GLOBAL CLIMATE OBSERVING SYSTEM

WMO UNESCO UNEP ICSU

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

REPORT OF THE GCOS ATMOSPHERIC OBSERVATION PANEL

Second Session

(Tokyo, Japan, March 20-23, 1995)

July 1995

GCOS - 17

(WMO/TD No. 696)

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

TABLE OF CONTENTS

ANNEXES

REPORT OF THE GCOS

ATMOSPHERIC OBSERVATION PANEL

1. OPENING OF THE SESSION

1.1 Dr. Lennart Bengtsson, Chairman of the Atmospheric Observation Panel (AOP), opened the second session of the AOP at the Japan Meteorological Agency in Tokyo, Japan, on 20 March 1995 and welcomed the participants (see Annex I). The Chairman invited the participants to provide a brief personal introduction.

1.2 The Chairman briefly reviewed the overall concept of GCOS, stressing the importance of the discipline-oriented panels such as the AOP in developing the requirements for observations, and in establishing mechanisms for implementation. He noted the output of the first session (Hamburg, April 1994), and reminded the participants that the continuing work of the AOP would provide critical input to the Joint Scientific and Technical Committee (JSTC) for GCOS. As a member of the JSTC, he will report the results of the Panel meeting at JSTC-V, also scheduled to meet in Japan in October 1995.

1.3 The Chairman reviewed the provisional agenda, which was briefly discussed and accepted (see Annex II), proposed working hours for the session, and informed the participants about the material arrangements for the meeting.

2. GCOS PROGRESS REPORT

2.1 Dr. Spence, Director of the Joint Planning Office (JPO) for GCOS, reviewed the recent GCOS planning activities since the last meeting of the Panel. The Director described the meetings and output of the other panels and task groups, pointing out the links to the AOP. He noted in particular the drafts of both the Data and Information Management Plan and the Plan for Space-based Observations which were submitted to the AOP for comments before final publication later this spring.

2.2 He reminded the Panel that it was established to develop specific scientific and technical input concerning atmospheric observations and will be expected to formulate and design the long-term systematic observing system as an integrated part of GCOS. The Panel should co-ordinate its activities with the other panels and working group to ensure consistency among the programme components. The Panel should make specific recommendations regarding implementation.

3. PANEL CHAIRMAN STATEMENT

3.1 The Chairman, referring to the terms of reference of the Panel (see Annex III), reviewed the objectives and progress made at the first session. He advanced his plan for the meeting, including actions needed to be taken. He provided an overview of the importance of the AOP in defining requirements and proposing mechanisms to implement the needed observing system components.

3.2 The Chairman reviewed the types of data that were advanced by the first AOP meeting:

- the 3-D state of the atmosphere including second order moments, vertical fluxes of heat, moisture and momentum, as well as other similar physical and dynamical quantities;
- data for the determination of the state of the surface of the earth, SST, soil moisture, vegetation, albedo, roughness, snow, ice, etc;
- data for the determination of clouds, and of radiation fluxes at the surface and at the top of the atmosphere;
- data on the composition of the atmosphere;
- data for process studies (not principally a GCOS activity);
- data for long-term monitoring.

3.3 In regard to these types of data, the AOP has:

(1) proposed an upper-air baseline network consisting of selected upper-air stations;
(2) initiated development of a surface baseline network of selected SYNOP stations;
(3) considered the strategy to obtain observations of atmospheric constituents;
(4) evaluated satellite systems for monitoring atmospheric properties;
(5) evaluated the requirements for global observations of the hydrological cycle, precipitation, river runoff, and lake water levels.

3.4 The Chairman noted that considerable progress had been made to establish the upper-air network. He urged the Panel to consider what steps could be taken toward a similar network for surface observations. He noted that atmospheric composition requirements still needed further definition, but noted that experts were in attendance to provide such expertise during later agenda items, and that a baseline network could be developed in concert with ongoing activities of the Global Atmosphere Watch (GAW). He noted that the satellite systems were to be addressed as part of the space plan agenda to be discussed later in the meeting. The Chairman noted that, although hydrological cycle observations were being considered next month at the second session of the GCOS/GTOS Terrestrial Observation Panel, the AOP should outline requirements for such observations as part of the global climate modelling efforts. Finally he exhorted the Panel to provide specific recommendations where possible to lead to enhanced observational capability for climate purposes.

3.5 The Chairman took the opportunity to report some recent scientific results to the Panel. He reviewed recent models which combined natural, anthropogenic, and chemical forcing processes. He utilized observations from the Microwave Sounding Unit (MSU) in conjunction with output of the Max Planck model to show encouraging comparisons when the atmospheric constituents were explicitly included. He noted the importance of including the sulphate components to provide improved agreement between models and observations.

4. INVITED REPORTS

The Chairman invited a number of participants to provide brief reports.

4.1 Japanese GCOS Activities

4.1.1 Dr. Matsuno, Chairman of the Japanese Study Committee for GCOS, described the work of the Committee and provided a comprehensive review of the scope of climate observations in Japan. The Terms of Reference of the Study Committee are to:

(1) review and assess existing domestic observing systems relevant to the GCOS and to propose potential Japanese contributions to it;

(2) provide scientific expertise to support the Joint Scientific and Technical Committee for the GCOS.

The Study Committee is composed of Japanese members of the JSTC, academic and government scientists, and other experts. It is sponsored by the Science and Technology Agency (STA) and the Japan Meteorological Agency (JMA).

4.1.2 In his presentation, Dr. Matsuno noted the extensive observational activity in Japan. He reviewed the contributions of JMA through the Observations Department and the Marine Department, as well as the Meteorological Research Institute and the Meteorological Satellite Center. These include meteorological stations, coastal and ocean observations, and aircraft observations of chemical constituents. He also described the ongoing and planned activity of the National Space Development Agency of Japan (NASDA), noting the contributions of both geostationary and polar orbiting satellites. The ADEOS missions were of particular interest to the Panel, since they will include key instruments identified by the GCOS Space-based Observation Panel as contributing to the overall GCOS requirements. The TRMM and ALOS missions were also reviewed. Dr. Matsuno reported on the extensive oceanographic activity of Japan Marine Science and Technology Center (JAMSTEC). The Center currently deploys a number of ocean buoys, and has advanced a major deployment effort as a contribution to the Global Ocean Observing System (GOOS) which will make major contributions to climate issues.

4.2 The Asheville Meeting

4.2.1 The Chairman reviewed the outcome of a meeting in Asheville, NC on Long-term Climate Monitoring of the Global Climate Observing System (GCOS) held January 9-l 1, 1995[1]. The meeting, co-sponsored by NOAA, was attended by about 100 climate scientists.

---

[1] Karl, T., F. Bretherton, W. Easterling, K. Trenberth, and R. Quayle: Long-term climate monitoring of the Global Climate Observing System (GCOS), *Earth System Monitor*, March 1995 (Article reprinted in GCOS *Newsletter, 3,* May 1995)

4.2.2 The meeting developed a series of general and specific recommendations (see Annex IV). The Panel expressed its appreciation to the attendees of the Asheville meeting for the quality, depth, and scope of the comments and recommendations, In subsequent discussion, the Panelists provided numerous comments in support of the recommendations.

4.2.3 One general recommendation (Annex IV, page 7, Recommendation 6) prompted discussion by the Panel. This recommendation identified the need for overlapping measurements of both old and new observing systems for both *in situ* and satellite subsystems as part of general practice. The Panel thought the recommendation could be interpreted to mean a station by station comparison, but noted that such an interpretation could be extremely costly and difficult to implement. The Panel suggested that a more practical approach would be to recommend that when local or regional networks of stations change sensors, a comparison be made at various representative (but not necessarily all) locations for up to one year to produce overlapping data which would be useful in establishing the difference characteristics of the sensors. Additional suggestions included the use of cross-validation of instruments, and the use of space and *in situ* instrumentation to provide additional calibrations. Panel members urged that attention be given to related activity that reduces the observational inhomogeneities.

4.2.4 Panelists recommended that the operational and research communities establish close dialogue on long-term observations. Members urged that the operational community publicize their methods more widely to provide opportunities to improve techniques.

4.3 Weather Extremes

4.3.1 As a new participant in the AOP, Dr. Wu provided an overview of the GCOS programme and documents from his perspective. He uiged that attention be focused on detecting low-frequency modes in historical data, and that transition zones be given more consideration.

4.3.2 Regarding extremes, Dr. Wu focused on four topics including: (1) regional climate simulation, (2) relations between ENS0 and monsoons, (3) tropical storms, and (4) blocking events. He related these topics to the critical observations required to characterize associated weather extremes. For (1) adequate observations of the hydrology and fine-resolution vegetation are needed; for (2) the TOGA network should be supplemented by observations from the Tibetan plateau. For (3) and (4) upper ocean temperatures and related exchange processes are important. A precis of his comments may be found in Annex V.

4.3.3 In the subsequent discussion, it was recognized that a great effort has been made by the climate observing community in collecting and archiving data sets relevant to weather extremes. The Panel noted that it would be very beneficial for the study of global change: (1) to assemble existing datasets from various global and regional climate centres in conjunction with other ongoing programmes (e. g . , WCRP, IGBP), (2) to archive those datasets in a consistent manner, and (3) to disseminate them for public use. These efforts would also provide the primary source material on historical weather extremes.

4.3.4 The Panel emphasized the importance of gathering information on the occurrence of extreme weather phenomena and recommended that efforts be made to examine the feasibility of creating a database on drought, floods, tropical storms, and other related phenomena with a goal of obtaining a minimum set to track such events over long periods. It was agreed that the starting point for gathering such information should be a review of the World Climate Programme and its existing databases. The Panel also recognized the need to identify specific user requirements and to provide guidelines to improve the identification and measurement of extreme phenomena.

4.4 Hydrological Cycles

4.4.1 Dr. Kang reviewed the issues associated with hydrological cycles. He described the situation with regard to precipitation observations, illustrating the detailed precipitation observing network in the Republic of Korea, a high-resolution network similar to that in many countries. He characterized the international problem to be one of data distribution. Currently, information on precipitation is not as effectively shared among the countries as it could be, so it has been difficult to develop regional or global datasets.

4.4.2 The Panel recognized that precipitation data are required by the communities engaged in monitoring and predicting the response of the atmosphere to forcing on climate timescales. The data also provide insight into the efficiency of the atmospheric components of the hydrological cycle. At present this process is an area of active research in the World Climate Research Programme's (WCRP) Global Energy and Water Cycle Experiment (GEWEX). The operational data requirement in terms of temporal and spatial resolution and accuracy should await the outcome of the GEWEX programme. It was noted that GEWEX is producing global precipitation datasets spanning the period 1986 to 1995 (and extending beyond). Also, the Global Precipitation Climatology Centre (GPCC) has been established in the Deutsches Wetterdienst in Offenbach, Germany to support the project. GPCC is also a designated data centre for GCOS users as well. The Panel was very supportive of both activities.

4.4.3 Mr. Sato reviewed the issues associated with surface hydrological processes. He provided an overview of the observational data requirements for use in Land Data Assimilation Systems (LDAS). The major problem in surface hydrology is how to initialize soil moisture and snow depth, which play vital roles in seasonal-to-interannual climate forecasts. Physically, this problem requires quantifying snow depth when the precipitation is in the solid phase and ambient temperatures are below 0°C, and quantifying soil moisture otherwise. These properties of the land surface affect albedo and surface flux and hence the near-surface air temperature, humidity, and the depth of the planetary boundary layer. He noted that there is little hope of measuring soil moisture representatively on the global scale by either terrestrial or space-based methods, although snow depth is more amenable to direct measurements. Therefore, a more indirect measurement strategy is called for in which relatively straightforward measurements of precipitation, surface air temperature, humidity, wind, insolation, and downward terrestrial radiation are coupled through a model of the local land-surface process to yield an "equivalent soil moisture" or "equivalent snow depth", and a measure of runoff. It is a "land" data assimilation system (LDAS). Given the uncertainty of modelling these processes it is obviously sensible and necessary to verify the runoff components through appropriate hydrological measurements (e. g . , river flow). To achieve effective closure of the problem, the data requirement are as identified in the table of Annex VI. Production, intercomparison, and validation of global soil moisture and snow depth distribution are major research subjects of the International Satellite Land-Surface Climatology Project's (ISLSCP) Global Soil Wetness Project.

4.4.4 The Panel noted that some of the identified datasets have known sources and are exchanged routinely (except sub-daily/daily precipitation data -- many of which are captured but are not exchanged). Panelists noted that the distribution of precipitation in time and space is significant; for a given monthly accumulation the effects of uniform drizzle or high intensity episodic precipitation on a soil moisture calculation are obviously quite distinct.

4.4.5 While in principle model-derived precipitation can be used in lieu of observations, the Panel noted that there is a danger that soil moisture thus derived may drift to unnatural extremes unless effectively confirmed by measurements.

4.4.6 The global and regional climatology of precipitation is difficult to derive from existing observations particularly over the oceans. The Panel recognized that various datasets do not show a consistent picture of precipitation today. Given the spatial and temporal scale associated with precipitation, it will be difficult, if not impossible, to provide coverage from ground-based measurements alone. Therefore development of methods for inferring precipitation intensity from space were strongly endorsed by the Panel. In this regard, the TRMM mission to be flown late in the decade is expected to be of great value. For the mission, ground truth measurements will be required and high-resolution networks such as those installed in Japan and Korea will be expected to make important contributions.

4.4.7 Mr. Sato also pointed out that cloud parameters (cloud fraction and cloud top temperature) derived from geostationary meteorological satellites are quite useful in the initialization of moisture and divergence fields in the tropics. They will also be essential to initialize cloud liquid water in atmospheric data assimilations in the near future. As a result, the Panel recommended the production and real time exchange of the cloud data over the Global Telecommunication System (GTS) be pursued in the appropriate WMO bodies.

4.5 <u>Data Assimilation</u>

4.5.1 As a result of the extensive discussion on data assimilation in the preceding agenda item, Dr. Julian provided a brief comment on the participation of climate experts in the reanalysis projects. Considering the various aspects of observational data incorporated or assimilated into climate data assimilation systems and future reanalysis efforts, the Panel recommended that in future reanalysis efforts the climate community be represented in planning and on appropriate advisory groups. While climate data assimilation systems, whether used with historical data (reanalysis mode) or with current ongoing data, use a fixed model-assimilation system the input observational data are not similarly homogeneous in time. For climate change detection on the decadal time scales, it is important to understand how the assimilation of inhomogeneous input data affects the resulting 4-D analyses. The Panel believes that observing system impact experiments should be considered and future reanalysis efforts performed with a database designed to be as homogeneous in time as possible.

4.5.2 The Panel also considered the specific recommendation concerning reanalysis activity from the Asheville meeting. The principal objective of the reanalysis effort is to provide climate communities with a climate data base as reliable as possible by using and adhering to the state-of-the-art analysis/forecast system. The Chairman expressed the view that another principal outcome of the reanalysis effort would be to obtain information to improve numerical weather prediction. The Panel urged that the climate community identify particularly valuable subsets of data from the reanalysis for consideration and actively collaborate with the reanalysis projects with the principal aim of reducing bias in the observations. When the first reanalysis products are available, the climate community should evaluate them and make recommendations for improveing future reanalyses. The Panel reiterated its support for the reanalysis efforts, and wished to continue reviewing the progress.

4.6 Other Reports

4.6.1 Dr. Spence reported on recent activities regarding data and product requirements. A recent WMO Inter-Commission Task Team meeting was convened to determine those data and products which should be shared internationally. The report of the meeting was discussed by the Panel to be certain that the requirements identified by the Task Team included those necessary for GCOS. The Panel accepted that GCOS needs would be met by the parameters that were identified in the Task Team Report (Available from the JPO), but made a few editorial suggestions for transmission to the Task Team. The Panel recommended that absent members be provided with a copy for their comments, and the remarks be collected by the JPO for future meetings of the Task Team. The Panel urged that the AOP and other GCOS panels be invited to continue their review of such data and product assessments, and that their input be ensured in future documents prepared by the Task Team.

5. IMPLEMENTATION CONSIDERATION

5.1 Upper-air Network

5.1.1 Dr. Baede led the discussion of the GCOS Upper-air Network. This network of about 150 stations, selected from stations in the WMO Global Observing System (GOS), were chosen to provide a relatively homogeneous distribution. The criteria for selection included long-term quality and reliability with a good prospect of future continuity (see the Report of the Atmospheric Observation Panel, first session, Annex VII).

5.1.2 At its first session in Hamburg the Panel requested Dr. Baede, Rapporteur on GCOS to the WMO Commission for Basic Systems (CBS) Working Group on Observations (WGO), to stage a review of the proposed GCOS Permanent Upper Air Observation Network (GUAN) from a feasibility point of view. Dr. Baede presented his report of the review based on comments received from the Rapporteur on Regional Aspects of the GOS, the Chairman of the WMO Executive Council Working Group on Antarctic Meteorology, the CBS Rapporteur on Upper Air Observations, and the Representative on the Working Group on Observation of the CBS Lead Centre for Radiosonde Data. He reported that all those approached had been very co-operative and had returned very useful comments. Additionally, the initial list of prospective stations was sent by the WMO Secretariat to concerned WMO Members for their comments. A number of responses had been received and incorporated in a final version of the report to be submitted to the WGO.

5.1.3 Dr. Baede noted that many of the suggested changes and additions specified in the report would improve the proposed GUAN and should be adopted. Some of the suggested changes could potentially be important contributions to the GUAN, but in some cases would require improved performance and monitoring. He proposed to establish a standing list of stations, including information on network enhancements and station upgrades as proposed in the original proposal, and stations requiring additional monitoring to assure quality control.

5.1.4 Dr. Baede concluded his introduction by saying that the WGO had resolved that the proposed network, if amended and updated as proposed, would be a feasible initial step towards the establishment of a GUAN.

5.1.5 The Panel thanked Drs. Baede, Julian, Sarukhanian and Zbar, as well as those who contributed to the review, for their valuable work. It noted that the establishment of a GUAN, as part of the GCOS Initial Operational System (IOS), had made considerable progress since its first meeting. In further discussing the report to the WGO, the Panel requested the WMO Secretariat to continue collecting comments from the Members concerned but to impose a clear deadline for their replies. These comments would be incorporated in the final Report of the proposed GUAN to be submitted by the Chairman of the WGO.

5.1.6 The Chairman of the Panel stressed that it should be made clear to countries why their station(s) had been selected and that these stations should be highlighted as GCOS Stations and recognized as important contributions of WMO Members to the IOS. It should also be made clear that identifying these stations in the IOS should in no way diminish the value of other stations which were not selected -- they serve other important functions, and should continue.

5.1.7 The Panel emphasized the importance of maintaining the GUAN, including the stations on the standing list, once it has been established. It recommended that the Lead Centre for Radiosonde Data, through CBS, be invited to carry out this task as a part of the operational maintenance programme. The Panel suggested that it would be very useful for the Lead Centre to report on the average altitude reached by upper air stations. Furthermore, Members should be requested to take the necessary steps to promote the implementation of the proposed vertical enhancements and station upgrades.

5.1.8 Dr. Baede noted that several desirable properties/characteristics of upper-air stations, over and above present requirements for the World Weather Watch (WWW) Global Observing System (GOS) upper-air stations, were brought to his attention. He therefore proposed that the Panel introduce the concept of "high performance stations", as a desirable component of the GUAN. The Panel concluded that countries operating GUAN stations should be encouraged to do so according to "best practice". Best practice in operational performance should address, *inter alia*, the following elements:

- long-term continuity;
- provision of detailed metadata;
- use of high altitude soundings (up to 5 hPa if possible);
- rigorous quality control at stations;
- back-up release in case of failure;
- co-location with atmospheric constituent measurements (e.g., GAW stations).

CBS should be requested to incorporate this "best practice" concept into its manuals and guides on the WWW GOS. The Panel also stressed the importance of radiosonde intercomparisons, and expressed support for the ongoing efforts to develop a reference station for this purpose.

5.1.9 Dr. Sarukhanian presented a list of actions required to finalize the GUAN, together with a time schedule as follows:

1. Members who have not submitted their comments on the GUAN list will be requested to do so before 1 June 1995;

2. A complete report to be prepared by CBS WGO on the basis of replies received before 1 July;

3. A final report to be sent to the Chairman of AOP (copy to Director, Joint Planning Office for GCOS) from CBS WGO by 1 July;

4. A final list of stations to be prepared by GCOS consultant and submitted to Chairman of AOP by 1 September;

5. A final list to be approved by JSTC-V upon submission by the Chairman of AOP in October;

6. The final approved list to be sent to Members concerned from JSTC in November 1995 with a letter in which Members will:

   (a) be urged to give the stations in the baseline upper-air network high priority for implementation within the regional basic synoptic networks and to make long-term commitments to maintain and operate the stations,

   (b) be invited to initiate, where necessary and possible, joint schemes for funding and managing observing systems, to cover large data-void areas and meet the needs of GCOS.

The Panel approved the proposed schedule and requested the Director of the Joint Planning Office to monitor progress. The Panel also recommended that a set of guidelines be prepared which would assist Members in upgrading existing stations for inclusion in the network in the future.

5.2 Surface Reference Network

5.2.1 At AOP-I, the Panel considered the desirability of establishing a surface reference network based on similar considerations as the upper-air network. A subset of reliably reporting, high-quality, homogeneously distributed stations would be important as a global data base for climate. Criteria would include: (1) record quality; (2) representativeness of the location; (3) area1 coverage; and (4) prospect for continuity in the future.

5.2.2 The Panel recalled the earlier efforts made by the Commission for Climatology (CCl) toward the development of a network of Reference Climatological Stations (RCS) suitable for monitoring and research on climate change. Data from such a network can describe inter-annual variability and inter-decadal and longer trends which must be documented in order to describe climate change and corroborate climate models. At the AOP-I, it was recommended that GCOS co-operate with the CC1 and its working groups to develop proposals for a surface reference network.

5.2.3 The Panel noted with appreciation that the World Climate Data and Monitoring Programme (WCDMP) convened a joint meeting of the CC1 Working Group on Data and a Task Group of the CC1 Working Group on Climate Change Detection (WGCCD) with active AOP participation. As a result of the meetings, a Conceptual Design and Rationale for the network was developed (see Annex VII), and recommendations from the Task Group (see Annex VIII).

5.2.4 The Panel agreed with the rationale of selection and with the proposal that the network should be composed of approximately 800 surface stations. In considering the list of variables to be measured at the stations, the Panel expressed its opinion that the measurement of temperature, with sufficient time resolution to accurately calculate average daily temperature, is essential. The Panel therefore recommended to include it in the list of measured variables.

5.2.5 With respect to an implementation strategy, and in light of the recommendations of the Task Group, the Panel recommended that the following actions be taken:

1. The AOP and WGCCD will establish a task team of experts in order to prepare an initial design of a GCOS Permanent Surface Observation Network starting from proposals made by the Climate Research Unit at the University of East Anglia;

2. The proposed design to be submitted to the AOP will be forwarded to the CBS WGO for review from the point of view of technical quality and feasibility;

3. The WGO will prepare a report containing their comments and submit it to the CBS Advisory Working Group. The Advisory Working Group will subsequently request WMO Members to provide their comments on the proposed list of stations included in the GCOS Permanent Surface Observation Network;

4. As was done with the GCOS Upper-air Network, a final report will be prepared by the CBS WGO on the basis of replies from Members, and will be submitted to AOP;

5. On the basis of this report the AOP will finalize a list of stations for JSTC approval;

6. After approval, the list will be sent to WMO Members urging them to give the stations in the GCOS Permanent Surface Observation Network high priority for operation and maintenance.

The Panel urged that the task should be completed within the year.

6. ATMOSPHERIC CONSTITUENTS

The Chairman invited Dr. Whelpdale to provide an overall context for a review of requirements for atmospheric constituents. Dr. Whelpdale presented an outline for the subsequent discussion which addressed the background, the needs for observations and information, the recommendations from the Asheville meeting on constituents, and a review of the observational activities underway.

6.1 Chemical Constituent Input for Models

6.1.1 Dr. Rasch was invited to present an overview of the chemical constituent requirements for various models. He reviewed the use of data first in Chemical Transport Models (CTM) which are a combination of models representing the linking of meteorological and chemical processes in the atmosphere. He contrasted the approach where chemistry is embedded in a General Circulation Model (GCM) where observations and analyses are used for verification and as supplemental datasets, and the approach where chemistry is embedded in an off-line model driven by archived data based on formerly computed GCMs via analyzed data sets.

6.1.2 Dr. Rasch noted that recent models have become more comprehensive, and are now including such processes as:

- convection and planetary boundary layer transports;
- aqueous chemistry;
- surface chemistry on particles;
- aerosols;
- scavenging;
- in-cloud photolysis.

Such processes place new demands on observations, and lacking adequate measurement, models are guided by statistics or parameterizations. The latter are often not consistent since there is inadequate information for consistency or mismatches in parameterizations used.

6.1.3 Dr. Rasch concluded by noting that current needs include information on clouds and aerosols both to understand climate and to drive the chemistry models. He recommended that, in addition, a set of easily measured tracers with disparate lifetimes and/or source distributions should be observed, and archived for use by the modellers.

6.1.4 Panelists were concerned to know the spatial and temporal scales and resolutions required. Dr. Rasch noted that nearly 90% of the current observations are taken at the surface, but that tropospheric observations are required at many points. He observed that some of the more complex models are able to simulate 3-D distributions, but additional observations are required to validate the simulations.

6.2 Current Constituent Observations

6.2.1 Dr. Whelpdale reviewed the efforts made by GCOS and by others to address observations of chemical constituents. He noted the work of a specific Task Group in 1992, and the work of the AOP and JSTC as well as the work of the WMO Executive Council (EC) and Commission for Atmospheric Science (CAS) EC Panel of Experts/CAS Working Group on Atmospheric Chemistry and Environmental Pollution. Based on the work of such groups, he described the type of information required. For climate, the principal need is for climate forcing variables, biogeochemical cycles, trends, and fluxes at the boundaries.

6.2.2 The composition measurement needs include:

1. Trace gases (CO,, O_3 -- total, profile, surface, CH_4, CO, N_2O, CFC, HCFC, HFC, PFC, H_2O -- stratosphere, OH, and various isotope ratios);

2. Aerosols (troposphere, stratosphere, concentrations, size distributions, composition; sulphates, carbonaceous, volcanic);

3. Others (UV-B -- surface, profile).

These should be obtained from measurements at the surface, of profiles, and from satellites.

6.2.3 The Panel, noting that Japanese scientists currently use flights of Japan Airlines to acquire valuable information on CO_2 concentrations between Japan and Australia, encouraged the investigation of the more extensive use of commercial airline flights to make routine measurements of selected chemical species in order to acquire information on their horizontal and vertical distributions.

6.2.4 Dr. Whelpdale provided an update on the activities of the Global Atmosphere Watch (GAW), particularly on ozone and aerosols. He noted that the GAW includes a small number of “global” stations and a larger number of “regional” stations. The programme includes quality control, and provisions for archiving various sorts of data for future use. The Panel agreed that many of the requirements for GCOS will be met through the GAW activities.

6.2.5 Dr. Whelpdale briefly reviewed the recommendations from the Asheville meeting regarding atmospheric constituents which focused principally on greenhouse gases (see Annex IV). He also noted that there was considerable “informal guidance” from the Asheville meeting regarding collaboration (instrument and network design, analysis and interpretation), integration of observations (in *situ,* satellite, ground based), emphasis on high quality from few sites (rather than global coverage at mediocre quality), and strengthened links among users and observers, and among modellers, theoreticians, and observers.

6.2.6 Dr. Matsuo informed the Panel about the WMO World Data Centre for Greenhouse Gases located in JMA. The Center is one of several which archives data related to atmospheric chemistry. Other centres retain information on ozone, turbidity, radiation, and aerosols. During the subsequent discussion, Panelists were concerned to learn that while much data are collected, dissemination and user access mechanisms are limited and require improvement. The Panel contrasted the approach of the World Weather Watch which has three principal elements to attend to the collection of observations, the distribution of observations, and the generation (and subsequent distribution) of appropriate products. This paradigm may be relevant to the observations of atmospheric chemistry. The Panel recommended that Dr. Whelpdale review the role of CAS with regard to the establishment of distribution protocols for constituent information. The Panel was pleased to learn about the activities of the centre at the University of Thessaloniki in Greece. It serves as a point of distribution for ozone mapping information to the user community. Similar activities were encouraged.

6.3 Development of Recommendations

6.3.1 The presentation and subsequent discussion by the Panel on atmospheric chemical constituents emphasized the essential role of chemical measurements in GCOS. Chemical data are necessary for the quantification of radiative forcing, for model validation, and to elucidate biogeochemical cycles. The species of primary interest for climate characterization are the greenhouse gases, ozone, and the aerosols. These species are in mm strongly influenced by a variety of other species, which therefore must also be measured (e.g., NO_x, SO_x, CO). For model validation, the measurement of a suite of tracer species with a variety of lifetimes and with spatially varying source distributions would be useful.

6.3.2 It was agreed that an integrated approach, employing both terrestrial and space-based observing methods, would be required to meet these needs. Satellite observations have significant capability for global observations principally in the stratosphere and mesosphere while surface based methods offer the best hope for tropospheric measurement probably through the next decade.

6.3.3 The Panel was provided with a comprehensive document prepared by Mr. Vet of the Canadian Atmospheric Environment Service, for the Joint Planning Office which provided an overview of the existing and planned observations of atmospheric constituents. In light of that document, the Panel noted that the various observational systems now in place for measurement of chemical species and related parameters are relatively new, and still evolving. Substantial progress has been made recently in data-sparse areas, and in improving the quality assurance procedures. The Panel commended these accomplishments and urged that additional steps be taken now to ensure the overall integrity of the chemical measurement systems. These should include the establishment of procedures to monitor operational aspects such as station reporting and quality, access to and full use of the data, and the availability of metadata. In this regard, monitoring centres such as the GAW World Data Centres (WDC) or the Quality Assurance/Science Activity Centres are encouraged to perform basic analyses of the various datasets, both as a quality assurance step, and as a basic service for potential data users (e.g., the WDC for Greenhouse Gases in Japan, the Ozone Mapping Centre in Greece). The Panel recommended that CAS take the appropriate actions to ensure data quality and access.

6.3.4 In view of the rapid evolution of systems to monitor atmospheric composition, the Panel agreed that it is premature to recommend the establishment of a complete atmospheric composition reference network at this time. Nevertheless, the global stations of GAW and the NDSC would appear to be a suitable nucleus for such a network. The Panel urged that the responsible agencies strive for comprehensive and very high quality measurement programmes at these sites. The Panel noted that the provision of information on the vertical distribution of chemical species is a more pressing requirement than additional surface measurements for some key applications (e. g . , model validation). Therefore, where appropriate and feasible, surface observations at the sites should be supplemented with routine vertical profile or multi-level measurements.

6.3.5 The number and distribution of measurements of the longer-lived greenhouse gases appear to be adequate to assess radiation forcing and model validation. Additional sites (perhaps using flask sampling) are required to determine source and sink distributions. In the case of ozone measurements, additional vertical profile information is required, particularly in the tropics and sub-tropics, and in the upper troposphere/lower stratosphere regions. Improved co-ordination and data handling are required for surface ozone measurements. The Panel noted with interest the plans for an International Tropospheric Ozone Year (ITOY), which will not only enhance knowledge of ozone behaviour in data-sparse areas, but also lead to improved long-term monitoring. The Panel strongly supports this initiative. Long-term climate-related measurements of aerosol remain problematic. Recent initiatives of the International Global Atmospheric Chemistry (IGAC) project to study the radiative aspects of regional aerosols are welcomed, as are the instrument development and testing projects within GAW. Ozone and aerosol measurements are a high priority for GCOS, and the Panel urged CAS to enhance and develop, respectively, these programmes in GAW as quickly as possible.

6.3.6 In order to advance this aspect of GCOS, the Panel recommended the holding of a workshop to evaluate further "customer" needs for climate-related atmospheric composition measurements (e.g., modellers, GCOS panelists, policy makers, synthesis groups). The Panel reiterated its earlier recommendation that the JSTC work to establish a forum to encourage close collaboration and interactions between the operational and scientific programmes in this area. This forum could consist of representatives of the individual networks and scientists responsible for the major scientific programmes in atmospheric sciences. The scientific members of this forum should provide advice on the type of network, measurement programme, type of instrumentation and assist in establishing new stations or abandon existing stations.

6.3.7 The Panel recommended that the results of the GCOS activities concerning chemical constituents be consolidated in a document which, after review by JSTC-V, could be widely distributed.

7. THE INITIAL OPERATIONAL SYSTEM

7.1 Specific Activities to be Developed

7.1.1 The Panel expressed its appreciation for the support received from the various WMO bodies in the establishment of the upper-air network, and encouraged similar support for the surface network. The panelists agreed to actively participate in developing further the recommendations from the Asheville meeting, the implementation of the surface reference network, and the activities in support of chemical constituent observations.

7.2 Inputs to the Space and Data Plans

The Plan for Space-based Observations

7.2.1 Dr. Ryder, Chairman of the GCOS Space-based Observation Panel (SOP), reviewed the latest draft (March 1995) of the GCOS Space-based Observation Plan. He outlined the approach that had been taken by the initial Task Group in preparing a draft for review by the GCOS science-based panels such as the AOP, and by representatives of the scientific community. Noting that the SOP would meet in May, he solicited input from the members of the Panel for inclusion.

7.2.2 Panelists expressed their appreciation for the extensive work that had been done in preparing the draft plan. Panelists were pleased to see that the atmospheric instruments were featured prominently in the plan. They were very supportive of the activities noted in the plan to engage developing countries as well as those with active space programmes. Mr. Haruyama provided an agency perspective, and urged that the space plan provide adequate links to the agencies so that their plans may be responsive to the user requirements. He used the NASDA Tropical Rainfall Measurement Mission (TRMM) as an illustration. The mission will generate significant new observations of precipitation in the tropics, but the relevance of the data to GCOS has not been made explicit in the plan. Dr. Ryder agreed to take the comments to the SOP meeting.

The GCOS Data and Information Management Plan

7.2.3 The Panel reviewed the final draft of the GCOS Data and Information Management Plan and discussed, in detail, the objectives, the system vision, and the strategy behind the plan. The Panel agreed that the plan has been designed in such a way that it may serve a broad range of users who require information from primary data (Level I) to final climate products (Level IV). In view of the rapidly evolving communication technology, and considering that the volume of information as well as the range of products are likely to change considerably with time, the Panel urged the use of flexible telecommunication services as noted in the plan (e.g., Internet) as a realistic approach to meet GCOS needs.

7.2.4 The Panel strongly recommended that the JSTC give careful attention to the need for long-term commitments by nations, not only to provide primary observations and communication facilities, but also to provide the necessary processing infrastructure required for the provision of climate predictions and climate change assessments. While this is implicitly anticipated in the plan, it is not fully spelled out.

7.2.5 Satellite data processing, for example, requires substantial human resources and computing facilities in order to transform measurements into useful geophysical parameters. Recent experience suggests that for some parameters this should be undertaken preferably within the framework of 4-Dimensional Data Assimilation (4-DDA) in order to explore the full information content. Climate monitoring requires long-term homogeneous data sets of the three dimensional state of the global atmosphere. This will require dedicated reanalysis archives based not only on a frozen data-assimilation system, as is the case with the ongoing reanalysis activities of the European Center for Medium Range Weather Forecasts (ECMWF) and the U.S. National Meteorological Center (NMC), but also the usage of a quasi-homogeneous observational data set.

7.2.6 In order to provide the community with ongoing information of the state of the Earth's climate system including the composition of the atmosphere as well as projections of the future evolution and its effect on the climate and the environment, systematic modelling and predictions will have to be undertaken. The necessary human and computing resources must be seen as a substantial activity and must be assured by nations on a long term basis.

7.2.7 Finally, the Panel stressed the necessity that data and products to be provided within the framework of GCOS-related and supported projects should be made available at minimum cost to the users and that the climate research community at large should be invited and encouraged to use the information.

7.2.8 The Panel was informed that a new practice on international data and product exchange, which had been developed by the WMO Executive Council Working Group on Commercialization of Meteorological and Hydrological Services, would be considered by the Twelfth WMO Congress in June. Panel members were reassured by those involved in the preparations for the Congress that the new practice would facilitate the continued free and open exchange (i.e., data exchange at no more than the incremental cost of meeting the specific request and to users without discrimination) of information required by the GCOS user community for bona-fide research purposes.

8. CLOSURE OF THE MEETING

8.1 In mid-afternoon on 23 March 1995, the Chairman closed the meeting and thanked the participants for their contributions. Although no firm date was selected, the Panel will plan to reassemble in spring 1996.

Annex I

List of Participants

Dr. Lennart BENGTSSON **(Chairman)** Max-Planck-Institut fur Meteorologie Bundesstrasse 55 20146 HAMBURG, Germany	Tel: 49 40 4117 3349 Fax: 49 40 4117 3366 Email: bengtsson@dkrz.d400.de
Dr. Alphonsus P. M. BAEDE Koninklijk Nederlands Meteorologisch Instituut Postbus 20 1 3730 AE DE BILT, Netherlands	Tel: 3130 20 6446 Fax: 3130 21 0407 Email: baede@knmi. nl
Mr. Yukio HARUYAMA Earth Observation Planning Department National Space Development Agency of Japan l-29-6, Hamamatsu-cho , Minato-ku TOKYO, 105, Japan	Tel: 81 3 5401 8687 Fax: 81 5401 8702 Email: haruyama@rd.tksc.nasda.go.jp
Dr. Paul JULIAN P.O. Box 600 SUITLAND, MD 20752, U.S.A.	Tel: 1 301 423 9420 Fax: 1 301 423 9420 Email: 75031.1433@compuserve.com
Dr. In-Sik KANG Department of Atmospheric Sciences Seoul National University Kwanak-ku, SEOUL 15 1, Republic of Korea	Tel: 82 2 880 6718 Fax: 82 2 883 4972 Email: kang@climate1 .snu.ac.kr
Mr. Yuji KANO Office of Climate Program Administration Department Japan Meteorological Agency l-3-4 Otemachi, Chiyoda-ku TOKYO 100, Japan	Tel: 81 3 3211 4966 Fax: 81 3 3211 2032 Email: inad-jma@hq.kishou.go.jp
Dr. Taro MATSUNO Professor Hokkaido University 3-l • 1 Minato-cho HAKODATE 041, Japan	Tel: 81 11 706 2365 Fax: 81 11 726 6234
Dr. Takayo MATSUO Head, Japan Climatic Data Center Observations Department Japan Meteorological Agency l-3-4 Otemachi, Chiyoda-ku TOKYO 100, Japan	Tel: 81 3 3211 4966 Fax: 81 3 3211 4640 Email: jcdc@hq.kishou.go.jp

Dr. Kei MUNEYAMA
Japan Marine Science and Technology Center
2-15 Natsuhsima-Cho
YOKUSUKA, 237 Japan

Tel: 81 468 663 811
Fax: 81 468 660 970
Email: muneyama@mstkid.jamstec.go.jp

Dr. Philip RASCH
National Center for Atmospheric Research
P.O. Box 3000
BOULDER, CO 80301, U.S.A.

Tel: 1 301 497 1368
Fax: 1.301 497 1324
Email: prj@ncar.ucar.edu

Dr. Peter RYDER
Meteorological Office
London Road
BRACKNELL RG12 2SZ, United Kingdom

Tel: 44 344 85 4608
Fax: 44 344 85 4948
Email: pryder@meto.govt.uk

Dr. Masaro SAIKI
Planning Division, Administration Department
Japan Meteorological Agency
l-3-4 Otemachi, Chiyoda-ku
TOKYO 100, Japan

Tel: 81 3 3211 4966
Fax: 81 3 3211 2032
Email: inad-jma@hq.kishou.go.jp

Dr. Eduard SARUKHANIAN
Observing System Division
World Weather Watch Department
World Meteorological Organization
Case Postale No. 2300
1211 GENEVA, 2 Switzerland

Tel: 41 22 730 8227
Fax: 41 22 734 2326
Email: wwwmail@www.wmo.ch

Mr. Nobuo SATO
Numerical Prediction Division
Forecast Department
Japan Meteorological Agency
l-3-4 Otemachi, Chiyoda-ku
TOKYO 100, Japan

Tel: 813 3211 4966
Fax: 813 3211 2453
Email: kz1n-stu@j.asahi-net.or.jp

Mr. Kuniyuki SHIDA
El Niiio Monitoring Center
Oceanographic Division, Marine Department
Japan Meteorological Agency
l-3-4 Otemachi, Chiyoda-ku
TOKYO 100, Japan

Tel: 81 3 3211 4966
Fax: 81 3 3211 3047
Email: k_shida@hq.kishou.go.jp

Dr. Keisuke TAIRA
Director, Center for International Cooperation
Ocean Research Institute
University of Tokyo
Minamidai 1-15-1, Nakano
TOKYO 164, Japan

Tel: 81 3 5351 6417
Fax: 81 3 5351 6418
Email: taira@ori.u-tokyo.ac.jp

Dr. Tatsushi TOKIOKA
Head, Office of Climate Program
Administration Department
Japan Meteorological Agency
l-3-4 Otemachi, Chiyoda-ku
TOKYO 100, Japan

Tel: 81 3 3212 8341
Fax: 81 3 3211 2032
Email: tokioka@hq.kishou.go.jp

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

Tel: 1 416 739 4869
Fax: 1 416 739 4288
Email: dwhelpdale@dow .on.doe.ca

Dr. Guoxiong WU
State Key Laboratory for Atmospheric Sciences
Geophysical Fluid Dynamics (LSAG)
Institute of Atmospheric Physics
P.O. Box 2718
BEIJING 100080, China

Tel: 86 1257 1939
Fax: 86 1256 2347
Email: gxw@sgi50s.iap.ac.cn

Dr. Frederick S. ZBAR
National Weather Service, NOAA
Office of Meteorology • Rm 13 118
1325 East-West Highway
SILVER SPRING, MD 20910, U.S.A.

Tel: 1 301 713 1867
Fax: 1 301 589 1321
Email: fzbar@smtpgate. smcc.noaa.gov

Secretariat

Dr. Thomas W. SPENCE
Director, Joint Planning Office
c/o WMO
Case Postale 2300
CH-1211 GENEVA 2, Switzerland

Tel: 41 22 730 8401
Fax: 41 22 740 1439
Email: jpo@gcos. wmo. ch

Annex II

Agenda

1. Opening of the Session

2. GCOS Progress Report

3. Panel Chairman Statement

4. Invited Reports
   - 4.1 Japanese GCOS Activities
   - 4.2 The Asheville Meeting
   - 4.3 Weather Extremes
   - 4.4 Hydrological Cycles
   - 4.5 Data Assimilation
   - 4.6 Other Reports

5. Implementation Consideration
   - 5.1 Upper-air Network
   - 5.2 Surface Reference Network

6. Atmospheric Constituents
   - 6.1 Chemical Constituent Input for Models
   - 6.2 Current Constituent Observations
   - 6.3 Development of Recommendations

7. The Initial Operational System
   - 7.1 Specific Activities to be Developed
   - 7.2 Inputs to the Space and Data Plans

8. Closure of the Meeting

Annex III

Terms of Reference for the Atmospheric Observation Panel

Recognizing the need for specific scientific and technical input concerning atmospheric observations, the Joint Scientific and Technical Committee (JSTC) for GCOS hereby establishes an Atmospheric Observational Panel for climate with the following terms of reference,

Term of Reference:

- In accordance with the GCOS Plan, to formulate and design a long-term systematic observing system for the atmosphere as an integrated part of GCOS, with the objective to monitor, understand and provide information for the possible prediction of the dynamical, physical and chemical processes that determine the state of the atmosphere from seasonal to multi-decadal time scales;

- To seek review and implementation support from the operators of other relevant research or operational programmes (e.g., WWW, GAW, WCRP, IGBP) and to collate, review, publish, and prioritize data requirements and observing system specifications, to ensure the best possible support for GCOS;

- To coordinate the activities with other GCOS panels and task groups to ensure consistency of requirements with the overall programme;

- To report regularly to the JSTC.

Chairman. Dr. Lennart Bengtsson, Germany

Annex IV

Long-term Climate Monitoring of the Global Climate Observing System (GCOS)

International Meeting of Experts, January 9-11, 1995 Asheville, NC USA

Thomas Karl[2], Francis Bretherton[3], William Easterling[4], and Kevin Trenberth[5]

1. BACKGROUND

The documentation of long-term climate variations and changes is important for several reasons. Such information is essential to understand impacts on managed and unmanaged social and biophysical systems. Additionally, the early detection of anthropogenically-induced climate change rests upon an observing system capable of delivering adequate long-term data. In its report, the IPCC (1995) posed several questions to the scientific community regarding the present and past states of the climate for which our present observing system and data management practices have failed to deliver the quality of data required to deduce unequivocal information about the rates, and often even the sign of multi-decadal changes and variations. Answers to specific questions such as:

(1) Is the climate warming?
(2) Is the hydrologic cycle changing?
(3) Is the atmospheric/oceanic circulation changing?
(4) Is the climate becoming more variable or extreme?

are thwarted due to an inadequate or non-existent climate observing system. Each of the above questions is actually quite complex, not only from the standpoint of a multivariate problem, but because of the various aspects of spatial and temporal sampling that must be considered. Obviously, without adequate answers to such basic questions, understanding climate change and its predictability is not possible.

The development of a Global Climate Observing System (GCOS) offers the opportunity for scientists to do something about existing observing deficiencies in light of the importance of documenting long-term climate change that may already be affected by anthropogenic changes of atmospheric composition and land use.

As an important step toward improving the present situation, a workshop was held to help define the long-term monitoring requirements minimally needed to address the four questions

---

[2] **National Climatic Data Center, Asheville, NC**

[3] **University of Wisconsin, Madison, WI**

[4] **University of Nebraska, Lincoln, NE**

[5] **National Center for Atmospheric Research, Boulder, CO**

posed above, with special emphasis on detecting anthropogenic climate change and its potential impact on managed and unmanaged systems. The workshop focused in on three broad areas related to long-term climate monitoring:

(A) the scientific basis of the long-term climate products (including their accuracy, resolution, and homogeneity) required from our observing systems as related to the detection issue and the four questions posed by the IPCC;

(B) the status of long-term climate products and the observing systems from which these data are derived; and

(C) implementation strategies necessary to fulfil item (A) in light of the existing systems.

Item C was treated more in terms of feasibility rather than a specific implementation plan.

2. INTRODUCTION

NOAA and the GCOS Joint Planning Office (JPO) helped to support a total of 94 participants who met for three days in Asheville, North Carolina, USA. About half the participants were from non-government institutions and the other half were affiliated with national governments. Nine participants also represented world organizations. Scientists from ten countries participated, including North America (Canada and the USA), Europe (Czech Republic, Finland, France, Germany, the Netherlands, and UK), Australia, and Japan.

There have been many planning meetings specifically for GCOS, but this was one of the first involving a whole community. Given the many previous planning meetings for GCOS it is important to recognize the extensive work by committees already in place and to move ahead from there, rather than reinventing suggestions already being acted upon. Of course, this was not easy as many participants were not familiar with all the GCOS reports. However, the workshop should be viewed as helping to define realistic GCOS goals as related to the consensus of some of the world's leading scientists with special interests in decadal-to-centennial time-scale climate monitoring.

In his opening remarks, John Townshend, speaking on behalf of the Chair of the Joint Scientific and Technical Commission, Sir John Houghton, reviewed the overall tasks of GCOS and the challenges ahead. He noted that the tasks included:

1. collating the data on observational systems,
2. objectively defining the needs,
3. assessing the capabilities in scientific terms,
4. defining the deficiencies of observational systems, and

5. defining improvements in observing systems.

Clearly, these actions will all lead to improvements in observation, assimilation, and information systems which, in turn, again serve as a basis for re-examining vital GCOS issues. Dr Townshend noted that there will be competition for resources and vigorous questions of the value of environmental monitoring and research. There will be changing policy priorities that will need to be addressed and pressures of commercialization. A special challenge will be to balance national policies with international responsibilities.

Additional challenges arise from the inherent complexity of the Earth system, with enormous variation in both time and space. Dr Townshend pointed out the difficulties in obtaining an overall understanding of current and future observing systems, and thus achieving a clear picture of how planned capabilities will be eventually realized. He indicated that it is important to recognize that deficiencies can often be met in a variety of different ways. Planning should recognize that parts of observing systems will fail, but it is impossible to predict which component will fail. Moreover, the impact of either improvements or decay in observing systems is often very difficult to assess. Accordingly, there are many difficulties in prioritizing observing systems.

Dr Townshend went on to discuss the challenges in maintaining and operating GCOS. He recognized the contemporary decay of the *in situ* system, and the problems in ensuring continuity and consistency of observations through time. Often there is a conflict between technological advance and consistency. Maintaining global spatial coverage is a difficult problem and there is always the question of how much redundancy should be built into the system. Continuity of funding is also an issue.

Thomas Spence, Director of the Joint Planning Office for GCOS, described the overall framework through which GCOS operates. GCOS was established after the Second World Climate Conference and relies on the overall World Climate Programme infrastructure to help meet its goals. Dr Spence noted that in addition to climate change detection and response monitoring, the goals of GCOS are to enhance national economic development and enhance research toward improved understanding, modelling and prediction of the climate system. He also described the common interests of GCOS with respect to other Global Observing systems such as the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS). The ocean and land climate modules of those observing systems are identical to the ocean and land components of GCOS.

Dr Spence indicated that the concept, scope, scientific and technical guidance of GCOS is the responsibility of the Joint Scientific and Technical Commission (JSTC), established through a Memorandum of Understanding among WMO, IOC, UNEP, and ICSU. The JSTC includes Atmospheric, Terrestrial, Ocean, Space-based Observation, and Data and Information Management Panels. Scientifically and technically sound and economically feasible recommendations are expected from these panels and are a prerequisite to any implementation of changes or additions to existing observing systems. In this regard, he noted that the first priority of GCOS is to define the Initial Operational System which will consist of the current operational components and essential augmentations, including a comprehensive data management system.

Gregory Withee, speaking on behalf of the USA focal point for GCOS, Robert Winokur, who is also a Vice-chairman of the GCOS Joint Scientific and Technical Committee, challenged the participants to address four items of particular concern.

1. What is the science behind monitoring?

2. How can different measurement systems be used together?

3. How can we prioritize our most important global monitoring concerns?

4. How can we best use the measurements we have?

A number of principles for long-term climate monitoring were introduced by the meeting organizer, Tom Karl, based on the work of Karl et al., (1995), and the USA National Research Council Climate Research Committee work. These principles point out that:

1. Data management, analysis, and diagnostics are a key part of a relevant long-term climate monitoring system;

2. Prior to implementing changes to existing systems, or introducing new observing systems, an assessment of the effects on long-term climate monitoring should be standard practice;

3. Routine assessments of the long-term climate monitoring capability of existing systems should be standard practice;

4. Processing algorithms and changes in these algorithms must be well documented;

5. Knowledge of instrument, station, and/or platform history is essential and should be treated with as much care as the data themselves;

6. *In situ* and other observations with a long uninterrupted record should be given special consideration;

7. Calibration, validation and maintenance are critical to long-term climate monitoring;

a. Observing systems should be complete, possibly including both “low technology” and “high technology” components and ground truth validation;

9. The transition from research to operational measurements for long-term climate monitoring must be planned in an orderly and systematic manner;

10. Data management systems must facilitate access (minimum cost and freedom of data availability) and data analysis.

Following these introductory lectures and papers, a series of technical papers were presented and discussed during the first two days of the meeting. These papers (most of which will appear in a forthcoming volume of *Climatic* Change) were used as the basis for developing recommendations in three break-out groups that met one evening and the subsequent day. The panels were divided into the following categories:

(1) climate forcings and feedbacks,

(2) climate responses and feedbacks, and

(3) climate impacts.

The task of each break-out group was to develop a set of recommendations that could be used by the GCOS JSTC to help ensure an adequate global long-term climate monitoring capability. It is important to understand that it was not possible to set priorities with respect to the set of specific recommendations developed at this workshop as related to the myriad of needs within each of three break-out group topics. To set priorities complete information is required: i.e., a finite number of choices, limited options, and a complete set of issues. Obviously priorities change as assumptions, impacts, and users are varied. Instead, the set of recommendations developed from this meeting should be viewed opportunistically as related to each characteristic of the climate system, forcings, feedbacks, responses, and impacts. All are important, and should be implemented to achieve an adequate long-term global climate observing system.

3. RECOMMENDATIONS

Much of the motivation and related discussion associated with each of the recommendations from the break-out sessions will be included in three separate reports in various states of drafting. Francis Bretherton is author and chair of the Climate Forcings and Feedbacks Report, Kevin Trenberth the Climate Responses and Feedbacks Report, and William Easterling the Climate Impacts Report. In this section a summary of the recommendations that were put forward from each of the working groups is presented. Additional details will be available in each area-focus report and in the technical papers of the meeting.

In developing the recommendations from this workshop, careful attention was paid to the boundaries of the area of interest, specifically, decade to centennial climate monitoring. The GCOS effort on these time scales cannot be viewed as operational versus academic, but rather a partnership among observing system operators, analysts, and modellers. Experience with the weather prediction and greenhouse gas flask sampling communities indicates that operations and research can indeed be an effective team. This takes time, leadership, and organization. GCOS interests on decade-to-centennial time scales will have to ensure that such a partnership is forged.

3.1 General Recommendations

Recommendation 1:

Prior to implementing changes to existing systems or introducing new observing systems, an assessment of the effects of these changes on long-term climate monitoring should be performed as standard practice.

Recommendation 2:

Continued efforts should be made to improve the quality and volume of the historical data base.

Recommendation 3:

Establish the capability for assessing the data quality of observations important for long-term climate monitoring, detection, and attribution. This should include the chain of activities involved in the processing of data into useful products.

Recommendation 4:

Establish a routine, long-term climate assessment centre whose tasks would include regular examination and re-examination of the ocean climate data base in order to produce up-to-date state-of-the-ocean climate assessments.

Recommendation 5:

Develop an information management system dedicated to the gathering, quality control, assembly, and archiving of ocean climate data; and a system of telemetry, communication and permanent storage dedicated to the objectives of the system.

Recommendation 6:

Overlapping measurements of both *the* old and new observing systems for both *in-situ* and satellite data must become standard practice.

Recommendation 7:

Provide on-board calibration of operational satellite sensors, especially radiances based on solar reflectance.

Recommendation 8:

Develop the capability to control polar orbiting satellites so diurnal sampling is not biased.

Recommendation 9:

Pursue alternative means for calibrating stratospheric measurements from satellites; e. g . , utilize the ozonesonde network as the rocketsonde network has decayed.

Recommendation 10:

The full and open international exchange of data at minimal cost of reproduction must be given a high priority.

Recommendation 1 I :

It is recommended that GCOS give high priority to the development of metadata information systems which users can readily access and query. It is further recommended that metadata be given high priority and that GCOS make a similar recommendation to WMO. Initial focus should begin with surface temperature, precipitation, and pressure. The metadata should include past and present information required to interpret the representativeness, accuracy, and bias of the measurement, such as time and place of observation, site exposure, instrumentation and methods, data formats, methodology used to process the data, and where and how the data may be accessed.

3.2 Climate Forcings and Feedbacks

Recommendation:

Greenhouse gases (CO,. CH,. CO. N,0, CFCs, H_2O vapor) --- To better understand large natural changes in greenhouse gas growth rates, expand the present flask sampling network. Tropospheric 0, is also an important greenhouse gas which may be increasing. Ozonesondes, the only current feasible technique for obtaining profiles must be expanded in geographic coverage and improved in quality. Upper tropospheric and stratospheric water vapor measurements must be expanded, as current measurements are suggestive of important increases, but this is based on a single site.

Recommendation.

Aerosols --- Satellite-borne lidar should be encouraged to measure global optical depth, but by themselves these data cannot provide the necessary chemical information to provide a quantitative connection to temporally and spatially variable aerosol sources. To a large degree aerosol monitoring should be viewed as a research problem. As such, expand a small number of aerosol observation sites in areas where key aerosol types exist (e . g . , industrial haze, biomass, combustion smoke). These sites should be equipped with a complete set of aerosol characterization instruments, and complemented with frequent flights of instrumented aircraft to document horizontal and vertical variability. Intensive observations should be continued for a few to several years, after which a plan should be developed for long-term monitoring of a subset of aerosol characteristics. Measurement methods must be developed, optimized, and standardized.

Recommendation:

Solar energy --- Improve the present solar monitoring instruments aboard spacecraft by using up-to-date technology, and provide overlapping satellite coverage for total irradiance as well as spectrally resolved irradiances. Complete spectral variability is required for understanding physical mechanisms, but present-day instruments need to improve accuracy. A complementary ground based solar monitoring program is needed for modelling, reconstruction, and validation.

Recommendation:

Clouds --- Integrate satellite and *in-situ* data. Evaluate the loss of cloud type observations as stations become automated. Diurnal sampling bias is a serious satellite problem and could be overcome to a significant degree by the use of three polar orbiters, one in a precessing orbit and the other two with constant equatorial crossing times. Overlapping satellite coverage is critical for trend detection. *In-situ* measurements should be expanded, especially over the southern hemisphere, and must include cloud cover, morphological types, and base heights. Cloud base *(in-situ)* and cloud top measurements (satellites) are critical cloud properties whose accuracy must be a high priority.

Recommendation.

Water Vapor --- For radiosondes (and rawinsondes): develop a new cost effective sonde or equivalent technology; standardize algorithms converting relative humidity to dew point temperatures; standardize reporting procedures; develop station histories and an archive of relevant metadata; improve humidity sensors with respect to response time, performance at low temperatures, low humidity, and high humidity; as routine practice develop a reference radiosonde intercomparison for all operational sondes. For satellites: implement GEWEX (GVAP) priorities to make existing data useful (Geostationary and Polar Orbiters). More precise pre-launch calibrations of the water vapor channels are required and higher vertical resolution can and should be achieved using existing technologies.

Recommendation:

Radiation Budget --- The Earth's radiation budget provides vital diagnostic tools for evaluating changes in clouds, aerosols, and surface radiative forcing. Long-term monitoring, not necessarily from operational satellites, should be a high priority.

3.3 Climate Responses and Feedbacks

Recommendation:

Model Reanalysis --- Reanalysis activities should be encouraged and should occur at regular intervals (every 5 to 10 years) as data assimilation systems improve. Additional reanalyses should be undertaken that address the needs of decadal-to-century time scales and the problem of a continually changing data base.

Recommendation:

CLIMAT Data --- Upgrade the network by taking advantage of the "information superhighway". Countries should be asked to submit more stations per unit area and more in real time.

Recommendation.

Greenhouse-sensitive Variables --- To determine which variables to monitor for the climate change detection problem perform detailed signal-to-noise analyses of global climate model experiments forced with realistic "transient" anthropogenic forcings of the increases in greenhouse gases and changes in atmospheric aerosol.

Recommendation.

Reference Stations --- Global baseline surface and upper air networks should be established and maintained on multi-decade time scales. Data from these stations should be freely, openly, and widely distributed. Changes at the stations should be documented with special care, including long-term overlapping observational periods. Funding mechanisms should be established to assure continued operation of baseline stations.

Recommendation:

Tropospheric and Stratospheric Temperature --- Design and fly a satellite-based system with redundant stable instruments that are capable of producing continuous time series of temperature. The next set of NOAA satellites will no longer contain instruments that match the present MSU channels. This constitutes an increased risk of failure. The problem should be rectified.

Recommendation.

Surface Marine --- Improve the: (1) *in situ* sea surface temperature (SST) by converting to ship hull thermometry and depth sensors, (2) SST analyses by blending *in situ* data with precision satellite data, (3) air temperature measurements from ships, e.g., by using electronic sensing and/or better placed screens, (4) *in situ* surface pressures, e.g., by using electronic barometers, (5) the near-surface winds by using automated instruments that measure true wind and thus eliminate the need for using the Beaufort wind scale, and (6) the measurements of surface humidity, e.g., by using electronic humidity sensors with salt protection. Support the fusion of *in situ* observations of winds with those from remote sensing, such as from scatterometers and altimeters. Increase the number and improve the assessment of surface wave measurements. Pursue the prospects for improved estimates of precipitation over the ocean using several technologies. Rescue and digitize data that are now in manuscript form only, particularly where these data fill space/time gaps (such as the Kew and Kobe collections). Maintain existing buoy networks.

Recommendation:

Sea Level --- A subset of the Global Sea-level Observing System (GLOSS) network, preferably those with long consistent records, should be supported. These stations should be geocentrically located. Implement a fully operational long-term precision altimeter satellite mission, accompanied by a small number of precision, satellite reporting sea level gauges.

Recommendation:

Subsurface Ocean --- Implement a global network of subsurface autonomous floats (e.g., ALACE) measuring Lagrangian velocity at intermediate depths, and profiles of temperature, subject to successful demonstrations by the World Ocean Circulation Experiment (WOCE). Existing long-time series stations measuring temperature, salinity, etc., should be maintained and, on the basis of further scientific assessment and improved technology, new time series stations should be established at formerly occupied sites or at carefully selected new sites. Many bathymetry data sets are only marginally adequate for modem climate studies. It is recommended that these data sets should be enhanced. A concerted effort should be mounted to digitize all upper ocean and interior ocean data that presently exist on fragile, non-permanent media. Efforts should be continued to trace and make part of the permanent archive temporarily "lost" data (e.g., as in the IOC GORDA data archaeology project).

Recommendation:

Cryosphere --- Optimize the procedure for blending satellite data and *in situ* measurements of snow to produce historical time series of gridded snow depth, area1 coverage, and water equivalent. Ensure a period of overlap (about 2 years) of new automated NOAA/NESDIS snow cover and sea ice (Navy/NOAA Joint Ice Centre) products and current products; assess and demonstrate continuity before discontinuing the older product. Establish a central archive of lake ice data. The archive should contain historical data now held by various national agencies and other sources. Implement data quality control and reformatting, and use the existing data to define an optimal network for monitoring by satellite in the EOS era. Establish an altimetric baseline for decadal sampling of ice sheets. Increase the spatial density of shallow cores, particularly in the interior of the ice sheets, with a view to determine the temporal and spatial correlation of accumulation, and their dependence on geographic location, and direct measurement of fim densification.

Recommendation:

Precipitation --- *In situ* precipitation measurements are being used as the basis for calibration of models and remote sensing data, but virtually all *in situ* measurements are affected by biases that change in time. Modernization of these networks is now creating additional biases which need to be well understood prior to implementing changes. Unbiased *in situ* measurements should be a high priority. The fusion of gauge, satellite, radar, and model-generated precipitation estimates should be given a high priority. Streamflow and lake level data should be improved and benchmark data sets developed, free of anthropogenic influences. These data can serve as critical reality checks for precipitation variations.

3.4 Climate Impacts

Consumers of impact-related climate data from GCOS include resource managers, planners, governments (regional, national, state, local), and climate impact researchers. As such, focus in this area must look beyond the climatological field and consider a broader spectrum of socio-economic biophysical interests. The need for clear high-end products is chronic.

Recommendation:

Climate Indices --- More focus is needed on customer needs and moving information to decision-makers. To help this process, emphasis should be placed on the development of leading indicators of change related to: (1) climate extremes including droughts, floods, and storms; (2) ecosystem health including ecotonal change and biodiversity;

change and biodiversity; (3) renewable resources including water, agriculture, forests, and fisheries; (4) greenhouse responses including minimum temperatures and glacial retreats, and (5) early warnings of major climate events such as ENS0 and volcanic effects. To this end GCOS should consider establishing a working group on climate indices to asses the present suite of indices to maintain coherence and much needed focus for this topic.

Recommendation:

Other Global Products --- An immediate need exists for long-term global products making use of both *in situ* and satellite data, including weekly snow cover, spring onset of greenness, weekly drought index, and land cover change. These products should take advantage of observations from multiple observing systems to provide the most complete and unbiased representation of the climate system. In addition, very high resolution data (e.g., Landsat, SPOT) should be assessed every five years to provide detailed information on land use changes. This could be used to complement data from medium resolution instruments, and is needed for assessing carbon stocks. A working group should be established to assess existing products, identify what is currently available and what can be added to the product suite.

Recommendation:

Data for Indices and Other Climate Products --- GCOS should encourage support for the data needed to construct climate indices and products. This includes both long-term and near-real time data required to update the products and indices.

4. CONCLUSION

Clearly there are many opportunities for GCOS to improve our long-term climate monitoring capabilities. And clearly monitoring requires the synthesis of observations, analyses, and modelling . As already acknowledged, the recommendations put forth through this expert meeting cannot be easily viewed in terms of priorities, but rather should be used in an opportunistic fashion. All the recommendations should be considered as important. Despite these words there are two general recommendations that stands out among ail others.

First, adequate long-term climate monitoring will continue to be critically dependent on developing a partnership among network operators, data managers, analysts, and modellers. Such a partnership exists for weather prediction and must now be supported for long-term climate prediction. All participants must be stakeholders in long-term climate monitoring.

Second, GCOS may be best served by using the recommendations from this meeting of experts in an opportunistic sense -- all the recommendations are important.

Annex V

Weather Extremes

Prepared by Wu, Guoxiong
State Key Laboratory of Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)
Beijing, China

Weather extremes are usually referred to as severe local or regional events that regulate the regional distribution of climate variables. Although large-scale atmospheric circulations, such as planetary waves, the Hadley cell, the Walker circulation, or the extratropical jet stream, can determine the sequence of weather extremes which are characterized as the climate regimes of a given region, the detailed structure of weather extremes is determined by atmospheric motions taking place on synoptic scales or mesoscales. The study on the impacts of global change on weather extremes is thus associated with the simulation of regional climate change.

Simulation of Regional Climate Change

The three methods for regional climate change simulation, as summarized by Giorgi and Meams (1991), are the so-called empirical, semi-empirical, and modelling approaches. The empirical approach assumes that the atmospheric circulation internally adjusts itself to give similar responses to different forcing under similar lower boundary conditions (Wigley et al., 1986). It uses either data from recent instrumental records or paleoclimatic analogues, but suffers from the basic limitation that it does not account for possible variations in atmospheric forcings in a deterministic and physically consistent fashion. The semi-empirical approach links coarsely resolved GCM outputs to regional surface variables by using empirical statistics. It treats large-scale forcings explicitly through the use of GCMs, and accounts for mesoscale forcings in an empirical fashion. Both empirical and semi-empirical approaches are computationally inexpensive, but technically only valid for prediction within the range of the data used to develop them (Giorgi and Mearns, 1991).

A modelling approach is more commonly used to study regional climate change. Limitations of computing resources and development of adequate model physics parameterization prevent running GCMs at mesoscale resolutions. Efforts then have been devoted to nesting of high resolution models for particular regions of interest within a coarse resolution GCM. One example is the embedding of the fine mesh NCAR limited area model (LAM) of MM4 in the general circulation model CCM1. This was done by Dickinson et al. (1989) and Giorgi and Bates (1989) for the climate study for the western U.S. region. Such coupled models can be used to study the impacts of global change on weather extremes occurring in the region covered by LAM, such as fronts, tropical and extratropical cyclones, orographic-induced circulation, sea breeze, and severe storms. The development of LAM itself needs large amounts of climate data.

ENS0 and Monsoon

ENS0 is a dominant mode of atmospheric variability in the tropics. As noted by the Intergovernmental Panel on Climate Change (IPCC), GCMs are capable of simulating the seasonal tropical atmospheric anomalies for El Niño periods if the observed SST in the tropics is prescribed (IPCC, 1990). The following is documented in “Climate Change 1992” (referred to as IPCC 1992 hereafter) concerning the model study of the influence on ENS0 of increasing the concentration of greenhouse gases.

Using tropical ocean-atmosphere models, Lau et al., (1991), Nagai et al. (1991), Philander et al. (1991) and Latif et al. (1991) have successfully simulated interannual variations that resemble some aspects of ENS0 phenomena, although the amplitude of the simulated SST anomalies is generally less than that observed (IPCC, 1990) and model resolution appears to have an important influence on the simulated behaviour. Meehl (1990) claims some success in simulating ENSO-like disturbances in a global low-resolution ocean-atmosphere GCM, though it should be recalled that not all tropical SST variations are associated with ENSO. The patterns of tropical sea level pressure changes that are characteristic of ENS0 in the present climate are also present with doubled CO, (Meehl et al., 1991b). The patterns of the tropical precipitation and soil-moisture anomalies are similar in the control and doubled CO, cases, with the dry areas becoming generally drier and the wet areas becoming generally wetter with increased CO_2. These results, however, are yet to be confirmed with other models.

Baker (1987) indicated that the occurrence of El Niño in 1986-87 may be associated with earthquake swarms in the seabed of the northeast Pacific Ocean. More evidence of the linkage between El Niño and seismicity were recently reported by Walker (1995). To investigate this discovery, experiments using coupled ocean-atmosphere GCMs and seismicity data for the Pacific Region may be required.

Indian monsoon rainfall is negatively correlated with ENS0 events (Rasmusson and Carpenter, 1982; Yasunari, 1991). The SST of the Arabian Sea and the equatorial Indian Ocean, which strongly affects the Indian monsoon activity, is positively correlated with the SST of the eastern equatorial Pacific. Numerical experiments based on the L9R15/IAP (Institute of Atmospheric Physics) revealed that the snow melt in early spring on the Tibetan Plateau has strong effects on the onset of the Indian monsoon and on the summer rainfall in Southeast Asia region (Wu et al., 1995). This is because less snow cover on the plateau in spring season produces more sensible heating to the atmosphere. Therefore the atmospheric circulation will be adjusted, and the monsoon onset is earlier.

In order to simulate the Indian monsoon activity and its association with ENSO, we need to have more information about the Indian Ocean, including SST, surface energy budgets, wind stress, surface ocean current, and about the surface and boundary characteristics of the Tibetan Plateau, such as snow depth, depth of frozen soil layer, soil type, surface temperature and moisture, energy budget, and vertical profiles of wind, temperature and moisture, etc.

Tropical Storm (TS)

Another important extreme event is the occurrence of a tropical storm. The first attempt to simulate typhoon-type vortices by large-scale GCMs was made by Manabe et al. (1970) at the Geophysical Fluid Dynamics Laboratory (GFDL). The capability of higher-resolution models to predict TS formation as well as to simulate the geographical and seasonal distributions of storm activity has also been demonstrated by Bengtsson et al. (1982, 1985, 1994a, 1994b). The ability of GFDL models to simulate the formation of TS was further assessed by the comprehensive study of Broccoli and Manabe (1990). In this aspect, Wu and Lau (1992) emphasized the importance of developing suitable criteria for detecting the formation of TS rather than other kinds of perturbations such as baroclinic cyclones, continental lows and equatorial easterly perturbations.

The impacts of doubling CO, on TS formation and convective precipitation have been documented in IPCC 1992 as follows (B4.4, IPCC, 1992).

Broccoli and Manabe (1990) and Haarsma et al. (1992) found that the spatial and temporal distributions of modelled tropical disturbances are similar to those observed. On doubling CO, Haarsma et al. (1992) found that the number of simulated tropical disturbances increased, with little change in their average structure and intensity. However, as noted in IPCC 1990, Broccoli and Manabe (1990) found an increase in the number of tropical storms if cloud cover was prescribed, but a decrease if cloud was generated within the model.

In the IPCC 1990 report a consistent increase in the frequency of convective precipitation at the expense of large-scale precipitation was noted, with the implication of more intense local rain at the expense of gentler but more persistent rainfall events. This tendency has been found in recent simulations using the CSIRO model (Gordon et al., 1991; Pittock et al., 1991) and a high resolution UKMO model (J. Gregory, personal communication). Pittock et al. (1991) find a systematic increase in the frequency of heavy rain events with doubled CO_2 and a consequent decrease in the return period of heavy rainfall. These changes are related to a systematic increase in the frequency of penetrating convection in the tropics and mid-latitudes on doubling co, (IPCC, 1990).

Nicholls (1979) has shown that, the passage of a strong TS can reduce the sea temperature by several degrees in the top ocean layer of about 60 metres in thickness. In this regard, a coupled ocean-atmosphere GCM with fine vertical resolution in the top ocean layer is required to better simulate TS formation, and observations of sea temperature in the top layer ocean is required to pursue the further study of TS formation.

Blocking

The degree of success of GCMs in simulating anomalous atmospheric flows and blocking has been shown by Benzi et al. (1986). On the other hand, IPCC 1992 summarized the progress as follows (B4.5, IPCC, 1992).

The simulation of persistent large-scale anomalies (e.g., blocking) has proved difficult to forecast with extended-range NWP models (Tibaldi and Molteni, 1990; Miyakoda and Sirutis, 1990). However GCMs can simulate some of the statistical properties of blocking in the Northern Hemisphere as recently shown by Hansen and Sutera (1990) for the National Center for Atmospheric Research (NCAR) CCM and by Kitoh (1989) for the Meteorological Research Institute (MRI) GCM. Tibaldi (1992) has examined the space-time variability of blocking in the Max Planck Institute (MPI) ECHAM model, using the blocking index of Tibaldi and Molteni (1990) applied to 5-day mean December to February 500 hPa fields in the Northern Hemisphere. While the variance of both the low- and high-frequency components is reasonably well simulated, the magnitudes are systematically underestimated.

The formation of blocking highs over Northeast Asia is associated with a bi-directional energy cascade of synoptic cyclones generated along the baroclinic zone over Europe and Western Asia (Wu et al., 1994). Land surface properties in these regions, such as temperature, soil moisture, albedo, and components of the energy budget are required to represent the development of baroclinic systems in these regions so that the downstream formation of blocking can be simulated.

The impact of SST anomaly in the extratropics on the development of blocking depends on the energy release from physical processes, particularly at the sea surface (Shukla, 1986). In this regard, observation and calculation of latent heat flux, sensible heat flux, and short and long wave radiation at the surface are needed for simulating blocking events.

References

Baker, E.T., 1987, Nature, 329, 149-151.

Bengtsson, L., H. Bottger, and M. Kanamitsu, 1982, Tellus, 34, 440-457.

Bengtsson, L., H. Bottger, 1985, Tellus, 37.

Bengtsson, L., 1994a, Max Planck Inst. Meteor., Report No.123, Hamburg.

Bengtsson, L., 1994b, Max Planck Inst. Meteor., Report No.139, Hamburg.

Benzi, R., 1986, Anomalous atmospheric flows and blocking, Adv. Geophy, 29.

Broccoli, A.J., and S. Manabe, 1990, Geophys. Res. Lett., 17, 1917-1920.

Dickinson, R.E., R.M. Errico, F. Giorgi, and G.T. Bates, Clim. Change, 15, 383-422.

Gordon, H.B., P. Whetton, A.B. Pittock, A. Fowler, M. Haylock and K. Hennessy, 1991.

Giorgi, F., and G.T. Bates, 1989, Mon. Wea. Rev., 117, 2325-2347.

Giorgi, F., and L.O. Mearns, 1991, Reviews. Geophy., 29, 191-216.

Haarsma, R.J., J.F.B. Mitchell, and C.A. Senior, 1991, Clim. Dyn.

Hansen, A.R., and A. Sutera, 1990, J. Atmos. Sci.. 47, 380-392.

IPCC, 1990, Climate change: The IPCC Scientific Assessment, J.H. Houghton, G.J. Jenkins and J.J. Ephraums (Eds.) Cambridge University Press, Cambridge, UK, 365pp.

IPCC, 1992, Climate change: The Supplementary Report to the IPCC Scientific Assessment, J.T. Houghton, B.A. Callander and S.K. Varney (Eds.), Cambridge Univ. Press, Cambridge, UK, 200pp.

Latif, M., M. Flugel and J-S Xu, 1991, Max Planck Inst. Meteor., Report No.52, Hamburg.

Kitoh, A., 1989, Jap. Met. Geophys., 40, 83-101.

Lau, N.-C., S.G.H. Philander and M.J. Nath, 1992, J. Clim., 5.

Manabe, S., J.L. Holloway, Jr., and H.M. Stone, 1970, J. Atmos. Sci., 27, 580-613.

Meehel, G.A., and W.M. Washington 1990, Clim. Change, 16, 283-306.

Meehel, G.A., G.W. Branstator and W.M. Washington, 1992.

Miyakoda, K., and J. Sirutis, 1990, Mon. Wea. Rev., 118, 1065-1081.

Nicholls, N., 1979, Mon. Wea. Rev., 107, 1221-1224.

Philander, S.G.H., R.C. Pacanowski, N.-C. Lau and M.J. Nath, 1992, J. Clim., 5.

Pittock, A.B., A.M. Fowler, and P.H. Whetton, 1991, Hydrology and Water Resources Symp., Perth, Australia, October.

Rasmusson, E.M., and T.H. Carpenter 1982, Mon. Wea. Rev., 110, 354-384.

Shukla, J., 1986, Advances in Geophysics, 29.

Tibaldi, S., 1992, Proc. NATO workshop on prediction of interannual climate variations, 22-26 July, 1991, Trieste, Italy. J. Shukla (Ed.).

Tibaldi, S., and F. Molteni, 1990, Telus, 42A, 343-365.

Walker, D.A., 1995, EOS, 76, No.4, p33.

Wigley, T.M.L., P.D. Jones, and P.M. Kelly, 1986, Green house effect, climate change and ecosystems. SCOPE 29, Edited by B. Rolin et al., pp271-322.

Wu, G.-X., H. Liu, F. Chen, Y.-C., Zhao, 1994, Acta Meteor. Sinica, 52, 306-320.

Wu. G.-X., and N.-C. Lau, 1992, Mon. Wea. Rev., 120, 958-977.

Wu, G.-X., H. Liu, 1995, To appear in PSA Congress, June, Beijing.

Yasunari, T., 1991, The monsoon year - a new concept of the climatic year in the tropics, Bulletin Amer. Meteor. Soc., 1331-1337.

Annex VI

Observational Data Requirement for the Realization of Land Data Assimilation System

Prepared by Nobuo Sato
Numerical Prediction Division, Forecast Department
Japan Meteorological Agency
Tokyo, Japan

Introduction

Land surface processes play important roles in the earth's climate system. Although we have more surface observation stations over the continents than over the oceans, our knowledge of the land surface characteristics as a lower boundary condition of the atmosphere is very limited.

Sea surface temperature (SST) is globally observed by ships and satellites and its time scale of variation is more than a month. For predictions with time periods of less than a month, specification of observed SST as a time-constant lower boundary condition is enough. Ocean-atmosphere coupled models are needed for predictions longer than a season.

On the other hand, *in situ* soil moisture observations are very limited and they are not at all exchanged. Remote-sensing of soil moisture by microwave techniques is not at a satisfactory level,

Soil moisture immediately affects the partition of surface energy into sensible and latent heat fluxes, affects surface air temperature, humidity, planetary boundary layer (PBL) depth and local circulations in a few hours. Large scale circulation over continents is affected in a time range longer than several days. This means that we need knowledge on global soil moisture distribution (and snow depth which becomes a source of soil moisture in the spring) at all time scales.

In recent years most Numerical Weather Prediction (NWP) and climate models have land surface parameterization schemes with prognostic soil moisture. How to initialize soil moisture and snow depth is an important and urgent issue in short-term climate prediction as well as in NWP.

There are a few climatological soil moisture data sets. Those data were derived by integrating land surface parameterization schemes (usually a bucket model) in time under climatological atmospheric forcings. The soil moisture thus derived may depend on the formulation and parameters of land surface parameterization schemes employed, and atmospheric forcings. The most serious problem of the climatological data sets is that they are not well validated. Another problem associated with the climatological soil moisture is that interannual variation is not given. Therefore, it is quite difficult to perform sensitivity studies of anomalous atmospheric circulation to soil moisture anomaly by GCMs. The extreme examples are 1987 early summer (dry U.S. continent) and 1993 summer (wet midwest U.S.).

Initialization of soil moisture and snow equivalent water, and its validation is an issue of foremost importance, and it should be given a significant place in climate modelling .

Building Land Data Assimilation System (LDAS)

The LDAS is a system by which land surface processes are described and derived by applying the concept of data assimilation.

There are three methods to initialize soil moisture. The first method is to perform time integration of off-line, one point land surface parameterization (LSP) schemes under atmospheric forcings. The atmospheric forcings are precipitation, downward surface solar and long wave radiative fluxes, surface wind, air temperature and humidity. Evapotranspiration, sensible heat flux, runoff, surface temperatures and soil moisture in the soil layers are derived in the course of time integration. This has been used as a method to validate off-line LSPs and many studies have been done along these lines. The problem of this method is that the soil moisture thus derived may not be compatible with the GCM that has the same LSP scheme in it.

The second method is to use observed surface temperature and specific humidity. The first guess soil moisture is adjusted so that the simulated diurnal variation of surface temperature and specific humidity is made close to observations. This method can not be applied where the land surface is covered by snow. It should be noted that the diurnal range of surface temperature and specific humidity depends on not only soil moisture but also on entrainment at the PBL top.

The third method to derive soil moisture is to perform the conventional atmospheric four dimensional data assimilation with a coupled land-atmosphere model. For the soil processes the data assimilation becomes a forecast-forecast cycle, because no observed soil data is assimilated. Unlike off-line, one point LSPs, all the necessary atmospheric forcings are computed in the model. The method may suffer spin-up regarding precipitation and climatic drift. The soil moisture in some parts of the world may drift to unnatural and extremely dry or wet states if no forcing to return to climatology is applied.

In the future, a new methodology such as four dimensional variational assimilation or Kalman filter will be applied to the assimilation of remote sensing data and comprehensive and consistent description of the land surface processes will be made possible.

ISLSCP Global Soil Wetness Project

Recently the International Satellite Land Surface Climatology Project (ISLSCP), a sub-program of GEWEX, initiated a global soil wetness project in order to solve some issues surrounding land surface processes. The overall aim of the global soil wetness project is to generate data sets of soil moisture and snow equivalent water on 1x1 degree grids for the two years, 1987-88. The generated products are then validated and intercompared. The methodology adopted in the project is the first method described above, that is, time-integration of land surface parameterization (LSP) schemes under hourly atmospheric forcing.

JMA, NMC, ECMWF, CSU/NASA, NASA and COLA will participate in the project. The generated products will be intercompared by the Center for Climate System Research, University of Tokyo in collaboration with JMA.

The atmospheric forcings, soil and vegetation parameters on 1x1 degree mesh global grids will be provided by NASA. They are fields of:

(a) Six-hourly, four-dimensional data assimilation products from ECMWF;

(b) Six-hourly convective and large scale precipitation from NMC reanalysis calibrated by monthly precipitation;

(c) Monthly downward solar and long wave radiative fluxes in three hour time slices from ISCCP;

(d) Monthly vegetation parameters from NASA;

(e) Soil texture, slope and depth;

(f) Monthly runoff from the Global Runoff Data Center for 96 major river basins (for validation).

The generated global fields will be validated against operational or field experiment, *in situ* measurement, basin wide runoff, and measurements inferred from satellite remote sensing. The validation will be made by a team of hydrologists.

Observational Data Requirements for LDAS

No matter what the observations over land are used for, atmospheric forcing or validation of land surface processes, more land surface data is necessary. The problem here is that they are observed but not exchanged on a real-time basis.

The required surface observations needed for LDAS are listed in the table below. The observation time interval should be less than 6 hours in order to resolve the diurnal variation. Measurement of soil moisture is recommended, at least at some selected climate zones and for the purpose of validation and as ground truth for satellite remote sensing. Because the large scale water balance is checked by runoff and soil moisture storage, river discharge data is an important part of land surface hydrology. The activation of WRDC is requested.

Table -- Observational Data Goals for Land Data Assimilation System (LDAS)

Variable	**Temporal/spatial resolution**
Surface air temperature	6-hourly minimum, 50km/20km (global/regional)
Surface air humidity	6-hourly minimum, ditto
Surface wind	6-hourly minimum, ditto
Precipitation	6-hourly desirable, ditto
Total surface insolation (or sunshine duration & some measure of atmospheric turbidity)	daily, ditto
Surface downward long wave radiation	daily, ditto
Cloudiness (used for the computation of surface downward long wave radiation)	6-hourly desirable, ditto
Snow depth	daily, ditto
Soil moisture (surface zone)	daily, 500 km
Soil moisture (root zone)	2 days, 500 km
Soil moisture	5 days, 500 km
Vegetation	lo-days, 50/20km (global/regional)
Runoff	weekly/monthly, river basins

Annex VII

GCOS
Permanent Land-based Surface Climate Observation Network
Conceptual Design and Rationale

By the
World Climate Data and Monitoring Programme
February, 1995

CONTENTS

1. Introduction

GCOS (Global Climate Observing System) is a joint endeavour of four major organizations (WMO/UNESCO/UNEP/ICSU) to provide the data needed to understand the nature and variability of the global climate system in order to prepare strategies for the future, in the light of world environmental change. GCOS plans to reach its objectives by making optimal use of existing networks and research programmes. To do so, it has recently developed an Initial Operational System (IOS), including a data management component, which will assemble baseline data banks to support climate monitoring, model verification and the detection of climatic change. Global upper air and surface climate networks to feed this database are now being planned. This report is an initial conceptual plan for the surface climate network.

The partitioning of effort among terrestrial, oceanic and atmospheric GCOS components is managed through the Joint Scientific and Technical Committee (JSTC). The Atmospheric Observation Panel (AOP) is responsible for the air programme. At its First Session, held in Hamburg, April 25-28, 1994, the AOP accepted a proposal from the WMO Commission for Climatology (CCl) Working Group on Climate Change Detection to help in the identification of the surface climate network. The AOP recommended that a Task Group be established, having representatives from the CC1 Working Groups on Climate Data and Climate Change Detection and the AOP, with the purpose of specifying a baseline network, selected from stations which would qualify as WMO Reference Climatological Stations. The meeting of that Task Group took place in Geneva, January 31-February 1, 1995. As a result of its deliberations, the Task Group was able to develop a process to select a network that would meet GCOS' scientific objectives. A framework was developed to help guide the implementation of the network (see Appendix).

2. GCOS Surface Climate Network Requirements

It is desirable that GCOS networks be permanent, of high quality, well-distributed geographically, and dedicated to the frequent, regular observations of basic parameters. It is planned to refer GCOS proposed atmospheric networks to the WMO Commission for Basic Systems (CBS) regarding technical feasibility, representativeness, optimal geographical coverage, overall programme quality, and practical issues of data availability and commitment to future operations.

The surface climate observation programme should support the four GCOS atmospheric research priorities, as documented at the First Session of the AOP by Dr. K. E. Trenberth, following review of the work of the Task Group on Atmospheric Processes:

(a) monitoring and prediction at seasonal to interannual time-scale;
(b) detection of anthropogenically-induced climate change;
(c) climate monitoring and regional climate anomalies;
(d) climate forcings.

Prediction at seasonal to inter-annual time scales (a) requires numerical weather prediction (NWP) products for global analyses and to initialize ocean models. These are obtained from synoptic stations.

Climate change detection (b) requires selected representative, homogeneous, long-term data and accompanying metadata files for trend analysis and the verification of models. In choosing climate elements, air temperature is the most important, for reasons that are outlined below. Atmospheric pressure and precipitation are also important. Observations of humidity, cloud, sunshine and wind are also useful, particularly in a corroborative sense. These observations may be obtained from long-term synoptic stations, avoiding sites with strong anthropogenic influences. A preferred choice would be those synoptic stations which also qualify as national or WMO Reference Climatological Stations (RCSs). Long-term measurements at sites with a natural environment, such as national parks, ecological research areas and agricultural research stations are ideal candidates for RCSs. Unfortunately, these are rarely synoptic stations.

The monitoring of global climate and regional climate anomalies (c) requires a broad range of observations. These are obtained from synoptic stations, preferably those which also qualify as RCSs.

The study of climate forcings (d) requires cloud, radiation, precipitation, aerosols, and a number of land-surface characteristics. Many of these parameters are not usually measured at meteorological stations, even when they are upgraded for climatology, and would need special observations.

3. Recommendations of the CCl/AOP Task Group on Baseline Surface Climate Network Design

The rational and criteria for the network were discussed during the process which led to the development of a framework outline for the network by the Data Requirements Task Group (see Appendix).

3.1 Overall Size and Operations

At Hamburg, the AOP had recommended that the WMO Secretariat prepare a list of approximately 200 candidate-stations, based on the CC1 proposal. The network size relates to the detection of major climatic variability on the annual time-scale. This is now considered inadequate. Over the past year, papers in the scientific literature have demonstrated that regional (1000-km scale) concentrations of sulphates and other aerosols in the troposphere, which also have marked seasonal variability, can have effects on hemispheric climate. Global monitoring for the detection of climatic change must take into account these anthropogenically-iced influences.

The Task Group recommends a network of 800 land-based global surface climate observing stations. This is a density of one station per 250 000 km^2 of the land surface, and including large islands. Even so, the group recognizes that the full, desirable programme cannot be met presently. A baseline network that meets most conditions is practical, and this can be enhanced in future as opportunities are presented. It is also recognized that the ultimate network should include all elements noted by Dr. Trenberth, but an initial effort should be made to obtain regular observations of the most important elements needed for monitoring and climate change detection.

For overweighing cost advantages, there must be considerations of minimum size and possible station collocation with upper-air observations, but the network must be large enough to field answers to scientific questions of global importance, and its component stations must consistently report good quality observations. As well, many should meet, or be close to meeting, WMO criteria for RCSs. It may be noted that the WMO RCS standards recommend a minimum density of 2-10 stations per 250 000 km^2 (WMO, 1986).

3.2 Elements Measured

The Task Group recommends that the baseline network take daily measurements of:

- maximum and minimum air temperature,
- precipitation,
- atmospheric pressure,
- humidity,
- cloud,
- sunshine,
- wind.

Since it is unlikely that the observational programmes at a selection of 800 stations from the world network will include each of these elements, the priority in station choice should be: (a) maximum and minimum temperature (essential); (b) precipitation, pressure (very desirable); (c) humidity, cloud, sunshine, wind (desirable).

3.3 Network Standards

The network should be selected from reliable stations currently in operation on a daily basis, with prospects for continuation. It is desirable to have an unbroken operation over the past 30 years, at least, in order to have a reference period for verifying trends and anomalies. The most representative station, or stations, within each 250 000 km^2 grid-box over the terrestrial surface is to be chosen. The siting of stations is to be according to WMO standards, with particular regard to minimising existing and future urban influences. The stations should be equipped with good quality instrumentation and have regular maintenance. The observed data should be subject to careful quality control. It is important also to have adequate station histories and other metadata in order to interpret the climatological time-series.

3.4 Data Sources/References

Although official records list a great number of surface meteorological observing stations throughout the world, only a fraction of these are suitable for climatological analysis. Tabulations of actual data transmissions through the Global Telecommunications System (GTS) indicate extensive areas of the planet where half or less of the designated stations actually reach the circuits (Laver, 1995). Each month, the GTS carries 1200-l 800 CLIMAT reports. A recent census of the number of global stations for which monthly temperature averages could be calculated reliably indicated 1250 stations, of which only 900 had an available 30-year reference period (Jones, 1994). These are stations belonging to the WMO World Weather Watch (WWW) and the CLIMAT networks. It includes also a selection by the WMO WWW Secretariat of 141 reliable surface stations which are collocated with the GCOS upper air baseline network. Apart from reliability and collocation, these stations have not yet been evaluated as to being suitable for climate research.

The Second Congress of WMO in 1955 called on each Member to establish and maintain a selection of climatological stations at places where the exposure will remain unchanged over a very long period. Subsequently at the Fourth WMO Congress in 1963, as an amendment to the Technical regulations of WMO, a reference climatological station was defined as " a climatological station where homogeneous series of observations over a period, not less than 30 years,have been made or are expected to be made under specified conditions including adequate exposure and accurate instrumentation and adequate overlap (at least two years) when instruments are changed. A survey conducted in 1990 among WMO Members indicated approximately 2300 long-term, homogeneous stations in existence (WMO, 1993). However, the stations are unevenly distributed over the globe, and the network has not been independently evaluated. Some of the stations are included in the WMO CLIMAT and WWW networks.

The United States National Climatic Data Center in co-operation with the Department of Energy has assembled a baseline Global Historical Climatology Network (GHCN). The data have been scrutinized for high scientific quality. Version 1 of GHCN, which was released in 1992, contains monthly mean temperature for more than 6000 stations, monthly precipitation totals for 7500 stations, and sea-level pressure for more than 1850 stations. Forty per cent of the stations have more than 50 years of record. Version 2 is in preparation, and is expected to have a two-fold increase in station numbers (Davidson, 1995).

The Climate Research Unit (CRU) at the University of East Anglia, U.K. has developed, with the support of partners in the U.S.A. and the U.K., global long-term temperature and precipitation databases which are continually updated. These have been used for sentinel studies of global warming over the past century, and were selected by the Intergovernmental Panel on Climate Change (IPCC) for the 1990, 1992, and 1995 reports on the state of world climate.

Other useful data sources include: (a) surface measurements of the Global Atmospheric Watch (GAW) network; (b) files compiled by the International Data Rescue (DARE) Co-ordination Centre, Brussels; and (c) country historical climate databases, including data from reference climatological stations, compiled by a number of WMO Members.

3.5 Implementation

The overall implementation of the recommended network requires several steps beyond this conceptual phase, including completion of the network design, approvals and reviews from GCOS and WMO Commissions, Regional Associations and Members, and finally obtaining the data for the proposed IOS Data Information Centre.

The Task Group has recommended a procedure which may shorten the station selection process. It has requested the CRU (Climate Research Unit, East Anglia) through P. D. Jones and M. Hulme to propose an initial 800-station list. The CRU has unique qualifications to do this. It is aware of the present status of global surface climate observing (Jones, 1994). It produces most of its analyses on 250 000 km^2 grid-boxes, and currently makes use of data from 900 stations each month. The information provided by CRU would be considered in the light of other data sources, and presented to the GCOS AOP for review at the earliest occasion. Subsequently, comments would be solicited from WMO organizations and others. Finally, a special task group of experts would be struck by AOP and CC1 to scientifically design the proposed network, certifying its capability to resolve pertinent, specific questions.

4. Technical Rationale

4.1 Network Size

As was mentioned in section 3.1, recent serious consideration by the scientific community of the climatic effects of tropospheric aerosols, which have significant seasonal variability, caused the Task Group to deem an air temperature network of 200 stations to be inadequate for climate change detection support. The original idea was derived from the work of Jones (1994, and earlier) who calculated that 95 per cent of annual global and hemispheric-scale climatic variability can be detected by a network of 170 temperature stations. However, documenting the probable causes of climatic variability denoted by air temperature fluctuations is aided by observations of other elements, such as precipitation, although to do so may cause an increase in the number of measuring sites. However, the Task Group concluded that the evidence of retardation of global warming by regionally-concentrated aerosols, most from anthropogenic sources, suggests that global monitoring must be capable of distinguishing finer-scale variability, and ought to include, as well, some measurements of other elements besides temperature.

A network of 800 stations, with most taking synoptic observations, would permit some multi-element analyses. As well, as demonstrated by Jones, an 800-station network, distributed at a density of one station per 250 000 km^2, provides even spatial coverage of the Earth's land area, including large islands. This is an attractive attribute for global monitoring. It is also not far from the upper limit of available stations reporting in near-real time. In section 3.4, it was noted that the GTS distribution of the monthly CLIMAT messages has a lower limit of about 1200 stations, and Jones indicates that he can only use about 900 of these (lower limit for reliability). This represents a loo-station cushion against closures, and to offset the fact that several stations do not consistently report month after month.

In the plan, the 800-station network is intended to be a baseline, having near-real time capabilities, For other GCOS requirements, data from other good quality stations are available, such as those in the GHCN. Moreover, as the WMO RCS network develops, it is intended that it will have a minimum density of from two to ten stations within each 250 000 km' grid-box. Well-managed baseline networks with strong user-support will enable the growth of high quality observation programmes, perhaps helping to discourage the recent tendency for diminishing numbers of reporting stations.

4.2 Elements Measured

4.2.1 Air Temperature

Air temperature is the most common element used in climate monitoring. There are a number of reasons why. Temperature has been measured in much the same way for more than 200 years. Radiation shelters, instrument calibration, exposure standards and times of observation have varied, but temperature records from the 18th century can be interpreted in modem terms.

Temperature is an integrative measurement of heat responding to energy balance and water balance processes. Day-to-day accumulations of heat units relate to phenological stages of the biosphere, and are important to high latitude and high altitude hydrology, or for other situations where there are many freeze-thaw cycles during the year.

Air temperature at 1.4 m is a conservative element which is representative over horizontal distances up to 40 km and beyond, depending on acceptable error. Measurement systems are comparatively simple, and are found in much the same form throughout the world. Data from modem electronic sensors can be merged with thermometer data. Many stations have records exceeding 100 years in length, which can be valuable for trend analysis and model verification. As well, three and four-dimensional studies of temperature contribute to our understanding of critical climate system processes. Recent inter-annual and inter-decadal maximum and minimum temperature trends, representing daytime and nighttime conditions, have been shown to differ significantly on regional scales. The GCOS network should measure both. Maximum and minimum temperatures, along with the derivatives of mean daily temperature and daily temperature range, are valuable parameters for the analysis of climate variability and change.

4.2.2 Precipitation

Precipitation is a principal element of the hydrological cycle which has encouraged comparatively dense networks in most parts of the world. Rain gauges are comparatively inexpensive to buy, and usually have a long life before they start to leak, but they become rather useless in cold climates over much of the year, where snowfall has to be measured by larger gauges shielded against undercatch during wind, or by ground surveys. Precipitation has high spatial variability, requiring dense networks at times, but it can also be areally estimated using the hydrological water balance. Precipitation, accumulated over a period of time, is useful for model validation. Precipitation, in spite of its measurement difficulties, is a very desirable baseline climate element.

4.2.3 Atmospheric Pressure

Pressure, like temperature, has been measured with mercury and aneroid barometers in the same way for many decades. Measurements need to be precise as changes are small. At land stations measured pressure is adjusted to equivalent sea-level values for spatial analyses. Model studies have found pressure as a useful element for attributing variability, primarily due to it being a good indicator of atmospheric circulation. The usefulness is enhanced in three and four-dimensional studies. Pressure is a very desirable baseline climate element.

4.2.4 Humidity

Changes in the atmospheric water balance may be monitored using surface and upper-air humidity measurements. Unfortunately, humidity is measured by a number of methods, none of them having an accuracy greater than +/-5 per cent, the error being greatest in cold climates. Nevertheless, the value of atmospheric water vapour to climate models and climate variability studies means that it is a desirable element to the observation programme.

4.2.5 Sunshine/Cloud

Sunshine and cloud, although complementary, are measured differently, and cannot be substituted for each other without a large error of estimate. These elements sometimes serve as proxy for solar radiation, but are also useful in a corroborative sense for comparisons with the behaviour of other elements. At surface stations, cloud is measured by visual estimate. A number of sunshine instruments are in existence, but the most common is based on the 19th century Campbell-Stokes design. As radiation equipment becomes more reliable and affordable, sunshine stations are being closed. Presently, however, sunshine and cloud are desirable elements.

4.2.6 Wind

Like precipitation, there are a number of problems in spatial comparisons of surface wind data, relating to variable anemometer performance characteristics, exposure heights, and unwanted turbulence created by nearby obstacles. However, wind measurement analysed three-dimensionally, and over time, is a sensitive monitoring tool because of strong process links with other climate elements. It is a desirable element for the GCOS network.

4.3 Network Standards

A climatological network used for research must be operated under the highest standards specified by WMO. High standards for instrumentation and maintenance should not be compromised, and the data must be subject to regular, consistent quality control as specified by WMO. For the study of climate, particularly beyond the inter-annual scale, station histories and other metadata are needed to verify trends and anomalies. Metadata files may be of secondary importance to real-time requirements of meteorological services, but are very much needed for climatology. Indeed, for inter-decadal research, detailed metadata files are essential.

4.4 Data Sources

The selection of surface climate stations for the GCOS baseline network is an iterative process. The first consideration must be the reliability of reports, but this must be ultimately balanced with other qualities. For this reason, we have sought the advice of the Climate Research Unit who are the custodians of the IPCC surface climate database. The CRU climatologists, themselves, undertake active research with the data, and publish the results in the international literature. One of the databases they work with is the approximate size of the proposed GCOS baseline. The next step is to examine the 800 reliable, equally distributed stations against other criteria. How well do these stations compare with WMO RCS stations, or stations in the GHCN, or elsewhere,(for example, in the repositories of WMO Members, or in DARE files)? What better stations can be substituted? What mechanisms can be initiated to attract additional stations, and how might their data be used? Through each of these stages the advice of tiers of experts must be sought, from the international to regional and country levels.

5.0 References

Davidson, K. D. 1995: CC1 Rapporteur's progress report on the status of development of global baseline datasets at NCDC, presented at the Working Group on Climate Data meeting, Geneva, January, 5 p.

Jones, P .D. 1994: Land surface temperatures - is the network good enough?, 12 + page manuscript submitted to the Journal of Climatology.

Laver, J.D. 1995: CC1 Rapporteur's progress report on climate data and information exchange over the GTS and liaison with CBS Working Group on Data Management, presented at the Working Group on Climate Data meeting, Geneva, January 3 p +

WMO, World Climate Programme (Data), 1986: Guidelines on the selection of reference climatological stations (RCSs) from the existing climatological station network, WCP-116, WMO/TD No. 130, 12 p + appendices.

WMO, World Climate Data and Monitoring Programme, 1993: Report of the experts meeting on reference climatological stations and national climate data catalogues, (Offenbach am Main, 25-27 August 1992), WCDMP No. 23, WMO-TD No. 535, 14 p + annexes.

APPENDIX

Framework for Establishing a GCOS Permanent Land-based Surface Observation Network

Purpose:

The prime purpose of the network would be to meet the land-based surface data requirements on global to large regional scales for the detection of anthropogenic climate change, the monitoring of climate and the analysis of climate variability. The network data will also be useful for the development and validation of climate models, the development and verification of climate predictions and for a variety of other climate applications and services.

Size:

Approximately 800 stations

Criteria:

- most representative station(s) in a 250,000 km^2 area box
- operational on a daily basis with plans to continue into the future
- adequately situated, especially with regard to minimizing existing and future urban influences
- minimum 30-year record of parameters desirable
- quality instrumentation and maintenance
- careful quality control of data
- adequate METADATA

Parameters:

- ***essential:*** maximum and minimum temperatures
- ***very desirable:*** station pressure and precipitation
- ***desirable:*** relative humidity, sunshine, cloudiness and wind

Data Sources/References:

- IPCC Global Surface Temperature Data Set

- Global Historical Climate Network
- Reference Climatological Stations in WMO Member countries
- WMO Member candidate stations for a global Reference Climate Station network
- WMO CLIMAT station network
- Stations in WMO countries from which 1961-1990 Climatological Standard Normals are available
- WMO Global Atmosphere Watch network
- WMO World Weather Watch network
- GCOS Baseline Upper Air network
- International Data Rescue Co-ordination Centre

Implementation Strategy

1. Request the University of East Anglia to propose a list of stations based primarily on their database;
2. Inform the presidents of CCl and CBS of plans;
3. Take into consideration the other listed data source/references and make any minor adjustments deemed necessary;
4. Present the list of stations along with its rationale to the next meeting of the GCOS Observation Panel (scheduled for 20 -23 March 1995 in Tokyo);
5. Seek the comments and input of WMO Regional Associations/Members;
6. Initiate a scientific investigation by several experts to evaluate the list through creation of a special task group of the Working Group on Climate Change Detection.

Annex VIII

Recommendations from the Data Requirements Task Group of the CCl Working Group on Climate Change Detection

30 January to 2 February 1995
Geneva, Switzerland

RECOMMENDATIONS

1. A formal mechanism be arranged for the Working Group to present its views on the data requirements and representations of data used in the IPCC assessments. It was proposed to request permission from the IPCC, through the co-ordinator Dr B. Callendar at the Hadley Centre, U.K.,to enter the formal review process of those chapters where there are data issues pertaining to climate change detection.

2. Expertise on the data requirements related to atmospheric trace gas radiative forcing as well as with sulphur aerosols is needed in the working group.

3. There should be a closer association with the World Climate Research Programme (WCRP), particularly the Climate Variability (CLIVAR) project, and the Global Atmospheric Watch (GAW) activities with the view to designating rapporteurs for coupled atmosphere-ocean modelling and the climatic effects of tropospheric aerosols.

4. The Working Group should actively support GCOS in addressing the recommendations of the January 1995 Asheville meeting on "GCOS Monitoring Requirements for Documenting and Detecting Long-term Climate Change, particularly with regard to evaluating data in near-real time with the help of metadata files, developing human dimension climate change indicators, and developing proxy and tropospheric aerosols data sets that are suitable for climate change detection purposes.

5. The recommendations of the Inter-Programme Data Management Co-ordination Meeting (Geneva, November 1994) should be supported, particularly those related to climate change detection such as compilation of data catalogues, comprehensive metadata files, improved data access and the feasibility of inter-programme co-ordination by CBS.

6. Work closely with GCOS in establishing surface and upper air reference station networks, taking the lead in the initial selection of stations for the establishment of the GCOS Permanent Land-based Surface Observation Network. The Working Group should establish a small task group of experts to conduct a scientific review of the network.

7. The importance of WMO Member countries establishing and maintaining reference climatological station networks for the purpose of regional to national scale climate change detection studies should be emphasized.

8. Provide global and regional data sets to countries having CLICOM, in order to promote the international exchange of data, to obtain feedback on data being used and to catalyse the development of science. The Carbon Dioxide Information Analysis Center (CDIAC) and the National Climatic Data Center should be approached regarding assistance to provide such data sets.

9. To encourage more frequent and complete documentation of metadata, appropriate revisions should be included among the planned enhancements to the CLICOM.

10. Assist in developing co-operative projects with the System for Analysis, Research and Training (START) programme for the training of personnel to work with climate data, for the ultimate purpose of promoting climate change detection research at the regional level. This could begin through the training of CLICOM operators and researchers in developing countries. It was recommended that the Secretariat initiate contact with the START office in Washington, U.S. A, and upon favourable response, arrange for participation by members of the Working Group interested in the capacity-building issue at a future START programme-planning meeting.

11. The following list of actions and responsibilities should be considered in developing the implementation plan for the Climate Change Detection Project:

   a) Review and comment on the WMO annual statements on the status of the global climate;

   b) Collaborate with GCOS on issues of mutual concern;

   c) Encourage and assist in the development and establishment of reference climatological station networks including those designated for GCOS;

   d) Interact with the World Climate Research Programme (WCRP), particularly the Climate Variability (CLIVAR) project;

   e) Expand the expertise of the Working Group in coupled ocean-atmosphere models through creation of a rapporteur;

   f) Expand the expertise of the Working Group in the area of atmospheric aerosol forcing data requirements;

   g) Establish linkages with the Global Atmosphere Watch (GAW) programme;

   h) Examine possible linkages with the Past Global Changes (PAGES) project within the International Geosphere-Biosphere Programme (IGBP) in order to improve understanding of inter-century climatic variability, particularly during the past millennium;

i) Encourage and promote mechanisms for capacity-building of the climate change detection issue (data aspects).

12. Seek ways to familiarize officials drafting international climate change framework conventions, for example the forthcoming "Conference of the Parties" of the importance of climate change detection, and the need for much greater co-operation among countries in sharing clirnatological data for the common good. An informal discussion with Dr. B. Bolin, regarding a suitable contact was suggested.

13. Review and comment on the likely role of "new" response data from reanalysis projects, remote sensing (eg MSU data) in enhancing or replacing traditional response data sets.

14. The president of CCl be advised in writing of the results of this meeting, in particular, those related to the design of climate monitoring networks suitable for climate change detection and strengthening a long-term dialogue on data issues in climate research.

15. The full Working Group should meet in 1996. The timing should be co-ordinated with the anthropogenic climatic change panel of CLIVAR in order to arrange, if possible, a one-day joint session.

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 l-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)
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 l-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 .bct or /gps-verl **.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 Socioeconomic Benefits of Climate Forecasts: Literature Review and Recommendations (Report prepared by the GCOS Working Group on Socioeconomic 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. 68 1)	Plan for the Global Climate Observing System (GCOS), Version 1 .0, May 1995 [ftp://www.wmo.ch/Documents/gcos/gp-verl .txt or /gp-verl .wp5]
GCOS-15 (WMO/TD-No. 684)	GCOS Plan for Space-based Observations, Version 1.0, June 1995 [ftp://www.wmo.ch/Doccuments/gcos/sp-verl .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]