ANNUAL REVIEW OF THE WORLD CLIMATE RESEARCH PROGRAMME

AND

REPORT OF THE TWENTY-SECOND SESSION OF THE JOINT SCIENTIFIC COMMITTEE (Boulder, CO, USA, 19-23 March 2001)

1. ANNUAL SESSION OF THE JOINT SCIENTIFIC COMMITTEE FOR THE WORLD CLIMATE RESEARCH PROGRAMME

The principal task of the annual session of the WMO/ICSU/IOC Joint Scientific Committee (JSC) for the World Climate Research Programme (WCRP) is to review the scientific progress in the programme during the preceding year. Through arrangements kindly made by Drs K. Trenberth and S. Solomon, the 2001 session of the JSC, the twenty-second, took place in Boulder, CO, USA meeting at the Mesa Laboratory of the National Center for Atmospheric Research (NCAR), and also, for part of the time at the NOAA Laboratory in Boulder itself. The session was opened by the Chairman of the JSC, Professor P. Lemke, at 0900 hours on 18 March 2001. The list of participants is given in Appendix A. This report summarizes the information presented to the JSC on the progress in the WCRP during the preceding year and records the recommendations by the JSC for the further development of the programme (these recommendations are compiled for convenience in Appendix B).

Dr T. Killeen, Director of NCAR, welcomed all participants and expressed his pleasure that the session of the JSC was being held in Boulder. The role of NCAR, supported by the USA National Science Foundation, was to serve as a focus for research on atmospheric and related science problems. Much of the work carried out at NCAR was thus directly relevant and important for the WCRP. Dr Killeen wished participants a pleasant and enjoyable stay in Boulder and offered any assistance necessary from NCAR to ensure the success of the JSC session.

The Chairman of the JSC thanked Dr Killeen for his welcome and expressed on behalf of all attending gratitude for the arrangements made for the session of the JSC in Boulder, the excellent facilities provided and hospitality offered. He especially thanked Drs K. Trenberth and S. Solomon for the efforts and time they had put into the organization of the session.

The Chairman spoke of his own pleasure at having been elected to serve as Chairman of the JSC, and looked forward to presiding, for the first time, over a session of the Committee. There were many challenges to be faced. In particular, the JSC needed to give thought to the long-term future of the WCRP and the desirable balance between WCRP core investigations of the physical climate system and the increasing need to be involved with the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions of Global Environmental Change Programme (IHDP) in broader Earth system science and global environmental change activities.

The Chairman continued by extending greetings to participants in the JSC session, particularly to new members of the Committee attending for the first time, namely Professor P. Cornejo (Escuela Superior Politecnical de Litorale, Guayaquil, Ecuador), Dr K. Denman (Canadian Centre for Climate Modelling and Analysis, University of Victoria, Canada), Dr S. Gulev (P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russian Federation), Dr V. Meleshko (Main Geophysical Observatory, St Petersburg, Russian Federation), Professor L.A. Ogallo (Drought Monitoring Centre, Nairobi, Kenya), and Dr G.B. Pant (Indian Institute of Tropical Meteorology, Pune, India). The Chairman noted with regret that three of the recently appointed members (Professor J. Shukla, Center for Ocean-Land-Atmosphere Studies, Calverton, MD, USA), Professor T. Yasunari (University of Tsukuba, Japan) and Dr M.T. Zamanian (Islamic Republic of Iran Meteorological Organization) were unable to attend, as well as Dr D. Cariolle of the longer-serving JSC members. The particular reason for the absence of Professor Shukla was that he was receiving during the week of the JSC session the first Sir Gilbert Walker Indian Meteorological Society Gold Medal, a new international award created by the Indian Meteorological Society and to be awarded biennially to a distinguished international scientist having made a significant contribution to monsoon studies. On behalf of the Committee, the Chairman expressed warmest congratulations to Professor Shukla for his achievement and this well-deserved recognition of his work. A message was sent to Professor Shukla relaying the congratulations of the JSC.

The Chairman acknowledged with appreciation the participation of observers on behalf of two of the organizations sponsoring WCRP: Mr A. Alexiou, IOC; Dr D. Carson (as well as Director of the WCRP), WMO. ICSU was unfortunately not able to be represented on this occasion. The Chairman also noted with pleasure the attendance of Professor B. Moore, Chair of the Scientific Committee for IGBP, and Professor A. Underdal, Chair of the Scientific Committee for IHDP. In view of the growing interactions between the global environmental change programmes, representation by each in the sessions of the main scientific committees of the others was now essential. Professor Yan Hong, Vice-president of the WMO Commission for Atmospheric Sciences (CAS), would speak on behalf of this body as needed.

The Chairman voiced his gratitude for the customary participation of the chairs or representatives of WCRP steering or working groups who would brief the JSC on activities in their respective fields and advise on future actions to be taken. These included: Dr A. Busalacchi, Co-chair of the CLIVAR Scientific Steering Group; Dr H. Cattle, Chair of the ACSYS/CliC Scientific Steering Group, and Dr I. Alison and Dr R.G. Barry, Vice-chairs of the ACSYS/CliC Scientific Steering Group; Dr M.-L. Chanin and Professor M. Geller, Co-chairs of the SPARC Scientific Steering Group; Drs P. Killworth and W.G. Large, Co-chairs of the WOCE Scientific Steering Group; Dr K. Puri, Chair of the CAS/JSC Working Group on Numerical Experimentation (WGNE); Professor S. Sorooshian, Chair of the GEWEX Scientific Steering Group; Dr P.K. Taylor, Co-chair of the JSC/SCOR Working Group on Air-Sea Fluxes (Dr S. Gulev, the other Co-chair of the Working Group on Air-Sea Fluxes, was also present in his capacity as a member of the JSC).

The Chairman was especially pleased to note the attendance of Dr C. Dick, the new Director of the ACSYS/CliC International Project Office and who had taken up his duties in June 2000 and was thus present at a JSC session for the first time. Dr P. Try, Director of the International GEWEX Project Office, and Dr J. Gould, Director of both the International WOCE and International CLIVAR Project Offices were participating as they now had done over a period of several years. Dr M.-L. Chanin, as well as Co-chair of the SPARC Scientific Steering Group, represented the SPARC Office.

The Chairman welcomed Professor P. Tyson, who was taking part in the session as Chair of the Scientific Steering Committee for the joint WCRP/IGBP/IHDP global change System for Analysis, Research and Training (START). The Chairman was gratified by the interest manifested by GCOS with the attendance of Dr P. Mason, Chair-designate of the GCOS Steering Committee, as well as Drs M. Manton and N. Smith as Chairs of, respectively, the joint WCRP/GCOS Atmospheric Observation Panel for Climate (AOPC) and the Ocean Observations Panel for Climate (jointly sponsored by WCRP, GCOS and the Global Ocean Observing System, GOOS). The Chairman also noted with pleasure that Dr L. Charles (NASA Headquarters and NASA representative to the Committee on Earth Observing Satellites, CEOS) and Dr D. Clark (National Geophysical Data Center and World Data Centers, NOAA/NESDIS in Boulder and NOAA representative to CEOS) would be present for the discussion of the key relationship between WCRP and the space agencies (agenda item 2.5) and that Dr T. Koike would provide details of the steps towards the implementation of the Co-ordinated Enhanced Observing Period (CEOP)(see agenda 5.3). Finally, the Chairman observed with particular satisfaction the attendance of Dr W.L. Gates, past Chair of the JSC, who would clearly be able to give valuable advice on many of the issues to be considered by the JSC.

The Chairman looked forward with anticipation to the scientific lectures by leading local scientists that had been arranged, namely "The tropical tropopause regions: interannual and long-term variations" by Dr G. Reid, NOAA Aeronomy Laboratory and the Co-operative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado, and "Climate Modelling at NCAR" by Dr J. Kiehl, NCAR.

2. REVIEW OF OVERALL PROGRESS AND CO-ORDINATION OF THE WCRP

2.1 Main developments and events since the twenty-first session of the JSC

Fifty-second session of the WMO Executive Council

The progress report on the WCRP was well received by the fifty-second session of the WMO Executive Council (Geneva, May 2000). Favourable comments were made on the implementation of a number of specific activities, including the CLIVAR studies of the Variability of the American Monsoon System (VAMOS), of the Asian-Australian monsoon, and of African climate variability. The Council had particularly looked forward to being informed of the results of the GEWEX Co-ordinated Enhanced Observing Period (CEOP) and the prospect offered of assessing the influence of continental heat and moisture sources and sinks on the global climate system and its anomalies. More generally, the Council stressed the importance of close collaboration between WCRP projects and GCOS in building up the multi-year global observational datasets required in the investigation of all aspects of climate, and reiterated the complementary roles of WCRP and GCOS in improving global climate observing systems (see section 2.3 for further discussion of interactions between WCRP and GCOS).

Another item raised stemmed from a letter from the Chairman of the Standing Meteorological Committee of the League of Arab States to the Secretary-General of WMO urging that attention be given to the improved understanding of climate processes and the potential effects of climate change in arid and desert areas, especially those prevalent in many Arab States. The WMO Executive Council strongly encouraged the JSC to consider the additional research that needed to be undertaken in CLIVAR and GEWEX to meet this challenge. The Council advised the JSC to draw fully on the scientific interest in and expertise on this topic that already existed in Arab States.

In considering this request, the JSC recalled that the Conference on the WCRP in 1997 had already emphasized that special attention needed to be given to sensitive key regions (such as arid or desert areas, mountainous zones, polar regions, and small island countries) and to understanding the climate processes having an important role in these sensitive regions). It had been recommended that appropriate regional projects, involving local concerned nations and drawing on local expertise, should be promoted. The JSC now saw an important opportunity for WCRP to develop appropriate activities in arid and desert areas, including the possibility of collecting valuable new observational data. It was emphasized that questions relating to arid and desert areas needed to be seen in an overall global context and links to other aspects such as the Asian-Australian monsoon, African climate variability and the North Atlantic Oscillation should be explored. The role of the high optical thicknesses of mineral aerosols in desert regions might also be taken up. In relation to hydrological aspects, it was noted that the US National Academy of Sciences had recently completed a comprehensive multi-year study of water management in middle Eastern countries and that this might also be a useful source of information.

The JSC suggested that a WCRP Task Team or Planning Committee should be set up to consider how best to carry forward the research needed and/or undertake initiatives that would lead to an improved understanding of climate processes and the effects of climate change in arid and desert areas. The JSC invited the GEWEX and CLIVAR Scientific Steering Groups to nominate representatives for the Task Team, which was expected also to include a senior research scientist from the Meteorology and Environmental Protection Agency (MEPA) in Saudi Arabia.

Regarding the modus operandi of the Task Team, the JSC agreed that, at this stage, a fairly open brief (but on the general lines set down by the WMO Executive Council and the JSC itself) was appropriate. A starting point might be to review current work going ahead (especially in the WCRP) which could help in an improved understanding of the climate processes that play a part in maintaining arid and desert areas and how climate change may affect (enhance?) aridity or desertification. Additional activities needed in WCRP to make further advances in the required understanding and knowledge could then be recommended. These might encompass observational studies and even dedicated field programmes, as well as theoretical and modelling investigations. Subsequently (or alternatively), it might be thought appropriate to plan a workshop or seminar to review the overall status of science in this area, and to agree on recommendations for what else needed to be done. Such a workshop could bring together interested scientists/experts from the international scientific community as well as from arid and desert regions (in particular Arab States). The Task Team should submit a report on its progress and plans to the Chairman of the JSC for the twenty-third session of the Committee in March 2002 (and subsequent sessions as required).

In discussion of another agenda item ("WMO satellite activities") at the Executive Council, the WMO mechanism for policy level interaction with operators of environmental satellites was considered. Consultative meetings were being arranged between WMO and senior personnel of agencies providing environmental observation satellites. The first such meeting had taken place in January 2000, but without WCRP involvement. The Executive Council at its fifty-second session noted that the meetings were germane to the needs of all WMO programmes including WCRP (and GCOS). Thus, for the future, WCRP would be invited to participate in the consultative meetings thus ensuring that the observational needs for climate research would be directly considered. The Director of the WCRP had participated in the second meeting in January 2001 (see section 2.4 where the relationship between WCRP and space agencies is further discussed),

Intergovernmental Oceanographic Commission (IOC)

The Director of the WCRP had attended the thirty-third session of the Executive Council of IOC (Paris, June 2000). He had drawn attention to climate research priorities in the coming years, noting in particular the crucial role of, and need for, systematic and sustained observations of all the key climate variables. The Director of WCRP expressed his anticipation of continuing strong support from IOC for the WCRP. The JSC was also informed that IOC was planning and hosting a "Global Conference on Oceans and Coasts at Rio +10: Assessing Progress, Addressing Continuing and New Challenges", to be held in Paris in December 2001. The Conference would aim to provide an assessment of the progress achieved in all aspects of the post-UNCED (Rio 1991) agenda for oceans and coasts, to identify the continuing and new challenges, and to examine ocean and coastal sector cross-cutting issues. The JSC invited the Director of the WCRP to follow the development of the planning and organization of the Conference and to respond positively to any specific requests from the IOC for input or representation of the WCRP.

Intergovernmental Panel on Climate Change (IPCC)

Professor Y. Ding, in his capacity as Co-chair of IPCC Working Group 1, described the concluding stages of the IPCC Third Assessment. Reports from the three working groups, including summaries for policy makers, technical summaries, and extensive basic scientific material, had been approved by working group plenary meetings. The reports were being considered by the full IPCC plenary session in April 2001 and were expected to be formally accepted.

The Working Group 1 Assessment Report was, of course, of direct interest and concern to the WCRP. The report reiterated that "further action is required to address remaining gaps in information and understanding", particularly in respect to improving the ability to detect, attribute and understand climate change, to reduce uncertainties, and to project future climate changes. Specifically, there was a need for additional systematic and sustained observations, modelling and process studies. High priority areas for action identified were:

- Systematic observations and reconstructions:
    - Reverse the decline of observational networks in many parts of the world.
    - Sustain and expand the observational foundation for climate studies by providing accurate, long-term, consistent data including implementation of a strategy for integrated global observations.
    - Enhance the development of reconstructions of past climate periods.
    - Improve the observations of the spatial distribution of greenhouse gases and aerosols.

- Modelling and process studies:
    - Improve understanding of the mechanisms and factors leading to changes in radiative forcing.
    - Understand and characterise the important unresolved processes and feedbacks, both physical and biogeochemical, in the climate system.
    - Improve methods to quantify uncertainties of climate projections and scenarios, including long-term ensemble simulations using complex models.
    - Improve the integrated hierarchy of global and regional climate models with a focus on the simulation of climate variability, regional climate changes and extreme events.
    - Link more effectively models of the physical climate and the biogeochemical system, and in turn improve coupling with descriptions of human activities.

Cutting across these foci were crucial needs associated with strengthening international co-operation and co-ordination in order to better utilise scientific, computational and observational resources. This should also promote the free exchange of data among scientists. A special need was to increase the observational and research capacities in many regions, particularly in developing countries. Finally, there was a continuing imperative to communicate research advances in terms relevant to decision making, a goal to which the IPCC Working Group 1 Assessment was contributing.

Professor Ding continued by drawing attention to the plans for the next assessment which was being considered for the period 2002-2006, aiming for completion in 2007 before the first commitment period in the Kyoto Protocol. Particular foci of the assessment would be modelling, the carbon cycle (biogeochemical and biogeophysical processes), extreme events, regional climate prediction, consequences of anthropogenic interference and uncertainties. It was hoped to continue to entrain the WCRP community fully in the preparation of the report.

The JSC was pleased to observe how relevant WCRP activities in many areas were to the priority research requirements as expressed by IPCC (especially to the "modelling and process studies" highlighted above). The JSC also recognized the high quality of the work and science in the IPCC reports. However, the JSC reiterated its concern at the major demands placed on the available time of scientists by IPCC assessments, and accordingly viewed with disquiet the plan that a further assessment would begin in 2002. It was agreed that the Chairman of the JSC should write to the Chairman of the IPCC emphasizing that WCRP was making (and was happy to make) as many contributions as possible to the IPCC assessments. The letter would point out that WCRP would certainly consider how to reinforce efforts in the research priority areas signalled in the Third Assessment Report, and that WCRP would welcome improved collaboration with IPCC identifying additional issues that WCRP might take up. Nevertheless, attention would also be drawn to the demands on scientists' time of the 5-year cycle of assessments and suggesting the possibility of "streamlined" assessments (i.e. not a full account of all aspects in each assessment).

2.2 Highlights of activities in the WCRP

The Chairman recalled the overall objectives of the WCRP, namely to determine to what extent climate can be predicted and the extent of man's influence on climate. These objectives were reaffirmed at the Conference on the WCRP in August 1997. The Conference also recommended overall research priorities for the coming years:

- assessing the nature and predictability of seasonal to interdecadal variations of the climate system at global and regional scales, and providing the scientific basis for operational predictions of these variations for use in climate services in support of sustainable development;

- detecting climate change and attributing causes, and projecting the magnitude and rate of human-induced climate change, regional variations, and related sea level rise (as needed for input to the IPCC, UNFCCC and other Conventions).

These priorities gave clear emphasis to providing practical deliverables of global relevance and value. Furthermore, the Conference urged that WCRP maintain awareness of and sensitivity to evolving user requirements.

The basic approach of WCRP has been and continued to be the encouragement of the fundamental research required into understanding the behaviour of the physical climate system through a number of large-scale research, observational and modelling projects and related activities. Detailed accounts of achievements in the various components of the WCRP over the past year, and specific issues on which the advice and guidance of the JSC were required are included in the subsequent sections of this report. Specific highlights noted during the initial review of main developments since the twenty-first session of the JSC included the strategic planning process undertaken within GEWEX to recommend changes in objectives, primary science questions and new activities that might be needed as GEWEX moved ahead (see section 5.1). The JSC would be especially interested to see progress in the long-standing critical problem of cloud-radiation feedback. The steps towards the implementation of the GEWEX Co-ordinated Enhanced Observing Period (CEOP) were also of particular importance.

In CLIVAR (see section 9), plans for internationally co-ordinated activities were continuing to be developed, with notable progress in the study of the Variability of the American Monsoon System (VAMOS). A new CLIVAR Ocean Observation Panel has also been established to provide oversight of all the sustained and near-sustained ocean observations, including an ENSO observing system, required to support CLIVAR research. Co-operation with the IGBP Past Global Changes (PAGES) has continued to develop, and the Working Group on Climate Change Detection, sponsored jointly by CLIVAR and the WMO Commission for Climatology, has recently organized two very successful regional workshops to develop climate indices using daily time-series data.

The JSC noted that WOCE was now well into its final stages and the series of workshops to complete the Analysis, Interpretation, Modelling and Synthesis (AIMS) phase (see section 8.1) was continuing. A book based on lectures at the WOCE 1998 conference was about to be published, and funding had been secured to support the production of atlases of physical and chemical properties of the global oceans based on WOCE observations. Planning was underway for a final WOCE Conference in late 2002. The JSC would need to ensure that all aspects of the study of the ocean's role in climate would continue to be addressed as required after the conclusion of WOCE (some of the research at least would be taken up by CLIVAR).

Following the formal establishment of CliC as a WCRP project at the twenty-first session of the JSC, the first session of the new ACSYS/CliC Scientific Steering Group was held in October 2000 (see section 10). ACSYS would formally conclude at the end of 2003 and it would be necessary to ensure a smooth transition to CliC of ACSYS activities that needed to be continued. Some of the ACSYS hydrological studies might be taken up by GEWEX.

The highlight in SPARC in the past year was the Second SPARC General Assembly ("SPARC 2000") in November 2000. The event was highly successful with over 300 participants and the results underlined the validity of the approach now being developed by the SPARC Scientific Steering Group to integrate more closely the various activities being undertaken, in particular, to examine variations of the stratospheric circulation and fields of temperature, water vapour, and ozone together (see section 6.3.4). The important SPARC Water Vapour Assessment, a state-of-the-art appraisal of the concentration, distribution and variability (including trends) of water vapour in the upper troposphere and lower troposphere (see section 6.3.3) had been published.

In the area of climate modelling, two significant workshops had been organized, the first in October 2001 by the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) on decadal predictability (see section 4.2.10), the second jointly by the Working Group on Numerical Experimentation (WGNE) and the Australian Bureau of Meteorology Research Centre on the current status of model systematic errors (Melbourne, Australia, October 2000)(see section 4.1.2). Another significant development was the discussion of a joint approach to study of the cloud-climate forcing problem by WGCM and the GEWEX Radiation Panel. WGCM was also planning with the Global Analysis, Interpretation and Modelling (GAIM) element of IGBP, the organization of co-ordinated experimentation with carbon dioxide as a prognostic variable (see section 4.2.11). Among the studies undertaken by WGNE, the evaluation and intercomparison of the global surface flux products from the main numerical weather prediction centres (the "SURFA" project) has attracted interest from GCOS and from such activities as the Global Ocean Data Assimilation Experiment (GODAE) (see section 4.1.7).

Another notable event was the publication of the landmark report by the JSC/SCOR Working Group on Air-Sea Fluxes (WGASF), a comprehensive assessment of the state of the art in regard to air-sea flux determination. Leading on from this, a WCRP/SCOR workshop on intercomparison and validation of ocean-atmosphere flux fields was being organized (to be held in Washington D.C. in May 2001) (see section 7.1). This could be expected to give directions for the overall WCRP approach needed to make progress in determining air-sea fluxes more accurately.

2.3 Climate monitoring and co-operation/liaison with global climate observing initiatives

Global Climate Observing System (GCOS)

Dr P. Mason, Chair-designate of the GCOS Steering Committee, presented a report on GCOS, emphasizing the major challenges faced as GCOS moved from the planning phase to implementation. Progress was being made, notably by the Atmospheric Observation Panel for Climate, AOPC, and the Ocean Observations Panel for Climate, OOPC (see below), but GCOS achievements needed to be advertised, and many more supporting national actions stimulated.

Interactions with UNFCCC were continuing, namely following up the decisions at the Fifth Conference of the Parties (COP-5) of the UNFCCC (Decision 4/CP.5 - Revised guidelines for the preparation of national guidelines related to research and systematic observation; Decision 5/CP.5 - Deficiencies in climate observing networks) (these decisions were reported in full at the twenty-first session of the JSC). GCOS has duly endeavoured to engage the UNFCCC Parties in the major issues related to systematic observation and to inform them of the GCOS progress and plans. To this end, a paper "The Global Climate Observing System: progress report on developments in global observing systems and activities related to Decision 5/CP.5" was submitted to the thirteenth session of the COP Subsidiary Body on Scientific and Technical Advice (SBSTA) that took place in conjunction with the sixth session of COP in November 2000. Attention was drawn to the continuing degradation in components of the Global Observing System (in particular the GCOS Surface Network, GSN, and the GCOS Upper Air Network, GUAN). This was noted with concern, and it was agreed that Parties needed to work actively together to reverse the trend. It was also recognized in this context that the IGOS Partnership (see section 2.4) had an important role in developing global observing systems for the oceans and the carbon cycle (particularly terrestrial sources and sinks), and in supporting systematic observation. The outcome of the first GCOS regional workshop (held in Samoa in August 2000), which highlighted the capacity-building that was needed in the South Pacific region to support systematic climate observations, had also been relayed to SBSTA. A further report was planned to be submitted to the next session of SBSTA in May 2001 summarizing, firstly, the progress in defining and implementing a "synthesis" process for the detailed reports from Parties that should be presented at the next UNFCCC Conference of the Parties in November 2001, and, secondly, recent developments in global observing systems for climate. Subsequently a broader "adequacy" report would be prepared and Dr Mason looked forward to WCRP participation in and contributions to this work. Another aspect of this was to give clear guidance on the basic and broader needs of GCOS for space-based requirements as requested by the consultative meeting between WMO and senior personnel from space agencies providing environmental observation satellites (see section 2.1).

In regard to the basic organization of GCOS itself, it was noted that the (GCOS) Global Observing Systems Space Panel, which was intended to serve the needs of both GCOS and the Global Terrestrial Observing System (GTOS) had been discontinued. In the case of GCOS, the issue of the space-based observations needed to complement in situ measurements would now be dealt with in a more integrated way by including two remote-sensing experts on AOPC and OOPC. The GCOS Steering Committee was also seeking to establish direct liaison with CEOS. Another change was that the Joint Data and Information Panel had been dissolved, thus placing extra responsibilities on AOPC and OOPC. The Global Observing System Information Centre (GOSIC) had assumed a key role as a reference centre enabling access to the increasingly wide variety of data sets from all the three global climate observing initiatives (GCOS, GOOS and GTOS).

In conclusion, Dr Mason reiterated the importance of co-operation and interaction between WCRP and GCOS in view of the complementarity and interdependence of the two programmes. On one hand, WCRP was a key partner in the GCOS implementation strategy, on the other, full account would be taken in GCOS of the priorities and requirements of climate research. In this respect, whilst AOPC and OOPC were represented at JSC sessions (by virtue of the WCRP co-sponsorship), the (GCOS/GTOS) Terrestrial Observation Panel for Climate (TOPC) was not. Dr Mason raised the question of whether TOPC should also be invited to attend. The JSC requested that the Chairman and the Director of the WCRP further discuss this matter with the Chair of the GCOS Steering Committee and the Director of GCOS.

WCRP/GCOS Atmospheric Observation Panel for Climate (AOPC)

Dr M. Manton, Chair of AOPC, reported how the work of the panel was developing. Particular attention continued to be given to building up an effective GCOS Surface Network (GSN) and GCOS Upper Air Network (GUAN). Operational monitoring of GSN performance was now being undertaken by Deutscher Wetterdienst and JMA, and of GUAN by the United Kingdom Meteorological Office, the US National Climatic Data Centre, and ECMWF. Much remained to be done to ensure the quality and consistency of data and that reports were submitted routinely by GSN and GUAN stations. In parallel, progress was being made in building up a historical GSN data archive at the US National Climatic Data Centre.

AOPC had also established, with the OOPC (see below), a joint task group to examine and evaluate differences between various sea surface temperature and sea-ice analyses, to identify sources of discrepancies, and to recommend steps to be taken to ensure the quality and consistency of the analyses. Among other ocean-related issues being considered by AOPC was the data coverage provided by drifters, in particular measurements of sea-level pressure, climate observations from voluntary observing ships (to which 200 ships contribute), and the opportunities offered by the Automated Shipboard Aerological Programme.

The JSC encouraged the further extension of AOPC work on these lines, expressing appreciation particularly for the build up of the historical GSN data archive. The JSC stressed the importance of maintaining as many GSN and GUAN stations as possible, at the same time underlining that a policy of open access to all GSN and GUAN data was essential. Finally, it was again recalled that, in the analysis of atmospheric temperature changes over the past two decades, the differences between surface and Microwave Sounding Unit (MSU) measurements had not been fully explained (although the disparity did not invalidate the conclusion that the surface air temperature had been rising). The JSC supported an internationally co-ordinated analysis of MSU and related data and agreed that WCRP should co-operate with and assist in this to the extent possible.

WCRP/GCOS/GOOS Ocean Observations Panel for Climate (OOPC)

Dr N. Smith, Chair of OOPC, presented the main highlights of OOPC work. A number of mechanisms were now in place that would very much aid in implementation of oceanographic observations, namely the recently created Joint (WMO/IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM), CEOS/IGOS-P (the ocean theme, see section 2.4), GOOS regional activities (e.g. MEDGOOS), and the "Partnership for Observations of the Global Ocean" (POGO), an umbrella under which ocean institutions intended to work together more closely in the future. Considerable thought was now also being given to the issue of data management for the ocean and marine environment following an appeal for action that had been widely distributed by Dr Smith (see section 2.5 for further discussion of this matter).

Regarding the joint OOPC/AOPC study of sea surface temperatures referred to above, a pilot project was being planned within the framework of the Global Ocean Data Assimilation Experiment (GODAE, see below). A particular purpose was to examine different definitions and determinations of sea surface temperature (i.e. skin, sub-skin or bulk) and to explore, in conjunction with other WCRP projects where appropriate, new avenues for research and development (e.g. shallow profilers, the inclusion of Voluntary Observing Ships/Ships-of-Opportunity). OOPC was collaborating with WGNE in the surface flux analysis project (SURFA, see section 4.1.7), and planned to assemble high-quality surface reference flux data sets in order to test NWP flux products, including data from arrays of surface mooring sites (e.g. TAO and TRITON), and possibly from the VOSCLIM and sea-surface temperature projects. Other important activities underway were:

(i) implementation of a fixed point time series of ocean measurements (a pilot project has been initiated);
(ii) review of the ENSO observing system to take account of the difficult resource situation and the need better to define the framework for evaluating impacts (a workshop was being planned for September 2001 that would document characteristics of the real-time data stream including spatial and temporal sampling, assess the impact and relative priority for operational applications on one hand and research on the other, establish metrics to be used for ongoing assessment, and recommend a process for guiding the evolution of the ENSO observing system);
(iii) planning for sustained observations in the Indian Ocean: the possibility of forming a consortium of countries with interests in the Indian Ocean was being explored and multi-national joint action plans initiated.

With respect to GODAE, Dr Smith reported that a strategic plan had now been published (see **http://www.bom.gov.au/bmrc/ocean/GODAE/Strategic-Plan.pdf)**, and the first draft of an implementation plan prepared. The theme running through GODAE was the generation of globally consistent fields of the ocean state for use in synoptic ocean analyses and hindcasts, short-range forecasts, reanalyses and initial conditions for climate forecasts by synthesizing multi-variate satellite and in situ data. GODAE remained fully on track for implementation of its operational phase in the period 2003-2005. One of the key elements in this respect was the "ARGO" initiative, involving the deployment of a global array of profiling floats, representing a substantial enhancement of global ocean and climate observing systems. Initial commitments have been good, and it was anticipated that there would be around 1500 floats in the water by the beginning of GODAE in 2003, with a reasonable prospect of nearly full implementation by the end of 2005. However, there remained concerns whether the overall global distribution required would be achieved and whether floats could be deployed as necessary in certain national economic-exclusion zones. A specific strategy for assembly, quality control and distribution of ARGO data had been developed.

The JSC was impressed by the continuing progress and range of activities being developed under the guidance of the OOPC. The sea surface temperature was of particular interest, and it was suggested that the OOPC might wish to note earlier discussions in the WCRP (in which both GEWEX and CLIVAR had been involved) on the most appropriate definition of sea surface temperature. The JSC recognized the major importance of GODAE and the ARGO deployments for WCRP, in particular CLIVAR (see section 9.4). One specific question raised was whether the foreseen float deployment in high latitudes was adequate.

2.4 Relationship between WCRP and the space agencies

The continuing development of the WCRP depends fundamentally on global remotely-sensed data, and exploiting to the full the new generation of Earth observation satellites foreseen in the coming years. At its twenty-first session (March 2000), the JSC recognized that it was essential to discuss developing WCRP requirements for remotely-sensed data with space and/or satellite-operating agencies at the earliest possible stage in view of the lead time for planning missions, and for WCRP to be able to influence these. Thus, following the recommendation of the JSC made last year, the Committee on Earth Observation Satellites (CEOS) had been formally invited to participate in this year's session and, as noted in Section 1, was represented by Dr L. Charles (NASA representative to CEOS) and Dr D. Clark (NOAA representative to CEOS).

Drs Charles and Clark outlined the role of CEOS as a forum where space agencies could exchange views and ensure a co-ordinated approach to satellite-observing programmes. CEOS was supported by a number of specific groups, namely: a Strategic Implementation Team, SIT; a Working Group on Information and Services; and a Working Group on Calibration and Validation. Moreover, CEOS had initiated the concept of the "Integrated Global Observing Strategy", IGOS, in order to meet the extensive and expanding requirements for environmental measurements from a growing number of international research programmes (including, of course, WCRP). IGOS was intended as an international integrated approach embracing both space-based and in situ measurements, taking into account the overall requirements and providing a framework in which national and international agencies could commit specific elements. It was foreseen that this would reduce unnecessary duplication of observations, stimulate improvements by reallocation of resources where appropriate, and enable optimization between various observational systems. IGOS particularly aimed to build partnerships between data producers and users to meet these objectives. The IGOS partnership, IGOS-P, now included, as well as CEOS itself, WMO, ICSU, IOC, UNEP, GOOS, GCOS, GTOS, IGFA, IGBP and WCRP.

Drs Charles and Clark continued by elaborating on the "theme" concept that had been agreed for enhanced or for development of measurement programmes in different environmental areas. Themes were selected by the IGOS-P in conjunction with users. Procedures for submitting themes by one or more IGOS partners for consideration and development had been laid out. The theme should be based on sound, consolidated observational requirements. Objectives should be clearly defined and focussed, the respective roles and responsibilities of data producers and users spelt out in detail (including identification of specific commitments needed), milestones and performance criteria set down, and resources requirements indicated. Partners' meetings would then be invited to endorse the proposed theme or ask for modifications or additions. However, the "approval" given would never be stronger than "in principle". The acceptance of a theme report would also include agreement on the partners responsible for overseeing its implementation. These partners should monitor whether commitments were indeed being undertaken, come forward with back-up solutions in cases where data providers were not able to maintain their commitments, and ensure that appropriate arrangements were in place for Data Information Systems and Services. The activities would also be regularly evaluated in terms of the new commitments which had materialized and to allow re-evaluation of the requirements in the light of scientific and technological advances. Drs Charles and Clark advised WCRP, as an IGOS partner, to follow this process in order to foster the types of observational activities needed to support the development of the WCRP. This was in line with recommendation from the twenty-first session of the JSC that the WCRP should seek to exploit fully CEOS and IGOS partnership mechanisms.

The JSC noted the status of various IGOS themes of interest to WCRP. In particular, meetings of the CEOS-SIT and IGOS partners in Geneva in June 2000 had considered that the GEWEX Co-ordinated Enhanced Observing Period (CEOP) (see section 5.3 for a full account of the current status of CEOP) could be a significant initial step towards an IGOS Water Cycle theme. CEOS-SIT duly encouraged the CEOS agencies to pay close attention to CEOP and to respond to the formulated requirements for remotely-sensed data in the vicinity of the intensive observation sites. In its turn, the IGOS partners encouraged the development of CEOP as a precursor to a water cycle theme and invited the WCRP, together with other interested parties, to assemble a "water cycle theme" report. At a plenary meeting of CEOS in November 2000, a further presentation was given on CEOP (by Professor T. Koike, supported by Dr R. Lawford), following which strong support was promised by the space agencies. This included the establishment of a CEOP Satellite Working Group, providing full access to satellite observations for field campaigns at reference sites, and encouraging the preparation of statements of specific requirements for consideration by the appropriate space agencies. The JSC acknowledged with appreciation the particular efforts of Professor Koike to capture the interest and support of the space agencies for CEOP.

With regard to the development of an integrated global observing strategy report for the water cycle theme, a workshop was organized under the leadership of Dr R. Lawford in January 2001. Forty-five participants from many different countries representing a variety of international and national organizations were able to put together a preliminary draft. Three priority areas were identified - precipitation, surface hydrology, and applications. An advisory team was nominated to assist in development of the proposal, as well as a writing team. A report on progress would be presented at an IGOS partners meeting in June 2001, with the full draft proposal to be submitted to the IGOS partners for review in November 2001. The JSC expressed gratitude to Dr Lawford for having undertaken the lead role in the co-ordination of this activity and his considerable personal contribution.

There were three other main IGOS themes at various stages of development, all of direct relevance to the WCRP. The ocean theme, approved by the IGOS partners in November 2000, was intended as a major step towards the establishment of a global ocean observing system comprising an extensive programme of remote sensing, in situ measurement networks, and a data products and services element. GOOS and IOC would lead the implementation of the ocean theme. Secondly, a proposal for an integrated global carbon observations theme, under the direction of IGBP, was being developed. However, the integration of the terrestrial, atmospheric and ocean components has posed some difficulties. Ocean scientists preferred first to develop an inventory and strategy for ocean carbon observations before preparing a fully integrated plan. The initial background document has been produced and was reviewed by the GOOS Steering Committee in March 2001. A separate document on terrestrial carbon observations has also been compiled, and submitted directly to the IGOS partners for approval. The "ocean" and "terrestrial" documents together would form the basis for the integrated global carbon observations theme. Thirdly, a draft proposal for an integrated global atmospheric chemistry observations theme was presented to the IGOS partners in November 2000. The proposal was received favourably, but it was pointed out that areas of duplication with the carbon observations theme needed to be avoided. The atmospheric chemistry observations theme in fact built on and was a significant expansion of an earlier CEOS pilot activity "The Ozone Project", and the contributors to the ozone report (WMO, IGBP/IGAC and WCRP/SPARC, as well as CEOS itself) formed the nucleus for the atmospheric chemistry observations theme. In respect to the work in this area and noting that the report of the ozone pilot project had been published (by WMO), the JSC urged CEOS to begin implementation of aspects in the ozone report that did not need wait until the wider atmospheric chemistry observation theme was finally adopted.

The JSC stressed other vital issues from the point of view of the WCRP, namely the need to ensure continuity of time-series of parameters inferred from remotely-sensed data, the calibration of new sensors, the systematic overlap of new types of observations, and validation of systems. Real resources and efforts devoted to careful processing and comparative analyses of data streams from old and new satellites were necessary. The importance of the optimal combinations of remotely-sensed data with, and validation against, in situ observations were reiterated. The CEOS representatives recommended that WCRP, as a partner, should present these requirements to an IGOS partners meeting, from which they could be relayed to a CEOS plenary session.

The JSC noted other contacts between WCRP and space agencies. Firstly, the Director of the WCRP had written on a number of occasions to various space agencies about specific requirements brought forward by WCRP scientific steering or working groups. Secondly, as mentioned in section 2.1, WCRP had been represented at the (second) WMO Consultative Meeting on High-level Policy on Satellite Matters in January 2001. This had proved to be a valuable forum for the interaction of WCRP with the space agencies, most of whom were represented at a very senior level. The satellite operators, both operational and research, reaffirmed their willingness to work with the WMO user community over the next decade to obtain maximum benefit from meteorology-related satellite programmes. A set of guidelines for requirements for observational data from operational and research satellite missions was set out.

2.5 Data management

The question of co-ordination of data management activities in the WCRP was raised at the twenty-first session of the JSC in March 2000. It was noted that data assembly and management in the various WCRP component projects were being conducted more or less independently, and the JSC encouraged interaction and liaison between project offices in this area. There have only been limited steps so far in this direction, although issues connected to data management continue to receive much attention in WCRP projects individually. In ACSYS/CliC, for example, specific problems connected with access to, and the availability of, observational and model reanalysis data, and, more generally, improvements to be made in ACSYS/CliC data management, have been considered. In GEWEX likewise, the need to refine the processing, organization, and management of GEWEX data products has been discussed (in particular to ensure the cross-consistency of different data sets). GEWEX hoped that its ideas in this area could serve to improve data management within WCRP as a whole.

In the ocean and marine environment, the whole issue had recently been brought to a head by a proposal for implementation of a comprehensive data and information management system distributed widely by Dr N. Smith, Chairman of OOPC (as noted in section 2.3). Dr Smith noted a whole range of problems including: too little telemetric capacity and too restrictive modes; no broad agreement on ensuring coherent, integrated data holdings; inadequate investment in terms of resources and intellectual engagement; poor or inappropriate take up of modern information technology; lack of agreement on common standards, formats and practices or imperfect application of those that do exist; no agreed strategy for exchanging/handling non-conventional ocean, or coastal and biological, observations. Dr Smith proposed a step-wise approach to the definition of an efficient and effective data and information management system for the ocean and marine environment that would exploit "leading-edge" information technology, and serve the oceanographic (and wider) communities. In this wide-ranging and ambitious undertaking, many specific topics would be tackled such as telemetry and communications, information standards, solutions developed outside oceanography, an assessment of relevant information technology, data set integrity, data and product servers etc.

The JSC recognized fully the importance of Dr Smith's initiative and strongly encouraged the development of his proposal. The JSC urged all groups in the WCRP to lend assistance to, and to co-operate with, Dr Smith in this area in considering such concepts as the assembly of a global climate data base, generic standards for data and meta-data exchange, definition of (self-describing) formats for data, the architecture for data and product servers and data exchange, and the development of user interfaces especially for climate research applications. More specifically for the WCRP, the JSC recommended that a meeting of leaders of WCRP data management groups and/or project office directors should be convened to assess the extent to which the problems identified by Dr Smith for data management for the ocean and marine environment were concerns for the WCRP as a whole. The JSC suggested that Dr Smith and representatives of GCOS should also be invited to participate. The meeting would be expected to provide overall guidelines for data management practices in the WCRP as a whole, and what might be needed at various timescales in the future.

3. CO-OPERATION AND INTERACTIONS BETWEEN THE GLOBAL ENVIRONMENTAL CHANGE PROGRAMMES

3.1 Global Change Open Science Conference

In the field of co-operation between the global environmental change programmes, the IGBP/IHDP/WCRP Global Change Open Science Conference: Challenges of a Changing Earth, to be held in Amsterdam in July 2001, would be a particular highlight. IGBP had taken the initiative in proposing and leading the planning of the Conference, but WCRP and IHDP were both now fully entrained in ensuring that the conference structure and content fully reflected the evolution of all aspects of global change research. The Conference was one of the biggest joint challenges faced by IGBP, WCRP and IHDP, firstly to present the results of the last decade of international global change research, emphasizing the implications for global sustainability, and, secondly, to point the way towards the next decade of Earth System science on the lines of the vision presented by Professor B. Moore at the twenty-first session of the JSC in March 2000. The latter posed fundamental questions about the approach to global change science, and it was anticipated that the Conference would come forward with a landmark declaration emphasizing, in addition to the threat of significant climate change, concerns over the ever-increasing human modification of other aspects of the global environment and the implications for human well-being, and point the direction to a new system of global environmental science. The commitment of the global change programmes to work together would be reiterated, as well as the importance of forming new partnerships among governmental research institutions, university and industrial groups, and of increasing the dialogue between the scientific community and policymakers at a number of levels. Another challenge would be to involve fully the scientific communities of the developing regions in the world, building on the progress made by START (see section 3.4) in the past decade.

The programme for Conference plenary sessions was now virtually complete and had been specifically designed to place the wealth of excellent science under the heading "global change research" into the broader context of Earth System science and global sustainability. Issues such as the latest evidence of rapid climate change, the relationship between biodiversity and Earth System science, and the potential for advances in technology to mitigate global environmental change would be addressed. Poster sessions were also an absolutely central feature of the Conference with six hours of dedicated viewing time, providing a forum for specialists to show their research in the context of the "bigger picture". The poster sessions would be organized in eight broad integrative themes (including, of interest to the WCRP scientific community: the water cycle, water resources, water security; climate variability and climate change; oceans and coasts; the atmosphere and its interfaces, air quality). Within each theme, "poster clusters" (i.e. groups of posters on more specific themes and topics) would be organized, particularly to enable, for example, coherent presentations of WCRP, IGBP and IHDP core projects. Another key element of the Conference would be three parallel sessions acting as a bridge between the more detailed science of the poster sessions and the context-setting presentations at the plenary. Each period of parallel sessions had several topics, selected to minimise overlap, with discussion of twenty-one major global issues being planned such as the carbon cycle, ENSO in the context of past and future climate variability, "ground-truthing" Earth System models, predicting land-use change, the cryosphere and global change, coupled Earth System modelling, the oceans and global change, vulnerability of water resources, non-linear responses to global change, global change and mountain regions. On the basis of invited talks and presentations chosen from submitted abstracts, each topic would, as far as possible, be addressed in an interdisciplinary manner exploring physical and biogeochemical issues in tandem with socio-economic drivers and effects. In many cases, a poster cluster would be associated with the parallel session that would draw attention to those posters and encourage continuing discussion off-line. A final promotion campaign was underway across the broad global change community and beyond to non-governmental organizations, policy and private sectors, with attention also being given to attracting and enabling the attendance of scientists and students from developing countries. Wide interest in the Conference was manifest and an attendance of well over a thousand was expected.

With regard to WCRP participation and contributions, chairs of WCRP scientific steering or working groups and project offices had been kept fully abreast of the developing plans for the Conference during the past year and strongly encouraged to ensure the full and appropriate attendance of their respective scientific communities. However, it remained to ensure that WCRP science was fully presented in the poster and parallel sessions. The JSC emphasized the importance of all WCRP projects/groups being represented at the Conference and urged submissions of posters or poster clusters by all groups. The Director of the WCRP should be informed of material being prepared or submitted in order to provide any co-ordination necessary. The JSC also strongly encouraged the WCRP scientific community, especially JSC members and other participants in the JSC session, to make every effort to attend the Conference.

3.2 Joint WCRP/IGBP/IHDP projects

At the twenty-first session of the JSC, reference was made to the consideration being given to three possible new joint WCRP/IGBP/IHDP projects on "cross-cutting" issues of major relevance to society and global sustainability, namely global environmental change and food systems, the global carbon cycle, and water resources. These projects would depend critically on research in the various WCRP, IGBP and IHDP core projects already being undertaken or planned but unprecedented interdisciplinary cooperation would be required to bring the separate elements into an integrated framework. New work would need to be initiated where gaps were identified, and strategic partnerships developed with other research institutions outside the three programmes and with policy and management bodies to ensure that the projects were designed and implemented in the most effective manner and the user-oriented results required were provided. Discussions between WCRP, IGBP and IHDP were now well underway to develop a common vision of the issues involved and to consider how to make progress jointly. As summarized in the following paragraphs, planning has moved forward significantly on two of the proposed projects: Global Environmental Change and Food Systems (GECaFS) and the Global Carbon Cycle. Exploratory meetings on the overall scope of a water resources project were continuing.

Global Environmental Change and Food Systems (GECaFS)

The JSC was informed at its session in March 2000 of the results of initial scoping meeting which discussed a cross-cutting "food and fibre" initiative at which WCRP, IGBP, IHDP, ICSU and other interested parties had been represented. The JSC had endorsed WCRP's involvement in and contribution to the activity. Dr D. Whelpdale, member of the JSC, had agreed to participate on behalf of WCRP in the six-person GECaFS planning group, whose members represented the broad interests of the co-sponsors.

Dr Whelpdale briefed the JSC on the status of the project. The overall goal as now set down was "to estimate the impacts of global environmental change on food production, availability and accessibility across biophysical and socio-economic systems from regional to global scales, and to analyse the effectiveness of adaptive strategies to reduce societal vulnerability and increase societal robustness". The fundamental questions it was intended to answer, of interest to the scientific community, development agencies and society at large, were:

- given changing demands for food, how will global environmental change additionally affect food provision and vulnerability in different regions among different social groups?
- how might different societies and different categories of producers adapt their food systems to cope with both global change and changing demands?
- what would be the environmental and socio-economic consequences of adaptations to these changes?

It was envisaged that research in GECaFS would be organized in terms of individual projects, issue- and region-specific, and integrative studies drawing together individual projects either thematically (e.g. coastal systems), geographically (e.g. the peri-Arctic region), or both. Individual demonstration projects (the vulnerability of food provision systems in the Indo-Gangetic Plain to increasing climate variability and the environmental consequences of adapting access to irrigation through institutional reform; the effect of global environmental change on different types of shrimp production and whether increased shrimp production could contribute to forcing global environmental change) have been proposed and would be presented to interested strategic partners and donors at a meeting in Washington D.C. in April 2000. As well as raising the visibility of GECaFS, the opportunity would be taken to seek advice from potential partners and donors and to invite indications of support for GECaFS and the concepts being put forward.

To make further progress, the planning group made recommendations how best GECaFS might be developed, steered and co-ordinated. An International Project Office needed to be established (with multi-donor support) and an Executive Officer appointed. In this respect, the UK National Environmental Research Council (NERC) has assigned funds to help establish a GECaFS Project Office in Wallingford, UK with effect from January 2002. NERC was also ready to urge other IGFA members to contribute to the costs of the Project Office. Dr J. Ingram of the NERC Centre for Ecology and Hydrology was expected to take up the position of (full-time) Executive Officer. (Dr Ingram served on the planning group and has taken the lead in organizing the work of the group, and developing the basic GECaFS concepts and ideas.) Other elements of the GECaFS management structure proposed were an "Executive Committee" (that would include representatives from each of WCRP, IGBP and IHDP) with the task of ensuring the implementation of plans approved by a Science Management Committee. Reports would be submitted directly to the annual meeting of the Chairs and Directors of the Global Environmental Change Programmes (which could then be forwarded to the governing scientific committees of each Programme).

The JSC expressed satisfaction at the progress in planning and organizing GECaFS over the past year and voiced its gratitude to Dr D. Whelpdale for having represented WCRP so effectively in the initial planning group. The JSC also acknowledged the thought, commitment and efforts of Dr Ingram in having so successfully moved GECaFS to its current status. The JSC endorsed the plans that had been proposed and the suggested management structure. The JSC nominated Dr Whelpdale as the WCRP representative on the Executive Committee.

The Global Carbon Cycle

In respect to the organization of a carbon cycle initiative, IGBP had taken the lead. Different strands of activity had been brought together at an International Workshop on Integrated Carbon Cycle Research, hosted by Professor B. Moore, in New Hampshire, USA in October 2000. Subsequent to the workshop, a document "The Global Carbon Cycle: A Prospectus for International Research", outlining the organization of a joint WCRP/IGBP/IHDP project, was being drafted. The three fundamental scientific themes that would be taken up were the geographical and temporal patterns of carbon sources and sinks, the control and feedback mechanisms (both anthropogenic and non-anthropogenic) that determined the carbon cycle on scales of years to millennia, and the likely dynamics of the global carbon cycle into the future. Much research on the global carbon cycle was, of course, already underway or planned and the strategy of the joint project would be to build on this. However, by developing a single, unified, mutually agreed framework, research gaps would be identified and redundancy of effort lessened. A central challenge would be synthesis of the massive array of different measurements and case or process study results in a consistent manner. This would be complemented by efforts to put in place an expanded and improved global network of carbon observations and the promotion of specific studies that would provide the basic mechanistic knowledge essential to understand interactions between changing land use, demographic change and economic development. Questions such as the means by which the ocean circulation and nutrients affect ocean carbon uptake, or the response of soil carbon to changing temperature and moisture would also need to be tackled. It was proposed that the project should be managed by a scientific steering committee including three to five members nominated by each of the sponsoring programmes. In order to demonstrate the co-sponsorship and co-ownership of the joint project from the outset, each programme was also being asked to identify a Co-chair.

The document on the global carbon cycle would highlight the wealth of relevant research already going on in WCRP, IGBP and IHDP (for review of the foreseen WCRP input, see following paragraphs), but national and regional carbon research programmes would also contribute strongly. Moreover, as described in section 2.4, the proposed IGOS carbon observations theme could be extremely valuable in obtaining flexible and robust, international, integrated carbon observations over the next decade.

The JSC had already recognized that WCRP had a fundamental contribution to make to the global carbon cycle project, and at its twenty-first session established a small ad hoc sub-group under the leadership of Dr M. Chahine (Jet Propulsion Laboratory, CA, USA) to prepare a summary of actual and potential WCRP activities that were important or essential in this area. The report of the ad hoc subgroup "WCRP Global Carbon Cycle Study: A Proposed Framework" had been distributed in advance to participants in the JSC session. The report noted that WCRP projects encompassed unique global atmospheric and oceanic observation capabilities, and extensive expertise in remote-sensing techniques. In combination with modern variational data assimilation methods, this would enable the required synthesis of the considerably array of different types of measurements and offer the prospect of quantifying the worldwide distribution of carbon dioxide and its sources and sinks with unprecedented temporal and spatial resolution. WCRP projects also fostered the collection of global information on a range of physical parameters and processes that affected terrestrial ecosystems and biogeochemical processes over land (such as ground water availability, soil freezing and thawing, snow cover) as well as ocean processes (e.g. upwelling) that governed the rate of marine productivity and carbon sequestration. Furthermore, under WCRP auspices, a range of experimentation with coupled global climate models was being organized providing the projections of future climate conditions needed to assess how feedback mechanisms might change. In order to ensure that the input from WCRP was fully taken into account, Mr S. Benedict (ex-staff member of the Joint Planning Staff) who had assisted in the compilation of the report of the (WCRP) ad hoc sub-group, was serving as a member of the drafting team for the joint prospectus document.

The JSC was pleased to see the progress that had now been made in laying out the framework for a joint WCRP/IGBP/IHDP project on the carbon cycle. The JSC particularly appreciated the work of Dr Chahine and the other members of the ad hoc sub-group established at the twenty-first session of the JSC in reviewing the principal contributions that would be made by the WCRP to the joint project. This input was recognized as relevant and valuable in planning the overall WCRP/IGBP/IHDP joint project. The JSC encouraged the continuing development of the joint project and of the activities in WCRP that were important to it. The JSC duly agreed on the nomination of Dr R.E. Dickinson (Georgia Institute of Technology, Atlanta, USA) to serve as the WCRP-designated co-chair of the (joint) scientific steering group for the project and welcomed Dr Dickinson's acceptance of this task. The JSC noted that it remained to identify two to three other WCRP representatives whose expertise would complement Dr Dickinson's and to ensure that the full scope of WCRP's activities were reflected. In this connection, it would seem appropriate to include scientists with oceanographic and climate modelling expertise.

Water Resources

A scoping meeting for a possible joint WCRP/IGBP/IHDP on water resources was held in Paris, September 2000 with the participation of representatives of sixteen different programmes and organizational interests. A need for a research partnership on water issues that would enhance both the visibility and credibility of the scientific community in this area was apparent. While the global environmental change programmes could take the lead in establishing such a partnership, a broad range of parties would have to be involved in implementing the type of research agenda required (which, inter alia, would depend on resolving serious issues of data availability and data exchange). The central focus of activity might be the question of what needed to be done to increase the security of the water system in the face of global environmental change, as well as assessing the impact of a changing frequency of extreme events. This would incorporate elements of the global environmental change programmes and studies of human-environment interactions, with spatial scales from local to global and temporal from short-term urgent issues to long-term management implications to be spanned. In all cases, both water quantity and quality would have to be considered. Specific aspects to be taken up could include: the vulnerability of human systems to changes in water supply and quality; the state of the world water system and the reasons for changes during the past few decades; lessons to be learned from previous experience/strategies.

Discussions were continuing to identify and articulate key research questions of interest to the global environmental change programmes, and to consider other potential partners and individuals who could be involved. The Director of the WCRP has maintained close contact with Professor Sorooshian, Chairman of the GEWEX Scientific Steering Group, as discussions have proceeded. Professor Sorooshian has proposed nominees to represent WCRP (and GEWEX) in the further planned meetings.

The JSC voiced strong encouragement to the development of this joint project and reiterated that it saw WCRP playing a prominent role, particularly given WCRP's lead in planning an IGOS water cycle theme (see section 2.4).

Co-ordination and interaction of joint projects with existing WCRP activities

With the development of the joint projects, their complexity and wide scope, the JSC considered it essential that a direct and close JSC overview be maintained, particularly to ensure that the appropriate interactions and feedbacks with existing WCRP core projects were taking place. The JSC decided to appoint from among its members "mentors" for each of the joint projects who would report directly to the JSC on the status and progress being made. Dr D. Whelpdale was nominated as the mentor for GECaFS, Dr J. Church for the carbon cycle, and Professor T. Yasunari for the water resources project.

3.3 Interactions between WCRP and IGBP

In addition to the physical processes which are the object of WCRP study, biological and chemical processes also have a vital role in the full interactive climate system. There is thus a particularly close relationship between WCRP and IGBP in addressing various key issues of mutual interest, and this relationship has continued to be reinforced. Professor B. Moore, Chair of the IGBP Scientific Committee, noted that new opportunities for co-operation and joint IGBP/WCRP projects were developing as a consequence of the major Earth System science review undertaken by IGBP, and as plans for a new overall IGBP structure were drawn up leading to an "IGBP Phase II" at the beginning of 2003. IGBP was giving much attention to considering how to achieve the right balance between fundamental science "building blocks" (or core projects with disciplinary or sub-system oriented research) and the need to develop new interdisciplinary approaches (with partners such as WCRP), both of which were necessary for the advancement of Earth system science. A number of IGBP core projects would thus be significantly re-organized at the end of 2002. The JSC realized that it would also need to consider the same types of issue from the point of view of the WCRP as joint activities between the WCRP and IGBP, IHDP and others were taken up, whilst at the same time pursuing the WCRP stated objectives.

In the field of atmospheric chemistry, although it remained to be determined how IGBP efforts would be organized in the future (e.g. a "follow-on" from IGAC), a particularly interesting prospect was joint WCRP/IGBP activities addressing the issue of "Atmospheric Chemistry and Climate". (A proposal for a joint WCRP/IGBP assessment of atmospheric and climate changes was discussed at the twentieth and twenty-first session of the JSC but little progress has so far been made). Dr S. Solomon was asked to discuss co-operation in this area with Dr G. Brasseur (Chair of the existing IGAC Scientific Committee). At the same time, the importance of carrying forward the successful co-operation between SPARC and the atmospheric chemistry community, as represented by IGAC in studies of chemical processes in the upper troposphere/lower stratosphere (see section 6.4.2) was emphasized. These efforts could be a principal building block of an "Atmospheric Chemistry and Climate" initiative.

Another area ripe for co-operation and where a strong WCRP contribution was definitely needed was in the developing (IGBP) Surface Ocean-Lower Atmosphere Study (SOLAS). This has the goal of achieving a quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and how this coupled system affected and was affected by climate and environmental change. (The progress made in the definition and planning of SOLAS and JSC discussion of how the WCRP could play a part is described fully in section 7.2). In IGBP, the future evolution of the Biosphere-Atmosphere Hydrological Cycle (BAHC) core project was also under review. In this area again, the prospect of increased co-operation with GEWEX seemed to be imperative. In building up the required comprehensive models of the full climate system, a direct and strong connectivity between the Global Analysis Integration and Modelling (GAIM) element of IGBP (for which an increasingly important role was foreseen in IGBP Phase II) and WCRP/WGCM was clearly essential. The series of modelling experiments now being jointly planned by WGCM and GAIM with carbon dioxide as a prognostic variable, and comparison of simulated evolutions of carbon dioxide and the associated climate response (see section 4.2.11) was a primary example of the co-operation needed. The IGBP Past Global Changes (PAGES) core project was expected to continue in IGBP Phase II; the productive scientific co-operation between PAGES and CLIVAR (see section 9.3) should certainly be further built up. (There are a number of other formal and informal links and joint activities between individual WCRP and IGBP projects as described under various agenda items.) The JSC proposed that the Chairman of the Committee and the Director of the WCRP should continue to consider jointly with their counterparts in IGBP the further development of linkages between WCRP and IGBP.

The JSC noted that Professor Moore would be stepping down as Chair of the Scientific Committee for IGBP at the end of 2001. The JSC wished to place on record its highest appreciation of the work of Professor Moore in his guidance of IGBP over the past few years, and in particular, his seminal role in developing such a clear vision of Earth System science. As noted above, this was already having a profound influence on the approach and structure of IGBP, and would, no doubt, certainly have a (positive) effect on many WCRP activities and co-operation between WCRP and IGBP in the overall study of global change. The JSC had also greatly valued the participation of Professor Moore in the sessions of the committee in his capacity as Chair of the IGBP Scientific Committee, and his many outstanding contributions to JSC discussions in a large number of areas. The JSC looked forward to a similar fruitful relationship with

Professor Moore's successor, Dr G. Brasseur (who, as noted above, was currently Chair of the IGAC Scientific Committee).

3.4 Development of regional contributions to global change research

Global Change System for Analysis, Research and Training (START)

Professor P. Tyson briefed the JSC on the continuing implementation of and plans for the WCRP/IGBP/IHDP Global Change System for Analysis, Research and Training (START). He recalled that the basic remit of START was the establishment of regional research networks of collaborating institutions to undertake studies of regional aspects of global change, assess regional impacts, and to provide regionally important information to policy makers and governments. These activities underpinned the enhancement of scientific capacity in developing countries by strengthening and connecting existing institutions and by training scientists. Substantial efforts were also made in mobilizing the resources necessary to augment scientific capabilities and infrastructure in developing countries. The "end products" of START were intended to be: increased understanding of global change issues at a regional level; increases in regional research initiatives and publications; increase in the number of scientists trained in global change research; improved regional infrastructure for global change research; development of regional data bases and improved access to data; and enhanced regional co-operation in global change research and training.

Activities conducted under the auspices of START fell into four major categories: land use change and impacts on terrestrial ecosystems; regional climate variability and change; changes in atmospheric composition and its impacts; global change and coastal zone, land-ocean interactions and international water. These were often pursued in concert with the core projects of the cosponsors. Among specific highlights in the past year was the initiation in the START East Asia Regional Centre of a major multi-year project examining the aridification of northern China, linkages to global environmental change, and possible mitigation and adaptation measures (this project has evolved from the earlier study of the coupling between an apparent weakening of the monsoon and land cover change). In the Climate Prediction and Agriculture (CLIMAG) initiative (see below), regional demonstration projects were being organized in South Asia and Western Africa with support from the Asia-Pacific Network for Global Change Research (APN) and the European Union. Another important event was a three-week training institute in Hawaii on climate variability and society in the Asia-Pacific region, co-sponsored by APN and NOAA. The principal objective was to spread more widely knowledge on emerging climate predictive capabilities and application tools which have potentially substantial economic and societal benefits in a variety of sectors. Scientists from the START networks in southern Africa, east, south-east and south Asia have prepared regional syntheses of global change science for a volume "The Earth System: Regional-Global Linkages" in the IGBP synthesis series.

Professor Tyson noted areas in which enhanced WCRP-START collaboration would be important, namely regional climate variability and change, regional analyses of climate data, identification of indices for climate change detection, and monitoring trends in climate extremes. START facilities and networks were available to assist WCRP projects in studies of these topics as appropriate on a regional basis. The JSC recognized that this was a significant opportunity that should be taken up by the WCRP and requested all WCRP project groups/sub-groups to consider how to make use of the possibilities. An excellent example of what could be accomplished was provided by the regional APN Asia-Pacific Workshops on Indicators and Indices for Monitoring Trends in Climate Extremes (organized under the leadership of Dr M. Manton and as reported at the twenty-first session of the JSC) and that arranged by CLIVAR and the WMO Commission of Climatology Working Group on Climate Change Detection to develop regional climate indices for Africa (see section 9.3). The JSC strongly encouraged such regional analysis workshops.

Climate Prediction and Agriculture (CLIMAG)

Professor Tyson outlined the recent steps in the implementation of CLIMAG, which had originally stemmed from a proposal made by the JSC in 1996 for an initiative to foster the use of climate variability predictions for agriculture. START was leading the development of this capacity building project (now jointly sponsored by START/WCRP/IGBP/IHDP). Specific efforts were being aimed at enhancing the interfaces between meteorological, agricultural and social sciences communities, developing the capability in tropical regions for the integrated use of climate and agricultural modelling in order to improve techniques for forecasting yields, and to assess the type of climate prediction information needed by regional and national decision-makers and the means by which such information can be used. This required insights into the socio-economic feasibility of the project, the technical possibilities and relevant climate processes.

CLIMAG was now being led by an international steering group (chaired by Profesor H. Grassl), which was co-ordinating the planning and organization of regional demonstration and pilot projects, to identify the strategic research challenges posed by CLIMAG and to seek the assistance of START's sponsors (WCRP, IGBP, IHDP) in addressing the gaps, and to develop social science components. The regional demonstration projects referred to above include the "South Asia Mixed Cropping System" (collecting household socio-economic and agricultural data, analysis and refinement of available climate and crop models, identification of operational information systems) and one in West Africa investigating the potential of seasonal climate forecasts for improving food crop production, aiding decision-making by end-users in the effective employment of seasonal climate forecasts, and reducing food insecurity by enhancing regional early warning systems. Two other activities in a pilot phase were the "Southeast Asia Rice Cropping System" and the "Fiji Sugar Cane System".

3.5 Joint funding initiatives

As discussed at the twenty-first session of the JSC, another issue being jointly considered by WCRP, IGBP and IHDP was ensuring sufficient stable core financial resources to enable the successful development of the programmes. A common strategy for fund raising was being considered, including attempting to identify new opportunities and approaches for obtaining resources. With the backing of ICSU, a joint Resource Development Committee has been set up (including the Director of the WCRP and Dr J. Gould, Director of the WOCE and CLIVAR International Project Offices, as representatives of the WCRP. The meeting of the chairs and directors of the global environmental change programmes in Geneva in August 2000 had proposed basic guidelines for the modus operandi of the Resource Development Committee and for attracting funding. Emphasis was placed on a cautious approach to possible donors, or to establishing partnerships, i.e., making no commitments, exploring options with more than one potential corporate partner, and avoiding potential partners that could damage the legitimacy and credibility of the global environmental change programmes (such as active members of the Climate Coalition!). A structure for setting up a "Global Environmental Change Fund" and concrete procedures to be followed have also been discussed (ICSU would be closely involved in these procedures). Once a fund was established, the Resource Development Committee would manage the fund in accord with policies established by the chairs and directors of the global environmental change programmes, ICSU bodies and donors.

The Resource Development Committee has duly commenced a careful dialogue with foundations and/or corporations, where some interest in the global environmental change programmes was apparent. This initiative of the global environmental change programmes and the establishment of the Resource Development Committee was also presented to the International Group of Funding Agencies (IGFA) meeting in October 2000. The availability of money for international and co-ordination activities was extensively discussed. A set of commitments was embodied in a document "Statement on the Mode of Operation between Funding Agencies for Global Change Research Programmes Collaborating in IGFA, and ICSU and International Global Change Research Programmes regarding support for Integration and Co-ordination of International Co-operation in Global Change Research". The document was sent to all IGFA members, ICSU, and the global environmental change research programmes for endorsement.

The JSC observed that only limited progress had been made so far in this area, and in particular that there was no notable positive result for WCRP itself. Nevertheless, the JSC fully recognized the importance of trying to widen the funding base for the projects of the global environmental change programmes, and encouraged further steps forward.

4. CLIMATE MODELLING

Climate modelling activities in the WCRP are organized round two main working groups: the joint CAS/JSC Working Group on Numerical Experimentation (WGNE) concerned with the refinement of the atmospheric component of climate models and the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) overseeing the development of fully coupled atmosphere/ocean/land/cryosphere models to study climate variations on time-scales from several years to a century and to provide confident projections of climate change resulting from natural and anthropogenic causes. The Chairman of WGNE, Dr K. Puri, described the main activities related to atmospheric modelling being undertaken by or under the auspices of his group (section 4.1). In the absence of Professor L. Bengtsson (who chaired the 2000 session of WGCM) or the new Chairman of WGCM, Dr J. Mitchell, an account of the status of WGCM projects was given by Dr R. Newson (section 4.2). The activities of the joint WGNE/WGCM panel on regional climate modelling are outlined in section 4.3.

4.1 Atmospheric modelling activities in support of the WCRP

4.1.1 Organization of WGNE work

In view of their respective roles at the core of climate modelling in the WCRP, close co-ordination was maintained between WGNE and WGCM. WGNE also worked in conjunction with the WCRP Global Energy and Water Cycle Experiment (GEWEX) in the development of atmospheric model parameterizations and, in this respect, WGNE sessions were held jointly with the "GEWEX Modelling and Prediction Panel". Likewise, WGNE followed the progress of the SPARC "GRIPS" project (focussed on the intercomparison of model stratospheric climate simulations) in the effort to refine the representation of the stratosphere in atmospheric models (see section 6.2.1).

WGNE additionally had an important role in support of the WMO Commission for Atmospheric Sciences (CAS) in reviewing the development of atmospheric models for use in weather prediction on all timescales. The close relationship between WGNE and operational (NWP) centres by virtue of the CAS connection underpinned many aspects of WGNE work and provided a strong impetus for the refinement of the atmospheric component of climate models. WGNE sessions duly included reviews of progress at operational centres in topics such as data assimilation, numerics, physical parameterizations, ensemble predictions, seasonal prediction, forecasting tropical cyclone tracks, and the verification of precipitation forecasts. This relationship was being further reinforced as WGNE collaboration with the CAS World Weather Research Programme (WWRP) continued to develop, in particular through the involvement in the planning of the Hemispheric Observing System Research and Predictability Experiment (THORPEX). WGNE also followed progress in various relevant national initiatives such as the Earth Simulator/Frontiers Research System for Global Change in Japan.

The following paragraphs review the main activities of WGNE in support of WCRP objectives, including especially items of interest and recommendations arising at the sixteenth session of the group kindly hosted by the Bureau of Meteorology Research Centre (BMRC), Melbourne, Australia, in October 2000.

4.1.2 Review of model systematic errors

A highlight of WGNE activities in the past year was the Workshop on Model Systematic Errors in October 2000 (jointly organized by BMRC and WGNE as the Twelfth Annual BMRC Workshop) in conjunction with the WGNE session in Melbourne. The workshop was attended by representatives of virtually all the world's active modelling groups, and an extensive range of papers was presented orally or in poster form during the course of the week. The abstracts of presentations given at the workshop have been compiled as BMRC Research Report No. 80, and a summary of the main findings and conclusions has been included in the report of the sixteenth session of WGNE and the latest edition (No. 31) of the WGNE annual review in research activities in atmospheric and oceanic modelling.

The workshop revealed what has been achieved in recent years, what has been learned and where difficulties remained. Most notable was the marked decrease in errors, especially in short- and medium-range weather forecasts. However, there might merely be a delay in onset, since errors, with the same sort of signature, still appeared with increasing magnitude at around ten days or so. What had undoubtedly helped was a general improvement in understanding of the nature of model errors, allied with practical advances such as the finer model resolutions that could now be employed in the vertical and horizontal. There has also been much progress in the representations of physical processes, in particular radiative transfer and cloud/radiation interaction, deep convection, and surface and boundary layer behaviour. The major steps forward in data assimilation (in particular use of variational methods) and in model initialization will also have contributed significantly to a reduced error growth in the early stages of predictions. However, the workshop did not point to any one single "breakthrough", but rather incremental advances resulting from detailed work and study of individual aspects of models one by one.

The JSC wished to place on record its appreciation to BMRC for its efforts and support in organizing this workshop which was regarded by all who participated as having been very successful, helpful and productive with many useful interactions and discussions.

4.1.3 WGNE model intercomparison activities

As well as promoting the organization of periodic events such as the Workshop on Model Systematic Errors mentioned above, the key element in the ongoing WGNE quest to identify errors in atmospheric models, their causes, and how they may be eliminated or reduced, was a series of model intercomparison exercises.

Atmospheric Model Intercomparison Project

The most important and far-reaching of the WGNE-sponsored intercomparisons was the Atmospheric Model Intercomparison Project (AMIP), conducted by the Programme for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory, USA, with the support of the US Department of Energy. AMIP was now well into its second phase (AMIP-II), which, like the first, called for a community standard control experiment (January 1979-March 1996) in conjunction with careful specific analyses of various aspects of the simulations. The atmospheric concentration of CO_2, sea surface temperature and sea-ice distributions, solar constant and relevant orbital parameters to be used have been specified. Recommendations have also been made for a zonal monthly ozone climatology, land-sea mask and topography, concentrations of greenhouse gases such as methane, nitrous oxide (if considered separately), and a background monthly aerosol climatology. Nineteen modelling groups have now submitted AMIP-II simulations to PCMDI and at least another five have expressed their intentions to do so soon. WGNE has suggested that a time limit should now be set for collecting simulations.

Over the past few years, PCMDI has taken several strides forward in handling the voluminous AMIP-II data sets. An automatic system has been put in place to organize the simulations, perform extensive quality control, document problems, and make the data accessible (via FTP) to interested users. The status of the AMIP data base and model integrations were posted nightly on the AMIP home page (**http://www-pcmdi.llnl.gov/amip**). These facilities were essential to the substantial range of diagnostics studies that have been organized, and half of the AMIP-II simulations were now available to the groups carrying out these studies (with the remainder expected to be on line during 2001). These diagnostic projects were a key component of AMIP. Based on AMIP-I experience, the specification and procedures for acceptance of these projects has been improved. Currently, research was in progress in over thirty (approved) sub-projects (the full list may also be found on the AMIP home page). One aspect which WGNE discussed was what might constitute an adequate model resolution for climate studies (this question had also come up at the Workshop on Model Systematic Errors). Furthermore, resolution was clearly important in the treatment and prediction of extreme weather events which was another subject of increasing attention. WGNE suggested that these issues could be tackled through an AMIP sub-project on resolution and asked the AMIP panel to consider how this might be taken up (the WGNE-appointed AMIP panel oversees details of AMIP implementation).

PCMDI itself also prepared a number of basic diagnostics, including a "quick-look" set of diagrams and statistics. Among these, plots of zonal means of every AMIP-II variable, tailored for every model and complemented by observational and reanalysis products, have been placed on the AMIP home page. Climatological maps would be made public early in 2001. More specialized "Taylor diagrams" and plots were also being constructed for each simulation. In addition, PCMDI routinely compiled the standard WGNE set of diagnostics of mean climate (and variability statistics would be added as WGNE proposals in this respect developed). These basic statistics were indicating some degree of improvement in the AMIP-II simulations compared to AMIP-I. Nevertheless, overall the mean or median of all the simulations seemed to be superior in many respects.

The AMIP panel was expected to meet early in 2001 to solidify plans for the continuation of AMIP. It was foreseen that AMIP would become a "quasi-operational" community exercise in which modelling groups would periodically contribute revised model simulations (e.g. every two or three years). The experimental protocol would be updated annually by extending the sea surface temperature/sea-ice boundary conditions to near present and reviewing the standard output list. Consideration will also be given to the organization of a second international AMIP conference, possibly in conjunction with the eighteenth session of WGNE in October 2002 (the first international AMIP Conference was held in May 1995, see WCRP-92). By that time, comprehensive results from the AMIP-II diagnostic sub-projects should be available.

"Transpose" AMIP

Various means can be used to examine parameterization errors in atmospheric circulation models, including, of course, the approach of AMIP itself in which time averages from long climate simulations were analyzed. The AMIP approach did suffer from the drawbacks that cause and effect were often difficult to separate, the parameterizations might be operating in unrealistic or erroneous states, and that errors in the parameterization might be balanced by other model errors. The technique of nudging model states towards reanalyses restrained the model circulation so that the behaviour of the parameterizations might not be typical. One particular method that did appear to hold promise was the analysis of an evolution of ensemble of forecasts and to examine how parameterizations behaved before the predicted state diverged too far from the truth. The concept of such an approach being developed was that climate models might be run in NWP mode, and the evolution of the forecast and of various variables examined - this was being termed a "transpose" AMIP. More specifically, predicted variables would be compared with values from reanalyses over regions where these variables were known to be correct from comparison with observations (i.e. data rich areas over the US and/or Europe) in forecasts of only a few days during which the state may be considered "correct". The intention was very much to try and learn why there are model errors, rather than just what the errors were.

The initialization and spin up of the forecasts were likely to be critical aspects of whether useful results could be obtained, especially in trying to assess model treatments of cloud and radiation. A pilot project was being undertaken at NCAR with the CCM using initial data provided by ECMWF (which then had to be interpolated to the CCM grid).

Snow Models Intercomparison Project (SNOWMIP)

SNOWMIP was being undertaken under WGNE auspices by Météo-France (Centre National de Recherches Météorologiques, Centre d'Etudes de la Neige, CNRM/CEN) and was aimed at evaluating the different types of snow models that have been developed for applications ranging from climate modelling, snow stability and avalanche forecasting. The basic approach to be followed would be point validations of the simulated evolution of the snow mantle. An atmospheric forcing would be supplied (as well as heat flux from the soil for those models which did not include a coupling with the underlying ground surface). Figures to be collected included bulk properties and fluxes every hour for all models and internal characteristics of the snow mantle every three hours. Various sensitivity studies would also be undertaken. Data sets from sites in various parts of the world would be used (e.g. from Col de Porte in the French Alps where excellent radiative and precipitation measurements were available; from Sleepers River in the Appalachians; Goose Bay, Canada). Over twenty groups have expressed interest in participating in the exercise. Data sets were distributed at the end of 2000, with results to be submitted by the end of March 2001. A workshop was being planned in conjunction with IAMAS Assembly in Innsbruck, Austria, 2001, to review the results. More information is available on the web site **http://www.cnrm.meteo.fr/snowmip/**. It was noted that this project was relevant to the GEWEX Global Land-Atmosphere Study (GLASS) (see section 5.5.2) and that appropriate liaison should be established between SNOWMIP and GLASS.

Other relevant work in this area was an intercomparison of snow depth analyses at the Canadian Meteorological Centre (CMC), Deutscher Wetterdienst (DWD) and the Japan Meteorological Agency (JMA) (undertaken by JMA in response to a request from the WCRP/GCOS Atmospheric Observation Panel for Climate). One factor contributing to the differences seen was the wide variation of input observations of snow depth (from SYNOPs) (e.g., DWD and JMA did not use any SYNOP data from the USA). Additionally, significant discrepancies could be seen in the analysed fields, particularly in data-sparse areas, pointing to possible shortcomings in snow analysis methods (which were still somewhat rudimentary). Progress in this area would depend on an enhanced exchange of observations of snow depth, as well as a careful evaluation of model predictions of snow-related fields.

Comparison of deterministic predictions of stratospheric activity

An initial intercomparison of deterministic predictions of stratospheric activity at lead times of a few days for a period in October 1994 (as described at recent JSC sessions) has now been concluded, since the results collected were becoming relatively old. However, in the past two or three years, there has been growing interest in the representation of and prediction in the stratosphere and several major global operational centres had significantly increased the vertical extent and resolution of their models and associated data assimilation and predictions in the stratosphere and into the mesosphere (50-60 km). This development was linked to need to make optimum use of data from new operational satellites such as NOAA-15 and NOAA-16, and AMSU/HIRS radiance measurements. WGNE thus endorsed a new activity aimed at carrying out quantitative intercomparisons of stratospheric analyses in terms of mean fields and biases and variances, and of model predictive skill in the stratosphere. BMRC expressed willingness to lead these further studies and, in collaboration with interested data centres, will arrange the assembly of required data sets, lay down common diagnosis and verification procedures, and identify a period for study. This work will complement closely that carried out in SPARC "GRIPS" (see section 6.2.1).

International Climate of the Twentieth Century Project

The objective of the International Climate of the Twentieth Century Project, developed under the leadership of the Center for Ocean-Land Atmosphere Studies and the UK Meteorological Office Hadley Centre for Climate Prediction and Research, was to assess the extent to which climate variations over the past 130 years could be simulated by atmospheric general circulation models given the observed sea surface temperature fields and sea-ice distributions and other relevant forcings such as land-surface conditions, greenhouse gas concentrations and aerosol loadings. The initial experimentation being undertaken involved carrying out (four-member) ensembles of integrations with the observed sea surface temperature and sea ice as the lower boundary conditions (the HadISST 1.1 analyses provided by the Hadley Centre). However, data availability and reliability prior to 1949 were limiting factors in specifying all the required forcing fields. A small common set of diagnostic quantities was being saved from all integrations to facilitate comparison and quantitative analysis. The project was complementary to other internationally-co-ordinated numerical experimentation projects, notably AMIP, and the general guidelines were similar to these activities. Fifteen groups were participating. Results from the initial set of experiments were expected to be reviewed at an international workshop later in 2001.

4.1.4 Studies of model dynamical cores and numerical algorithms

With the advent of massively parallel processing and distributed computer architectures, the development of refined numerical algorithms to extract the best performance possible from the machines available at modelling centres was receiving much attention. In this area, effective collaboration has been established between modelling and computer science centres.

A comprehensive view of activities was provided by the Eighth Workshop on the Solution of Partial Differential Equations in Spherical Geometry in December 1999. New numerical algorithms were being constructed for integration of the primitive atmospheric equations, and algorithms employed in other areas of fluid dynamics were being adapted to the atmospheric equations. The set of shallow water equations was a particularly good test bed since they encompassed the essential computational difficulties of full atmospheric modelling. New techniques being examined in this manner included cell-integrated semi-Lagrangian transport schemes and Osher's scheme (a higher order finite volume scheme of the upwind type) applied on a reduced grid (stereographic in polar regions). Triangular or icosahedral grids were also being used with such schemes as Lagrange-Galerkin finite elements (solving the equations in Cartesian space), third and fourth order three-dimensional Cartesian methods, polynomial reconstructions (originally developed for unstructured grids and thus applicable to variable meshes), and genuinely multi-dimensional accurate and non-oscillatory upwind techniques (also on unstructured grids). Furthermore, attention has been directed to cubed sphere or gnomonic mappings which include high resolution finite-volume shock-capturing methods with limiters to the second order, and control-volume-based finite element schemes. New quasi-uniform meshes have been developed such as Fibonacci grids which had structures resembling the seeds on a sunflower or the scales on a pineapple. Theoretical work has provided the basis for the definition or near optimal interpolation points on the sphere although appropriate approximation methods have not as yet been elaborated.

Test cases

A few of the newer methods have been applied to three-dimensional baroclinic models with promising results. However, in this respect, although the shallow water test suite has been useful, there was now a need for (simple) tests of the various schemes for a baroclinic system before they were introduced into complete models when complex feedbacks could obscure the effects of the changes. Tests have been devised including the treatment of a breaking Rossby wave on the polar vortex as an initial value problem, and of a growing baroclinically unstable wave. These were both deterministic tests, but without analytic solutions and a high resolution reference computation was required. Furthermore, an assessment of the long-term characteristics of new methods was being attempted based on the "age-of-air" concept in the stratosphere. This required a Lagrangian particle code to separate the effect on the age of the air by the dynamics as represented in the new schemes (and hence the advection of air), and that of the transport approximations themselves when used with that dynamical representation. The test being considered involved an extension upward into the stratosphere of the idealized Held-Suarez forcing (used to drive model dynamical cores in test mode), but, so far, the resulting atmosphere has been too sluggish to produce realistic ages.

Aqua-plant experiments

There was also a requirement to test the interactions of physics parameterisations with each other and with the dynamics. Stripped down versions of atmospheric models with very simplified surface conditions, in particular "aqua-planet" experiments with a basic sea surface temperature distribution, offered a useful vehicle in this regard, and their value in understanding the performance and effects of different representations of physical processes in individual models has been clearly demonstrated. For example, a suite of experiments has been run with the Hadley Centre atmospheric model (version HadAM3) to investigate sensitivity to an idealized set of four different zonal hemispherically symmetric sea surface temperatures, and how the organization of tropical convection and the tendency for rain to occur on or off the equator were affected. Further tests were run with an off-equatorial sea surface temperature maximum and zonally assymetric sea surface temperature anomalies. Similar experimentation has also been carried out at NCAR (with CCM3).

WGNE recognized that such "aqua-planet" experiments could have wide application in evaluating interactions of various processes in models, and encouraged individual groups to carry out these types of tests (especially using the idealized sets of sea surface temperature distributions referred to above). An intercomparison of the various results obtained would clearly be of considerable interest and the possibility of assembling results at one centre should be explored. WGNE would keep studies in this area under review.

4.1.5 Atmospheric model parameterizations

The GEWEX "modelling and prediction" thrust, with which WGNE worked in close association, was devoting efforts to the refinement of atmospheric model parameterisations, notably those of cloud and radiation, and land surface processes and soil moisture (see full descriptions in section 5.5). In the discussion of the GEWEX modelling and prediction thrust, WGNE also had the opportunity to review the plans for the GEWEX Co-ordinated Enhanced Observing Period (CEOP) (see section 5.3). It was noted that a range of topics of interest to the modelling community would be taken up, in particular the experience to be gained in using standard, special and new observational information, assessment of the capabilities of global and regional models to simulate and predict key continental-scale features of water and energy cycles, the opportunity for global validation of products, and regional intercomparisons and model transferability over the globe. Regional and global model evaluations would be supported by special test experiments over the La Plata River basin and the Canadian prairies. Moreover, CEOP offered the opportunity of diagnosing how well improved assimilated model products characterized water and energy budgets over land, and how the land was interacting with the atmosphere. Conversely, CEOP needed WGNE's expertise in global and regional modelling and experience in organizing model intercomparisons.

WGNE urged modelling centres to consider how to take advantage of the opportunities provided and what experimentation/research/validation could be carried out, and for example, whether model systematic errors might be affected in any way. Attention was drawn to the possibility of organizing appropriate budget diagnostic studies in the framework of AMIP. WGNE also stressed the importance of as much as possible of the data collected in CEOP being available in real-time so that rapid feedback could be provided from operational centres. On the practical side, it was suggested that information on CEOP and the range of data planned to be collected should be more widely advertised, together with regular updates on progress in implementation. Regarding the foreseen role of national weather services (either to carry out special operations in support of CEOP or to provide additional data), it was pointed out that an official request should be made to these centres as soon as possible.

4.1.6 Orographic representation in models

At the WGNE session in October 2000, problems and recent developments in the representation of orography in models were reviewed. There remained a variety of questions in respect to treating roughness and gravity wave effects, the use of envelope or silhouette approaches, and whether a specific lift parameterization might be needed. Significant research effort was being directed to these and related issues. In particular, there was continuing investigation of co-ordinate systems adapted to capturing orographic effects. For several dynamical problems, it appeared that the conservation of the maximum height may be more important than conservation of mountain volume. Although the treatment of planetary waves was improved by such techniques as "valley-filling", envelope orography and silhouette techniques, there were consequently problems with data assimilation. Thus, the general trend has been to go back to a mean orographic representation in recent years, complemented by an inclusion of a low-level (gravity-wave) drag. With regard to roughness effects, the "effective roughness" concept, with horizontal scales ranging from a few meters to a few kilometers, was in wide use. Various results have indicated that benefits can be achieved with increased roughness values (for example, in the second COMPARE case study carried out in 1995 and 1996, increased roughness gave better results than envelope orography at least for meso-scale models). The appropriate momentum flux profile induced by gravity wave drag continued to be a subject of discussion. Recent refinements (which are essentially a mixture of complex theories and empiricism) have included taking into account the effects of blocked flow, of high drag states, of trapped lee waves, and of critical levels in the presence of shear. Among a number of outstanding problems were how the planetary boundary layer and clouds might affect gravity wave drag, the relevance of high drag states, and the behaviour of schemes in the stratosphere (this last aspect was being studied in SPARC-GRIPS). Another topic attracting renewed attention was that of lift forces. Clearly, orography was responsible for a lift force acting on the flow: it has recently been suggested that this might have a large impact on the planetary waves in an atmospheric circulation model (in contrast to the drag which mainly influences the zonal wind). In this case, a specific parameterization of lifting effects might be needed in some models (in addition to a lift forcing proportional to the mountain volume).

In summary, it was noted one model might include several complex schemes to take account of various orographic effects, often interacting in a complicated manner. It appeared that a simpler unified approach was required, in particular to avoid double-counting effects. Momentum budget studies, detailed comparison with observations and studies with very fine-scale models would all certainly serve a useful purpose, but available relevant observational data sets were limited. It was also proposed that the question of orographic representation in models could be treated by a further COMPARE case study, perhaps again exploiting the unique data sets collected in the Franco-Spanish Pyrénées Experiment (PYREX) a few years ago.

4.1.7 Model-derived estimates of ocean-atmosphere fluxes and precipitation

Progress was now being made in the implementation of the updated WGNE evaluation and intercomparison of global surface flux products (over ocean and land) from the operational analyses of a number of the main NWP centres (the "SURFA" project). As well as the increasing concern in NWP centres with improving the treatment of surface fluxes, this activity responded to the request of the joint JSC/SCOR Working Group on Air-Sea Fluxes for a WGNE initiative to collect and intercompare flux products inferred from operational analyses. Furthermore, the GCOS/GOOS/WCRP Ocean Observations Panel for Climate has underlined the requirement for high quality surface flux products that would have to be provided from routine operational analyses to meet its objective of implementing the ocean observing systems and assembling the data sets for the purposes of climate studies. The Global Ocean Data Assimilation Experiment (GODAE), aiming to provide a practical demonstration of real-time global ocean data assimilation as a basis for complete synoptic descriptions of the ocean circulation at high spatial and temporal resolution, also had requirements for high quality global real-time products (see section 2.4). Moreover, the study of land-surface fluxes was of growing importance in the context of the new Global Land Atmosphere System Study (GLASS) (see section 5.5.2).

In the initial pilot study that has now begun, eleven operational NWP centres have been invited to submit full global fields of various surface products at twelve-hour intervals (accumulated fluxes for predictions from 00-12, 12-24, 24-36 and 36-48 hours) to PCMDI. Advantage was being taken of AMIP experience in setting the standards, formats, and procedures for assembling SURFA data sets and developing software for diagnostics and studies of the products received. Documentation of the models and operational assimilation/analysis systems would be built up. The goals of the project were to provide the participating NWP centres with routine (i.e. yearly) evaluation of their surface fluxes and how they might change as a result of modifications of assimilation and forecast models, to offer a basis for co-operation between NWP centres and relevant observational programmes in comparing surface fluxes, and to stimulate detailed comparisons with high quality direct measurements. If the pilot study proved to be sufficiently useful and succeeded in involving the various communities concerned with surface fluxes, it was intended that SURFA should evolve into a long-term exercise with collection of data in near-real time. In this latter regard, strong interest was being shown in SURFA by GODAE and GCOS. The opportunity would also be taken to present and advertise SURFA at the Workshop on the Intercomparison and Validation of Ocean-Atmosphere Flux Fields in Washington, DC in May 2001 (being organized by the JSC/SCOR Working Group on Air-Sea Fluxes, see section 7.1).

4.1.8 Modelling large-scale atmospheric transport

A series of workshops to assess the ability of atmospheric models to simulate the global distribution of inert or chemically interacting matter has been organized under WGNE auspices. The planning of a further workshop aimed at assessing how models treat and resolve the size distribution of multiple aerosol types by examining the results of a standard comparative simulation was only moving ahead slowly. The Brookhaven National Laboratory of the US Department of Energy has agreed to act as the focal point for the work, to specify the observational data required, and to evaluate the model results obtained.

4.1.9 Reanalyses

At ECMWF, the ambitious and comprehensive 40-year reanalysis project (ERA-40) has received support from the European Commission for a three-year period. Several years of preparatory work have now culminated in the first year of experimental production (September 1986-August 1987) using a 60-level T159 forecast model coupled with an ocean wave model. Using this as a spin-up, production of a first stream 1987-2001 had begun (but with a slightly updated version of the model to overcome problems noted with the phase of the S2-tide). A much wider selection of data sources was being used for ERA-40 than the earlier fifteen-year reanalysis project (ERA-15). This included a full set of TOVS raw radiances beginning in October 1978 with the original TIROS-N observations. With regard to conventional data, a merged set bringing together many sources (NCEP/NCAR, COADS, US Navy, Canadian and Russian snow observations, Australian Antarctic information, data from the University of Wisconsin and the British Antarctic Survey), as well as the ECMWF operational data base, has been assembled. A surprisingly large amount of extra data was available (in particular a significant increase in the number of radiosonde and pilot wind soundings from NCEP). Radiosonde biases have been calculated since 1957. Special attention has been paid to the assimilation of the satellite radiance data, with the operational system being modified to include raw radiances from the HIRS and SSU instruments that have flown (with the MSU instruments) on TOVS satellites since 1978. More generally, there has been significant technical development of the assimilation system to meet the needs of ERA-40 and many of the deficiencies noted in ERA-15 have been rectified (e.g. the time continuity of the analyses, wind speed over the oceans, the Hadley circulation (with a double ITCZ over the Pacific now being produced), stratospheric humidity (now evolving realistically), annual cycle in tropical stratospheric winds).

The original NCEP/NCAR reanalysis from 1948 was continuing to be carried forward to the present in a quasi-operational manner (two days after data time) and has now been extended to a total period of nearly 53 years. The ready accessibility of the reanalysis either electronically or on CD-ROM has underpinned its wide exploitation in many parts of the world (e.g. the majority of papers at the recent conference on Southern Hemisphere Meteorology made use of the NCEP/NCAR reanalysis). As noted above, NCEP co-operated with ECMWF in producing a merged data set of conventional data holdings, in which it was found that NCEP had significantly more data than ECMWF. It was hoped that this merged data set of conventional observations could be used for all future reanalyses. Regarding further reanalysis activities, a joint NCEP/DOE reanalysis (NCEP-2) for the period 1979-1999 has now been completed (available electronically). This was based on an updated forecast model and data assimilation with corrections for many of the problems seen in the original NCEP/NCAR reanalysis, and also provided improved diagnostic outputs. The possibility of extending the second reanalysis backwards pre-1979 was being explored. A regional reanalysis over the USA was also being prepared for the period 1979-2003 (and would then continue in quasi-real time), using a 32km resolution, 45-layer model. Particular features would be assimilation of precipitation (using a nudging technique) and fixed and evolving bias corrections to radiances. Streams of input information would include SSM/I ocean surface wind speed and total column precipitable water, surface land observations, three-hourly US air force nephanalyses, cloud-top pressures (from HIRS), snow-depth analyses, reanalysed sea surface temperature, and hurricane position, depth and radius of maximum wind. The expectation was that the regional reanalysis would offer a superior product for the North American sub-continent taking advantage of the intrinsic ability of regional models to offer more detailed results for domains of interest than global models, as well as exploiting the boundary conditions provided by the existing global reanalysis to drive a regional system.

It was noted with interest that the Japan Meteorological Agency was also studying the feasibility of undertaking a reanalysis project, with particular emphasis being given to the behaviour of the Asian monsoon and tropical cyclones. This initiative was strongly encouraged.

4.1.10 Observing system and observation impact studies

The main focus of WGNE discussions on data assimilation/analysis systems at its most recent session was on observing system and observation impact studies (although, as customary, the latest developments in the data assimilation/analysis at the main operational centres were reviewed). It was noted that, at the international level, a number of groups were working to assess the potential effect of changes in observing systems. In particular, the WMO/CBS Expert Team on Observation Data Requirements and Redesign of the Global Observing System has instituted a rolling review of user requirements combined with an objective critical assessment of the capabilities of observing systems. A "statement of guidance" aimed principally at influencing the design of future satellite programmes was being prepared. The WMO/CBS Expert Team to Evaluate the Impact of Changes in the Global Observing System on the Global Data Processing System has carried out a study of the impact of the loss of Russian Federation RAOBs on NWP skill in the northern hemisphere. However, the variability of scores/verification statistics was too great for this approach to give any conclusive results: parallel observing system experiments were needed. The second CGC/WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction was held in France in March 2000. Compared to the previous meeting of the group in 1997, more attention was given to the impact of satellite data on NWP, to the use of targetted observations, and to experiments with more advanced data assimilation methods. A summary of the main conclusions was being prepared which would be considered by the appropriate WMO working groups and/or expert teams and then by CBS itself. This should lay the foundation for further impact studies (e.g. observing system experiments) to provide guidance for the redesign of the Global Observing System.

The JSC welcomed the co-operation between WGNE and the CAS World Weather Research Programme (WWRP) in the planning of the Hemispheric Observing System Research and Predictability Experiment (THORPEX) whose goal was to develop and demonstrate the utility of a mix of in situ and satellite observing systems. Representatives from WGNE have participated in the International Science Working Group considering the planning of THORPEX, the status of which was reviewed at the WGNE session. Clearly, theoretical and numerical research would be fundamental to the success of THORPEX (including such aspects as identification of atmospheric regimes that produce weather systems with low predictability, localising sensitive areas, development of new observing strategies, and investigation of the practical predictability of different flow regimes). It was stressed that the THORPEX science plan should contain a thorough description of the scope of the research envisaged and procedures for co-ordinating this research, and should be aimed at examining new observing technologies and approaches. In field campaigns, the deployment of several observing systems to give some possible redundancy was encouraged. The importance of the effective deployment of observing systems based on numerical and theoretical studies of both network design and synoptic targeting when possible was stressed. Adequate resources (preferably from the same sources as the observations themselves) would have to be provided for the numerical experimentation support, since operational NWP centres could not be expected to put in the considerable extra efforts required.

The International Science Working Group had now concluded its task and was being replaced by a THORPEX Programme Steering Committee, supported by a number of focussed sub-committees in areas such as data assimilation, observing systems and verification and impacts. Appropriate liaison members to other relevant groups (such as WGNE, CLIVAR, GEWEX/CEOP) would also be appointed.

4.1.11 Ensemble prediction

Use of ensembles to give an idea of the likely spread of predictions, to provide a basis of the probability of different results occurring, and for computing ensemble means which may have more skill was now very much a cornerstone of forecasting or climate projections on all timescales. Recent years have seen remarkable progress in the application and use of ensemble prediction systems underpinned by rapid advances in the provision of singular vectors, initial perturbed states, etc. At its most recent session, WGNE reviewed the status of work in this area.

Several instances were seen of the power of the ensemble approach in picking out useful predictability. For example, in increasing the resolution of an ensemble prediction forecast model, probabilistic skill scores such as that of Brier were seen to advance by a much larger margin than the skill of the deterministic control forecast. A possible explanation for this type of finding was that a particular event might be poorly forecast by the control integration, but could be reasonably captured by a number of ensemble members. Increasing resolution might only slightly change the performance of the control integration, but could significantly improve the predicted evolution by ensemble members which had already given some indication of the event.

Another valuable approach has been the use of targeted diabatic singular vectors in the tropics as initial perturbations in generating ensemble predictions of tropical cyclone tracks. It has been found that the ensemble spread may now generally encompass the actual track whereas, previously, there was only a relatively small spread of predictions. Furthermore, preliminary results of using singular vectors with humidity as a component of the initial perturbations showed that faster growth rates were achievable in summer than winter, consistent with the observation that forecast error doubling times are shorter in summer than winter.

The use of the concept of "potential economic value" was now coming into use as a measure of ensemble performance. For instance, in the case of extreme weather events, the value of an ensemble-mean forecast was plainly limited. Optimal value could be obtained by using the full probability distribution obtained from the ensemble prediction system. The potential economic value could also be significantly enhanced by increasing the number of members of the ensemble. Generally, ensemble prediction readily lent itself to commercial applications. For example, an electricity forecast demand model could be driven successively by all the members of an ensemble, thereby deriving a forecast probability distribution of electricity demand. The mean of this probability distribution has been shown to be a more skilful prediction of demand than could be obtained either by a state-of-the-art statistical model, or a demand forecast based on a (high-resolution) deterministic NWP model prediction.

The application of so-called "Poor Man's" ensembles was also discussed, using as an example precipitation forecasts over the Australian region. The ensemble was created from the operational products from various centres available in real-time over the Global Telecommunications System. The approach appeared to have encouraging potential, at the same time being a cheap and efficient means of obtaining an objective ensemble of forecasts, which might be especially useful for short-range purposes. A systematic analysis of Poor Man's ensembles was being undertaken at the United Kingdom Meteorological Office.

4.2 Progress in coupled modelling

4.2.1 Overall scope of work of WGCM

WGCM endeavoured to maintain a broad overview of modelling activities in the WCRP in its basic task of building up the comprehensive climate models required fully to understand and predict climate variability on seasonal to interannual to decadal timescales and for making more confident projections of anthropogenic climate change. In particular, there were many fundamental modelling issues where close interaction with WGNE was necessary e.g., questions related to numerical methods such as application of semi-Lagrangian techniques or linear grids offering substantial advances in the speed of integration, the parameterization of various physical processes. In this connection, the JSC invited the WGCM to report on feasibility of and/or questions related to using the various available new numerical techniques in climate modelling applications.

In other areas of WCRP modelling, the work carried out in GEWEX aimed at improved treatment or land-surface processes in models (the "Global Land Atmosphere System Study", GLASS) (see section 5.5.2), and the studies of the parameterization of cloud systems (the GEWEX Cloud System Study, GCSS) (see section 5.5.1) were of major interest.

In respect to the work on model simulations of the stratosphere undertaken in SPARC (see section 6.2.1), WGCM agreed that a full representation of the stratosphere was needed in climate models in order to be able to simulate realistically chemistry-climate coupling and solar forcing. In the results reported by the CLIVAR Working Group on Seasonal-to-Interannual Prediction (WGSIP), see section 9.1.4), the serious shortcomings highlighted in the performance of coupled models in even such basic features as the representation of the annual cycle was disturbing. To make progress in seasonal-to-interannual prediction, much more attention and concentration needed to be given to the basic development and systematic improvement of the models being used. WGCM also noted the strong evidence of the need to elaborate an appropriate coupled ocean-atmosphere data assimilation approach for initializing seasonal forecasts.

The following paragraphs summarize the principal activities being undertaken by the WGCM itself including the main items of interest and recommendations from the most recent session of the group, kindly hosted by the Scripps Institution of Oceanography, CA, USA, in October 2000. The WGCM session had been preceded by a workshop on "Decadal Climate Preditability" also at the Scripps Institution of Oceanography. This provided useful input to WGCM discussion on natural climate variability on multi-annual timescales and beyond (see section 4.2.10).

4.2.2 Cloud-climate forcing and feedback

WGCM has for a long time emphasized the importance of an improved understanding of the role of cloud feedback in climate sensitivity, pointing out that the representation of cloud-climate forcing and feedback in models was one of the most uncertain areas in climate simulations and projections of climate change. The GEWEX Radiation Panel was also beginning to consider how to examine this problem (see section 5.4). Dr. G. Stephens, (then) Chair of the GEWEX Radiation Panel, participated in the WGCM session for a joint discussion by the two groups of the fundamental issues to be faced in considering feedbacks linked with clouds and their representation in models.

From the outset of the discussion, it was recognized that it was not adequate to think of cloud/climate feedback in the type of simplified manner generally used up to now. Rather, the full functional dependence of the radiation budget (throughout the atmosphere) on cloud (which in turn depended on the general circulation and temperature, moisture and other variables), on moisture (again, in turn, a function of the general circulation, cloud, temperature etc. and on other atmospheric parameters) had to be considered. In the case of imposed forcing (e.g. increased greenhouse gas concentrations in the atmosphere), this introduced a whole range of feedbacks which affected the climate response including such aspects as the relationship between cloud properties and their key radiative characteristics, the relationship between the atmospheric circulation at large-, meso- and cloud-scales and cloud properties, and many others that have not hitherto been taken into account. In many cases, the relevant observational data have not been collected (nor is it even possible to collect the data required). For instance, in the case of the relationship between clouds and circulation, the most complete description was from numerical weather prediction models and related activities such as forecast verification, data assimilation etc. There was certainly a gap in global observations of clouds in the context of atmospheric circulation. The key to progress lay in a combination of modelling and observations to establish a (predictive) understanding of the relationship between clouds and the circulation, and of the many other feedbacks/relationships involved.

Close co-operation between WGCM and the GEWEX Radiation Panel in exploring the complex questions involved in cloud-forcing/climate feedback and in the organization of appropriated combined modelling/observational studies was thus essential. AMIP and CMIP could provide a valuable framework for the type of studies involved and the GEWEX Radiation Panel and GCM would consider jointly formulation of appropriate AMIP and CMIP projects, the type of analysis techniques necessary, and the observational data sets required. Model data sets would have to be collected for certain periods at much higher space- and time-resolution than normally specified in AMIP or CMIP (as well as additional parameters) in order to be able to see clearly gross weather features and the associated cloud systems. At the same time, closer interaction between climate modellers and numerical weather prediction groups in assessing valid cloud statistics and the relationship with other atmospheric variables was needed.

The JSC strongly welcomed and endorsed the joint approach being considered by WGCM and the GEWEX Radiation Panel in the investigation of cloud/climate feedback. The JSC stressed the importance of continuing and developing this joint approach and looked forward to a report on progress at its next session.

4.2.3 Coupled Model Intercomparison Project (CMIP)

CMIP was one of the most important and long-standing initiatives of WGCM, having been started in 1995, comprising two components: CMIP1 to collect and document features of global coupled model simulations of present-day climate (control runs); CMIP2, to document features of climate sensitivity experiments with CO_2 increasing 1% per year. CMIP1 and CMIP2 data bases have been established at PCMDI. Data from the control runs of global coupled models (CMIP1) have been collected from twenty-one modelling groups in eight countries (representing virtually every group in the world with a functioning coupled model), and from transient climate integrations from sixteen groups (all that were expected). Using the PCMDI data bases, ten CMIP1 and fifteen CMIP2 diagnostic subprojects were currently in progress on a wide range of subjects. Four of the CMIP2 projects have begun during the past year, namely: simulation of cryospheric change in coupled models; a study of climate impacts models; evaluation of the uncertainty in the rate of oceanic heat uptake and its contribution to overall uncertainty in climate change projections; and coupling between changes in hydrological and energy budgets. (The other subprojects were outlined in the report of WGCM to the JSC last year). An extension to CMIP2, "CMIP2+" has now been initiated aiming to assemble sets of extra data (beyond the basic fields originally collected in CMIP1 and CMIP2) at higher temporal resolution so that additional processes, as simulated in coupled models, especially such aspects as feedback mechanisms (e.g. cloud-climate forcing as discussed in section 1) and ocean mixing could be investigated in more detail. Modelling groups have been duly invited to submit available history files for control runs and 1% transient integrations, but only limited new data have so far been received at PCMDI. Nevertheless, WGCM has strongly encouraged the continuation of "CMIP2+", noting that daily data or data at higher temporal resolution for a certain period would enable for the first time much more detailed studies of characteristics of coupled models (of the same type that have already been performed in AMIP). Further consideration was being given to the data sets to be compiled and the research community was being advised of the availability of the extended CMIP1/CMIP2 data base.

In reviewing the continuing development of CMIP, note was taken of remarks in the IPCC Third Assessment Report. Work carried out in CMIP, including certain diagnostic projects had been an important contribution to various parts of the report. The need to continue and refine model intercomparison projects was particularly stressed (with an implied role for WGCM to take the lead role in organizing and overseeing such activities). Requirements highlighted were for an intercomparison of coupled models run under standardized experimental conditions for the twentieth century, co-ordinated well-designed experiments to explore the impacts of resolution (horizontal and vertical), systematic exploration of model uncertainties linked to parameterizations, and an intercomparison of model sensitivities.

WGCM had previously examined the possibility of a third phase of CMIP ("CMIP3") focussed specifically on twentieth and twenty-first century coupled model simulations to meet the requirements expressed by IPCC. It was seen that the exact approach to be followed was complicated by the numerous scenarios employed and lack of agreement on forcing data sets. Moreover, there was the open question of how such an activity would be linked to that of the IPCC Data Distribution Centre which intended also to archive data from twentieth or twenty-first century runs. A number of general ideas were put forward on how a "CMIP3" might be organized. Firstly, it appeared appropriate that the criteria set by the IPCC Data Distribution Centre should be followed, particularly that only runs with full three-dimensional coupled atmosphere-ocean general circulation models should be considered. It was thought that the period of integration should be from 1850 (if possible 1700) to the present, with at least three runs per forcing to be undertaken (to permit an ensemble approach to evaluation). For initialization, existing control runs could be employed (although the issue of mixing present-day temperatures with radiative forcing conditions in 1700 would have to be examined). One common run with greenhouse forcing only would certainly be useful, but other integrations including other (non-standardized) forcings (e.g., solar, aerosol, volcanisms, changes in land-cover use) should be encouraged. It was agreed that it would be essential for the radiative forcing to be documented, and the forcing data employed to be in the public domain (or made public). Nevertheless, WGCM finally came to the view that, before embarking on a CMIP3, the CMIP2+ data collection should be completed, especially in regard to the archival of daily data, and the organization of appropriate diagnostic sub-projects. Such a complete data set from a coupled model would be the first ever of its kind available for model intercomparison, and would offer unique and exciting opportunities for analysis. This would be of value not only to the climate diagnostics community, but also to ocean modellers (who could take advantage of the entire history tapes of ocean data from the coupled model). Altogether, the further experience would help in setting up a more focussed and relevant CMIP3 in the future.

More generally, the overall importance of maintaining the CMIP data base and the basic atlas of CMIP coupled-model results (including overview figures and various statistical summaries etc) which were distinctive pointers to the level of performance of coupled models was emphasized. The data base was very valuable in showing whether such characteristics as ENSO were being successfully reproduced. The JSC urged WGCM also to pursue actively studies of CMIP simulations of decadal variability. The JSC agreed with the suggestion of WGCM that modelling groups should have the possibility of withdrawing earlier integrations and replacing them with more recent results. It could be foreseen that technological developments would have an impact of CMIP, with progress being made in the direction of a distributed archival structure. Nevertheless, PCMDI would retain its key role in acting as a clearing house, a data referral centre, and holding data subsets from groups not willing or able to offer local access.

The JSC was impressed with the scope of CMIP, the exciting range of results being achieved, and the contributions in many areas of climate research. The JSC acknowledged the excellent work of the CMIP panel (established by WGCM) and chaired by Dr J. Meehl of NCAR in overseeing the detailed planning of CMIP. The particular insight that had been provided by Dr G. Boer (Canadian Centre for Climate Modelling and Analysis) as a member of the CMIP (who had now stepped down) was also noted. Further, the JSC voiced appreciation for the essential role of PCMDI as the central archive for CMIP integrations and providing a large range of software facilities in support of the diagnostic sub-projects.

4.2.4 Idealized sensitivity experiments

As described at the last session of the JSC, intercomparison of results from equilibrium doubled CO_2 experiments (in which the atmosphere was coupled to a simplified slab ocean, thus not involving the complexity of the ocean response) had shown significant differences in inferred cloud forcings and changes in the top-of-the-atmosphere fluxes in different models. This work was now being formally written up and had also fed into the IPCC Third Assessment Report.

There was considerable interest in the community in maintaining this study, and various protocols for continuing to evaluate the inferred feedbacks were being discussed (including a project supported by the

European Union). It did appear timely to convene a workshop on this topic to establish a generally acceptable experimental plan, and the opportunity to attach such a workshop to an event such as the European Geophysical Society Annual Assembly, an IUGG/IAMAS Assembly, or even the planned GEWEX Conference in Paris in September 2001 was being explored.

Under this item, results from studies of climate sensitivity at the Japan Meteorological Research Institute were also noted. Two new Japanese coupled ocean-atmosphere general models, that from the Meteorological Research Institute (MRI2) and that from the Centre for Climate System Research and the National Institute for Environmental Studies (CCSR/NIES2) showed respectively the minimum and maximum climate sensitivities in the transient climate change integrations included in the IPCC Third Assessment Report. On the other hand, earlier versions of these models showed intermediate sensitivities. In discussing possible reasons why the models had changed in this respect, it was recalled that the earlier version of the Meteorological Research Institute coupled model (MRI1) demonstrated a La Niña-like transient response in the Pacific region to increased CO_2 forcing. However, when the atmospheric component of MRI1 was coupled to a mixed-layer ocean, the equilibrium response in the Pacific region was dominated by an El Niño-like signal, and the climate sensitivities shown by the fully coupled and mixed layer versions were different. In contrast, both the coupled and mixed-layer versions of MRI2 showed weak El Niño-like responses, together with (similar) low climate sensitivities. The atmospheric component of MRI2 was a modified form of the model employed operationally by the Japan Meteorological Agency. Differences in cloud parameterization and relevant cloud feedback processes in MRI1 and MRI2 appeared to be mainly responsible for the lower climate sensitivity of MRI2.

In the case of the CCSR/NIES2 model, two main factors were thought to contribute to the enhanced climate sensitivity compared to the earlier model version. One was the choice of radiation parameters for the gas absorption coefficients (although both the new and older values appear realistic compared with line-by-line computations), the other the change in cloud-radiation feedback consequent to modified values for parameters used in the convection and boundary layer representations. Experimentation with mixed layer models suggested that the first factor explained about two-thirds of the enhanced sensitivity, the second about one-third. Integrations were now being carried out with both the earlier and more recent model versions to examine the changes in the simulated transient response.

These types of results underlined the need to continue to investigate the magnitude of various feedbacks and the relative roles of dynamics and thermodynamics, and illustrated the useful information that could be deduced from mixed-layer or slab ocean models in studying changes in responses following model developments.

4.2.5 Standardized forcing scenarios

An IPCC Special Report on Emission Scenarios (SRES) has proposed four modified scenarios based on various assumptions regarding demographic and technological developments. A number of centres have now undertaken runs using the SRES scenarios, as well as continuing runs using other forcing data sets (e.g. as being contributed to CMIP2). It was noted that there remained considerable uncertainties in aerosol forcing and modelling centres were encouraged to conduct runs for greenhouse gas and aerosol forcings separately in order to improve understanding of the latter, and to be able better to scale results from one scenario to another.

4.2.6 Initialization of coupled models

An appropriate initialization of coupled models was essential for a realistic control integration, and for subsequently being able to assess the signal versus noise ratio in transient climate change experiments. The satisfactory initialization of the ocean component was the key and was a particular scientific challenge, as well as being potentially demanding in terms of computer resources because of the long timescales involved. Various techniques have been tried to accelerate convergence to an initialized equilibrium state, but none have been entirely successful. Moreover, an approach used at one model resolution did not always appear to work for a different model resolution. This issue was further touched on in item 4.2.7 in the discussion of ocean model development and in item 4.2.10 in the review of the results of the Workshop on Decadal Climate Predictability where the importance of initialization of coupled models had been raised.

The JSC advised that, in studying the problem of initializing coupled models, a detailed assessment of the different physical processes in the ocean (and atmosphere) should be made.

4.2.7 Ocean model development

Working Group on Ocean Model Development

As reported at the twenty-first session of the JSC, a joint WGCM/WOCE Working Group on Ocean Model Development had been formally established to give specific attention to a number of questions on the performance of ocean models and to the refinement of the ocean component of coupled models. The group has very much recognized the need to document the status of and advances in ocean modelling for climate studies. Research on methods to improve ocean models, particularly for climate purposes, would then be encouraged through workshops and other appropriate activities. Advice to climate modelling centres would be formulated, underlining what ocean modellers knew was required to reproduce the mean state of the ocean. As a first step in this process and based on the discussions at the first session of the group, an authoritative and comprehensive survey "Developments in Ocean Modelling" had been drafted (and has been submitted to "Ocean Modelling" for publication). The paper reviewed research developments in primitive equation ocean models which were, or could be, important for the ocean component of realistic global climate models used for simulating or predicting large-scale, low frequency climate variations or changes. The text had been written with an audience of modellers concerned with the ocean component of coupled models in mind, although not necessarily experts in the design and implementation of ocean model algorithms. Aspects to be taken into account and carefully considered in defining the vertical and horizontal co-ordinate systems and timestepping, in treating barotropic dynamics, in the formulation of the surface mixed layer and bottom topography, in the representation of overflows, in advection of momentum and tracers, in the parameterization of mesoscale eddies and horizontal momentum friction were all described.

The final section of the report took up the question of the optimal grid resolution for climate models, and the related issues of whether mesoscale eddies needed to be fully resolved to quantify accurately poleward heat transport, whether it was important to resolve further sub-mesoscale features and even non-hydrostatic processes, what resolution was required to simulate large-scale sea surface temperature patterns, and in how much detail the sills and passages (especially in the North Atlantic and Arctic) should be represented to provide reliable predictions of variations and potential changes in the thermohaline circulation. No answer was given, but in discussion at the WGCM session, it was estimated that a resolution of at least 1/10° was needed to resolve mesoscale eddies and no resolution higher than 1° generally, with 1/4° near the equator, could suffice to give a basically reasonable ocean simulation. In any event, ocean simulations based on relatively coarse resolutions should be compared with a high resolution ocean simulation. It was also pointed out that the use of adaptive grids and/or finite elements should be explored.

The second session of the Working Group on Ocean Model Development was held in March 2001. One of the main results from this meeting was the decision to launch the pilot phase of an ocean model intercomparison project (OMIP) that should demonstrate the feasibility and value of a co-operative assessment of the performance of global ocean-ice models. Initially, seven groups were expected to participate, with the overall exercise being co-ordinated by NCAR. A common initialization, integration protocol and forcing were agreed, basically following the example of the "mini-OMIP" conducted in Germany by the Alfred Wegener Institute, Bremerhaven and the Max-Planck Institute for Meteorology, Hamburg when comparing the MOM and HOPE models. Forcing would be from a global flux data set based on refined ECMWF reanalysis products. However, individual groups would also test alternative sets of initial data, integration periods, and forcing air-sea flux data sets. A key element would be investigation of the impact of varying ocean model resolutions. In the pilot phase, the target would be to examine the primary aspects of the large-scale ocean circulation, i.e. fields that could be compared to WOCE climatologies and derived products such as overturning rates and meridional fluxes of heat and freshwater. Moreover, there was the potential for supplementary tracer experiments (e.g. CFC-uptake) to explore the effects of ocean model formulations on the simulation of trace gas distributions. OMIP would additionally offer the possibility of assessing the behaviour of various sea-ice treatments coupled to global ocean models of various resolution, with identical forcing. The Working Group on Ocean Model Development was eager to co-operate with the ACSYS/CLIC NEG in discussion of the questions involved.

Other issues discussed at the second session of the Working Group on Ocean Model Development included the initiative on the "Dynamics of Overflow Mixing and Entrainment" (DOME). The quality of the ocean model representation of the thermohaline circulation was very dependent on how well overflows from the Nordic Seas into the North Atlantic were treated, and DOME sought to provide a comprehensive evaluation of these treatments by a variety of intercomparison and sensitivity experiments. The Working Group, noting that few CIMP diagnostic sub-projects were concerned with the role of the ocean, also strongly encouraged the appropriate extension of CMIP projects.

The JSC recognized that considerably more institutional, organizational and technical support was essential to be able to progress to a fully-fledged OMIP and to enable the further required developments of ocean models (most activity in this area at present depended on relatively small mainly academic groups).

In particular, a centre that could undertake the efforts involved in mounting a full OMIP needed to be identified.

High resolution coupled ocean/atmosphere integrations

The Working Group on Ocean Model Development has suggested that simulations from relatively coarse ocean models (as normally used in coupled ocean/atmosphere integrations) should be compared with that from a high resolution ocean and WGCM has also noted the concerns that relatively coarse resolution ocean models may result in systematic errors in ocean simulations. Coupled modelling groups have thus been urged to carry out a reasonably long integration with a high resolution coupled model as a means of identifying errors and assessing their significance. Work on these lines was only proceeding slowly. The Hadley Centre was carrying forward a run with a 1/3° oceanic and 2.5°x 3.75° atmospheric models. This had reached seven years and was being continued. A better representation of heat flow through channels was definitely evident. Plans have been made at NCAR for an integration with a T85 atmosphere and 2/3° resolution ocean. A high resolution experiment was also being considered by the Southampton Oceanography Centre (with a high resolution ocean coupled to the CSIRO atmospheric model).

4.2.8 Detection and attribution of climate change

There remained a number of outstanding issues in the quest to detect and attribute climate change. A first significant need was to be able to include estimates of model uncertainties in detection statements (e.g., in the form of the time-space covariance of model error). A first shot at this could be provided by the distribution of mean and deviations of simulations from many models forced in an identical manner. This information was more or less available for greenhouse gas forcing, but was also needed for some form of aerosol forcing. A linked question was the assessment of the uncertainty in model simulations of internal climate variability on timescales from annual to multi-decadal which was at present a major gap in detection statements. The CMIP data base could clearly be an important source of data in this respect. Secondly, as already noted in section 4.2.5, signals of anthropogenic change needed to be identified more clearly, and anthropogenic effects separated from normal influences. This would require ensembles of greenhouse gas runs only, as well as natural forcing (solar and/or volcanic jointly or separately) only. Thirdly, an overall assessment of how well the twentieth century could be modelled should be made; this would be based on simulations with the best estimates of all forcings (anthropogenic and natural) combined. Ensemble runs for critical periods would be valuable (e.g. for the last decades of the twentieth century when satellite data were available and for the period 1920-1940) to understand better what drove the early twentieth century warming (anthropogenic forcing and internal climate variability, or anthropogenic and natural forcings combined) and to see whether the lapse rate evolution indicated by observations could now be modelled. The proposed third phase of CMIP (see section 4.2.3) could offer the possibility of contributing in an important manner to the detection and attribution issue, but the type of points raised above would need to be taken into account in the planning of a CMIP3.

Other issues were the need to compare model results with observations in a like manner (e.g. use of a data mask to match model coverage with that sampled in observations; comparisons with a range of available reconstructions of hemispheric scale temperature evolution over the last millennium taking into account the limitations and strength of each record to simulate as closely as possible what is monitored by proxy data). The detection of changes in other more societally relevant variables was also beginning to be explored. Questions were also being raised as to how (present-day) data collection could be improved better to meet the requirements for detection of climate change, and modellers were being asked for advice on where more data were needed for detection and sampling climate variability. These aspects were especially important in the development and implementation of the Global Climate Observing System Global Surface and Upper Air Networks.

4.2.9 Palaeoclimatic modelling

Results from the first phase of the Palaeoclimate Modelling Intercomparison Project (PMIP) and the results of the experimentation to study the simulation of the climates of the mid-Holocene (6000 BP) and the Last Glacial Maximum (21000 BP) as reviewed at the third PMIP workshop (Canada, October 1999) have now been published in the WCRP Report Series (No. 111). (Some of the principal results were described at the twenty-first session of the JSC).

As to future directions of PMIP, there was much interest in the involved community in the extension of activities in the direction of coupled model simulations and new time intervals. However, the mid-Holocene and Last Glacial Maximum have been the focus of PMIP up to now and it was considered that these should remain central. Thus, for the mid-Holocene, the model-model and model-data comparisons would be extended to include results from coupled atmosphere-ocean model runs now available. The first of such runs have shown the importance of ocean feedback, and sensitivity experiments have indicated that vegetation feedback also needed to be considered. A common coupled ocean-atmosphere-vegetation experiment would be defined. For the Last Glacial Maximum, no new standard experiment would be undertaken for the time being. Instead, attention would be given to reconsidering the sea surface temperatures used (the CLIMAP values appear to have been relatively warm). Reliable estimates of sea surface temperature would be essential for future simulations and to validate the ocean models expected to be employed more and more in the coming years in coupled model simulations of the Last Glacial Maximum.

Two other periods of general interest were the early Holocene (10-11000BP) when insolation forcing was strong but ice sheets were still present. The design of a standard (co-ordinated) experiment was being discussed. The inception of the Ice Age at the end of the last interglacial period (115,000 BP) was already being modelled by some groups, but it was judged premature to organize common experimentation as yet. However, a contact list of interested scientists/groups would be established, exchange of information fostered, and a special session dedicated to the studies of this period and the results being obtained would be included in the next PMIP workshop (planned for later in 2001 in Europe).

The continuation of work carried out under PMIP auspices was strongly encouraged, since the simulations of palaeoclimate were an independent test of models and a valuable tool in assessing model performance not otherwise available. The JSC duly urged that continued support should be given to palaeo-modelling and allied palaeo-data studies.

4.2.10 Atmosphere-ocean predictability on decadal timescales

The proceedings of the Workshop on Decadal Predictability, organized under the auspices of WGCM and that had taken place at the Scripps Institution of Oceanography in October 2000 during the week preceding the session of WGCM itself, have now been published as a WCRP Informal Report (No. 1/2001) and as CLIVAR Report No. 39. The proceedings included a summary of the main findings and recommendations from the workshop, together with extended abstracts of the presentations made.

It was noted that, overall, work and understanding in this area were still fairly rudimentary. There was only tenuous statistical evidence of predictability on decadal timescales, and a limited number of practical or robust results from modelling studies (either simulations or predictions). In considering further activities that could be undertaken, WGCM had stressed the need for work and numerical experimentation to explore mechanisms which might underlie decadal predictability (noting that the principal foci of the workshop had been statistical analysis and model simulation of certain specific modes). It was also suggested that a diagnostic project using the extended CMIP data base (see section 4.2.3) could be useful in this respect and in understanding time-scale interactions. WGCM, in the light of its own discussions (see section 4.2.6), was very aware of the difficulty of initializing coupled models (as needed for decadal prediction) and thus did not consider the time yet ripe to take up the "Historical Decadal Forecast Project" suggested by the workshop. Nevertheless, work to investigate the many outstanding questions was strongly encouraged. The importance of developing data assimilation of coupled ocean-atmosphere systems (which would also help in specifying the observational system needed) was particularly stressed. WGCM would maintain an active overview of activities in this area.

4.2.11 Carbon-cycle modelling

Co-operation between WGCM and IGBP/GAIM

It had been hoped for some time to co-operate with the Global Analysis, Integration and Modelling (GAIM) element of IGBP in an effort to model the observed interannual variations in CO_2 and to assess the relative contributions of the atmosphere, ocean and terrestrial components of the Earth system to these variations. Professor I. Fung (University of California, Berkeley), as representative of GAIM, had participated in the WGCM session in October 2000 to discuss how the two groups could jointly proceed in this area.

The importance of working together in the development of comprehensive Earth system models was mutually agreed. As a first step, WGCM and GAIM would organize jointly a series of experiments with CO_2 as a prognostic variable. Interested modelling groups would be invited to undertake co-ordinated transient model runs using fully coupled atmosphere-land-ocean-carbon models with specified (fossil fuel) CO_2 emissions for a contemporary period (1800-2000) and for the period 2000-2100 using various emission scenarios. (Other forcings could also be included in terms of equivalent CO_2). The atmospheric CO_2 concentration would be able to evolve freely (depending on the model representation of carbon processes and absorption into or exchanges with ocean/land surfaces). The simulations of the evolution of CO_2 and the climate response would be compared. This project would be in marked contrast to the type of experimentation fostered by WGCM so far where the actual atmospheric carbon dioxide concentration has been specified. It was recognized that some of the predicted changes (both in the simulated model climate and carbon dioxide concentrations) could be very large and model dependent, and considerable care would be required in designing the experiments and analysing the results.

WGCM and GAIM were working together to define a detailed experimental protocol. PCMDI has agreed to act as a clearing house for assembling the simulations and to advise on the list of diagnostics to be collected.

Reports of carbon-cycle integrations

Several groups have already carried out integrations incorporating a representation of the carbon cycle. At the Institute Pierre-Simon Laplace, a fully coupled climate/carbon cycle model has been constructed. A pre-industrial (1860) equilibrium was established for the ocean/atmosphere, with the carbon cycle model being set to equilibrium with the corresponding simulated climate. Two runs, one a control, the other with anthropogenic carbon dioxide emissions, were undertaken from 1860 conditions up to 2100. Up to the "present", observed carbon dioxide emissions were used, and the simulated carbon dioxide concentration followed closely that actually seen. An interesting result was an indication of qualitative differences in the feedback associated with changes in the biospheric and oceanic uptake compared to a previous off-line experiment.

At the Hadley Centre, the third version of the coupled ocean-atmosphere model (HadCM3) has been linked with ocean carbon and dynamic global vegetation models. The latter represents the state of the biosphere in terms of the soil carbon, and the structure and coverage of five plant functional types within each model gridbox. However, the additional computational expense of including an interactive carbon cycle made it necessary to reduce the ocean resolution (to 2.5°x 3.75°), with the consequence that flux adjustments had to be used in the ocean component to counteract climate drift. The complete climate-carbon model was brought to equilibrium with a "pre-industrial" atmospheric carbon dioxide concentration of 290 ppmv and employing an observed land cover data set. The equilibrium condition was stable with negligible net land-atmosphere and ocean-atmosphere carbon fluxes in the long-term mean and no discernible drift in the atmosphere carbon dioxide concentration. The simulated carbon cycle displayed significant interannual variability, driven by model-generated ENSOs (which is consistent with the observational record). Transient simulations were then carried out for the period 1860-2100 using carbon dioxide emissions given by the IPCC IS92a scenario, firstly with fixed vegetation (i.e. a "standard" GCM climate change simulation), secondly with interactive carbon dioxide and dynamic vegetation but no direct impacts of CO_2 on climate (i.e. on "off-line" carbon cycle projection but neglecting climate change), and thirdly a fully coupled climate-carbon cycle simulation. The experiments demonstrated strikingly the potential importance of climate-carbon cycle feedbacks if we are successfully to predict climate change over the next hundred years. For example, the potential conversion of the global terrestrial carbon sink to a source (as seen during the course of the fully coupled climate-carbon integration was critically dependent on the long-term sensitivity of soil respiration to global warming). This sort of question, as well as the magnitude of the other feedbacks in the real Earth system, were still very much a subject of debate.

In this context, the realistic representation of vegetation and of the part it played in the carbon cycle was crucial since it is believed that 600 Gtonnes of carbon dioxide per year pass through plant stomata (compared to an exchange of 250 Gtonnes per year between the atmosphere and ocean). The joint development by various institutions (the Potsdam Institute for Climate Impact Research, the Max-Planck Institute for Biogeochemistry and Lund University) of a dynamic global vegetation model was duly noted. An approach from "first principles", building up from bare ground, was being followed. Nine plant functional types have been specified (i.e., tropical broad-leafed evergreen and raingreen, temperate needle-leaved and broad-leaved summergreen, boreal needle-leaved evergreen and summergreen, "cool" grasslands, "warm" grasslands) and four vegetation tissue pools. A "mixed grid cell" parameterization was employed where the different plant types could compete dynamically, taking into account soil texture, temperature, precipitation, solar irradiance, and carbon dioxide. Evapotranspiration, net ecosystem exchange and change in soil moisture were computed. Changes in plant types were determined based on factors such average growth, establishment, soil litter, biogeochemistry and mortality (e.g. competition, general mortality, heat stress, water stress, fire).

4.2.12 Requirement for long-term climate integrations

At several points, the problem of identifying specific effects from individual forcings (e.g., see sections 4.2.5 and 4.2.8) has been mentioned. However, there was considerable difficulty in inferring such effects from the results of model integrations in view of the high natural variability, the short observational records of forcing, and the fact that the model response to forcing was strongly non-linear. Long-term climate integrations were required as a control to provide a better estimate of natural variability from which a forced signal could be more clearly identified. Also, as an adjunct to the PMIP studies (see section 4.2.9), long control runs of the order of a 1000 years to compare simulated variability with that inferred from available observations and proxy data over the last millennium (e.g. as presented at the joint PAGES/CLIVAR workshop in Venice, November 1999) were expected to be a revealing indicator of model realism and as a possibly effective means of studying the role of external forcing. Only relatively few integrations of this type have so far been undertaken.

WGCM has therefore encouraged modelling groups to consider if possible long (control) integrations (i.e. without forcing) for an extended period (e.g. 1000 years). These integrations, which should be initialized with pre-industrial levels of greenhouse gases, would provide a valuable reference and control for CMIP. The runs could also be regarded as a ten-member ensemble of 100 year integrations and provide plentiful sets of initial conditions for initialising other experiments. A firm basis for assessing (model-simulated) internal or natural variability on all time- and space-scales would also be established, and for comparison with proxy data. However, it was noted that the interpretation of the latter was not straightforward and careful consideration was needed of the range of parameters to be collected from the model integrations adequately to describe the simulated low-frequency patterns and to be able to compare with proxy indices. Various details were being considered, including specification of data that it would be useful to collect from these integrations. The interest of the palaeo-data and PMIP communities in such experimentation would also be assessed.

Looking further ahead, following the assessment of simulated internal variability, a more comprehensive attempt to identify the impact and signature of external forcing could then be attempted. This, however, would involve the painstaking and difficult task of assembling a credible long-term record of appropriate external forcing data.

4.2.13 IPCC

As noted in section 4.2.3, the current IPCC assessment had emphasized the importance for future assessments of an intercomparison of coupled models run under standardized experimental conditions for the twentieth century, experiments to explore the impacts of resolution (horizontal and vertical), and systematic examination of model uncertainties linked to parameterizations and of the dependence of climate sensitivity on parameterizations. Attention had also been drawn to the value of continuing palaeoclimatic experimentation, and to increasing climate model resolution in the stratosphere. WGCM observed that the initiatives already being undertaken by itself would go a long way towards meeting the requirements expressed by IPCC. However, much of the work involved was highly complex and time-consuming, e.g., the type of cloud-climate feedback analysis discussed in section 4.2.2 would be a major project.

WGCM had also reiterated that modelling groups were still faced with a daunting array of fundamental problems. However, large amounts of time were currently being spent by very many leading scientists in the repetitive IPCC assessment process and participation in drafting meetings etc. In WGCM's opinion (as has been expressed at previous sessions of the group), this was a matter of concern when so much work was needed in the refinement of climate models themselves. WGCM strongly underlined the view that the intervals between IPCC assessments should be significantly increased.

4.3 Regional climate modelling

Following reviews carried out by WGNE and WGCM in respect to regional climate modelling, the JSC established a joint WGNE/WGCM ad hoc panel to summarize the current state-of-the-art in the field of regional climate modelling and to take up questions that had been raised. These included the technical items noted by WGNE (choice of domain size, scale dependency of model parameterizations, consistency of simulated energy and water budgets in inner and outer models, the care needed in handling the lateral boundary conditions) as well as aspects emphasized by the JSC itself (the limitations imposed by the performance of the global driving model, the predictability/reproducibility of smaller scales simulated in regional climate models). The panel was also asked to consider whether any co-ordinated or focussed experimentation should be organized (e.g. "identical twin" experiments).

The work of the group had so far proceeded by exchange of e-mails, with discussion mainly focussed on how to proceed with the assessment of regional models, their utility and application and how to structure the report. The intention had been that the panel might organize a workshop in 2001 or 2002 aimed at increasing the awareness of the community at large to uncertainties in the use of regional climate models. However, in the meantime, a workshop on "Regional climate research: needs and opportunities" had been arranged in the USA (by the US National Science Foundation and Department of Energy) in early April 2001, which would be likely to discuss not only some of the topics to be taken up by the joint WGCM/WGNE panel, but also the sort of ground that might have been covered in a (WCRP) workshop on regional climate modelling. The ad hoc panel was expected to take advantage of the USA workshop and the material presented there in its work, as well as using it as an opportunity for face-to-face discussions.

Regarding the scientific questions that had been raised by WGNE, it was noted that many of these had been addressed in the paper by Giorgi and Mearns (JGR, 1999). This had emphasized the need for "customization" of a regional model for its domain of operation. Whilst this could be advantageous, there was uncertainty as to whether the same performance could be expected in a changed climate. Nevertheless, concerns remained at the proliferation and use of regional models without due scientific consideration.

5. THE GLOBAL ENERGY AND WATER CYCLE (GEWEX)

Professor S. Sorooshian, Chair of the GEWEX Scientific Steering Group, led a general review of GEWEX activities, giving special emphasis to the strategic planning for GEWEX Phase II (see section 5.1). Supporting presentations were given by Dr P. Try, Director of the International GEWEX Project Office, who summarized some of the main highlights in the practical implementation of GEWEX in the past year and the preparations for the Fourth International Conference on GEWEX in Paris in September 2001 (see section 5.6) and Dr T. Koike, University of Tokyo on the Co-ordinated Enhanced Observing Period (CEOP) (see section 5.3).

The present range of activities in GEWEX continued to be organized in three main thrusts: hydrometeorology (as described in section 5.3); radiation studies (section 5.4); modelling and prediction (section 5.5). The overall GEWEX requirements for global observations and the continuing assembly of a range of global climatological data sets are outlined in section 5.2.

5.1 Planning for GEWEX Phase II

During the past year, the GEWEX Scientific Steering Group has considered the primary science questions and the changes in objectives and strategy that were now needed to begin to move to "GEWEX Phase II". The essential foundation for GEWEX Phase II would be the new series of Earth system satellites, some already launched and beginning to provide data, and others planned in the near future. The series includes ESA's ENVISAT; the NASA Earth Observing Satellites TERRA and AQUA; the Japanese National Space Development Agency (NASDA) ADEOS satellites; and specialist missions such as the Tropical Rainfall Measuring Mission (TRMM), Cloudsat, and PICASSO. GEWEX Phase II would aim to build on the projects in Phase I to provide refined global descriptions of the Earth's environment, more advanced representations of key processes in models on which to base predictions, detailed regional descriptions of critical phenomena, and an increased focus on water resource applications. The JSC agreed that the overall guiding goals for GEWEX Phase II should be expressed in the following terms:

- production of consistent descriptions of the Earth's energy budget and water cycle and their variability and trends, and data sets for the validation of models;

- enhancing the understanding of how energy and water cycle processes contribute to climate feedbacks;

- developing improved parameterizations encapsulating these processes and feedbacks for atmospheric circulation models;

- interacting with the wider WCRP community in determining the predictability of energy and water cycles;

- interacting with the water resource and applications communities to ensure the usefulness of GEWEX results.

In GEWEX Phase I, a "parameter-oriented" approach to produce the best possible descriptions of the energy and water cycles and the processes involved had been followed, supported by studies of energy and water budgets on the continental scale and of the mescoscale coupling of land and atmosphere and hydrological processes, as well as fostering applications of results to water resource management at a local scale. In Phase II, emphasis would shift towards the integration of GEWEX global data sets in order to provide a comprehensive description of the processes driving the energy and water cycles on which model improvements could be based. Attention would particularly be given to wet processes, greater exploitation of satellite data, and expanded efforts in water resource applications. Key elements of the Phase II strategy would include more extensive diagnostics and intercomparisons of data sets (especially those inferred from the new series of satellites and continuing selected Phase I data sets to provide overlap and give a basis for continuity), the development of integrated data sets revealing the joint variability of parameters and processes, and an improved understanding of errors. Other elements would be to establish the global transferability of coupled land-atmosphere and cloud parameterization schemes and enhanced exploitation of satellite data in regional studies. These ideas would be put to the test in the planning and implementation of CEOP which would thus be an important bridge from GEWEX Phase I to Phase II. Complementary to the foregoing would be the continued development of the GEWEX Cloud System Study (GCSS), the Global Land-Atmosphere System Study (GLASS) and a proposed atmospheric boundary layer study (see section 5.5), aiming at the improvement of parameterizations in atmospheric circulation and land-atmosphere models. A broadening of the international participation in GEWEX would also be sought, as well as increasing co-operation with other relevant international organizations and activities in the effort to enhance the application of GEWEX results to water resource issues.

Specific initial activities leading to GEWEX Phase II were now being planned, including:

- preparation of a document evaluating GEWEX Phase I, what had been accomplished and where further effort was needed;

- definition of a series of structured intercomparisons of the new satellite data streams, particularly designed to support diagnosis of cloud and precipitation processes, and heat and water transport;

- assembly of an integrated global energy budget and water cycle data set, including error definitions;

- emphasis in CEOP on delivering integrated data sets;

- fostering interactions between the modelling community and the process-oriented studies in GEWEX.

5.2 GEWEX global data sets

The new series of Earth system satellites referred to in section 5.1 went a long way to meeting the requirements of GEWEX for global observations (and those of the WCRP as a whole). Complementary specialist missions, such as TRMM, also provided valuable data for GEWEX. TRMM was very much an example of a collaborative international effort which should be supported and which has provided unprecedented coverage of the horizontal and vertical structure of tropical rain systems that was already being exploited in parameterization and assimilation studies. The continuity of these measurements was important and follow-on missions and other complementary proposals such as the Global Precipitation Mission were certainly needed. "Cloudsat", carrying a cloud-profiling radar capable of studying the three-dimensional structures of (thick) clouds important to weather and climate and their effect on radiative transfer, was another mission of outstanding potential value for GEWEX and the WCRP as a whole.

GEWEX has taken the responsibility in WCRP for several global climatological data projects[*] based on merging satellite data with current in situ (atmospheric, land/ocean surface) measurements. This involved close interaction with space agencies in tracking the status of global environmental observing systems, monitoring retrieval procedures and data quality control, organizing data archiving and data distribution on the appropriate media, and assisting (through workshops, symposia and data management meetings) in the international co-ordination of projects.

Attention was being given to the development of these projects beyond 2000, now that the new Earth observing platforms were beginning to come on line. The set of observations required to close the global water and energy cycles and the availability of these data both in the past and the future would be

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[*] These include the International Satellite Cloud Climatology Project, the Surface Radiation Budget, the Global Precipitation Climatology Project, the Water Vapour Project and the Global Aerosol Climatology Project. For a full description of the status of these various data sets, see section 5.4.

assessed. This should enable a judgement to be made whether the new observing systems and new data products met the requirements, or whether refined analysis techniques should be developed. However, such new data sets would require validation and interpretation against existing (longer-term) data sets to ensure continuity. Thus, support to the GEWEX global data projects (as they existed at present) must be maintained, as well as finding additional resources for systematic comparisons of old and new data sets (see also section 2.5). In this context, the GEWEX Scientific Steering Group has recommended that the GEWEX climatological data projects should be extended for at least another five years. The Director of the WCRP has written to the space agencies and institutions involved, and agreement has been secured for the continued support of the GEWEX climatological projects until at least the end of 2005. Furthermore, efforts would be made, to the extent possible, to calibrate, control the quality of, and adopt processing software to data from the changing satellite systems.

5.3 Hydrometeorology

The building blocks of the GEWEX hydrometeorology thrust, overseen by the GEWEX Hydrometeorology Panel, were the "continental-scale experiments", regional initiatives to investigate energy and water budgets over large river basin/drainage areas and study the physical processes that determine surface fluxes of energy and water over land. There were currently five such projects: the GEWEX Continental-scale International Project (GCIP) in the Mississippi River Basin; the Baltic Sea Experiment (BALTEX); the MacKenzie GEWEX Study (MAGS), the Large-scale Biosphere-Atmosphere (LBA) Experiment in Amazonia; and the GEWEX Asian Monsoon Experiment (GAME). A further experiment, the Coupling of the Tropical Atmosphere and Hydrological Cycle (CATCH), a 3-5 year study in Sahelian Africa to evaluate and develop the present capability of predicting the impact of climate variability on water resource management and crop production has also been planned. Overall, progress was manifest in the data bases that have been built up, the supporting process and modelling studies carried out, and the increasing recognition of the importance of the role of continental-scale hydrometeorology in the climate system. A further major step forward would be the implementation of the Co-ordinated Enhanced Observing Period (CEOP) in the period 2001-2003, as well as the assembly of global land surface data bases for modelling studies and setting out guidelines for model transferability and global applications studies.

GEWEX Continental-scale International Experiment (GCIP)

GCIP was the most mature of the GEWEX continental-scale experiments having been initiated as a full-scale five-year programme in 1995 to characterise the regional water and energy budgets in the Mississippi River basin. A series of focussed studies in different parts of the basin have been undertaken. Particular findings have included the marked influence of vegetation on evapotranspiration rates and on the quantity and distribution of convective precipitation in summer months, the importance of taking into account soil moisture anomalies in prediction of summer precipitation, the effects of winter snow cover and its melting pattern on the spring hydrology with possible feedbacks on springtime precipitation, the successful representation of sub-grid scale precipitation variability using downscaling techniques, and how land surface heterogeneity could significantly affect local moisture recycling. GCIP has also been able to demonstrate the utility of climate forecasts in the management of water resources and has provided significant insights and results in this area. Most recently, the focus in GCIP has shifted to the examination of the modulation of the large-scale atmospheric circulation by land surface processes in the northwest area of the Mississippi River basin over an entire annual cycle. GCIP was now beginning to evolve into the "GEWEX Americas Prediction Project" (GAPP), which would extend the GCIP scientific and strategy approach to other climatic regions in the USA, and place additional emphasis on understanding how land surfaces could influence the climate system and predictability. A GAPP science plan and implementation strategy was being prepared, with work also beginning on a detailed implementation plan.

The Baltic Sea Experiment (BALTEX)

The main scientific objectives of BALTEX were the determination of the energy and water cycle in the region of the Baltic Sea through a combined observational and modelling exercise, and the development of an advanced coupled, high resolution forecasting system permitting a refined handling of complex atmospheric processes and improved flood prediction. The central phase of BALTEX (known as "BRIDGE") comprised a continuous series of additional observations at various sites over the BRIDGE period (October 1999-February 2002) and five enhanced observation periods with special process studies and field activities. A follow-up intensive analysis period from early 2002 up to 2005 was being planned. Results so far have pointed to a number of limitations in the observational system and in the way the observations were exploited. Nevertheless, good model representations of the water cycle and energy budget over the region have been obtained. A pressing concern in the models was the treatment of the land surfaces and snow cover (model snow melts too fast in general).

GEWEX Asian Monsoon Experiment (GAME)

The central thrust of GAME was to understand the role of the Asian monsoon in the global energy and water cycle. A series of process studies in different climatic zones, including a tropical monsoon region, the Tibetan plateau, a large river (the Huai-He) basin, and a cold region location (Siberia) has been undertaken. A monitoring and observational network has been set up in each area and linked to allow measurements to be analyzed and used in models. Crucial components were the GAME Asian Automatic Weather Station Network where surface meteorological data at about ten sites in a variety of regions were collected, and the GAME Archive Information Network data sets and analyzed products were assembled. The first phase of GAME was expected to end in 2002. The proposed second phase (to be known as the "Co-ordinated Asian Monsoon Experiment" (CAMP)) would focus on applying improved analysis methodologies to obtain a comprehensive view of the monsoon and its special atmospheric and hydrological characteristics as a unified system.

The MacKenzie River GEWEX Study (MAGS)

MAGS was specifically aimed at understanding and modelling the high latitude water and energy cycles that played a major role in the global climate system. Studies in MAGS have provided an understanding of the advective processes which were the source of most of the moisture and precipitation in the MacKenzie Basin and which could be depicted as a "conveyor belt" of moisture moving across the coastal mountain ranges. The amount of water vapour being transported in this way gave an indication of the snow accumulation in the winter season and thence a measure of expected snow melt and run-off during the summer. At this latter time of year, local evaporation of water from vegetation and open water surfaces, not advection, appeared likely to be the major source of atmospheric moisture over the MacKenzie Basin. However, model evaluations were revealing inadequacies in estimates of surface fields that needed further examination. Blowing snow was also a high latitude phenomenon that has been extensively studied in MAGS. A major highlight in the past year has been the confirmation of extension of the research programme into a second five-year phase, when, like GAME, the emphasis would shift to obtaining a unified view and interrelationship of the atmosphere and hydrological cycle in high latitudes.

Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA)

The overall goals of LBA were to investigate the behaviour of Amazonia as a regional entity, and how changes inland use and climate in the Amazon basin could affect local biological, chemical and physical processes and sustainable development in the region, and to assess the role of Amazonia in the global climate system. The LBA field phase began at the end of 1998 with a first intensive observing period in January/February 1999 based on two closely coupled exercises, namely a wet season atmospheric mesoscale campaign and a ground-validation experiment for TRMM. A further intensive observing period in southwest Amazonia from October to December 1999 was designed to study the transition from dry to wet seasons. Seventy research projects were now in various stages of implementation covering all the main LBA foci (physical climate, carbon cycle dynamics, biogeochemistry, atmospheric chemistry, land surface hydrology and water chemistry, land use and land cover changes, remote sensing studies and human dimensions), with particular efforts being made to quantify and understand the exchanges of energy, water, carbon, trace gases and nutrients between the atmosphere and the land surface and river systems of Amazonia at all scales. Early results have indicated that Amazonian forests could be taking up carbon at a low but, on the global scale, significant rate, but that the uptake could be highly sensitive to temperature. This could mean the region would change from being a sink to sources of carbon even if there were only a modest temperature rise (1°C or so). Improved quantification of the carbon balance in this region of the world was a high priority for LBA, especially in view of the attention being given to this question in the consultations on the implementation of the UN Framework Convention on Climate Change. LBA was expected to continue for several more years (up to 2005), taking advantage of TRMM measurements, and the launches of EOS "TERRA", ENVISAT, the Chinese-Brazilian Earth Resources Satellite, and Landsat 7.

Coupling of the Tropical Atmosphere and Hydrological Cycle (CATCH)

Progress was continuing to be made in the planning of CATCH, a continental-scale experiment in West Africa. This initiative developed as a follow-on to the results achieved in the HAPEX-Sahel experiment in Niger from 1991 to 1993 that studied atmosphere/land surface interactions in the Sahel region. CATCH was a longer-time scale experiment to enable examination of interannual and decadal variability of the water cycle in the region. Specific targets included the improvement of hydrometeorological observations over a period and reference area sufficiently large to document atmosphere-land surface interactions, and better characterization of the modes of variability of rainfall over the region and the relationship with the variability of water resources. Emphasis was being placed on multi-scale observational systems and modelling in order to relate large-scale circulation patterns to the life cycle of meso-scale convective systems down to the characterization at fine resolution of rainfields at the ground. There were indications that drought periods were linked to a significant decrease in the number of convective systems observed each year. Two major steps so far were the collection of a ten-year (1989-1999) high resolution, high quality rainfall data set over the Niamey area and the installation of a hydrometeorological network in the Oueme catchment area. The future support that could be given to CATCH was in course of discussion.

La Plata Basin study

A new regional scale project in the La Plata river basin was being considered, probably under the joint auspices of GEWEX and CLIVAR.

Water and Energy Budget Closure Task (WEBS)

WEBS was a specific activity within the GEWEX hydrometeorological thrust with the purpose of using observations and model analyses to close the water and energy budget on a regional scale for each of the continental-scale experiments. Issues being taken up were: the assembly of high temporal resolution data sets, essential for accurately quantifying the water budget; the sensitivity of the spatial resolution of the sampling; the use of runoff as an independent variable for testing closure; development of high resolution four-dimensional data assimilation with the appropriate input to provide the best products for determining budgets; process studies of precipitation, clouds, soil moisture/run-off etc. in order to improve model treatments of the water and energy cycle.

The Co-ordinated Enhanced Observing Period (CEOP)

The overall goal of CEOP was to pull together the observations being taken and results being achieved by the continental-scale experiments (as outlined above) to explore the influence of continental hydrometeorological processes on the predictability of the global atmospheric circulation and changes in water resources, with a particular focus on heat and moisture source and sink regions. CEOP would evidently depend very heavily on the success of the WEBS task outlined above. The main data collection phase would be from July 2001 to October 2003, drawing on and integrating a number of other studies in the GEWEX hydrometeorological thrust. A draft science plan has been produced, focussing on the objectives of improving the estimates of water and energy fluxes and reservoirs over land areas and documenting and understanding the seasonal march of monsoon systems in different regions. A draft implementation plan was also being prepared. The requirements foreseen were high resolution regional data sets in monsoon areas as well as in other energy source/sink domains, and "model location time series" (MOLTS) around key basins and areas (intended to allow validation of low-resolution data sets from global models). Full details of CEOP planning are available on the Internet at **http://www.msc-smc.ec.gc.ca/GEWEX/GHP/CEOP.html**.

Important practical steps forward recently included the establishment of co-operation with WGNE in considering how to take advantage of the data sets being provided and what experimentation/research/validation could be carried out (see section 4.1.5). Moreover, the IGOS partners saw CEOP as a significant initial step towards an IGOS Water Cycle theme (see section 2.4) and the CEOS Strategic Implementation Team was encouraging CEOS agencies to respond to the formulated requirements for remotely-sensed data in the vicinity of the key basins and areas. Thirdly, Dr T. Koike had been nominated as the lead scientist and director of implementation of CEOP and was giving attention to the overall organizational structure required for this significant global initiative.

The JSC welcomed the progress in the planning and organization of CEOP and expressed particular appreciation to Professor Koike for taking up the overall leadership of CEOP. The JSC particularly noted that CEOP was a first step towards exploiting fully data from the new generation of satellites and in that respect was attracting interest and attention from agencies (as noted above). The JSC encouraged the continuing development of CEOP and its implementation and urged other WCRP projects, notably CLIVAR and ACSYS/CliC, to consider their involvement in CEOP.

Water Resources Applications Project (WRAP)

Recognizing the need to develop stronger links between GEWEX and the wider water resource community, WRAP has been designed to provide information on the GEWEX scientific and technical approach and how this might be modified to be of greater societal relevance. Among specific questions that would be discussed were the influence of local versus non-local controls on precipitation over land, the extent to which controls varied from region to region, the feedback mechanisms in the hydrological cycle and how they might affect wet and dry spells, and how well the soil moisture field could be determined in collaboration with water resource agencies. WRAP would also provide an important means of interacting with the WMO Hydrology and Water Resources Programme and respond to the expectations and requirements of this Programme (e.g. collaboration in risk assessment associated with water resource management).

5.4 Radiation

The overall broad goal of the GEWEX atmospheric radiation physics thrust, led by the GEWEX Radiation Panel, was an improved assessment of cloud-climate feedback, essential in achieving more confident projections of climate change. The general approach being followed was to use existing and new data sets to quantify the extent to which clouds affected the radiative heating of the atmosphere, in turn influencing the atmospheric circulation and feeding back to clouds. The GEWEX Radiation Panel was co-operating with WGCM in considering a number of the basic questions to be faced and in developing a combination of observations and model results to establish a (predictive) understanding of feedbacks/relationships involved (see section 4.2.2). The JSC reiterated the importance of continuing and developing the co-operation between the GEWEX Radiation Panel and WGCM in this area.

Specific activities and projects being undertaken by the GEWEX Radiation Panel are summarized in the following paragraphs.

International Satellite Cloud Climatology Project (ISCCP)

ISCCP has now completed more than seventeen years of data collection. Radiances from operational meteorological satellites, with the exception of INSAT, continue to be collected by the relevant Sector Processing Centres and delivered to the ISCCP Global Processing Centre at the NASA Goddard Institute for Space Studies in New York in accordance with the defined procedures. Currently operating satellites are NOAA-14, NOAA-15, GOES-8, GOES-10, GMS-5, METEOSAT-5 and METEOSAT-7 with METEOSAT-6 and GOES-11 in reserve. NOAA-16 has now begun operations in parallel with NOAA-14 (NOAA-16 will replace NOAA-14 in due course). METEOSAT-5 was expected to continue operating over the Asian sector until the end of 2003. If the launch of first METEOSAT Second Generation craft (MSG-1) to replace METEOSAT-7, scheduled for mid-2002 were successful, and either METEOSAT-6 or -7 were still healthy, one of these satellites would be moved to replace METEOSAT-5 at the end of 2003. The launch of the first operational polar orbiter from Europe (METOP-1) was now planned for 2005. The launch of MTSAT to replace GMS-5 failed, but action was taken to extend the life of GMS-5 until the launch of MTSAT-R (planned for mid-2003). Discussions with China were being pursued with the goal of ensuring their contribution to ISCCP (FY-2B was successfully placed in orbit in 2000, with operations expected to begin in 2001, and FY-2C following in 2003; also operational was the polar orbiter FY-1C, with FY-1D scheduled for 2001). Discussions have also continued in the effort to obtain INSAT data (by an extension of the agreement that has led to these data being available for GPCP).

With regard to data delivery, budget shortfalls at NOAA have resulted in a backlog of data from NOAA-14 and -15. Steps were being taken for all data to be transferred by FTP rather than magnetic media. The monthly satellite-to-satellite radiance normalization data, provided by the Satellite Calibration Centre, Lannion, France were complete until September 2000. However, activities at the Global Processing Centre itself were severely hampered during 1999 and 2000 by a series of computer problems. Nevertheless, monitoring results for the calibration of the polar orbiting radiometers that serve as the reference standard were complete until April 2000. Furthermore, the archival of Stage B3 data has been resumed, with delivery complete until December 1997 (14.5 years). Stage DX, D1 and D2 data were available in the archive for the period July 1983 to December 1995, but some additional checking of the last two years of data was required. Moreover two CD-ROMs containing the D2 data for 1983-1988 and for 1989-1993 have been released with a third planned covering 1994-1999 when D-data up until this date have been processed (expected by mid-2001). Full details of the status of ISCCP cloud product data sets and up-to-date calibration information are posted on the ISCCP home page **http://isccp.giss.nasa.gov**. A paper reviewing the characteristics of the various ISCCP data sets, in particular the C- and D-series, and discussing the estimated accuracy of the ISCCP cloud climatology also appeared in the Bulletin of the American Meteorological Society in November 1999.

Surface radiation budget

It was gratifying that the Surface Radiation Budget Project, as conducted by the NASA Langley Research Center, was selected for funding as part of the NASA Modelling Data Analysis Research (MDAR) Earth Observing System Interdisciplinary Science Program (EOSDIS) for a three-year period from April 2000. The main effort would be the release and validation of a twelve-year surface radiation budget data set. Intercomparisons would also be made with surface atmospheric radiation budget products inferred from the Clouds and Earth's Radiant Energy System (CERES) mission and from the latest NASA Data Assimilation Office reanalysis. A surface radiation budget users group was being established composed of both US and international scientists from the relevant disciplines.

Specifically, the focus during 2000 was the preparation and evaluation of algorithms needed to provide 1° x 1° surface radiation products. Two years of data (1986, 1992) have been checked using short-wave and long-wave quality check algorithms, with ten monthly-averaged flux estimates now having been released to selected members of the user team for further testing and evaluation.

Baseline Surface Radiation Network (BSRN)

The objective of the BSRN was to observe surface short- and long-wave radiative fluxes at the highest attainable accuracy in a number of contrasting climatic regions. These measurements were valuable in assessing theoretical treatments of radiative transfer in the atmosphere (including particularly validation of the surface radiation budget climatology), verifying climate model computations, and for monitoring regional trends in surface radiation. Under the auspices of the BSRN, an international coalition of scientists interested in acquiring the most accurate possible measurements has come together. Twenty-four sites were currently active in a variety of locations (polar regions, mid-latitude forested and plain areas, mountain massifs, tropical rainforests, deserts, with a substantial proportion of the irradiance data collected being submitted to the central BSRN archive at the Swiss Federal Institute of Technology in Zurich (over 1200 station-months of data meeting BSRN specifications). An additional thirteen sites were either under development or preparing to submit their first data to the archive. However, the BSRN archive has suffered various computer, resource and staffing problems during the past year, resulting in a temporary cessation of data import and export and the BSRN web page (**http://bsrn.ethz.ch**) has not accurately reflected the status of the BSRN as a whole. The operation of the archive was expected to be back to normal by mid-2001. Another very important BSRN activity was to advance instrument calibration and measurement capabilities, with improvements having been made in infrared calibration standards, recommendations made on the measurement and validation of diffuse (shortwave) irradiance, and proposals put forward for the standardization of observing procedures for aerosol optical depth.

GEWEX Water Vapour Project (GVaP)

Following the successful results of the initial pilot phase of GVaP, the implementation stage, aimed at improving knowledge of the variability of water vapour, its radiative effects, feedbacks and change due to human activities, was now underway. The 1999 GvaP integrated observing test data sets were being released, and a GvaP science and implementation plan (based on both national US and international commitments) and taking into account the findings and results of the comprehensive SPARC assessment of water vapour in the upper troposphere and lower stratosphere (see section 6.3.3) was being finalized.

Global Precipitation Climatology Project (GPCP)

GPCP products, inferred from blended or merged satellite data taking into account where possible in situ gauge data, now included monthly mean precipitation estimates on a 2.5° x 2.5° grid for the globe from 1979[*], pentad estimates on a 2.5° x 2.5° grid from 1979, and daily 1° x 1° estimates from 1997. The basic geostationary satellite data were now collected at 1° x 1° three-hourly time intervals with global coverage since METEOSAT-5 was relocated over the Indian Ocean. Through the Indian/US Co-operative Agreement in satellite activities, INSAT geostationary satellite data have also been available since 1999 (although some issues with regard to navigation, calibration and zenith angle correction were still being analyzed). A study was also being made of obtaining precipitation estimates from ISCCP DX data, a source of high resolution geostationary data from 1983 to 1986 on which refinement of GPCP values for this period could be based (GPCP only began operations in 1986 and thus had not collected these data).

All the GPCP products were available on-line from World Data Center A (**http://www.ncdc.noaa.gov/wdcanet-ncdc.html**). The separate components of the merged analyses could also be accessed (e.g. the geostationary precipitation index inferred from infrared observations, microwave

[*] This data set replaces an earlier version of monthly mean precipitation estimates on a 2.5° x 2.5° grid that began in 1987 but was not global in coverage.

emission and scattering values from the Special Sensor Microwave Images (SSM/I), and the gridded gauge fields as prepared by the Global Precipitation Climatology Centre (GPCC) (at Deutscher Wetterdienst). Also, high density surface reference data sets for comparison and validation could be obtained from the GPCP "Surface Reference Data Center" at the University of Oklahoma.

GEWEX aerosol studies

The principal activity under this heading was the GEWEX Global Aerosol Climatology Project, set up in 1998, to analyse satellite radiance data, supplemented with available surface observations and ground validation measurements, to infer the global distribution of aerosols, their properties, radiative forcing effects and seasonal and interannual variations. Detailed information on this project can be found at the web site **http://gacp.giss.nasa.gov**. One particular achievement was the development of an advanced two-channel aerosol retrieval algorithm based on AVHRR data at the Goddard Institute for Space Sciences and applied to NOAA-9 observations (February 1985-November 1998). Data from AVHRR instruments on other NOAA satellites should now be processed to create a global aerosol climatology for the full period of NOAA satellite coverage, but this required the development of a procedure to "reconcile" the calibration changes in different AVHRR instruments. Retrieval results also needed to be validated. In the longer term, retrievals from more recent (advanced) instruments such as MISR, MODIS and POLDER would be considered.

Ocean surface turbulent fluxes

The possibility of obtaining estimates of global ocean evaporation, the diurnal variation of sea surface skin temperature and the surface heat flux from satellite data at high-resolution space and time-scales was being actively explored by the radiation science community (although this was not a formally approved GEWEX or WCRP "international" project). As well as drawing on satellite radiance measurements as have past approaches, the use of scatterometer and ocean altimetric data now offered the prospect of significant refinement to the type of algorithms that could be employed.

Currently, an intercomparison of in situ data, satellite-derived input parameters, flux data sets and NWP products, as well as of flux algorithms was being organized. An extensive web-based library of in situ data sets (including direct turbulent flux measurements, skin and bulk sea surface temperature, wave information and vector winds) has been assembled. All the data sets have been rewritten in a common format using the same units to facilitate use and interpretation of satellite data (e.g., SSM/I and TRMM brightness temperatures, TRMM retrieved products, ISCCP and TOVS products). NCEP analyses of surface turbulent fluxes have been co-located with the in situ measurements (and co-location with scatterometer winds was expected to be undertaken during 2001). The comparison of the NCEP analyses with the in situ data was advancing: this comparison would be extended to ECMWF surface flux products from 1999 onwards (when the new wave model was introduced) and to the ERA-40 reanalysis fields. Regarding flux algorithms, ten different formulations used either in satellite retrievals of general circulation models were available on the project web site (**http://paos.colorado.edu/~curryja/ ocean/intercomparison-cg.html**) and were being evaluated. Satellite skin sea surface temperature retrieval methods were also being assessed. A workshop to review preliminary results would take place in May 2001 (immediately preceding the JSC/SCOR Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux fields, see section 7.1) where the principal findings would be reported. The various intercomparisons/studies being undertaken would also need to be conducted in conjunction with WGNE "SURFA" project (see section 4.1.7).

Profiling clouds, precipitation and water vapour

A new effort was being considered aiming to provide profiles of clouds, precipitable water and water vapour as well as other radiatively important constituents such as aerosols, in the troposphere. It was intended to build on work already begun in preparing for Cloudsat and to develop standards for processing and archiving radar and lidar data to make these more generally useful and accessible, especially for modelling groups. Periods of co-ordinated data acquisition would be organized as a means of identifying differences between the various observing systems. A common data protocol and linked data base structure would also be needed in order to be able to access simultaneously in situ and remotely-sensed data, invaluable in refinement of processing algorithms.

5.5 Modelling and prediction

The modelling and prediction thrust of GEWEX had the objective of developing and evaluating improved interactive model formulations of atmospheric and land-surface processes that regulate the global hydrological and energy cycle. This thrust, which included specifically the GEWEX Cloud System Study (GCSS) and the Global Land-Atmosphere System Study (GLASS), was conducted by the GEWEX Modelling and Prediction Panel (GMPP). An atmospheric boundary layer study was also now being proposed. In view of the close relationship between the activities of the Modelling and Prediction Panel and those of WGNE, as noted in section 4.1.1, the two groups met jointly.

5.5.1 GEWEX Cloud System Study (GCSS)

The primary objective of GCSS was the development of refined parameterizations of cloud systems within atmospheric models used for numerical weather prediction and climate simulations through a better understanding of the coupled physical processes in different types of cloud systems. Emphasis was placed on determining the effects of clouds acting as systems rather than on individual clouds or the role of individual cloud processes. Five different cloud types were being specifically studied: boundary layer; cirrus; extra-tropical layer clouds; precipitating convectively driven cloud systems; polar clouds. In each area, a series of case studies drawing on observations from various field programmes was being conducted to evaluate the simulations of cloud-resolving or cloud-system models and the treatment of the relevant processes. Single-column models were also valuable tools particularly in making connections between general circulation models and data collected in the field, thereby facilitating observationally based evaluations of new parameterizations in isolation from the large-scale dynamics. Ultimately, cloud parameterizations must, of course, be tested in full climate simulations or in numerical weather prediction models and the organization of such activity was being considered. Attention was now turning increasingly to parameterization development, especially by reviewing specific new treatments of clouds and their representation and their performance in single-column or cloud system models. Full details of the scientific issues being addressed in GCSS and the studies carried out or underway were described in the recent version of the GCSS Science and Implementation Plan (**http://www.gewex.com/gcss_sciplan.pdf)**. A general GCSS meeting was being planned for 2002 bringing together all the scientists working on the various different cloud types and experts from the (large-scale) atmospheric modelling communities.

5.5.2 Global Land-Atmosphere System Study (GLASS)

Encouraging progress was being made in the planning and implementation of the Global Land Atmosphere System Study (GLASS), which aimed to develop a new generation of land-surface schemes for incorporation into general circulation models in support of weather and climate prediction on all time scales. New schemes would, in particular, include biophysical processes and the evolution of vegetation, and give increased importance to the horizontal complexity of the surface. Up to now land surface scheme validation and intercomparison projects such as the Project for Intercomparison of Land-surface Schemes (PILPS) and the Global Soil Wetness Project (GSWP) have made major contributions in assessing the performance of land-surface schemes. In GLASS, these were being supplemented by new experimentation specifically designed to address issues of sub-grid scale variability of the surface, and the feedbacks between the changing land surface and the atmospheric circulation (e.g., co-ordinated experiments to explore the sensitivity to different approaches to soil moisture modelling in climate change predictions).

To facilitate the range of testing, validating and intercomparison of land-surface schemes required at a wide range of scales, GLASS has been structured round four main scientific thrusts:

Local-scale/off-line intercomparisons: this would essentially be a continuation of PILPS activities, in particular phase 2 projects. Activities to test how CO_2 flux was represented in current land-surface schemes would also be undertaken;

- Global-scale/off-line intercomparisons: again this would build on the existing GSWP, using ISLSCP-II data to drive off-line simulations of soil moisture and its interannual variability over a ten-year period. (A preparatory step would be a run with an updated version of ISLSCP-I data). Questions that would be particularly taken up were the sensitivity of land-surface schemes to errors in the forcing data, how well schemes could be validated at a global scale with remotely-sensed data, how closely the drying cycles in different schemes compared, and whether schemes operated in similar soil moisture stress ranges;

- Local-scale/coupled intercomparisons: the plan here was to employ a (common) simplified single column model and extend PILPS-type experiments by including coupling with the atmosphere. ARM/CART data would be used as a basis for the experimentation and intercomparisons. A "parameter estimation" procedure should ensure that the same effective values were used for key parameters. This work should help in clarifying the feedbacks between land-surface schemes and the planetary boundary layer, the effect of surface heterogeneities on the planetary boundary layer, and whether the behaviour of land-surface schemes was different in off-line mode to when coupled with the planetary boundary layer;

- Global scale/coupled intercomparisons: the work in this thrust would aim to assess the role of land surface processes in determining climate sensitivity to anthropogenic forcing, and in climate variability and predictability. The first step was to explore the impact of improved specification of land-surface conditions on short-range forecasts, in particular such aspects as the geographical distribution of the strength of the land-atmosphere feedback, its inter-model variation, and the part played in the predictability of the hydrological cycle.

These scientific thrusts were complemented by work to set up an infrastructure to facilitate GLASS intercomparisons and to help the community involved to move towards standard methods for coupling land-surface schemes to atmospheric models. Standards for data transfer were being specified, the continued availability of data from past experiments ensured, and software for modelling and analysis of land-surface processes distributed. The full GLASS implementation plan contained more details of the activities foreseen (**http://hydro.iis.u-tokyo.ac.jp/GLASS**).

5.5.3 Proposed atmospheric boundary-layer study

A major continuing problem in the performance of coupled models was the large-scale systematic errors in surface net energy fluxes over the oceans, especially in the tropics and sub-tropics. A dominant cause of these errors often appeared to be excessive latent heat flux in trade wind areas and excessive downward shortwave fluxes in regions of marine stratus/stratocumulus cover. At ECMWF, verification against ocean buoy data indicated that forecast near-surface specific humidities were too low, resulting in enhanced evaporation . Furthermore, comparison of boundary layer depth as estimated by lidar measurements from the space shuttle with the average model-simulated planetary boundary layer pointed to the latter being too deep (by about 100-200m). This was probably linked to a dry bias consequent to the entrainment of too much dry air through the top of the planetary boundary layer because of an unsatisfactory representation of cloud/inversion interactions. The well-known problems in models with marine stratus might also involve cloud/radiation interaction as well as errors in maintaining or dispersing the cloud cover.

The GEWEX Modelling and Prediction Panel was accordingly proposing to undertake an atmospheric boundary layer study aimed particularly at improving the parameterization of the boundary layer. This was of increasing importance as the development of coupled atmosphere-ocean-land surface models continued. The physical processes involved were often not as well understood as appeared at first sight, manifested by, for example, the difficulties in simulating marine stratus clouds, in representing shallow cumuli and their radiative effect, in quantifying surface fluxes in light wind conditions, and in predicting the depth of the planetary boundary layer and the effects of entrainment. Outstanding issues included the interactions of the planetary boundary layer with moist convection and with the land surface, the simulation of the diurnal cycle over tropical continents, and the behaviour of the planetary boundary layer over topography. The main goal of the proposed study would thus have the overall goal of improving the representation of the atmospheric boundary layer in models, based on advancing understanding of the relevant physical processes involved. It was intended that the study would provide a framework, similar to those set out for GCSS and GLASS, in which scientists working on boundary layer research issues at different scales would interact.

The JSC recognized the need for activities in this area but pointed out that the boundary-layer was a topic of interest and concern across the whole WCRP. In view of the cross-cutting nature of the activity, it was recommended that CLIVAR in particular should be closely involved in and associated with the development of the work. The JSC also recalled that following the TOGA-COARE Conference in 1998, well-considered recommendations had been made for the continued study of coupled ocean-atmosphere boundary layer phenomena. It was important that an initiative on the boundary layer should be conducted in collaboration with the concerned group in TOGA-COARE as well as that leading the Eastern Pacific Investigation of Climate (EPIC, see section 9.1.3). The new WCRP air-interactions group being established in succession to the JSC/SCOR Working Group on Air-Sea Fluxes (see section 7.1) would also need to be consulted. The JSC observed that the essential connection with WGNE in this area would be ensured by the joint meetings of WGNE and GMPP.

5.6 The Fourth International Scientific Conference on the Global Energy and Water Cycle

Planning was well underway for the Fourth International GEWEX Scientific Conference, taking place in Paris in September 2001. This was the latest in the series of major international conferences, organized by the GEWEX scientific community every two to three years, focussed on the scientific progress made and programmatic achievements. The conferences have been held successively in various regions of the world (the first in the United Kingdom in 1994, the second in the USA in 1996, the third in China in 1999, and the fourth now in France in 2001). The conferences were operated on a near self-sufficient basis with substantial support being provided by the hosts, as well as significant contributions from sponsors. In particular, the International GEWEX Project Office devoted major efforts to seeking sponsors (as well as assisting in the practical organization of the Conferences). Only limited direct support from the WCRP was needed, mainly to assist participation from developing countries or from countries with economies in transition.

The fourth conference was being kindly hosted by the Institute Pierre-Simon Laplace in Paris, who were also overseeing all the local arrangements. A first circular giving details of the Conference was widely distributed in December 2000, and announcements have been placed in EOS, Bulletin of the American Meteorological Society etc. More information was available on a web page especially established for the conference (**http://www.ipsl.jussieu.fr/gewex**), via which intending participants could register and submit abstracts. Based on previous experience, there were expected to be some 40 oral presentations and up to 300 posters (the latter would be allocated prime time morning and afternoon sessions). A provisional programme would be available by the end of June. At this time of transition of GEWEX from Phase I to Phase II, it was foreseen that the conference would include reviews of the accomplishments in the first phase, as well as looking forward to the future.

6. STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE (SPARC)

Dr M.-L. Chanin and Professor M. Geller, Co-chairs of the SPARC Scientific Steering Group, summarized the main recent developments in SPARC during the past year, including the principal items discussed and recommendations from the eighth session of the SPARC Scientific Steering Group, held in Argentina in November 2000. A major event in SPARC in the past year was the Second SPARC General Assembly ("SPARC 20002") also held in Argentina in November 2000.

6.1 The Second SPARC General Assembly

The Second SPARC General Assembly ("SPARC 2000") took place as planned in Mar del Plata, Argentina, 6-10 November 2000. All who participated (over 300 scientists) regarded the Assembly as a considerable success and scientifically important and interesting. As well as 60 oral presentations, there were nearly 200 poster displays all centred round principal themes of SPARC (stratospheric processes and their role in climate; stratospheric indicators of climate change; modelling and diagnosis of stratospheric effects on climate; UV observations and modelling). Many organizations and bodies, national and international, offered sponsorship, assistance or support, enabling the attendance of many young scientists and students. The extensive participation from South American countries was particularly gratifying. The Conference attracted wide media attention. Two side events, a lecture by Nobel Laureate Dr P. Crutzen, and an Argentine-wide competition amongst schoolchildren to depict graphically the ozone hole over Antarctica, was also very successful and had drawn several reports in the media. Organisationally, lessons learnt were that there had been too many oral presentations and not enough "prime" time had been allowed for viewing the posters. As was often a problem with a conference of this type, the standard of oral presentations was very varied, with speakers often over-running their allotted slots and there not being enough time for discussion. A summary of the main scientific highlights at the Assembly was included in SPARC Newsletter No. 16 (published in March 2001). The Assembly proceedings (summary and abstracts of papers presented) have been made available on a CD-ROM (copies can be requested from the SPARC Office). The very high cost of printing and distribution of voluminous reports of this nature had, on this occasion, dissuaded the production of a hard copy version of the Assembly proceedings.

In brief, the Assembly clearly demonstrated the progress made in recent years in understanding dynamical, chemical, radiative and transport processes in the stratosphere. At the same time the importance of the stratosphere as an integral part of the climate system had become much more fully appreciated. Thus increasing effort was being given to understanding the exchanges of mass, momentum, and energy between the stratosphere and troposphere, where complex non-linear processes were often involved, and improved knowledge of tropospheric/stratospheric coupling, the essential key, was still required. On the observational side, many papers gave evidence of the ability to synthesize the range of conventional and remotely-sensed data now available, leading to considerable advances in the understanding of variations in stratospheric features. This was underpinning convergence among the various tasks that have been undertaken in SPARC, lending weight to the SPARC Scientific Steering Group's views on adapting the overall strategy followed so far, namely that closer integration of activities and looking at changes in the observed fields of such variables as temperature, water vapour and ozone together were required. The important role of upper tropospheric/stratospheric water vapour was also referred to repeatedly. In the Assembly, it was inevitable that the question of ozone depletion would be raised. It appeared that the decrease of ozone in the Arctic and Antarctic and other variations were now well understood quantitatively. It was also suggested that the seasonal depletion seen in ozone in mid-latitudes might not be entirely chemically driven. In the session on modelling and diagnosing stratospheric effects on climate, a popular subject was the Arctic Oscillation (or annular mode), including observational and numerical studies. In the latter, Arctic Oscillation patterns seemed to appear in response to greenhouse gas, ozone, solar and volcanic forcings. Regarding the effects of the solar cycle, there was still considerable divergence: progress in quantifying this with a greater degree of confidence depended on developing models with the capability of representing more fully the important coupled radiative/chemical/dynamical interactions that were involved. It was also apparent that there were still many shortcomings in simulating accurately the behaviour of the coupled troposphere/stratosphere system in models. With respect to UV observations and modelling, one point commonly emphasized was the need to co-ordinate ground-based measurements of UV to provide ground-truth for estimates inferred from remotely-sensed data in the years to come. Several contributions indicated changes that could occur in UV consequent to changes in ozone, clouds and aerosols.

The JSC acknowledged the work of the Scientific Organizing Committee of the Assembly (chaired by Professor A O'Neill, University of Reading, UK) and that of the Local Organizing Committee (chaired by Dr P. Canziani, University of Buenos Aires, Argentina) in ensuring the success of this event, and expressed appreciation to the numerous and generous sponsors.

6.2 Modelling Stratospheric Effects on Climate

6.2.1 Intercomparison of stratospheric models

The "GCM Reality Intercomparison Project for SPARC" (GRIPS) has grown both in the number of research groups involved and the range of tasks being tackled. The first phase of GRIPS has been focussed on a simple intercomparison of model stratospheric simulations, and as reported at the twenty-first session of the JSC, a wide range of skills was apparent. Detailed accounts of findings from the first phase of GRIPS had been or were now being published (Pawson et al, Bulletin American Meteorological Society, 2000; Koshyk et al, Journal of Geophysical Research, 2000; and Amodei et al, to appear in Annales Geophysicae). New data from various modelling groups continued to be collected, with analysis now being focussed on mechanisms that may be involved in causing stratospheric variability (e.g. wave or diabatic forcing). Specific experimentation might also be organized to explore the sensitivity of the stratospheric circulation to various forcing mechanisms and their interaction.

The second phase of GRIPS was now underway, including an extended validation of models and carrying out controlled experiments to test parameterization schemes, including particularly investigation of radiative codes in use, of model responses to the formulation of mesospheric drag, and of gravity wave parameterization. Models have been shown to be very sensitive to the radiation code employed, and this was clearly a major factor affecting the convergence of different model simulations.

Progress has also been made in setting out the objectives and plans for the third phase of GRIPS. The main goal was to try to explain the observed variability in the stratosphere in the period 1979-1999, taking into account natural variability and known forcing mechanisms (changes in aerosol loading, solar variations, changes in atmospheric concentrations of ozone and carbon dioxide). As a further step, experiments would be run with imposed climate change scenarios from 2000 to 2020 (using the best possible predictions of trace gas concentrations).

6.2.2 Stratospheric reference climatology

A refined climatology of the means and variabilities of basic stratospheric parameters was needed for GRIPS, as well as a number of other SPARC initiatives. A series of monthly global climatologies of temperature, zonal winds, and various atmospheric trace constituents (N_2O, O, CH_4, H_2O, O_3, NO_2, HNO_3, etc.) have been assembled from UARS and other data (e.g., HRDI). Monthly and daily stratospheric circulation statistics have been inferred from available stratospheric analyses or reanalyses including those from NCEP, UKMO, Free University of Berlin, and NASA/GSFC. Other data compiled include upper-level radio-sonde winds from Singapore (as an indicator of the phase of the QBO) and statistics on tropopause height. These data sets can now be accessed via the SPARC Data Centre (**http://www.sparc.sunysb.edu/)**. Also a technical report was being drafted (to be published during 2001 as a SPARC Report "SPARC Intercomparison of Middle Atmosphere Climatologies") giving a basic description of the data sets, and attempting to quantify uncertainties and interannual variability, including identification of possible biases. A comparison would also be drawn with available rocket-sonde data.

6.2.3 Climate forcing in the stratosphere

As reported at the twenty-first session of the JSC, SPARC has completed a review of stratospheric aspects of climate forcing in order to provide, for the use of the climate modelling community, the current best estimates of the relevant parameters (a full account was given in SPARC Newsletter No. 14, January 2000). The various data sets compiled or recommended (e.g., ozone as a function of latitude and height, stratospheric aerosols, changes in the solar constant since 1988 and variations in the solar spectrum during a typical solar cycle) were available at the SPARC Data Centre. This work had fed into the consideration of the detection and attribution of a stratospheric role in climate change in the IPCC Third Assessment Report (see section 6.5.4 and article "Detection and Attribution of a Stratospheric Role in Climate Change: an IPCC Perspective" in SPARC Newsletter No. 16).

6.2.4 Stratospheric data assimilation

Stratospheric data assimilation involved interdisciplinary exchange within the stratospheric community and establishing links to numerical weather prediction centres. Efforts in this area were especially important in view of the new streams of stratospheric data coming on line from (research) satellites in the next few years (e.g., ENVISAT, the NASA EOS series, etc.). A review of the status of stratospheric data assimilation and specific related problems (including data availability) was thus being undertaken. This initiative would be co-ordinated with the JSC/CAS Working Group on Numerical Experimentation which has the leading role in WCRP for data assimilation questions.

In this same area, it was noted that, a "Data Assimilation Research Centre" was being set up in the United Kingdom (with support from the UK National Environmental Research Council). This would be based on a modified 3DVAR NWP system, spanning the troposphere and stratosphere and incorporating a simple parameterization of ozone chemistry. A complementary off-line 4DVAR system, with more extensive chemistry enabling an advanced assimilation of chemical data, would also be developed. Collaborating centres included the NASA Goddard Data Assimilation Office, NCAR, the Centre National de la Recherche Scientifique, the Royal Netherlands Meteorological Institute, UKMO, ECMWF and a number of university groups.

6.3 Long-term changes in the stratosphere

6.3.1 Stratospheric Temperature Trends

The objectives of the first phase of SPARC activities in this area were the intercomparison of various relevant data sets (radiosondes, lidars, rocket-sondes, satellite measurements etc.) containing temperature values, assessment of the temperature trends apparent in the lower stratosphere and up to the level of the mesosphere, and evaluation of the extent to which these trends could be explained by specific causes. The progress made has been reported at previous sessions of the JSC and the first phase has now been completed. The results formed the basis of the chapter in the 1999 WMO/UNEP Ozone Assessment on stratospheric temperature trends. A summary was expected to be published in Reviews of Geophysics in February 2001, and a full account was in preparation as a SPARC report (to be published by NOAA). The work carried out also provided important input to the IPCC Third Assessment Report in particular for the discussion of radiative forcing of climate change, climate processes, and detection and attribution.

The intention was now to follow several complementary lines of activity. Firstly, the various stratospheric temperature data sets would be continuously updated and new comparisons made with recent model simulations (as a basis for inferring the possible causes of changes). Secondly, plans were in hand to extend the temperature analyses to the upper stratosphere and mesosphere in collaboration with the International Commission of the Middle Atmosphere (ICMA) and the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). Thirdly, improved estimates of temperature trends in areas having high uncertainties (e.,g. near the tropopause and stratopause) were required. Beyond this, it was clear that temperature trends were closely linked with changes in other stratospheric parameters (ozone, water vapour, dynamical activity, etc.), and activities would have to become increasingly integrated with the SPARC studies in these areas.

What has been strongly emphasized by the different groups of scientists who have been involved in this work has been the value of the SPARC umbrella under which coherent international research into stratospheric temperature trends (using both observations and models) has been carried out and plans for the future drawn up. It was viewed as important to keep the international "expert" SPARC temperature trends sub-group, comprising observationalists, modellers and diagnosticians together.

6.3.2 Understanding ozone trends

The first phase of SPARC activity in this area, providing an authoritative assessment of trends in the vertical distribution of ozone (published as SPARC Report No. 1 in 1998, and an essential foundation of the 1999 WMO/UNEP Ozone Assessment) has also now been completed. A new effort was being planned to consider the question of stratospheric ozone changes and their causes (stimulated equally by the need to prepare for the drafting of the next WMO/UNEP Ozone Assessment due to begin in the middle of 2001). As noted in section 6.1, there was considerable discussion of these issues at the SPARC General Assembly. Thus, at the invitation of the Co-chairs of WMO/UNEP Ozone Assessment, SPARC was participating in the organization of a workshop in March 2001 bringing together leading scientists in the field of ozone trends research in order to take stock of the current state of scientific understanding, to facilitate the formulation of common scientific viewpoints, and to encourage prompt submission of peer-reviewed publications that would form the basis of the WMO/UNEP Assessment.

In the longer-term, an evolution to studying trends of stratospheric parameters jointly (e.g. including temperature) was foreseen (as was similarly noted by the temperature trends group).

6.3.3 Stratospheric and upper tropospheric water vapour

Notable progress has been made in this area, and the comprehensive landmark Water Vapour Assessment has now been completed (published as SPARC Report No. 2 on WCRP No. 113)(the executive summary has also been included in SPARC Newsletter No. 16).

SPARC had attached considerable urgency and priority to the preparation of this assessment in view of the important role of water vapour in the stratosphere and upper troposphere, and the uncertainty attached to this, in climate changes likely to result from increases in atmospheric CO_2 concentrations. Questions such as the concentration, distribution and variability (long-term changes or trends) of water vapour in the upper troposphere and lower stratosphere had been specifically explored. The processes controlling the present distribution of upper tropospheric/lower stratospheric water vapour were also studied to the extent possible. Among the key findings was that the concentration of stratospheric water vapour in the "overworld" (i.e. where the potential temperature is greater than 380K) was determined by dry air upwelling through the tropical tropopause, methane oxidation in the stratosphere, and transport by the poleward and downward (Brewer-Dobson) mean circulation. At the tropical tropopause, air was dried by a complex mix of processes acting on a variety of spatial and temporal scales. Water vapour in the upper troposphere was controlled by local and regional circulations and seasonal changes of upper atmosphere temperature. Regarding the trend in stratospheric water vapour, a 2 ppmv increase since the middle 1950s was apparent: this was certainly significant in comparison with typical current stratospheric water vapour concentrations of 4-6 ppmv. The increase in the concentration of tropospheric methane since the 1950s (0.55 ppmv) was likely to be responsible for half of the increase in stratospheric water vapour over the period (photochemical oxidation of methane in the stratosphere produced approximately two molecules of water vapour per molecule of oxidized methane). It was not clear what was responsible for the remainder of the observed increase in stratospheric water vapour. In the upper troposphere, a twenty-year record of humidity was now available from instruments on operational satellites. However, assessing long-term trends was difficult because of the substantial natural variability in the large-scale circulation (e.g., during ENSO events), and the way that changes in temperature and water vapour could separately affect the (relative) humidity in the upper troposphere. Although statistically significant positive and negative long-term changes were apparent in different latitudinal bands, no striking overall global trend has been revealed in the analyses carried out so far. As to the measurements of water vapour (on which the above assessments were based, there has been a significant increase in the number and quality of observations in the stratosphere over the past 25 years, particularly with the advent of remotely-sensed data: the accuracy of the various satellite-based measurements in the upper troposphere were of sufficient quality for climatological and process studies and no major inconsistencies have been found that would inherently limit their use in describing the long-term behaviour of upper tropospheric humidity. On the other hand, the operational radio-sonde network did not produce water vapour data suitable for estimating long-term changes, process studies, or for validation of upper tropospheric humidity measurements. However, emerging data sets from improved quality quasi-operational aircraft and ground-based instrumentation showed promise for process studies, climatological analyses and validation of water vapour content inferred from remotely-sensed data.

A series of recommendations was made for improving the monitoring of water vapour in the upper troposphere and lower stratosphere. Among these was the need for further studies, including well designed intercomparison experiments and laboratory work, to quantify and understand the difference between various stratospheric water vapour sensors, particularly for in situ instruments that provided the critical high-resolution data used in studying the transport of water vapour between the troposphere and stratosphere and the processes involved. Also, strong validation programmes, including correlative measurements, should support the efforts to obtain improved measurements based on satellite data - this has been lacking in the upper troposphere. Better radiosonde observations of water vapour and wider exploitation of LIDARs were required. It was further pointed out that greater attention must be paid to the continuity of measurements in order to determine more accurately long-term changes in both the stratosphere and upper troposphere. However, reliance should not be placed on observations from one instrument or one approach: a range of complementary measurements was required. To be able to quantify dynamical effects which influence long-term changes, all measurements, whether satellite or in situ, should be collected with simultaneous methane observations. Satellite sensors with a history of high quality measurements should be included in future missions in the effort to monitor long-term changes in stratospheric and upper tropospheric water vapour. In order to gain a better understanding of the present distribution of water especially in the upper troposphere, a study of the role of convection was required, involving joint measurements of water vapour, cloud microphysical properties, and chemical species (providing a history of the air). Elsewhere, more (in situ and remotely-sensed) observations of the tropical tropopause were necessary to enhance knowledge of stratosphere-troposphere exchange in this region.

The JSC voiced its congratulations to the SPARC Scientific Steering Group on the completion of the Water Vapour Assessment.

6.3.4 An integrated understanding of stratospheric climate change

As noted in the three foregoing sections, the SPARC studies of long-term changes in the stratosphere (of temperature, ozone and water vapour), so far conducted separately, have now produced initial sets of results, all of which underlined that trends in one parameter were closely linked with changes in other parameters and that, increasingly, an integrated approach would be required. In the light of the fairly large body of information on the parameters that described change in the stratosphere over the last two decades, the SPARC Scientific Steering Group was taking up the following questions:

(i) Are the different observed data variations providing a consistent picture of the stratospheric climate variations, including the possibility of a trend over the past two decades (e.g., ozone and temperature) upon which shorter time scale variations are superimposed?

(ii) Can model simulations, employing the known forcings that have acted upon the system over the past two decades, be used in conjunction with the observed data to reproduce the changes in the observed parameters, and thereby lead to explanations of the causes of these changes?

There were many challenges in providing satisfactory answers such as the changes in ozone that were not the same from one decade to the next, aerosols from two volcanic eruptions perturbing the chemical and radiative budgets, temperature variations with different trends in low, middle and high latitudes (punctuated by sharp transient warmings in the aftermath of the volcanisms), the 11-year cycle in solar irradiance. SPARC was uniquely placed to tackle these issues, thereby providing valuable input to IPCC and the WMO assessments. The task would bring together many currently separate SPARC initiatives as well as being likely to involve interactions with other WCRP activities. In particular, AMIP-style model simulations would be planned, focussed on the stratosphere, specifying appropriate inputs such as (monthly-mean) greenhouse gases, ozone, water vapour and aerosols (but without interactive chemistry at least in the initial phase). An ensemble of runs from different initial conditions should be undertaken, including a set of simulations without any "forcing" in order to understand the internal dynamical fluctuations of the modelled stratospheric climate system. Initially, the scope of the project would not be too ambitious, and an assessment would be made of what had been achieved after three years.

6.4 Stratospheric processes

6.4.1 Gravity wave processes and their parameterization

Progress continued to be made in the construction of a stratospheric gravity wave climatology based on high-resolution radiosonde data. Following the workshop in Abingdon, UK, in July 1999 (reported at the twenty-first session of the JSC), data have been reanalysed and a further range of climatological and research products have been obtained, including climatologies of wave energies and propagation directions as a function of latitude. A number of articles for publication in the refereed literature, summarizing the overall work and research that have been involved in this project, were being prepared.

The planning of the international field experiment to investigate the gravity-wave field forced by tropical convection (the "Effects of Tropical Convection Experiment", ECTE) was also progressing. During the six-week intensive observation period (late October-early December 2002) the intense diurnal convection that occurred over the Tiwi Islands, north of Darwin, Australia, would be investigated. A detailed plan of the scientific objectives and instrumentation to be deployed during the field campaign may be viewed at **http://www.princeton.edu/~kph/EXP2**.

A preparatory campaign (the Darwin Area Wave Experiment, DAWEX), under the auspices of SPARC and the SCOSTEP project "Equatorial Processes Including Coupling" (EPIC), would be undertaken late in 2001 (i.e. Austral spring). DAWEX was intended to characterize the wave field in the middle atmosphere over Northern Australia prior to the onset of, and then during, intense diurnal convection (known locally as "Hector"). DAWEX would involve only ground-based instrumentation (including the Australian Bureau of Meteorology Research Centre Doppler radar, balloon soundings from Darwin and from nearby locations operated by the Japanese Radio Science Centre for Space and Atmosphere, a radar to monitor winds in the mesosphere and lower thermosphere, and airglow imagers to observe the wave field near the mesopause and in the thermosphere), and thus the lead time for the implementation of this activity was shorter than for ECTE.

6.4.2 Lower stratospheric/upper tropospheric processes

Transport and mixing in the lower stratosphere and upper troposphere were fundamental to SPARC, and the key to many issues taken up by SPARC, e.g., the upper tropospheric/lower stratospheric ozone budget, mid-latitude water vapour distribution and tropical dehydration. However, there was still no overall strategy and theoretical framework for studying stratospheric-tropospheric exchange, paradigms that could be tested, or an obvious common measurement/diagnostic approach. Thus, the role played by SPARC in this area up to now was to keep under review the key questions that needed to be addressed and to bring the different communities involved in this subject together in various focussed workshops. In view of the importance of the tropopause (where climate/ozone issues come together), a workshop on this topic had been arranged in Germany in April 2001. Questions that would be taken up included:

- what is the tropopause, how well is it known, why does it take the form that is observed?
- what is the role of the tropopause in upper tropospheric/lower stratospheric physical/chemical/dynamical processes and the implications for tropospheric chemistry/climate?
- how may the tropopause be expected to change in the future?

As well as the above initiative, several joint SPARC-IGAC studies of chemical processes in the upper troposphere/lower stratosphere were going forward. Amongst these, the latest findings on the role of organic peroxy radicals in ozone photochemistry were reviewed in SPARC Newsletter No. 15 (and a formal paper was now in press in the Journal of Geophysical Research). A careful evaluation of recent laboratory measurements on the quantum yield of ozone photolysis has also been completed, and was being submitted to the Journal of Geophysical Research. The SPARC Scientific Steering Group judged this type of joint activity with IGAC to be extremely beneficial to both projects and crucial in the study of important upper tropospheric/lower stratospheric chemical reactions. Stimulating interactions between modellers, and field and laboratory chemists were being generated, with new people being brought in. The climatology of and trends in upper tropospheric ozone was another area where co-operation could be fruitful.

6.4.3 Penetration of UV radiation into the lower stratosphere and troposphere

Increasing UV flux into the troposphere (consequent to decreasing stratospheric ozone) could enhance the photo-dissociation of the ambient chemical species leading to greater tropospheric concentrations of the hydroxyl radical and perturbations in the distribution and lifetimes of such compounds as CO, O_3, CH_4, H_2O_2, HCFCs, HFCs etc. It was essential to know the actinic flux distribution in the lower stratosphere and troposphere and to determine the climatology of photodissociation rate constants (J values) for various radicals as a function of altitude, and to make marked progress in model calculations. A joint SPARC-IGAC initiative was proposed in 1999 with the objectives of evaluating existing data (including J values and actinic flux measurements), considering the requirements for new instrumentation and organizing validations of computations of radiative transfer at UV wavelengths. This activity would fit well with and complement the joint SPARC-IGAC studies of chemical processes in the upper troposphere and lower stratosphere (see section 6.4.2). However, little progress had yet been made, and the connection with IGAC needed to be strengthened.

It was noted that a workshop on the impacts of UV took place in Mar del Plata in November 2000, immediately following the SPARC General Assembly (see section 6.1). Despite the interest manifested by participants in the SPARC Assembly, it was not felt that this was a subject that should be taken up by SPARC at present.

6.5 Other scientific issues

6.5.1 Dynamical Coupling of the Stratosphere and Troposphere

(Somewhat speculative) reports given to the SPARC Scientific Steering Group at its 1999 session on two aspects of what were thought to be manifestations of the dynamical coupling of the stratosphere and troposphere, the quasi-biennial oscillation (QBO) and the Arctic Oscillation (AO), were relayed to the twenty-first session of the Joint Scientific Committee. At the most recent session of the SPARC Scientific Steering Group, the possible link between the AO and North Atlantic Oscillation (NAO) was discussed. There were similarities between the AO and NAO in the surface pressure patterns and features derived as a leading "mode" of variability of the combined troposphere-stratosphere system. It was thus suggested that the AO and NAO could be different manifestations of the same underlying dynamical phenomenon: this was supported by evidence of a downward propagation of the AO signal. This opened up questions concerning the mechanism for the downward propagation of the AO, and whether there could be a stratospheric influence on the large-scale variability of the troposphere (and thus whether, with a prior knowledge of the state of the stratosphere, changes in the large scale circulation in the troposphere could be predicted!). The SPARC Scientific Steering Group intended to keep under review any new scientific developments or results in this area. The JSC recognized the interest in this topic at present, which was also of relevance for CLIVAR and ACSYS/CliC. The JSC urged that the CLIVAR and ACSYS/CliC Scientific Steering Groups, as well as SPARC, keep the questions involved under review, but did not consider that any (joint) specific activity needed to be organized in the WCRP at present in view of the multiplicity of workshop/symposia on this subject currently being organized by the scientific community at large.

6.5.2 Solar forcing and climate variability

As requested by the JSC, SPARC was keeping under review research on solar forcing, its variability as a source of variations in climate, and possible underlying mechanisms. As noted last year, although changes in the solar spectrum were known to affect ozone, temperature and the actinic flux in the middle atmosphere, there was still no consensus whether tropospheric climate was influenced by these changes (this lack of consensus was clearly apparent at the SPARC General Assembly, see section 6.1). The data analysis planned in the European Project Solar Influence on Climate and Environment (SOLICE), and modelling activities in GRIPS and SOLICE, which were all still at an early stage, might help throw further light on this issue (although, again as noted in section 6.1, models with the capability of representing more fully the important chemical/dynamical/radiative interactions that were involved were required).

In this context, Professor Geller reported that serious questions on the validity of the statistical analysis earlier employed in suggesting the relationship between solar effects and (northern hemisphere) land surface temperatures were now being raised. The earlier study had been extended backward in time by using temperature reconstructions and relating these to solar behaviour. However, there was improper correlation between different periods of temperature records and lack of consistent filtering of the solar data set. In fact a corrected analysis appeared to show that recent global mean temperatures were departing from the earlier "solar control", pointing to the role of human influence. Likewise, the analysis, based on ISCCP data sets, indicating possible cloudiness variations associated with changes in solar output and cosmic rays, had been seriously challenged.

In respect to the latter issue, the JSC invited the GEWEX Scientific Steering Group to give its view on the application of GEWEX/ISCCP data sets in this manner, and on the suitability of the analyses that had been carried out. However, the JSC did not consider further overall action was necessary at present in the WCRP on the subject of solar influences on climate so soon after the latest intensive IPCC discussions of the topic.

6.5.3 Stratospheric aerosols

The subject of stratospheric aerosols has been a subject of much discussion for many years, but no organized activity has been undertaken. The SPARC Scientific Steering Group has now invited a small group of experts to examine the existing climatologies, identify consistencies and inconsistencies, and to advise on steps required to obtain a better knowledge of the composition of stratospheric aerosols and their optical and chemical properties.

6.5.4 Review of the role of the stratosphere in climate change in the IPCC Third Assessment Report

A number of points were raised in the IPCC Third Assessment Report on the role of the stratosphere in climate change. The full assessment of this role proved difficult for a number of reasons including:

- uncertainties in trends in water vapour in the upper troposphere and lower stratosphere
- the relatively short observational record in the stratosphere
- the uncertainties in respect to the dynamical links between the stratosphere and troposphere

It was noted that the SPARC Scientific Steering Group was actively pursuing the issues of trends in water vapour in the upper troposphere and lower stratosphere (with the Water Vapour Assessment having recently been completed, see section 6.3.3) and of stratospheric-tropospheric links (with the organization of a workshop on the tropopause in April 2001, see section 6.4.2).

Other obstacles were the poor stratospheric resolution in climate models used for detection and attribution, the limited simulations of internal climate variability in the stratosphere, uncertainties in solar and volcanic forcing reconstructions and responses, and the absence of adequate coupling between stratospheric chemistry and circulation in climate models. Again, the SPARC GRIPS activity (see section 6.2.1) would advance work in these areas.

The main conclusions expressed regarding the role of the stratosphere in climate change were that stratospheric ozone depletion had been a major contribution to the observed cooling in the lower stratosphere over the last twenty years, and that a much greater understanding and appreciation of the important role that stratospheric processes play in climate variability and change was emerging.

6.6 Overall SPARC strategy

Hitherto, SPARC initiatives have been fairly focussed and dealt with in a fairly "self-contained" manner (by sub-project working groups). There was obviously a need for specific continuing efforts (e.g. refinement of a gravity wave climatology and the understanding the role of gravity waves in stratospheric dynamics; upper tropospheric/lower stratospheric chemistry and microphysics; the tropopause; solar forcing and climate variability; a range of specific modelling issues identified in GRIPS; and stratospheric data assimilation). However, it did now appear timely to integrate the knowledge acquired across SPARC in order to progress towards the goal of an overall understanding of all aspects of stratospheric variability and change, interactions with the troposphere, and their role in climate. This was now being put into practice in the new SPARC initiative "An integrated understanding of stratospheric climate change" (see section 6.3.4). SPARC should also remain in a position to provide the best available information on relevant stratospheric questions for the periodic international assessments such as those of IPCC and WMO/UNEP. This required a forward-looking approach to identify new questions that could arise.

6.7 Interactions with other programmes and activities

As noted at several points in the preceding text, SPARC maintained strong links and/or interacted widely as appropriate and necessary with several other programmes. Especially noteworthy was the co-operation with IGAC (the joint SPARC-IGAC activity on upper tropospheric/lower stratospheric chemical processes, see section 6.4.2; the planned initiative on the penetration of UV radiation into the lower stratosphere and troposphere, see section 6.4.3; possible collaboration in considering climatologies of stratospheric aerosols and their properties, see section 6.5.3). However, an improved mechanism was needed to ensure that the joint planning necessary was carried forward in a timely and organized manner, and it was suggested that a small SPARC/IGAC liaison group might be formed for this purpose. This would be explored with the IGAC Scientific Steering Committee.

Reference has also been made to collaboration with SCOSTEP in several areas. In particular, the JSC encouraged the establishment of a joint SPARC/SCOSTEP working group to take up the issues of upper stratospheric temperature trends (see section 6.3.1). SPARC and SCOSTEP were also co-sponsoring the Darwin Area Wave Experiment, DAWEX (see section 6.4.1).

Good co-operation continued between SPARC and the WMO Global Atmosphere Watch (GAW). Progress in several areas of SPARC depended fundamentally on the measurements made by the GAW network of ground-based ozone instruments and ozone sondes. These measurements were an essential complement to the increasing range of remotely-sensed ozone observations.

6.8 The SPARC Data Centre

The SPARC Data Centre at the State University of New York at Stony Brook, supported by NASA, has now been in operation for more than a year. Good progress was being made in assembling key stratospheric data sets in a readily accessible form. Recent new additions included high-resolution temperature and wind observations from radiosondes, selected GRIPS model results, and data sets used in preparing the WAVAS report (water vapour measurements from aircraft campaigns, ground measurements and satellite data). A full account of the work of the Data Centre and the approach being followed was contained in SPARC Newsletter No. 15. The website **http://www.sparc.sunysb.edu/** may be consulted for the full list of data sets available, and for information on access and downloading.

6.9 The SPARC office

As well as its regular responsibilities of compiling and editing SPARC Newsletters, updating the SPARC mailing list, maintaining contacts with the SPARC community of scientists, organizing various SPARC meetings and periodically revising the SPARC home page, particular support has been given to the preparation of the SPARC water vapour assessment report (see section 6.3.3). Substantial efforts were devoted to seeking sponsors for the Second SPARC General Assembly, and assisting in the arrangements for the Assembly was a major task during 2000. Following the encouraging development reported at the twenty-first session of the JSC that a full-time support position in the SPARC Office had been offered by the French Centre National de la Recherche Scientifique, a suitable candidate had been found who began work in June 2000 and was providing very efficient management support. However, a project scientist working (half-time) in the SPARC Office, left in November 2000: a suitable (post-doctorate) replacement was being sought.

7. AIR-SEA FLUXES

7.1 Organization of Workshop on the Intercomparison and Validation of Ocean-Atmosphere Flux Fields

Drs P.K. Taylor and S. Gulev, Co-chairs of the joint JSC/SCOR Working Group on Air-Sea Fluxes, reported on the status of the activities undertaken by the group. It was recalled that, at the twenty-first session of the JSC, the substantively final version of the report of the joint JSC/SCOR Working Group on Air-Sea Fluxes had been presented, providing a comprehensive assessment of the state-of-the-art in regard to air-sea flux determination. The report may be accessed at **http://www.soc.soton.ac.uk/JRD/MET/WGASF** and has been published in the WCRP report series (WCRP-112, Intercomparison and Validation of Ocean-Energy Flux Fields). The report contained an extensive evaluation of flux products, including in situ data sets, those inferred from remotely-sensed data, and model-based fields (i.e. from reanalyses or operational analyses). Major discrepancies between different types of data sets were still apparent.

Attention has since been given to the organization of the joint WCRP/SCOR Workshop on the Intercomparison and Validation of Ocean-Atmosphere Flux Fields, being held in Washington, DC, in May 2001. The workshop would bring together the different scientific communities interested in air-sea fluxes and, as a first step, review the Working Group report, collect feedback from the community as a whole, and provide a wide opportunity to comment on and debate as appropriate the conclusions and opinions of the Working Group. The latest developments in obtaining flux and flux-related parameters from in situ and remotely-sensed data, and from model output fields would also be presented, as well as studies of uncertainties inherent in various fields. Although primarily concerned with global-scale flux climatologies, the elaboration of flux parameterizations, and ideas for field experiments and collection of high quality flux data would also be discussed. Most importantly, the Workshop would, like the earlier WCRP Workshop on Air-Sea Flux Fields in 1995, promote further inter-disciplinary consultations, and encourage feedback and dialogue between the producers and users of surface fluxes and related data. This would be a basis for agreeing on an effective and balanced strategy and the internationally co-ordinated initiatives needed to make progress in studying, determining more accurately, and making appropriate use of air-sea fluxes. The workshop has been successful in attracting wide interest in the scientific community and well over a hundred abstracts have been submitted. Following introductory presentations of the report of the Working Group on Air-Sea Fluxes and reviews of other activities related to air-sea fluxes, sessions would be devoted to descriptions of flux products from modelling and data assimilation, the validation of flux products, flux fields from remote sensing, and flux measurements and parameterizations. Break-out groups would then be tasked with considering the strategy for making further progress in the study and utilization of ocean-atmosphere fluxes (addressing specifically issues such as how to define the best parameterizations and obtain the highest quality measurements necessary to estimate air-sea fluxes, how to validate flux estimates, and how to improve flux products in the future).

The JSC noted that, following the workshop, the existing JSC/SCOR Working Group on Air-Sea Fluxes (which had been established as a limited-life group) would formally come to the end of its mandate. However, in view of the number of outstanding questions relating to physical air-sea interactions in WCRP and the expected follow-up required to the work of the Working Group on Air-Sea Fluxes, the JSC recognized that a new WCRP "air-sea interactions" group would need to be established. The follow-on working group should foster collaboration on surface flux issues between the scientific activities having requirements for surface flux data, including, for example, CLIVAR, GODAE (see section 2.3) and SOLAS (see section 7.2). The working group should also consider, in conjunction with flux producers, how the best possible flux estimates could be obtained (e.g. from reanalysis projects). This was allied to the requirement to review ongoing research into flux parameterizations and their implementation in data assimilation and satellite retrievals (e.g. to assess the work on ocean surface turbulent fluxes that has been undertaken in GEWEX which was primarily based on satellite estimates). Other areas where work was needed was on flux variability and the role of this variability in interannual to centennial fluctuations, such as the North Atlantic and Arctic Oscillations in middle and high latitudes, and ENSO etc. There also remained much to do in evaluating the quality of surface fluxes (their "strengths and weaknesses"), and organization of specific efforts to resolve uncertainties in time-mean magnitudes of fluxes. New directions should be explored (e.g. to provide tools to assist in determining bio-chemical fluxes) and the specification of the Earth observing system(s) needed to give a comprehensive coverage of surface fluxes considered.

The JSC nominated Dr P.K. Taylor as chairman-designate of the new group and invited him to put forward terms of reference and a proposed membership for consideration by the Chairman of the JSC following the Washington workshop on air-sea fluxes. The possibility of the co-sponsorship of the new group by SCOR also needed to be discussed. (In this respect, the JSC was informed that, at its General Meeting in Washington, DC, October 2000), SCOR had very much appreciated the work of the Working Group on Air-Sea Fluxes and the report that had been produced, and was strongly supportive of continuing joint activity with the WCRP in this area, possibly in the form of a new joint JSC/SCOR working group).

7.2 Surface Ocean-Land Atmosphere Study (SOLAS)

The JSC has been following with interest and contributing to the development of SOLAS planning for a number of years. Professor P. Schlosser reviewed the progress that had now been made.

It was recalled that the basic scientific focus of SOLAS was the interaction between the atmosphere, climate and marine bio-geochemical processes and it was envisaged that SOLAS, when the scientific mission, foci, and hypotheses were fully elaborated, would become a major activity of both the WCRP and IGBP. SOLAS was intended to build on the work of other projects such as IGAC, JGFOFS and WOCE and should also be closely linked to CLIVAR. Partnerships should be established between atmospheric and marine research scientists in the biogeochemical, atmospheric chemistry and physical oceanography communities - these partnerships and overcoming barriers to interdisciplinary science were essential if SOLAS was to succeed.

A science plan for SOLAS has now been drafted (Dr P.K. Taylor participated in the drafting team on behalf of WCRP). The goal of the SOLAS initiative has been specified as "to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and how this coupled system affects and is affected by climate and environmental change". SOLAS would be focussed on processes at the air-sea interface and include a natural emphasis on the atmospheric and upper boundary layers, whilst recognizing that some of the processes to be studied would, of necessity, be linked to significantly greater depth scales. SOLAS was being designed in such a way to use hypotheses to ensure that observations and experiments which were carried out in the project were well focussed, as well as being relevant to understanding key climatic interactions. A further characteristic would be that these hypotheses should be able to be tested as far as possible.

A number of foci have been defined:

(i) Biogeochemical interactions and feedbacks between ocean and atmosphere: the objective was to quantify feedback mechanisms involving biogeochemical coupling across the air-sea interface which could only be achieved by studying the ocean and atmosphere in concert. These couplings included emissions of trace gases of importance in atmospheric chemistry and climate, deposition of nutrients that controlled marine biological activity and carbon uptake, and the production of chemically-active particles by bubble bursting. Specific topics to be taken up included: dimethylsulphide and climate; iron and marine productivity; iron and marine nitrogen fixation; nitrogen deposition and marine productivity; marine particle and gas emissions and atmospheric chemistry; radiation and trace gas biogeochemistry.

(ii) Exchange processes at the air-sea interface and the role of transport and transformation in the atmospheric and oceanic boundary layers: the objective was to develop a quantitative understanding of processes responsible for air-sea exchange of mass, momentum and energy to permit accurate calculation of regional and global fluxes. This required establishing the dependence of these interfacial transfer mechanisms on physical, biological, and chemical factors within the boundary layers and the horizontal and vertical transport and transformation processes that determined these exchanges. Specific issues that would be studied included: exchange across the air-sea interface; processes in the oceanic boundary layer; processes in the atmospheric boundary layer.

(iii) Air-sea flux of CO_2 and other long-lived radiatively active gases: the objective was to develop a quantitative understanding of the upper ocean mechanisms which created the regional, seasonal and interannual structure and variation of these fluxes in order to assess their sensitivity to variations in environmental forcing. The air-sea CO_2 flux was a key inter-reservoir exchange within the global carbon cycle. Experimental, observational and modelling studies linking biological uptake, respiration, marine calcification and mixed-layer physics with upper-ocean CO_2 were necessary to predict changes in oceanic carbon uptake over the next century. The ocean also played a key role in the global budgets of other long-lived radiatively active gases including N_2O and to some extent CH_4. Specific activities would include: geographic and interannual variability of air-sea CO_2 fluxes; CO_2 flux changes over the next 100 years; air-sea flux of N_2O and CH_4.

The full SOLAS science plan (which includes discussion of a number of issues common to all SOLAS activities such as modelling, remote sensing, time series, coastal zones and palaeo-research) can be accessed at **http://www.ifm.uni-kiel.de/ch//solas/main.html**.

The JSC welcomed the progress made in the definition and planning of SOLAS. The increased emphasis given to physical aspects (i.e. focus (ii)) was particularly appreciated, and this made SOLAS look very relevant to the WCRP. The JSC noted that the science plan had been submitted to SCOR for review, and SOLAS had been officially recognized as a new SCOR programme. The science plan had also been presented to the Scientific Committee for the IGBP where it had been endorsed after review. The JSC agreed that WCRP should also be directly involved in the further development of SOLAS, and nominated two of its members (Drs K. Denman, Professor P. Schlosser) to be included in the proposed SOLAS Scientific Steering Committee. Furthermore, the JSC was of the view that the new WCRP air-sea interactions group discussed in section 7.1 to take up the outstanding questions relating to physical air-sea interactions might also assist in the development of focus (ii) of SOLAS (and might even, subject to the agreement of all concerned, become a "SOLAS Focus (ii) subgroup".

8. WORLD OCEAN CIRCULATION EXPERIMENT (WOCE)

The report on WOCE was presented by Professor P. Killworth and Dr W. Large, Co-chairs of the WOCE Scientific Steering Group, and Dr J. Gould, Director of the WOCE International Project Office. WOCE, the oldest of WCRP's projects, would formally conclude at the end of 2002. The project's roots dated from 1980, but the exploitation of the results would continue long beyond the formal end of WOCE. The time span of WOCE of more than 20 years gave a stark indication of the long-term funding and organizational challenges that must always be considered when large, international climate research projects were conceived. The main attention in WOCE was now being given to activities that further built up WOCE science and ensured the project's legacy. In particular, substantial progress has been made in the past year in the interpretation of WOCE data sets. Although many of these studies were very much of an oceanographic nature, all provided a basis for improving the realism of ocean models.

8.1 Review of WOCE achievements in the past year

8.1.1 Scientific progress

Central to the concluding Analysis, Interpretation, Modelling and Synthesis (AIMS) phase of WOCE has been a series of regional and specific subject-based workshops. In the former category, the first workshop on the Pacific was held in 1996, followed by workshops on the South Atlantic and Southern Ocean in 1997, on the Indian Ocean in 1998, and on the North Atlantic in August 1999. These workshops have had significant impact in encouraging collaborative regional analysis and interpretation projects, and in accelerating publication of specific basin results. There was a further workshop during 2000 reviewing the variability seen during the WOCE observational period (1990-1997), and attempting to assess the extent to which the WOCE period could be said to be representative of the mean state of the ocean. The main findings of the workshop were that significant variability was seen almost everywhere and in almost every quantity observed. Furthermore, there were pronounced deviations from the "norm" during WOCE both in the extreme positive state of the North Atlantic Oscillation and in the period leading up to the onset of and during the 1997/1998 ENSO event. Comparison with WOCE era hydrography with earlier sections has revealed significant decadal-scale changes in ocean properties in all regions: these were also manifest from the records of the few long time series stations. A marked seasonal signal was apparent in the Indian Ocean down to a depth of 3000m. In the modelling results reported, it was noted that global ocean data assimilation was now a technical reality and was already being widely undertaken at a resolution of 2°. Unconstrained models showed considerable skill in reproducing ocean mesoscale variability. The overall conclusion, that WOCE years were not synoptic nor representative, was in many ways not surprising, but in this respect, useful guidance has been provided to CLIVAR in developing its ocean observational strategy.

A view of the present understanding of many other WOCE science issues can be drawn from the "WOCE book" ("Ocean circulation and climate: observing and modelling the global ocean") that was now being published (see section 8.1.3). However, as the title of the book implies, many of the new insights so far have come from the various improved observational techniques used in WOCE and from the progress made in modelling the ocean. It was still too early to draw any novel far-reaching conclusions concerning the ocean's role in climate or to finalise estimates of ocean property transports and their divergences (see also section 8.3).

8.1.2 WOCE bibliography

The WOCE International Project Office has maintained, since 1995, an on-line bibliography of refereed and non-refereed articles that were relevant to the scientific objectives of WOCE and have used WOCE results. The bibliography grew by 900 references in the past year and now contained over 5100 entries (3500 from refereed journals). 1300 of these were attributable as an output measure of WOCE.

8.1.3 Publication of "WOCE book"

The work undertaken in compiling the book "Ocean Circulation and Climate - Observing and Modelling the Global Ocean", edited by Drs G. Siedler, J. Church and J. Gould, was described at the twenty-first session of the JSC. The book had its roots in the plenary lectures at the 1998 WOCE Conference in Halifax, Canada, and was being launched shortly after the present session of the JSC at the European Geophysical Society meeting in France. The book would be a long-lasting tribute to those who planned and carried out WOCE, and provided a comprehensive account of the enormous advances during the 1990s in the ability to observe and model the global oceans, stimulated in large measure by the pursuit of WOCE objectives. The book also contained a summary of the current understanding of the ocean's role in climate, and an assessment of the remaining scientific and organizational challenges.

8.1.4 Second version of WOCE data

A second version of WOCE data, occupying 15 CD-ROMs, was distributed in July 2000. The contents were:

(i) Data Information Unit and Bathymetry: the design, implementation and status of WOCE, describing elements of the experiment, the available data sets, the participating scientists, bibliography, and the details of software to access the WOCE global data set: also contained bathymetry data along the WOCE sections;

(ii) Hydrographic Programme (2 CDs): data and documentation for the one-time and repeat hydrography and time series stations (Bermuda and Hawaii);

(iii) Upper ocean temperature data: quality controlled temperature profile data for the upper 1000m of the water column largely from XBT probes;

(iv) Subsurface floats: trajectory data from acoustically-tracked and autonomous (ALACE) subsurface floats from the WOCE period and pre-WOCE deployments;

(v) Surface velocity data: compilation of data from individual drifters as well as interpolated surface velocity fields;

(vi) Current meter data: time series of data from moored arrays during WOCE documenting boundary currents and flows through passages together with flow statistics;

(vii) Acoustic Doppler current profiles: upper ocean (top 300m) current velocity profiles from WOCE cruises;

(viii) Sea level: fast delivery and delayed-mode sea level data, together with computed tidal constituents from coastal and island sites and data from bottom pressure recorders;

(ix) Surface meteorology: ship-based data from over 400 WOCE cruises;

(x) Surface fluxes: tropical Indian (1970-1999) and Pacific (1861-1999) pseudostress fields from Florida State University; tropical Atlantic pseudostress and sea surface temperature from ORSTOM (1964-1999); tropical Indian Ocean fluxes from Florida State University (1960-1989); global air-sea heat, momentum and fresh water flux climatologies (1980-1993) from Southampton Oceanography Centre; global daily mean stress (1997-1999) from the Naval Operational Global Atmospheric Prediction System;

(xi) Satellite altimetry: TOPEX POSEIDON 1992-1999 (0.5° and 1.0° gridded);

(xii) Satellite sea surface temperature: as inferred from AVHRR measurements (1990-1999)(0.5° and 1.0° gridded);

(xiii) Satellite sea surface winds: from ERS-1/2 and NSCAT fields on 1° grid;

(xiv) Electronic atlas of WOCE hydrographic programme data and visualisation tools for hydrographic and upper ocean thermal data.

The second version differed from the earlier 1998 version in having a more uniform format (NetCDF) and also included more data. However, some data still remained proprietary (WOCE data-sharing policy allowed principal investigators to retain rights to float data for two years after the end of the trajectory).

8.1.5 WOCE atlases

In terms of scope and accuracy, the survey of the global oceans between the late 1980s and 1998 in the WOCE hydrographic programme was unprecedented, with approximately 10,000 full depth profiles of temperature and salinity together with discrete samples of nutrients and chemical tracers being collected. In order to leave a permanent record of the WOCE achievement, a series of definitive large-format atlases of physical and chemical properties of the global oceans based on WOCE observations for each ocean basin were being prepared. The intention was to publish and distribute the atlases free of charge to principal investigators and libraries. The data analysis and preparation of the plates was being supported by various national funding sources. The Director of the WOCE International Project Office has managed to secure funding from BP AMOCO for the actual publication and distribution of 1500 copies of the atlases. Printing of the volumes would extend over the next two to three years (in fact beyond the life of the WOCE international Project Office: the International CLIVAR Project Office would complete the work).

8.2 On-going activities and outstanding issues

8.2.1 Ocean model development

The joint WGCM/WOCE Working Group on Ocean Model Development had been established to give specific attention to various questions on the performance of ocean models and to stimulate the development of these models for use for research in climate and related fields. The activities of this group, in particular the preparation of an authoritative and comprehensive survey "Developments in Ocean Modelling", and the planning for a pilot ocean model intercomparison project, are described in detail in section 4.2.7.

8.2.2 Compilation of WOCE data sets

Steps were being taken towards preparing the third (and final) version of the WOCE CD-ROMs (planned to be available at the final WOCE Conference in November 2002, see section 8.3). Outstanding issues were the integration of all the different types of WOCE data into a resource that was fully searchable so as to encourage maximum usage, ensuring that WOCE Data Assembly Centres (together with the WOCE International Project Office) tracked down and obtained any missing data, coping with continuing data flow once funding for the Data Assembly Centres has finished, and considering the contribution of the Data Assembly Centres to CLIVAR.

Regarding the status of the WOCE Data Assembly and Special Analysis Centres, it was apparent that the funding of some elements would not be continued until the end of WOCE. For other elements, funding was uncertain and this could hinder the pursuit of missing data and the production of the third version of the CD-ROMs. Devising a strategy and finding the means to complete these activities and to ensure the completion of the archive of WOCE data and metadata at the USA National Oceanographic Data Centre was a vital challenge in the concluding phase of WOCE.

Another issue was the data from profiling floats, whose development and introduction was a major technical advance stimulated by WOCE. The floats were extensively deployed in the second part of the field phase, and were now forming the basis of the planned global ARGO programme (see section 2.3). Formally, however, the WOCE data management system did not include a profiling float data assembly centre (although the velocity data were held by the subsurface float data assembly centre). Moreover, the ARGO programme was not as yet considering how to save the float profiles collected during the WOCE period. It was hoped to rectify this situation by inviting all known investigators to submit their profiling float data over the coming year for inclusion in the third version of the WOCE CD ROMs and the WOCE archive.

The JSC expressed concern at the uncertain status of the WOCE data management system and the future handling of continuing WOCE data streams. The JSC asked the WOCE Scientific Steering Group to provide a summary at the session of the JSC in March 2002 of the range of activities needed to support sustained monitoring of the "climate of the ocean", indicating that WOCE elements needed to be carried forward, what would be taken up by CLIVAR, what would be handled elsewhere, and what issues were in danger of being overlooked.

8.2.3 WOCE field programme summary

It was planned to produce a WOCE field programme summary in parallel with the third version of the WOCE CD-ROMs. The summary was intended to provide full details of WOCE observations made from 1990 to 1998 (including any relevant observations prior to 1990), presenting the information in an easily searchable format and structure that could be related to aims of the field programme set out in the WOCE Implementation Plan. The document should be issued electronically and in a hard copy form to ensure maximum accessibility, and would also be a "metadata" addition to the WOCE global archive. The WOCE International Project Office was in the process of compiling the material required, but no source of funding for production and distribution had as yet been identified.

8.3 Future activities and events

In the remaining months of WOCE, substantial efforts were still required in the compilation of WOCE data sets, the preparation of the WOCE atlases and field programme summary, and taking steps to ensure that arrangements for essential elements of the WOCE data management system to be carried forward were put in place. The two main final events foreseen were, firstly, the concluding workshop of the AIMS phase, addressing the fundamental WOCE objective of assessing oceanic transports of mass, heat, and freshwater and their divergences, and the implied air-sea exchanges (Southampton, UK, June 2001). Estimates of these quantities would be derived from inversions of global and basin-scale WOCE data, ocean-only models (with and without assimilated WOCE data), coupled models and air-sea flux climatologies. The physical transport terms were also essential in estimating transports of carbon and nutrients, and there would thus be close interaction with JGOFS work on fluxes of nutrients and carbon. Plans were also being drawn up for the "final WOCE conference" to mark the formal end of WOCE as a WCRP project. The conference would be held in San Antonio, Texas in November 2002 and would seek the full involvement of climate research scientists (aiming to avoid a purely oceanographic focus). With the title "WOCE and beyond" attention would not be focussed on the end of WOCE, but rather on highlighting WOCE accomplishments and the start of a new era of quantitative oceanography. The Conference would feature challenging talks in the five morning plenary sessions, and four poster sessions with a different theme each afternoon.

The JSC especially appreciated the synergy between WOCE and JGOFS activities in enhancing the understanding of the role of the oceans in the carbon cycle, a key item of interest to both WCRP and IGBP.

The JSC therefore encouraged the maximum co-operation between WOCE and JGOFS in their concluding phases, in particular the possibility of organizing joint events and/or the close association of JGOFS with the WOCE Conference in November 2002. The JSC also agreed that a final comprehensive review and celebration of WOCE achievements should be a special feature of the session of the JSC in March 2003 (following the Conference in 2002).

8.4 The WOCE International Project Office

WOCE continued to be overseen on a day-to-day basis by the International Project Office (co-located with the International CLIVAR Project Office in Southampton, UK - see section 9.6). The staffing level was now 1.5 full-time equivalent scientific positions and 0.75 full-time equivalent secretarial support. Activities included production and distribution of reports of meetings and workshops and of the International WOCE Newsletter, assembly of a bibliography of WOCE-related papers, and maintaining the WOCE web site. The efforts needed to ensure an orderly conclusion of WOCE in 2002 would be a major challenge as staffing levels and the already limited resources decreased.

9. CLIMATE VARIABILITY AND PREDICTABILITY

Dr A. Busalacchi, Co-chair of the CLIVAR Scientific Steering Group, and Dr J. Gould, Director of the International CLIVAR Project Office, presented a comprehensive account of the status of CLIVAR. Over two years had elapsed since the International CLIVAR Conference (Paris, December 1998) where the CLIVAR Initial Implementation Plan had been launched. At the Conference, countries had indicated their likely interest in and possible commitments to CLIVAR implementation. Since then, countries had developed their own implementation plans and, in some cases, established budgets in support of CLIVAR modelling and observational research. Generally, countries had taken a wide range of approaches, and efforts were occasionally focussed on specific areas within CLIVAR rather than the project as a whole. In the USA, a national implementation plan had been drawn up, and CLIVAR issues were dealt with by an interagency group comprising NASA, NOAA, NSF and DOE. A US CLIVAR Project Office had also been established and this was of major assistance in fostering improved links between the US CLIVAR activities and the international programme. In Germany, national CLIVAR programmes for both the atmosphere and ocean have been set, and in Canada, a major CLIVAR-related initiative is under review. In the UK, a number of activities dealing with aspects of the coupled ocean-atmosphere system were being undertaken under the auspices of the National Environment Research Council (e.g. Coupled Ocean-Atmosphere Processes and European Climate, COAPEC; an initiative on abrupt climate change). Whilst national supporting activities of the type indicated above would remain the mainstay of CLIVAR, the exploitation of supra-national mechanisms (e.g. the Asia-Pacific Network, the Global Environmental Fund, European Union) needed to be more fully explored. Within the European Union, there were already various projects (with a three-year funding cycle in the "Energy, Environment and Sustainable Development" domain) that would contribute to CLIVAR seasonal-to-interannual prediction studies. CLIVAR had now set in train the process of refining the initial implementation plan taking account of new scientific knowledge and integrating national contributions.

The paragraphs below summarize the overall situation. Although structured around the three basic CLIVAR themes (seasonal-to-interannual variability and prediction, decadal-to-centennial climate variability and predictability, extending the climate record and anthropogenic climate change), there are many cross-cutting issues, particularly relating to implementation, blurring the distinctions between the themes.

9.1 Seasonal-to-interannual variability and prediction

The experience of TOGA demonstrated that improvement in our ability to predict climate on seasonal to interannual timescales required development and implementation of appropriate observing systems, improvements in numerical models of the phenomena under consideration, and identification of appropriate tests and indices of model performance. In all these areas CLIVAR was developing strategies aimed at improvements in prediction of monsoon systems and ENSO events.

9.1.1 Sustained ocean and atmosphere in situ observing systems

The Pacific equatorial array

The array of moored buoys in the tropical Pacific Ocean was now known as the "TAO/TRITON array" in recognition of JAMSTEC having assumed responsibility for maintaining sites along 156°E, 147°E, and 138°E in the western Pacific with TRITON moorings. Several overlapping time series from co-located TRITON buoys and the ATLAS moorings in the original Tropical Atmosphere Ocean array were obtained to ensure the comparability and consistency of measurements from the two systems. Wind, sea surface temperature, air temperature, relative humidity, and subsurface temperature from the ATLAS and TRITON buoys were now being transmitted on the GTS and have been merged into a unified data set available from NOAA's Pacific Marine Environmental Laboratory (**http://www.pmel.noaa.gov/tao/**), mirrored at JAMSTEC (**http://www.jamstec.go.jp/ jamstec/TRITON**). In the eastern South Pacific, there were plans for an extension of the array from the equator to 45°S but this depended on funding from the World Bank's Global Environmental Facility.

The Atlantic

Improvements in seasonal-interannual climate prediction required the establishment of equatorial observing arrays in other oceans. The Atlantic now had PIRATA (Pilot Research Array in the Tropical Atlantic) in place supported by the USA, France and Brazil, but the integrity of the present array was being seriously compromised by vandalism particularly in the Gulf of Guinea. This was calling into question the cost-effectiveness of the array in that area, and there was no obvious solution to the problem.

Indian Ocean

The tropical Indian Ocean remained the least well observed. It had been planned that two Triton buoys would be deployed in November 2000 in the eastern equatorial Indian Ocean (at 0°, 90°E and 5°S, 95°E) as initial building blocks for the development of a basin-scale moored buoy array. However, concerns over the moorings' ability to remain on station in strong currents have required design modifications and these have delayed the first deployments for over a year. Moored buoys maintained by India were in place around the subcontinent. More generally, the overall importance of the establishment of an integrated sustained basin-scale ocean observing system in the Indian Ocean has now been widely recognized, and, as a component of this, the implementation of an Indian Ocean moored buoy array was receiving priority within the context of CLIVAR, GCOS and GOOS. Proposals were being drawn up and support would be sought both from donor nations and the Global Environmental Facility.

Other equatorial observations

Measurements of temperature and salinity profiles complementing the observations from moored buoys would come from the global Argo array of profiling floats (see sections 2.3 and 9.4). However, the Argo array would be relatively sparse (typically 300km spacing) and hence might not be effective at resolving the detailed meridional structures in the tropical ocean nor might it provide the near-surface current observations available from moored buoys and surface drifters.

Another significant contribution was made by the Surface Velocity Programme (SVP), an international effort to obtain long-term global observations of near-surface currents, using current-following, satellite-tracked buoys (drifters) with subsurface drogues designed to make the drifter accurately follow the horizontal water motion. Surface drifter deployments have and would continue to offer measurements of surface current, temperature, atmospheric pressure. In 1999, the drifter array provided some 32000 daily average velocity and sea surface temperature observations within 20° of the equator. In some cases, surface salinity observations were also provided by the drifters, although these continued to suffer from the longstanding problems of biofouling and sensor drift. Drifters were good platforms for monitoring sea surface temperature and hence detecting and correcting satellite biases introduced by clouds and aerosols. While equatorial regions were likely to be covered by existing programmes, CLIVAR would need to promote extra-tropical deployments.

Valuable detailed information (at a spatial resolution of 50 km or less) also came from the high density Volunteer Observing Ships XBT lines traversing the equatorial region. The recommendations made for the requirements for XBT networks for climate research at the International Conference on the Ocean Observing System for Climate in October 1999 met CLIVAR's global needs. It appeared that the high density lines were likely to be funded even though more sparsely sampled XBT lines were being cut as the implementation of ARGO accelerated.

Atmospheric observations

In situ atmospheric observations were provided by the World Weather Watch network of operational surface and upper air stations. CLIVAR strongly encouraged the work of the GCOS Atmospheric Observation Panel for Climate in building up the GCOS Surface Network (GSN) and the GCOS Upper Air Network (GUAN) comprising stations selected on the basis of their value for climate monitoring (in terms of location, quality and record length) as well as for synoptic meteorology (see section 2.3). New locations at which atmospheric observations (particularly upper-air) would be required and existing sites that should be maintained would be specified for the regional implementation of CLIVAR (African climate variability, Asian-Australian monsoon, American monsoon system studies - see section 9.1.3).

9.1.2 Remotely-sensed data

Remotely-sensed data have become the mainstay of all aspects of climate monitoring and research and were, of course, essential for CLIVAR. The use of remotely-sensed data in the preparation of atmospheric analyses and global climatological data sets of precipitation, cloud etc. was the responsibility of other components of the WCRP (in particular, the data assimilation/analysis efforts overseen by WGNE - see section 4.1, and by GEWEX - see section 5.3). Remotely-sensed data were now equally the cornerstone of ocean observation. For instance, altimetric measurements from TOPEX/POSEIDON, complemented by those from ERS-2, together with sea surface temperature data, were fundamental in monitoring the evolution of the 1997/8 El Niño/La Niña event and low latitude variability in other oceans. The expected launch of Jason-1 during 2001 as a follow-on to TOPEX/POSEIDON was eagerly anticipated and would provide key input across the entire range of CLIVAR interest. The availability of scatterometer data was also of concern to CLIVAR, as these provided essential information on surface wind fields. The long record from the scatterometers on the ERS satellites proved, unfortunately, to be of limited utility because of the narrow swath and shared duty with synthetic aperture radar data. Of greater value have been the short lived NSCAT and later Seawinds sensor on QuikSCAT, the latter expected to continue to operate to 2004. A further Seawinds sensor was scheduled for launch on Japan's Advanced Earth Observing Satellite (ADEOS-II) in November 2001. CLIVAR would require continued accurate surface vector wind measurements up to and beyond 2010, especially in view of perceived shortcomings in NCEP and ECMWF surface wind analyses.

Information on global precipitation was also vital to many elements of CLIVAR research. In this respect, the Tropical Rainfall Measuring Mission (TRMM) covering latitudes 40°N to 40°S had provided much valuable data since 1997. The plans for a Global Precipitation Mission were also highly relevant to CLIVAR's requirements. Complementary to precipitation was the measurement of sea surface salinity and, in this context, the ESA Soil Moisture Ocean Salinity (SMOS) mission planned for launch around 2004, was also awaited. On many of these issues, there was a close convergence of interest between CLIVAR and GEWEX (e.g. see section 5.1) and, in particular, CLIVAR depended on GEWEX for the provision of high quality surface radiation data.

9.1.3 Regional studies

African climate variability

Significant progress has been made in the past two years in assessing the state of knowledge of African climate variability and in the preparation of an implementation plan designed to achieve a more fundamental understanding of this variability, its causes, and its relationship with global climate. Attention would be given particularly to evaluating the performance of the current generation of models in simulating variability over Africa and to identifying model shortcomings that might account for deficiencies in these simulations. The main initial activities would be centred round the documentation and understanding of the annual cycle and interannual variability over Africa and its role in the global climate system. It was intended to produce an electronic atlas of the key variables and diagnostics that described the annual cycle and interannual variability at a large-scale (i.e. concerned with the whole continent, surrounding oceans, and global interactions), and at a regional scale to enable local issues to be considered. The data assembled, as well as a basis for research, would be used for evaluating model simulations. In this respect, there was evidence of problems in models even in reproducing such basic aspects as the annual rainfall cycle: this was symptomatic of inadequacies in the global and regional climate simulated and in climate predictions. A specific study would also be made of the period from 1997-2001 covering the extreme East African/Southern Africa rainfalls in 1997/1998, the Mozambique floods, and the severe drought followed by intense precipitation in East Africa. This study was expected to indicate the key processes playing a role in climate anomalies in Africa (these could include the impacts of ENSO combined with the effects of regional ocean forcing, remote interactions, and land surface processes).

Other topics to be taken up were intraseasonal variability (an analysis and diagnosis of intraseasonal variability and associated regional circulations as well as a study of the variability of tropical cyclones in the Atlantic and Indian Oceans) and, as a lower priority, decadal variability, which, for the present would be limited to documenting observed decadal rainfall anomalies and to the extent to which these were represented in multi-decadal model simulations forced with observed sea surface temperatures.

The plans for the study of African climate variability have been constrained by the smaller community of scientists involved than in other CLIVAR research areas. In view of this and of the limited means available to research programmes in Africa, there was a need for co-ordination between relevant international activities, especially those under the WCRP umbrella (e.g. strong linkages with GEWEX in obtaining land-surface data and with CEOP). It was also hoped to take advantage of new resources for observations that could come from the Global Environment Facility).

The Variability of the American Monsoon System (VAMOS)

Planning for VAMOS was in full swing with great interest being shown by research scientists throughout the American sub-continent. VAMOS included a number of studies of important phenomena with a demonstrated potential for prediction. The establishment of partnerships between interested scientists was being fostered in order to develop the research programmes required and funding was being sought. Also, the widest possible participation in field programmes was being encouraged in order to bring local expertise into the international arena and to enhance scientific exchange and capacity building. The appointment of Dr C. Ereño as a part-time staff member of the International CLIVAR Project Office based in South America enabled the essential co-ordination between the many CLIVAR and VAMOS-related activities that were now developing in Central and South America.

The two main foci currently of VAMOS internationally co-ordinated efforts were the Monsoon Experiment South America (MESA) and the North American Monsoon Experiment (NAME). These experiments would provide a strong linkage between CLIVAR, with its emphasis on the behaviour of the coupled ocean-atmosphere system, and GEWEX in its studies of the role of land-atmosphere processes. Together, the relative importance of interactions between the atmosphere, ocean and land in modulating the American Monsoon System would be assessed. The implementation of the supporting infrastructure required would be a decisive contribution to the establishment of a climate and hydrological monitoring capability through the Americas.

MESA comprised three stages, the first a study of the South American low-level jet (as part of a broader programme on American low-level jets) and participation in the (US-led) Eastern Pacific Investigation of Climate (EPIC). The former was designed to assess the role of low-level jets in the hydrological cycle and determine relationships between the circulation and the rainfall over adjacent mountain complexes. EPIC involved a field programme investigating the warm pool in the eastern tropical Pacific. The second stage of MESA would, on one hand, take up the climatology and hydrology of the La Plata basin (jointly with GEWEX - see section 5.3), and, on the other, implement "VAMOS EPIC" with the objectives of data analysis, monitoring and modelling together with pilot observational studies of climate variability in the eastern Pacific from the USA to the Chilean coast. The third stage, towards the end of CLIVAR, would have the goal of consolidating the preceding research activities into a comprehensive monitoring capability for the Americas.

NAME would involve empirical and modelling studies supported by the development of relevant data sets and enhanced monitoring (e.g. carrying on elements of the existing Pan-American Climate Studies, PACS; the US CLIVAR-GEWEX Warm Season Precipitation Initiative), as well as field activities in the core region of the North American monsoon in the summers of 2003 and 2004. The NAME science and implementation plan may be consulted at **http://www.cpc.ncep.noaa.gov/products/precip/monsoon/NAME.html**.

Asian-Australasian monsoon

The role of various factors in the variability of the Asian-Australasian monsoon at intraseasonal and interannual timescales continued to be investigated. In particular, the results of the Joint Air-Sea Monsoon Interaction Experiment (JASMINE) in 1999/2000, exploring the hypothesis that intra-seasonal variability (i.e. active and break periods) of the Asian-Australasian monsoon was linked to coupled ocean-atmosphere interaction in a region of large cross-equatorial surface pressure gradient, were being evaluated. A JASMINE-II process experiment was being planned in the Bay of Bengal in 2004. Other studies contributing important data were the South China Monsoon Experiment (SCSMEX) with a field phase in 1998 closely co-ordinated with GEWEX Asian Monsoon Experiment (GAME), (see section 5.3), and the Bay of Bengal Experiment (BOBMEX).

There have also been recently a number of other new insights into the Asian-Australian monsoon system and, more generally, seasonal-to-interannual variability in the south Asian region. Although no sustained relationship between the Asian monsoon and ENSO has been apparent in recent years, there was still evidence of correlation with other tropical-wide oscillation indices. For example, the observed effect of the tropical biennial oscillation on Indian monsoon rainfall was a manifestation of a "flip-flop" of the system on a biennial time scale. Furthermore, there was evidence of an atmospheric telecorrection pattern linking Asian monsoon anomalies to major floods and droughts over North America during the boreal summer (distinct from those associated with ENSO). Other research has shown strong similarities between dominant modes of subseasonal and interannual variability in the Asian summer monsoon.

On the modelling side, a comparative study has been undertaken (in conjunction with the CLIVAR Working Group on Seasonal-to-Interannual Prediction, WGSIP - see section 9.1.4) of atmospheric model treatments of monsoon circulations when subject to the 1997/1998 El Niño sea surface temperature anomalies. The results were now being analyzed. It has also been proposed to carry out an intercomparison of ocean models, all driven with identical 18-year fields of surface fluxes, in the simulation of sea surface temperature anomalies in regions that may be affected by monsoons. Funding to support this initiative was being sought from the Asia-Pacific Network.

The JSC appreciated the progress in CLIVAR in the developing regional studies (namely of African climate variability, the Variability of the American Monsoon System and the Asian-Australian monsoon) in the past year. The JSC emphasized the importance of co-ordination with various related activities in GEWEX (in particular GAME, see section 5.3). The opportunity for the development of regional capabilities and for fostering regional contributions should also be taken, and in this context, collaboration with relevant programmes of the WMO Commission for Atmospheric Science should be considered. Full use also needed to be made of START possibilities, facilities and networks (see section 3.4). The JSC was pleased to see the attention that had been captured by VAMOS, especially in South and Central America, but urged that the link (through CLIVAR) to WCRP as the parent programme must be stressed and widely advertized.

9.1.4 Refinement of seasonal-to-interannual predictions

The CLIVAR Working Group on Seasonal-to-Interannual Prediction (WGSIP) has the responsibility of considering how operational seasonal-to-interannual predictions can be further refined, the improvements that can be made in the skill of probabilistic seasonal forecasts (e.g. by exploiting ensemble predictions and/or multi-model ensembles), examininig the dependence of model predictions on the data used for forecast initialization and the way the data are assimilated, and the assessment of relevant observing systems and their effectiveness. These activities needed to be supported by research into relevant modes of climate variability and predictability on seasonal to interannual timescales and seasonal effects interacting with monsoonal flows.

A key element of WGSIP work has been a dynamical seasonal prediction study with the objective of assessing the predictability of the mean circulation and rainfall up to a season in advance. In the first phase, ensembles of forecasts from winter and summer periods in various years using observed initial conditions from successive days and prescribed boundary conditions were prepared by a number of modelling centres. Results showed that, as would be expected, the skill varied significantly from model to model and case to case. The skill of the multi-model ensemble was nearly the same as that of the best available model, except for cases when some members had a very low degree of performance (anomaly correlation coefficient less than zero). Models reproduced the northern hemisphere 500 hPa geopotential anomaly for the winter 1982/1983 better than other winters (1986/87, 1987/88, 1992/93), this apparently being attributable to the very strong El Niño conditions in that winter. Generally, lower levels of skill were seen in the summer cases. The accuracy of precipitation forecasts was limited except in regions directly affected by ENSO. The second phase, now being initiated, would comprise a more extensive suite of experiments to clarify the questions on predictability outstanding from the first phase and, in particular, persisted or predicted sea surface temperatures would be used rather than specified temperatures. Details of results obtained so far in this WGSIP study and of the organization of the second phase can be viewed at **http://www-pcmdi.llnl.gov/smip**.

Findings from the related US dynamical seasonal prediction experiment and the European Union Programme on Prediction of Climate Variations on Seasonal and Interannual Timescales (PROVOST) were also noted. In the former, there appeared to be a distinct response to ENSO forcing including particularly the PNA pattern over North America. PROVOST experiments indicated, as observed in the WGSIP seasonal prediction study, a nearly universal advantage of multi-model ensembles, except when one or more models were very poor.

In other areas, WGSIP work on diagnostics of intraseasonal variability in CMIP runs has continued and, as noted in section 9.1.3, WGSIP was co-operating in the experimentation on the simulations of monsoonal circulations during 1997/1998 El Niño. WGSIP followed carefully and with encouragement the efforts of several modelling centres in the elaboration of new coupled models for seasonal forecasting and the impetus being given in this area both by the networking activities of the International Research Institute for Climate Prediction (IRI) and the European Union "DEMETER" project ("Development of a European Multi-model Ensemble System for Seasonal-to-Interannual Prediction"). Further, WGSIP kept under review the overall status of operational seasonal-to-interannual predictions (a report was given at the twenty-first session of the JSC on factors that might have been responsible for the limited levels of skill achieved in forecasts of the 1997/1998 El Niño). The predictions of the flooding events in Mozambique and Venezuela in 2000 were now being assessed and could be expected to lead to specific numerical experimentation projects.

9.2 Decadal-centennial variability and predictability

Fundamental work was still required in this area in documenting what kind of decadal signals existed in both the atmosphere and ocean and characterising their timescales and spatial patterns, discovering driving mechanisms and interactions with regional phenomena, and assessing the extent to which there was predictability on decadal timescales. The overall situation had been well reviewed by the Workshop on Decadal Predictability in October 2000 organized by the Working Group on Coupled Modelling (see section 4.2.10). Other local manifestations/characteristics of decadal-centennial climate variability in individual ocean basins were being considered by the scientific community as summarized in the following paragraphs.

Southern Oceans

The circumpolar extent of the Southern Ocean meant that it had potentially a fundamental role in the global climate system, in particular as the essential channel for the global thermohaline circulation which has been closely linked to climate variability on decadal timescales and climate change. Recent findings have shown that the closure of the global thermohaline circulation depended on water mass transformation in the Southern Ocean and the circulation was, consequently, more sensitive to air/sea exchange than if closure occurred through mixing in the ocean interior. Modelling results have also indicated the potential sensitivity of the overturning circulation to surface warming and freshening. The Antarctic Circumpolar current was another important feature in carrying anomalies which could both affect both regional and global climate from one basin to another (e.g. as manifested in the Antarctic Circumpolar Wave). However, much remained to be done in understanding ocean-atmosphere-ice coupling in the Southern Ocean and the regional and global implications. The water masses formed in the Southern Ocean, accounting for more than half the volume of the world ocean, carried the signature of climate variability into the ocean interior and were a sensitive indicator of climate change. The water masses also spread north to the tropical thermocline where they might well modulate interannual climate variability (e.g. ENSO) on decadal timescales. Consideration was duly being given to an internationally co-ordinated "Southern Ocean Project" to take up issues such as: the variability of the coupled climate system in the Southern Oceans, including such features as the Antarctic Circumpolar Wave and teleconnections; sub-Antarctic mode water formation and exchange with lower latitudes; stability of the overturning circulation. The conduct of this project would depend on the full global implementation of ARGO (see section 2.3) including deployments under the extensive areas of winter sea-ice in the Southern Ocean, repeat high density XBT sections by research ships, merchant vessels and Antarctic supply vessels, moored arrays to measure the outflow of deep and bottom water, in situ observations as a basis for refining estimates of air-sea fluxes inferred from remotely-sensed data and atmospheric models, and improved determination of freshwater input and sea-ice volume.

Atlantic Ocean

The North Atlantic Oscillation and its changes in phase and amplitude have become increasingly a focus of scientific attention in recent years. The behaviour of the North Atlantic Oscillation was evidently of intense interest to CLIVAR in view of the strong effects in the Atlantic and Arctic Oceans in inducing substantial changes in surface wind patterns and altering the heat, freshwater and momentum exchange at the ocean surface. This in turn modified the strength and character of the Atlantic's wind-driven and thermohaline circulations, the Arctic gyre and ice-export into the Atlantic. Changes in the North Atlantic Oscillation also had a wide range of impacts on marine and terrestrial ecosystems. Until recently, changes in the amplitude and phase of the North Atlantic Oscillation from one winter to the next were considered unpredictable. However, the prolonged upward trend over several years has led to speculation that the variability of the North Atlantic Oscillation was not only due to chaotic atmospheric processes over the North Atlantic, but might be responding in a more or less systematic way to more slowly changing elements of the climate system.

It was a tantalising question to discover what elements were responsible and whether these might hold the key to the predictability of the North Atlantic Oscillation. As noted in section 6.5.1 (where dynamical coupling of the stratosphere and troposphere was discussed), the North Atlantic Oscillation signal can be traced not only at the surface but also throughout the upper troposphere and stratosphere and was probably closely linked to the stratospheric "Arctic Oscillation" as different manifestations of the same underlying dynamical phenomenon. It was well established that tropospheric variability could drive stratospheric variability, but recent evidence (as noted in section 6.5.1) suggested the downward propagation of the Arctic Oscillation and that there might be some stratospheric control of the troposphere. In this case, the observed trend in Atlantic surface climate might be influenced by processes affecting the stratospheric circulation on long time scales. Reductions in stratospheric ozone and increases in greenhouse gas concentrations which had a significant radiative cooling effect in the stratosphere were obvious candidates. The JSC recalled that it had asked the CLIVAR, ACSYS/CliC and SPARC Scientific Steering Groups jointly to keep the questions involved in this issue under review (see section 6.5.1).

There was also evidence that the ocean might have an appreciable role (e.g. the tendency of the ocean to preserve its thermal state from one winter to the next could impress some persistence on the atmosphere). Moreover, in experiments with atmospheric models forced by the known evolution of the global sea surface temperature field and sea ice cover, the low frequency variations in the observed NAO oscillation had been reproduced (i.e., in response to changes in ocean surface temperatures and sea-ice cover). New recent results hinted at a linkage between the trend in the NAO and the progressive increase in tropical sea surface temperatures, particularly the warming in the tropical Indian and Pacific Oceans. This pointed to the importance of investigation of the NAO in a global rather than a regional context.

Pacific Ocean

The main question for CLIVAR in the Pacific Ocean was the "interdecadal Pacific climate mode" that extended over the whole Pacific Ocean in a fairly simple spatial pattern and that might modulate the frequency and amplitude of ENSO events on decadal timescales. Consideration continued to be given to the development of CLIVAR science in the Pacific and the requisite basin-wide ocean and atmospheric sampling, regionally enhanced observations, and relevant oceanic and atmospheric process studies. For ocean sampling, an approach combining remote sensing, ARGO profiling floats, surface drifters, time series stations (including surface reference sites for improved surface flux estimations), high density XBT lines, and repeat hydrography. Attention was also being given (in conjunction with other interested programmes) to sustaining and adding to the atmospheric observations made across the Pacific basin. Studies of western boundary currents, equatorial currents, and mixing processes in the ocean were of high interest as were improved knowledge of atmosphere-ocean links in the eastern tropical Pacific and in the Kuroshio extension regions and of cloud processes in key regions of the Pacific.

Indian Ocean

As noted in section 9.1.1, the Indian Ocean remained the least well observed ocean and thus insights into decadal variability in and around the Indian Ocean were limited. However, as noted earlier, the importance of establishing an integrated sustained basin-scale ocean observing system in the Indian Ocean has now been widely recognized.

9.3 Anthropogenic climate change

The responsibility for providing improved and increasingly confident projections of anthropogenically induced climate change from coupled models of the global climate system rested with the Working Group on Coupled Modelling whose activities were described in section 4.2. CLIVAR itself worked with the IGBP PAGES core project to increase the reliability and resolution of the past climate record in order to assist in the effort to detect climate change which, inter alia, required historical records of key variables and proxy data to construct long time-series. In particular attention was being given to the construction of the palaeo-climate record inferred from sedimentary, coral, tree ring and ice core data in order to put the shorter instrumental record of recent climate variability in a wider context. As part of the "PAGES/CLIVAR Intersection", a series of workshops was being planned over the next three to four years focussing on specific phenomena such a ENSO, the NAO and abrupt climate change. These workshops would bring together the palaeo and climate communities in the search for a better understanding of natural climate variability.

CLIVAR also sponsored jointly with the WMO Commission on Climatology a working group on climate change detection. This working group has concentrated on the development and verification of climate change indices. The results of this work, and the changes indicated in climatic extremes in the second half of the twentieth century, provided useful material for the IPCC Third Assessment Report. However, the analyses did not cover the entire globe, and the CCl/CLIVAR Working Group on Climate

Change Detection has organized regional climate change workshops to prepare in a hands-on manner indices in various regions. Two workshops had so far taken place in the Caribbean in January 2001 and the other in Morocco, involving many African countries, in February 2001. Data exchange remained an obstacle to progress in this area. Whilst the derived indices were available, access to the original data was often also needed in order to assess the validity of the indices.

9.4 Overall implementation issues

Surface fluxes

The CLIVAR Scientific Steering Group claimed that progress in various aspects of CLIVAR was being hampered by uncertainties and biases in some of the estimates of air-sea fluxes of heat and momentum. The JSC pointed out that consideration of this issue was receiving high priority in the WCRP. The authoritative "Intercomparison and Validation of Ocean-Atmosphere Energy Flux Fields" (WCRP-112) had recently been completed by the joint JSC/SCOR Working Group on Air-Sea Fluxes, and was being considered at an international JSC/SCOR workshop in Washington DC in May 2001 (see section 7.1). The workshop would bring together the different scientific communities involved in producing and using air-sea flux data sets, and would provide an excellent opportunity to agree on an effective and balanced strategy and further internationally co-ordinated initiatives needed to make progress in determining air-sea fluxes. Moreover, WGNE has organized an evaluation and intercomparison of global surface products from the operational analyses from a number of the main NWP centres (see section 4.1.7): the products would also be compared with measurements from a series of open ocean flux reference sites. In GEWEX, the possibility of inferring estimates of surface evaporation and heat flux from satellite data at high resolution in space and time was being actively explored (see section 5.4). All these activities would be monitored and collaboration fostered as required by the new WCRP "air-sea interactions" group established by the JSC (as a successor to the Working Group on Air-Sea Fluxes) at the present session of the JSC (see section 7.1).

ARGO

A central plank in meeting CLIVAR observational requirements was the deployment of the global array of profiling floats as part of the "ARGO" initiative being organized under the guidance of the WCRP/GCOS/GOOS Ocean Observations Panel for Climate (OOPC) (see section 2.3). As noted earlier, there were concerns whether the overall global distribution required would be achieved. ARGO was a key element of the Global Ocean Data Assimilation Experiment (GODAE)(as also described in section 2.3), and the pilot activity in the Atlantic planned for 2003/2004 could be the proof of concept of the four-dimensional assimilation in the oceans of in situ and remotely-sensed data. CLIVAR followed with close interest the development of GODAE from this perspective and the implementation of the data management systems necessary to handle real-time and delayed-mode data streams.

Hydrography and carbon measurements

The CLIVAR assessment of decadal timescale change in the oceans had as its foundation the WOCE global hydrographic survey. Re-occupations of a subset of WOCE lines were planned and it now appeared (as noted in section 9.1.1) that the level of coverage of these lines required could be achieved. From the CLIVAR standpoint, it was the changes in physical parameters (temperature and salinity) that were important. However, the foreseen re-occupations of various lines offered an opportunity also to compile a new post-WOCE inventory of ocean carbon. The JSC requested that the possibility of collecting such ocean carbon measurements be urgently considered.

Data management systems

The provision of timely high quality atmospheric and oceanic data and products (including palaeo- and historical instrumental data) to the CLIVAR research community represented a formidable challenge. The development of the required data management systems could not be done in isolation, and would, as a starting point, build on and improve the systems implemented and used successfully in TOGA and WOCE. Close collaboration with GCOS and GOOS was also necessary, especially in respect to data management systems to be put in place for GODAE and ARGO in order to avoid duplication of effort. It was certainly necessary to exploit the full potential of the new information technology in the establishment of an appropriate distributed data system. Pressure particularly needed to be applied on oceanographic institutions and investigators to ensure the timely release of oceanographic data. In contrast, in the case of atmospheric data, these were in most cases readily accessible for research purposes under the terms of the Twelfth World Meteorological Congress/Resolution 40, although action was needed to follow up a few isolated exceptions. Overall, the issues involved went beyond CLIVAR alone, and, in some cases cut across the entire WCRP. Some of the questions and concerns had already been discussed by the JSC (see section 2.5), and a meeting of leaders of WCRP data management groups and/or project office directors had been proposed to consider guidelines for data management practices and, if appropriate, a climate data and information strategy for the WCRP as a whole.

9.5 The International CLIVAR Project Office

The International CLIVAR Project Office continued to be hosted by the United Kingdom, with support also from the USA, Japan, Canada, and Germany. Funding for the Director of the Office and a secretary was provided by the UK, whilst the USA support was especially valuable in meeting the costs of additional staffing, enabling the recruitment of Dr C. Ereño located in Argentina to help with VAMOS activities (see section 9.1.3), as well as two new staff members for the International CLIVAR Project Office in Southampton, UK (in place of Dr F. Semazzi, who had held the post of "CLIVAR Chief Scientist", but has now returned to the USA). CLIVAR also continued to benefit from the services of Dr A. Villwock working at the Institute für Meereskunde in Kiel (supported by Germany). The hiatus between Dr Semazzi's return to the USA and the recruitment of new staff has meant that support for some activities (e.g. representation at meetings, the timely production of meeting reports) has suffered. A high priority activity was the development and maintenance of a good quality web site, together with a searchable data base of CLIVAR projects and a gallery of images reflecting CLIVAR research initiatives. Additional support (i.e. funding to hire staff or staff secondments) was constantly being sought, and the assistance of JSC members in this respect was urgently requested.

10. THE ARCTIC CLIMATE SYSTEM STUDY (ACSYS) AND THE CLIMATE AND CRYOSPHERE (CliC) PROJECT

The Chairman of the ACSYS/CliC Scientific Steering Group, Dr H. Cattle, introduced this item. He recalled that CliC had been formally established as a WCRP project, and the original ACSYS Scientific Steering Group reconstituted as the ACSYS/CliC Scientific Steering Group at the JSC session in March 2000. It had subsequently been a busy year with continuing progress in ACSYS, the exciting steps in developing CliC, and considering the transition from ACSYS to CliC (ACSYS was planned to conclude at the end of 2003). Dr Cattle himself reviewed the status of ACSYS (see sections 10.1.1 to 10.1.7), and Dr I. Alison and Dr R. Barry, Vice-chairs of the ACSYS/CliC Scientific Steering Group, respectively Antarctic sea-ice research projects (see section 10.2) and the development of CliC (see section 10.3).

10.1 The Arctic Climate System Study

A full description of ACSYS implementation and achievements was available at **http://www.npolar.no/acsys/impplan/index.htm**. ACSYS continued to undertake a series of activities concerned with the Arctic Ocean circulation, developing Arctic sea-ice climatology and research, the Arctic atmosphere and hydrological cycle, and modelling Arctic processes.

10.1.1 Arctic Ocean circulation

Exchanges of water mass between the Arctic and peripheral seas

Various international and national research projects continued to assemble data needed to quantify the exchange of water masses between the North Atlantic and Arctic Ocean. During a cruise establishing current meter moorings in the Fram Strait and between Bear Island and Fugloya, measurements at higher spatial resolution than previously were obtained in these regions. The variability observed suggested that short-term estimates based on a single CTD survey could be misleading: time series over several years from moored instruments were required to obtain reliable estimates.

In the Canadian Archipelago, ocean current, temperature and salinity measurements have been taken in the area east of Resolute Bay for two years. The problem of measuring the direction of currents so close to the magnetic pole has now been solved (as well as that associated with measurement of ice drift using upward-looking sonars). Studies of the structure of the flow entering through the Bering Strait and exiting through the Canadian Archipelago and investigations of shelf-basin processes (by Canada, in collaboration with the USA and Japan) have also continued.

A new development was the planning of an international project, the "Arctic/Subarctic Ocean Flux Study", a co-ordinated effort to obtain the required measurements of the fluxes through the main gateways to and from the Arctic Ocean over a sufficiently long period of time. This project, which would be a major contribution to ACSYS, was expected to begin in 2003. The International ACSYS/CliC Project Office has been helping in the development of the science plan, and ACSYS would be represented on the international scientific steering committee that would oversee the project.

Deep basin oceanography

Under the leadership of the International Arctic Research Centre (Fairbanks, Alaska), consideration was being given to a study of the Nansen and Amundsen basins in the Arctic Ocean, with the intention of providing a quantitative observationally-based assessment of the circulation and water mass transformation, and identifying the mechanisms involved. Long-term oceanographic moorings would be deployed, and currents, temperature and salinity measured using upward-looking sonars. Vertical cross-sections of velocity in the near-bottom and upper-ocean layers would be obtained from Doppler current profilers. The ACSYS/CliC Scientific Steering Group was keenly supporting this initiative which would help significantly in meeting ACSYS/CliC objectives.

In the Arctic Ocean, an increase in "core" Atlantic water temperature has been observed over the last decade, accompanied by a retreat of the "cold halocline". This was likely to modify the existing balance of heat fluxes in the upper layers of the Arctic Ocean with reductions in sea-ice formation, the Arctic ice-cover and mean ice thickness. The status of the atmospheric boundary layer, sea-ice cover and water column in eastern part of the Arctic Ocean following the anomalously warm decade 1990 was examined by a high-latitude cruise undertaken by a research vessel "Akademie Fedorov" of the Russian Federation in the period August-September 2000. A preliminary analysis showed that the Atlantic water temperature in the Arctic Ocean at the time of the cruise was higher than the mean climatic value and the maximum values recorded before 1990.

10.1.2 Arctic sea-ice

Activities related to sea-ice in ACSYS embraced four elements: Arctic Ocean sea-ice climatology, the export of ice to temperate oceans, ocean-ice-atmosphere interactions, and sea-ice processes. A particularly important objective (of ACSYS and CliC) was the accumulation of long-term observations of sea ice to enable study of natural variability and changes that might be anthropogenically induced. These data were also essential in the verification and refinement of sea-ice models. Attention has been given to identifying the best sea-ice data sets for ACSYS use, and to developments such as the use of the Radarsat Geophysical Processor System for determining sea-ice motion, as well as to the derivation of near-ice edge sea surface temperatures, production of ice analyses based on data assimilation techniques, and the estimation of sea-ice thickness.

Sea-ice climatologies

New data sets that became available during the past year included a 10 CD set of weekly ice charts for the period 1968-1998 covering the Canadian Exclusive Economic Zone (from the Canadian Ice Service). Charts for the period 1962-1967 were expected to follow during 2001. A US/Russian Joint Sea Ice Atlas (1950-1994) was released on a CD-ROM.

Concern was voiced at changes in the preparation of certain Arctic (and Antarctic) ice analyses at the USA National Ice Centre. These had implications for continuity and consistency in the time series of the analyses which were widely used by the climate research and modelling communities. It was suggested that a letter should be sent on behalf of WCRP emphasising WCRP/ACSYS/CliC requirements in this area, although it should be remembered that the USA National Ice Centre had primarily an operational role and did not, a priori, serve the research community.

Ice thickness

Ice thickness studies in the Arctic continued to draw on measurements made by moored sub-surface and submarine sonars, as well as remotely-sensed data. In respect of the first, monitoring by moored instrumentation in the Canadian Beaufort Sea was entering its second decade. No significant trends in ice thickness have been detected in this area over the past 10 years and thick old ice (5-7 m) was as common as it was in 1990. Ice-draft data from eight cruises by nuclear submarines were now available through the USA National Snow and Ice Data Center, and data gathered as part of the US Submarine Science Experiment (SCICEX) during the summer of 1998 and the winter of 1999 were expected to be released soon. Furthermore, USA data from before 1987 were to be declassified following their digitization at the University of Washington. A meeting was held in 2000 to discuss practical issues relating to submarine sonar data, including the need for improved accuracy of calibration, greater understanding of systematic and random errors that occured in the measurements, and declassification of a greater amount of associated meta data. Another workshop, under ACSYS auspices, would be held late in 2001 or the first half of 2002 to take further the question of quality control of sonar data from submarines and moored buoys, this being an essential prerequisite to the establishment of a uniform sea-ice thickness data base continuing data obtained from different technologies (submarine versus mooring) and from different agencies. As a consequence of the questions in this area, archival of ice-thickness data was lagging far behind observations.

Remotely-sensed data now contributed an increasingly large fraction of the available information, with estimates of the thin ice fraction from Radarsat now provided on a quasi-operational basis in the northern hemisphere winter half-year (November to May). There was reasonable agreement between the values of young ice concentration and thickness inferred from the Radarsat Geophysical Processor System and those from AVHRR, but the uncertainties in both were large. Ice thickness estimates were also sensitive to the depth assumed for any snow cover.

Putting the data sources together, it was expected that, by the end of ACSYS, a reasonably complete knowledge of the overall ice volume within the central Arctic (representing about one third of the area of ice in the northern hemisphere) would have been built up. There still remained a critical need for observations in the seasonal ice zone and marginal seas: this would mainly have to be met by sonars, but a better knowledge of ridge consolidation and the possible significance of this in the computations of the ice volume from sonar measurements was required. Ice thickness data were also missing in parts of the Beaufort Sea which could be expected to have the thickest ice in the Arctic Ocean. It has been recommended that future submarine cruises should consider making measurements in this area (in collaboration with Canada since the required tracks lay within the Canadian Exclusive Economic Zone).

More generally, it was still far from possible to monitor the total sea-ice volume of the northern hemisphere as a whole and the variations that might occur. Until the development of effective satellite-based techniques (not expected for several years), evaluating the total sea-ice volume was a logically daunting and expensive challenge. The ice-cover of the sub-Arctic seas has, of course, not been a priority for ACSYS, but it will be critical for CliC. In this context, it was noted that the area covered by northern hemisphere seasonal sea-ice in winter which might be expected to be the first to respond to changing climate, exceeded that of perennial ice in the central Arctic. Although the extent of seasonal ice has been relatively well monitored, there was little information on its thickness and motion.

Sea-ice movement

The movement of sea-ice was another key parameter in understanding the evolution of the Arctic ice-cap. The International Arctic Buoy Programme (IABP) was the principal source of data for an ACSYS sea-ice motion climatology, although Radarsat products were now available for the 1996-1997 and 1997-1998 northern hemisphere winters. An evaluation of the Radarsat products indicated that, under optimum tracking conditions, the Lagrangian ice-motion vectors were as accurate as those from buoys. However, this might not be the case in the less-than-optimum conditions encountered in the northern hemisphere summer, at the edge of image swaths, within a few hundred kilometres of coastlines, or other areas where the deformation was large. The irregular timing and long intervals (more than three days) between Radarsat observations also posed difficulties in interpretation. Eulerian ice-drift measurements have now also been obtained for the period 1990 to 2000 from sonar measurements at three sites in the Beaufort Sea. Nevertheless, there remained a critical need for observations of sea-ice motion in the seasonal ice zone and marginal seas that was not being met by the IABP or Radarsat products.

Export of ice from the Arctic Basin

There was a major requirement for long sequences of observations of ice thickness and drift in the Fram Strait and in all the other strategic channels between the Arctic and temperate oceans. Measurements have been made in the Fram Strait since 1987 using moored ice-profiling sonars and satellite imagery, and these have been augmented by further sonar-based ice-drift data since 1997. The feasibility of studying the flux of sea ice through the Canadian Arctic archipelago was being studied. The interest in this topic has been substantially reinforced following recent research results indicating a strong influence of interdecadal atmospheric oscillations on sea-ice export from the Arctic Ocean.

Ocean-ice-atmosphere interactions

Effort was needed to improve understanding of the interactive processes involved in the adjustment of the heterogeneous ice-atmosphere-ocean system in the Arctic to external perturbations. The Surface Heat Budget of the Arctic (SHEBA) study in 1998 was the principal activity in this domain so far. Interpretation of the data collected and associated modelling work was continuing and it has been shown that more than half of the north polar ice cover was seasonal and that much of the new ice production was in coastal polynyas. Other relevant initiatives included the International North Water Polynya Project, and on-going Canadian studies in the Bathurst Polynya and in the Canadian Arctic archipelago.

Sea-ice processes

The all-weather, high-resolution Synthetic Aperture Radar (SAR) was stimulating new insights into sea-ice processes and the mechanics involved, needed to understand and model the evolution of sea-ice cover and thickness. Also, the slip lines visible in velocity fields at 30-150 km separation inferred from Radarsat observations revealed the granular flow behaviour of sea-ice floes. Coastal boundaries had a critical effect which was currently not well represented in models. A workshop on the dynamics of sea-ice in March 2000 reviewed progress and outstanding problems. The need for a pack-ice rheology with anisotropic features to handle specific directional weaknesses was identified. The requirement for observations of very thick ridged ice for critical tests of ridging theory was also reiterated (the gap in this type of observations was noted above).

10.1.3 The Arctic atmosphere

In its studies of the Arctic atmosphere, ACSYS drew extensively on the ECMWF and NCEP/NCAR reanalyses (see section 4.1.9). The preparation of the 40-year ECMWF reanalysis (ERA-40) now underway and which should avoid some of the shortcomings seen in earlier reanalyses was of particular significance (ACSYS worked closely with ECMWF on the use of improved sea-ice data sets and a refined representation of sea-ice for ERA-40). The reanalyses had so far been useful in investigating recent trends in the Arctic Oscillation and the relationship with other Arctic features. (The Arctic Oscillation was closely linked with the North Atlantic Oscillation - see discussion of the stratospheric manifestation of these oscillations in sections 6.5.1 under SPARC, and of the North Atlantic Oscillation in section 9.2 under CLIVAR). As recorded in section 6.5.1, the JSC asked the SPARC, ACSYS/CliC and CLIVAR Scientific Steering Groups jointly to keep the questions involved in the Arctic/North Atlantic Oscillations under review.) Other areas where the reanalyses have been useful was in providing the surface atmospheric forcing required to drive sea-ice models, and descriptions of the Arctic atmospheric hydrological cycle (see also section 10.1.4) and the Arctic frontal zone.

An important contribution to ACSYS studies of the Arctic atmosphere (as well as to CliC goals) would also be made by a new large programme being planned by the USA National Science Foundation, namely the Study on Environmental Arctic Change (SEARCH), which would explore the nature and causes of recent climate trends in the Arctic. A dedicated reanalysis in the Arctic has been proposed as a component of SEARCH.

10.1.4 The Arctic hydrological cycle

The major components of the ACSYS hydrological programme were the compilation of an Arctic hydrological data base, and the development of Arctic hydrological modelling. In respect to the former item, particular attention was being given to the assembly of research-quality Arctic run-off and precipitation data sets, including supporting studies of the adequacy of measurements of solid precipitation. An Arctic run-off data base was being constructed on behalf of ACSYS by the Global Run-off Data Centre (GRDC) in Germany, which, in May 2000, received nearly 4000 mean monthly data sets from a "Pan-Arctic" run-off data base compiled at the University of New Hampshire, USA. These included over 1600 monthly mean data sets from the territory of the Former Soviet Union, and daily discharge data from 56 stations in the Russian Arctic, thereby alleviating the problem noted at the twenty-first session of the JSC of the availability of run-off data for the 1990s from Russia. (North American data had been previously received and were basically up to date.)

An Arctic precipitation data archive has been organized, on behalf of ACSYS by the Global Precipitation Climatology Centre, also in Germany, and a new Arctic precipitation climatology was being prepared (with support from the German Polar Research Programme). Detailed information on the status of the Arctic precipitation data archive may be found at **http://www.dwd.de/research/gpcc/acsys**.

With regard to measurements of solid precipitation, it has long been an ACSYS objective to explore the possibility of blending precipitation forecasts from reanalyses with station records in an effort to provide fields suitable for use in hydrological models. This issue has gained in urgency as the already sparse Arctic precipitation network has declined, with the closure of many stations in the Former Soviet Union and

Canada. Unfortunately, existing reanalyses show significant biases in precipitation, although the temporal variability may be reflected reasonably accurately. This opened the way to combining reanalyses with other atmospheric parameters in a statistical downscaling approach.

Concerning the use of hydrological models at high latitudes, the initial objective was to assess the capabilities to simulate high latitude water and energy cycles. A phased approach was being followed, with the first step an intercomparison of models (in a local-scale, offline mode) in the framework of the Project for Intercomparison of Land-Surface Parameterization Schemes (PILPs) (now a component of the GEWEX Global Land-Atmosphere System Study, GLASS - see section 5.5.2). A test using data from the Torne River Basin in Sweden has been organized.

10.1.5 ACSYS data and information flow management

Actions were being taken to ensure the visibility and ready accessibility of data collected by ACSYS, including the production of documentation on a CD-ROM. As indicated at various points in the foregoing text, ACSYS-related data and data sets continued to grow (e.g. the new Canadian sea-ice charts, see section 10.1.2, Arctic sea-ice thickness data). Information on available ACSYS Arctic hydrological, meteorological, sea ice, glaciological, oceanographic, radiation, remotely-sensed and modelling data sets was compiled by the ACSYS Data and Information Service (ADIS)(see web site **http://www.npolar.no/oelke/adis.html)**. However, there was concern over the lack of funding in ACSYS (as in other components of the WCRP) for supporting data management activities.

10.1.6 Modelling activities

The modelling activities being undertaken were already being extended to meet the wider requirements of CliC, consequent to the reconstitution of the ACSYS Numerical Experimentation Group as the "ACSYS/CliC Numerical Experimentation Group". A second sea-ice model intercomparison was being organized, in which a hierarchy of single-column thermodynamic sea-ice models would be forced with atmospheric and oceanographic data collected during the SHEBA field experiment (see section 10.1.2), and results verified against the corresponding sea-ice observations. Like the first intercomparison, the objective was to provide the basis to refine the sea-ice thermodynamic parameterizations used in climate models. The possibility of organizing an Arctic Ocean Model Intercomparison was also being considered. Other studies that the ACSYS/CliC Numerical Experimentation Group was expected to take up were ice-ocean interactions in the Southern Ocean (focussing on the Weddell Sea), the role of ice sheets in climate (including response to climate change) and ice shelf-ocean interactions, and model representations of snow cover and frozen ground (in conjunction with the GEWEX Global Land-Atmosphere Study, see section 5.5.2, and the WGNE Snow Models Intercomparison Project, see section 4.1.3).

10.1.7 Transition of ACSYS to CliC

As noted above, ACSYS had a planned end date of 31 December 2003, and ACSYS would continue as a separate visible programme (jointly with CliC) until then. Since CliC was focussed on the interactions of the cryosphere with the other components of the physical climate system, most, if not all, ACSYS activities would need to be continued in CliC in one form or another. Certain ACSYS activities, such as the polar hydrographic ocean sections (see section 10.1.1) and the assembly of Arctic run-off and precipitation data sets (see section 10.1.4) were also plainly relevant to other WCRP projects, in particular CLIVAR and GEWEX, and the approach would be to maintain and develop joint activities in such areas. This was necessary not only for scientific reasons but also for logistic considerations (since there was a relatively small dedicated community active in Arctic field work and common use needed to be made of observing platforms).

Seeing that CliC did have a considerably broader remit than ACSYS, the ACSYS/CliC Scientific Steering Group had agreed on the need for a final ACSYS Conference (i.e. specifically focussed on ACSYS). This was expected to be organized in 2004, with the theme "Progress in understanding the Arctic Climate System".

The JSC endorsed the basic approach adopted by the ACSYS/CliC Scientific Steering Group for the transition from ACSYS to CliC over the next few years.

10.2 WCRP Antarctic sea-ice research

10.2.1 WCRP International Programme for Antarctic Buoys (IPAB)

IPAB, a co-operative effort of nineteen agencies and institutions from twelve different countries with interests in near-surface meteorology and oceanography in the Antarctic and Southern Ocean, was established to maintain an observational network of drifting buoys and supporting data collection systems in the ocean around Antarctica. The objective was to support research in the region into global climate processes and climate change, to provide real-time operational meteorological data, and to establish a basis for on-going monitoring of atmospheric and oceanic climate in the Antarctic sea-ice zone.

Since the inception of the programme (originally for an initial period of five years), a total of 120 buoys have been deployed south of 55°S. The number of platforms with meteorological sensors (reporting via the GTS) has remained fairly constant in the range of 12 to 18. Deployments have been concentrated in the Weddell Sea and off the coast of East Antarctica, but recently a number have been placed in the Ross and Bellinghausen Sea region. Seasonally, the buoy numbers show a peak in May after new deployments during the southern hemisphere summer, but then there is a steady decrease as a result of instrument failures and of northward drift taking buoys out of the region of interest to IPAB. Although the number and distribution of buoys fall well short of optimum requirements, the data provided have had significant benefits for operational meteorological products and have contributed in a fundamental manner to the understanding of the dynamics of Arctic sea ice, including the derivation of a climatology of sea-ice drift in the Weddell Sea and off East Antarctica.

Despite the value of the high-latitude southern hemisphere buoy data in NWP, National Meteorological Services have not supported IPAB as strongly as hoped. The majority of deployments have been made in connection with specific research programmes. Increasing the involvement of National Meteorological Services is one of the major issues facing IPAB. The Thirteenth World Meteorological Congress in 1999 recognized the importance of the data being collected and urged National Meteorological Services having interests in the southern Ocean and Antarctic to participate actively in IPAB. A letter to this effect, signed by the Secretary-General of WMO, was duly sent to National Meteorological Services in 2000.

A record of all data collected in IPAB, including those that do not report via the GTS and those that measure location only, was maintained by the IPAB Co-ordinating Office (currently hosted by Antarctic Co-operative Research Institute in Australia). These data have recently been transferred to the USA National Snow and Ice Data Center in Boulder, and would be released to the research community on a CD-ROM. Data reported in real time on the GTS were also archived by the Marine Environmental Data Service, Canada in its capacity as the Responsible National Oceanographic Data Centre for drifting buoy data. Comprehensive information on IPAB, including details of buoy deployments, was available at **http://www.antcrc.utas.edu.au/antcrc/buoys/ buoys.html**.

The participants in IPAB, with support from WMO and WCRP, have now resolved to continue the programme indefinitely. A new chairman has been appointed and the IPAB Co-ordinating Office was being transferred to the Scott Polar Research Institute, Cambridge, UK. The JSC expressed its satisfaction at this development and appreciation of the accomplishments of this self sustaining project of WCRP.

10.2.2 Antarctic sea-ice thickness project

At the time of the session of JSC, there were six moorings with upward-looking sonars deployed by the Alfred Wegener Institute for Polar and Marine Research, Germany along the Greenwich meridian in the Weddell Sea. Recovery and re-deployment would be attempted during 2001. In February 2000, two moorings with upward-looking sonars were recovered by the Antarctic Co-operative Research Centre in the area off East Antarctica. Loss of moorings to icebergs continued to be a major problem. More detailed information on the project's activities and results was available at **http://www.awi-bremerhaven.de/Research/ansitp/index.html**.

10.3 The Climate and Cryosphere (CliC) Project

10.3.1 The CliC Science and Co-ordination Plan

An advanced draft of the CliC Science and Co-ordination Plan had been reviewed at the twenty-first session of the JSC, on the basis of which the JSC had endorsed CliC as a new project in the WCRP that would undertake an in-depth study of the role of the cryosphere in climate. Following further reinforcement of some sections of the text, in particular that concerned with icebergs, the final version of the plan has been printed and distributed (WCRP-114; WMO/TD No. 1053).

10.3.2 The promotion of CliC

The ACSYS/CliC Scientific Steering Group has made significant efforts during the past year in advertising the establishment of CliC and engaging the attention and involvement of the scientific groups and bodies having an interest in cryospheric research. Presentations on the objectives of CliC and on the CliC Science and Co-ordination Plan have been given by the Chairman and Co-vice Chairs of the ACSYS/CliC Scientific Steering Group to, inter alia, numerous working groups/meetings of the Scientific Committee for Antarctic Research (SCAR), the British Antarctic Survey, the Australian Antarctic Science Advisory Committee and USA Polar Research Board as well as USA agencies (NSF, NOAA and NASA). A number of countries were beginning to consider national CliC programmes or making relevant national contributions.

10.3.3 CliC Implementation Plan

The structure for an initial CliC Implementation Plan has been set down and a timetable agreed for preparing the draft. Three ad hoc writing groups on land-snow/ice interactions, land ice and sea level, sea-ice/ocean interactions have been established and substantial contributions to the draft plan have already been compiled. A "CliC Implementation Plan" Task Group was now reviewing and further developing the draft.

The CliC Implementation Plan would be the focus of a CliC Commitments Conference being considered for October 2002.

10.3.4 Co-operation with CLIVAR and GEWEX

Co-operation with CLIVAR and GEWEX in areas of mutual concern would be fundamental in the development of CliC. In particular, in the whole area of the Southern Ocean and climate, where Antarctic sea-ice processes and interactions with the ocean were key issues, it was foreseen that the implementation of CLIVAR would be carried forward in collaboration with CliC. A joint CLIVAR/CliC Southern Ocean Panel was being formed to plan the implementation of observational and modelling activities needed to evaluate the role of ocean-ice-atmosphere interactions in global and regional climate variability and change. There was equally a requirement to develop and strengthen ACSYS/CliC/CLIVAR interactions in the future, especially in promoting repeat hydrography sections in the Arctic Basin.

With GEWEX, there would be close interaction in endeavours dealing with cold regions hydrology, and ACSYS/CliC would be able to contribute to CEOP by way of expertise in validation of satellite-derived products in high latitudes and in cryospheric questions in general. Equally, the accurate assessment of solid precipitation was critical for both CliC and the GEWEX hydrometeorological thrust, and a joint ACSYS/CliC/GEWEX solid precipitation workshop was being planned for later in 2001.

10.3.5 International ACSYS/CliC Project Office

The original International ACSYS Project Office has now become the International ACSYS/CliC Project Office. The JSC acknowledged the major contribution made by the Norwegian Polar Institute in continuing to host and provide the main support for the operation of the Office. The Japanese Marine Science and Technology Agency (JAMSTEC) also continued to make an important contribution. The new Director of the Project Office, Dr C. Dick, had taken up his duties in June 2000.

The specific tasks undertaken by the International ACSYS/CliC Project Office included co-ordination of national commitments of resources and logistic support required to implement ACSYS and CliC, developing data management for ACSYS and CliC and ensuring the timely flow of scientific data, and assisting in the organization of ACSYS/CliC meetings, workshops and conferences. However, there was a pressing need to obtain further resources, both manpower and financial, to be able to carry forward the work of the Office in the manner required, especially in the area of data and information management. The assistance of JSC members in encouraging and arranging for suitable secondments/financial support from their countries was urgently requested.

11. ADMINISTRATIVE MATTERS

11.1 Internal matters of the JSC

The JSC discussed in executive session various matters bearing on the overall management, organization and structure of the WCRP.

The JSC noted that the five Officers of the Committee (Professor P. Lemke, Chairman; Professor B. Hoskins, Vice-Chairman; Dr J. Church, Professor Y. Ding and Professor A. Sumi, Officers) had been elected for two-year terms at the twenty-first session of the JSC in March 2000, and no changes in this respect needed to be considered at the current session.

11.2 Organization and membership of WCRP scientific and working groups

The JSC reviewed the organization and membership of the principal WCRP working and steering groups and proposed renewals of appointments or nominated new members as appropriate.

JSC/CAS Working Group on Numerical Experimentation (WGNE)

Membership of the WGNE is determined by consultation between the Chairman of the JSC and the President of CAS. No changes were due to be made and the composition of WGNE remained:

Membership	Expiry of appointment	
K. Puri (Chair)	31 December	2001
P. Bougeault	"	2001
Chen Dehui	"	2001
V. Kattsov	"	2003
S. Lord	"	2001
A. Lorenc	"	2001
M. Miller	"	2001
H. Ritchie	"	2001
T. Tsuyuki	"	2001
W. Wergen	"	2001
D. Williamson	"	2001

JSC/CLIVAR Working Group on Coupled Modelling

The term of the Chair of the Working Group on Coupled Modelling, Professor L. Bengtsson, expired on 31 December 2000 and he had now stepped down from the group. The JSC expressed deep appreciation to Professor Bengtsson for his outstanding service on the Working Group on Coupled Modelling which he had led so effectively since 1995 and which he had established as a prominent working group in the field of climate modelling. The JSC also acknowledged Professor Bengtsson's wider contributions to climate research activities. At its twenty-first session in March 2000, the JSC had nominated Dr J. Mitchell as Vice-chair of the group in the expectation that he would take up the Chairmanship when the term of Professor Bengtsson came to an end. Dr Mitchell had agreed to accept this responsibility. The JSC proposed that Dr M. Latif (Max Planck Institute for Meteorology, Hamburg, Germany) should be invited to serve as a member of the group in place of Professor Bengtsson. The constitution of the group has thus become:

Membership	Expiry of appointment	
J. Mitchell (Chair)	31 December	2001
C. Boening	"	2002
T. Delworth	"	2003
G. Hegerl	"	2002
S. Joussaume	"	2001
M. Latif	"	2004
H. Le Treut	"	2001
B. McAvaney	"	2001
G. Meehl	"	2001
A. Noda	"	2001
A. Weaver	"	2003
D. Webb	"	2001

WOCE Scientific Steering Group

As WOCE would come to its formal end in 2002, it was decided at the twentieth session of the JSC (March 1999) that the membership of the WOCE Scientific Steering Group should be fixed for the remaining duration of the Experiment. The composition of the group thus continued as:

Membership	Expiry of appointment	
P. Killworth (Co-chair)	31 December	2002
W. Large (Co-chair)	"	2002
S. Imawaki	"	2002
W. Jenkins	"	2002
K. Speer	"	2002
D. Stammer	"	2002
L. Talley	"	2002
E. Tziperman	"	2002

CLIVAR Scientific Steering Group

Since the annual session of the CLIVAR Scientific Steering Group closely followed that of the JSC, changes in or renewal of membership to take effect from 1 January 2001 were agreed in advance by the Chairman of the JSC on behalf of the Committee. Drs T. Palmer and K. Trenberth were invited to serve on the group for a further period of two years. Dr I. Simmonds (University of Melbourne, Australia), Dr P.L. da Silva Dias (Instituto de Pesquisas Espacias, Brazil), Dr M. Suarez (NASA Goddard Space Flight Center, USA) and Dr K. Takeuchi (Hokkaido University, Japan) were invited to join the Group for initial terms of three years. The memberships of Drs K. Hanawa (Tohoku University, Japan), J. Mitchell (Hadley Centre for Climate Prediction and Research, UK), N. Nicholls (Bureau of Meteorology Research Centre, Australia) and E. Sarachik (University of Washington, USA) came to an end on 31 December 2000. The composition of the CLIVAR Scientific Steering Group was now:

Membership	Expiry of appointment	
A. Busalacchi (Co-chair)	31 December	2002
J. Willebrand (Co-chair)	"	2001
J. Jouzel	"	2001
D. Martinson	"	2001
T. Palmer	"	2002
P.L. da Silva Dias	"	2003
I. Simmonds	"	2003
M. Suarez	"	2003
K. Takeuchi	"	2003
K. Trenberth	"	2002
R. Weller	"	2002
G. Wu	"	2002
F. Zwiers	"	2002

ACSYS/CliC Scientific Steering Group

Following the establishment of CliC as a new project in WCRP, the ACSYS Scientific Steering Group was re-established as the ACSYS/CliC Scientific Steering Group (still including members of the former ACSYS group whose terms did not expire 31 December 2000). A number of further changes in membership were now made. In particular, six new members having expertise in specific cryospheric areas were nominated namely: Dr M. Burgess, Geological Survey of Canada (frozen ground, permafrost); Dr M. Drinkwater, European Space Agency (remote-sensing, sea-ice); Professor V.M. Kotlyakov, Institute of Geography of the Russian Academy of Sciences (glaciers); Dr T. Ohata, Institute of Low Temperature Science, Hokkaido, Japan (cold region hydrology); Professor Qin Da He[*], Chinese Academy of Sciences (glaciers, ice cores); and Dr H.J. Zwally, Oceans and Ice Branch, NASA Goddard Space Flight Center (ice sheets, sea level). Dr E. Fahrbach was invited to serve a further term of two years until 31 December 2002. Dr G. Alekseev, Dr P. Jones, Professor T. McClimans, Dr H. Melling, Dr T. Takizawa and Dr V. Vuglinsky were now leaving the ACSYS/CliC Scientific Steering Group following the expiry of their terms of membership on 31 December 2000. The new composition of the ACSYS/CliC Scientific Steering Group was thus:

[*] Professor Qin Da He has subsequently also become Permanent Representative of China with WMO

Membership	Expiry of appointment	
H. Cattle (Chair)	31 December	2001
I. Allison (Vice-chair)	"	2001
R. Barry (Vice-chair)	"	2001
M. Burgess	"	2004
M. Drinkwater	"	2004
E. Fahrbach	"	2002
T. Fichefet	"	2001
B. Goodison	"	2001
V. Kotlyakov	"	2004
T. Ohata	"	2004
Qin Da He	"	2004
H. Zwally	"	2004

GEWEX Scientific Steering Group

Several terms of membership on the GEWEX Scientific Steering Group expired on 31 December 2000, and a number of new appointments to the group were made, namely: Dr T.P. Ackerman, Pacific Northwest National Laboratory, USA; Dr L. Gottschalk, University of Oslo, Norway; Dr Y. Kerr, Centre National d'Etudes Spatiales, France; Dr Z. Kopaliani, State Hydrological Institute, Russian Federation; Professor K. Nakamura, Nagoya University, Japan; Professor D.A. Randall, Colorado State University, USA; Professor M.F. Silva Dias, University of San Paolo, Brazil; Professor K. Takeuchi, Yamanashi University, Japan; and Dr Guxiang Wu, Chinese Academy of Sciences. The terms of the Chairman, Professor S. Sorooshian and of Dr A. Hollingsworth were extended by two years. Dr R. Curran, Professor Y. Ding, Dr M. Moncrieff, Dr J. Noilhan, Dr W.B. Rossow, Professor I. Shiklomanov, Dr R. Stewart, Professor B. Wilkinson, and Professor T. Yasunari were stepping down from the group. The membership of the GEWEX Scientific Steering Group and dates of expiry of appointments were thus now:

Membership	Expiry of appointment	
S. Sorooshian (Chair)	31 December	2002
T. Ackerman	"	2004
R. Atlas	"	2002
L. Gottschalk	"	2004
A. Hollingsworth	"	2002
Y. Kerr	"	2004
Z. Kopaliani	"	2004
K. Nakamura	"	2004
D. Randall	"	2004
U. Schumann	"	2002
M.F. Silva Dias	"	2004
K. Takeuchi	"	2004
G. Wu	"	2004

Working Group on Radiative Fluxes/GEWEX Radiation Panel

The JSC agreed that, in future, the GEWEX Radiation Panel (originally the WCRP Working Group on Radiative Fluxes) would be formally regarded as a GEWEX sub-group and the GEWEX Scientific Steering Group was delegated to select the membership of the Panel. However, the JSC stressed that the number of members of the panel should if possible be decreased from the existing level of fourteen and that a balanced geographical representation should be maintained. The JSC did not agree to the name "GEWEX Flux Panel" that had been suggested for this group.

SPARC Scientific Steering Group

The main change in the membership of the SPARC Scientific Steering Group was that Dr M.-L. Chanin was relinquishing her position as Co-chair of the group which she had held since the inception of SPARC in 1992. The JSC voiced its appreciation and gratitude to Dr Chanin for her outstanding contributions to SPARC during her period of service, which had helped this WCRP project become an important focus for international stratospheric science. Dr Chanin's wider contributions to the WCRP had also always been valuable and relevant. The JSC was pleased that it did not as yet have to say farewell to Dr Chanin, as she was continuing to serve as Director of the SPARC Office. Other members of the SPARC Scientific Steering Group who were now leaving were Dr V. Khattatov and Dr P. McCormick. The JSC agreed to the nomination of Dr A. O'Neill, University of Reading, UK as the new Co-chair of the SPARC Scientific Steering Group in succession to Dr M.-L. Chanin, and to the appointment of Dr P. Canziani, University of Buenos Aires, Argentina, Dr A.R. Ravishankara, NOAA Aeronomy Laboratory, USA, and Dr V. Yushkov, Central Aerological Observatory, Russian Federation to the group. Other members whose terms expired on 31 December 2000 were invited to serve for a further period of two years. The composition of the SPARC Scientific Steering Group thus became:

Membership	Expiry of appointment	
M. Geller (Co-chair)	31 December	2002
A.J. O'Neill (Co-chair)	"	2002
P. Canziani	"	2004
C. Granier	"	2002
K. Hamilton	"	2002
D. Karoly	"	2002
T. Peter	"	2002
A.R. Ravishankara	"	2004
U. Schmidt	"	2002
T. Shepherd	"	2002
S. Yoden	"	2002
V. Yushkov	"	2004

JSC/SCOR Working Group on Air-Sea Fluxes

The mandate of this group would formally come to an end following the Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux Fields in May 2001 (see section 7.1). Until then the membership remained as:

- S. Gulev, P.P. Shirshov Institute of Oceanology, Moscow, Russian Federation (Co-chair)
- P. Taylor, Southampton Oceanography Centre, Southampton, UK (Co-chair)
- B. Barnier, Laboratoire des Ecoulements Géophysiques et Industriels, Institut Mécanique de Grenoble, France
- F. Bradley, CSIRO Centre for Environmental Mechanics, Canberra, Australia
- T. Charlock, NASA Langley Research Center, Hampton, VA, USA
- P. Gleckler, Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Livermore, CA, USA
- K. Kutsuwada, School of Marine Science and Technology, Tokai University, Japan
- D. Legler, US CLIVAR Office, Washington, DC, USA
- R. Lindau, Institut für Meereskunde, Kiel, Germany
- D. Rothrock, Polar Science Center, University of Washington, Seattle, WA, USA
- J. Schulz, Max Planck Institut für Meteorology, Hamburg, Germany
- A. da Silva, NASA Goddard Space Flight Center, Greenbelt, MD, USA
- A. Sterl, Royal Netherlands Meteorological Institute, De Bilt, Netherlands
- G. White, NOAA National Centers for Environmental Prediction, Washington, DC, USA

As noted in section 7.1, a new WCRP "air-sea" interactions group would need to be established to follow up outstanding questions relating to physical air-sea interactions in the WCRP. Dr P.K. Taylor was nominated as Chairman-designate of this group. Dr Taylor was invited to put forward terms of reference and proposed membership for the group for consideration by the Chairman of the JSC following the Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux Fields.

WCRP/GCOS/GOOS Ocean Observations Panel for Climate

Proposed changes in the membership of the Ocean Observations Panel for Climate, jointly sponsored by the WCRP and GCOS and GOOS, were endorsed. The membership was now:

- N. Smith, Bureau of Meteorology, Melbourne, Australia (Chair)
- E. Campos, Instituto Oceanografico, University of Sao Paolo, Brazil

- T. Dickey, Ocean Physcis Laboratory, University of California, Santa Barbara, USA
- E. Harrison, NOAA Pacific Marine and Environment Laboratory, Seattle, USA
- J. Johanessen, Earth Sciences Division ESA-ESTEC, Noordwijk, Netherlands
- M. Kawabe, Ocean Research Institute, University of Tokyo, Japan
- J.R. Keeley, Marine Environmental Data Service, Department of Fisheries and Oceans, Ontario, Canada
- J. Picaut, Laboratoire d'Etudes en Geophysique et Oceanographie Spatiale, Toulouse, France
- R. Reynolds, NOAA/NESDIS, Washington, DC, USA
- P.K. Taylor, Southampton Oceanography Centre, UK
- R. Weller, Woods Hole Oceanographic Institution, USA
- W. Zenk, Institut für Meereskunde, University of Kiel, Germany

WCRP/GCOS Atmospheric Observation Panel for Climate

Following agreed changes, the membership of the group jointly sponsored by the WCRP and GCOS has become:

- M. Manton, Bureau of Meteorology Research Centre, Melbourne, Australia (Chair)
- P. Arkin, NOAA Office of Global Programs, Silver Spring, USA
- E. Harrison, NOAA Pacific Marine Environmental Laboratory, Seattle, WA, USA
- P. Jones, Climatic Research Unit, University of East Anglia, Norwich, UK
- S. Maeda, Japan Meteorological Agency, Tokyo, Japan
- C. Nobre, Centro de Previso de Tempo e Estudos Climaticos, INPE, Brazil
- R. Okoola, Department of Meteorology, University of Nairobi, Kenya
- D. Parker, Hadley Centre for Climate Prediction and Research, Bracknell, UK
- T. Peterson, National Climatic Data Center, Asheville, NC, USA
- J. Schmetz, EUMETSAT, Darmstadt, Germany
- G. Stephens, Colorado State University, Fort Collins, USA
- M. Suzuki, National Space Development Agency, Tokyo, Japan

11.3 Publications

The following reports were produced by the Joint Planning Staff for the WCRP in various series between the twentieth and twenty-first sessions of the JSC:

WCRP Report Series

WCRP-111 Paleoclimate Modelling Intercomparison Project (PMIP) (Proceedings of workshop, La Huardière, Canada, 4-8 October 1999) (WMO/TD-No. 1007)

WCRP-112 Intercomparison and Validation of Ocean-Atmosphere Energy Flux Fields (Final report of the Joint WCRP/SCOR Working Group on Air-Sea Fluxes) (November 2000) (WMO/TD-No. 1036)

WCRP-113 SPARC Water Vapour Assessment (WAVAS) (December 2000) (WMO/TD-No. 1043) (limited distribution only)

WCRP-114 Climate and Cryosphere (CliC) Project, Science and Co-ordination Plan - Version 1 (WMO/TD-No. 1053)

Informal WCRP reports and documents

4/2000 CLIVAR Variability of the American Monsoon System (VAMOS) (Report of third session of panel, Santiago, Chile, 8-9 April 2000) (also ICPO Report No. 37)

5/2000 CLIVAR Africa Implementation Plan (June 2000) (also ICPO Report No. 35)
6/2000 Arctic Climate System Study (ACSYS) (Report of meeting on data and data management in support of sea-ice/ocean modelling, Koblenz, Germany, 28 June-1 July 1999)

7/2000 CLIVAR (Report of eighth session of Scientific Steering Group, Southampton, UK, 10-14 May 1999) (also ICPO Report No. 36)

8/2000 Stratospheric Processes and their Role in Climate (SPARC) (Report of seventh session of Scientific Steering Group, Paris, France, 2-5 November 1999)

9/2000 JSC/CAS Working Group on Numerical Experimentation (Report of fifteenth session, Monterey, CA, USA, 25-29 October 1999)

10/2000 Arctic Climate System Study (ACSYS) (Report of eighth session of Scientific Steering Group, Louvaine-la-Neuve, Belgium, 15-19 November 1999)

11/2000 Arctic Climate System Study (ACSYS) (Report of first session of Numerical Experimentation Group, Kiel, Germany, 16-19 November 1998)

1/2001 Decadal predictability (Report of joint WGCM/WGSIP workshop, La Jolla, CA, 4-6 October 2000) (also ICPO Report No. 39)

2/2001 CLIVAR (Report of second session of Atlantic Implementation Panel, Orense, Spain, 1-2 December 2000 (also ICPO Report No. 38)

3/2001 CLIVAR/PAGES (Report of workshop on "Climate of the last millenium", Venice, Italy, 8-12 November 1999)(also ICPO Report No. 41)

4/2001 CLIVAR (Report of workshop on shallow tropical and sub-tropical overturning cells in the ocean, Venice, Italy, 9-13 October 2000)(also ICPO Report No. 42)

5/2001 JSC/CLIVAR Working Group on Coupled Modelling (Report of fourth session, La Jolla, CA, USA, 9-11 October 2000) (also ICPO Report No. 40)

7/2001 Arctic Climate System Study (ACSYS)/Climate and Cryosphere (CliC) Project (Joint report of first session of ACSYS/CliC Numerical Experimentation Group and Arctic Regional Climate Model Intercomparison Project Workshop, Fairbanks, Alaska, USA, 11-15 September 2000) (edited by G.M. Flato and A.H. Lynch)

Special WCRP Reports

- Annual Review of the World Climate Research Programme and Report of the Twenty-first Session of the Joint Scientific Committee (Tokyo, Japan, 13-17 March 2000) (WMO/TD-No. 1049)

Technical Document

- Arctic Climate System Study (ACSYS)(Report of fourth session of sea-ice ocean modelling panel and workshop on sea-ice thickness measurements, Monterey, CA, USA, 7-11 April 1997)(WMO/TD-No. 991)

Others (including reports produced by project offices)

- World Ocean Circulation Experiment (WOCE)(Report of thirteenth session of the Data Products Committee, College Station, TX, USA, 5-7 April 2000)(WOCE Report No. 170/00)

- World Ocean Circulation Experiment (WOCE)(WOCE Global Data, version 2.0, CD-ROM set)(WOCE Report No. 171/00)

- Arctic Climate System Study (ACSYS)(Barents and Kara Seas Oceanographic Data Base)(IACPO Informal Report No. 5)

- Arctic Climate System Study (ACSYS)(Report of the third session of the Data Management and Information Panel, Boulder, CO, USA, 30 May-2 June 2000)(IACPO Informal Report No. 6)

Reports produced by the International CLIVAR Project Office also have a WCRP Informal Report number and have been included in the list of those reports. Other reports/documents available were listed on and were accessible through the WCRP Home Page: **http://www.wmo.ch/web/wcrp/otherwcrpreports.htm**. Generally, an increasing number of reports were available electronically (via the WCRP Home Page). The JSC welcomed this development but requested that reports/documents should be in pdf format.

11.4 WCRP resources

The JSC was informed of the proposed activities to be supported by and draft budget for the Joint Climate Research Fund (JCRF) for the WCRP in the next biennium 2002-2003. Nominally, the total budget for activities was about 10% higher than for the biennium 200-2001 and the allocations for the main WCRP activities had been proportionately increased.

The indicated WMO contribution to the JCRF for 2002-2003 was due to be considered by the WMO Executive Council at its session in June 2001*. The draft budget, as presented, benefited from a high conversion rate of the expected ICSU and IOC US dollar contributions to Swiss Francs. If the dollar/Swiss Franc exchange rate were to fall as appeared probable, the nominal budget would also decrease. Moreover, IOC was uncertain of being able to pay the amounts foreseen on the grounds that IOC supported directly a considerable number of activities of benefit to ocean-related climate research and the WCRP.

As well as its contribution to the JCRF in support of WCRP activities, WMO separately covered the cost of the Joint Planning Staff. However, in the provision of this, a 13% vacancy factor has been assumed. Thus it would not be possible to maintain the level of approved staffing, even though the Joint Planning Staff was already very seriously overstretched in terms of the even-increasing workload and range of duties it was called on to undertake. Consequently, it was impossible for the Joint Planning Staff to undertake any responsibilities beyond those already being carried, and, indeed, a decrease in the effort that would be available in the period 2002-2003 seemed inevitable.

In view of the pressure on resources, especially staffing, all JSC members were called on to act strongly as spokespersons for the WCRP in their home countries and to stress to national institutions, funding agencies etc. the importance of supporting and increasing financial contributions to the WCRP. Furthermore, JSC members were urged to investigate possibilities for obtaining national or institutional resources to cover the cost of attendance of individual national participants in WCRP meetings, working group sessions, etc. JSC members should also encourage increased national contributions to the ICSU fund for the WCRP (approaches needed to be made to the relevant national scientific council or body in members' countries).

12. DATE AND PLACE OF NEXT SESSION

The JSC gratefully accepted the kind invitation put forward by Dr J. Church to host the twenty-third session of the Committee in Hobart, Tasmania, Australia from 18 to 23 March 2002.

13. CLOSURE OF THE SESSION

The Chairman thanked all participants for their contributions to the session, the high level of scientific discussions, and the steps that had been taken in the further development of the WCRP. He especially acknowledged the very interesting scientific presentations that had been given to the Committee by Dr G. Reid on the interannual and long-term variations of the tropical tropopause, and Dr J. Kiehl on climate modelling at NCAR. The Chairman reiterated his gratitude to Drs K. Trenberth and S. Solomon for the excellent arrangements that had been made for the JSC session, the very good facilities, and generous hospitality. He also asked that the appreciation of the JSC be relayed to all the support staff who had so ably assisted and provided service to the meetings.

The twenty-second session of the WMO/ICSU/IOC Joint Scientific Committee for the WCRP was closed at 15.00 hours on 23 March 2001.

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* The WMO Executive Council, at its session in June 2001, agreed on the planned budget of and activities to be supported by the JCRF.

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