GLOBAL CLIMATE OBSERVING SYSTEM

WMO   IOC of UNESCO   UNEP   ICSU

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

GEF Global Environment Facility

UNDP

REPORT OF THE GCOS REGIONAL WORKSHOP FOR SOUTH AND SOUTHWEST ASIA ON IMPROVING OBSERVING SYSTEMS FOR CLIMATE

New Delhi, India
11-13 October 2004

March 2005
GCOS - 97
(WMO/TD No. 1259)

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL COUNCIL FOR SCIENCE

NOTE

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the World Meteorological Organization concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Editorial Note: This report has been produced without editorial revision by the WMO Secretariat. It is not an official WMO publication and its distribution in this form does not imply endorsement by the Organization of the ideas expressed.

FOREWORD

The GCOS Regional Workshop for South and Southwest Asia, which is described in this report, is the start of a process. GCOS looks forward to working with the principal stakeholders in the region, building on national, regional, and international efforts to improve systematic observations for climate. We plan do so in part through working collaboratively with the countries of the region in the development of a Regional GCOS Action Plan.

During the workshop, we made progress in identifying national and regional needs for climate as they relate to climate policies, national activities, and sustainable development. We also identified deficiencies in current observing systems for climate and agreed on a number of key regional priorities. We began discussion of developing a Regional Action Plan that can serve as a vehicle to articulate the needs and priorities of the region and bring these to the attention of the Parties to the United Nations Framework Convention on Climate Change and donor agencies. We also began a discussion of a way forward that includes a resource mobilization strategy without which no Action Plan can succeed.

In the process, it is essential that we seek support for the plan from your national authorities and regional bodies. GCOS will work with you, but the plan needs to be yours – regionally focused, regionally motivated, and regionally owned. GCOS values your participation in the Regional Workshop for South and Southwest Asia and looks forward to working with you as we seek to improve systematic climate observations in the region.

I wish to express my appreciation to the Government of India for its hospitality and the fine reception that we all enjoyed in New Delhi. I also wish to thank Dr S.K. Srivastav, Director-General, India Meteorological Department, for his efforts and for those of his staff, which were major factors in the success of the workshop.

Alan Thomas
Director
GCOS Secretariat

(Intentionally blank)

TABLE OF CONTENTS

ANNEXES

EXECUTIVE SUMMARY

The Global Climate Observing System (GCOS) held a Regional Workshop for the countries of South and Southwest Asia at Le Meridien Hotel, New Delhi, India, from 11-13 October 2004. GCOS organized this eighth workshop in its Regional Workshop Programme in collaboration with the Indian Meteorological Department. The workshop was made possible through financial assistance provided by the Global Environment Facility/United Nations Development Programme (GEF/UNDP), the India Meteorological Department, and the United Kingdom Meteorological Office. Their contributions are gratefully acknowledged.

The goals of the workshop were to identify gaps and deficiencies in GCOS-related climate observing systems in South and Southwest Asia and to initiate a discussion on the development of a Regional GCOS Action Plan aimed at improving regional capabilities in atmospheric, oceanic, and terrestrial data collection and in the production and delivery of climate products and services. The proposed Regional Action Plan will contribute to global and regional efforts to detect climate change, monitor the climate system, and plan for and adapt to the impacts of climate variability and climate change. At the same time, it will enhance the abilities of the nations of South and Southwest Asia to address their domestic requirements for climate data and services.

In context setting, opening remarks, Dr A. Thomas, Director, GCOS Secretariat, outlined the history and rationale underlying the GCOS regional workshop programme. He stressed the urgent need to enhance systematic observations of the global climate system. He pointed out that the workshop represented the first step towards the development of a Regional GCOS Action Plan for South and Southwest Asia to address identified needs. He encouraged participants to contribute actively to the identification of key regional deficiencies in systematic climate observing programmes and to propose initiatives for inclusion in the Regional Action Plan to address those deficiencies. He also emphasized that the completion of a Regional Action Plan would provide a solid basis for resource mobilization efforts to achieve significant improvements in climate-related infrastructure, systems, and capacities in South and Southwest Asia.

Subsequent workshop presentations and plenary discussions addressed user needs for climate observations; the status, deficiencies, and needs of atmospheric, oceanic and terrestrial observational networks; and related telecommunications, data management, data exchange, and archiving issues. Substantial emphasis was laid on the vital issue of resource mobilization. During their deliberations, workshop participants highlighted the following issues and deficiencies and proposed that projects aimed at addressing these issues be given priority in the Regional Action Plan:

- Strengthening the meteorological networks, i.e., the GCOS Surface Network (GSN), GCOS Upper-Air Network (GUAN), and Regional Basic Climatological Network (RBCN)

- Establishing Global Atmosphere Watch (GAW) aerosol monitoring within the region

- Monitoring glaciers and permafrost for water resources

- Preparation of databases for climate assessment, including data rescue

- Building capacity for satellite applications to climate and national development

- Enhancing the availability and use of hydrological data

- Establishing an Indian Ocean observing system for climate

- Developing capabilities within the region for assessing climate variability and change, including regional modelling.

In addition, participants identified the following somewhat broader issues to include as recommendations in the Regional Action Plan: enhancing regional coordination to facilitate addressing regional priorities, including the designation of national focal points for GCOS; and improving data exchange, availability and management within South and Southwest Asia.

At the conclusion of the workshop, it was agreed that a follow-up meeting to write the Action Plan would be held at a to-be-determined location, with tentative dates being late January or early February 2005. Dr S.K. Srivastav, Director-General, India Meteorological Department, was nominated to chair this meeting. National representatives were requested to nominate appropriate individuals to participate in the writing activity and to forward their nominations to the GCOS Secretariat by 15 November. It was stressed that project summaries that address the priorities identified above should be prepared well in advance of the writing group meeting to facilitate their incorporation into a first draft of the Regional Action Plan. The overall objective will be to finalize a Regional GCOS Action Plan for South and Southwest Asia within six months of the New Delhi workshop.

INTRODUCTION

The GCOS Regional Workshop for South and Southwest Asia was held at Le Meridien Hotel, New Delhi, India, from 11-13 October 2004. The Indian Meteorological Department hosted the workshop, which was made possible through financial assistance provided by the Global Environment Facility/United Nations Development Programme (GEF/UNDP), the India Meteorological Department, and the United Kingdom Meteorological Office. Participants included World Meteorological Organization (WMO) Permanent Representatives and national Climate Change Coordinators from nations in South and Southwest Asia, along with invited experts from various disciplines related to observations of the climate system. A copy of the workshop agenda and a list of attendees are attached to this report.

OPENING CEREMONY

The eighth GCOS Regional Workshop commenced with the lighting of a ceremonial candle by the participating dignitaries. Following this short ceremony, Dr S.K. Srivastav, Director-General, India Meteorological Department and Permanent Representative of India with WMO, formally welcomed participants to the Workshop and to Delhi on behalf of the Government of India and the India Meteorological Department. Noting the vital importance of climate in sustaining life on earth and that a change in climate will affect life forms and biodiversity, he stressed that it is the collective responsibility of the climate community to keep watch on the climate system. He then drew attention to the regional and global dimensions of the challenge posed by a changing climate and pointed out that monitoring the climate system must be seen in this broader context. The consequent need for a collective approach to climate monitoring underpinned the decision to hold a regional workshop in South and Southwest Asia. He concluded by expressing his and his Service's strong commitment to development of a Regional GCOS Action Plan and the hope that the workshop objectives would be achieved.

Dr A. Thomas, Director, GCOS Secretariat, expressed his thanks to the India Meteorological Department for undertaking to host the workshop in New Delhi. In a brief review of the GCOS programme, he summarized its objective as being to establish a long-term, user-driven, global climate observing system, built upon existing observing systems. A vital goal was to ensure that these observational systems meet climate standards. This could encompass the development of new observing systems where necessary. Noting that the United Nations Framework Convention on Climate Change (UNFCCC) recognizes the importance of research and systematic observations, Dr Thomas indicated that the Conference of the Parties (COP) to the Convention has concluded that present observational systems are inadequate to meet its requirements. In consequence, COP-5 (Decision 5/CP.5, 1999) had invited GCOS, with support from UNDP and GEF, to organize Regional Workshops aimed at the development of Regional GCOS Action Plans to address identified deficiencies in observational networks and systems in developing regions of the world. The New Delhi workshop is intended to address these requirements and focus the attention of participants on developing a regional strategy to address priority needs for observing systems in the region. Dr Thomas emphasized that the workshop represented a first step towards the preparation of a draft Regional Action Plan with a target date for completion of the Plan in early 2005. He concluded by thanking the India Meteorological Department, the GEF/UNDP, and the UK Met Office for their support for the workshop and by expressing his appreciation to the delegates for their commitment to the GCOS planning process.

In his plenary address, Dr R.K. Pachauri, Chairman of the Intergovernmental Panel on Climate Change (IPCC), drew attention to IPCC needs for climate observations. He pointed out that the

Panel relies heavily on the work of GCOS to respond to those needs. He complimented the Government of India and the GCOS Secretariat for their initiative in organizing the present workshop, which has provided an important opportunity for the countries of the region to work together to create knowledge and to understand the climate. He then emphasized the need to bring the scientific and development communities together to work on a regional basis with the goal of "mainstreaming" climate and climate change with development. Highlighting the need for increased attention to observations of extreme events, Dr Pachauri indicated that the 4th IPCC Assessment would attempt to come to grips with such events and their regional impacts. He stressed that the scientific community must raise its voice in support of the need for increased funding for studies of adaptation to climate and its extremes, asking national governments and the global community to support increased GCOS activity. He also cited the importance of historical records of non-instrumental climatic indicators, emphasizing the necessity of preserving these important time series, which provide insights into past climatic variability and extremes. On an information note, Dr Pachauri drew attention to the fact that the next session of the IPCC would be held in New Delhi in November, bringing 300 to 500 delegates from 192 countries to India. He expressed his thanks to the Government of India for hosting that important global forum. He concluded his presentation by expressing his best wishes to the organizers and participants for a successful workshop.

The Resident Representative of the United Nations Development Programme in New Delhi, Dr M. Olson, welcomed participants to the workshop on behalf of the UNDP. She emphasized that her organization and GEF were happy to support this important forum, which had brought together national Climate Change Coordinators with the climate science community. She pointed out that the UNFCCC relies on the climate community for information regarding the impacts of climate on people, noting that climatic impacts and vulnerability to them vary between countries. She then drew attention to three UNDP priorities or areas of emphasis:

1. The poor. Climate and its impacts are felt most by the poorest people.

2. The national communications programme funded by GEF. In particular, its linkage to issues or gaps related to climatic impacts, vulnerability and adaptation, and

3. Capacity-building with a focus on strengthening all systems, including monitoring systems for climate. Here the UNDP endorses three important principles - re-inventing locally against a global framework, building on existing capacities, and staying engaged in the face of difficulties.

She concluded her presentation by expressing her compliments to the Government of India and the India Meteorological Department for organizing the workshop.

Prof. V.S. Ramamurthy, Secretary, Department of Science and Technology, India, then delivered the formal Inaugural Address. He drew attention to the impacts of variations and extremes in our present climate. Pointing out that, for example, glaciers are now retreating and might disappear within 50 years, he indicated that we did not know if these were periodic changes or a reflection of real climatic warming. Given that spatial and temporal changes in climate are so poorly understood, the climate community needs a good observational system to answer such questions. Pointing to our current inability to predict conditions one month ahead, the accuracy of extrapolations of climate 100 years in the future must be questioned. His view was that we need: (1) good "climate quality" observations sustained over the long term, and (2) having these observations, we need to build models and expertise to understand them, incorporating the influences of the oceans, land, and atmosphere. Strong networks and interactions and open exchange of data and information across national borders were also essential elements. Prof. Ramamurthy concluded by emphasizing that climate, climatic variations and climate change affect all of us and that their impacts represent a greater threat than weapons of mass destruction. He expressed the hope that the present workshop would provide useful input to the process of addressing these challenges.

Following the Inaugural Address, Mr A.K. Bhatnagar, Deputy Director General, India Meteorological Department, expressed thanks to the distinguished guests and delegates and adjourned the session.

SUMMARY OF WORKSHOP PRESENTATIONS AND DISCUSSIONS

THEME 1: Setting the Context

Chairman: Mr A.M.H. Isa, PR of Bahrain and President RA II, WMO
Rapporteur: Mr B. Mukhopadhyay

In the opening presentation of this first session, Dr Thomas summarized the mission, goals and strategy of GCOS, reviewed the major GCOS observing networks and discussed the relationship between GCOS and the UNFCCC. He indicated that COP-9 (Decision 11/CP.9) has urged Parties to address the findings in the “Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC” (hereafter, the 2nd Adequacy Report) and requested GCOS to prepare a 5-10 year Implementation Plan to address these needs and issues. The Implementation Plan is now available on the Internet.[1] It has a particular focus on critical issues in the 2nd Adequacy Report, the "essential climate variables (ECVs)," unrestricted data exchange, adherence to climate monitoring principles, improvements in satellite and *in situ* observing networks and in infrastructure, and on ensuring the participation of Least-Developed Countries (LDCs) and Small Island Developing States (SIDS). COP-9 has, moreover, requested the Group on Earth Observations (GEO) to treat global climate monitoring as a priority, urged GEF to address identified high priority needs of non-Annex 1 Parties and instructed its Subsidiary Body for Implementation (SBI) to incorporate GCOS climate monitoring principles into the Convention's reporting guidelines for systematic observations. As a result of these initiatives, the emphasis on systematic monitoring of climate has been strongly reinforced. Dr Thomas went on to point out that a GCOS Cooperation Mechanism has now been established with a view to providing a source of stable, long-term funding for priority observing systems in LDCs and SIDS and described, briefly, its structure, priorities, and early achievements.

He then drew attention to the importance of the GCOS Regional Workshop Programme and its linkage to national reporting under the UNFCCC. The present workshop was intended to identify needs and priorities related to climate observing systems in South and Southwest Asia, focus attention on a regional strategy to address these requirements, including the vital issue of resource mobilization, and underpin national reporting on systematic observations to the UNFCCC. He concluded by stressing the need for participants to assess regional and national priorities in relation to requirements for climate observations including contributions to baseline GCOS networks and needs related to climate impacts and adaptation. Furthermore, a consensus must be reached on a process and priorities for a regional GCOS Action Plan, including an approach to resource mobilization (see Annex 3).

[1] Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, GCOS-92, October 2004 (WMO/TD No.1219). Can be accessed at: http://www.wmo.int/web/gcos

In the subsequent presentation entitled "Developing a Regional Action Plan for South and Southwest Asia," Prof. P. Mason, Chairman of the GCOS Steering Committee, identified the purpose of a Regional GCOS Action Plan as being to meet policy and planning needs for local and global climate information, to ensure efficient actions that give the best national and regional benefits, and to improve national and donor engagement in supporting key climate observation programmes and systems. Stressing that Regional GCOS Action Plans are a key output of each workshop, he indicated that these Plans must first focus on the regional components of key GCOS global observational networks, reflecting agreement among stakeholders on what is most important and best benefits the region as a whole. At the same time, purely regional needs for climate observations could also be incorporated, such as those related to regional and national climatic impacts and vulnerability. He then summarized the status of previous Regional Action Plans and outlined recommendations from the 2nd Adequacy Report, identifying the progress achieved and deficiencies that remain to be addressed. He drew particular attention to requirements for the production of climate products to meet user needs, particularly those of policy makers and the UNFCCC, to the fundamental importance of observational standards and to the need for capacity-building.

In discussing the need for observations of the essential climatic variables, he identified requirements for daily (or more frequent) observations to address the critical issue of climatic extremes and their impacts. Following a review of the various GCOS networks, he suggested that a Regional Action Plan should aim to strengthen global networks; improve telecommunications and data exchange; focus on regional priorities, needs, and issues; build data management, analysis and applications capacity; and improve the recovery of historical data. He saw the goals for the workshop as being able to reach a consensus on regional priorities, to outline practical and fundable projects to address these priorities (i.e., projects that would be easily identifiable and appealing to potential donors), and to begin the process of drafting the Regional GCOS Action Plan. When the Plan is finalized, it would be useful to present it to SBSTA/COP for its endorsement. He concluded his presentation by stressing the importance of assuming regional ownership of the planning process, of implementation of the Action Plan, and of the need for a coordinated strategy to address the difficult issue of funding (see Annex 4).

Plenary discussion following the above presentations centred on the following topics:

- An informal evaluation of the implementation of Regional GCOS Action Plans up to this point. The preparation of these Plans has raised the visibility of systematic climate observations with donors and Parties to the UNFCCC. The clearly-defined projects in these Action Plans have provided targets for donors. Implementation of the Pacific Islands Action Plan is proceeding well, with four donor countries supporting projects aimed at effecting improvements in upper-air networks. The biggest gaps in these networks exist in Central Africa, on islands, and in South America, with South and Southwest Asia coverage reasonably good. Some support has also been provided for enhanced monitoring of atmospheric chemistry, notably in China. At the same time, emphasis needs to be increased on monitoring of glaciers and on hydrologic networks. GCOS is working closely with the WMO's Voluntary Co-operation Programme and other potential donors to address funding requirements for such improvements. There is, however, a continued need to increase the visibility of GCOS and associated requirements for climate observations both domestically with national governments and with donors. An important issue is how to sustain enhanced observational programmes and stations, given that donor agencies are reluctant to undertake the open-ended commitments associated with long-term, systematic, monitoring of climate.

- The Global Earth Observation System of Systems (GEOSS). This is, in concept, a system of systems with 9 application areas, of which climate is one. The initiative is largely a political thrust aimed at gaining the attention of governments. GCOS, along with the WCRP and WMO, is very active in the GEOSS process as it relates to climate and welcomes the greater political visibility associated with the latter initiative. GCOS sees itself as a practical implementation arm or mechanism within the broader GEOSS process.

- The importance of long-duration historical data records in identifying climatic variations and extremes. In this context, attention was drawn to the importance of metadata in facilitating the interpretation of historical data records.

- The diverse climates of the Indian sub-continent. These are currently not well represented by the limited number of Indian climate stations in the GCOS networks. In consequence, a need exists to improve the quality and spatial distribution of stations in these networks to better represent the varied climates of the region.

- Observations from glaciers. An increased emphasis was welcomed, with several participants (e.g., Nepal, Pakistan) drawing attention to the importance of glaciers to their nations.

- The inclusion of observation stations in GCOS networks. This was cited as building staff motivation, encouraging improvements in station networks, and improving the quality of observations.

THEME 2: User Needs for Climate Observations

Chairman: Dr A. Thomas, Director, GCOS
Rapporteur: Dr S. D. Attri

In the opening presentation under Theme 2, Dr Qamar-uz-Zaman Chaudhry addressed the important topic of "User Needs for Climate Observations: Extreme Weather Events." In discussing the question, "what is extreme weather?" he pointed out that, though statistical definitions are straightforward, the answer depends to a significant extent on what a region is prepared for and accustomed to experiencing. He then went on to review the evidence for climate change, the underlying science, the potential effects of global warming on extreme events and their associated economic, ecological and human costs. Recalling that world-wide weather and climate-related economic damage has increased greatly during the past two decades, he stressed that we must focus attention on improving our knowledge and understanding of past and emerging climatic trends, natural climatic variability, and the connection between global warming and the occurrence of extreme events. This will require enhanced monitoring of the atmospheric, oceanic and terrestrial components of the climate system and improvements in data assimilation and modelling. He went on to present a detailed review of the present status of monitoring programmes for climate system components, suggesting specific improvements in each area. He concluded by reiterating the need to improve our understanding of the earth system and advocating enhanced cooperation between nations in addressing this challenge, including full and open, real-time, exchange of climate data and information across national borders (see Annex 5).

Dr A. Gupta next discussed “Observational Needs for Disaster Preparedness in South Asia”. Presenting extensive statistics on natural disasters experienced in the region over the past decade, he highlighted that more than half of these disasters were climate related. Drawing attention to the very severe regional impacts of extreme weather and climate events (about 77 percent of related deaths worldwide occurred in South Asia), he identified contributing factors, including very high population density, low-lying coastlines, coastal bathymetry, and tropical influences on weather and climate. Looking ahead, he cited IPCC projections that extreme events are likely to occur more frequently as global warming proceeds. In the face of this scenario, he advocated that disaster preparedness must incorporate the likely impacts of climate change on the frequency and intensity of such events and on the vulnerability of different regions to them. This approach will require improved climate observation and prediction systems and, to that end, he presented a number of proposals and initiatives. He then outlined an Integrated Disaster Management Concept and presented a case study of GIS Based Tropical Cyclone Management applied to the Andhra Pradesh Cyclone of December 2003. He also drew attention to a new initiative under the seven-nation BIMSTEC Forum (Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation) to establish a Centre for Weather and Climate that would aim to strengthen weather and climate observational networks, establish a regional data bank, and enhance related modelling capability. He concluded his presentation with four GCOS-related recommendations advocating improvements in observational networks, data quality, data exchange and archiving, and human resources development.

In addressing "Climate Information Needs for the Agricultural Sector," Mr F.Y. Abdo observed that improved climate information was needed to underpin planning and decision-making aimed at increasing the productivity and competitiveness of the agricultural sector. He described the various types of climatic data, derived data, and products used in agricultural applications, providing examples of areas of application such as crop selection, planning agricultural activities, drought mitigation, and water management. He then outlined corresponding requirements for agronomic data such as for information on crops, livestock, soils, pests, and diseases and pointed to the utility of remotely-sensed parameters such as surface temperature and vegetation indices. In discussing the various models used in agriculture, he indicated that plant growth, plant pest and disease control, and water requirement models were the most commonly used. Various types of forecasts also have application in this sector, ranging from forecasts of expected weather to forecasts and guidance related to daily, weekly, monthly and seasonal agricultural characteristics. He concluded his talk with examples of several applications of observed data and derived products (see Annex 6).

Following the above presentations, the following issues were highlighted during the plenary discussion:

- The importance of extreme events and how to include these in long-term predictions of climate behaviour. It was emphasized that high frequency observational data are needed to address these events and that this leads to an increasing requirement for daily or even hourly observations, since time-resolution is often a most critical consideration. At present, the most optimistic use of forecasts beyond two weeks is in estimating probabilities of extremes and not in predicting specific events. Participants, however, cited seasonal forecasts as being helpful in identifying areas that were vulnerable to extreme events and also drew attention to the importance of U.S. seasonal predictions of tropical cyclones in the Atlantic.

- The importance of observational network density. This is a very important area in which extensive work is underway in the US and Europe that targets observation of meso-scale convective events. It was pointed out, however, that WMO norms for network density address the synoptic scale. Moreover, GCOS has, to date, focused its efforts on the global scale due to its limited capabilities, with national and regional networks being an issue for the WMO's Commission for Basic Systems (CBS).

- The value of satellite remote sensing data. It was emphasized that this data adds detail to the information provided by conventional *in situ* observing stations and networks. GCOS noted that it sees a significant role for satellite data in addressing climate issues.

- Meteorological research. This, and not simply meteorological data, was stressed as being very important in South and Southwest Asia.

THEME 3: Atmosphere: Status, Deficiencies, and Needs

Chairman: Prof. S.K. Dube, Director, Indian Institute of Technology, Kharagpur
Rapporteur: Dr G. Srinivasan

In the opening presentation entitled "Implementing the GCOS Baseline Surface and Upper-Air Networks", Mr R. Thigpen summarized the status of the GCOS Surface Network (GSN), the GCOS Upper-Air Network (GUAN), and the Regional Basic Climatological Network (RBCN), with particular emphasis on South and Southwest Asia. He outlined the rationale underlying the establishment of these global networks, the criteria for station selection, and the current global distributions of the network stations. Stressing the vital importance of data from these networks, he summarized the GCOS performance standards and reporting and archiving requirements that apply to these data. Statistics from the Global Monitoring Centres were used to illustrate the need for improvements in timeliness and reliability of reporting and in coding of CLIMAT and CLIMAT TEMP messages from some stations. Particular emphasis was given to the requirements to provide historical data and regularly updated metadata to the World Data Centre. He concluded his talk with specific recommendations for improvements in the operations of GSN and GUAN stations in the region, suggesting that enhanced regional cooperation could be an effective approach to addressing problems and citing the importance of developing a good Regional GCOS Action Plan (see Annex 7.) As a related issue, he requested participants to check that the names and contact information for their national focal points for GSN and GUAN were correctly identified and to advise him of any changes.

Mr A.M.H. Isa addressed the "Observing System Needs of Southwest Asia." He began by stressing the need to monitor existing observing networks for climate on a regular basis to ensure that they are adequate to meet the challenges presented by climate variability and climate change and their impacts. He identified data quantity and quality, weaknesses in equipment calibration, funding for new technology and telecommunications, and data exchange as being key issues that must be addressed in Southwest Asia. Drawing attention to the need to recover important historical data records for the region, he pointed out that some of these might be accessible through the UK Met. Office. He went on to recommend enhancement of marine observing systems in the Red Sea, Arabian Sea and the Persian Gulf, highlighting the value of such observations in initiating and verifying climate models. In view of the importance of atmospheric chemistry, he recommended selective expansion of the GAW network in the region. As an overarching issue, he also cited the need for improvements in telecommunications systems to facilitate improved data exchange. Following a brief review of satellite and ground-based remote sensing systems currently being used in the region, he urged that continued priority be given to climate-related applications of satellite and radar data. Noting significant recent improvements in climate data management systems in some countries in the region, he encouraged wider adoption of the more powerful ORACLE-based system that is now available as a replacement for CLICOM. He concluded his presentation by reiterating the importance of following established practices and standards in the conduct of observing programmes and by presenting a series of specific recommendations aimed at ensuring that regional climate observing programmes meet GCOS standards and requirements (see Annex 8).

Prof. P. Jones spoke on "Data Rescue Issues and Requirements of Observational Systems for Determining Long-Term Trends". He pointed out that the availability of long-duration digital observational records has become an important issue as climatologists attempt to determine whether changes in average and extreme conditions are underway. Noting that the earliest records for some countries have either been lost or are held in the archives of former colonial powers, he encouraged continued efforts to rescue and digitize these data. He drew particular attention to a number of recent and planned workshops on the occurrence of extreme climate events that have been sponsored by the Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI), highlighting planned workshops in South and Southwest Asia. He emphasized that data rescue efforts should include paleoclimate (proxy) records, such as information from tree rings, ice cores, and corals, and historical archives in the form of diaries and national documents. He also stressed the importance of ensuring the homogeneity of observational time series, drawing attention to various methodologies available and illustrating his talk with case studies and examples of reconstruction of data time series. Noting the vital importance of long-duration data time series from GSN and GUAN stations, he suggested that digitization efforts within a country should give priority to these stations. He concluded his presentation by recommending digitizing the daily records for essential climate variables at all GSN sites, encouraging participation in regional ETCCDMI meetings and maintaining contacts with those working on data rescue in other countries (see Annex 9).

The "WMO Global Atmosphere Watch (GAW): A Key Programme for GCOS" was the topic of a presentation by Dr A. Weidensohler. He began by outlining the mission, underlying motivation and programme focus of the Global Atmosphere Watch (GAW), noting its emphasis on measurements of ozone, greenhouse gases, ultra-violet radiation, selected reactive gases, precipitation chemistry, aerosols and natural radio-nucleides. He followed with a description of the GAW Monitoring Components and the structure of GAW Scientific Advisory Groups, World Calibration Centres, and World Data Centres. He devoted the remainder of his talk to the aerosol component of the programme, highlighting that aerosol impacts on the functioning of the climate system are not well understood. After a quick review of GAW station networks and a discussion of the core and additional aerosol variables, he outlined the GAW strategy for aerosol monitoring. He emphasized that its aims were to understand the spatial and temporal variability of all key aerosol parameters, establish new stations where needed, strengthen links with the user community and other interested organizations, and pursue applications of GAW data for regional air quality model validation and studies. He then described the roles of the World Calibration Centre for Physical Aerosol Properties, Leipzig, Germany, the World Optical Depth Research and Calibration Centre, Davos, Switzerland, and the World Data Centre for Aerosols, Ispra, Italy. In concluding his presentation, he stressed that he and his colleagues looked forward to future cooperation and contributions to GAW from the region (see Annex 10).

In "New Systems for Dissemination of Climate and Weather Products for Reducing Risks," Dr S.K. Srivastav drew attention to the high degree of vulnerability to extremes of weather and climate in South and Southwest Asia. He summarized the early warning process as involving the production of early warning products from observational data inputs and the dissemination of these products to the target users in sufficient time to facilitate adaptive actions aimed at mitigating adverse impacts. Good dissemination systems are, therefore, needed to ensure effective delivery of early warnings of severe events. He then described a digital data broadcast system developed by the India Meteorological Department (IMD), using the telecommunications capabilities of the Asia Star satellite. In this system, data and products are routed to Singapore, uploaded to the satellite and then re-broadcast across the Asia Star footprint. He pointed out that reception of these broadcasts is by means of a simple, lightweight, and inexpensive antenna. This new dissemination system began distributing data and products in July 2003, with a pilot project at 10 IMD stations. The system currently supports the delivery of synoptic and ship observations, charts, model outputs and other information.

Plenary discussion centred on the following topics;

- Specific questions were raised regarding instrument calibration procedures for aerosol parameters. This is a particular concern in the Indian context since about 6 aerosol monitoring centres are operated in that country. Dimming of solar radiation has been observed in India, particularly in winter, and concern exists regarding its possible impact on monsoon circulation. In response, it was indicated that instruments can either be sent to the World Calibration Centres for calibration or, alternatively, the Calibration Centres can provide reference standard instruments on a loan basis. The Calibration Centres are anxious to assist countries with their aerosol monitoring programmes, and participants were encouraged to contact the Centres for advice and assistance. The GCOS Secretariat undertook to distribute information on technical specifications and calibration algorithms for instruments in response to a specific request from an Indian participant.

- In response to a question regarding the frequency with which GSN and GUAN performance monitoring reports are updated, Mr Thigpen stated that the report presented during his talk is updated every month. However, he agreed that the Japan Meteorological Agency (JMA) and Deutscher Wetterdienst (DWD) Monitoring Centres' performance reports occasionally fell a little behind schedule and encouraged participants to contact him directly should they wish to review the performance of individual stations.

- In response to a question regarding the sources of data used to reconstruct a historical time series for Kathmandu, Prof. Jones reported that in the British Library he had located measurements made at Kathmandu between 1880 and 1940 by the Indian Meteorological Department. Some additional observations had also been taken at the Indian embassy. His aim in reconstructing records for Kathmandu was to develop a time series for use in calibration of tree ring data from that region of Nepal.

- The India Meteorological Department's digital data broadcast system was applauded by several participants as providing a valuable telecommunications option, particularly for LDCs. It was clarified that the IMD owns the Asia Star satellite channel being used for the broadcasts and that the satellite operator has no control over the data flow. The products broadcast over the channel are freely available, though a capability exists to protect data so that only the interested country receives it. Data and products are currently being broadcast on a three-hourly basis but this can be changed to an hourly frequency, during, for example, severe weather. While there are no plans at present to distribute data via the Africa Star satellite, it was indicated that this could be done without great difficulty.

THEME 4: Oceans: Status, Deficiencies, and Needs

Chairman: Dr H. Gupta, Secretary, DOD
Rapporteur: Dr O.P. Singh

In the opening talk on the second day of the workshop, Dr S. Sheyte discussed "Climate Observations for the North Indian Ocean: the Outstanding Issues." He began by describing important features of the Indian Ocean, pointing out that it represents about 20 percent of the global oceans but is the only ocean with no outlet to the north. Recalling that the Indian Ocean supports the most intense monsoon on earth, he then described its major current systems. He drew attention to the relatively stable circulations in the south and the marked seasonal and other temporal variations that occur in the north. This time dependence presents a significant challenge for monitoring of the North Indian Ocean. Equally, however, it is important to monitor cross-equatorial flows as these have important implications for the heat budget of the northern basin. He reviewed sea-surface temperature (SST) patterns and drew attention to their influence on the atmosphere citing relationships with rainfall anomalies in East Africa and Australia. This suggests that monitoring of SST anomalies must also to be a high priority in the northern basin. In addition, the vulnerability of coastal regions in the Bay of Bengal and elsewhere to storms and storm surges points to the need for sea level monitoring and storm surge prediction systems. In concluding his presentation, he indicated that, while a first order understanding of the large-scale circulation of the Indian Ocean currently exists, basic oceanographic studies are needed in some regions. He also reiterated that an observing system for climate must address aspects of special interest discussed earlier, including equatorial circulations, intra-seasonal oscillations and monitoring of cyclones and their associated phenomena (see Annex 11).

Dr K. Radhakrishnan next addressed "Indian Ocean GOOS: Climate-Related Observations in the Indian Ocean - Status, Deficiencies, Needs and Action Plan". Beginning with a brief overview of the observing systems currently operated by various countries in the Indian Ocean, he then outlined common concerns underlying the establishment of an Indian Ocean GOOS. In particular, the need was highlighted for systematic ocean observations to address weather and climate-related issues, with important research priorities including the coupled ocean-atmosphere monsoon system, South Indian Ocean climate modes, decadal variability and warming trends, the cross-equatorial cell and inter-annual monsoon variability, ocean modelling, and various process studies. Against this backdrop, he described current Indian Ocean Argo, XBT, drifting and moored buoy deployments and tide gauge programmes and pointed to specific needs for targeted expansion of these monitoring activities. A major deficiency was the absence of a unified approach for the systematic and sustained observation of the unique, complex, ocean-atmosphere system in the region. Consequently, the Indian Ocean Panel (IOP) is preparing a plan for sustained, basin-scale, ocean observations. The Panel is currently soliciting comments on the draft plan, which is scheduled to be finalized by April 2005. It will then be presented to JCOMM/GOOS/GCOS, and commitments from national agencies will be solicited for its implementation (see Annex 12).

Mr S. Kumar delivered the concluding talk in this session, titled "Ocean Data Management and Exchange in the Indian Ocean Region". He began by summarizing recent workshops and other initiatives directed towards improving data management in the Indian Ocean. He then reviewed the present status of ocean data management in the region, describing the International Oceanographic Data and Information Exchange (IODE) Data System, with its network of National, Responsible and World Data Centres, and outlining the forms of data handled by these Centres. He also briefly reviewed the IODE Policy on the need for timely, free, and unrestricted international exchange of oceanographic data. Referring to deficiencies in data management systems identified by a recent regional survey, he pointed to the needs to address very large increases in data volumes and types, improved data integration, generation of value added products, and issues of scale. In response, the IODE plans to move to a more decentralized, "products and services-oriented" model of data management. He then outlined the Indian Ocean Global Ocean Observing System (IOGOOS) strategy for data and information management and capacity-building, including the related structures and approach to coordination, along with a 10-year work plan for implementation. He concluded by drawing attention to the recent Ocean Data and Information Network for the Central Indian Ocean (ODINCINDIO) Workshop held in Tehran. The major ODINCINDIO objectives focus on strengthening national oceanographic data centers (NODCs), providing training and education, enhancing national and regional marine data, metadata and information databases, and pursuing the development and dissemination of useful products.

During plenary discussion following the above presentations, the following issues were raised:

- One participant asked whether a specific ocean project could usefully be included in a Regional GCOS Action Plan for South and South West Asia. In response, it was noted that the Indian Ocean Panel has drawn up an implementation plan that should address GCOS requirements. Consequently, a specific project for inclusion in the Regional GCOS Action Plan may not be necessary. However, it would be appropriate to endorse the IOP Plan in the GCOS Action Plan.

- A participant pointed out that the Indian Climate Committee places great emphasis on the Arabian Sea and the Indian Ocean Monsoon, and has identified a related requirement for sustained observations (i.e., over several decades) in the equatorial portion of the Indian Ocean. It was indicated that the Indian Ocean Panel plans to augment the ocean observing network in equatorial waters. The Panel has proposed a zonal spacing of 500km and a meridional spacing of 100km for Argo floats in that area, with a 5-day sampling frequency, while an upcoming International Buoy Programme for the Indian Ocean (IBPIO) meeting will address requirements for equatorial drifting buoy deployments.

- A participant drew attention to an apparent data gap in the Northern Indian Ocean and questioned why additional observations had not been proposed in that area. In view of the impact of the Arabian Sea on winter disturbances moving from the Mediterranean to Pakistan and India, it would be useful to have additional observations from the Arabian Sea. In response, it was indicated that the observing network design emphasized areas where important oceanic features were present or where changes were occurring. In addition, operational feasibility was a factor in identifying sites where buoys or other monitoring platforms would be located, since some locations presented difficulties in access and mooring.

- One participant expressed concern that conditions off the coast of South Africa are important in the context of long-term variability, yet the proposed ocean observing network does not cover the behaviour of the oceans in that region.

- In the context of the linkage between GCOS and the UNFCCC and long-term climate variability and change, it was stressed that the oceans community must be ready to capture small magnitude, long-term, variations. This highlights the need for emphasis on high-quality measurements.

- Prof. Mason drew attention to the GCOS interest in tide gauge measurements, advocating that an increased number of gauges be GPS-equipped. He also pointed out that, while satellite data are very useful, they are not ideal for detecting small decadal changes of around 0.5^0C. Consequently, GCOS places a high priority on measurements from buoys and other *in situ* platforms.

- Dr Thomas noted that the GCOS Implementation Plan nearing completion has an Ocean section that, on the broad scale, is consistent with regional proposals for enhanced ocean monitoring. He commented that the ocean-related information presented during the New Delhi workshop would be helpful in improving the Implementation Plan.

THEME 5: Terrestrial Observations: Status, Deficiencies, and Needs

Chairman: Prof. P. Jones, Director, Climatic Research Unit, University of East Anglia
Rapporteur: Dr A. Gupta

In the opening presentation on the terrestrial component of the climate system, Dr S.A. Awan addressed the "Status, Deficiencies, and Needs for Hydrological Observations for Climate". He first emphasized that meteorological and hydrological observations provide the essential inputs for flood forecast models and that the effectiveness of a hydrological and meteorological data system depends on its reliability, compatibility and calibration. He then summarized the hydrological data, information and products required to provide warnings of floods and droughts. After reviewing the status of data generation at global, regional and national levels and the modes of telecommunications used to relay data and products, he expanded on this theme through a case study of real time transmission and collection of hydrological data in the Indus River Basin in Pakistan. This provided an opportunity to illustrate various hydrometeorological instruments, telecommunications systems, and the observing station networks, including weather radars, and to highlight their capabilities and limitations. He concluded his presentation by identifying needs for capacity-building, capacity improvement and infrastructure development related to hydrological operations (see Annex 13).

Prof. S.I. Hasnain followed with a talk on "Glacier and Permafrost Observations in Hindu-Kush Himalaya". Pointing out that Himalayan glacier basins are subject to both monsoon and westerly influences, he discussed factors contributing to their ablation including higher temperatures, decreased albedo, and an increased rainfall component in precipitation. He drew attention to the hundreds of glacier lakes in the region and to the potential flood threat that these pose in the face of a warming climate. In outlining the desired attributes of benchmark glaciers, he advocated increased glacier monitoring and the establishment of at least one benchmark glacier in each of the countries in the Hindu-Kush region. He then described the mass balance monitoring programme on the Chota Shigri glacier and went on to report on a successful 2002 mass balance training workshop at that glacier that drew participants from India, Bhutan and Nepal. Finally, he presented a proposed road map to address the issue of glacier retreat, including specific recommendations for evaluation of the Chota Shigri glacier mass balance measurements and extension of the regional monitoring network to include at least one glacier in each country in the Hindu-Kush Himalayan region. He noted that the South Asia Centre of the NASA/USGS GLIMS (Global Land Ice Measurements from Space) project is located with the Glacier Research Group at Jawaharlal Nehru University, New Delhi and stressed the value of intensified satellite monitoring of glacier characteristics and behaviour.

On the subject of permafrost, Prof. Hasnain drew attention to its important role as a long-term reservoir for carbon and methane, with about 14 percent of the world's carbon being stored in frozen ground. As temperatures rise, the release of these greenhouse gases is, however, beginning in some permafrost regions, and this could accelerate the greenhouse effect. Unfortunately, little permafrost monitoring and research has been carried out in the Himalayan region, with the Tanggula Mountains, Tibetan Plateau, being the only site for which data are presently available. In consequence, Prof. Hasnain suggested that a network of permafrost monitoring sites be established in the Hindu-Kush Himalaya as part of the Global Terrestrial Network for Permafrost (GTN-P) (see Annex 14).

Plenary discussion following the above presentations centred on the following issues and topics:

- A participant from Nepal endorsed the emphasis placed on glacier monitoring, reinforcing the need to establish a benchmark glacier in each country. He pointed out that some glaciers in his country are retreating at a rate of about 10 metres each year, posing a major concern in view of the desire to use glacier runoff for power production. He also drew attention to a memorandum of understanding with Japan under which the monitoring of four glaciers in Nepal has been carried out since 1973. He concluded by expressing the hope that GCOS would assist Nepal in establishing a benchmark glacier within his country, indicating that Nepal hoped to be able to undertake systematic monitoring of glaciers within the next year or two.

- The importance of permafrost in relation to exchange and storage of greenhouse gases was reiterated with participants stressing the need to develop projects in the relevant countries of the region. In this context, the relevance of the activities of the International Permafrost Association was cited and attention was drawn to the value of linking regional permafrost activities to international initiatives, programmes and expertise.

- Considerable interest was displayed in trends in glacier outflows and discharges in glacier-fed rivers in Pakistan and elsewhere in the region. While no information was immediately available, it was indicated that the relevant records would be examined with this issue in mind.

- In response to a question regarding the methods used to calibrate radar estimates of precipitation in Pakistan, it was stated that observations from rain gauges within the area of the radar's coverage were used to calibrate the radar returns.

THEME 6: Climate Change Assessment Tools

Chairman: Prof. P. Mason, Chair, GCOS Steering Committee
Rapporteur: Mr R.P. Lal

Drs D. Hemming and K.R. Kumar delivered a joint presentation on "The Use of the PRECIS Climate Model to Undertake Regional Climate Predictions for South and Southwest Asia and the Asian Summer Monsoon". In her opening remarks, Dr Hemming indicated that Regional Climate Models are the preferred tool for downscaling Global Climate Model (GCM) outputs into finer scale climate scenarios needed to assess national vulnerability and adaptation and underpin national communications required under the UNFCCC. In this context, the United Kingdom's Hadley Centre aims to assist in capacity-building and technology transfer by supplying PRECIS freely to developing countries, training national experts in its operation, and providing subsequent follow-up support. Dr Hemming then outlined the capabilities of the model, its modest requirements for PC-based computing power, and its portability. She concluded by listing locations where training courses have been held, illustrating where the model is currently being used to develop regional climate scenarios, and encouraging participants who wished to host a PRECIS workshop to approach her or the Hadley Centre (see Annex 15).

Dr Kumar expanded on regional modelling with a talk entitled "PRECIS Applications for Regional Climate Change Studies over India". He drew attention to the Joint Indo-UK Collaborative Programme on Climate Change Impacts in India, which focuses on the development of future climate scenarios for India and the preparation of scenario products for impact assessments. He then presented the results of model simulations using different emission scenarios for selected future time periods. He drew attention to the role of the Indian Institute of Tropical Meteorology, Pune, as the regional centre for PRECIS application and data coordination for South Asia, and pointed out that extensive data from 10 experiments at 50km resolution for all South Asian countries is available and accessible at the Institute. He also noted that a training workshop for South Asia had been organized by the Hadley Centre at Thimphu, Bhutan, in July 2004, with six countries participating, and that PRECIS is now available at institutes in Bhutan, India, Pakistan, Nepal, Bangladesh and Sri Lanka. In concluding his talk, he re-emphasized that PRECIS has been demonstrated to be a powerful tool with which to build consistent regional climate change scenarios and added that it also fosters regional collaboration and scientific consistency in climate change assessments (see Annex 16).

In a wide-ranging presentation, Dr P.C. Joshi discussed "Satellite Observations for Climate Studies over South and Southwest Asia: Current Status and Future Prospects". He began by reviewing current and planned Indian missions for weather and climate studies, identifying the individual satellites (INSAT 2A,3A,3D; Kalpana-1; OCEANSAT 1/2; and MEGHA-TROPIQUE), including their onboard suites of sensors, their launch dates, and their areas of application. Examples of information and products derived from meteorological satellites were presented, ranging from imagery of convective clouds and fog to derived fields of quantitative precipitation and outgoing longwave radiation. Dr Joshi then provided similar information for the Indian Remote Sensing satellites (the IRS series; RESOURCESAT 1; RISAT), highlighting the wide ranging applications of their data in agriculture, land use planning, hydrology, forest and wetland surveys, coastal studies, mineral prospecting, and other areas. Examples were shown of applications such as the monitoring of snow cover, glaciers retreat, sea-surface temperature and wind speed, and crop cover.

Areas of active research included estimation of rainfall rate, seasonal changes in sea ice in the Antarctic, derivation of estimates of soil moisture, ocean colour mapping, and aerosol optical depth. Where future Indian satellite missions were concerned, he drew particular attention to discussions regarding a possible Indian CLIMATSAT, focused on climate monitoring, and indicated that suggestions from GCOS regarding this developing programme would be welcomed. He briefly drew attention to the activities of the Indian Meteorological and Oceanographic Satellite Data Centre (MOSDAC) and to capacity-building courses delivered by the Space Applications Centre, Ahmadabad. He concluded his presentation with a series of recommendations addressing satellite data exchange, regional validation of satellite-derived parameters, involvement of academic and other institutions in satellite applications, collaboration with international satellite experts, and capacity-building. In addressing capacity-building needs, he noted that a UN-affiliated Centre for Space Science and Technology Education in Asia Pacific Region, located in India, represents an important resource (see Annex 17).

Plenary discussion after the preceding talks drew out the following:

- There was widespread interest in the PRECIS model, and a number of specific questions were raised regarding its operating characteristics, requirements for input data, its applicability for determining probabilities of occurrence of events, and its utility for decision-making. In response, it was explained that PRECIS contains the full capability of a state-of-the-art GCM, but scaled to a regional scale. It requires the same input data as the GCM, albeit on a finer resolution, while its boundary conditions are supplied by the GCM. It would be necessary to run the model a number of times using different input values in order to obtain indications of probability.

- It was indicated that the Hadley Centre is very interested in finding a regional partner in South West Asia with whom to work in providing training and applying PRECIS there. In response, the delegate from Pakistan offered to act as a partner in hosting a training workshop and implementing PRECIS in that part of the region.

- It was pointed out that GCOS is enthusiastic about PRECIS, since it delivers relevant policy information to government decision-makers. The importance of having observational data within individual countries was, however, also stressed.

- It was stressed that satellite operators and agencies engaged in surface-based climate monitoring activities must work together to ensure that the best use is made of satellite and *in situ* observations.

- In response to a specific question regarding the resolution at which data from Indian satellites could be made available to other countries for drought monitoring purposes, it was suggested that this question should be directed to the relevant Data Centre.

- Dr Thomas indicated that GCOS uses a number of mechanisms in its attempts to ensure that GCOS requirements are conveyed effectively to the satellite community (e.g., through CEOS and WMO). Consequently, he expressed a strong interest in working with Indian and other satellite operators to ensure that climate monitoring requirements were incorporated into satellite programmes.

THEME 7: Resource Mobilization

Chairman: Dr A. Mathur, President, Synergy Global
Rapporteur: Dr T.A. Khan

Mr J. Williams addressed the vitally important issue of resource mobilization in his presentation, titled "Mobilization of Resources for Financing Requirements of the Global Climate Observing System in South and Southwest Asia". The purpose of his presentation was to inform efforts towards obtaining financing to meet priority GCOS needs in the region. His presentation encompassed the Global Development Agenda and the availability of overseas development assistance in Asia. It addressed how to become part of the Development Agenda and implications for the formulation of a Regional GCOS Action Plan. After highlighting that all donors are now working to a common development agenda for reducing poverty worldwide, he identified the OECD's Millenium Development Goals (MDGs) and their associated development targets. Projects or activities that do not contribute directly to achieving these development targets will be unlikely to receive funding support. Pointing to the substantial amount of donor financing flowing towards South and Southwest Asia, he identified the most likely potential sources of funding for improvements to the climate observing system in the region. He flagged needs to work much more closely with the development community, focus on the vulnerability of the poorest people to climate events, and set priorities in consultation with users of climate data and products. He then presented an approach to the formulation of a Regional GCOS Action Plan aimed at optimizing success in obtaining donor support for project implementation. He suggested that the Action Plan should not be a technical document but one that seeks to set a shared agenda between scientists, governments, and donors, and is written in a form in which governments and donors can understand and engage. Following a review of potential areas of interest of major donors, he encouraged those drafting the Regional GCOS Action Plan to "think like a donor....focus on national development priorities....and think poverty!" He concluded his talk by offering some specific suggestions regarding the objective, focus, tone, and structure of the proposed Plan. As an example, an appropriate objective could be "Coping with climate variability today in order to cope with climate change tomorrow and deliver the MDGs;" a primary focus might be on "Improving water resource management throughout the region;" and the primary beneficiaries "People living in poverty". The Plan should be based on a regional partnership that includes all principal stakeholders. It should highlight to potential donors the development impact that would result from investments in its implementation. Finally, its structure should be one that meets the expectations and requirements of donor agencies and governments.

Participants raised the following points during the plenary discussion following the presentation by Mr Williams:

- A key issue is to integrate climate risk into the development process. This risk will increase as time goes on. It may be useful, therefore, to package Action Plan projects in the context of coping with climate variability in order to cope with climate change. Moreover, since the development community is accustomed to dealing with means or averages and is uncomfortable with variability, the climate community could assist by bringing the variability aspect to the discussion.

- It will be important to focus the Regional GCOS Action Plan projects on the MDGs and to write projects in a way that maximizes the likelihood of obtaining funding for their implementation. Climate change will, clearly, impact on progress towards achieving the MDGs.

- An important challenge is find a goal or goals of common interest to donors. Transboundary water management is the critical water issue at the regional scale and should perhaps be highlighted in the Regional Action Plan.

THEME 8: First Steps in Developing a Regional Action Plan

Chairman: Mr A.K. Bhatnagar, Deputy Director General, India Meteorological Department

Dr Thomas initiated discussions under this theme by briefly summarizing past experience with the development and implementation of Regional GCOS Action Plans. He then identified the next steps as being to reach agreement on the high priority projects to be included in a Regional GCOS Action Plan and to identify a writing team that would participate in a subsequent meeting at which a draft of the Action Plan would be prepared. He stressed the need for members of this writing group to prepare project descriptions well in advance so that their meeting would be as productive as possible. He also indicated that the draft Action Plan would subsequently be circulated to workshop participants for review, and that their comments would be incorporated in the final version of the Plan.

Dr D. O'Neill followed with a presentation entitled "An Introduction and Initial Discussion of the Framework Action Plan". He drew participants' attention to the framework document, which had previously been distributed, pointing out that it was intended to assist in formulating a Regional GCOS Action Plan by proposing a structure and offering some initial suggestions regarding content for their consideration. Following a brief review of the document, he pointed to the many questions included in its various sections and stressed that these questions were intended to stimulate input regarding the most appropriate structure for the Plan and what should be included in it. He then challenged workshop participants to take ownership of the development of the Action Plan, to reach consensus on its key thrusts, and to propose specific projects and recommendations to give substance to the Plan. He also requested that participants suggest improvements and corrections to the background material contained in the Framework Document.

The Chairman called for general discussion of the proposed approach outlined by the preceding speakers and for initial suggestions for high priority projects that should be included in the Regional Action Plan. In response, participants offered the following observations and suggestions:

- A Regional GCOS Action Plan must reflect different national needs. While common projects are desirable, the Action Plan must also be sensitive to the real problems faced by individual nations. Projects should take into account the fact that there are substantial variations in national capacities across the region.

- The climate science community must interact more effectively with the climate change process within their own countries. In view of the fact that National Communications under the UNFCCC represent a major category of user, the national Climate Change Coordinators are a key link and there needs to be a much closer relationship with them. This aspect needs to be reflected in the Regional Action Plan.

- Several potential project areas were proposed. Needs were identified to improve the GSN and GUAN networks and to ensure the quality and sustainability of these stations. The need to undertake capacity-building for applications of remote sensing to hydrology was stressed. Enhanced aerosol monitoring was advocated as a regional priority. Data rescue, including digitization of records that currently exist in hard copy formats, was indicated to be an important priority.

- In response to a question regarding the availability of funding, Dr Thomas indicated that several directions were being pursued to raise the resources needed for implementation of projects. He cited the US Climate Change Science Initiative's support for work on some GUAN stations as an example of success in obtaining donor assistance for meaningful projects. He also suggested that sharing regional capacities through bilateral arrangements with other Asian countries that have well developed capabilities could also be a useful option, noting that India has a very active programme and substantial capability, as do Japan and China.

THEME 9: Framework Action Plan

Chairman: Dr S.K. Srivastav, Director-General, India Meteorological Department
Rapporteur: Dr W. Westermeyer

In an opening statement on the third day of the Workshop, the Chairman emphasized that there was a need to increase emphasis on climate issues within the region in order to accommodate the GCOS objectives within National Meteorological and Hydrological Services. He then requested participants to summarize their individual country interests and requirements in relation to the GCOS programme. The following encapsulates observations and comments made by participants:

- The need to upgrade obsolete observing stations and to network radars was identified in Bahrain.

- In Bhutan, assistance and expertise to develop their programme would be helpful.

- The desire was expressed to see data from Indian upper-air and surface climate stations fully utilized in the GCOS programme.

- An Iranian interest was to establish ocean observing networks in the Caspian Sea and the Sea of Oman in order to participate fully in GCOS.

- Interest was expressed in participating in the GCOS programme on behalf of Iraq.

- A representative from the Maldives noted that his country has climate stations and a tide gauge network that can contribute data to GCOS.

- There are 13 synoptic stations in Nepal, some with more than 30 years of record, but none of these is designated as GSN stations. There is interest in establishing an upper-air station in a data gap area in the central Himalaya to support weather forecasting and contribute to GCOS. Enhanced glacier monitoring, establishment of a benchmark glacier, and data rescue were also identified as priorities.

- Needs exist for data rescue and for an increase in the number of meteorological, climate and ocean observations in Oman. Other priorities include increasing the awareness of decision-makers regarding climate issues and capacity-building in data analysis and satellite applications.

- In Pakistan, the need to review the selection of GCOS stations was identified, possibly replacing some stations and placing emphasis on their data quality and sustained operation. In addition, the importance of full and free exchange of climate information, including oceanographic and hydrologic data, was stressed, and there was support for enhanced glacier monitoring, including identification of at least one benchmark glacier.

- Qatar indicated support for GCOS.

- Improving the quality of its upper-air programme is a priority in Sri Lanka. In addition, there is interest in obtaining advice about commencing oceanographic observations in this country.

- The United Arab Emirates operate a very dense surface network, including two ozone monitoring stations and two ultraviolet radiation stations. In addition, they currently have one upper-air station and plan to add three more. Planning is underway to establish marine observing stations in the Persian Gulf and to receive data from Indian satellites. While there is a very good climate database in the country, a shortage of qualified personnel was identified as a concern. A need was expressed for assistance in training staff.

- There are more than 20 surface observing stations in the Republic of Yemen, but no upper-air stations and no ocean stations.

- Bahrain has expanded services to include climatology. The country possesses a long climate data record, extending back to 1932, and digitization of historical data is underway. Bahrain operates one GSN station, but it no longer has a GUAN station. Data management and data rescue were identified as the most important issues in Bahrain.

Following the round-table session summarized above, a general discussion took place regarding GSN and GUAN stations. Several participants indicated that the most appropriate stations have not always been chosen for inclusion in these networks. Prof. Jones then described the process used during the initial selection of these stations. Where there was disagreement with the selections, however, he encouraged participants to contact Mr Thigpen and propose alternative stations for inclusion in these key GCOS networks. Mr Thigpen, in turn, stressed his willingness to work with participants to improve the station selections, noting that a GCOS focal point in each country was needed to facilitate this process.

The Chairman then focused participants' attention on the preparation of a Regional GCOS Action Plan, including the approach, the selection of high-priority projects, and the issue of funding for its implementation. He re-emphasized the need to reach consensus on priorities and projects and to identify individuals for a writing team to draft the Action Plan. Building on earlier workshop presentations and discussions, extended debate then took place that resulted in general agreement on the project areas and recommendations that should be included in the Plan. These project areas and recommendations are listed in Table 1 below.

Table 1. REGIONAL GCOS ACTION PLAN FOR SOUTH & SOUTHWEST ASIA

PROJECTS

- **Strengthening the meteorological networks e.g., GSN, GUAN, and RBCN**
- **Establishing GAW aerosol monitoring within the region**
- **Monitoring glaciers and permafrost for water resources**
- **Preparation of databases for climate assessment (including data rescue)**
- **Building capacity for satellite applications to climate and national development**
- **Enhancing the availability and use of hydrological data**
- **Establishing an Indian Ocean observing system for climate**
- **Developing capabilities within the region for assessing climate variability and change**
- **Regional modelling**

BROADER ISSUES/RECOMMENDATIONS

- **Enhancing regional coordination to facilitate addressing regional priorities, including designation of GCOS focal points**
- **Developing a means to improve data exchange, availability, and management within the region.**

Workshop participants then proceeded to discuss the composition and specific tasks of the writing team and the timing and location for a follow-up meeting. During these discussions, Dr Thomas confirmed that GCOS had funds available to support a writing group meeting involving 12 to 15 people. He observed that preparation of a Regional GCOS Action Plan represents a first important step in a continuing process, since future changes in observing systems may be expected as new areas of interest develop. This suggested that there should be some flexibility in the Plan to facilitate adapting to developments that may occur in the future. Against that backdrop, he stressed the importance of getting work underway as quickly as possible on the actual preparation of the Action Plan. Dr Westermeyer elaborated that the Regional GCOS Action Plan should be seen as a strategic, agenda-setting document. In consequence, Action Plan projects could be presented in summary form with each summary being 3 to 5 pages in length. He drew attention to the suggested format for these project summaries contained in the framework document, noting that it was desirable to have some consistency in their format. He also stressed the value of presenting these summary projects to decision-makers and potential donors, while recognizing that the projects would require further elaboration before being submitted formally to donors for funding.

The Chairman summarized the conclusions and agreements of the preceding discussion, indicating that:

- A follow-up meeting to write the Action Plan will be held at a to-be-agreed location, with possible dates being in late January or early February 2005. Offers by the Islamic Republic of Iran and Pakistan to host the meeting were gratefully acknowledged.

- WMO Permanent Representatives and national representatives were requested to nominate appropriate individuals to participate in the writing activity. These nominations should be forwarded to Dr Westermeyer as soon as possible and, in any event, no later than 15 November, with copies to Dr Srinivasan.

- Project summaries that address the priorities identified in Table 1 should be prepared by regional experts well in advance of the writing group meeting. It was suggested that these summaries be completed within two months of establishing a writing team, with a view to preparation of a first draft Action Plan for subsequent review and refinement at the writing group meeting.

- Dr Srivastav agreed to chair the follow-up meeting of the writing team.

- The overall target will be to finalize a Regional GCOS Action Plan for South and Southwest Asia within six months.

In the context of the preceding decisions, it was emphasized that the best regional experts should be chosen as writing group participants. Moreover, an individual's identification as a writing team member should represent a commitment by his or her country to prepare the relevant project summary. Furthermore, to ensure representation of all climate system components, the oceans community will be approached to identify a writing group participant and, correspondingly, the participation will be sought of experts on hydrology and glaciers. It was pointed out that it will also be important to have one or two national Climate Change Coordinators on the writing team. Dr Thomas asked delegates to forward suggestions for the most appropriate individuals from that community. The value of advice from outside experts in formulating a Regional Action Plan was also stressed, with Prof. Mason and Mr Williams agreeing to assist in fine-tuning the document.

CLOSING CEREMONY

In closing remarks to participants, the President of WMO's Regional Association II, Mr Isa, indicated that the workshop had provided valuable insight into the GCOS programme and an opportunity to discuss issues most relevant to the region. He expressed his thanks and those of the participants to the Chairman, the India Meteorological Department, and the Government and people of India for hosting the workshop. He also thanked the invited experts, the behind-the-scene staff, and the GCOS team for their contributions to its success.

Speaking on behalf of the GCOS Secretariat, Dr Thomas also expressed his deep appreciation to Dr Srivastav, the staff of the India Meteorological Department, and the Government of India for the outstanding manner in which they had organized and supported the workshop and for the wonderful hospitality they had extended to participants. He went on to acknowledge the financial support provided for the workshop activity by the UNDP/GEF, the Government of India, and the UK Met Office, all of which had made it possible to hold the workshop. He concluded by thanking delegates for their active participation in the workshop and expressed his appreciation for their agreement to move ahead with the process of developing a Regional GCOS Action Plan.

In formally ending the workshop, Dr Srivastav, Director-General, India Meteorological Department, indicated his gratitude to all participants for their contributions to the success of the workshop. Describing it as a privilege to have welcomed participants to New Delhi and to have worked together to address important substantive issues, he concluded by wishing everyone a safe journey home.

(Intentionally blank)

Annex 1

GCOS Regional Workshop for South & Southwest Asia
New Delhi, India 11-13 October 2004
Venue: *Napoleon Hall*, Hotel Le Méridien New Delhi,
Windsor Place, New Delhi - 110001

WORKSHOP AGENDA

Day 1 *October 11 2004, Monday*

09:30 – 10:30 **Opening Ceremonies**

Introduction of Dignitaries: Mr A.K. Bhatnagar, Deputy Director-General, India Meteorological Department
Welcome Address: Dr S.K. Srivastav, Director-General, India Meteorological Department
Remarks on GCOS: Dr A. Thomas, Director, GCOS
IPCC Needs for Climate Observation: Dr R.K. Pachauri, Chairman, IPCC
Remarks: Dr Maxine Olson, Resident Representative, UNDP, New Delhi
Inaugural Address: Prof. V. S. Ramamurthy, Secretary, Dept of Science & Technology
Vote of Thanks and Conclusion: DrA.K.Bhatnagar

10:30 – 11:00 **Tea/Coffee Break**

11:00 – 12:10 **Theme 1 Setting the context**
Chairman: Mr A. Majeed H. Isa, PR of Bahrain and President RA II, WMO
Rapporteur: Mr B. Mukhopadhyay

1. Overview of GCOS - Alan Thomas, Director, GCOS (20)
2. Developing a Regional Action Plan for South and Southwest Asia,- P. Mason, Chair, GCOS Steering Committee (40)
3. Discussion (10)

12:10 – 12:15 **Break**

12:15 – 13:30 **Theme 2 User Needs for Climate Observations**
Chairman: Dr Alan Thomas, Director, GCOS
Rapporteur: Dr S. D. Attri

1. User Needs for Climate Observations: Extreme Weather Events - Qamar-uz-Zaman Chaudhry (20)
2. Observational Needs for Disaster Preparedness in South Asia - Akhilesh Gupta (20)
3. Climate Information Needs for the Agricultural Sector - Fayez Yaseen Abdo (20)
4. Discussion and Workshop Recommendations (15)

13:30 – 14:30 **Lunch**

14:30 – 16:00 **Theme 3 Atmosphere: Status, Deficiencies, and Needs**
Chairman: Prof. S.K. Dube, Director, IIT, Kharagpur
Rapporteur: Dr G. Srinivasan

1. Implementing the GCOS Baseline Surface and Upper Air Networks - Richard Thigpen (30)
2. Observing System Needs of Southwest Asia - A. Majeed Isa (30)
3. Data Rescue Issues and Requirements of Observational Systems for Determining Long-Term Trends - Phil Jones (30)

16:00 – 16:15 **Tea/Coffee Break**

16:15 – 17:45

4. WMO Global Atmosphere Watch (GAW): A Key Programme for GCOS - Alfred Weidensohler (30)
5. New Systems for Dissemination of Climate and Weather Products for Reducing Risks - S.K. Srivastav (30)
6. Discussion and Workshop Recommendations (30)

(*1900 hrs Cultural programme followed by Dinner- hosted by Secretary, Department of Science & Technology)*

Day 2 *October 12 2004, Tuesday*

09:30 – 11:30 **Theme 4 Oceans: Status, Deficiencies, and Needs**
Chairman : Dr Harsh Gupta, Secretary, DOD
Rapporteur: Dr O. P. Singh

1. Climate Observations for the North Indian Ocean: the Outstanding Issues - Satish Sheyte (30)
2. Indian Ocean GOOS: Climate related Observations in the Indian Ocean - Status, Deficiencies, Needs and Action Plan - K. Radhakrishnan (30)
3. Ocean Data Management and Exchange in the Indian Ocean Region - Srinivasa Kumar (30)
4. Discussion and Workshop Recommendations (30)

11:30 – 11:45 **Tea/Coffee Break**

11:45 – 13:15 **Theme 5 Terrestrial Observations: Status, Deficiencies, and Needs**
Chairman : Prof. Phil Jones, Director, Climatic Research Unit, University of East Anglia, UK *Rapporteur: Dr Akhilesh Gupta*

1. Status, Deficiencies, and Needs for Hydrological Observations for Climate - Shaukat Ali Awan (30)
2. Glacier and Permafrost Observations in Hindu-Kush Himalaya - Syed Iqbal Hassnain (30)
3. Discussion and Workshop Recommendations (30)

13:15 – 14:15 **Lunch**

14:15 – 15:15 **Theme 6 Climate Change Assessment Tools**
Chairman : Paul Mason (?)
Rapporteur: Mr R.P. Lal

1. The Use of the PRECIS Climate Model to Undertake Regional Climate Predictions for South and Southwest Asia and the Asian Summer Monsoon - Rupa Kumar Kolli and Dr Deborah Hemmings (30)
2. Satellite Observations for Climate Studies over South and Southwest Asia: Current Status and Future Prospects - P.C. Joshi (30)

15:15 – 15:30 **Tea/Coffee Break**

15:30 – 16:45 **Theme 7 Resource Mobilization**
Chairman: Dr Ajay Mathur, President, Synergy Global
Rapporteur: Dr T.A. Khan

1. Mobilization of Resources for Financing Requirements of the Global Climate Observing System in South and Southwest Asia - J. Williams, United Kingdom (30)

2. Discussion (45)

16:45 – 16:50 **Break**

16:50 – 17:45 **Theme 8 First Steps in Developing a Regional Action Plan**
Chairman: Mr A. K. Bhatnagar, Deputy Director General, India Meteorological Dept.

1. Brief statement by A. Thomas on GCOS experience with Regional Action Plans (10)
2. An Introduction and Initial Discussion of the Framework Action Plan - Des O'Neill (45)

Day 3 *October 13 2004, Wednesday*

09:30 – 11:30 **Theme 9 Framework Action Plan**
Chairman: Dr S.K. Srivastav, Director General, India Meteorological Department *Rapporteur: Dr William Westermeyer*

1. Review of priorities as determined during first two days and discussion of potential project proposals

11:30 – 12:00 **Tea/Coffee Break**

12:00 – 01:30 Discussion of potential projects - continued

2. Next steps and conclusion of workshop - A. Thomas and (Session Ends)
Lunch

(Intentionally blank)

Annex 2

LIST OF PARTICIPANTS

Mr Fayez S.Y. ABDO
Jordan Meteorological Department
P.O.Box 341011 Amman 11134
Amman Civil Air Port marka
Amman Jordan
JORDAN
Tel.: +962 6 4892408
Fax: +962 6 4894409
E-mail: fzabdo@yahoo.com

Mr Hossain Md AKRAM
Director
Bangladesh Meteorological Department,
Dhaka – 1207
BANGLADESH
Tel.: +88 02 8116634
Fax: +88 02 8118230 / 8119832
E-mail: bmdswc@bdonline.com

Mr Ahmed AL-KHAYAT
Qatar
Tel.: +974 466 6011
Fax: +974 466 6021
E-mail: kalmadfaa@yahoo.com

Mr Mohmed Abdullah AL-LISANI
CAMA/YMS, Hadda St. Sana'a
P.O.Box. 7145
REPUBLIC OF YEMEN
Tel.: 9671 419771
Fax: 9671419770 / 419778
E-mail: Allisain107@yahoo.com

Ms Sheikha Mowaza AL-MUALLA
PR of UAE with WMO
Ministry of Communication
P.O. Box. 900
Abu Dhabi
UNITED ARAB EMIRATES
Tel.: 9712 666 0 888
Fax: 9712 666 1575
E-mail: uaemet@uaemet.gov.ae

Mr Said Hamed ALSARMI
P.O. Box 1684, AC111
Muscat-Sultanate of Oman
OMAN
Tel.: 968 9 984 8081
Fax: 968 519363
E-mail: s.alsarmi@met.gov.om

Dr S.D. ATTRI
Director, EMU
India Meteorological Department
New Delhi-110003
INDIA
Tel.: 91 11 24620701
Fax: 91 11 24699216, 24623220
E-mail: sdattri@yahoo.com

Dr Shaukat Ali AWAN
Chief Meteorologist
Hydrological Advisor of Pakistan with WMO
Flood Forecasting Division
46-Jail Road
Lahore – 54000
PAKISTAN
Tel.: 92 42 9200208, 7531891
Fax: 92 42 9200209
E-mail: saliawan2002@yahoo.com

Mr P.M. Jayatilaka BANDA
Dept of Meteorology
Baudhaloka Mawatha
Colombo 7
SRI LANKA
Tel.: 94 11 2692756
Fax: 94 11 2698311
E-mail: jayatilakamet@hotmail.com

Mr A.K. BHATNAGAR
Executive Director (EMRC) & DDGM (T)
India Meteorological Department
New Delhi-110003
INDIA
Tel.: 91 11 24621472
Fax: 91 11 24699216, 24623220
E-mail: ashokbha@hotmail.com

Dr Qamar-uz-Zaman CHAUDHRY
Headquarters office
Pakistan Meteorological Department
Sector H-8/2, Islamabad
PAKISTAN
Tel.: 92 51 9257314
Fax: 92 51 4432588
E-mail: qamarc@hotmail.com

Mr Gaurav DAHAL
GPO 8832, Min. of Population and Environment
Singha Darbar, Kathmandu
NEPAL
Tel/Fax: 00977 1 4422212
E-mail: dahalgaurav@rediffmail.com

Mr Kumbu DUKPA
Natural Environment Commission
Thimpu
BHUTAN
Tel.: +975-2-323384
Fax: +975-2-323385
E-mail: kdukpa_nec@hotmail.com

Dr Akhilesh GUPTA
NCMRWF
A – 50, Instititional Area
Sector – 62, Phase 2
Noida
INDIA
E-mail: akgupta@ncmrwf.gov.in

Dr H.K. GUPTA
Secretary, Department of Ocean Development
Mahasagar Bhavan, Block No. 12
CGO Complex
New Delhi 110 003
INDIA
Tel.: +91 11 243 60874, 243 62548
Fax: + 91 11 243 62644
E-mail: dodsec@dod.delhi.nic.in

Dr Tahir Hassan HANTOSH
Iraqi Meteorological Organisation
Baghdad AL-Mansoor
P.O. Box 6078
IRAQ
Fax: 77 88 927
E-mail: imodania@yahoo.com

Prof. Syed Iqbal HASNAIN
Vice Chancellor
University of Calicut
Calicut University
Mallapuram – 673635
Kerala
INDIA
Tel.: +91 494 2400241/44 Ext. 102/150
Fax: +91 494 2400361
E-mail: iqbalhasnain@hotmail.com

Dr Debbie HEMMING
Hadley Centre Meteorological Office
FitzRoy Road, Exeter EX1 3PB
UNITED KINGDOM
Fax: 44 1392 88 5681

Mr A. Majeed H. ISA
Director of Meteorology
Ministry of Transportation
P.O. Box 586
BAHRAIN
Tel.: 97317 321177
Fax: 97317320 630
E-mail: amhisa@bahrain.gov.bn and
maj2299@hotmail.com

Prof. Philip JONES
Climate Research Unit
University of East Anglia
Norwich, NR4 7TJ
UNITED KINGDOM
Tel.: +44 1603 592090
Fax: +44 1603 507784
E-mail: p.jones@uea.ac.uk
or p.jones@vea.ac.uk

Dr P.C. JOSHI
Head, ASD/MOG/RESIPA
(Atmospheric Science Division/Meteorology and Oceanography Group/RESIPA)
Space Application Centre (SAC)
Jodhpur Tekra
Ahmedabad – 380015
INDIA
Tel.: 079 26916103 (Off), 079 26862437 (R)
Fax: 079 26916078
E-mail: pcjoshi35@hotmail.com

Dr Gholamali KAMALI
Islamic Republic of Iran Meteorological Organization
P.O. Box 13185-461, Tehran
ISLAMIC REPUBLIC OF IRAN
Tel.: +98 21602 5047
Fax: +98 21600 0417
E-Mail: Intl-Affairs@Irimet.Net

Dr Amin Daoud KARAIEN
Technical Adviser
Ministry of Communication
P.O. Box 900
Abudhabi
UNITED ARAB EMIRATES
Tel.: 97 12 666 2905
Fax: 9712 666 1575
E-mail: dramin@uaemet.gov.ae

Dr K. Rupa KUMAR
Deputy Director
Indian Institute of Tropical Meteorology
Homi Bhabha Road
Pune - 411008
Maharashtra
INDIA
Tel.: +91-20-2589-3600
Fax: +91-20-2589-3825
E-mail: kolli@tropmet.res.in

Mr Shravan KUMAR
IMD, Pune
Nominee of PR of India
Add. Director General of Meteorology (Research)
India Meteorological Department
Shivaji Nagar, PUNE-411005
INDIA

Prof. Paul MASON
Dept of Meteorology
University of Reading
Earley Gate, PO Box 243
Reading RG6 6BB
UNITED KINGDOM
Tel.: 44 118 378 8957
Fax: 44 118 378 8791
E-mail: p.j.mason@reading.ac.uk

Mr Amir Hussain MESHKATEE
41 Shahid Rabbani, St Shahid
St. Pasdarsn St.
Post Code 16649-65433
Tehran
ISLAMIC REPUBLIC OF IRAN
Tel.: 98 021 252 9768
Fax: 98 021 826 7994
E-mail: ameshkatee@yahoo.com

Mr B. MUKHOPADHYAY
Director, EMRC
India Meteorological Department
New Delhi-110003
INDIA
Tel.: 91-11-2461 1842 or 1710
Fax: 91-11-24699216, 24623220
E-mail: bmukho@yahoo.com

Mr Hussain NAEEM
Ministry of Environment and Construction
Huravee Building, Ameer Ahmed mage 20-05
Male
MALDIVES
Tel.: 960 32486
Fax: 960 322286
E-mail: env@environment.gov.nv

Dr Desmond O'NEILL
110 Johnson Crescent
Lower Sackville, NOVA SCOTIA B4C 3A5
CANADA
Tel.: 1 902 865 7208
Fax: 1 902 865 7208
E-mail: desoneill@eastlink.ca

Dr R.K. PACHAURI
Director-General
TERI
Darbari Seth Block, Habitat Place
Lodhi Road
New Delhi - 110 003
INDIA

Dr K. RADHAKRISHNAN
Director
Indian National Centre for Ocean Information Services (INCOIS)
Department of Ocean Development
Government of India
Plot No. 3
Nandagiri Hills, Jubilee Hills
Hyderabad – 500 033
INDIA
Tel.: 91 40 2389 5000
Fax: 91 40 2355 1096
E-mail: radhakr@incois.gov.in

Ms Usha RAO
Programme Analyst
Sustainable Environment and Energy Development
UNDP, New Delhi
INDIA
E-mail: usha.rao@undp.org

Mr R. K. SETHI
Director Climate Change
Ministry of Environment & Forest
Paryavaran Bhawan
CGO Complex
New Delhi – 3
INDIA
Tel.: 24362252
E-mail: sethi_rk@yahoo.com

Mr Muhammad Zahir SHAH
Ministry of Environment
CDA Block-4
Islamabad
PAKISTAN
Tel.: 9205871
Fax: 9205871 and 9202211
E-mail: zahirshahmohmand@hotmail.com

Dr Satish R. SHETYE
National Institute of Oceanography
Dona Paula
Goa - 403 004
INDIA
Tel.: 91 832 456700 Ext. 4310
Fax: 91 832 456702/456703
E-mail: shetye@csnio.ren.nic.in
shetye@darya.nio.org

Mr Kuniyuki SHIDA
RCD, World Meteorological Organization
7 *bis*, avenue de la Paix, P.O. Box No. 2300
CH–1211, Geneva 2
SWITZERLAND
Tel.: 41 22 730 83 18
Fax: 41 22 730 80 47
E-mail: kshida@wmo.int

Dr Madan lal SHRESTHA
Department of Hydrology and Meteorology
P.O.Box – 406, Babar Mahal
Kathmandu
NEPAL
Tel.: 977 1 4256193
Fax: 977 1 4262348

Mr Kingzang SONAM
Meteorology Section
Hydromet Service Division
Dept of Energy, Thimpu
BHUTAN
Tel.: 975 02 323703
Fax: 975 02 324999
E-mail: kinzang_sonam@hotmail.com

Dr G. SRINIVASAN
Director, EMRC
India Meteorological Department
New Delhi-110003
INDIA
Tel.: 91 11 24611842
Fax: 91 11 24699216, 24623220
E-mail: srini@imdmail.gov.in

Dr S.K. SRIVASTAV
Director General and PR of India with WMO
India Meteorological Department
New Delhi-110003
INDIA
Tel.: 91 11 24611842
Fax: 91 11 24699216, 24623220
E-mail: sks@imdmail.gov.in

Mr Richard K. THIGPEN
15205 Baughman Drive
Silver Spring
Maryland
USA
Tel.: 301 598 5683 or 301 452 7669
Fax: 301 598 5683
E-mail: thigpenr@erols.com and
Rthigpen@wmo.int

Dr Alan THOMAS
Director
Global Climate Observing System
c/o World Meteorological Organization
7 *bis*, Avenue de la Paix
P.O. Box 2300, CH–1211 Geneva
SWITZERLAND
Tel.: 41 22 730 8275
Fax: 41 22 730 8052
Athomas@wmo.int

Mr A.J. WAFIR
Department of Meteorology
Orchid Building, Orchis Marg
Male 20-05
MALDIVES
Tel.: 960 323302
Fax: 960 320021
E-mail: admin@meteorology.gov.mv

Dr William WESTERMEYER
Global Climate Observing System
c/o World Meteorological Organization
7 *bis*, Avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2
SWITZERLAND
Tel.: 41 22 730 8083
Fax: 41 22 730 8052
E-mail: WWestermeyer@wmo.int

Dr Alfred WIEDENSOHLER
Institute for Tropospheric Research
Permoserstr, 15, 04318 Leipzig
GERMANY
Tel.: 49 341 235 2467
Fax: 49 341 235 2361
E-mail: ali@tropos.de

Mr Jim WILLIAMS
Mount Ararat
Cave Hill
Maidstone, Kent ME15 6DX
UNITED KINGDOM
Tel.: 44 1622 755022
E-mail: mountararat@btinternet.com

Mr Arjan Omar ZAMREEQ
SAUDI ARABIA

(Intentioanlly blank)

Annex 3

THE GLOBAL CLIMATE OBSERVING SYSTEM AND THE GCOS REGIONAL WORKSHOP PROGRAMME

Alan Thomas
Director, GCOS

Mission of GCOS

The Global Climate Observing System (GCOS) was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU). GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. It addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes. Although GCOS does not make observations or generate data products itself, it does stimulate, encourage, coordinate and otherwise facilitate the taking of the needed observations by national and international organizations in support of both their own requirements and of common goals.

Purpose of the Workshop

The United Nations Framework Convention on Climate Change (UNFCCC) has recognized the importance of research and systematic observation. Further, its Conference of Parties (COP) has noted that high quality data for climate-related purposes is not available in many instances due to inadequate geographic coverage, quantity, and quality of the data produced by current global and regional observing systems. Most of the problems occur in developing countries, where lack of funds for modern equipment and infrastructure, inadequate training of staff, and the high costs of continuing operations are often the major constraints. Decision 5/CP.5 in 1999 invited the Secretariat of the Global Climate Observing System, in consultation with relevant regional and international bodies, to organize regional workshops to facilitate improvements in observing systems for climate. The central goals of the GCOS Regional Workshop programme are:

- To assess the contribution of the region to GCOS baseline networks;
- To help participants understand guidelines for reporting on observations to the UNFCCC;
- To identify national and regional needs and deficiencies for climate data (including needs for assessing climate impacts and conducting vulnerability and adaptation studies; and
- To initiate the development of Regional Action Plans for improving climate observations.

Expected Outcome

The GCOS Regional Workshop for South and Southwest Asia is designed to help participants identify deficiencies in climate observing systems and to focus their attention on developing a regional strategy to address priority needs for observing systems. Given the strong recognition by the UNFCCC Conference of the Parties (COP), a substantial opportunity now exists to obtain the support of the Parties to make much needed improvements in observing networks that will benefit not only the global concerns of COP but also national and regional purposes. GCOS would like to see participants develop a regional strategy—a Regional Action Plan—that identifies high priority observing system needs for the region and that can be used as the basis for seeking funding to address these needs. The first steps in developing such a plan can be taken at this workshop, and a draft version of the plan could be prepared and circulated for approval by perhaps March 2005. With resources limited both nationally and internationally, a regional plan for improving observing systems is practical, achievable, and fundable.

Annex 4

THE IMPLEMENTATION PLAN FOR THE GLOBAL OBSERVING SYSTEM FOR CLIMATE IN SUPPORT OF THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

EXECUTIVE SUMMARY

1. Introduction

The Global Climate Observing System (GCOS), in consultation with its partners, has prepared an implementation plan that addresses the requirements identified in the Second Report[2] on the Adequacy of Global Observing Systems for Climate in Support of the United Nations Framework Convention on Climate Change (UNFCCC) (hereafter called the 'Second Adequacy Report'). This plan specifically responds to the request of the Conference of the Parties (COP) to the UNFCCC in its decision 11/CP.9 to develop a 5- to 10-year implementation plan. As requested, the implementation plan (the Plan):

- Builds on the Second Adequacy Report and draws on the expressed views of Parties with respect to that report;
- Takes into consideration existing global, regional and national plans, programmes and initiatives, including those of the European Global Monitoring for Environment and Security programme and the Integrated Global Observing Strategy Partnership, as well as the plans of the Group on Earth Observations;
- Is based on extensive consultations with a broad and representative range of scientists and data users, including an open review of the Plan before its completion;
- Includes indicators for measuring its implementation;
- Identifies implementation priorities and resource requirements.

2. Meeting the Needs of the UNFCCC for Climate Information

This Plan, if fully implemented by the Parties both individually and collectively, will provide those global observations of the Essential Climate Variables and their associated products, to assist the Parties in meeting their responsibilities under Articles 4 and 5 of the UNFCCC. In addition, it will provide many of the essential observations required by the World Climate Research Programme and Intergovernmental Panel on Climate Change. Specifically the proposed system would provide information to:

a. Characterize the state of the global climate system and its variability;
b. Monitor the forcing of the climate system, including both natural and anthropogenic contributions;
c. Support the attribution of the causes of climate change;
d. Support the prediction of global climate change;
e. Enable projection of global climate change information down to regional and local scales;
f. Enable characterization of extreme events important in impact assessment and adaptation, and to the assessment of risk and vulnerability.

[2] The Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC, GCOS-82, April 2003 (WMO/TD No. 1143).

As noted in the Second Adequacy Report, “Without urgent action and clear commitment of additional resources by the Parties, the UNFCCC and intergovernmental and international agencies, the Parties will lack the information necessary to effectively plan for and manage their response to climate change”.

2.1 Essential Climate Variables

The Second Adequacy Report established a list of the Essential Climate Variables (ECVs) (see Table 1) that are both currently feasible for global implementation and have a high impact on the requirements of the UNFCCC. Clearly, there are additional climate variables that are important to a full understanding of the climate system. Many of these are the subjects of current on-going research, but are not currently ready for global implementation on a systematic basis. As our knowledge and capabilities develop, it is expected that some of these variables will be added to the list of ECVs.

Table 1. Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements

Domain	Essential Climate Variables
Atmospheric (over land, sea and ice)	**Surface:** Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour. **Upper-air:** Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties. **Composition:** Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases[3], Aerosol properties.
Oceanic	**Surface:** Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure. **Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.

[3] Including nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs).

Terrestrial[4]	River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance.

2.2 Implementation Actions and Associated Cost Implications

The Plan includes over a hundred specific actions to be undertaken over the next 10 years, across the three domains. Many of the proposed actions are already underway, at the least as part of research activities, and most of the required coordination mechanisms have been identified. The costs of undertaking these actions are summarized in Table 2 by cost and type of action. Priority should be given over the first 5 years to those actions that will address the critical issues identified within the Second Adequacy Report, specifically improving access to high-quality global climate data; generating integrated global analysis products; improving key satellite and *in situ* networks; and strengthening national and international infrastructure, including the enhancing of the full participation of least-developed countries and small island developing states.

The Plan is both technically feasible and cost-effective in light of the societal and economic importance of climate observations to the considerations of the UNFCCC. It involves global extension and improved operating practices for observing systems that are currently supported and functioning for other purposes. While its implementation is dependent on national efforts, success will be achieved only with international cooperation, coordination and in some cases, sustained technical and financial support for the key global reference observation sites in least-developed countries. While the Plan focuses on meeting global requirements, such global data and products are also relevant to regional and local needs. In the case of extreme events, which are usually of a small scale and/or short-lived, the Plan provides for global estimates of many such phenomena. Finally, the Plan will be updated over time as networks and systems become operational and as new knowledge and techniques become available.

[4] Includes runoff ($m^3 s^{-1}$), ground water extraction rates ($m^3 yr^{-1}$) and location, snow cover extent (km^2) and duration, snow depth (cm), glacier/ice cap inventory and mass balance ($kg\ m^{-2} yr^{-1}$), glacier length (m), ice sheet mass balance ($kg\ m^{-2} yr^{-1}$) and extent (km^2), permafrost extent (km^2), temperature profiles and active layer thickness, above ground biomass (t/ha), burnt area (ha), date and location of active fire, burn efficiency (%vegetation burned/unit area).

Table 2. Summary of incremental annually recurring costs (in US-$)

Cost Category*	Number of Common Actions	Number of Atmospheric Actions	Number of Oceanic Actions	Number of Terrestrial Actions	Total
I – <100K	4	8	7	11	30
II – 100K-1M	8	4	11	13	34
III – 1M-10M	2	11	17	11	42
IV – 10M-30M	1	8	6	2	17
V – 30M-100M	0	1	0	0	1
Uncosted Actions[5]	6	-	-	-	6
Total Number	21	32	41	37	131
Estimated total cost profile[6]	**34.4M**	**282.8M**	**211.2M**	**102.6M**	**631.0 M**

*K: 1000s of US-$, while M: 1 000 000s of US-$.

The estimated costs are incremental to the expected future support of the current observing systems and associated infrastructure. The cost estimates include both the costs of transition of current systems from research to operations as well as those wholly associated with new systems. The new observations and infrastructure for climate will serve many applications other than just the climate needs of the Parties. For example, as the climate component of the proposed Global Earth Observation System of Systems (GEOSS), they would meet the needs of many other GEOSS applications. Satellites, though a major cost item accounting for some 40% of the total cost profile, provide unique global coverage. In all cases the costs noted are simply indicative and would need to be refined by those charged with executing the actions.

Key Action 1: Parties need, both individually and collectively, to commit to the full implementation of the global observing system for climate, sustained on the basis of a mix of high-quality satellite measurements, ground-based and airborne *in situ* and remote-sensing measurements, dedicated analysis infrastructure, and targeted capacity-building.

3. Agents for Implementation

The global observing system for climate requires observations from all domains – terrestrial, oceanic, and atmospheric – which are then transformed into products and information through analysis and integration in both time and space. Since no single technology or source can provide all the needed observations, the ECVs will be provided by a composite system of *in situ* instruments on the ground, on ships, buoys, floats, ocean profilers, balloons, samplers, and

[5] Costs covered in domain actions.
[6] Estimated total cost profile assumes average costs (in US-$) of 0.1M for Category I actions, 0.5M for Category II, 5.0M for Category III, 20.0M for Category IV, and 65.0M for Category V.

aircraft, as well as from all forms of remote sensing including satellites. Meta-data (i.e., information on where and how the observations are taken) are absolutely essential, as are historical and palaeo-climatic records that set the context for the interpretation of current trends and variability. Although these individual activities are to be coordinated internationally through a variety of programmes, organizations and agencies, success will depend mainly on national and regional entities that will translate the Plan into reality. Collectively, all of these entities are referred to in the Plan as the 'Agents for Implementation'.

The Plan outlines a comprehensive programme that marshals contributions from virtually all countries and organizations dealing with Earth observations and requires continuing and strengthened coordination and performance monitoring. An International Project Office is needed to help coordinate the activities of the component elements of the system, to interact with regional bodies addressing aspects of the Plan, to monitor the performance of the system, to identify deficiencies in the system, and to coordinate measures to correct such deficiencies. It could also oversee the implementation of the GCOS Cooperation Mechanism (see Section 3.4 in the Executive Summary).

Key Action 2: Parties need to provide support for an International Project Office to provide overall coordination, to monitor performance, to report regularly on implementation, to initiate corrective actions, and to oversee the GCOS Cooperation Mechanism.

3.1 International Agents

The networks, systems, data centres and analysis centres identified within this Plan are almost all funded, managed and operated by national entities within their own requirements, plans, procedures, standards and regulations. This Plan calls on all contributing networks and systems to respond to the actions contained in it and, where appropriate, to adjust their plans, procedures and operations to address the specified climate observing requirements. GCOS will continue to emphasize with all relevant international and intergovernmental organizations the need for their Members to: (a) undertake coordination and planning for systematic climate observations where this is not currently being undertaken; and (b) produce and update on a regular basis plans for their contributions to the global observing system for climate, taking into account the actions included in this Plan. For this to be effective, it will also be essential for the Parties to ensure that their requirements for climate observations are communicated to these international and intergovernmental organizations.

Key Action 3: The international and intergovernmental organizations need to incorporate the relevant actions in this Plan within their own plans and actions.

3.2 Regional Agents

For some observations, regional planning and implementation of climate observing system components is particularly effective as a means of sharing workloads and addressing common issues. The GCOS Regional Workshop Programme has established a framework for interested nations to work together to optimize their networks and to identify both national and GCOS network needs in each region. Regional Action Plans, one of the outputs of these workshops, are being developed and some elements of them are finding support from member nations and/or donors for implementation.

Key Action 4: Parties need to complete development and alignment of Regional Action Plans for observations in the context of this Plan.

3.3 National Agents

The needs of the UNFCCC and other users for global climate observations and products can be addressed only if plans are developed and implemented in a coordinated manner by national organizations. As noted in the Second Adequacy Report, with the exception of the main meteorological networks and the planning for individual activities, most climate-observing system activities are poorly coordinated, planned and integrated at the national level. All Parties need national coordination mechanisms and national plans for the provision of systematic observation of the climate system. Such mechanisms are usually best sustained when national coordinators or focal points[7] are designated and assigned responsibility to coordinate planning and implementation of systematic climate observing systems across the many departments and agencies involved with their provision.

Key Action 5: Parties are requested to undertake national coordination and planning and produce national plans on their climate observing, archiving and analysis activities that address this Plan.

Reporting by the Parties[8] on systematic climate observation activities as part of their National Communications under the UNFCCC is essential for planning and monitoring the implementation of the global observing system for climate. The response by Parties to the Second Adequacy Report emphasized that accurate and credible information relative to all aspects of climate observations must be exchanged, according to the relevant guidelines (decisions 4/CP.5 and 11/CP.9).

Key Action 6: Parties are requested to submit information on their activities with respect to systematic observation of all ECVs as part of their national communications to the UNFCCC utilizing an updated Supplementary Reporting Format.

3.4 Participation by all Parties

Recognizing the common requirement for information on climate variability and change, the need for all Parties to improve global observing systems for climate in developing countries has been a consistent theme in the considerations by COP on systematic observation. There are many ways that systems can be improved, including for example through developed-country agencies working with organizations and personnel from developing countries, and the donation of equipment and the training of personnel. The GCOS Cooperation Mechanism has been established by a core set of countries to provide a coordinated, multigovernmental approach to address the high-priority needs for stable long-term funding for key elements of the global observing system for climate, especially in least-developed countries, small island developing states and some countries with economies in transition. It will complement and work in cooperation with existing funding and implementation mechanisms (e.g., the World Meteorological Organization (WMO) Voluntary Cooperation Programme, the United Nations Development Programme, and the many national aid agencies), many of which deal with climate-related activities and support capacity-building in particular.

---

[7] The GCOS Steering Committee has developed guidelines for such functions.
[8] Reports are available through the UNFCCC Secretariat.

Key Action 7: Parties are requested to address the needs of least-developed countries, small island developing states and some countries with economies in transition for taking systematic climate observations by encouraging multilateral and bilateral technical cooperation programmes to support global observing systems for climate and by participating in the GCOS Cooperation Mechanism.

4. Access to Climate Data

4.1 High-Quality Climate Data

Ensuring that high-quality climate data records are collected, retained and made accessible for use by current and future generations of scientists and decision-makers is a key objective of this Plan. As a result, investment in the data management and analysis components of the system is as important as the acquisition of the data. The Plan calls for strengthening the current International Data Centres[9] and seeking commitments for new Centres so that all ECVs have an appropriate infrastructure.

Key Action 8: Parties need to ensure that International Data Centres are established and/or strengthened for all ECVs.

The flow of data to the user community and to the International Data Centres is not adequate for many ECVs, especially for those of the terrestrial observing networks. Lack of national engagement and/or resources, restrictive data policies, and inadequate national and international data-system infrastructure are the main causes of the inadequacy.

In decision 14/CP.4, the COP urged Parties to undertake free and unrestricted exchange of data to meet the needs of the Convention, recognizing the various policies on data exchange of relevant intergovernmental and international organizations. Yet, as the Second Adequacy Report points out repeatedly with respect to almost all of the variables, the record of many Parties in providing full access to their data is poor. This Plan is based on the free and unrestricted exchange of all data and products and incorporates actions to: develop standards and procedures for meta-data and its storage and exchange; to ensure timely, efficient and quality-controlled flow of all ECV data to climate monitoring and analysis centres and international archives, and to ensure that data policies facilitate the exchange and archiving of all ECV data and associated meta-data.

4.1.1. International Standards and Guidance

The international programmes and Technical Commissions of WMO and the Intergovernmental Oceanographic Commission (IOC) exist to provide the standards, regulatory material and guidelines for the collection of climate data in the Atmospheric and Oceanic Domains. There is at present no equivalent international body or technical commission for climate observations for the Terrestrial Domain. A key requirement for successful implementation of this Plan is the urgent establishment of such an international body by the relevant international organizations, including WMO, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), and the International Council for Science (ICSU).

[9] International Data Centres are responsible for monitoring, product preparation and dissemination as well as archiving.

Key Action 9: The relevant intergovernmental organizations including WMO, FAO, UNEP, and ICSU need to create a mechanism for establishing standards, regulatory material and guidelines for terrestrial observing systems.

4.1.2. GCOS Climate Monitoring Principles

The GCOS Climate Monitoring Principles (GCMPs) provide basic guidance regarding the planning, operation and management of observing networks and systems, including satellites, to ensure that high-quality climate data are available and contribute to effective climate information. The GCMPs address issues such as the effective incorporation of new systems and networks; the importance of calibration, validation and data homogeneity; the uninterrupted operation of individual stations and systems; the importance of additional observations in data-poor regions and regions sensitive to change; and the crucial importance of data management systems that facilitate access, use and interpretation of the data. These principles have been adopted or agreed by the UNFCCC, WMO, Committee on Earth Observation Satellites (CEOS) and other bodies. The implementation actions now call on all data providers to adhere to the GCMPs and to initiate effective programmes of data quality control.

Key Action 10: Parties need to ensure that their climate-observing activities which contribute to GCOS adhere to the GCMPs.

4.1.3. Data Stewardship and Management

Climate observations that are well documented, and have good meta-data about the systems and networks used to make them, become more valuable with time. The creation of climate-quality data records is a fundamental objective of the global observing system for climate. International standards and procedures for the storage and exchange of meta-data need to be developed and implemented for many climate observing system components, including those of the operational satellite community. It is essential that all such data be properly archived and managed with the full expectation that they will be reused many times over in the future, often as a part of reprocessing or reanalysis activities. Good stewardship of the data also requires that data be migrated to new media as technology changes, be accessible to users, and be made available with minimal incremental costs.

Key Action 11: International standards for meta-data for all ECVs need to be established and adopted by the Parties in creation and archiving of climate data records.

4.2 Domain-Specific Observing Networks and Systems

The global observing system for climate is an integrated system comprised of complementary satellite and *in situ* components. With greater attention to climate monitoring issues, satellites are expected to become an increasingly more important means of obtaining observations globally for comparing climate variability and change over different parts of the Earth. Therefore, a system of satellites and satellite sensors implemented and operated in a manner that ensures the long-term accuracy and homogeneity of the data through the adoption of the GCMPs, is a high priority within the Plan. At the same time, some ECVs will remain dependent on *in situ* observations for long-term trend information, for calibration and validation of satellite records, and for measuring variables not amenable to direct satellite measurement (e.g., sub-surface oceanic ECVs). Consistent with the role of satellites, the Plan details the substantial effort required to ensure the operation and refinement of *in situ* networks.

Some of the key domain-specific components merit highlighting.

4.2.1 Atmospheric Domain

Many atmospheric networks and systems, including some satellite components, are relatively mature, having been in existence for several decades, albeit generally for non-climate purposes. As a result, a key action for this domain is to ensure the full global implementation of these networks and systems for climate purposes. Other key actions respond to the need for additional baseline observations to enable full use of existing measurements, improvements relating to a few important but poorly- observed variables, and the use of reanalysis techniques to generate needed climate information products.

The GCOS Surface Network (GSN), together with the other surface atmospheric networks, provides the basic observations of the surface climate in which we live. The GCOS Upper-Air Network (GUAN), together with related satellite observations, provides a baseline for the upper atmosphere. Network and system improvements are proposed in many areas, including the extension of the GSN to include all relevant surface ECVs. Indeed, the advantages of collocated measurements imply that greater efforts should be made to establish sites where many of the ECVs for both the Atmospheric and Terrestrial Domains are observed. In the upper atmosphere, water vapour plays a critical role in climate feedback, and supplements to the current baseline observations are needed from reference networks and GPS-based techniques.

Key Action 12: Parties need to: (a) ensure the implementation and full operation of the baseline networks and systems contained in Table 3 in accordance with the GCMPs, in order to specifically resolve reported problems, to ensure the exchange of these data with the international community, and to recover and exchange historical records; (b) establish a high-quality reference network of about 30 precision radiosonde stations and other collocated observations; and (c) exploit emerging new technology including the use of radio-occultation techniques and ground-based Global Positioning System (GPS) sensing of the total water column.

Table 3. Existing atmospheric baseline networks and systems

- GCOS Surface Network (GSN).
- The atmospheric component of the composite surface ocean observation system including sea-level pressure (see Key Actions 17 and 18).
- GCOS Upper-Air Network (GUAN).
- Global Atmosphere Watch (GAW) global CO_2 network.
- MSU-like radiance satellite observations.
- Total solar irradiance and Earth radiation budget satellite observations.

With the societal importance of precipitation, there is further urgent need for improved global analyses including unbiased estimation of precipitation over the oceans and at high latitudes and further development and understanding of the implications of automation on precipitation measurements.

Key Action 13: Parties are urged to: (a) establish a reference network of precipitation stations on key islands and moored buoys around the globe and at high latitudes; (b) submit national precipitation data (preferably hourly data) to the International Data Centres; and (c) support the further refinement of satellite precipitation measurement techniques.

The total solar irradiance and Earth radiation budget measurements provide overall monitoring of the solar radiation and the net greenhouse effect within the atmosphere. Clouds, as well as water vapour, strongly affect this Earth radiation budget and provide the most uncertain feedbacks in the climate system. It is vital to maintain long-term records concerning the overall radiation of the Earth. Cloud properties are of particular importance and research, some of which is in progress, is needed to improve the monitoring of clouds. Surface radiation measurements over land are an important complementary observation and the baseline surface radiation network needs to be extended to achieve global coverage.

Key Action 14: Parties need to: (a) ensure the continued operation of satellite measurements of the Earth radiation budget and solar irradiance (e.g., the NASA Earth Radiation Budget Experiment); and (b) support research to extend and improve current capabilities for monitoring clouds as a high priority.

Greenhouse gases and aerosols are the primary agents in forcing climate change; continuous observations that are spatially and temporally homogeneous are therefore required. For the greenhouse gases, elements of the needed networks are in place but extension and improved attention to calibration are needed. Aerosols are a complex variable and the Plan proposes a key action in the establishment of an improved reference network and a global network for the aerosol-related optical depth variable.

Key Action 15: Parties need to: (a) fully establish a baseline network for key greenhouse gases; (b) improve selected satellite observations of atmospheric constituents; and (c) extend existing networks to establish a global baseline network for atmospheric optical depth.

4.2.2 Oceanic Domain

New technology, developed and proven by the oceanic climate research programmes of the 1990's, has allowed the ocean community to design, and commence implementation of, an initial oceanic climate observing system. The first action of the initial system is the global implementation of the surface and sub-surface networks, including the establishment of data analysis systems. This will allow for a composite system of satellite and *in situ* observations collected by operational and research groups to be synthesized into information products. Sustaining this system will require national designation of and support for Agents for Implementation, and the establishment of effective collaboration between research and operational groups. This will also require the continuity of existing and predominantly research-based *in situ* and satellite activities.

Key Action 16: Parties need to: (a) complete and sustain the initial oceanic observing system for climate; (b) designate and support national Agents for Implementation for implementing this system; (c) establish effective partnerships between their ocean

research and operational communities towards implementation; and (d) engage in timely, free and unrestricted data exchange.

The surface ocean network will provide information about the patterns of ocean surface temperature, pressure, winds, salinity, sea level, waves and sea ice that are important both to the global climate and its regional distribution and to marine resources and coastal societies. In particular, sea ice, which plays a key and complex role in climate feedback, requires continued research into improved *in situ* and satellite measurements.

The surface observing network depends critically on the continuity of satellite observations, most of which are in research rather than operational status (Table 4), and on the full implementation of the *in situ* activities identified in this Plan.

Key Action 17: Parties need to ensure climate quality and continuity for essential ocean satellite observations (see Table 4).

Table 4. Essential ocean satellite systems

• Sustained support for vector-wind (scatterometer), sea-ice, sea-surface temperature (microwave and infra-red) and ocean-colour measurements. • Continuous coverage from altimeters to provide high-precision and high-resolution sea-level measurements (1 high-precision and 2 lower-precision altimeters).

Key Action 18: Parties need to provide global coverage of the surface network by implementing and sustaining: (a) the GCOS baseline network of tide gauges; (b) an enhanced drifting buoy array; (c) an enhanced Tropical Moored Buoy network; (d) an enhanced Voluntary Observing Ships Climatology (VOSClim) network; and (e) a globally-distributed reference mooring network.

The sub-surface ocean network will provide critical information on ocean climate variability and change. The network will provide a capacity for monitoring the regional oceanic uptake of heat, freshwater and carbon, and identification of abrupt climate change arising from changes in the planetary hydrological cycle processes. In association with the surface observations, they also provide the basis for seasonal-to-interannual predictions that can be critical in giving forecasts of the likelihood of extreme climatic events.

Key Action 19: Parties need to provide global coverage of the sub-surface network by implementing and sustaining: (a) the Argo profiling float array; (b) the systematic sampling of the global ocean full-depth water column; (c) the Ship-of-Opportunity Expendable Bathythermograph (XBT) trans-oceanic sections; and (d) the Tropical Moored Buoy and reference mooring networks referred to in Key Action 18 above, as well as the satellite altimetry system described in Table 4.

In recognition of the importance of potential changes to the ocean carbon cycle and marine ecosystems, the Plan contains a number of important research and implementation actions dealing with the establishment of an observing network for the partial pressure of carbon dioxide

(pCO_2) and the measurement of the state and change of carbon sources and sinks in the oceans.

Finally, continuing climate research and technology programmes for the oceans are needed to enhance the efficiency and effectiveness of observing efforts, and to develop capabilities for important climate variables that cannot currently be observed globally. This need for enhanced capability is particularly acute for remote locations, for improved understanding of the ocean ecosystems, for improving the estimates of uncertainty, and for understanding the mechanisms of climate change.

4.2.3 Terrestrial Domain

The climate observing system in the Terrestrial Domain remains the least well-developed component of the global system, whilst at the same time there is increasing significance being placed on terrestrial data for climate forcing and understanding, as well as for impact and mitigation assessment.

The Plan proposes actions designed to achieve an initial coordinated and comprehensive observational programme for all terrestrial ECVs. The nature of the Terrestrial Domain is such that priority is being placed on obtaining global products for all ECVs from a range of research-level satellite sensors supported by an increasing number of reference and baseline *in situ* networks.

Key Action 20: Parties are urged to support the operational continuation of the satellite-based products given in Table 5.

Table 5. Priority terrestrial satellite products

- Daily global albedo from geostationary and polar orbiting satellites.
- LAI and fAPAR products to be made available as gridded products.
- Gridded fire and burnt area products through a single International Data Centre.
- Snow cover of both hemispheres.
- Digital elevation maps of the ice sheet surfaces and full glacier inventory from current spaceborne cryosphere missions.
- Specification and production of land-cover characterization data sets.

A coordinated reference network is needed for: *in situ* observations of the fullest possible range of terrestrial ECVs and associated details relevant to their application in model validation; process studies; validation of observations derived from Earth observation satellites; and to address intrinsic limitations in some of these, such as the saturation of LAI measurements. Opportunities for collocation of Atmospheric and Terrestrial Domain reference network sites should be sought whenever possible.

Key Action 21: Parties are urged to develop a global network of at least 30 reference sites (collocated with atmospheric sites if possible) to monitor key biomes and to provide the observations required in the calibration and validation of satellite data.

The hydrological variables are of critical societal importance. Many are observed but not well exchanged for the purposes of assessing global climate change. The proposed international body (Key Action 9 above) is intended to establish standards for, and to facilitate the exchange of, terrestrial data for climate and other purposes. The Plan proposes specific actions to continue with the implementation of the Global Terrestrial Networks (GTNs) for hydrology (including specific lakes and rivers components), for glaciers and for permafrost.

Key Action 22: Parties are urged to: (a) fill the identified gaps in the global networks for permafrost, glaciers, rivers and lakes; (b) provide support for the designated International Data Centres; and (c) submit current and historical data to the International Data Centres.

5. Availability of Climate Products

Use of observations for policy and planning purposes depends on access to information beyond the basic observations. To meet the needs of all nations for climate information, the global observing system for climate must generate useful climate products. The preparation of climate products almost invariably involves the integration of data in time and space, as well as the blending of data from different sources. Some products, such as reanalysis to climate standards, involve extensive data set preparation and significant computing and data management resources, and implicitly require estimation of uncertainties. Providing access to climate information for all Parties will involve significant information technology infrastructure. The best use of available resources will come via international coordination of these activities. Therefore, a sustained and coordinated application of reanalysis is one of the key actions of this Plan for all domains.

Key Action 23: Parties are urged to adopt an internationally-coordinated approach to the development of integrated global climate products and to make them accessible to all Parties. As far as possible, these products should incorporate past data covering at least the last 30 years in order to serve as a reference for climate variability and change studies.

Key Action 24: Parties are urged to give high priority to establishing a sustained capacity for global climate reanalysis, to develop improved methods for such reanalysis, and to ensure coordination and collaboration among centres conducting reanalyses.

6. Improving the System

Our ability to measure some key and emerging ECVs from *in situ* and remote sensing systems (both surface- and satellite-based) is limited by the lack of suitable instruments and techniques. The limitation can vary all the way from difficulties with the fundamental observing technique to those associated with instrumentation, algorithms, suitable calibration/validation techniques, spatial and/or temporal resolution, ease of operation, and cost.

The development, demonstration, and validation of existing and new techniques are vital to the future success of the global observing system for climate. It is critically important that as new global satellite-based observations of environmental variables are made, the validation of both the measurements themselves (e.g., radiances) and the retrieval algorithms be carried out under a sufficiently broad range of conditions that they can be confidently applied in the creation of a global data sets.

Research is needed to improve the ability to blend different data sets and/or data sources into integrated products. As new types of data are assimilated into models, it will also be important to understand the error characteristics of the new data and the models used. Data assimilation for climate purposes is still in an early stage of development and requires continued research support. As these developments occur, reprocessing of data to take advantage of the new knowledge will be vital to sustained long-term records.

Agents for Implementation

Intergovernmental organizations sponsoring component observing systems or activities:

- UNESCO and IOC – geology, Earth surface and ocean observing systems.
- WMO – meteorological, hydrological and atmospheric constituent observing systems.
- UNEP – environmental observations.
- FAO – land-surface, land-cover, water-use observations.
- ICSU – research into most observing systems.

Regional and specialized intergovernmental organizations sponsoring and/or operating component observing or analysis systems:

- EUMETSAT – Operational meteorological geostationary satellite systems and (soon) polar orbiting systems.
- ESA – Research and development environmental satellite systems.
- ECMWF – Integrated global analysis systems.

National agencies sponsoring and operating global satellite observing systems:

- USA, NOAA/NESDIS – Operational meteorological polar orbiting and geostationary satellite systems.
- USA, NASA – Research and development environmental satellite systems.
- Japan, JMA – Operational meteorological geostationary satellite systems.
- Japan, JAXA – Research and development environmental satellite systems.
- Russian Federation, ROSHYDROMET – Operational meteorological polar orbiting and geostationary satellite systems.
- Russian Federation, FSA – Research and development environmental satellite systems.
- China – Operational meteorological polar orbiting and geostationary satellite systems.
- India, ISRO – Research and development environmental satellite systems.
- India, IMD – Operational meteorological geostationary satellite systems.
- France, CNES – Operational polar orbiting satellite systems.

Intergovernmental Technical Commissions dealing with climate observations:

- WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) – Comprehensive Global Ocean Observing System.

- WMO Commission for Basic Systems (WMO CBS) – Responsible for the World Weather Watch (WWW) and its components: the Global Observing System (GOS), Global Telecommunication System (GTS), Global Data Processing System (GDPS) as well as WMO Space Programme.
- WMO Commission for Atmospheric Science (WMO CAS) – Atmospheric chemistry. Lead Commission for the Global Atmosphere Watch (GAW).
- WMO Commission for Instruments and Methods of Observation (WMO CIMO) – Standardization and compatibility of instrumentation. Instrumentation inter-comparisons.
- WMO Commission for Hydrology (WMO CHy) – Operational hydrology including observing networks, collection, processing, archiving and retrieval of hydrological data. Standardization of methods, procedures and techniques.
- WMO Commission for Climatology (WMO CCI) – Lead Commission for the World Climate Data and Monitoring Programme. Data archaeology.

Scientific Programmes and Advisory/Steering committees to the intergovernmental bodies:

- World Climate Research Programme (WCRP) – sponsored by ICSU, WMO and IOC of UNESCO – comprehensive climate research programme.
- International Geosphere Biosphere Programme (IGBP) – sponsored by ICSU – programme to understand the interactive physical, chemical and biological processes regulating the total Earth system, the changes in this system, and influences from human actions.
- Intergovernmental Panel on Climate Change (IPCC) – sponsored by UNEP and WMO –- assesses scientific, technical and socio-economic information for understanding climate change and its potential impacts.
- GCOS Steering Committee – sponsored by WMO, UNEP, UNESCO, and ICSU – provides scientific, technical and implementation guidance to the GCOS Sponsors and has established 3 domain-based scientific Panels:
  - Atmospheric Observation Panel for Climate (AOPC).
  - Ocean Observation Panel for Climate (OOPC).
  - Terrestrial Observation Panel for Climate (TOPC).

Climate observation systems; GCOS made up of contributions from:

- WMO World Weather Watch (WWW) Global Observing System (GOS) – comprehensive system for observing meteorological variable used in weather forecasting and other related applications.
- WMO Global Atmosphere Watch (GAW) – comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere on global and regional scales.
- Global Ocean Observing System (GOOS) – permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide.
- Global Terrestrial Observing System (GTOS) – programme for observations, modelling, and analysis of terrestrial ecosystems, for facilitated access to terrestrial ecosystem information, and to support sustainable development.

Coordination mechanisms and partnerships supporting observational objectives:

- Coordination Group for Meteorological Satellites (CGMS) – provides a forum in which the Space Agencies have studied jointly with the WMO technical operational aspects of the global network, so as to ensure maximum efficiency and usefulness through proper coordination in the design of the satellites and in the procedures for data acquisition and dissemination.

- Committee for Earth Observation Satellites (CEOS) – international coordinating mechanism charged with coordinating international civil spaceborne missions designed to observe and study planet Earth.
- Integrated Global Observing System-Partnership (IGOS-P) – provides a comprehensive framework to coordinate the common interests of the major space-based and *in situ* systems for global observation of the Earth into integrated observing strategies for a range of "themes" including: oceans, carbon cycle, water cycle, geohazards, coastal observations including coral reefs, atmospheric chemistry, land cover and cryosphere.

GCOS Climate Monitoring Principles

Effective monitoring systems for climate should adhere to the following principles[10]:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.

2. A suitable period of overlap for new and old observing systems should be required.

3. The results of calibration, validation and data homogeneity assessments, and assessments of algorithm changes, should be treated with the same care as data.

4. A capacity to routinely assess the quality and homogeneity of data on extreme events, including high-resolution data and related descriptive information, should be ensured.

5. Consideration of environmental climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.

6. Uninterrupted station operations and observing systems should be maintained.

7. A high priority should be given to additional observations in data-poor regions and regions sensitive to change.

8. Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of new system design and implementation.

9. The carefully-planned conversion of research observing systems to long-term operations should be promoted.

[10] The ten basic principles were adopted by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) through decision 5/CP.5 at COP-5 in November 1999. The complete set of principles was adopted by the Congress of the World Meteorological Organization (WMO) through Resolution 9 (Cg-XIV) in May 2003; agreed by the Committee on Earth Observation Satellites (CEOS) at its 17th Plenary in November 2003; and adopted by COP through decision 11/CP.9 at COP-9 in December 2003.

10. Data management systems that facilitate access, use and interpretation should be included as essential elements of climate monitoring systems.

Furthermore, satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and
(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be resolved.

Thus satellite systems for climate monitoring should adhere to the following specific principles:

11. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.

12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.

13. Continuity of satellite measurements (i.e., elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.

14. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.

15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.

16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.

17. Data systems needed to facilitate user access to climate products, meta-data and raw data, including key data for delayed-mode analysis, should be established and maintained.

18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on de-commissioned satellites.

19. Complementary *in situ* baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.

20. Random errors and time-dependent biases in satellite observations and derived products should be identified.

(Intentionally blank)

Annex 5

USER NEEDS FOR CLIMATE OBSERVATIONS: EXTREME WEATHER EVENTS

Dr Qarmar-uz-Zaman Chaudhry
Director General
Pakistan Meteorological Department

Introduction

Extreme weather, in the most obvious sense, is weather that lies outside a locale's normal range of weather intensity. It is therefore, by definition, infrequent or rare. Extreme weather is also potentially destructive, although not all extreme weather events end in disasters. For some weather events, the idea of what constitutes an extreme can vary from place to place. It often depends on what a region is used to experiencing and what it is prepared for. A 200mm rainfall would be an extreme event for Karachi, for example, but not for Dhaka. In Karachi such an event would come close to an emergency. In Dhaka it would be merely an inconvenience. Extreme events such as tropical storms, typhoons, and ice storms often require the presence of a number of special circumstances before they can take place. Many extreme events also come about as a result of a combination of factors, such as the merging of two weather systems or the occurrence of a severe weather event in tandem with some other factor that intensifies its impact.

Greenhouse Warming and Weather Extremes

Why would greenhouse warming cause an increase in weather extremes? One reason is that the additional warming will change the distribution of heat and thus the flow of energy through the climate system. This will in turn alter the circulation patterns of the atmosphere and the oceans, and it will also modify the hydrological cycle by which water is circulated between the earth's surface and the air. As a result, the position of many of the world's major storm tracks could shift significantly. To see what the effects of such a shift might be, one has only to look at what happens when circulation patterns are changed by an El Niño. Some areas would be exposed to more storms and heavier rainfalls, while others might see formerly reliable rainfalls give way to prolonged dry spells. Other areas might actually see improvements in their climates, but if the experience of recent El Niños is a guide, most localities would encounter at least some weather difficulties that they were poorly prepared to deal with. Over time, communities could adapt to these new conditions, but the costs could be substantial.

A second and more compelling reason for suspecting a link between greenhouse warming and weather extremes is related to the potential effects of a warmer climate on the physical processes that generate different types of weather events. Consider the example of rainfall. Precipitation is one half of the hydrological (or water) cycle. Evaporation (and transpiration from plants) is the other. A virtually certain outcome of a rise in global temperatures is a widespread increase in the amount of water that is moved through the cycle. That is because higher temperatures not only increase evaporation and transpiration but also raise the air's capacity to hold moisture. Consequently, more moisture will be available in the atmosphere to fall as rain and snow. Add to this a more unstable atmosphere due to increased convection over warmer land and sea surfaces, and the result is an increased potential for major precipitation events in many parts of the world. Because of changes in large-scale circulation patterns as well as regional differences in hydrological processes, the resulting increase in precipitation will not be spread uniformly around the world. In fact, some areas may receive less precipitation. However, climate models indicate that a warmer study, record sea-surface temperatures in 1995 accounted for 61% of the very large number of hurricanes that occurred that year. However, nearly half a dozen other conditions have to be met before a hurricane can develop, and it is not known whether these would become more or less common in a warmer climate. Projections from model studies of tropical storm behaviour carried out at the Max Planck Institute in Germany, though, show a significant reduction in hurricane activity, especially in the Southern Hemisphere, as a result of a warmer climate.

Tropical cyclone intensity could also be affected by a warmer climate. That is because the theoretical limit for hurricane strength depends upon the extent of the local energy imbalance between the atmosphere and the ocean. Experiments with climate models suggest that this imbalance will increase in a warmer world, thus significantly increasing the potential intensity of Tropical cyclone. The model showed a 5–10% increase in cyclone wind speeds as a result of a 2.2°C warming of the sea surface.

Is Extreme Weather Becoming More Common?

Is the world's weather becoming more extreme? So far, during the last 15-20 years alone, the world has witnessed at least half a dozen floods of epic proportions in Pakistan, Bangladesh, Canada and the United States, Central Europe, and Southern China, as well as intense droughts in Southeast Asia, Northern China, Northern Vietnam, North Korea, and Southern Europe. In 1993, the northeast coast of the United States received its biggest snowstorm in more than a century. At the end of 1996, it was the turn of Victoria, which was paralyzed by the biggest snowfall in its recorded weather history. Western Europe, usually noted for the moderation of its climate, was pounded by four major storms in the winter of 1990. In 1987, southern England was hit by its worst storm since 1705. In 2003 heat wave killed 3500 people in Europe and in 1995, heat waves killed more than 500 people in northern and central India.

The sheer number of such events within the past two decades raises some serious questions about the current and future state of the global climate. Are these events part of a long-term trend towards more extreme weather, or are they just a temporary aberration? Are they the result of purely natural forces? Or could they be linked in some way to climate change caused by the buildup of greenhouse gases in the atmosphere? The answers to these questions are vitally important

The number of extraordinarily severe floods, storms, and other weather calamities that have occurred within the past 15 to 20 years would seem to suggest that such events are becoming more common.

Increase in Extreme Weather: What Should Be Our Purpose?

Responses

It is clear that weather extremes are becoming an increasingly serious problem for our society. There is also a reasonable probability that global warming will make the problem worse. The difficulty is that we don't know for sure the extent to which the present wave of extremes is a natural climatic phenomenon, nor do we know the real potential for the intensification of extreme weather in a warmer climate. To diminish these uncertainties, we have to devote much more scientific effort to the study of severe weather as a feature of climate. This effort will have to focus on three areas in particular.

First, we need to have a much better grasp of present and emerging trends in severe weather. One of the chief difficulties here is that extreme weather events, by definition, occur infrequently. They are also usually limited in area and often short in duration. Consequently, they tend to leave a weak statistical trail or none at all.

The second requirement is for a better understanding of natural climatic variability. Some of this can be derived from the instrumental climate record – that is, the record of weather observations taken with properly calibrated instruments under controlled conditions. For some places, this information may extend back a century and a half or more, but for much of the world it is considerably shorter.

Finally, the possible connection between global warming and various types of weather extremes needs to be explored more thoroughly. We know of mechanisms by which global warming could increase the frequency or intensity of severe weather, but other physical processes could also have an important effect on the outcome.

Implications of an Increase in Weather Extremes

A possible connection between global warming and extreme weather is of more than academic interest. The economic, human, and ecological costs of even a small long-term increase in extremes would be substantial.

The ecological impacts of extreme weather on natural and agricultural ecosystems should not be overlooked either.

Components of Climate Monitoring Systems

Climate monitoring includes the observation, recording and analysis of the past and present state of climate based on "proxy" sources of data (such as tree rings and geological records) and measurements from systematic climate networks around the world. Only by understanding the past state of the climate and its natural variability can we determine the extent to which climate is changing and whether human activities are fuelling this change. To achieve this, scientists monitor five components of the climate system: atmosphere, oceans, hydrology, land surface, and the cryosphere.

Atmosphere
Atmospheric data include the type of information routinely measured for predicting the weather — temperature, wind velocity, air pressure, clouds and precipitation. This information is fundamental to monitoring the climate system and identifying when it changes.

Oceans
The world's oceans are a reservoir for heat and greenhouse gases such as carbon dioxide. Oceans cover seventy percent of the world's surface, making them an important player in our climate. Some of the key oceanographic parameters include temperature, salinity, currents, sea level, and CO_2 content.

Hydrology
The hydrological cycle describes how water flows around our planet and is an integral part of the Earth's climate system. We need to monitor and understand key aspects of the hydrological cycle (e.g., river and stream flow) to be able to build the computer models necessary to predict changes in the climate system.

Land Surface
Terrestrial systems (e.g., forests, soils and wetlands) play an important role in determining how long greenhouse gases stay in the atmosphere, and in absorbing and reflecting energy from the sun.

Cryosphere
The cryosphere refers primarily to ice, snow, permafrost, and glaciers and is a significant part of the climate system, particularly in high latitudes.

Improving the State of Climate Monitoring

For the data collected from climate monitoring to be useful, measurements must be taken over decades. Any gaps in information make it harder to spot trends and changes in climate. However, systematic climate monitoring has declined around the world in recent years. The existing atmospheric measurement network has fallen well below international standards. In 1999, the Climate Change Action Fund (CCAF) supported a comprehensive benchmark project entitled the "Preparation of a Canadian Global Climate Observing System (GCOS) Plan," which identified a number of actions required to address gaps in our systematic monitoring networks and help fulfill Canada's obligations under the UNFCCC in the area of monitoring. The CCAF subsequently supported a number of activities to determine how to fill the gaps in climate monitoring and plan for possible future activities. These projects have helped provide the much-needed information base for climate monitoring. They focused on the following areas:

Atmosphere
- Upgrading supplementary climate monitoring networks
- Creating a climate station history and procedures into a format that will make the information readily available.

Oceans
- Sea Level: identify changes resulting from climate variability.
- Ocean carbon content every ten years and the air-sea exchange seasonally
- Assessing how best to use data from ocean tide gauges in climate model and the need for additional sea level monitoring and high latitudes;
- Demonstrating how a combination of satellite and on-site information can describe both the season-to-season and year-to-year variations of ocean mass and growth. Microscopic ocean algae plays a role in the climate system as it takes up carbon dioxide from the atmosphere;
- Developing techniques to map sea level using satellite and on-site measurements;

Hydrology
- Analyzing the long-term record from network of hydrometric (river and stream flow) stations, and the usefulness of the existing hydrometric network for climate studies;

Land surface

- Producing a report on monitoring Global wetlands, including the production of a map.
- Producing a series of recommendations to the national Global Climate Observing System terrestrial programme. Many of the recommendations deal with measuring the movement, or flux, of greenhouse gases;

Cryosphere

- Identifying the specific Global Climate Observing System requirements for the cryosphere.

(Intentionally blank)

Annex 6

CLIMATE INFORMATION NEEDS FOR THE AGRICULTURAL SECTOR

Fayez S. Y. Abdo
Director, Agrometeorology Directorate
Jordan Meteorological Department

Introduction

Agriculture is the basic activity by which humans live and survive on the earth. Climate and weather data, information, and products are used extensively in the agricultural sector. Agrometeorological information and advice can help significantly to increase the quantity and quality of agriculture production, reduce losses and damage, and improve planning and decision making in the entire agriculture community. This presentation will review user needs in the agriculture sector from both climate observations and agrometeorological observations.

Data needed

Basic climate data

Climate is defined as the statistical description of weather over some past period or as an estimate of what the statistical characteristics of weather will be over some period in the future. Climatology refers to one of two things, either the **scientific study** of climate or a **quantitative description** of climate, showing the characteristic values of climate variables over a region. The first concept intends to meet the needs for studying climate change and climate variability, drought mitigation, combating desertification, mitigating natural hazards, managing natural resources, managing water resources, and planning and development.

The second concept can help provide the **historical data** needed for the description of climate characteristics over a region. Accordingly, it can provide the opportunity to determine the type of crops that can be grown in a region and the needed information for planning operational activities. Historical data should be long enough to capture the temporal variability of climate and also, with good geographical coverage, to explore the spatial variability of climate. This helps in the classification of the different types of climate predominating in a region or country. A minimum of 30 years of data is required for calculating ‘normal’ or ‘average’ for any element of data.

In addition to historical data, users need **real time data** for daily inquiries in operational agriculture. The basic climate data most used in agriculture are observations of rainfall, temperature of the air and soil, humidity, sunshine, solar radiation, and wind speed and direction. Basic data can be obtained from the CLICOM climate database or from any other database in use.

Derived data

In addition to the previous basic data, some other parameters need to be derived from basic meteorological elements such as net radiation, potential evapotranspiration, and accumulated temperatures above given thresholds (which used in irrigation and crop growth models). The INSTAT (INteractive STATistics) package is more commonly used in agrometeorology to obtain derived data and for climate data analyses, such as summary statistics (e.g., average 10-day, monthly yearly, etc.), water balance from rainfall and evaporation, start and end of rains, probability of the beginning and end of rains, probability of receipt a of quantified rainfall amount in a specified period, start of growing season, dry spell lengths, wind direction frequencies, potential evapotranspiration according to Penman, and crop performance index according to FAO methodology.

Agronomic data
In addition to meteorological observations, agrometeorological stations carry out other types agricultural observations on crops, soil, pests and diseases, and pastures. The most used observations are of plant development (phenology), soil moisture, and the occurrence of pests and diseases.

Remotely- sensed data
Two variables are now being extensively used from remote sensing, the Normalized Difference Vegetation Index (NDVI), which is a good indicator of current plant cover and its variation with time, and the surface temperature (Ts), which is a good indicator of climate and microclimate conditions prevailing close to the surface, as well as the moisture content of that surface.

Agrometeorological modelling
Modelling techniques are being increasingly used in all areas of plant science. Models of various sorts, from simple statistical associations, to complex simulation models, transform data to useful information. The models most used in agrometeorology are:

- Plant growth models
- Plant pests and disease control models
- Water requirement models

Forecasts and warnings
In addition to purely meteorological forecasts of expected weather, agrometeorological services issue weather forecasts of agriculture aspects (daily, weekly, monthly, and seasonal), including advisory guidance. They can also provide the following predictions and warnings:

- Forecast for occurrence of frost and heat waves;
- Prediction of onset of pest and disease on crops and animals;
- Forecast of crop sowing and yield maturing dates;
- Forecasts of rainy season ahead;
- Forecasts regarding pest and disease management operation;
- Prediction of periods of probable forest fire;
- Forecasting of crop and grassland products;
- Crop yield forecasts and assessment of crop condition;
- Warnings from hazardous weather phenomena for crops;
- Warning on the outbreak of pest and disease relevant to weather; and
- Early warning on sea states, strong winds, and storms for fisheries.

GCOS Baseline Surface and Upper-Air Networks - GSN and GUAN

Richard K. Thigpen
GCOS Secretariat

The GCOS Surface and Upper-Air Networks (GSN and GUAN) were established in 1999 and 1996 respectively to form a critical baseline calibration network for use in a variety of climate activities. The identification process that was followed was similar for the two networks. A group of CCI/CBS experts used lists of existing synoptic and climatological stations around the world and then developed a ranking process (based on certain criteria) that rated each station on its geographic location, historical record, quality of observations, and sustainability for the future. The objective was to identify stations that provided a good geographic coverage of the globe and also had long histories of operation so that there would be a good long-term historical database.

The identified stations are by definition an integral part of the WMO World Weather Watch / Global Observing System. They are listed in WMO Volume A, many of them identified in the Regional Basic Synoptic Networks (RBSN) and all of them should be in the Regional Basic Climatological Networks (RBCN) established by Resolutions of Regional Associations during the period from year 2000 (RA II) to 2003 (RA VI). As of 1 January 2004, the GSN consists of a total of 981 stations. The current total for the GUAN network is 152 stations. The current list of GSN and GUAN stations is available through the GCOS Web site (http://www.wmo.ch/web/gcos). Just as a point of reference, there are almost 11,000 stations in Volume A, around 5000 stations in the RBSN, and about 3000 stations identified as RBCN stations over the globe.

Network performance requirements, both minimum and target, are found in the "Guide to GCOS Surface and Upper-Air Networks: GSN and GUAN (GCOS-73)."

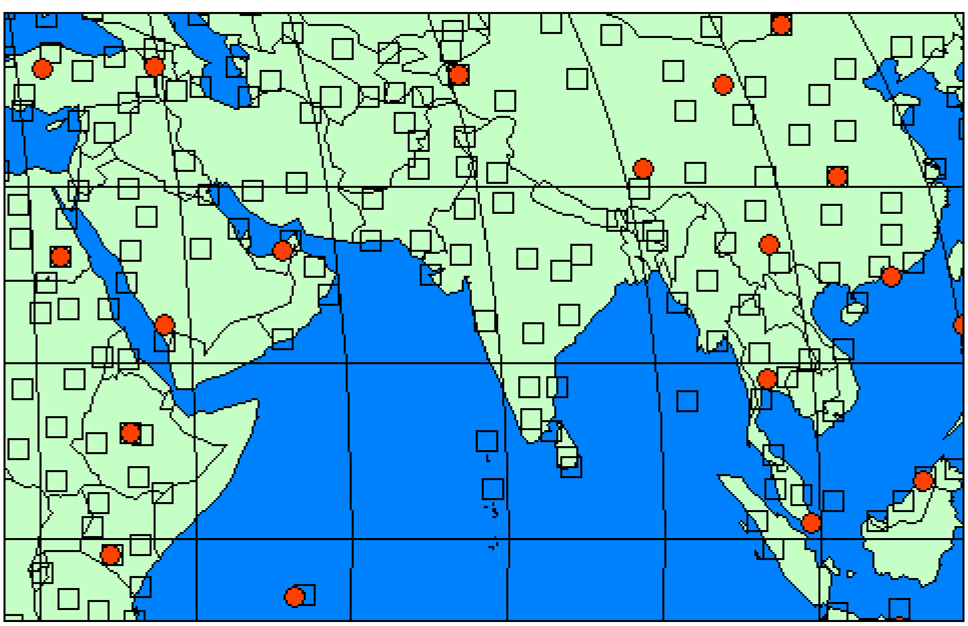
Minimum Criteria for GSN:
Good Global distribution -- 150-300Km spacing
Station Operations meet Minimum Requirements:
CLIMAT report monthly means of daily high, low, and mean temperature.
Monthly rainfall amounts.
(Target requirement includes daily temperature, precipitation, and pressure)
    Long good history of operations
    Historical data in archive
    Concurrence of the NMS

Minimum Criteria for GUAN
    Good Global distribution -- 5-10 Degree spacing
Station Operations meet Minimum Requirements:
At least 25 soundings/month with temperature, wind speed and direction to 100 HPa
(Target requirements includes temperature and wind to 5 HPa, and CLIMAT TEMP)
    Long good history of operations
    Historical data in archive
    Concurrence of NMS

This guide also contains the GCOS Climate Monitoring Principles as well as the format for the submission of historical data and explanations of the performance indicators used by the monitoring centres. This Guide may be found on the GCOS Secretariat home page. (http://www.wmo.ch/web/gcos/gcoshome.html).

The CBS Lead Centres for GCOS have been formally established and have begun their activities in Climate Centre Tokyo (JMA) for GSN and in the National Climate Data Centre Asheville (NOAA) for both GSN and GUAN. According to information provided by NCDC, in August 2004, 36 (75%) of 48 GSN stations located in this region were transmitting CLIMAT reports, 5 (10%) stations were operating but not transmitting CLIMAT reports, and 7 (16%) stations were silent (not producing synoptic data). Regarding the upper-air network, both of the 2 GUAN stations located in the region were transmitting TEMP and CLIMAT TEMP reports. A variety of network performance reports from the lead and monitoring centres can be found through the GCOS Secretariat home page.

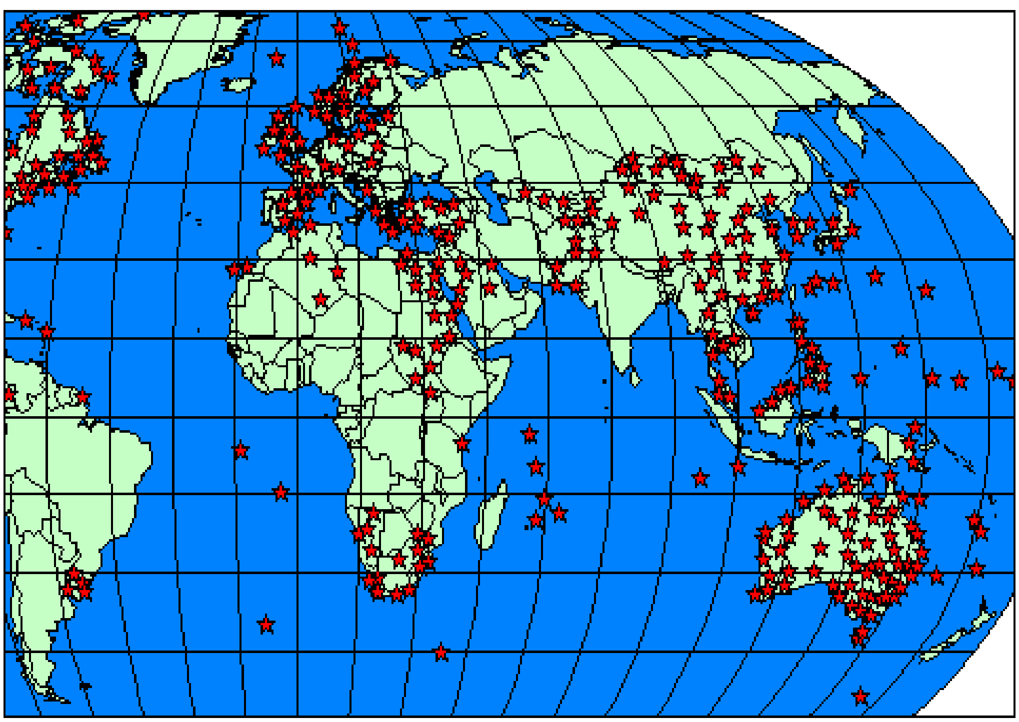
These data show that the performance of GSN in this particular region, as well as in others, has not yet achieved the level needed. There are a variety of reasons for this. First, observing stations in synoptic networks in some cases do not forever remain in operation. The NMSs may make changes in the operation or locations of their stations. Errors have existed in the identification of stations and their positions. Equipment has become obsolete and supplies have become prohibitively expensive for some operators. Synoptic stations may not prepare and send the monthly summary bulletins (CLIMAT and CLIMAT TEMP) upon which primary monitoring is based. Thus, some stations are identified as “silent” for GCOS purposes when in fact they are operating on a fairly regular schedule as synoptic stations. It has been reported for some time that roughly 40% of the stations in GSN and GUAN are “silent,” although more recent analysis indicates that the networks are actually working somewhat better. In addition network stations are generally not achieving target performance requirements, especially for GUAN, which specifies soundings twice a day, levels of 5 HPa, and CLIMAT TEMP reports.



In this diagram, the regional GSN stations are shown as “□” and the GUAN stations are shown with the “●”. Clearly the distribution of stations in this region is not ideal.

An important point is to establish a network of focal points for validation of GSN and GUAN stations in individual countries. In August of 2003, the WMO requested that Members identify a focal point to liase directly with the GCOS lead centres on GCOS matters. Although many Members responded many did not, and in February of 2004 an additional appeal was sent. Still some countries have not responded, including some in this region. Each host country should identify a national GCOS focal point to work with the World Weather Watch (WWW) and the GCOS Secretariat to validate that the information in the GSN and GUAN stations lists is correct. At the WMO, the WWW maintains and publishes the RBSN and RBCN lists, which include the GSN and GUAN stations. After this validation process, the same focal points would become the points of contact for the operation of these stations in their host country. Some regions have found it useful to establish a regional GCOS focal point to further improve coordination.

Another serious deficiency in the implementation of these networks so far is the lack of historical data from many of the stations. The National Climatic Data Centre (NCDC) in Asheville is responsible for building a permanent data base of GSN daily and monthly data submissions, along with the appropriate station metadata history, and for providing free and open user access to this information via their web site at http://lwf.ncdc.noaa.gov/servlets/gsn. This site contains all of the historical daily and monthly CLIMAT-formatted GSN data received (as of September 2004) at NCDC from 439 of these surface stations. Unfortunately, there are no historical data available from some countries in this region as seen in the following map.



The stations shown with a red star have historical data in the archive. It may be a technical issue as the historical data are either lost or not in a suitable form. In any case, of the 981 stations in the GSN, historical data for only 30% of stations is in the NCDC archive today, making the GSN substantially less useful for long-term climate analyses. There are current initiatives, from France and the US, that are intended to address the rescue of historical data.

These historical data are important to individual countries, to the region as a whole, and to the global climate community.

Progress, though slow, in improving both networks is being made recently through a variety of means, such as the regional workshops like this one conducted by the GCOS Secretariat, the efforts of the World Weather Watch and GCOS to correctly identify network stations, the analysis of operational problems, improvements to the monitoring function, and renovations of stations funded by donor countries. Regional Action Plans have been developed for some regions and should be prepared for this region as an outcome of this workshop. Our knowledge of the problems and operational issues would be improved. Working together, we can insure that these globally important networks operate well.

Recommendations for inclusion in your Regional Action Plan

1. Establish Regional and National Focal Points for the RBSN and RBCN, especially the GSN and GUAN Stations

2. Develop a Regional Network Improvement Plan/Proposal

3. Develop a Regional Plan for Rescuing and Sharing RBSN and RBCN Historical data with Emphasis on GSN and GUAN Stations

Annex 8

OBSERVING SYSTEM NEEDS OF SOUTHWEST ASIA

A.Majeed H. Isa[11]
Director of Meteorology
Kingdom of Bahrain

Introduction

The Conference of the Parties (COP) of the UNFCCC in 1998 specified the requirements for a global observation system for climate, and now we must analyse how well the (present) system meets with those UNFCCC requirements.

There have certainly been some improvements made during the last few years, but we need to continuously monitor the existing networks, as well as the accuracy of the data, through stringent quality control methods. We should also be utilising modern technologies for a better implementation of global climate observing systems.

The true value and importance of high-quality data in understanding climate related issues is now fully recognised, but it is also obvious that the geographic coverage and quality and quantity of such data is inadequate to meet the challenges that lie before us. Most of the problems lie within the developing world due to old equipment, insufficient funding, and inadequate maintenance of the existing network. There is also a shortage of well-trained staff.

The GCOS programme is designed to address the needs for capacity-building and to identify projects that address deficiencies in all aspects of climate observing systems, i.e., in atmospheric, oceanographic, and terrestrial networks.

Observations systems are fundamental to the operation of NMSs, and we can ascertain how well they can meet these requirements, and also the gaps where we fall short of meeting the needs. (This implies having an on-going process to validate the understanding of what is required). An inventory of available networks and datasets is a critical part of this process. It is necessary to standardise methods of making and collecting the observations to ensure that the data collected by each country will be compatible with others.

This involves issues of frequency of observations, exposure, accuracy, instrument response times, network densities, etc.

The WWW observing system calls for a basic regional synoptic network (RBSN) that specifies the surface and upper air observations required for exchange between countries.

There is a need for a survey of the current situation of stations within SW Asia to determine the specific needs of each country to meet its obligations.

---

[11] I wish to express my sincere gratitude to the Indian government, to the meteorological department, and to the Global Environment Facility/UN Development Programme who have made the necessary arrangements and for their support in organizing this workshop.

Automatic Weather Stations (AWSs) may be a suitable solution for surface synoptic weather observing in many cases. Upper air wind measurements have usually been obtained through wind finding radar or from the Omega radiosonde system, but this ceased to operate after 1997. Global positioning System (GPS) sondes have recently been in operation, but it is often said that these are expensive. There is an ongoing need for consumables of a reasonable cost to the nations, and bulk purchases of sondes by a centralised agency could supply the answer.

This presentation aims to evaluate the current observing systems in SW Asia and discuss the deficiencies and requirements for improving them.

Observing Systems--Current Situation
The present system in the Asia region suffers from the following distinct disadvantages:

Lack of both quantity and quality of data.
Lack of calibration and re-calibration of equipment.
Lack of adequate funding to acquire new technology.
Lack of adequate communications links for the exchange of data.

Telecommunications
There is little point in having a good observational network if the telecommunications system cannot disseminate the data and information efficiently and on time.

The collection of observational data within each country and the exchange of observational data and processed information between countries are made through the NMTNs and the RMTNs. Unfortunately the development of point-to-point circuits of the RMTNs is not homogeneous within the region. (Baghdad, Sanaa, and Afghanistan still have no GTS connection at all.)

Also, many countries supplement their point-to-point circuits by the reception of satellite based data distribution systems such as SADIS, MDD and ISCS.

It is essential to push for the maintenance and further development of the existing observation systems and telecommunications in addition to the development of alternative data sources such as the Aircraft Met. Data Relay (AMDAR).

Atmospheric Observations: GCOS Surface Network (GSN), GCOS Upper Air Network (GUAN), and Global Atmosphere Watch (GAW)

The coverage of atmospheric and hydrological cycle reporting stations is woefully inadequate in the southwestern parts of Asia in particular.

There are large tracts of largely uninhabited desert and scrublands with no information about the condition of lower or upper levels of the atmosphere, or what is happening with the hydrological cycle in these areas.

It is also necessary to ensure that ship SYNOP reports and sea-surface temperature reports are collected and disseminated in an organised way.

This lack of basic data puts day-to-day forecasting at a disadvantage, but probably more importantly, with the threat of global warming, is a hindrance to research into climate change.

Unfortunately there is another aspect to this lack of data, the unreliability of stations within some countries. This ranges from poor quality reporting (particularly with regard to pressure tendencies) to no reports at all from active stations. This is particularly true of upper air stations.

We need to think seriously about how rain gauges or fully automatic weather stations, including evaporometers, that can be positioned and serviced in inhospitable areas, and how we can encourage, motivate and train staff properly so that the existing network functions properly and expands.

It is also recognised that improvement of GSN and GUAN, and climate data management, including data rescue, are among the important issues in the region that need attention.

Data sparsity and unreliability are, perhaps, two of the biggest problems, as there are very large areas of desert and generally uninhabited scrubland.

Many SW Asian countries, especially some of the Gulf States, do not have the climate data accumulated by the British before independence. A good example is the Kingdom of Bahrain, which did not acquire this valuable data until 1991, nearly 20 years after independence. It is suggested that other states that may be similarly affected should make the necessary approaches to the UK Met. Office, which may hold them or know which armed service may hold them.

The network of communications and analysis within the GCC states of the Persian Gulf has steadily improved in recent years with generally homogeneous CDMS systems, but much work remains to be done within the region generally.

However, the climate data network system within SW Asia is an improving entity, but there are many areas with shortcomings that need to be addressed. At this stage it is probably just as well that I remind you that for SW Asia, apart from a few specialised climate stations, all climate data are drawn from *in situ* synoptic observing stations.

Marine Observing Systems

The provision of marine surface networks to meet the requirements of GCOS continues to be of the highest priority, since they contribute substantially to national economies, as well as being essential for the safety of life at sea, as recognized in the International Convention for the Safety of Life at Sea (SOLAS).

There is a great need within SW Asia to enhance and consolidate the marine surface network in the Red Sea, Arabian Sea, and the Persian Gulf so that global climate models can be initialised and verified.

It is suggested that a greater number of surface-drifting buoys are required to record sea-surface temperature and pressure, and in addition, oil-rigs and all voluntary observing ships entering or transiting our region should be required to pass on their full observations on time. The collection and distribution of these valuable observations needs to be greatly improved. Some oil tankers do not include their position with the observation because they do not want to give their position away to rivals, but this renders the message useless. This is particularly so when oil prices are high, and much oil is sold on the European spot-markets. These missing or delayed sea-surface observations would be of great value in initialising and verifying climate models.

Global Atmosphere Watch (GAW)

Homogeneous observations of the spatial distribution of greenhouse gases, including carbon dioxide must be continued to identify the sources and sinks. This can be achieved through the continued operation of the existing observing stations, and also through the enhancement of the Global Atmosphere Watch (GAW) network in specified areas in the SW Asia. There is also a need to improve the distribution and calibration of ground-based observations in order to support satellite data for the global monitoring of ozone.

There is an increasing awareness of the linkage between human health and the climate. Air quality information and measurement of sulphur dioxide, the global carbon cycle, soil carbon, nitrous oxide etc, at a number of sites in the region can assist in coping with problems.

The exchange of real time data should be developed and improved.

Satellite and Radar Observations

The two main meteorological satellite systems covering the SW Asia region are the geostationary Meteosat and the NOAA polar orbiters.

Their value is mainly restricted to their use as nowcasting and forecasting tools, but Saudi Arabia utilises them for climate research. Specialised research satellites that measure specific parameters over a wide area such as ozone distribution, stratospheric aerosols, and sea-surface temperatures are a future planning requirement, and will be of great value to climate research and seasonal forecasting when they have been in operation for some time.

It is essential that satellite observations of total solar irradiance and Earth radiation are continued without interruption and with strict adherence to the GCOS Climate Monitoring principles. New technologies should be exploited including GPS based system sensing of column water vapour.

Weather radar is only a sporadic tool within SW Asia at the present moment and more radar systems are urgently required. It would also be of great value if the existing radar systems could be networked in order to give a more comprehensive cover, especially within GCC states. Not only will this prove to be a greatly improved nowcasting and forecasting tool, but will be of great value to climate research and modelling.

Database Management

It should be documented that there have been significant improvements and upgrades of CDMSs throughout SW Asia. Most countries relied on the old CLICOM system that has now been replaced by a number of members, particularly GCC States, by the more powerful ORACLE based system CLDB supplied by Microstep of Slovakia.

Several members are now using this system, and it seems a very good, cost-effective idea for multiple states within a region to use the same supplier with a proven track-record. In this manner, systems can be easily evaluated and prospective customers re-assured. Training can also be organised within the region thus making significant savings on the manufacturers training fees.

However, the new database management had been demonstrated and evaluated for its performance on standard criteria. It uses multi-tier, server relational databases. Implementation has resulted from bi-lateral as well as multi-lateral co-operation, coordinated through the WMO's technical cooperation programme.

In conclusion please be aware of the importance that should be placed on established WMO practices when implementing observing programmes at GSN stations.

General Recommendations

- A detailed history of local conditions, instruments in use, operating procedures, and data processing methodologies should be catalogued and stored (metadata).
- A recognised baseline regional observing network (e.g., GSN or GUAN) needs to be studied to provide regular and reliable data that can be gradually improved upon and extended.
- Sustainable GSN and GUAN networks that meet the requirements of GCOS should be ensured.
- Government and decision makers need to be convinced of the importance of GCOS and the uses of GCOS in the socio-economy of the states.
- Request the government with strong justification to make investment, and ensure an adequate budget to support and maintain efficiency.
- Quality control of data should be regularly and routinely assessed.
- The focus on bringing additional observing stations to data sparse areas should become a high priority. Urgent attention should also be given to poorly observed parameters through regional workshops.
- Services should be tailored to meet the needs of the users.
- It will be of great value to climate research and modelling if the existing radar systems could be networked.
- Historical observational records from colonial power meteorological services and also from private sector sources should be sought.
- Utilizing satellite reception in the field of climatology.
- Identify those countries that are capable of improving the situation without help and identifying those countries that most need help.
- Formulate a programme for countries to acquire the minimum capability.
- Set up a mechanism within the SW Asia region for the exchange of data.
- There is a requirement for more sea/ocean observations.
- Each member to take initiative to record old data into the new system.
- Set up training and capacity-building programme and members requiring training on CDM should make use of facilities at RMTCS such as India.
- WMO to conduct workshop on CDM in the area.

(Intentionally blank)

Annex 9

DATA RESCUE ISSUES AND REQUIREMENTS OF OBSERVATIONAL SYSTEMS FOR DETERMINING LONG-TERM TRENDS

Phil Jones
Climatic Research Unit
University of East Anglia, Norwich, UK

In almost all regions and countries of the world considerably more climate (e.g. temperature, precipitation and pressure) data are available than is generally realized. GCOS refers to these climate data as Essential Climate Variables (ECVs) in its evolving Implementation Plan. Often the lack of long records is due partly to digitized data only being available for recent years, but also because the earliest archives in many countries have been lost or are held in former colonial archives. The earliest records generally available are monthly averages or totals as this was all that was possible to analyse (except for some extreme events) prior to the 1950s. Some countries have made considerable efforts to digitize their daily records back as far as possible, but there are still many issues with the earliest data due to homogeneity (see later).

With the growing interest in climate change, the digital availability of the records has become an issue as climatologists seek to determine whether changes are occurring – not just gradually in averages, but also changes in the incidence of extremes. Rightly or wrongly, the public, government and the media perceive much of the climate change issue through extremes. In the first two IPCC reports little could be said about changes in the frequency of extremes because most studies were limited spatially and also to more recent periods. Recently, the Expert Team on Climate Change, Detection, Monitoring and Indices (ETCCDMI) have encouraged a number of continental-scale studies through regional workshops. Participants come with data for their countries and this is analysed with an evolving software package. The results from a number of workshops have been published in the peer-review literature enabling the most recent IPCC report to have something to refer to. More workshops have taken place recently or are planned soon, so that AR4 (the 4th Assessment Report of the IPCC due in early 2007) will have a near-complete picture of changes in extremes over land areas produced with a consistently–defined set of extreme indices. For the south-Asian region, regional workshops are planned in Turkey (October 4-9, 2004 for southwest Asia) and Pune (?February, 2005 for south Asia from Sri Lanka to Mongolia).

All data rescue efforts should not forget paleoclimatic (proxy) records. These include information from natural archives such as tree rings, ice cores and corals and historical archives in the form of national documents and diaries. In the south Asian region, the former are not very plentiful and are limited at this time to the mountaineous regions of the Himalaya. Documentary records are extensively analysed in China, but have received little attention in other parts of the region, probably because few written archives exist.

To monitor climate over the long term requires homogenous records of the major climatic variables. Homogeneity is the climatic term for consistency and means that the data recorded should only be varying due to the vagaries of the weather and climate. Most climatic records have homogeneity issues because instruments have improved over time, automation has recently taken place and the sites where the measurements are taken have been moved or the environs around the site have changed. To assess homogeneity it is important to have neighbouring records and when it is known sites and instruments will change, to take parallel measurements for at least a year in order to adjust the records of the former to the new site/instruments/observing practice. Almost all studies of the homogeneity of climatic time series have emphasised monthly-average data. A few studies have begun to look at the long-term homogeneity of daily series. So far, all have just considered the issues of appropriate tests for homogeneity. The more difficult step of adjusting daily series for homogeneity has yet to solved. One study (in Canada) has shown that applying monthly adjustments to the daily series is both appropriate and the best method from a statistical viewpoint. All aspects of homogeneity testing (monthly and daily timescale) take considerable time and it is inevitable that there will be a trade-off between what resources for the work are available and the types of analyses that will be attempted with the adjusted data.

The GCOS surface network (GSN) and upper air network (GUAN) have been selected to be the best reporting sites in a country and also sites where instruments and location will likely remain the same for some time. Both networks have monitoring centres to assess reception rates and data quality. An additional requirement of membership of the GSN and GUAN is that the daily record from the site be archived at the archive and analysis centre. Where possible, any digitization of records in a country should prioritize the GSN and GUAN sites.

Recommendations

Data Rescue

- Digitize the daily records for the Essential Climate Variables (ECVs) for all GSN sites within the country.

- Send representatives to the regional ETCCDMI meetings and maintain contacts with the invited experts and those working in the neighbouring countries (i.e. share experiences and develop local expertise).

Requirements

- Parallel readings are essential when changes in GSN and GUAN sites and instruments are likely to take place.
- Homogeneity testing can be very labour intensive. There isn’t a simple universal software package available and adapting the general principles to the specific needs of a country or region is likely to be the best approach. Consideration should be given to the potential uses of the adjusted series in developing appropriate strategies.
- Send all daily archival data to the GSN and GUAN archival centres.

Annex 10

GLOBAL ATMOSPHERE WATCH – AEROSOL PROGRAMME

Alfred Wiedensohler
World Calibration Center for Physical Aerosol Properties
Leibniz Institute for Tropospheric Research, Leipzig, Germany

Overview

In order to predict climate change, it is critical to monitor the changing composition of the earth's atmosphere as affected by the release of gases and aerosols through natural and man-made processes. Almost a half a century ago during the International Geophysical Year (IGY), scientists began a long-term atmospheric chemistry measurement programme at key stations around the world. To coordinate and harmonize this effort, the WMO's Global Atmosphere Watch (GAW) was created in 1989, combining earlier WMO programmes dating back to the early sixties. The GAW mission is threefold:

1. Systematic monitoring of the atmosphere's chemical composition and related physical parameters on a global and regional basis.

2. Analysis and Assessment in support of environmental conventions and future policy development.

3. Development of a predictive capacity for future atmospheric states.

In 1992, GAW was incorporated into the Global Climate Observing System (GCOS) as its atmospheric chemistry component.

Two points should be made about GAW's role within GCOS. (1.) It should be noted that GAW differs from the other components of GCOS in that the trends and global distribution of atmospheric chemistry parameters are primarily used in predictive climate models and are not a direct measurement of climate change per se. (2) GAW has an additional objective of coordinating regional air quality measurements worldwide. Associated with the air quality objective is the GAW Urban Meteorology and Environment Project (GURME), which has been established to assist meteorological services in developing countries with urban air quality forecasting.

It has long been recognized that climate change and air quality are closely linked.
The results of deteriorating air quality particularly in urban areas are commonly known to cause a range of environmental issues. For example, respiratory illnesses are intensified during haze and smoke events. As urbanization increases in the coming decades, the release of aerosols and gases from cities into the atmosphere will continue to be one common point of interest between climate change and air quality researchers.

To build and maintain GAW's worldwide monitoring system, a network of stations has been set up which consists of Regional (over 300) and Global (22) stations, with additional observations made at contributing and associate stations. Though the programme at GAW stations vary depending on the monitoring goals of the station, a list of the parameters measured includes carbon dioxide, methane, nitrous oxide, chloroflurocarbons, total ozone, vertical ozone, surface ozone, precipitation chemistry, carbon monoxide, the physical and chemical properties of aerosols, and solar/ UV radiation.

To ensure consistency in the GAW worldwide monitoring network, a strong infrastructure had to be developed. This structure includes Quality Assurance/ Science Activity Centres (QA/SACs), World Calibration Centres (WCCs), World Data Centres (WDCs) and the GAW Training and Education Centre (GAWTEC). The QA/SACs and WCC provide a system for common calibration and quality assurance standards throughout the GAW system. The WDCs provide a depository for GAW data and conduct initial analysis and assessment of the data. Training in the GAW measurements system is provided in a number of ways: directly at the stations, visits to participating laboratories, technical workshops, or through GAWTEC.

In recent years, the GAW programme has broadened its scope by not only improving its infrastructure but also enlisting the help of the scientific community through the establishment of Scientific Advisory Groups (SAGs) for different parameters such as ozone, aerosols, greenhouse gases and precipitation chemistry. These groups have been very active in advising GAW on the appropriate scientific approach. Also, the recent advances in satellite technology have made it imperative that ground-based GAW measurement programme be closely coordinated with satellite measurements. This coordination has been actively pursued through the International Global Observing Strategy. In support of GCOS, the GAW system must continue to promote quality ground-based measurements, but it must also broaden its agenda and incorporate efforts to integrate ground- and satellite-based measurements to lead to a better understanding of climate change.

The experts attending this workshop come from countries that over the last decades have been growing at an ever-increasing rate in both population and agricultural/industrial development. The effect of such changes has had a direct impact on the air quality in the region and hence on the global climate.

Aerosol Programme

WMO Executive Council, through actions initiated by the Commission for Atmospheric Science (CAS) Working Group on Environmental Pollution and Atmospheric Chemistry, has placed high priority on improving the quality and spatial coverage of Global Atmosphere Watch (GAW) measurements. The WMO Scientific Advisory Group for Aerosol (SAG Aerosol) was established in 1997 to implement the aerosol measurement programme in GAW that addresses not only climate-related, but also air-quality issues. For developing countries in particular, regional aerosol pollution issues are frequently of concern. The SAG Aerosol recognizes that measurements directed at climate and regional environmental problems can frequently employ common methods. A key role of the SAG Aerosol is drafting guidelines for measurements, proposing standards for compatible observations, quality assurance and common systems for calibration, data analysis and data archiving.

It is the goal of the Global Atmosphere Watch (GAW) programme to ensure long-term measurements in order to detect trends in global distributions of chemical constituents in air and the reasons for them. With respect to aerosols, the objective of GAW is to determine the spatio-temporal distribution of aerosol properties related to climate forcing and air quality on multi-decadal time scales and on regional, hemispheric and global spatial scales. This information also adds to the accuracy with which sources, transport and sinks of pollution can be determined and long-term trends for prediction of climate change can be observed. Aerosols influence the atmospheric energy budget through direct and indirect radiative effects. Direct effects include the scattering and absorption of radiation and the subsequent influence on planetary albedo and the climate system. Indirect effects involve the influence of anthropogenic aerosol on available cloud condensation nuclei (CCN). An increase in aerosol number concentration tends to increase the CCN which in turn, leads to increased cloud albedo and to changes in the Earth's radiation budget. Cloud lifetimes and precipitation frequencies can also be affected. This alters the hydrological cycle and water supply. Scientific evidence indicates that in regions with high anthropogenic aerosol concentrations, aerosol forcing is of the same magnitude, but opposite in sign to the combined effect of all greenhouse gases [*IPCC*, 2001]. Furthermore uncertainties are great. IPCC [2001] estimates the average direct radiative forcing, through scattering of incoming radiation, at –0.4, –0.2, and +0.2 W m-2, for sulfate, biomass and fossil fuel black carbon aerosols, respectively, and the indirect forcing, through cloud condensation nuclei effects, at 0 to –2.0 W m-2 for all aerosols. Long-term monitoring of chemical properties of aerosols will be crucial in determining the role that aerosols play in climate, in documenting changes in the regional air quality and in providing a scientific basis for policy decisions regarding control strategies.

In addition to climate influence, atmospheric aerosols affect many aspects of human health and the environment. Aerosol mass and its toxic chemical components are known to have links to chronic respiratory and acute cardio-vascular problems. Aerosols are also closely linked to problems of visibility reduction, acid rain, and urban smog in many locations of the world.

Aerosol impacts depend on particle size. On a mass basis, two populations of particles, with characteristically different sources, sinks, sizes and chemical compositions, generally constitute the tropospheric aerosol. The sub-micrometer fraction ("fine particles") originates from condensation sources (both high and low temperature) and from atmospheric gas-to-particle conversion processes. It is primarily removed by precipitation and dry deposition processes. In contrast, the super-micrometer fraction ("coarse particles") is produced by mechanical processes (wind driven soil erosion and seawater bubble-bursting) and is mainly removed by sedimentation, impaction and interception at the Earth's surface. It has a considerably shorter atmospheric residence time than the sub-micrometer fraction. Size-segregated measurements therefore allow the determination of the aerosol properties of each of these two populations so that their atmospheric occurrence and hence effects can be evaluated separately. It also provides data for validation of models used in scientific assessments of climate change and air quality issues.

Since the atmospheric residence time of aerosol particles is relatively short (days to weeks in the troposphere and months in the stratosphere), a large number of measuring stations are needed. The World Meteorological Organization's Global Atmospheric Watch (GAW) network consists of 22 Global stations and numerous Regional stations that cover different types of aerosols including: clean and polluted continental, marine, arctic, dust, biomass burning, and free tropospheric particles.

Recently, the Scientific Advisory Group (SAG) for Aerosols of GAW recommended the development of a global aerosol network of ground-based stations. Table 1 summarizes the recommended list of comprehensive aerosol measurements to be conducted at some stations as well as a subset of core measurements to be made at a larger number of stations. Global stations are expected to measure as many of this list as possible while the GAW Regional stations and contributing partner network stations will measure the smaller set of core aerosol observations, to complete the global coverage. The Aerosol-SAG recommends that GAW stations should measure aerosol optical depth, mass concentration and major chemical components in two size fractions, aerosol light scattering and absorption coefficients.

Methodologies and procedures for measuring the recommended aerosol variables are presented in WMO-GAW report 153. Summaries of these procedures have been given elsewhere, along with the other components of the GAW programme. It should be noted at this point that suitable instrumentation is not presently available for some variables, and some calibration procedures require further international research efforts and coordination.

The Institute for Tropospheric Research in Leipzig, Germany, hosts the World Calibration Centre (WCCAP) for physical aerosol properties. To complement this important GAW facility, there is an urgent need for the establishment of a World Calibration Centre for aerosol chemistry as well as Quality Assurance /Scientific Activity Centres (QA/SACs) responsible for measurements of selected variables.

Continuous Measurement
Multi-wavelength optical depth
Mass in two size fractions
Major chemical components in two size fractions
Light absorption coefficient
Light scattering coefficient at various wavelengths
Hemispheric backscattering coefficient at various wavelengths
Aerosol number concentration
Cloud condensation nuclei at 0.5% supersaturation
Intermittent Measurement
Aerosol size distribution
Detailed size fractionated chemical composition
Dependence on relative humidity
CCN spectra (various supersaturations)
Vertical distribution of aerosol properties

Table 1: List of comprehensive aerosol measurements with a subset of core variables (identified in bold) that are recommended by the GAW Scientific Advisory Group on Aerosols for long-term measurements in the global network.

At the core of the GAW global network of Global, Regional and contributing partner stations is a willingness on the part of the participating organizations to pool their observations and make them publicly available. Public access to a comprehensive set of global aerosol observations is to be provided by the World Data Centre for Aerosols (WDCA) hosted by the Environment Institute of the Joint Research Centre, Ispra, Italy. This will be done in cooperation with data centres of contributing partner networks.

GAW participants endeavor to provide precise, accurate and timely observations of the aerosol parameters listed in Table 1. In order to achieve this and as important information for the user community, the data available from the WDCA should have certain characteristics:

1. They should be traceable to the original raw observational data. This requires the maintenance of an archive of the raw data, and the history of the processes applied to that data in deriving the processed data series submitted to WDCA. Such archives are normally the responsibility of the participating organization; however the WDCA can provide limited assistance as an "archive of last resort," where the alternative is the loss of the data.

2. They should be of known quality.

3. They should include all the information required by a user to permit the sensible use of the data. This is of particular importance in an organization like GAW where different participants may use different methods to measure individual parameters. They should include a contact point for the participant submitting the data. This aids the sensible use of the data and helps users recognize the work of the participants.

(Intentionally blank)

Annex 11

CLIMATE OBSERVATIONS FOR THE NORTH INDIAN OCEAN: THE OUTSTANDING ISSUES

Satish R. Shetye
National Institute of Oceanography
Dona Paula, Goa

The waters of the North Indian Ocean, i.e., the region that lies to the north of the hydrothermal front located just south of the equator, offer some unique features. This article aims at providing an overview of these features.

Forcing of this rather small and distinctly tropical basin by strongly time-dependent monsoonal winds makes the dynamics of the circulation in the basin strongly time-dependent and tropical in character. Precipitation over the basin is dominated by the seasonal migration of the Inter Tropical Convergence Zone (ITCZ). This period, also known as the Indian Summer Monsoon, generally occurs during the June-September period. The ITCZ is particularly active over the Bay of Bengal where it often exhibits activity that is higher than that anywhere else. In contrast to the Bay, the western and northern Arabian Sea experience hardly any precipitation, virtually no runoff, and high evaporation. This leads to a distinct near surface salinity gradient between the northeastern Bay and northwestern Arabian Sea. Barrier layers strongly influence mixed-layer physics in the bay and its surrounding waters. Another special feature of the mixed-layer physics is the mid-summer cooling that results from strong winds, currents, and upwelling during the summer monsoon.

Events during the monsoon show strong intra-seasonal variability (with periods ranging from one to several weeks) in both atmospheric and oceanic variables. While similar activity has been observed over the entire tropical belt, its intensity here during the monsoon is higher than anywhere else. The seasonal winds in the Indian Ocean do not support equatorial upwelling. Intense upwelling, however, occurs along the coast of Somalia and Arabia, and some also occurs off the southwest coast of India. Strong winds along the coast of Somalia lead to the formation of the Somali Current, unique for its strongly seasonal character.

The northern part of the Indian Ocean basin receives net heat influx across the air-sea interface. An important question is how does the ocean circulation remove this heat? It has been proposed that this is achieved by two overturning cells: one shallow (few hundred meters deep) and the other deep (in excess of 2000 m). Both are, however, yet to be clearly described.

A recent discovery has been the occurrence of the Indian Ocean Zonal Dipole (IOZD). It has been suggested that the IOZD forms a coupled ocean-atmosphere system, and hence monitoring the SST anomalies associated with it offers the promise of prediction of related seasonal climatic anomalies.

The Bay of Bengal is one of the most badly storm-surge-affected coastal regions of the world. Of 34 disasters listed in which the death toll was 5000 or more, 26 occurred along the coast of this bay.

Due to tropical character of the basin, no subtropical convergence occurs here. Hence ventilation has to occur from the south. This, together with high productivity of the Arabian Sea leads to an oxygen minimum layer with special implications to the biogeochemistry of the basin.

During the last few decades there has been progress in describing characteristics of the features listed here. However, the North Indian Ocean, in general, is still one of the not-so-well documented regions of the world oceans.

Annex 12

INDIAN OCEAN GOOS: CLIMATE RELATED OCEAN OBSERVATION SYSTEMS IN THE INDIAN OCEAN

K. Radhakrishnan
Director, Indian National Centre for Ocean Information Services, Hyderabad
Regional Coordinator (Indian Ocean), International Argo Project
Chairman, IOGOOS and Vice Chairman, IOC of UNESCO

Introduction

Ocean has a significant role in the weather and climate system because of its ability to store and transport heat, fresh water and carbon over a wide range of time and space scales. It is well known that (a) the heat capacity of the upper 3 metres of the ocean corresponds to the heat capacity of the entire atmosphere (b) the ocean is the largest store of biologically carbon holding approximately 50 times more carbon than the atmosphere and that (c) the feedbacks between ocean and atmosphere have a significant role in the variability in monsoon and climate. It is imperative to understand the processes and feedback mechanisms of the ocean-atmosphere system with proper assimilation of ocean data into the models

The Indian Ocean

The Indian Ocean, the third largest of world oceans, with more than 1.5 billion population around, is a unique and complex realm, essentially because of its typical geographical setting, the bi-annual reversal of monsoon winds and currents, the frequent cyclones in the Bay of Bengal, and the complex biogeochemical processes of the Arabian Sea. Climate variability in the recent past has caused a great deal of impact on the weather pattern resulting in droughts, floods, and heat waves in various countries of the Indian Ocean region. Understanding of the Indian Ocean is important not only for the 50 countries around this region, but also for the global community because of its tele-connections with the rest of the oceans and atmosphere. Yet, as compared to the Atlantic and Pacific, Indian Ocean still lacks systematic observations that are essential for understanding the oceanic processes and their impact on human life.

GOOS Regional Alliance in Indian Ocean (IOGOOS)

The Global Ocean Observing System (GOOS) of the Intergovernmental Oceanographic Commission (IOC), evolved in 1992 and co-sponsored by WMO, UNEP and ICSU, is an internationally organized system for effective management of marine environment and sustainable utilisation of its natural resources. GOOS envisages (i) an internationally accepted global design to address the broad realms of Oceans & Climate as well as Coastal Ocean, (ii) a set of GOOS Regional Alliances (GRAs) of countries/institutions that will focus on issues of common concerns and interests of the region and (iii) national contributions for implementation of the observational systems.

The GOOS regional Alliance in the Indian Ocean (IOGOOS) was formally launched on November 5, 2002 during the Indian Ocean Conference held at Mauritius, with 19 Members from 12 countries. Within a short time, IOGOOS has taken a place of pride among the GOOS Regional Alliances. The membership of IOGOOS has grown from 19 to 21 institutions from 13 countries. IOGOOS has been endorsed by the Intergovernmental Oceanographic Commission of UNESCO as one of the nine GOOS Regional Alliances. INCOIS, an autonomous institution

under the Department of Ocean Development is hosting the Secretariat of IOGOOS at Hyderabad for a period up to 2008.
The major initiatives of IOGOOS include (i) coordination of basin-scale observations in the region (ii) evolving a strategy for implementation of Ocean Data and Information Management in the region (iii) promotion of pilot project on areas of common concern for the region, and (iv) capacity-building.

IOGOOS-accomplishments on Climate related Ocean Observations
IOGOOS has developed a network of Resource Persons and is pursuing a time-bound action plan, in close association with the Intergovernmental Oceanographic Commission and its subsidiary bodies and Technical Commissions as well as national and regional organisations.
IOGOOS is providing a focus for the region, developing cooperation and opportunities for synergy among members, and creating the ability to take advantage of global initiatives such as Global Ocean Data Assimilation Experiment (GODAE), Climate Variability and Predictability Programme (CLIVAR) and Argo. IOGOOS is playing an important regional role in terms of observations and associated research, using pilot projects and focused initiatives to enhance the capacity and productivity of the region. It is facilitating regional cooperation with research programmes such as CLIVAR and Land Ocean Interactions in the Coastal Zone (LOICZ).
IOGOOS has been instrumental in the formation of the Indian Ocean Panel (IOP) to address the ocean and climate observing system in the region. The first meeting of IOP held at Pune in February 2004 assessed the state of the observing networks. IOGOOS members have played a key role in Argo deployments and in enhancing the tropical moored buoy array. The IOP is operated jointly with CLIVAR and is providing an energetic and effective link to the climate research community. An implementation plan will be prepared during 2004-05, including extension of the mooring array, assessment and review of the ship of opportunity programme, and initiating a series of observing system experiments.

IOGOOS Workshop held at Hyderabad in December 2003 finalised, along with the IOC Committee on Oceanographic Data Exchange (IODE) a strategy for ocean data and information management for the region. This being followed up with specific tasks on capacity-building, regional data archive, clearing house etc.

IOGOOS is working within the framework of the GOOS Coastal Panel and taking responsibility in collaboration with that Panel in the implementation of initiatives within the region, including contributions to the measurement of key common variables and testing of common methodologies.

Recognising the urgent need for satellite products and associated capacity-building, through all activities, IOGOOS agreed to assist in the development of enhanced SST products as well as other products for the coastal and biological community.

The Secretariat has developed an informative web site that is providing effective communication for the region. IOGOOS has thus developed a community spirit for the region, a ‘oneness’ among all agencies and participants for the benefit of the entire region.

Ocean Observing Systems for Climate: the Indian Scenario
The Ocean Policy Statement of India, 1982 has been the guiding framework for Ocean development in India. A strategic vision and perspective plan for Ocean Development for 2015 in India was set out in the year 2002 by the Department of Ocean Development (DOD), Government of India, with a mission to improve our understanding of the Ocean, specifically the

Indian Ocean, for sustainable development of ocean resources, improving livelihood, and timely warnings of coastal hazards that will make India an exemplary steward of her people and Ocean The Vision 2015 hinges around improving our understanding of ocean processes through conceiving and implementing long-term observational programmes and incubating cutting edge marine technology so that we are able to (i) improve understanding of the Indian Ocean and its various inter-related processes, (ii) assess the living and non-living resources of our seas and their sustainable level of utilization, (iii) contribute to the forecast of the course of the monsoon and extreme events, (iv) model sustainable uses of the coastal zone for decision-making, (v) forge partnerships with Indian Ocean neighbours through the awareness and concept of one ocean, (vi) secure recognition for the interests of India and the Indian Ocean in regional and international bodies. DOD has embarked on a user-driven agenda for ocean observations, and ocean-atmosphere modelling through an appropriate institutional mechanism, ensuring institutional synergy at national level.

A network of *in situ* ocean observing systems has been established and is sustained, as given below.
Active participation in the International Argo project by contributing 150 Argo floats as well as being the Regional Coordinator and Regional Data Centre for Indian Ocean.
Establishing a chain of 20 Moored Data Buoys at both shallow and deep waters in the Arabian Sea and Bay of Bengal (for measurement of a wide spectrum of met-ocean parameters) and enhancing further by 60 more buoys. The National Institute of Ocean Technology has developed.a moored data buoy.
An array of Drifting Buoys (for measurement of sea-surface temperature and atmospheric pressure).
Three Current Meter Arrays (for time series measurement of current vector at fixed locations and depths)
Three lines of Expendable Bathythermographs (for temperature profiles along the Ship routes).
Tide Gauges (for measurement of sea level).
The launch and operationalisation of the IRS Satellite constellation, including Oceansat-I (currently operational) and Oceansat-II (planned) by the Indian Space Research Organisation as well as a complementary effort on satellite coastal and oceanographic research project sponsored by the Department of Ocean Development aim at development of parameter retrieval from Indian and foreign satellites.
One of the important initiatives of DOD has been the national endeavour on Modelling of Ocean-Atmosphere System, taken in a mission-mode, to enhance the basic understanding and knowledge base on oceanic and atmospheric processes for ocean and climate predictability and catastrophic weather events, thus leading to improved operational predictions by the respective national agencies.

(Intentionally blank)

Annex 13

STATUS, DEFICIENCIES, AND NEEDS FOR HYDROLOGICAL OBSERVATIONS FOR CLIMATE

Shaukat Ali Awan
Chief Meteorologist and Hydrological Advisor to the PR Of Pakistan with WMO
Pakistan Meteorological Department (Flood Forecasting Division)

Introduction

Hydrological and meteorological observations provide necessary input for operating any flood forecasting model that gives numerical products of flood forecasts. Both the meteorological and hydrological parameters are measured by specific equipment, which should have following orientations: a) Precision in measurement (b) Operational compatibility (c) Sensitivity check/error elimination.

Hydrological Data & Information

Real time Data (for all available time intervals)
a) Precipitation, (b) Stage & Flow Data, (c) Reservoir inflow, pool levels & out flows

Information & Reports
a) Dam break, (b) Levee failure, (c) Ice Jam, Mud Flows, Land Slides, (d) Toxic Spill, (e) Storm Surge

Products

Floods
a) Hydrographs, (b) Flood travel times, (c) Flood forecasts, (d) Peak discharges (with an indication of their return intervals), (e) Peak Stage (with an indication of their return intervals) (f) Time to peak
Droughts
a) Hydrographs (recession limbs), (b) Droughts & low flow forecasts, (c) Minimum discharges (with an indication of their return intervals), (d) Minimum Stage (with an indication of their return intervals)

Major Rivers Basins In South & Southwest Asia

Helmed, Indus, Ganges, Brahum Butra, Meghna, Tigris

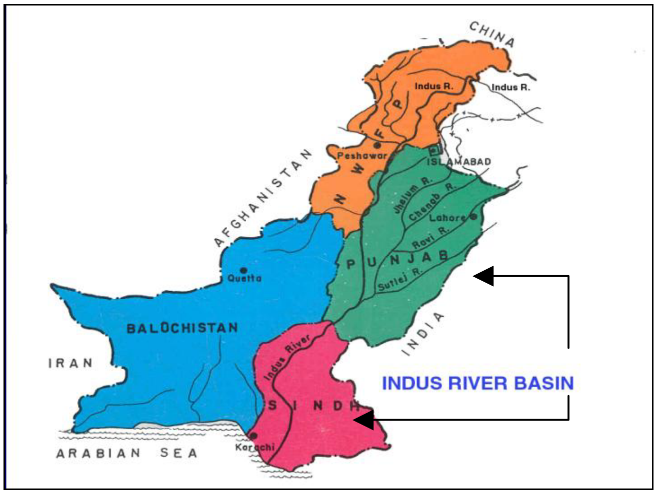
Present Status Of Data Generation & Collection

* International level GTN-H (Global Terrestrial Network for Hydrology)
* Regional level * Country level

Mode Of Transmission

* HF Radio Link * Telephone * Internet * V-Sat * Meteorburst

A Case Study
Real Time Transmission & Collection Of Hydrological Data In Pakistan



Data Multiplicity

The following departments collect the hydrological data independently:
* Agriculture Department * Water & Power Development Authority *Irrigation Department

Data Collection And Communication Systems
The following modes are used for transmission & communication
* Automatic Data Collection (Through Meteorburst Communication System)* Flood Telemetry Network * Snow and Ice Network
Manual Data Collection * HF Network * V-Sat

Hydrometeorological Parameters

The following hydrological parameters are measured by different instrumentation with the latest technology in use:
FLOOD TELEMETRY NETWORK
* River Stage Recording (Feet) * Rain (mm)
SNOW & ICE NETWORK
* Temperature / Relative Humidity (°C / %) * Snow Water Equivalent (accumulated values, mm) * Precipitation (accumulated values, mm) * Wind Speed & Direction (km/hr, ° with azimuth) * Solar Radiation (watt/m^2)
HF NETWORK
* River Stage (Feet) * Rain (mm) * Temperature (°C) * Evaporation (mm)
Hydrological Data Acquisition Systems

<u>HYDROLOGICAL MEASUREMENT FOR CHANNEL FLOW</u>
The following three types of equipment are used:

1. An ultrasonic system for discharge measurement of open channel flow location using differential ultrasound transit time technique.

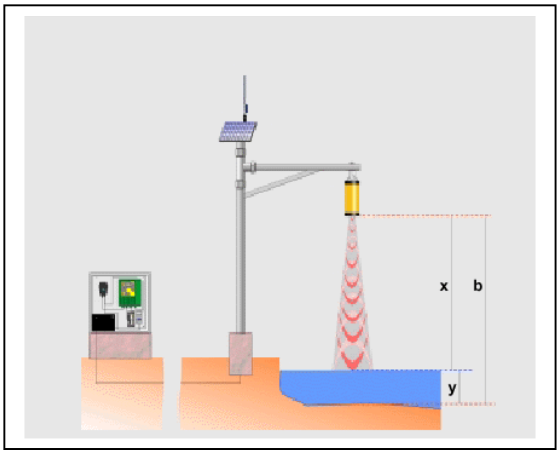
2. Radar sensor for the touchless measurement of water surface level.
3. Autonomous, cost-effective measurement station for collection of hydrological data (compact stations).

RADAR SENSOR FOR THE TOUCH LESS MEASUREMENT OF SURFACE WATER LEVEL

The radar sensor represents a new type of level measurement for surface water, which offers many advantages in hydrological field applications. The sensor does not come in direct contact with the water. Its compact design and the non-contact measuring principle, the sensor can be installed easily and inconspicuously, at no great cost in terms of time or money. The problems like disruption of measuring operation caused by high-water, silt accumulation, debris, plant growth etc. as well as time-consuming maintenance are eliminated.

Features

*Non-contact measuring principal,
no damage caused by silt accumulation or debris
*Simple, inexpensive installation - no difficult
fitting procedure necessary
*Cost reduction due to low maintenance requirements



Installation / Function

The water level is measured contactless from the air absolute measuring principle.

It sends radar waves (microwaves) perpendicular to the water surface. These waves are then mixed with the signals reflected on the surface. An intelligent signal processor (DSP) calculates the exact distance x between the sensor and the surface of the water. The data logger calculates the water level out of the system length and the distance and makes the stored values available for further processing.

RAIN GAUGE USING THE WEIGHING PRINCIPLE WITH INTEGRAL DATA LOGGER OR PULSE OUTPUT

Function

The weight of precipitation gathered in the collecting container is measured by an electronic weighing cell (resolution 0.01 mm / 0.01 inch). Beneath the defining ring of the measuring surface, the precipitation gets directly into the collecting container. Thus liquid or solid precipitation can immediately be measured, because there is no time delay as with tipping buckets, filter screens or inlet tubing's.

The high accuracy is obtained by an automatic self-calibration by means of a calibration weight. The use of frictionless link-joint elements guarantees a high long-time stability and a maintenance-free operation. Due to the measuring principle and design, the unit is ideally suitable for both, minimum and high precipitation rates and intensities. In addition a determination of evaporation is possible on the basis of the recorded precipitation event.

Advantages

- Weighing principle, high resolution (0.01 mm / 0.01 inch), exact, temperature compensated measurement of quantity and intensity, incl. fine precipitation (drizzle, fog catchment)
- No tipping buckets, filter screens, collecting inlet pipes
  no maintenance problems caused by snow, hail, leaves, bird excrements, insects, etc.
- Suitable for solid precipitation (e.g. snow, hail, freezing rain, grain)
- Siphon device˜ automatic drain-off system (optional)
- 40 inch (1,000 mm) collecting bucket for applications in areas with huge rainfall quantities or snow (mountains, rain forest, etc.)

MEASUREMENT STATION FOR COLLECTION OF HYDROLOGICAL DATA

Such Station is supplied with all components required to operate a measurement station: sensor, data-logger, communication equipment as well as a power supply. These components are mounted on a sub-frame at the factory to the customer's specification. The sub-frame can then be inserted into the station during installation. The housing is constructed using the diving bell principle, this means that an air pocket pre-vents the unit from flooding even if it is inundated by floodwater and prevents the instruments from being harmed.

The design and construction material of the unit also deter unauthorized access to the instruments as well as protection against the elements. In its standard design, the Compact Station has an integral stand with a base plate to secure it to a concrete foundation. Alternatively, it can be mounted to a bridge or convenient wall with other fixing options. The extension pole can have one, or if required, two solar panels as well as the communication antennae. The pole can also be used to mount meteorological sensors giving the unit even more flexibility. The customer can specify, GSM, radio or satellite options to communicate the data collected. The design of the Compact Station gives the customer a fully autonomous monitoring station that can be erected quickly and cost-effectively giving them an effective alternative to conventional monitoring stations.

Compact Station

This fully equipped measurement station can operate as a stand-alone unit thanks to its solar power supply and GSM communications option. It does not require any external utility supplies and can be mounted quickly and cheaply in a single day and as a rule permission to erect the sites are not required.

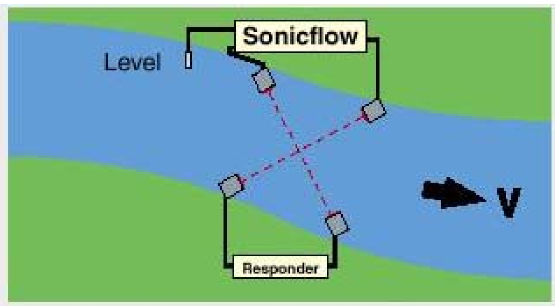
AN ULTRASONIC SYSTEM FOR DISCHARGE MEASUREMENT OF OPEN CHANNEL FLOW LOCATIONS USING DIFFERENTIAL ULTRASOUND TRANSIT TIME

Sonic flow

Sonic flow is a new ultrasonic measurement system designed to continuously log the flow velocity v in open channels. The Sonic flow system exploits innovative technology for signal processing and calculation of flow velocity. This technology is based on an intelligent digital signal processor (DSP) featuring very high measuring accuracy. In addition, it allows differential ultrasound propagation time measurements to be carried out even if the water level above the ultrasonic transducer is low.

a) Single-path arrangement (b) Single-path-reflector arrangement (c) Two-path cross arrangement (d) Two-path cross arrangement with responder

Measurement
An acoustic signal is transmitted at a defined angle so that it is simultaneously directed both towards and against the main direction of flow. The transit time for the signal transmitted against the main direction of flow is longer than the transit time for the signal transmitted in the main direction of the flow. The resulting time differential is directly proportional to flow velocity v in the measuring path.



Where the **"two-path-cross arrangement with responder"** * is used, laying of a connecting cable in or above the body of water is not necessary. This configuration is the preferred choice for waters with difficult inflow conditions, large water widths (5 ... 150 m) or for locations where it is not possible to lay a connecting cable.

Advantages

Suitable also for use in low water levels as only minimum coverage of the sensors is necessary. Functional design ensures that the system is user-friendly: Convenient evaluation software for professional processsing and remote transfer of data using a variety of communication methods (serial modem, GSM modem, satellite, etc.)

PRECIPITATION

Precipitation Sensors for Telemetering Devices Low Temperature Performance At subzero temperatures, recording rain gauges as well as rain gauges with resistance transmitters have to be put out of operation (solid precipitations usually cannot enter the measuring system). Moreover, collected water would freeze and possibly destroy the instrument. If equipped with an electrical heating device and a snow cross (extra cost), recording at light frosts is still possible. Models with a double-walled case or with a heating device can be used at tempera- tures down to -25 °C. The heating not only melts solid precipitations, but also protects the siphon and the collecting can from freezing. For hydrometric measurements, the inavoidable minimal evaporation losses and slight retardations between falling and recording are mostly of minor importance.

Needs

* New Technology * Equipment Development * Communication * Observing Stations *Data Generation & Reliability

Deficiencies

1. Reaching agreement among participating countries to proceed to establish a Network;
2. Defining needs which to be met;
3. Installing a real-time data collection and transmission system;
4. Upgrading national data processing and archiving system;
5. Establishing distributed regional databases;
6. Establishing a regional telecommunication network;
7. Preparing and disseminating hydrological information of national and regional interest;
8. Staff training;
9. Performance monitoring and follow-up.

Recommendations

1. Capacity-Building
2. Capacity Improvement
3. Centre Monitoring Country Wise & Regional Wise
4. Frequency Updating & Evolution
5. Infrastructure Development

Annex 14

GLACIER AND PERMAFROST OBSERVATIONS IN THE HINDU KUSH – HIMALAYA

Syed Iqbal Hasnain
Chairman, HIGH ICE, India
Vice-Chancellor, University of Calicut, Kerala, India

1. GLACIERS

The Hindu Kush–Himalaya with the immense Tibetan Plateau, constitute a major topographic part of planetary climate control, as well as huge catchments of snow and glaciers, which provide more than 80% of the lowland dry-season flows of the Indus, Ganges and Brahmaputra Rivers. The vulnerability of Himalayan glaciers is due to altitude range, variations in debris-cover, and summer air temperature. The glaciers located in central and eastern Himalaya are summer accumulation types nourished by the SW monsoon. The summer mass balance equals the annual balance. During the last decades climate variability has enhanced air temperature in higher elevations, causing negative effects on glacier mass balance, as follows:

- increased proportion of rain in the total precipitation reduces the accumulation by snowfall,
- higher temperature increases ablation by sensible heat, and
- decreased albedo, due to decrease of snowfall, increases ablation by insolation.

River	*Major River System*	*Mountain Area (km^2)*	*Glacier Area ($km^{2)}$*	*% glaciation*
Indus		268842	7890	3.3
Jhelum		33670	170	5.0
Chenab	**Indus System**	27195	2944	10.0
Ravi		8092	206	2.5
Sutlej		47915	1295	2.7
Beas		12504	638	4.4
Jamuna		11655	125	1.1
Ganga		23051	2312	10.0
Ramganga	**Ganga System**	6734	3	0.04
Kali		16317	997	6.01
Karnali		53354	1543	2.9
Gandak		37814	1845	4.9
Kosi		61901	1281	2.1
Tista		12432	495	4.0
Raikad		26418	195	0.7
Manas		31080	528	1.7
Subansiri	**Brahmaputra System**	81130	725	4.0
Brahmaputra		256982	108	0.4
Dibang		12950	90	0.7
Luhit		20720	425	2.0

Table 1: The current distribution of glaciers in Hindu Kush-Himalaya

In comparison to summer-accumulation type glaciers, most of which strongly depend on summer air temperature, variations of winter-accumulation type glaciers in the western Himalaya (Karakoram) depend on different combinations of much (little) snowfall in winter and high (low) air temperature in summer. If a combination of much (little) snow in winter and low (high) temperature in summer continues for several years, the tendency of glaciers to advance (retreat) becomes stronger.

2. PERMAFROST

Permafrost refers to permanently frozen ground without ice cover, which has formed due to freezing of underground water and moisture in soil. Permafrost has acted as a carbon sink for millions of years, locking away carbon and other greenhouse gases like methane, for thousands of years. It is estimated that 14 per cent of the world's carbon is stored under this frozen soil. But rising temperatures due to global warming is thawing the permafrost, and permafrost in some areas is now beginning to release its carbon. This could further accelerate the greenhouse effect. Studies indicate that a change in permafrost temperatures of -4 degrees Celsius to -1 degree Celsius (24.8-30.2 degrees Fahrenheit) decreases its ability to store the gases by at least 70 per cent.

There is no significant work in the Hindu Kush-Himalaya on permafrost till now. However, Yabuki, et al. (1994) have done measurements of ground temperature and soil moisture content in the permafrost area in Tanggula Mountains, Tibetan Plateau. According their observation permafrost thickness ranges from 20 to 130 m in the loose sediments, and from 130 m to 200m in the mountainous rocky region. Active layer ranges from 1.1 to 3.2 m in the loose sediments. This layer depth and seasonal variation of frost table depth are said to depend on air temperature and surface layer conditions such as vegetation, soil texture, soil moisture and so on. The seasonal variation of thawing depth of this active layer may be controlled by evaporation from the surface, soil moisture and the water table in the active layer.

Some oil companies in India like ONGC have done preliminary work on permafrost as a possible source of Gas Hydrates, an alternative energy fuel. The Laddakh region in J & K, and some of the regions at HP have the presence of permafrost. There is scope to set-up the permafrost observations in the Hindu Kush-Himalaya.

3. THE PRESENT STATUS OF THE STUDY OF GLACIERS IN EACH HINDU KUSH–HIMALAYA COUNTRY

I N D I A

In the last twenty years, several studies have been led in the Indian Himalaya. Two sites have been especially studied in the Central Himalayan range by Indian Scientists for glaciological purposes:

1. The Chhota-Shigri Glacier (32^0 $20'$ N, 77^0 $30'$ E, 5600-4200 m asl, approx. 10 Km^2) is located in the Chandra Valley (Lahul and Spiti, Himachal Pradesh) a tributary of the Chennab River, Indus Catchment. The glacier lies in a climatic transition zone under both influences from the SW Indian Monsoon during the summer and from the westerlies in the winter. Three scientific expeditious have been organized in 1986, 1987 and 1988. Several papers were published in International Journals among which: Hasnain et al (1989) and Kumar and Dobhal (1997) are noteworthy.

2. The Dokriani Glacier (30^0 51'N, 78^0 48 'E, 5300-4200 m asl, 6 Km^2) is located in the Bhagirathi Valley (Garhwal Himalaya, Uttaranchal), tributary of the River Ganga. The major climatic influence comes from the SW Monsoon. It has been studied from 1992 onwards. Among the various papers published, one can retain: Hasnain and Thayyen (1999) and Singh et al (2000).

Both valleys are equipped downstream with hydraulic works using the water resource for end-users needs.

The International Commission on Snow and Ice (ICSI) in its Bureau meeting held at Boulder, Colorado, USA in 1995 set up a Working Group on Himalayan Glaciology under the chairmanship of Prof. Syed Iqbal Hasnain, Jawaharlal Nehru University, India to prepare a report on the status of glaciology in the region. The Working Group has presented the report at the ICSI Bureau meeting held during Birmnigham, U.K IUGG in 1999. One of the important recommendations was to set-up a Regional Glacier Monitoring Network (RGMN) and to prepare a manual for monitoring the mass balance of mountain glaciers with particular attention to low latitude characteristics. In March 2001 ICSI convened a workshop at Kathmandu, Nepal in association with HKH–FRIEND (Flow Regimes from International Experimental and Network), under the auspices of UNESCO, and outlined the need for a training course to be held in one of the HKH– FRIEND countries (India, Nepal, Bhutan, Pakistan and Bangladesh). The manual was prepared by (G. Kaser, A. Fountain and P. Jansson and published by UNESCO, 59, Paris 2003), and a training course for the participants from India, Nepal and Bhutan was organized on a benchmark glacier Chhota-Shigri, Himachal Pradesh, India during September/ October 2002. During the training course the glacier was equipped with stakes in the ablation zone (mass balance monitoring). The field campaign in September/October 2003 expanded the stakes network, and field data used to calculate first complete annual mass balance (Kumar et al, 2004). The glaciological and hydrological monitoring of Chhota-Shigri glacier (benchmark) is continuing in association with Dr P. Chevallier, Great Ice Group, IRD, Montpellier, France. The Field campaign of September/October 2004 has been done.

N E P A L

Glaciological Expedition by Japanese scientists in collaboration with His Majesty's Government of Nepal started in 1968.

1. Glacier AX0I0 in the Shorong region (270^0 42 'N, 86^0 34 'E) is one of the most studied glaciers in Nepal. Mass balance, areal extent, and terminus retreat have been monitored regularly. The mass balance data is also figured in world Glacier Monitoring Service red book series. The significant papers published by Kadota & Ageta (1992) Kadota et al (1997) and Kayastha et al. (2000).

2. Yala glacier in the Langtang region is another well-studied glacier in the Nepal Himalaya. Ageta et al (1984) and Yamada et al (1992) studied the fluctuation in the terminus of glacier and observed retreat of 5 m. Similar surveys were conducted by Fujita et al. (1998). Another glacier in the Langtong area was studied is debris-covered Lirung Glacier. The Japanese scientists from Nagoya University were mainly involved in the investigations and their long-term air temperature records indicate annual air temperature rise of 0.27^0C per year. In the year 2001 the GEN (Glaciological Expedition Nepal) has published collection of all research papers both in English and Japanese.

Ten scientists from Nepal have participated in the Glacier mass balance training course conducted on benchmark glacier in India organized by the Glacier Research Group, School of

Environmental Sciences, Jawaharlal Nehru University, New Delhi. It has been recommended that ICIMOD in association with Department of Hydrology and Meteorology select a benchmark glacier in Nepal Himalaya to start regular mass balance monitoring. A steam-drilling machine was donated by UNESCO to the ICIMOD for the purpose. The benchmark glacier in Nepal will be the part of the Regional Glacier Monitoring Network (RGMN).

B H U T A N

The Department of Geology and Mines, Bhutan and ICIMOD (International Centre of Mountain Development, Kathmandu) has prepared glacier and glacier lakes inventory by using satellite imageries. There are 677 glacier and 2674 glacier lakes in the northern region of the country. One scientist from Bhutan was trained in the training course organized in India during September/October 2002. A steam-drilling machine was also donated to the Govt. of Bhutan by UNESCO with a request to identify a benchmark glacier and start monitoring mass-balance. The objective was to have a benchmark glacier in far eastern region of Himalaya. The glaciers in Bhutan are nourished by the SW Monsoon and come under the category of 'summer accumulative types.'

P A K I S T A N

The Karakoram, lying immediately north of the western part of the greater Himalaya is the highest of South Central Asian mountain systems. The region contains more than 16,000 km^2 of ice cover with 8 glaciers over 50 km in length and more than 20 over 30 km. Glacial melt waters make a major contribution to the flow of the Indus and sustain the livelihood of some 130 million people.

The Karakoram is very sensitive to climate change impact, since its glaciers lie within the variable influence of three major weather systems: The westerly storms, the SW summer monsoon, and Tibetan anticyclones. Winter storms dominate glacier nourishment. It has been observed by (Hewitt, 1990) and (Mayewski, et al 1980) that the pattern of advance and retreat in the region relates to the changing rigor of the summer monsoon.

In view of regional political consideration Pakistan was excluded from the ICSI/ UNESCO sponsored training course on mass balance held in India in 2002 and Regional Glacier Monitoring Network (RGMN).

4. RECOMMENDATIONS

1. The International Commission on Snow and Ice (ICSI) has provided training on Glacier Mass Balance measurement observation to twenty scientists from India, Nepal, and Bhutan in 2002. All the three countries were provided a steam drilling machine capable of drilling ice up to 12 m for installation of stakes in the ablation zone and density measurement meters. Thus the set-up of a Regional Glacier Monitoring Network (RGMN) within the frame of HKH-FRIEND has been successfully initiated. The next essential steps toward the highly needed target of a HKH RGMN are (1) the evaluation of the first mass balance measurements carried out on the Chhota Shigri (benchmark) Glacier in the Indian Himalaya and (2) the extension of the RGMN into other regions and toward a real and useful network within the HKH region.

2. At least one glacier per country within the Hindu-Kush Himalaya should have standard monitoring protocol:

- Network of monitoring stakes read on a monthly basis;
- Measurement of accumulation in the upper zone twice a year;
- Annual accurate mapping of glacier snout and ablation stakes;
- Cumulative rain-gauges around the glacier read on monthly basis;
- At least one rain-gauge with daily records;
- An hydrometric station on the channel with water level recorder and calibrated flume.

A portable automatic weather station should be installed on the ablation part of the glacier during the summer season from June to October, practically between the two field campaigns of mass balance measurements.

3. The South Asia Centre of the NASA/USGS-sponsored GLIMS project (Global Land Ice Measurements from Space) is located with the Glacier Research Group, Jawaharlal Nehru University, New Delhi, India. GLIMS is tracking glacier changes globally using Stereo multispectral Satellite images acquired since 2000. ASTER offers new capabilities to map and monitor supra-glacier lakes. Satellite monitoring may help us learn about key aspects of the behaviour and potential threat of glacier lakes.

4. A network of permafrost sites in the Hindu Kush-Himalaya could be set-up as part of the GTN-P. Presently the only site data available is in Tanggula Mountains, Tibetan Plateau.

(Intentionally blank)

Annex 15

GENERATING DETAILED SCENARIOS OF CLIMATE CHANGE

Geoff Jenkins and Deborah Hemming
Hadley Centre for Climate Prediction and Research
Met Office, EXETER, UK

Introduction

In order to investigate the impacts of climate change, and plan adaptation to it, all countries need to have estimates of how their climate will change in the future, in the form of scenarios. The only tool we have for predicting change, representing all components of the climate systems, atmosphere, ocean, cryosphere, land surface etc., and the relevant interactions and feedbacks between them, is the global climate model (GCM). In order to run global models even on the largest of supercomputers, the models generally have a resolution of some 300km square, and the predictions from them are not detailed enough to use directly to study impacts and adaptation. Over a distance of 300km there can be great changes in the terrain, such as mountains and coastlines, the effect of which is not adequately captured by global models. Hence we need to be able to downscale the global predictions to give a greater detail over individual countries in order for them to be useable.

Regional Climate Models

The most robust form of downscaling GCM predictions is the use of a regional climate model (RCM). This is a full physical climate model very similar to a GCM, containing the same representations of the climate system, but at a much higher resolution – typically 50km or 25km. Because of computer limitations it can only be run over a limited area (“domain”), typically 5000km x 5000km (about the size of Australia). It is “nested in” (or “driven by”) predictions from a global model, and therefore carries any uncertainty in the GCM predictions. Predictions from RCMs have substantial advantages for impacts studies, viz:

- they show greater geographic detail
- they take account of smaller-scale terrain features such as mountains and coasts
- they resolve smaller-scale weather features such as cyclones
- their representation of current climate is much better than in GCMs
- climate extremes simulated in RCMs are much closer to those observed than simulations in GCMs, and hence changes in extremes will be better predicted.

The Hadley Centre PRECIS regional climate model

In the past, RCMs have required supercomputers or large workstations to run on, and this has generally limited their availability to developed countries. Over the last few years the Hadley Centre RCM group has ported its current regional climate model to work efficiently on a PC, and made it possible for the user to set up the RCM area over anywhere in the world. A straightforward User Interface has been provided, together with analyses and graphical software. The whole system is known as PRECIS; Providing REgional Climate for Impacts Studies. With funding from UK ministries (Defra, Dfid and FCO) and from UNDP, the model is being made freely available to government and related institutes in developing countries.

To run PRECIS, users require a fast PC (the faster the better) with adequate memory and hard disk capacities, a digital tape drive with which to input global data and to store RCM output data. On a 3GHz PC, with a typical setup (50km resolution; 5000km x 5000km domain), PRECIS will run for 10 model years in about 1 month. PRECIS can also incorporate a full sulphur cycle, allowing prediction of aerosol cooling from sulphur dioxide emissions, with an increase of about 50% in run times.

Using PRECIS

To generate climate change scenarios using PRECIS involves ideally running the regional climate model to make a simulation of climate over the period 1961-1990 (the current WMO reference period) and then running to make a climate prediction over a future period (generally 2071-2100) under a particular scenario of future emissions (most commonly the IPCC SRES A2); the basic climate change scenario is the difference between these two. Running the model for as long as 30 years in each case is not essential; 10 years may be sufficient to make an initial estimate of changes in average climate although uncertainty in these estimates due to the effect of natural variability will be larger and little information on changes in climate extremes will be available.

Climate change scenarios for other emissions (for example, SRES A1F1 or SRES B1) or other time periods (for example 2041-2070) can be generated from a single climate change scenario (typically the 2071-2100 SRES A2) by scaling changes by the global temperature predicted by the GCM for the other time periods and emissions. It is normal practice for the climate change scenario to be added to a baseline observational data set (for example, 1961-90) to give the scenario of future climate, rather than using the model predictions directly.

The need for observational data

It is important to validate the model over the area of interest, which can be done in two ways:
(a) by comparing the 1961-90 model climatology with observational data for the same period (both seasonal means and distributions/extremes) and (b) by carrying out a run of the model driven by a re-analysis of global observations, such as that compiled by the European Centre for Medium Range Weather Forecasting (ECMWF) and known as ERA15 (and recently updated and extended to ERA40), and comparing the RCM output with day-to-day or month-to-month observations.

Validation allows users to assess the reliability of the model for specific outputs (e.g., precipitation) and in different regions. It is therefore important in estimating confidence in the predictions. In order to be able to carry out the validation, it is critical that countries maintain and extend national climatological observations, to GCOS standards. A good observational data base is also required to provide the baseline climate of the country (for example, over 1961-90), to which the PRECIS prediction of climate change can be added to form a climate scenario for a future period.

Uncertainties in climate scenarios

The PRECIS system will provide users with a detailed climate change scenario which can be used to investigate impacts. However, it is important the uncertainties in the scenarios are fully understood, so that adaptation can be properly designed to reflect these. The first uncertainty arises from our lack of knowledge of future emissions; this can be taken into account by developing scenarios for a wide range of SRES emissions profiles (for example, A1FI to B1). The second uncertainty is associated with our incomplete understanding of the climate system and our inability to model it perfectly – so called “science” or “modelling” uncertainty. This can be quite large in some regions of the world, as shown in the IPCC Third Assessment report. We can scope the modelling uncertainty by using global fields from a number of GCMs to drive the PRECIS RCM; currently PRECIS can accept the Hadley Centre GCM and soon will be able to accept fields from the German ECHAM4 model. In a few years we aim to have probabilistic GCM predictions to use with PRECIS.

The remaining uncertainty in scenarios is that due to natural variability of the climate system; we do not know if natural variability will act in the same direction as human-made climate change in a particular future period and location and hence accentuate it, or act in the opposite direction and hence reduce its effects. This uncertainty can be quantified by running the global model a number of times with different initial conditions, and driving the PRECIS RCM with each of these global predictions. It is clear from the above that, several experiments with PRECIS will be required in order to take account of these uncertainties, and it is more efficient for the work to be done in a collaboration between several countries, and the model domain chosen to include these countries.

Training for PRECIS users

In order to ensure that PRECIS is used in the most efficient way, but also to ensure that all the uncertainties in scenario generation are properly understood and appreciated, the model will be made available together with a week-long training course, ideally involving users from several neighbouring countries. This has already been done for users in India, China, West Africa (through ACMAD) and Southern Africa, Central America and the Caribbean. In 2004, courses will be run in Bhutan (for several countries on the Indian sub-continent) and Sao Paulo (for several South American countries). We would like to plan further courses in 2005 with groups of countries in other parts of the world.

Using PRECIS predictions

We believe that regional climate models such as PRECIS can provide useful information on future climate change, with clear advantages of corresponding GCM predictions, whilst always bearing in mind the uncertainties inherent in GCMs. The use of PRECIS by local centres of expertise will give national ownership of the scenarios. The scenarios can then be used:

(a) in publications, to effectively raise national awareness of climate change as an issue
(b) in National Communications to the UNFCCC
(c) to feed into models which estimate the impacts of change on agriculture, water resources, infrastructure, etc.

Hence PRECIS, used in conjunction with impacts models, will aid choice of efficient adaptation, through the process of mainstreaming climate change in planning by governments and businesses.

(Intentionally blank)

Annex 16

HIGH-RESOLUTION CLIMATE CHANGE SCENARIOS FOR SOUTH ASIA USING THE REGIONAL CLIMATE MODEL PRECIS

K. Rupa Kumar, S.K. Patwardhan, A.K. Sahai and K. Kamala
Indian Institute of Tropical Meteorology
Pune, India

The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) notes that the current versions of atmosphere ocean general circulation models (AOGCMs) have generally well simulated the features of the present day climate at the large and continental scale. The TAR also notes that the AOGCM resolution limitations, especially for impact application, are likely to remain for many years, so that regionalization work will be an important step to better understand regional climate change processes and to provide regional information for impact assessments. The effects of climate change are expected to be greatest in the developing world, especially in countries reliant on primary production as a major source of income. One of the high priorities for narrowing gaps between current knowledge and policymaking needs is the quantitative assessment of the sensitivity, adaptive capacity, and vulnerability to climate change, particularly in terms of the major agro economic indicators, which largely depend upon regional/local manifestations of climate change. Keeping in view the widely felt need for high-resolution regional scenarios of climate change for impact assessment studies, this project uses state-of-art techniques to dynamically downscale the global model projections for the Indian region.

Development of high-resolution climate change scenarios for India using the regional climate models (RCM) developed by the Hadley Centre for Climate Prediction and Research, Meteorological Office, UK constitutes one of the core projects of a Joint Indo-UK collaborative research programme on climate change impacts in India, in operation over the past 3 years. In the initial phase of the project, simulations performed by the Hadley Centre using an earlier version of the RCM, HadRM2, for present-day concentrations of greenhouse gases (GHG) and a future scenario (IS92a) of transient increase of GHGs up to the 2050s have been analysed to assess model skills and provide quantitative estimates of future changes at a resolution of ~50 x 50 km. Some additional scenarios using a pattern-scaling approach for the time slices 2020s and 2080s have also been developed. These scenarios have been extensively used in impact assessments by other groups in the Indo-UK programme, as well as several other projects under NATCOM, APN, START, etc.

The latest version of Hadley Centre Regional Climate Model, PRECIS developed by Hadley Centre has been used to generate the climate for the present (1961-1990) and a future period (2071-2100) under two different socio-economic scenarios both characterized by regionally focused development but with priority given to economic issues in one and to environmental issues in the other. The model simulations are performed with and without including the sulfur cycle, to understand the role of regional patterns of sulfate aerosols in climate change. Three ensembles have been simulated for the baseline, to estimate the uncertainties associated with the internal variability of the model. The lateral boundary conditions for PRECIS have been supplied by the Hadley Centre, which generated them through a two-tier strategy using global atmosphere-ocean (HadCM3) coupled and global atmospheric (HadAM3) general circulation models.

The high-resolution regional simulations generated using PRECIS have been studied in detail to evaluate the model's skills in realistically representing regional climatological features, especially summer monsoon characteristics. Mean climatologies, as well as extreme climatic events have been considered for this purpose. Extensive observational data over the past century and also reanalysis data have been used for model evaluation. PRECIS, by a better representation of the high-resolution features of the regional climatic processes, has been able to provide a vastly more realistic description of the local variations. The results indicate an all-round warming over the Indian subcontinent associated with increasing greenhouse gas concentrations, and also a slight increase in summer monsoon precipitation.

High-resolution regional climate change scenarios have been developed for various surface and upper-air parameters of critical importance to the impact assessments, both on monthly and daily time scales. The scenarios for the time slice 2071-2100 have been directly derived from the model simulations, but those for the time slices 2020s and 2050s have been derived from a pattern-scaling approach. Considerable effort is being made to archive the huge amount of scenario data products, and also to package the data products for direct use in impact assessment projects. Data are being provided to the impact assessment groups in the formats required by them. The scenario data generated under this project constitute one of the best sources of scientifically derived regional climate change estimates for the Indian subcontinent, and are expected to benefit a variety of climate change studies in the years to come, not only for India but also for the neighbouring countries.

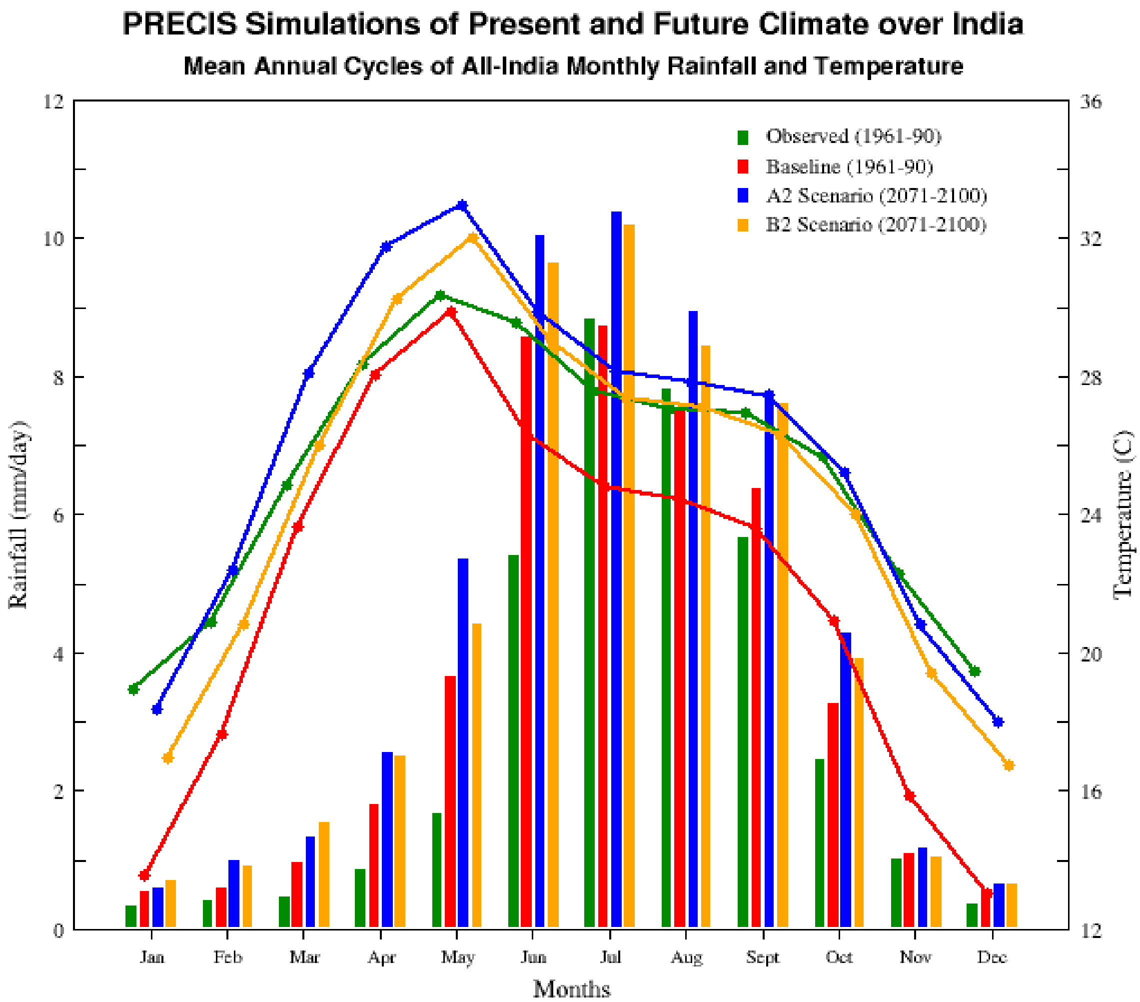


Figure 1. Observed and PRECIS-simulated Mean annual cycles (baseline for 1961-90 as well as projections for 2071-2100) of all-India mean rainfall and surface air temperature.

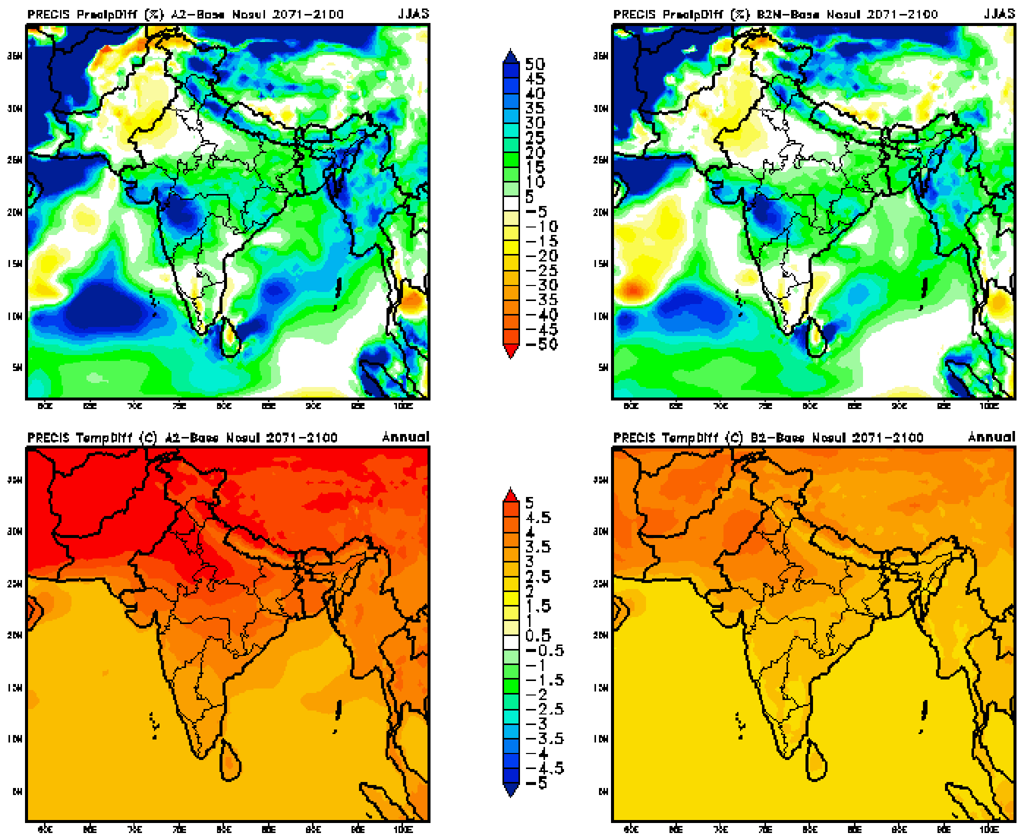


Figure 2. Spatial patterns of the changes in summer monsoon (JJAS) rainfall (%) and annual mean surface air temperature (°C) for the period 2071-2100 with reference to the baseline of 1961-1990, under two different SRES socio-economic scenarios, namely A2 and B2.

Annex 17

SATELLITE OBSERVATIONS FOR CLIMATE STUDIES OVER SOUTH AND SOUTHWEST ASIA: CURRENT STATUS AND FUTURE PROSPECTS

P.C. Joshi, Atmospheric Sciences Division
Meteorology & Oceanography Group, Space Applications Centre (ISRO)
Ahmedabad, India

The South and Southwest Asian region is a unique region encompassing different climate regimes. The vast oceanic region to its south has a strong controlling effect. The region is also the playground of Southwest monsoon vagaries. *In situ* observations cover only a small part of the region. Satellite observations thus play a crucial role. In the present paper we discuss the status, deficiencies and needs for satellite observations in South and Southwest Asia.

The region is covered by the Indian space observations programme and also international operational as well as R&D Missions. India has launched nine geostationary meteorological satellites to date, including INSAT-1 (four), INSAT-2 (three), INSAT-3 (one), and Kalpana-1 (one). At present three of these are in orbit: Kalpana (74° E), INSAT-2E (83° E), and INSAT-3A (93.5° E). INSAT-3A and Kalpana have VHRR with 2 Km. and 8 Km. resolution for visible and infrared / water vapour channels. INSAT-2E/3A carry an additional payload of a charged-coupled device (CCD) (visible, NIR, SWIR bands) with 1 Km. resolution.

The majority of satellites launched under the IRS series (polar orbiting) are meant for applications in resources management. IRS-P3 and IRS-P4, however, have many climatological applications. IRS-P3 launched in 1996 carried a modular opto-electronic scanner (MOS) operating in 18 narrow channels in the visible and near infrared bands (0.75-1.6 μm). IRS-P4 launched in 1999 carries a multi-frequency scanning microwave radiometer at 6.6, 10, 18, and 21 GHz in vertical and horizontal polarization. IRS-P4 additionally caries an ocean colour monitor (OCM) and has the capability to estimate chlorophyll and aerosols over the oceanic environment.

Among International missions METEOSAT, NOAA, TRMM & DMSP (particularly SSM/I) are the main satellites providing data over the region. Indian and international satellite data missions are used for variety of climatological applications in the region. Desertification and aerosols need to be observed by satellites for assessing their role in regional climate. A major thrust has been in the field of monsoon circulation. A major area emerging currently is the generation of land surface data from satellites and its use in regional climate models for impact studies.

In the near future India has plans to launch three important satellites: Megha-Tropique (with a microwave radiometer and sounder and radiation budget instrument), INSAT-3D (with an infrared sounder and advanced imager), and Oceansat-2 (with a Ku band scatterometer). The concept of a new series, “CLIMATSAT,” is under discussion for studying the climate of the region. The presentation will include the details of the missions and potential applications in the region.

A web based Meteorological and Oceanographic Satellite Data Centre (MOSDAC) is being set up at the Space Applications Centre (ISRO) in Ahmedabad. It will contain meteorological / climatological data from various Indian & international satellite missions.

The following observations need attention and discussion:

(i) Easy accessibility of the data to the users.
(ii) Retrieval and validation of satellite estimated parameters in different parts of the region.
(iii) More involvement of academic and national institutions in the region.
(iv) A tie-up with satellite observations over other regions for feedback to global climate change scenarios.
(v) A need for capacity-building for usage of satellite data.

Annex 18

LIST OF ACROYNYMS

BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CBS	Commission for Basic Systems (WMO)
CEOS	Committee on Earth Observation Satellites
CLICOM	CLImate COMputing
COP	Conference of the Parties (to UNFCCC)
DWD	Deutscher Wetterdienst
ETCCDMI	Expert Team on Climate Change Detection, Monitoring and Indices
GAW	Global Atmosphere Watch
GCMs	Global Climate Models
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GLIMS	Global Land Ice Measurements from Space
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GSN	GCOS Surface Network
GTN-P	Permafrost Monitoring Network
GUAN	GCOS Upper-Air Network
IMD	India Meteorological Department
IBPIO	International Buoy Programme for the Indian Ocean
IODE	International Oceanographic Data and Information Exchange
IOGOOS	Indian Ocean Global Ocean Observing System
IOP	Indian Ocean Panel
IPCC	Intergovernmental Panel on Climate Change
IRS	Indian Remote Sensing
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
LDCs	Least-Developed Countries
MDGs	Millenium Development Goals
MOSDAC	Meteorological and Oceanographic Satellite Data Centre
NASA	National Aeronautics and Space Administration
ODINCINDIO	Ocean Data and Information Network for the Central Indian Ocean
PR	Permanent Representative (WMO)
RBCN	Regional Basic Climatological Network
SBSTA	Subsidiary Body for Scientific and Technological Advice (UNFCCC/COP)
SIDS	Small Island Developing States
SST	Sea-Surface Temperature
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

USGS	US Geological Survey
WCP	World Climate Programme
WMO	World Meteorological Organization
XBT	Expendable Bathythermograph

Global Atmosphere Watch