relationships to the SST as well as to the land surface. Programmes like GEWEX Continental-scale International Project (GCIP), the GEWEX Asian Monsoon Experiment (GAME) and other GEWEX regional experiments could contribute in the same way. Furthermore, processes such as those involved in sea ice and high latitude oceans, and those altering marine biology and chemistry need to be considered.

4.4 The Panel reiterated the dependence of the climate community on elements of the WWW, noting that it is unlikely that a specific network for climate could be established at this time. However, it also acknowledged a concern that some WWW elements have declined recently, and the Panel considered that its first priority must be to reverse this decline and obtain assurances of a stable observing system for the future as well. The AOPC **recognised** that there are different observing network requirements for global and regional applications. (**Recommendation 6**).

¹⁰ Hadley Centre Climate Data Requirements, August 1994.

5. CURRENT ACTIVITIES AND DATA REQUIREMENTS

5.1 Upper-Air Network

5.1.1 Dr Sarukhanian gave a report on the GCOS Upper-Air Network (GUAN). The AOPC noted that CBS-XI (Cairo, Egypt, November 1996) had requested ECMWF, as the CBS lead centre for upper-air data quality monitoring, to compile information on the availability and quality of upper-air data obtained from GUAN stations and report to the JPO every six months. ECMWF agreed with this proposal and informed AOPC-III that the first report on availability and quality of upper-air data obtained from GUAN stations, including a stand-by list of stations, will be **available** in September 1997 and will cover the period from January to June 1997. (**Action 3; Action 4; Recommendation 7; Recommendation 8; Recommendation 9**).

5.1.2 The AOPC **recognised** the broad-based interest in the GUAN from many communities. Consequently, it suggested that broad-based support be obtained to maintain and upgrade the network. One particular example is the replacement for the OMEGA based upper-air system by alternatives. The Panel felt these systems should be supported not only by NMHS but other agencies involved in GCOS (e.g., agencies which contribute to United Nations Environment Programme (UNEP), Intergovernmental Oceanographic Commission (IOC), etc.). (**Recommendation 10**).

5.2 Atmospheric Constituents

5.2.1 Dr Whelpdale provided an overview of some earlier work of the Panel with regard to atmospheric chemistry, and cited the report of Mr Vet¹. In addition to the interests in this topic by AOPC, he identified other key players including SPARC, the International Global Atmospheric Chemistry Programme (IGAC), NASA, and WMO through NDSC and GAW. He informed the Panel that he chaired the sub-group of AOPC which met in Toronto, May 1997. The sub-group discussed climate-relevant atmospheric constituents and agreed on a table to be sent out for review.

5.2.2 An ad hoc working group agreed that water vapour, ozone and aerosols are among the priority observations. Furthermore, the meteorological parameters should be revisited **from** the perspective of the needs for the constituents measurements. Dr Croom presented the result of the ad hoc review, but stressed that up to now accurate numbers for resolution and accuracy still need to be agreed by the Panel. The reviewed short list of species **can** be found in **Annex V. (Action 5)**.

5.3 Radiation, Clouds and Aerosols

5.3.1 Mr Benedict reported on GEWEX projects referring to modelling and prediction (i.e., GEWEX Cloud System Studies (GCSS) and the Project for Intercomparison of Land-surface **Parameterization** Schemes (PILPS)), to radiation projects (e.g., the International Satellite Cloud Climatology Project (ISCCP), the Global Precipitation Climatology Project (GPCP)) and hydrometeorology projects

¹¹ GCOS Observation Programme for Atmospheric Constituents: Background, Status and Action Plan, September 1995 (GCOS-20).

(e.g., GCIP, GAME, the Baltic Sea Experiment (BALTEX) or the Global Runoff Data Centre (GRDC)). He reported on the availability of GEWEX data sets and pointed out that there is need for more validation and calibration. The Panel noted that for nearly all of the GEWEX programmes, data sets and products such as radiance, precipitation data, or cloud products, are available in various forms and on different media. **(Action 6)**.

5.3.2 Dr Sato presented the Global Soil Wetness Project (GSWP), a part of the International Satellite Land Surface Climatology Project (ISLSCP), which will cover generation, intercomparison and validation of global distribution of soil moisture or snow equivalent water as monitored from space between 1986 and 1995. This project will improve short-term climate prediction and land surface processes by comparing, and validating its products against observations. He noted that GPCP and ISCCP will need to contribute better precipitation and radiation data in order to improve the **parameterization** of atmospheric forcing. Further, he noted the need for more validation data, for example run-off data from the GRDC. Dr Sato concluded that GCOS should continue to collaborate with the appropriate research projects for data rescue and data archiving. He urged that GCOS seek to involve scientists who are both active data users and data providers. The AOPC **recognised** the need for interaction with the various GPCP and global soil moisture projects. **(Recommendation 11)**.

5.4 Land Surface Network

5.4.1 The AOPC received the **report**¹² of the second meeting of Experts on the GSN in De Bilt, Netherlands, June 1997 as well as a review of steps taken to establish the GSN by Dr Baede, the CBS Rapporteur on GCOS matters. The Panel approved a set of recommendations given in the report regarding the monitoring of availability and quality of the data and in particular, the inclusion of automatic weather stations in the GSN. The importance of having a suitable period of overlap of manual and automatic observations to quantify and understand any biases between the two procedures was stressed. As regard to the monitoring of the implementation of the GSN, the AOPC noted that CCl at its twelfth session (Ccl-XII, Geneva, August 1997) had agreed that the availability and quality of CLIMAT messages, the report of monthly means, from GSN stations being distributed over the Global Telecommunication System (GTS) be globally monitored by monitoring centres with assistance from regionally designated focal points. It noted and welcomed the offers of Germany and Japan to use their climate centres for this purpose.

5.4.2 The AOPC noted that Ccl-XII had also agreed that World Data Centres A and B for Meteorology could serve as the appropriate repositories of GSN data, historical climate data and metadata related to each GSN station. The AOPC should address institutional arrangements for monitoring, archiving and accessing these data, and provide guidance concerning metadata. **(Recommendation 12; Recommendation 13)**.

5.4.3 In the following discussion AOPC attendees agreed that the Panel needs to

¹² Report of the second Joint CCI/CBS meeting on the GCOS Surface Network, June 1997, (GCOS-35).

identify specific products to be generated from GSN. The AOPC noted as well the potential use of daily GSN data through JDIMP in support of CLIVAR related projects on “extreme climate events”. The AOPC noted that in situ observations are, and will be, an essential component of the system and there should be a balance between satellite and in situ observations. (**Action 7**).

5.5 Air Sea Interface

Dr Harrison gave a presentation on the air-sea interface observations for climate. He noted that the climate signal is not large compared with background variability, so bias and alias errors must be minimised. Sampling requirements merit special attention, if useful signal-to-noise ratios are to be obtained. In situ data density is particularly low over much of the Southern Hemisphere, the Indian Ocean, and the tropical Atlantic. It is difficult to assess the accuracy of present products because so few high quality independent in situ data exist. He noted that enhanced Southern Hemisphere and tropical data are required. Dr Harrison stressed that the AOPC should pay attention to the need for a network of ocean surface reference stations to evaluate long-period variability and trends.

5.6 Polar Observations

5.6.1 The Panel noted that the number of observations in polar regions is still sparse. It was brought to the Panel’s attention that there will be a meeting of the International Arctic Buoy Programme (IABP): “Scientific Achievements from the first 20 years”, in August 1998, in Seattle, USA. The Panel supported the use of the IABP assets to meet GCOS needs.

6. EMERGING TECHNOLOGIES

The Panel agreed to take into account changes in technology and future global networks. Examples cited were atmospheric soundings from space using the Global Positioning System (GPS)¹³ or the use of commercial aircraft as platforms for environmental **measurements**¹⁴.

7. DEVELOPMENT OF AN ATMOSPHERIC OBSERVATION PLAN

The Panel split into ad hoc working groups to draft sections of the Plan. Members and working group leaders are identified in Annex VI. The groups were assigned to work on: 1) the Outline of the Plan; 2) the Surface Climate and Interfaces; 3) Atmospheric Constituents; and 4) Atmospheric Dynamics and Thermodynamics.

7.1 Outline and Components of a Plan

The Panel agreed on a structure of the Plan (See Annex VI), having discussed

¹³ Bulletin of the American Meteorological Society, Vol. 77, No. 1, January 1996.

¹⁴ Bulletin of the American Meteorological Society, Vol. 77, No. 10, October 1996.

the elements drafted by the working groups. It outlined in particular Chapter IV entitled "Components of observing systems" which should containing five elements: (a) Atmospheric dynamics and thermodynamics, (b) Atmospheric constituents, (c) Surface climate, (d) Air-sea interface, (e) Air-land interface, and (f) Air-snow/ice interface.

7.2 Schedules, Assignments and Deadlines

The Panel participants agreed on having the draft outline for the Plan to be accomplished within the next 6 months [Action with Working Groups].

8. PANEL FINDINGS, RECOMMENDATIONS AND FUTURE ACTIONS

8.1 The Panel decided that the preparation of a draft summary of recommendations and actions of the AOPC-III meeting should be sent out via **email** for review and comments [Action with GCOS JPO completed.]

8.2 The Panel decided to set-up an **email** list server process for AOPC participants at WMO and to maintain an AOPC web page. [Action with GCOS JPO completed. List server address for AOPC is: **AOPC@www.wmo.ch**]

8.3 The list of recommendations and actions as found by the Panel are as follows:

Recommendation 1:

The following subdivision of responsibility as proposed at the recent JDIMP meeting is accepted. The development of the science issues and the identification and specification of variables to be observed should not be the purview of JDIMP. However, elements relating to the methods of collection, calibration, and quality control; formats, and codes for transfer of the data and the archival of data, information, and products as appropriate definitely should be the purview of JDIMP. The AOPC believed that they should monitor the JDIMP performance in practice.

Recommendation 2:

GCOS should use a range of agencies and resources to implement and maintain the GCOS network.

Recommendation 3:

The Plan should consider end-to-end implementation including institutional arrangements.

Recommendation 4:

JSTC/GCOS strongly support further re-analysis work.

Recommendation 5:

The importance should be stressed and the JSTC should be urged to decide how to deal with data **rehabilitation**¹⁵ as a GCOS objective.

Recommendation 6:

Recommend to CBS that there should be an appropriate period of overlapping observations (in general, at least one year) if instrumentation changes.

Recommendation 7:

Noting that a significant number of soundings at GUAN stations do not extend to 100 **hPa**, it is recommended that an GUAN evaluation report on this issue be prepared based on the ECMWF monitoring results. Members operating the GUAN stations should be encouraged to make every effort to maintain full sounding at least to 10 **hPa** since sounding measurements are needed to stratospheric levels.

Recommendation 8:

Liaise with JDIMP on GUAN data rehabilitation.

Recommendation 9:

JSTC to identify an institution to archive GUAN data and metadata (e.g., Asheville) and to ensure access.

Recommendation 10:

Although CBS has planned the conversion **from** Omega to alternative systems, it was noted that there is an urgent need for GCOS and its sponsors to solve the funding problem.

Recommendation 11:

It is considered as appropriate for GCOS to promote pilot projects and candidate observations for GCOS (e.g., soil moisture).

Recommendation 12:

Liaise with JDIMP on GSN data rehabilitation.

Recommendation 13:

JSTC to consider procedures for deciding institutional arrangements, for AOPC activities.

¹⁵ DATA REHABILITATION: includes data rescue, correction, homogenisation, archiving and ensuring access.

8.4 The list of actions and responsibilities recommended by the Panel are as follows:

Action 1:

In co-operation with GOSSP, ensure that data in the WMO stand-alone database is consistent with AOPC data needs and products. The working groups will review AOPC requirements and cross-check them with the corresponding database entries. The JPO will collect reports on modifications and inform Dr Hinsman, who is maintaining the database at WMO. [Action with all working groups¹⁶ and JPO.]

Action 2:

Part of the AOPC Plan is to review the data requirements for analysis of climate research and then to enter into the requirement database. [Action with all working groups.]

Action 3:

The GUAN main and stand-by lists should be revisited to meet concerns expressed in the meeting. The Panel needs to better define the purpose of GUAN, including required data density. [Action with working group 4¹⁷.]

Action 4:

IOS products (e.g., global fields of observed and derived parameters in the troposphere and stratosphere, with minimised instrumental and sampling bias; species concentration time series; heat fluxes; etc.) need to be identified and institutions to generate and disseminate the products. [Action with all working groups.]

Action 5:

Identify specific atmospheric constituents for the GCOS network. [Action with working group 3¹⁸.]

Action 6:

In co-operation with WCRP consider its role in supporting and using GPCP and ISCCP data, including the potential transfer from research to operational mode. [Action with chairman¹⁹.]

Action 7:

Better define the purpose of GSN, including required data density. [Action with working group 2²⁰].

¹⁶ All AOPC participants.

¹⁷ David Parker, Ulrich Cubasch, Eduard Sarukhanian, Alexandr Vasiliev.

¹⁸ Douglas Whelpdale, David Croom, Stuart Penkett, Céline Phillips.

¹⁹ Michael Manton

²⁰ Phil Arkin, Fons Baede, Ed Harrison, Raphael Okoola, Nobuo Sato, Guoxiong Wu

9. CLOSURE

The Panel expressed its high appreciation for the hospitality shown by ECMWF and thanked everyone involved in the local organisation. The Chairman closed the session at 11.30 hrs on Friday, 22 August, 1997. The next session was proposed for 28 April to 1 May, 1998, in Honolulu, Hawaii, USA.

ANNEX I

LIST OF PARTICIPANTS

Dr Phillip ARKIN National Centers for Environmental Prediction NOAA/NWS W/NP 4700 Silver Hill Road, Stop 99 10 WASHINGTON, DC 20233-9910, U.S.A.	Tel: +1 301 7638000 Ext. 7587 Fax: +1 301 7638434 Email: parkin@sgl17.wwb.noaa.gov
Dr Alphonsus P.M. BAEDE Koninklijk Nederlands Meteorologisch Instituut Postbus 20 1 3730 AE DE BILT, Netherlands	Tel: +3 1 30 2206446 Fax: +31 30 2210407 Email: baede@knmi.nl
Dr Vicente BARROS Departamento Ciencias de la Atmosfera University of Buenos Aires Riobamba 366 / 4" B BUENOS AIRES, Argentina	Tel: +54 1 7826528 Fax: +54 1 7833098 Email: barros@at1.fcen.uba.ar
Mr Samuel BENEDICT Climate Research Projects World Climate Research Programme WMO P.O. Box 2300 12 11 GENEVA 2, Switzerland	Tel: +41 22 7308247 Fax: +41 22 7340357 Email: seb@www.wmo.ch
Dr Ulrich CUBASCH Deutsches Klimarechenzentrum Bundestrasse 5 5 20 146 HAMBURG, Germany	Tel: +49 40 41173376 Fax: +40 40 441751 Email: cubasch@dkrz.de
Dr D.E. (Ed) HARRISON Pacific Marine Environmental Laboratory NOAA/PMEL/OCRD 7600 Sand Point Way NE SEATTLE, WA 98 115, U.S.A.	Tel: +1 206 5266225 Fax: +1 206 5266744 Email: harrison@pmel.noaa.gov
Dr Michael MANTON (Chairman) Bureau of Meteorology Research Centre GPO Box 1289K MELBOURNE, Vic. 300 1, Australia	Tel: +6 13 96694444 Fax: +613 96694660 Email: m.manton@bom.gov.au

Dr Raphael OKOOLA
Drought Monitoring Centre
University of Nairobi
P.O. Box 30197
NAIROBI, Kenya

Tel: +254 2 567888
Fax: +254 2 56788819
Email:
raphael.okoola@lion.meteo.go.ke

Mr David PARKER
Hadley Centre
Meteorological Office
London Road
BRACKNELL RG12 2SY, U.K.

Tel: +44 1344 856649
Fax: +44 1344 854898
Email: deparker@meto.gov.uk

Dr Stuart PENKETT
School of Environmental Sciences
University of East Anglia
NORWICH NR4 7TJ, U.K.

Tel: +44 1603 592016
Fax: +44 1603 452420
Email: M.Penkett@uea.ac.uk

Ms Céline PHILLIPS
SPARC Office
B.P. 3
9 1371 VERRIERES-LE-BUISSON, France

Tel: +33 | 644743 15
Fax: +33 | 644743 16
Email: sparc.office@aerov.jussieu.fr

Dr Eduard I. SARUKHANIAN
Observing System Division
World Weather Watch Department
World Meteorological Organization
Case Postale N 2300
1211 GENEVA 2, Switzerland

Tel: +41 22 7308227
Fax: +41 22 7342326
Email: sarukhan@www.wmo.ch

Dr Nobuo SATO
Office of Meteorological Satellite Planning
Observations Department
Japan Meteorological Agency
1-3-4 Otemachi, Chiyoda-ku
TOKYO 100, Japan

Tel: +81 3 32018677
Fax: +81 3 32171036
Email: kz1n-stu@j.asahi-net.or.jp

Dr Alexandr A. VASILIEV
Hydrometeorological Research
Centre of the Russian Federation
B. Predtechenskiy 9- 13
123242 MOSCOW, Russian Federation

Tel: +7 095 2521224 or 2523448
Fax: +7 095 2551582
Email: -

Dr Douglas WHELPDALE
Climate Research Branch
Atmospheric Environment Service
4905 Dufferin Street
DOWNSVIEW, Ontario M3H 5T4, Canada

Tel: +1 416 7394869
Fax: +1 416 7395700
Email: douglas.whelpdale@ec.gc.ca

Dr Guoxiong WU
State Key Laboratory of Numerical Modelling
for Atmospheric Sciences and Geophysical
Fluid Dynamics (LASG)
Chinese Academy of Sciences
P.O. Box 2718
BEIJING 100080, China

Tel: +86 10 62560172
Fax: +86 10 62562347
Email: gxwu@lasgsgi4.iap.ac.cn

Local Participants

Dr David BURRIDGE
Director, ECMWF
Shinfield Park
READING RG2 9AX, U.K.

Tel: +44 1734 499000
Fax: +44 1734 869450
Email: D@ecmwf.int

Dr David CROOM
DLC Consultants
Middle Ashbrook House
London Road
BLEWBURY OX1 1 9PF, U.K.

Tel: +44 1235 851247
Fax: +44 1235 445848
Email: d.l.croom@rl.ac.uk

Dr Rex GIBSON
Re-Analysis (ERA)
ECMWF
Shinfield Park
READING RG2 9AX, U.K.

Tel: +44 118 9499360
Fax: +44 118 9869450
Email: era@ecmwf.int

Dr David MITCHELL
Smith System Engineering Ltd.
Surrey Research Park
GUILDFORD GU2 5YP, U.K.

Tel: +44 1483 442147
Fax: +44 1483 442304
Email: dgmitchell@smithsys.co.uk

Dr Peter RYDER
8, Sherring Close
BRACKNELL RG42 2LD, U.K.

Tel: +44 1344 423380
Fax: +44 1344 423380
Email: peteryder@classic.msn.com

Secretariat

Dr Carolin RICHTER
Joint Planning Office
Global Climate Observing System
c/o WMO
P.O. Box 2300
1211 GENEVA 2, Switzerland

Tel: +42 22 7308272
Fax: +41 22 7401439
Email: Richter-C@gateway.wmo.ch

ANNEX II

AGENDA

- 1. ORGANISATION OF THE SESSION**
 - 1.1 Opening
 - 1.2 Welcome and Conduct of the Meeting
 - 1.3 Approval of the Agenda
- 2. TERMS OF REFERENCE**
- 3. REPORTS ON THE GLOBAL CLIMATE OBSERVING SYSTEM (GCOS), THE WORLD CLIMATE RESEARCH PROGRAMME (WCRP) AND RE-ANALYSIS PROJECTS**
 - 3.1 Global Climate Observing System (GCOS)
 - 3.2 World Climate Research Programme (WCRP)
 - 3.3 Re-Analysis Projects
- 4. REQUIREMENTS FOR CLIMATE OBSERVATIONS**
- 5. CURRENT ACTIVITIES AND DATA REQUIREMENTS**
 - 5.1 Upper-Air Network
 - 5.2 Atmospheric Constituents
 - 5.3 Radiation, Clouds and Aerosols
 - 5.4 Land Surface Network
 - 5.5 Air Sea Interface
 - 5.6 Polar Observations
- 6. EMERGING TECHNOLOGIES**
- 7. DEVELOPMENT OF AN ATMOSPHERIC OBSERVATION PLAN**
 - 7.1 Outline and Components of a Plan
 - 7.2 Schedules, Assignments and Deadlines
- 8. PANEL FINDINGS, RECOMMENDATIONS AND FUTURE ACTIONS**
- 9. CLOSURE**

ANNEX III

TERMS OF REFERENCE'

GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC)

Recognizing the need for specific scientific and technical input concerning atmospheric observations, the Joint Scientific and Technical Committee (JSTC) for the Global Climate Observing System (GCOS) established an Atmospheric Observation Panel for Climate (AOPC). At the Joint Scientific Committee JSC-XVI meeting, the World Climate Research Programme (WCRP) agreed to co-sponsor the work of the Panel which has been renamed the **GCOS/WCRP** Atmospheric Observation Panel for Climate (AOPC).

- o To liaise with relevant research, operational and end-user bodies (i.e., WWW, GAW), to determine the requirements for data to monitor, understand and predict the dynamical, physical and chemical state of the atmosphere and its interfaces on seasonal to multidecadal timescales;
- o To formulate and promote an overall system to provide long-term systematic data and information to meet those requirements,
- o To determine the current state of the atmospheric component of the global observing system for climate;
- o To identify gaps and inadequacies in the atmospheric component of the current global observing system for climate;
- o To propose and promote new systems, or enhancements to current systems and practices, to remove deficiencies;
- o To identify opportunities for the transfer of research observing systems to operational networks, and to promote such transfers;
- o To liaise with other GCOS panels and WCRP steering groups on climate observing system matters;
- o To report regularly to the JSTC for GCOS and the JSC for WCRP.

Chairman: Dr M. **Manton**

Last Meeting: 19 - ~~22~~- August , 1997 in Reading, UK

Next Meeting: April, 1998, in Honolulu, Hawaii, USA

. Subject to final approval of JSTC and JSC.

ANNEX IV

PROPOSED LIST OF VARIABLES

This list of variables stems from precedent discussion in AOPC sessions and needs to be discussed with respect to their climate relevance. The corresponding requirements should be thoroughly reviewed. The discussion should be based on former AOPC decisions, on the WMO database and reports of the Hadley Centre.

Variables: Aerosols (total column)
 Albedo
 Cloud base height
 Cloud cover
 Cloud liquid water - total column
 Cloud optical properties
 Cloud top height
 Cloud type
 Firn densification (ice sheets)
 Ice sheet geometry
 Ice sheet mass balance
 Lake and river freeze-up and break-up (timing)
 Land cover
 Ocean currents (speed and direction)
 Ocean salinity (sea surface, upper ocean)
 Ocean sea level
 Ocean temperature (sea surface, upper ocean)
 Ocean wave height.
 Precipitation - total liquid water content
 Precipitation - accumulated (solid and liquid)
 Precipitation rate
 Pressure - air
 Radiation - emissivity long-wave
 Radiation - incoming long-wave (surface)
 Radiation - outgoing long-wave (top of atmosphere)
 Relative humidity (atmospheric water content)
 Sea-ice concentration (extent)
 Snow cover area
 Snow depth
 Snow water equivalent
 Soil moisture
 Soil temperature
 Spectral vegetation greenness index
 Sunshine duration
 Surface water flow - discharge
 Temperature - air (lower troposphere)
 Temperature - air (higher troposphere/lower stratosphere)
 Temperature - air (higher stratosphere/ mesosphere))
 Temperature - air (2 metres above ground)
 Wind velocity (vector)

ANNEX V

LIST OF DISCUSSED ATMOSPHERIC CONSTITUENTS

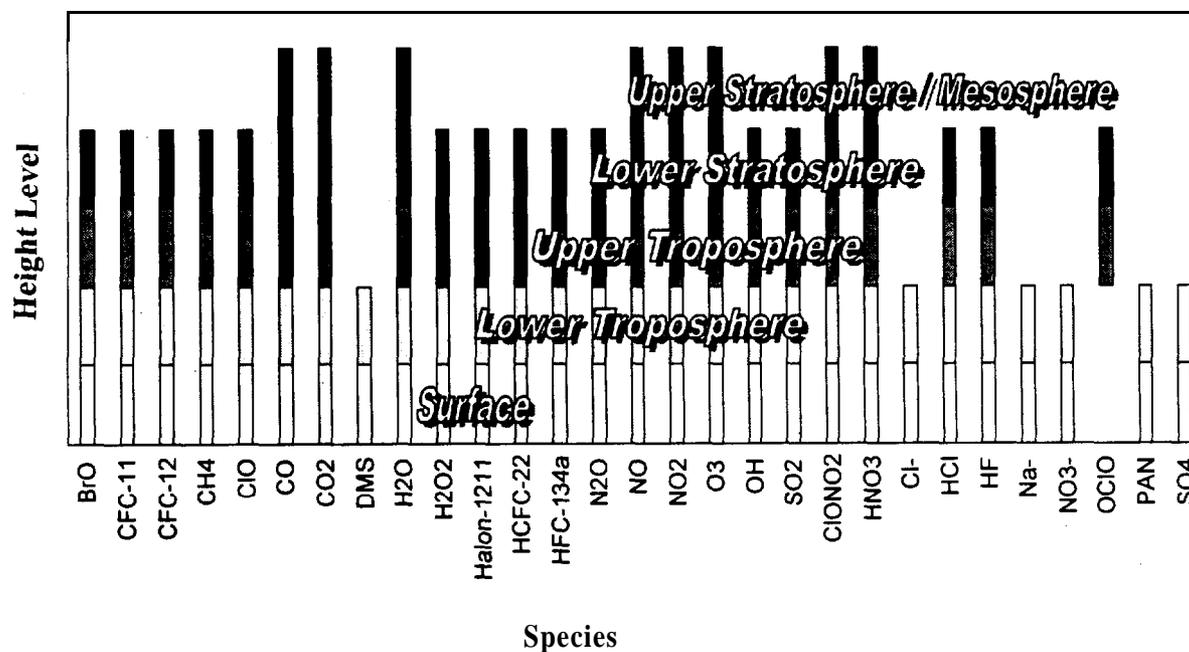
The following list of atmospheric constituents has been sent to participants of the *ad hoc* working group meeting in Toronto, May 1997, for comments. This table, which includes all comments received until August 7, 1997, will serve as base for further discussions on selecting a short-list of long-term monitoring low-bias observations.

Species	Name	Role
BrO	Bromine Oxide	Controller of Ozone
CFC- 11 (CFC13)	Trichloro-fluoro-methane	Ozone depleter (Anthropogenic, controlled)
CFC-12 (CF ₂ Cl ₂)	Dichloro-difluoro-methane	Ozone depleter (Anthropogenic, controlled)
CH ₄	Methane	Major Greenhouse Gas
ClO	Chlorine Monoxide	Controller of Ozone (depleter)
CO	Carbon Monoxide	Controller (sink of OH)
CO ₂	Carbon Dioxide	Major Anthropogenic Greenhouse Gas (GHG)
DMS [(CH ₃) ₂ S]	Dimethyl Sulphide	Controller; source of tropospheric sulphur
H ₂ O	Water Vapour	Principal Greenhouse Gas (not Anthropogenic)
H ₂ O ₂	Hydrogen Peroxide	Controller
Halon-1211 (CF ₂ BrCl)	Bromo-chloro-difluoro-mehtane	Greenhouse gas & ozone depleter (prevalent in Fire Extinguishers)
HCFC-22 (CF ₂ HCl)	Chloro-difluoro-methane	Greenhouse gas & replacement for CFCs
HFC-134a (CH ₂ FCFH ₃)	Tetrafluoro-ethane	GHG (Anthropogenic, not controlled);CFC replacement
N ₂ O	Nitrous Oxide	Greenhouse Gas
NO	Nitric Oxide	Pre-cursor & Controller
NO ₂	Nitrogen Dioxide	Pre-cursor & Controller
O ₃	Ozone	Greenhouse Gas & UV Shield
OH	Hydroxyl Radical	Controller; dominates tropospheric chemistry, but most resides in stratosphere
SO ₂	Sulphur Dioxide	Pre-cursor & controller
ClONO ₂	Chlorine Nitrate	Controller of chlorine in stratosphere
HN0 ₃	Nitric Acid	Pre-cursor & controller; sink of nitrogen oxides; gas/particle conversions & complementary to NO / NO ₂ measurements in lower troposphere

Additional Species (from comments received)

Cl-	Chlorine Ion	Ionic component of aerosols
HCl	Hydrochloric Acid	Source / sink for Cl
HF	Hydrogen Fluoride	
Na-	Sodium Ion	Ionic component of aerosols
NO3-	Nitrate Ion	Gas/particle conversions & complementary to NO/N02 measurements in lower troposphere
OCIO	Chlorine Dioxide	Indicator of active Cl
PAN (CH3CO3NO2)	Peroxy-acetyl Nitrate	Gas/particle conversions & complementary to NO/N02 measurements in lower troposphere
SO4-	Sulphate Ion	Ionic component of Aerosols

The figure shows **the** required level of observation for each atmospheric constituent. The height levels follow the terminology used for the WMO/CEOS database.



ANNEXVI

OUTLINE OF THE ATMOSPHERIC OBSERVATION PLAN

Working Group 1: “Outline of the Plan”

Members: Mike Manton, Vicente Barros, Carolin Richter, Peter Ryder

Working Group 2: “Surface Climate and Interfaces”

Members: Phil Arkin, Fons Baede, Ed Harrison, Raphael Okoola, Nobou Sato, Guoxiong Wu

Working Group 3 : “Atmospheric Constituents”

Members: Doug Whelpdale, David Croom, Stuart Penkett, Céline Phillips

Working Group 4: “Atmospheric Dynamics and Thermodynamics”

Members: David Parker, Ulrich Cubasch, Ed Sarukhanian, Alexander Vasiliev

Outline and Components of a Plan:

- I Background
- II Terms of reference and linkages to other activities
- III Requirements for atmospheric observations
[I, II and III drafted by WORKING GROUP 1].
- IV Components of observing system
 - (a) Atmospheric dynamics and thermodynamics
[Drafted by WORKING GROUP 4]
 - (b) Atmospheric constituents
[Drafted by WORKING GROUP 3]
 - (c) Surface climate
 - (d) Air-sea interface
 - (e) Air-land interface
 - (f) Air-ice/snow interface
[c, d, e and f drafted by WORKING GROUP 2]
- V Evolution of needs and technologies
- VI Recommendations
[V and VI drafted by WORKING GROUP 1]

For each component in Chapter IV the structure is as follows:

- i. Objectives: products/users
- ii. Observing systems needs
- iii. Current status
- iv. IOS (Increments)

- v. Implementation of **IOS**
 - Monitoring and quality control
 - Archiving / access
 - **Product** generation
- vi. Long-term increments

ANNEXVII

LIST OF ACRONYMS

ACSYS	Arctic Climate System Study
AG	Analysis Group (CEOS)
ALPEX	Alpine Experiment
AM	Active Microwave
AMIP	Atmospheric Model Intercomparison Project
AOPC	Atmospheric Observation Panel for Climate (GCOS)
BALTEX	Baltic Sea Experiment
BoM	Australian Bureau of Meteorology
CAS	Commission on Atmospheric Sciences (WMO)
CBS	Commission on Basic Systems (WMO)
CCI	Commission for Climatology (WMO)
CCR	Cloud Cleared Radiances
CDAS	Climate Data Assimilation System
CEOS	Committee on Earth Observation Satellites
CLIVAR	Climate Variability and Predictability (WCRP)
COADS	Comprehensive Ocean-Atmosphere Data Set
DAO	Data Assimilation Office
DEC-CEN	Decadal to Centennial Natural Climate Variability
ECMWF	European Centre for Middle-Range Weather Forecasts
ENSO	El Niño-Southern Oscillation
ERA	ECMWF Re-Analysis
ESA	European Space Agency
FGGE	First GARP Global Experiment
G3OS	GCOS, GOOS and GTOS
GAME	GEWEX Asian Monsoon Experiment
GARP	Global Atmospheric Research Program
GAW	Global Atmosphere Watch
GCIP	GEWEX Continental-Scale International Project
GCOS	Global Climate Observing System
GCSS	GEWEX Cloud System Studies
GEOS	Goddard Earth Observing System
GEWEX	Global Energy and Water Cycle Experiment
GMS	Geostationary Meteorological Satellite
GOALS	Global Ocean Atmospheric Land System
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GOSSP	Global Observing Systems Space Panel
GPCP	Global Precipitation Climatology Program
GPS	Global Positioning System
GRDC	Global Run-off Data Centre
GSN	GCOS Surface Network
GSWP	Global Soil Wetness Project

GTOS	Global Terrestrial Observing System
GTS	Global Telecommunication System
GUAN	GCOS Upper-Air Network
HIRS	High Resolution Infrared Sounder
IABP	International Arctic Buoy Program
IGAC	International Global Atmospheric Chemistry
IGOS	Integrated Global Observing Strategy
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project
ISLSCP	International Satellite Land Surface Climatology Project
JDIMP	Joint Data and Information Management Panel
JMA	Japan Meteorological Agency
JPO	Joint Planning Office (GCOS)
JSTC	Joint Scientific and Technical Committee (GCOS)
MARS	Meteorological Archive and Retrieval System
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration (USA)
NASDA	National Space Development Agency (Japan)
NCAR	National Centre for Atmospheric Research
NCEP	National Centres for Environmental Prediction
NDSC	Network for Detection of Stratospheric Change
NESDIS	National Environmental Satellite, Data and Information Service
NMHS	National Meteorological and Hydrological Services
NOAA	National Oceanographic and Atmospheric Administration (USA)
OOPC	Ocean Observation Panel for Climate (GCOS)
OSSE	Observing System Simulation Experiment
PACS	Pan American Climate Studies
PILPS	Project for Intercomparison of Land-Surface Parameter
QBO	Quasi-biennial Oscillation
SIT	Strategy Implementation Team (CEOS)
SMMR	Scanning Multifrequency Microwave Radiometer
SPARC	Stratospheric Processes And their Role in Climate
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
s s u	Stratospheric Sounding Unit
TAO	Tropical Atmosphere-Ocean Array
TIROS	Television Infrared Observation Satellite
TOGA	Tropical Ocean Global Atmosphere
TOPC	Terrestrial Observation Panel for Climate (GCOS)
TOVS	TIROS Operational Vertical Sounder
UNEP	United Nations Environment Programme
WCP	World Climate Programme
WCRP	World Climate Research Programme
WG/SAT	WMO CBS Working Group on Satellites
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWW	World Weather Watch (WMO)

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. 55 1) 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-ver 1. txt or /gps-ver 1. 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]
- G C O S - 1 2**
(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-ver 1. txt or /dp-ver 1. wp5]
- GCOS-14**
(WMO/TD-No. 68 1) Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995
[ftp://www.wmo.ch/Documents/gcos/gp-ver 1. txt or /gp-ver 1. 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-ver 1. 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-ver 1. 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) Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, third session (Cape Town, South Africa, March 19-22, 1996)
(FAO GTOS-1) [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 CCI/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]
- GCOS-29**
(WMO/TD-No. 794)
(UNEP/DEIA/MR.97-4) Report of the Global Observing Systems Space Panel, second session (Geneva, Switzerland, October 16-18, 1996)
[ftp://www.wmo.ch/Documents/gcos/gosp-2.wp5]
- GCOS30**
(WMO/TD-No. 795) Report of the sixth session of the Joint Scientific and Technical Committee for GCOS (Victoria, British Columbia, Canada, October 28-November 1, 1996)
[ftp://www.wmo.ch/Documents/gcos/jstc-6.wp5]
- GCOS31**
(WMO/TD-No. 803) Proceedings of the fifth meeting of the TAO Implementation Panel (TIP-5) (Goa, India, November 18-21, 1996)
- GCOS-32**
(WMO/TD-No. 796) GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 2.0, June 1997
[ftp://www . wmo.ch/Documents/gcos/top-ver2. wp5]
- GCOS-33**
(WMO/TD-No. 798) GHOST • Global Hierarchical Observing Strategy, March 1997
- GCOS-34**
(WMO/TD-No. 799) Initial Selection of a GCOS Surface Network, February 1997
[ftp://www.wmo.ch/Documents/gcos/gsn-1 .wp5]
- GCOS-35**
(WMO/TD-No. 839) Report of the second Joint CCI/CBS Meeting on the GCOS Surface Network (De Bilt, The Netherlands, June 25-27, 1997)
[ftp://www . wmo.ch/Documents/gcos/cbs-2. wp5]

- GCOS-36 Report of the Joint **GCOS/GOOS/WCRP** Ocean Observations Panel for
(WMO/TD-No. 844) Climate, second session (Cape Town, South Africa, February 1-13,
(UNESCO/IOC) 1997)
- GCOS-37 Report of the Global Observing Systems Space Panel, third session
(WMO/TD-No. 845) (Paris, France, May 27-30, 1997)
(GOOS-10) & (GTOS-9) [<ftp://www.wmo.ch/Documents/gcos/gosp-3.wp5>]
- GCOS-38 Report of the Meeting of Experts on Ecological Networks (Guernica,
(WMO/TD-No. 846) Spain, June 17-20, 1997)
(GTOS-10) [<ftp://www.wmo.ch/Documents/gcos/econet.wp5>]
- GCOS-39 Report of the **GCOS/GOOS/GTOS** Joint Data and Information
(WMO/TD-No. 847) Management Panel, third session (Tokyo, Japan, July 15-18, 1997)
(GOOS-11) & (GTOS-11) [<ftp://www.wmo.ch/Documents/gcos/dimp-3.wp5>]
(UNEP/DEIA/MR.97.8)
- GCOS-40 Report of the **GCOS/WCRP** Atmospheric Observation Panel for Climate
(WMO/TD-No. 848) third session (Reading, UK, August 19-22, 1997)