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ANNUAL REVIEW OF THE WORLD CLIMATE RESEARCH PROGRAMME

AND

REPORT OF THE TWENTY-THIRD SESSION OF THE JOINT SCIENTIFIC COMMITTEE (Hobart, Tasmania, Australia, 18-22 March 2002)

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. At the kind invitation of Dr J. Church and CSIRO Marine Research, and the Co-operative Research Centre for the Southern Ocean and Antarctica, the 2002 session of the JSC, the twenty-third, took place at the Wrest Point Convention Centre, Hobart, Tasmania, Australia from 18-21 March, and at the Antarctic Co-operative Research Centre, University of Tasmania, Hobart on 22 March. The session was called to order by the Chairman of the JSC, Professor P. Lemke, at 0835 hours on 18 March 2002. 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).

The session was formally opened by the Honourable Sir Guy Green AC KBE CVO, Governor of Tasmania, who extended a warm welcome to Tasmania to all participants and expressed his pleasure that the JSC was meeting in Hobart. The Governor observed that the venue was very appropriate since, through CSIRO, the Australian Bureau of Meteorology, the Australian Antarctic Division, and the Antarctic Co-operative Research Centre, Tasmania was playing an increasingly significant role in the international effort to measure and identify the causes of climate change. The Governor underlined the important responsibility of the WCRP in developing an understanding of the extent of human influence on climate and the major potential socio-economic benefits that would result from an improved capacity to forecast climate fluctuations, in particular increased productivity in farming and fishing and better informed decisions on environmental protection. WCRP was also unique in the scale and scope of science that it encompassed, but this entailed a number of special challenges. Firstly, attention should be given to increasing the governmental and public understanding of the nature and significance of climate issues which would underpin rational decisions in this area. In this regard, it was necessary that the community understand that unequivocal answers to questions about climate and environmental change were simply not possible and that the scientific statements and assessments were always provisional and always subject to some qualification or reservation. Secondly, WCRP results needed to be presented in a manner that was properly understood and that would enable environmental concerns to be debated with detachment and intellectual integrity. Noting the complexity of the WCRP, the Governor spoke of the achievement of the programme in promoting collaboration and co-ordination of effort between different scientific disciplines, governmental and non-governmental oganizations, and the academic community. The importance of maintaining a clear overview of the projects in WCRP and the fundamental question of developing collaboration between WCRP, the International Geosphere-Biosphere Programme(IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) were stressed. The Governor concluded by reiterating the crucial tasks to be considered at this session of the JSC and hoped that, as well as being productive, the meeting would be interesting and enjoyable.

On behalf of the Australian agencies sponsoring the JSC session, Dr J. Church added his welcome to participants and hoped that all would have an enjoyable time. He noted that the agenda for the session included many challenging questions, and looked forward to working through these and arriving at recommendations that would allow WCRP to move forward, both in its own studies of the physical climate system, and, in conjunction with its partner programmes, IGBP and IHDP, in the overall study of Earth system science and global change. Dr Church specifically emphasized the enormous value to all nations of the ability to predict climate, not only economically but also in the protection of the environment. Dr Church expressed gratitude for the support he had received from the sponsoring agencies for the JSC session, namely the Bureau of Meteorology, the Australian Greenhouse Office, CSIRO Atmospheric Research, the Antarctic Division, and CSIRO Marine Research, as well as to all those who had assisted in the local organization.

The Chairman of the JSC thanked the Governor of Tasmania for his welcome and his highly appropriate and inspiring remarks. It was for all a pleasure and privilege to be in Tasmania and have the opportunity to acknowledge the outstanding contribution of Australia to the WCRP. The Chairman also expressed deep gratitude to all the agencies who had sponsored the organization of the session. He personally thanked Dr J. Church and all the others who had made such substantial efforts in making the arrangements for the session. The Chairman especially noted the excellent facilities provided and the extensive hospitality being offered.

The Chairman continued by extending his greetings to the participants in the session, particularly to members of the Committee attending for the first time, namely Professor J. Shukla (Center for Ocean-Land-Atmosphere Studies, Calverton, MD, USA) and Dr M.T. Zamanian (Islamic Republic of Iran Meteorological Organization). (Professor Shukla and Dr Zamanian had been appointed to the JSC with effect from 1 January 2001 but had been unable to attend the session of the JSC in March 2001). The Chairman noted with regret that two JSC members, Professors P. Cornejo and T. Yasunari, could not be present.

The Chairman was pleased to welcome two of the representatives of the Australian agencies sponsoring the JSC session. These were Dr J. Zillman, Director of Meteorology and Head of Marine Agencies (also Permanent Representative of Australia with WMO), and Dr G. Paltridge (Antarctic Co-operative Research Centre). The Chairman further acknowledged with appreciation the participation of observers on behalf of the organizations sponsoring WCRP: Mr A. Alexiou, IOC; Dr D. Carson (as well as Director of the WCRP), WMO. Dr G. Paltridge would represent ICSU. The Chairman also noted with pleasure the attendance of the new Chair of the Scientific Committee for IGBP, Professor G. Brasseur, congratulating him on his appointment and particularly welcoming him to the JSC session. In view of the increasing interactions between WCRP and IGBP in many areas (see section 2.2), Professor Lemke emphasized that he regarded participation by WCRP and IGBP in the sessions of the main scientific committee meeting of the other as an essential duty. On the other hand, unfortunately, no representative of IHDP could be present on this occasion. Dr K. Puri would speak on behalf of the WMO Commission for Atmospheric Sciences as necessary.

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. Allison, Vice-chair of the ACSYS/CliC Scientific Steering Group; Professors M. Geller and A. O'Neill, Co-chairs of the SPARC Scientific Steering Group; Professor P. Killworth and Dr W.G. Large, Co-chairs of the WOCE Scientific Steering Group; Dr B. McAvaney, representing the JSC/CLIVAR Working Group on Coupled Modelling (WGCM); Dr K. Puri, Chair of the CAS/JSC Working Group on Numerical Experimentation (WGNE) (as well as representing CAS); Dr W. Rossow, Chair of the GEWEX Radiation Panel; 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) Exceptionally, on this occasion, Dr S. Zebiak, Chair of the CLIVAR Working Group on Seasonal-to-Interannual Prediction, was participating to assist in the discussion of agenda item 3 (Scientific direction, structure and priorities of the WCRP). The Chairman of the JSC also regarded it as noteworthy that, for the first time, a representative of one of the developing WCRP/IGBP/IHDP joint projects (see section 2.2), namely Dr R.E. Dickinson, Co-chair of the Scientific Steering Committee for the Global Carbon Project, had come to report on progress in this project.

The Chairman was further pleased to note the attendance of Project Office Directors: Dr C. Dick, ACSYS/CliC International Project Office; Dr J. Gould, International WOCE and International CLIVAR Project Offices; Dr M.-L. Chanin, SPARC Office; Dr P. Try, International GEWEX Project Office. The Chairman additionally welcomed Dr D. Legler, Director of the US CLIVAR Project Office, who would participate in some parts of the session.

The Chairman was gratified by the interest manifested by GCOS with the attendance of Professor P. Mason, Chair of the GCOS Steering Committee, as well as Drs M. Manton and N. Smith, 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). Dr M. Manton would also speak on behalf of the joint WCRP/IGBP/IHDP Global Change System for Analysis, Research and Training (START). The Chairman observed with satisfaction the attendance of Dr H. Kühr representing the International Group of Funding Agencies (IGFA).

Finally, the Chairman looked forward with anticipation to the scientific lectures by two leading Australian scientists that had been arranged, namely "Southern Oceans and Climate - Lessons from WOCE and Prospects for CLIVAR" by Dr S. Rintoul (CSIRO Marine Laboratories, Hobart) (also Co-chair of the CliC/CLIVAR Southern Ocean Panel), and "DIAGNOSE: a system for the real-time monitoring of climate variations and the diagnosis of their causes and impacts" by Dr N. Nicholls (Bureau of Meteorology Research Centre, Melbourne).

2. REVIEW OF OVERALL PROGRESS AND INTERACTIONS OF THE WCRP WITH OTHER ACTIVITIES/PROGRAMMES

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

Highlights in activities of the WCRP

The overall progress in the various components of the WCRP over the past year, and the issues on which the advice and guidance of the JSC were required, are summarized in detail at the appropriate parts of this report. At this point, only a few of the major highlights are reviewed.

In the Global Energy and Water Cycle Experiment (GEWEX), the emphasis was shifting towards analysis and diagnosis of the processes driving the energy budget and water cycle, including the integration of GEWEX global data sets into a more comprehensive and consistent description of these processes. This would depend on the combined exploitation of in situ and remotely-sensed data. Increased attention would also be given to the application of GEWEX results to management of water resources. The implementation plan for the Co-ordinated Enhanced Observing Period (CEOP) has been published and initial implementation steps were under way. The Fourth International GEWEX Scientific Conference was held in Paris in September 2001 focussing on central GEWEX themes, such as microphysics of clouds and cloud/aerosol interactions, the global water cycle and its sensitivity to climate change, and remote-sensing and land-surface processes.

The regional initiatives being undertaken in the Climate Variability and Predictability (CLIVAR) study focussed on African climate variability, the Variability of the American Monsoon System (VAMOS), and the Asian-Australian monsoon continued to progress. The planned deployment of the ARGO global array of profiling floats as part of the Global Ocean Data Assimilation Experiment, GODAE (see section 2.3) was also important for CLIVAR. Moreover, commitments have recently been made to repeat key oceanographic sections first surveyed during the World Ocean Circulation Experiment (WOCE). A major challenge for CLIVAR was to bring together the various regional initiatives and ocean basin data to provide an overall global view. Through generous support from the USA, the International CLIVAR Project Office has been able to hire new staff increasing the capacity to foster interactions between different CLIVAR activities. Steps have been taken to find a replacement for the current Director of the CLIVAR Project Office, who would be retiring in September 2002. An international CLIVAR Scientific Conference was being planned to be held in the USA in June 2004 to review what would have been accomplished by that time and to set realistic goals for the future.

The World Ocean Circulation Experiment (WOCE) was now well into the final stage of synthesizing the measurements collected during the field programme (1990-1998) into a dynamically consistent view of the ocean circulation in the 1990s. A substantial book on the ocean circulation and climate (based on presentations at the successful WOCE Conference in Halifax, Canada, 1998) has been published and the latest version of the WOCE data set distributed on CD-ROMs. Work on preparing a series of large-format atlases of the physical and chemical properties of the global ocean from WOCE observations was well under way. The achievements of WOCE would be celebrated at a final conference, "WOCE and beyond", San Antonio, Texas, USA in November 2002, marking the formal end of WOCE as a WCRP project.

An initial implementation plan was now being drawn up for the Climate and Cryosphere (CliC) project as the first step towards an international commitments conference in 2004. Efforts were being devoted to increasing awareness of CliC in the polar research community and to encouraging commitments to the project. In the meantime, the Arctic Climate System Study (ACSYS) was proceeding as planned with the collection of extensive new data sets on the Arctic Ocean circulation, sea ice, temperature and salinity, and exchanges of water masses with the North Atlantic. These data were of particular relevance and importance in the context of the ongoing international debate on the rate of ice reduction in the Arctic. When ACSYS came to its formal end in 2003, a considerable fraction of the activities would be continued under the aegis of CliC.

In the study of Stratospheric Processes and their Role in Climate (SPARC), the Darwin Area Wave Experiment (DAWEX), designed to characterize the forcing of the middle atmospheric circulation by the wave field generated during intense diurnal convection over Northern Australia in the austral spring, had been successfully carried out in the period October to December 2001 with the participation of scientists from Australia, Japan and the USA. A major workshop on the tropopause, focussing on the links between dynamics, transport, radiation and chemical processes, had also been organized. Collaboration continued to develop between SPARC and the IGBP International Global Atmospheric Chemistry project in the effort to improve the understanding of chemistry-climate interactions which could well be the basis for the long-discussed joint WCRP/IGBP action on "atmospheric chemistry and climate".

In the area of climate modelling, particular attention was being given to the future development of the two principal intercomparison projects, the Atmospheric Model Intercomparison Project (AMIP) overseen by the JSC/CAS Working Group on Numerical Experimentation (WGNE), and the Coupled Model Intercomparison Project (CMIP) overseen by the JSC/CLIVAR Working Group on Coupled Modelling (WGCM). Additionally, WGNE has the responsibility and leadership in WCRP for fostering the atmospheric reanalyses so important for many WCRP activities. It was gratifying to note the good progress being made in the comprehensive 40-year project at ECMWF (ERA-40) and that the Japan Meteorological Agency was undertaking a twenty-five year reanalysis (1979-2004), expected to be completed in 2005. WGNE was also closely involved, jointly with the CAS World Weather Research Programme, in planning "The Observing System Research and Predictability Experiment" (THORPEX) which would be likely to have significant implications and benefits for a number of WCRP projects. Another important initiative was that of WGCM in undertaking, in co-operation with the Global Analysis Interpretation and Modelling (GAIM) element of IGBP a comparison of results produced by coupled atmosphere-land-ocean-carbon models with specified CO_2 emission scenarios (the Coupled Carbon Cycle Climate Model Intercomparison Project, C4MIP). The joint ad hoc WGNE/WGCM panel had completed its review of the state of the art in regional climate modelling and recommendations put forward on what might usefully be done by WCRP in this area (see section 10.3).

Following publication of the comprehensive and authoritative intercomparison and validation of ocean-atmosphere energy flux fields in early 2001 (as reported at the twenty-second session of the JSC), the JSC/SCOR Working Group on Air-Sea Fluxes organized a major workshop on this subject in Washington, DC in May 2001. The workshop brought together members of many of the different scientific communities interested in air-sea fluxes which proposed a number of steps needed to refine estimates of fluxes. Further action by WCRP should be considered in the context of the relationship of the WCRP with the Surface Ocean-Lower Atmosphere Study (SOLAS)(see section 6.2).

Fifty-third session of the WMO Executive Council

The progress report on the WCRP had been well received by the fifty-third session of the WMO Executive Council and satisfaction was voiced at the achievements of the programme and the advances being made. The (then) Chairperson of the IPCC, Dr R. Watson, pointed out that WCRP provided a range of key findings and research results that underpinned IPCC Scientific Assessments. The Council also remarked that WCRP work laid the basis for operational climate predictions by National Meteorological and Hydrological Services, thereby contributing to an enhanced role for those services. The Council expressed interest in a number of specific WCRP initiatives including the CLIVAR investigations of the Variability of the American Monsoon System (VAMOS), the Asian-Australian monsoon system, and of African climate variability, as well as the Co-ordinated Enhanced Observing Period (CEOP) of GEWEX, SPARC activities, and the internationally co-ordinated model intercomparison activities and reanalyses conducted by WGNE and WGCM. The Council encouraged all WMO Members having interests in the Arctic, Antarctic and Southern Ocean to support and participate in CliC to the limit of available resources. Overall, the Council strongly supported the continuing development of the WCRP on the lines being followed by the JSC.

The Council reacted favourably to the developing co-operation between WCRP, IGBP and IHDP in global environmental change studies, in particular the consideration of the joint projects on food systems, the carbon cycle and water resources. The Council urged the relevant WMO programmes to be fully involved in the planning of these projects. Moreover, the Council wished to be informed of the main outcome and recommendations of the WCRP/IGBP/IHDP Global Change Open Science Conference (see below). A report would duly be provided to the fifty-fourth session of the Council in June 2002.

The Council also noted the establishment of a WCRP Task Team on Climate Research for Arid and Desert Regions to respond to the request made at its fifty-second session. The Task Team included representatives of CLIVAR and GEWEX as well as a senior research scientist from the Meteorology and Environmental Protection Agency (MEPA) in Saudi Arabia to provide the perspective of countries in arid regions and to draw on the expertise already built up in regional studies. The Task Team was expected to review current research in the WCRP which could help in an improved understanding of climate processes that were critical in maintaining arid and desert areas and to recommend additional activities needed to make further advances. Whilst welcoming these steps, the Council pointed out that, in the IPCC Third Assessment Report, particular attention had been drawn to the serious potential effects of climate change in arid and desert regions, including the threat of enhanced desertification and acute water shortages. The Council duly emphasized that co-operation between meteorologists and hydrologists to advise on management and husbanding of water resources should be an essential component of the work of the Task Team.

Since the Executive Council session, the Task Team had undertaken an initial exchange of views by e-mail. The Team had already agreed that, before realistic assessments of the implications of future climate conditions in arid regions could be made, the variability of past and present local climates needed to be adequately characterised. However, there were only sparse long-term observational records in these regions, whose representativeness was uncertain and only a few studies of impacts of past climate changes. Simulations of climate models in desert regions have also not been adequately verified. Appropriate development of climate observing and data management systems able to serve many applications ranging from climate research to policy issues was required, as well as efforts to reconstruct past climates and elaboration of suitable regional climate models. The Task Team planned to organise a multi-disciplinary workshop to frame strategies to meet these goals and to begin to answer the specific questions involved.

Twenty-first session of the Assembly of the Intergovernmental Oceanographic Commission (IOC)

A report on WCRP activities had been provided to the twenty-first session of the IOC Assembly (Paris, July 2001) by the Director of the WCRP and the Director of the International WOCE and CLIVAR Project Offices. The Assembly had expressed considerable satisfaction with the progress in the WCRP, particularly CLIVAR and the input being given to planning the range of ocean observations necessary for climate studies. The Assembly had stressed the importance of an ocean observing system for climate to society and exhorted governments to support and strengthen this system, particularly those components that would provide long time-series records. The Assembly had also voiced admiration for the achievements of WOCE, attributing its success to the sustained IOC/WMO/ICSU WCRP partnership. WOCE was cited as an outstanding example of planning, managing, and executing a large-scale, international, ocean science programme.

In its overall consideration of Ocean Science Programmes, the IOC Assembly adopted a resolution that these programmes should be restructured into three interactive lines of work namely Oceans and Climate, Ocean Ecosystems and Marine Environmental Protection, and Integrated Coastal Area Management. In so doing, there was acknowledgement of the need for effective collaboration with other international organizations and global and regional research programmes, including activities such as CLIVAR and SOLAS. The terms of reference for the programme elements in this new structure were due to be provided to the (ordinary) session of IOC Executive Council in June 2002.

Preparations for the World Summit on Sustainable Development (WSSD)

ICSU has been appointed as the "official representative of science" in the process of preparing for the WSSD taking place in Johannesburg, South Africa, 26 August - 4 September 2002. As ICSU was a sponsor of WCRP, this offered at least an indirect means of feeding any WCRP input that might be relevant or appropriate into the process. With the help of an ICSU grant for the purpose, a WCRP/IGBP/IHDP workshop on "Sustainable Development - the Role of International Science" was convened at ICSU headquarters in Paris in February 2002. WCRP input included a short working paper "WCRP Contributions to Science for Sustainability" based on material provided mainly by the WCRP Project Offices. Two short documents (one of two pages, one of ten) were drawn up for use in the first instance to aid ICSU's continuing involvement in the WSSD preparations. Consideration was also being given by the "Earth System Science Partnership" being developed by WCRP, IGBP, IHDP and DIVERSITAS (see section 2.2) as to how global environmental science could best be fed in both during the lead up to, and at, the Johannesburg summit.

WMO was also involved in and concerned about the WSSD process. The Director of the WCRP was taking part in and contributing as appropriate to the WMO considerations of the various matters of concern and the formulation of input.

IPCC Assessments

Several of the principal findings and conclusions of the IPCC Working Group 1 contribution ("Climate Change 2001 - the Scientific Basis") to the overall IPCC Third Assessment Report were reviewed at the twenty-second session of the JSC. The full Third Assessment Report had subsequently been published during 2001.

At the IPCC Bureau and Plenary meetings (September 2001), the preparation of a Fourth Assessment had been taken up. It was considered that the IPCC reports had proved extremely useful to both the scientific and policy communities and, accordingly, that another comprehensive report should be planned. However, it was also realised that the first three IPCC reports had required exceptionally hard work and dedication from the scientific community and that a fourth such report might be even more demanding. There had been extensive discussion concerning the timing (ranging between 2006 and 2008, i.e., five to seven years after the Third Report) and content (either focussed around particular policy questions or, again, a fully comprehensive review). The final decision on these matters would be made at the IPCC Plenary session in Geneva, 17-20 April 2002, when new Co-chairs for IPCC and for the Working Groups would also be appointed. Proposals for special reports or technical papers on two subjects of interest to WCRP were also expected to be considered at the session, namely "Climate Change and Water" (suggested by the so-called "Dialogue on Water and Climate"), and "Levels of the Greenhouse Gases in Atmosphere and Dangerous Anthropogenic Influence with the Climate System". The first of these would evidently be closely akin to the joint WCRP/IGBP/IHDP Joint Water Project (see section 2.2).

In the meantime, contacts have continued between WCRP and IPCC by way of discussions of opportunity between the Director of the WCRP, the IPCC Chairman and others in the IPCC. Furthermore, a response has been sent to a letter from Sir John Houghton (then Co-chair of IPCC Working Group 1 together with Professor Ding Yuhui) on the lines suggested at the twenty-second session of the JSC emphasizing the contributions to the IPCC Assessments resulting from the scientific work fostered by WCRP. A more detailed letter would also be sent (after April 2002) to the Chairman of IPCC summarizing how WCRP was responding to the high priority actions required to address gaps in information and understanding as identified in the IPCC Working Group 1 contribution to the Third Assessment Report. The intention would be to enhance the synergy between IPCC requirements and the research carried out under WCRP auspices.

Global Change Open Science Conference

The major IGBP/IHDP/WCRP Global Change Open Science Conference, *Challenges of a Changing Earth*, held in Amsterdam, 10-13 July 2001, was an outstanding success. It was gratifying that, of the 1400 participants from 105 countries, more than 400 were from (62) developing countries, and that there were 150 students.

The plenary sessions were the highlight of the Conference. Setting the stage was a stimulating presentation by Professor B. Moore (then Chair of the IGBP Scientific Committee), followed by authoritative reviews and accounts of the exciting scientific advances in the past decade, mainly as derived from the work of the international global environmental change programmes. The Conference also included parallel sessions on a range of topics (many of close interest to WCRP such as ENSO in the context of past and future climate variability, predicting land-use change, the cryosphere and global change, coupled Earth System modelling etc.) which were very well attended. The final day focussed on "Looking to the Future: Earth System Science and Global Sustainability". Another important feature was the large number of posters (over 800), mainly organized in clusters around specific themes, illustrating the rich world-wide scope of research underpinning the improving understanding of global change. A very active media campaign ensured that the Conference received strong attention in both the printed and electronic press, and fifty-five journalists attended the Conference with many more reporting from a distance. A book, containing short versions of all the plenary talks, would be published by Springer-Verlag as part of the IGBP series.

The Conference formally endorsed the 'Amsterdam Declaration', which reiterated the realities of global change and called for urgent action. The declaration also emphasised the importance of the co-operative approach to global environment now being developed by the global environmental change programmes. In this context, the three joint projects being developed and implemented jointly by IGBP, IHDP and WCRP (and now also DIVERSITAS) and requiring an integrated approach across a wide spectrum of research disciplines, were introduced.

Although the Conference had formally been a joint WCRP/IGBP/IHDP (and later DIVERSITAS) event, the JSC fully recognized that IGBP had very much taken the lead in the planning and organization, and had put in a major commitment of human and financial resources. The JSC wished to place on record acknowledgement of the sterling efforts of IGBP which certainly deserved most of the credit for the success of the Conference. It was noted that the subsequent meeting of "Chairs and Directors" of the global environmental change programmes in Amsterdam immediately following the Conference had proposed that, building on the success, further "Open Science Conferences" should be held at four-yearly intervals, the next Conference accordingly being due in 2005. The secretariats of the four programmes should share evenly in jointly providing the organizational support necessary. The Open Science Conferences should be complemented by a Global Change Young Scientists' Conference organized by START probably in 2003.

The JSC endorsed the principle of further Open Science Conferences, but expressed the view that four years was too short an interval between Conferences of this nature. Consideration could perhaps be given to linking the Conferences to the IPCC cycle. The JSC agreed that WCRP definitely should share fully in the organization and support of the next Conference.

2.2 Co-operation between the global environmental change programmes

Earth System Science Partnership (ESSP)

The Global Change Open Science Conference described above was a highlight of the growing collaboration between IGBP, IHDP, WCRP and DIVERSITAS in the field of Earth System Science. The development of the joint projects (see below) was another manifestation of working together in a co-operative approach on issues of major relevance to society and global sustainability. The meeting of "Chairs and Directors" of the four programmes following the Open Science Conference thus proposed to formalise the growing collaboration as the "Earth System Science Partnership" (ESSP). This partnership should provide the common platform required by the increasing emphasis on broad-scale integration in international Earth System science and on which programmes could work together on cross-cutting activities.

The three evolving joint projects and START (see below) were clearly examples of ESSP activities, as was the joint sponsorship/organization of periodic Open Science Conferences. Other proposals were being considered, in particular "Integrated Regional Studies". The pressure for more emphasis at the regional scale of Earth System science has been growing steadily and such studies would respond to this by fostering collaboration between regional scientific communities and drawing on input from these, and establishing the necessary regional-global links. The type of studies envisaged were beyond the scope or expertise of any one of the global environmental change programmes and thus logically should be co-ordinated under the ESSP.

The Chairs and Directors meeting in July 2001 had agreed that an interim common ESSP web site should be set up (**http://www.ESS-P.ORG**) and a communications team formed with representatives of the four global environmental change programmes and START.

The JSC discussed the establishment of the ESSP carefully. It was clear that collaboration and jointly-owned research activities between WCRP, IGBP, IHDP and DIVERSITAS, and START would continue to increase posing a real challenge to the programmes, their governing scientific committees and secretariats to ensure that the ESSP worked in both broad and specific senses. In this context, a fundamental issue was the relationship of the joint projects to the core activities of the four programmes. Other important points needed to be addressed regarding the overall governance, management structures, reporting procedures and resources of joint activities, including the questions of the extent the authority for these and related matters should be delegated by the programmes' governing scientific committees to the (informal) Chairs and Directors meetings. Additional aspects to be considered included the ESSP "corporate image", profile and communications, commitments from secretariat resources, the raising and provision of funds, and the possible establishment of (joint) international project offices.

Joint IGBP/IHDP/WCRP projects

Dr D. Whelpdale briefed the JSC on the status of the Global Environmental Change and Food Systems (GECaFS) joint project and the progress in the past year (the basic outline of the project and the fundamental questions it was intended to answer were presented at the twenty-second session of the JSC - see section 3.2 of the Report of the Twenty-second Session of the JSC). Distinguishing features of GECaFS were the novel interdisciplinary approaches to global environmental change in studying the vulnerability of food systems to impacts, adaptations and feedbacks, a methodology allowing an analysis of trade-offs between managing resources for food provision and environmental concerns, and a design for analyses at regional and sub-regional levels but which was globally applicable in concept. In the past year, there have been several important steps towards the implementation of the project beginning with a high-level seminar at the US National Academy of Science, Washington DC, April to bring on board the major agencies and potential collaborating partners. GECaFS was then formally launched at the meeting of the Chairs and Directors of the global environmental change programmes in July, a project leader (Professor P. Gregory, University of Reading) nominated and an executive committee put in place. At the beginning of the year, an international project office was established, hosted by the UK Natural Environment Research Council Centre for Ecology and Hydrology, Wallingford, and an executive officer (Dr J. Ingram from the same institution) appointed. A formal research partnership with the Consultative Group on International Agricultural Research (CGIAR) has been instituted, formal collaboration with WMO arranged, and negotiations entered into for collaboration with FAO. A number of institutions/agencies have offered funding support. On the scientific front, two workshops on rice-wheat rotational cropping systems would be taking place in India during the course of the year, on the Caribbean food system in Trinidad in April, and on Pacific coastal fisheries in Lima, Peru in June or July.

Dr Whelpdale summarized the type of support that GECaFS needed from WCRP. In particular, information on current and future climate variability and on extreme values of parameters relevant to food systems was required. WCRP could also contribute its expertise in constructing comprehensive models which included adaptive measures and their feedbacks on society and global environmental change.

The JSC noted the progress in the planning/implementation of GECaFS during the past year and expressed its encouragement and backing, especially for the steps taken in building up the relationship between climate data and information on one hand and food production on the other. The suggestion was made that attention be given to considering African food systems which were particularly vulnerable. The JSC stressed the importance of the WCRP scientific community becoming involved in GECaFS in order to relay the information on climate variability required, also pointing out the important contribution that would be made to the project by regional climate modelling. The JSC urged that the small amount of financial support being provided to GECaFS from the WCRP (Joint Climate Research Fund) (e.g., to support participation in the executive committee) be continued within the limit of available resources.

Dr R. Dickinson, Co-chair of the Scientific Steering Committee for the Global Carbon Project, reported on the highlights of the development of the project. To monitor, understand and predict the evolution of the carbon cycle in the context of the whole Earth system including its human components demanded new scientific approaches and syntheses that crossed disciplinary and geographic boundaries and that recognized the carbon cycle as an integral part of the human-environment system. The goal of the project was to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions together with the interactions and feedbacks between them, by determining and explaining the current geographical and temporal distributions of the major stores and fluxes in the global carbon cycle, the underlying mechanisms and feedbacks that controlled the dynamics of the carbon cycle, including its interactions with human activities, and the range of plausible trajectories for the dynamics of the carbon cycle into the future. Many relevant activities were already under way and thus the work of the project would be aimed at synthesizing the research emerging from WCRP, IGBP and IHDP, and other programmes, and develop the linkages required to do this, identifying gaps in research on the carbon cycle and seeking the means to fill them through partnerships or other means, and promoting specific research projects exploring the interactions of the biophysical and human dimensions of the carbon cycle and fostering the inter-community dialogue necessary to support such research. Implementation would be by way of pilot activities over a time frame of one to two years (initially a rapid assessment of the carbon cycle jointly with SCOPE, and summer schools on integrative aspects of the global carbon cycle) and longer-term core activities or flagship projects (initially improving understanding of space-time patterns in the contemporary carbon cycle, emergent properties of the coupled human-carbon climate system, carbon cycle consequences of regional development pathways, evolution of carbon sources and sinks through the twenty-first century). At the time of the JSC session there was no official project office or secretariat for the carbon project, and organization so far has been supported by the IGBP Global Change and Terrestrial Ecosystem (GCTE) Office in Canberra, Australia, and the IGBP/GAIM Office in Durham, NY, USA. There were several prospects for project research offices in various parts of the world.

The JSC welcomed the progress in the global carbon project and the definition of scientific themes, and wished to place on record its recognition of the leading part played by Dr R. Dickinson in developing the basic planning and concepts of the project. The important contribution to be made by many activities in WCRP to many different aspects of the project was reiterated. Particular mention was made of the key role of the ocean in the carbon cycle and the need to link/co-ordinate ocean observations of carbon clearly and effectively across the various projects and scientific communities active in this area.

The Joint Water Project was in a less advanced state of planning, with only a preliminary scoping document available. The fundamental and overarching scientific question that would be addressed was how humans were changing the global water cycle and cycling of associated hydrologically transported constituents, and what were the reciprocal social impacts of these changes. A series of guiding principles and set of initial questions that would indicate the scope of the activities to be pursued had been set down, i.e. assessment of the relative magnitude of changes in the terrestrial water cycle and constituent transport from and within continents that could be attributed to climate and land use change on one hand, and population and economic changes on the other; identification of the main mechanisms by which activities were affecting the global cycling of water and constituent transport apart from emission of greenhouse gases; the extent to which water management systems and ecosystems mitigated the effects of hydrological variability and change associated with a changing climate, and population and economic growth. In the initial phase of the project (0-2 years), it was expected that strong emphasis would be given to defining data needs and preliminary efforts to construct first generation data sets (mainly via co-ordination and synthesis with other programmes). This would include socio-economic data sets consistent with physical/bio-geochemical data which together would lead to the first generation of interactive models of human behaviour and the physical response of water and constituent cycles at global to continental scales. Subsequently, the development of first generation land models would be fostered as a means of predicting physical, chemical and biological aspects of human manipulation of surface water and constituent cycles. This should then enable construction of full interactive models capable of predicting the response of and feedbacks of the global water cycle, especially the terrestrial branch, to human manipulation.

The JSC appreciated the thrust of the scoping document on the Joint Water Project, the overarching scientific objective posed, and the recognition of the important role of many components of the physical climate system in water and constituent cycling questions. The JSC emphasized the leading contribution to be made by WCRP, in particular GEWEX, in the implementation of the project.

In conclusion of its consideration of these three joint WCRP/IGBP/IHDP projects, the JSC strongly reaffirmed its support for the overall concept and strategy of the projects as a basic link between climate and environmental studies and sustainable development. It was suggested that health-related impacts of global environmental change could be the subject of a further joint project in due course.

Interactions between WCRP and IGBP

In addition to the physical processes which were the object of WCRP study, biological and chemical processes also had a vital role in the full climate system. There was a naturally close relationship between WCRP and IGBP in addressing key issues of mutual interest, and this relationship has continued to be reinforced. Examples of existing active and fruitful collaboration included that between GEWEX and the IGBP study of Biospheric Aspects of the Hydrological Cycle (BAHC) (joint newsletter published in November 2001), CLIVAR and the Past Global Changes (PAGES) project, WGCM and GAIM (particularly in the joint organization of the Coupled Carbon Cycle Climate Model Intercomparison), and SPARC and the International Global Atmospheric Chemistry (IGAC) project. These joint activities were welcomed and strongly encouraged by the JSC.

With respect to the last of the above, the joint SPARC/IGAC activities could form the basis of the long-discussed WCRP/IGBP "atmospheric chemistry and climate initiative" (see detailed report in section 5.4.2). This was also reflected at a workshop in Stockholm in January 2002 considering the planning of the future of IGAC (at which SPARC was represented) which proposed that coupled chemistry-climate problems should be addressed jointly by SPARC and that a joint chemistry-climate workshop to plan a SPARC/IGAC "chemistry-climate" research agenda should be convened. Another area ripe for co-operation where WCRP had already contributed and where further WCRP support was being sought was the Surface Ocean-Lower Atmosphere Study (SOLAS) initiative (fully discussed in section 6.2). Professor P. Schlosser and Dr K. Denman represented WCRP (and the JSC) on the recently formed SOLAS Scientific Steering Committee. SOLAS was already being formally sponsored by IGBP, SCOR and the Commission on Atmospheric Chemistry and Global Pollution of the International Association for Meteorology and Atmospheric Sciences. Co-sponsorship also by WCRP would be welcomed.

Professor G. Brasseur, Chair of the IGBP Scientific Committee, reminded the JSC of the plans being drawn up for "IGBP Phase II" which would begin in January 2003 and which should offer new opportunities for co-operation and joint WCRP/IGBP activities. The structure of IGBP Phase II would be based on Earth system compartments (ocean, land, atmosphere) and interfaces (ocean-land, land-atmosphere, ocean-atmosphere) (involving significant re-organization of several of the existing IGBP core projects) with the ongoing GAIM and PAGES projects refocussed on cross-programme integration. A substantial integration role was also seen for the ESSP (see above), particularly through the joint projects on food, carbon and water, and the "Integrated Regional Studies". In more detail, with regard to the "ocean compartment", a new project focussing on ocean bio-geochemistry and ecosystems (a follow-up to the Joint Global Ocean Flux Study, JGOFS) would be developed to complement and work closely with the Global Ocean Ecosystem Dynamics (GLOBEC) project. An IGAC Phase II was being planned for the atmosphere, and a land project would be formed bringing together the GCTE and Land Use Cover Change (LUCC) communities. The land-ocean interface would be the subject of a Land-Ocean Interactions in the Coastal Zone (LOICZ) Phase II Project and the ocean-atmosphere would be dealt with by SOLAS. For the land-atmosphere interface a new initiative was envisaged built round a core of BAHC and GEWEX components (to be led by a joint IGBP/WCRP panel).

The JSC observed that the reorganization of IGBP and the new Phase II structure planned would have significant implications for the WCRP. The proposed involvement of GEWEX, especially its Global Land-Atmosphere System Study (GLASS), in the IGBP land-atmosphere project was of particular interest. It was noted that the GEWEX Scientific Steering Group had reacted positively to this possibility, and areas of potential collaboration would be identified and explored. The WCRP co-operation in "Integrated Regional Studies" being discussed as a component of IGBP Phase II (see above) also needed to be considered. However, the JSC did have some general concerns at several apparent overlaps of the new IGBP activities with WCRP, and the lack of acknowledgement of the projects already being conducted by WCRP in some of these areas. The JSC emphasized that the role of the WCRP as the leader in studying physical aspects of Earth system science should be clearly recognized and asserted. The JSC agreed that positive actions were necessary to build up the appropriate linkages, to obtain a full overview and to identify gaps or missing items. WCRP and IGBP needed jointly to find ways of bringing the different communities involved together. In this respect, the suggestion of joint (or back-to-back/overlapping) sessions of the JSC and IGBP Scientific Committees certainly merited consideration in the future.

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

Dr M. Manton reviewed START activities of relevance to the WCRP. One of the most interesting in this respect was the establishment in the past year of a new programme on Monitoring Extreme Events (MECE), designed to assist in the co-ordination of various activities assessing climate extremes that were being undertaken in a number of developing countries. Initial ideas included the promotion of common software in order to obtain consistent analyses across regions and development of a number of common indicators of surface climate. The IPCC workshop on climate extremes in Beijing in June 2002 should suggest other strategic directions that could be followed. The JSC urged that strong links be maintained with WCRP activities especially CLIVAR.

As well as its overall continuing work in the promotion of regional research programmes and capacity building, START was now focussing on encouraging young scientists in developing countries by offering competitive awards to individuals. This would now be complemented by the organization of a series of Global Change Young Scientists' Conferences (as referred to in section 2.1), at which young scientists from developing countries would have the opportunity to present their work and interact with their senior counterparts from the global environmental change programmes. The first conference was planned to be held in Trieste in 2003.

Dr Manton also outlined recent developments in the Climate Prediction and Agriculture (CLIMAG) project which had originally stemmed from a proposal made by the JSC in 1996 for a capacity building activity to foster the use of WCRP research results, especially climate variability predictions, for agriculture. START was now managing CLIMAG, and with support from the Packard Foundation, was sponsoring an advanced training institute in 2002 at the International Research Institute for Climate Prediction (IRI). This would involve twenty participants from appropriate organisations in developing countries who would have the opportunity to prepare a proposal for a one-year project that would be considered for funding. Dr Manton further reported that (at the invitation of Professor Ding) he had spoken on CLIMAG at an international conference on agriculture, science and technology in Beijing In November 2001. The session on climate and agriculture had been very useful but it was apparent that, generally, the agricultural community did not have climate impacts as a major focus of attention. Much effort was needed for the work of CLIMAG to be fully recognized and utilized. In this regard, the JSC encouraged the direct involvement in CLIMAG of bodies such as IRI with its emphasis on, and resources that could be provided for, forging links between science and society and applications research.

It was noted that Professor P. Tyson had now stepped down as Chair of the START Scientific Steering Committee. Two Co-chairs have been appointed in his place, Dr G. Pearman, CSIRO, Australia, and Professor S. Gadgil, Centre for Atmospheric Sciences, Institute for Atmospheric Science, Bangalore, India (Professor Gadgil has had strong links with WCRP and played a major role in the establishment of CLIMAG).

In general comments on START, the JSC acknowledged its important role and successful work in capacity building, and most recently the initiative of Young Scientists' Conferences. It was suggested that START activities should be better co-ordinated with other regional capacity building activities, especially in Africa, where particular efforts were essential. The JSC again urged WCRP core programmes to establish links with START whenever appropriate and possible, and to take advantage of START facilities and networks to aid in the effective transfer of WCRP knowledge to developing countries. It was noted that START (and other capacity building groups) strongly promoted the use of regional climate models for climate impact and other studies. An advanced draft of the review of the status of regional climate modelling by an ad hoc WGNE/WGCM panel was now available and would be discussed at this session of the JSC (see section 10.3). The review drew attention to pitfalls in regional climate modelling and emphasized that regional climate models should not be used indiscriminately. An international workshop was envisaged in the next year or so to consider the use of regional climate models in various applications and to plan an assessment of regional climate skill in reproducing fine-scale features associated with large-scale year-to-year anomalies. The JSC recommended that, when finalized, the review of regional climate modelling should be distributed appropriately to the START community, which should also be closely involved in the proposed international workshop on regional climate modelling, in recognition of the importance of the requirement to regionalize climate model results.

Joint funding initiative

As reported at the twenty-second session of the JSC, WCRP, IGBP and IHDP were jointly considering how to ensure sufficient stable core financial resources to enable the successful development of the programmes, including particularly attempting to identify new opportunities and approaches for obtaining funds. A joint WCRP/IGBP/IHDP "Resources Development Committee" had been set up to undertake a dialogue with foundations and/or corporations where some interest in global environmental change research was apparent. Unfortunately no significant progress has been made in this area since the last session of the JSC, and the Chairs and Directors meeting in Amsterdam in July decided that the Resource Development Committee should continue only in "sleeping" form.

In the meantime, representatives of all four global environmental change programmes (WCRP, IGBP, IHDP, DIVERSITAS) participated in the plenary session of the International Group of Funding Agencies for Global Change Research (IGFA) in Stockholm in October 2001. On behalf of the ESSP, Professor B. Moore gave a presentation to IGFA on the potential challenges that had to be taken up in global research. The top priority concerns for IGFA at this stage were the stabilization and increase in support for IHDP, DIVERSITAS and START.

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

Global Climate Observing System (GCOS)

Professor P. Mason, the new Chair of the GCOS Steering Committee, summarized recent developments in GCOS. Of primary importance were the continuing interactions with the UN Framework Convention on Climate Change. Drawing on the annually-submitted national GCOS reports (which can be viewed via the GCOS web site **http://www.wmo.ch/web/gcos/gcoshome.html**), an updated statement on developments in systematic (climate) observation had been prepared for the fifteenth session of the Subsidiary Body on Scientific and Technical Advice (SBSTA), Marrakesh, Morocco, November 2001. The GCOS statement emphasized that the IPCC Third Assessment Report had placed as first priority reversing the deterioration of the conventional observing network, and put forward the proposal for a second adequacy report on systematic observation, as well as drawing attention to the need for a funding mechanism to support observations from developing countries. SBSTA duly requested an interim report on key priorities for its sixteenth session (June 2002), and a full adequacy report in June 2003. The GCOS Steering Committee would consider the key priorities at its session in April 2002 among which were likely to be maintenance and improvement of the GCOS Upper Air Network (GUAN), transition of the ARGO deployment of a global array of profiling floats to operational status, improved exchange of climate-related data, the national collection of terrestrial observations, and ozone monitoring. For the preparation of the adequacy report, a joint GCOS/IPCC scoping meeting was being planned to provide input to a drafting team comprising the Chair of the GCOS Steering Committee and Chairs of the Atmospheric Observational Panel for Climate, the Ocean Observations Panel for Climate and the Terrestrial Observation Panel for Climate together with four or five experts in each domain. The target was to complete a draft by December 2002 which would then be made available to the community as a whole for comment. In particular, views from the JSC would be very much welcomed. It was recognized that the report must lay out realistic priorities that could be acted on by SBSTA and the UNFCCC Conference of the Parties (COP). It was yet to be decided whether the report would restrict attention to monitoring climate only, or whether reference should be made to the specialized data sets needed in understanding or throwing additional light on key climate processes.

Professor Mason also referred to the programme of regional workshops that was being organized by GCOS with support from the Global Environmental Fund (GEF). Workshops in the Pacific and West Africa had already taken place, and a third (in the Carribean) was in progress at the time of the JSC session. A workshop in south-east Asia was planned before the end of 2002. The workshops were designed to identify the priority capacity-building needs of developing countries to enable their participation in systematic observation and to assist in regional network planning.

WCRP/GCOS Atmospheric Observation Panel for Climate (AOPC)

Dr M. Manton, Chair of AOPC, informed the JSC how the work of the panel was advancing. There continued to be slow but steady progress in the implementation of the GCOS baseline networks for surface (GSN) and upper air observations (GUAN). A key element was the continuing work of Deutscher Wetterdienst and the Japan Meteorological Agency as monitoring centres for GSN data, as well as the initiative of ECMWF in extending the range of products generated to assist in the evaluation of the performance of the GUAN. However, GSN and GUAN could not be fully implemented until a supported end-to-end system was in place including the facility of liaising directly with the network operations. This situation would be eased with the foreseen establishment of "CBS Lead Centres for GCOS Data", but the complete end-to-end support required depended on the establishment of a GSN and GUAN project office.

Over the ocean, the VOSCLIM network offered the most promising prospect of baseline surface data for GCOS, although quality control and homogeneity were outstanding issues. Also the Automated Ship Aerological Programme (ASAP) was the only means at present of obtaining consistent in situ upper-air data over the oceans. The single ship providing ASAP data over the Southern Ocean has been shown to have a significant impact on upper-air analyses in the region. The plans to set up a small (but significant) network of ocean reference sites were also being encouraged (see also section 10.1.5): the value of these sites would be enhanced by the inclusion of instrumentation to monitor surface atmospheric parameters.

In collaboration with the Ocean Observations Panel for Climate (see below), a task group was examining and evaluating various sea surface temperature analyses to identify sources of discrepancies. The availability of microwave data from TRMM was suggesting that the variability of the sea surface temperature of the Indian Ocean could have been underestimated because of limitations of the previously used infrared satellite data. Also, jointly with the Ocean Observations Panel for Climate, efforts were being made to promote the recovery and analysis of pressure data that could provide additional information on key features such as storminess. A third joint activity was the identification of large-scale indicators of the state of the climate system (from composite data sets including reanalyses).

The AOPC continued to liaise with the CBS Expert Team on the Redesign of the Global Observing System. A particular item of discussion was the development of appropriate WMO regulations and procedures to ensure that timely and consistent data were obtained from the GPS receivers, now increasingly widely used, to measure total column water in the atmosphere; these measurements were of considerable potential value for climate. The climate needs for satellite observations have also been brought to the attention of the WMO Consultative Meetings on High-level Policy on Satellite Matters (see section 2.4).

In direct interactions with WCRP, the AOPC had been able to confirm to SPARC the high priority accorded in the GUAN to the continuity of upper air soundings particularly in the tropics and sites such as Macquarie Island in the Southern Ocean, particularly for monitoring the stratosphere. The AOPC has informed relevant national agencies of this priority. The generation of reanalyses products was also of key interest to AOPC, a specific concern being the reanalysis process (from data entry to product generation) to meet the requirements for an analysis for climate purposes. The JSC encouraged AOPC to explore this question with WGNE which had the responsibility for the WCRP cross-cutting reanalysis activities.

The JSC expressed appreciation for the work of AOPC in advancing activities on a broad front, in particular the implementation and monitoring of the GSN and GUAN. Bearing in mind the importance of the planned adequacy report (see above), the JSC urged the AOPC to complete its science and implementation plan as soon as possible, laying out the development of the atmospheric component of GCOS and highlighting the complementary nature of baseline and comprehensive observing systems. The establishment of systems for monitoring of climate forcing, requiring an appropriate blend of satellite and in situ data, also needed to be considered.

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

Dr N. Smith, Chair of OOPC, recalled that the panel had the primary responsibility for providing advice on requirements for sustained ocean data for climate and related physical ocean science. In this regard, OOPC worked closely with CLIVAR (see section 8.1). For implementation issues, a successful partnership with the new WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM)(established during 2001) would be essential.

Dr Smith reviewed the status of various activities developed under the guidance of OOPC. In the ARGO initiative (see **http://www.argo.ucsd.edu/**), 324 floats had been deployed in 2000, with 597 due in

2001. The average rate foreseen over the next three years was 758 per year, with most of the Atlantic covered by the end of 2003, and the Indian Ocean north of 20°S by the end of 2004. Attention was being given to finalizing all aspects related to real-time data exchange. Excellent progress was also evident in the planning of the Global Ocean Data Assimilation Experiment (GODAE) (see **http://www.bom.gov.au/GODAE/**). An implementation plan was expected to be published in June 2002. Several new projects were being initiated: development of a real-time ocean current data and product base; intercomparison and evaluation of North Atlantic ocean products; intercomparison and evaluation of North Pacific products; data and product services for GODAE. The Global Ocean Timeseries Observatory System was aimed at the development of a global network of multi-disciplinary time series stations supplying high-quality fixed-point data sets for testing and developing models and for monitoring change.

OOPC had also conducted a review of the tropical moored buoy network. It was concluded, not surprisingly, that the network was the most important contribution to monitoring and prediction of ENSO and that, from a scientific perspective, there was an outstanding case for continuation of the Pacific array in its present form. Moreover, the Pilot Research Array in the Tropical Atlantic (PIRATA) was strongly supported by its participants. Development of an Indian Ocean network was being discussed. In practice, the most serious threat to networks was posed by vandalism which, in some cases, reduced effectiveness beyond a point that made the approach viable.

The Ship-of-Opportunity Programme (SOOP), Automated Shipboard Aerological Programme (ASAP) and Voluntary Observing Ship (VOS) Programme were also central to the overall OOPC strategy, particularly in obtaining surface marine fields. In this last aspect, work has continued, jointly with WGNE and the "SURFA" project (see section 10.1.5) on the surface reference site project, with intercomparisons being conducted for several regions. The requirements for remotely-sensed data were being considered in the framework of the IGOS Partnership in the development of the "Oceans Theme" (see section 2.4).

The OOPC had concluded that, for some ocean basins, it seemed more effective to tackle the issue of ocean observations on a more comprehensive basis, including both research requirements and the more general needs of GOOS. This enabled a broader constituency to be involved, for example, in the Indian Ocean, where a "whole-of-ocean" approach to the science, design, planning and implementation of an overall ocean observing network was being taken, building upon the outcome of a meeting in November 2000. A similar strategy would be pursued in the South Atlantic, again bringing together all parties from the region with an interest in ocean observations at a GOOS/CLIVAR workshop in November 2002.

The JSC was impressed by the continuing progress and range of activities in which OOPC was involved. The JSC recognized that, following the creation of JCOMM and of ocean basin panels in CLIVAR, consideration should be given to the best way of providing oversight/co-ordination of sustained ocean observations globally. Another particular point emphasized was the importance of obtaining reliable observations of ocean surface salinity. Further attention also needed to be given to the number and coverage of deep ocean observations.

The JSC noted that Dr Smith was standing down as Chair of OOPC. The outstanding contribution of Dr Smith in building up the activities of the OOPC was fully acknowledged and applauded by the JSC.

The need for a Global Palaeoclimate Observing System

The JSC was informed of the initiative being taken by IGBP/PAGES for the immediate establishment of a co-ordinated international Global Palaeoclimate Observing System (GPOS) to complement GCOS, GOOS and GTOS (although GPOS would not be an operational activity in the same way). The role of GPOS would be to collect data on longer time-scales than the limited instrumental record that was available. Natural archives of past climate variability could provide this information. Unfortunately, some of the most valuable palaeoclimatic records were being rapidly altered or were being lost often as a result of human influence, and thus urgent action was necessary.

The JSC took note of and encouraged the planned activities. The JSC pointed out the considerable potential value of GPOS data for CLIVAR studies of long-term variability.

2.4 Interactions with space agencies

The Integrated Global Observing Strategy (IGOS)

The continuing development of the WCRP depended fundamentally on global remotely-sensed data and exploiting to the full the new generation of Earth observational satellites foreseen in the coming years. In this respect, IGOS, whose goal was to produce comprehensive global, regional and national environmental data and information for policy-makers and to support scientific and operational environment-related programmes, had significant potential importance for the WCRP. The IGOS Partnership (IGOS-P) was established in 1998 and, as well as the Committee on Earth Observation Satellites (CEOS) which had originally initiated IGOS, included GCOS, GOOS and GTOS; the international agencies sponsoring these systems, WMO, ICSU, IOC and UNEP; WCRP and IGBP; IGFA. It had been recognized that it was simply not practical to attempt to define a single comprehensive global system that could satisfy all the needs for environmental information, and, thus, a process of identifying, selecting and developing "themes" had been adopted. The first and most developed of these was the "Oceans Theme", for which a report had been published in January 2001. Others approved, and relatively advanced were the Integrated Global Carbon Observation and the Integrated Global Atmospheric Chemistry Observations Themes. In November 2001, the Integrated Global Water Cycle Observations (IGWCO) Theme was accepted (in which WCRP has the leading role - see below). Further proposals were for a Coastal Theme (with a Coral Reef sub-theme) and Geological-Geophysical Hazards theme. An IGOS brochure was produced in January 2002 (and had been distributed to JSC members).

The water cycle theme (IGWCO) was one of particular interest to WCRP and responsibility has been accepted for developing this theme on behalf of IGOS-P and the wider scientific and user communities. The JSC gratefully acknowledged the excellent work of Dr R. Lawford, who had organized the landmark IGOS Water Cycle Planning Workshop held in January 2001, and who had then led the "writing team" that produced the required "proposal" in a timely manner. The proposal had duly been considered and approved by IGOS-P in November 2001, the first formal step in the process of elaborating the theme.

In summary, the objectives set down for IGWCO were to:

(i) provide a framework for guiding decisions on priorities and strategies regarding water cycle observations for

- monitoring climate variability and change
- effective water management through the provision of better information
- sustainable development of the world's water resources
- specification of initial conditions for weather and climate forecasts

(ii) promote strategies that facilitate the processing, archiving and distribution of water cycle data products.

The next challenging stage was now to develop the approved proposal into an IGOS theme "report", similar to that for the ocean theme referred to above. An IGWCO report writing team, to include representatives of interested agencies and various scientific communities, was being established, together with an advisory team. A particularly important aspect of IGWCO was that it provided a wider framework under which IGOS-P and, in particular, CEOS, could be kept fully abreast of the rationale, aims and output from the Co-ordinated Enhanced Observing Period (CEOP), and which should thus encourage support for CEOP. IGOS-P had recognized CEOP as "the first element of IGWCO", and attention was being given to highlighting this relationship and the results from CEOP that would underpin IGWCO. Overall, the successful implementation of the major, ambitious IGWCO theme was of great significance for the WCRP.

Other contacts with space agencies

WCRP was represented in the annual session of the WMO Consultative Meetings on High-level Policy on Satellite Matters in February 2002, and had provided input in the form of a joint paper with GCOS "Evaluation of current and planned satellite missions for GCOS and WCRP". The aim of these consultative meetings was to foster dialogue between WMO and the operators of environmental satellites on policy issues concerning the use of satellite data or systems by the "meteorological" community at large (and for climate-related activities). The scope of the meetings has now been extended to include experimental and research systems (as well as operational satellites) - hence the request for the joint GCOS/WCRP paper at the recent meeting. The input from WCRP (and GCOS) was well received, with appreciation expressed for the past and present contributions by WCRP in articulating requirements for space missions for climate research, and in exploiting the data that were collected. At the recent high-level consultative meeting, WCRP was invited to assess the current gaps in existing or planned satellite systems, and possible weaknesses in data management activities. An ad hoc task team including at least one person from all the main WCRP project areas and a few representatives from space agencies was being established to prepare a document for submission to the next WMO consultative meeting.

With regard to data management issues, it was recalled that several aspects had been raised at the twenty-second session of the JSC (and were taken up again generally under item 3.2), and it was agreed that a response to the space agencies shoulder stem from this wider consideration. It was noted, in particular, that management of remotely-sensed data was of high priority for CEOP (see section 4.2.3). At this point in its discussions, the JSC again stressed strongly that far more resources (manpower and financial) were essential to exploit fully, interpret and analyse properly the huge volumes of new and additional remotely-sensed data that were now becoming available as the planned new generation of Earth observation satellites increasingly came on line. Although many times more data were being used than even a year or two ago, this only represented a small fraction of the total amount. To ensure that the full anticipated value and results were obtained from satellite systems, major focussed efforts were necessary. The JSC underlined that real commitments should be made by satellite operating agencies in this respect to ensure the continuity of climate parameters inferred from remotely-sensed data based on systematic overlaps and cross-calibration of new sensors, and to develop multi-wavelength/multi-instrument self-consistent analyses of parameters. The JSC urged that these requirements be reiterated to space agencies through all available channels and attention be given to finding persuasive arguments for enhancing space agency commitment to this issue.

3. SCIENTIFIC DIRECTION, STRUCTURE AND PRIORITIES OF THE WCRP

The JSC reviewed from a strategic programme-wide viewpoint the overall development and structure of WCRP scientific activities taking into account emerging new issues and challenges. In particular, a proposal was put forward by Professor J. Shukla that WCRP should develop a comprehensive interdisciplinary project on predictability and prediction of season-to-interdecadal variations at regional and global scales. Dr K. Trenberth also gave a presentation on "the need for a climate observing system". Building on these inputs and extensive in-session discussion, the JSC formulated a proposal for a new "banner" for the WCRP: a Predictability Assessment of the Climate System (see section 3.1). The JSC also took up again at this session the overall approach to data management in the WCRP (see section 3.2).

3.1 Predictability assessment of the climate system

Professor Shukla recalled the main objectives of the WCRP - to determine to what extent climate could be predicted and the extent of human influence on climate together with the research priorities set down for the programme at the conference in 1997, namely:

- 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, UNFCC and other conventions).

Professor Shukla emphasized that society needed to know what was and was not predictable, and economists required quantitative information on predictability. A large body of observational and modelling evidence from within and outside the WCRP had been assembled in the past two decades pointing to the influence of sea surface temperature, sea ice, snow depth, soil wetness, and vegetation on predictability at seasonal and longer time-scales. A comprehensive effort was necessary where all "forcings" were considered together as a basis for climate prediction. This exercise would expose clearly the deficiencies in current climate prediction systems in the supporting models (thus offering a strong impetus for model development) and in the climate observing system. In particular, demonstrably socially and economically beneficial climate forecasts would provide a compelling justification for sustained climate observations. Additionally, quantification of uncertainties in seasonal/interannual/decadal climate predictions with "perfect" knowledge of ocean, land and atmosphere conditions would lead to improved estimates of the uncertainties in projecting the regional climate variations that would result from global climate change.

For these reasons and many others, as well as the direct relevance to WCRP objectives and research priorities, Professor Shukla considered a comprehensive WCRP-wide initiative on predictability and prediction was essential. Professor Shukla proposed that the initiative could be centred round a major modelling and numerical experimentation effort designed to demonstrate the predictability and practical prediction of seasonal/interannual/decadal climate variations for the period 1979-2009. The full range of current global models (i.e. as used in NWP, seasonal-to-interannual predictions, fully coupled ocean-atmosphere models for climate change projections) should be employed. Co-ordinated seasonal prediction experimentation would be defined in which modelling groups would use the same initial atmospheric sea surface temperature, sea-ice, soil wetness, snow depth, and vegetation conditions (as well as specified atmospheric concentrations of carbon dioxide and ozone). The key (boundary forcing) parameters (sea surface temperature, ice cover, snow depth, soil wetness, vegetation) would evolve according to the individual internal schemes and predictions of the models. An ensemble of seasonal predictions would thus be obtained. For interannual- and decadal-scale predictability, multi-annual (2-10 years) integrations with coupled ocean-land-atmosphere models would be initiated from the same data. Modelling groups could employ their own assimilation and initialization methods to define the initial state for their model, but use the same "observed" global data sets for the atmosphere, ocean and land. All this would require extensive ocean, sea surface temperature, ice, vegetation, snow and soil wetness data sets at monthly (preferably weekly) intervals for the period 1979-2009 as well as a major infrastructure for verifying and assessing model simulations and predictions.

Professor Shukla additionally suggested that the above ideas on a prediction and predictability initiative could form the starting point and nub of a "Global Climate Experiment", of which the ultimate goal would be to assist society and policy makers in formulating necessary socio-economic decisions taking into account regional climate variations in the context of overall global climate change. The routine production of the required regional climate predictions would mean that, not just modelling activities, but, even more importantly, the large number of currently existing/planned observational programmes would have to be co-ordinated. The last time a major global effort was launched by the science community (that was now involved in the WCRP) was the Global Weather Experiment (or First GARP Global Experiment, FGGE) in 1979. This had led to major advances in short-range weather forecasting with very substantial socio-economic benefits. A global climate experiment, with the establishment of global climate observing systems and the development of improved climate models, could be expected likewise to lead to major advances. Such an experiment, building on the proposed prediction and predictability initiative, could comprise a "pre-operational phase" (2002-2009) which, as well as organized numerical experimentation on seasonal, interannual and decadal variations, would involve definition and establishment of global observing systems, and development of data assimilation for the entire coupled climate system. This would be followed by a ten-year "operational phase" (2010-2020) in which the target would be provision of a real-time description and prediction of climate variables, the hydrological cycle, quality of air and water etc, as a basis for planning sustainable development.

Dr K. Trenberth presented views on the need for a climate observing system. Whilst agreeing with Professor Shukla on some points, Dr Trenberth's perspective in other areas was different. The climate observing system at present was not adequate, being based on an eclectic mix of data mainly collected for other purposes, in particular operational weather forecasting. To provide the solid information needed for assessing the degree, nature and cause of climate variations, improved global observations of state variables and forcing terms, the means to process and understand these, and the ability to set the data in a coherent physical (and chemical and biological) framework using models were essential. All observations should be designed and taken with this purpose in mind. Specifically, the requirements for a comprehensive climate observing system were:

- observations from both space-based and in situ platforms to be taken in ways that met climate needs

- a global telecommunications and satellite data telemetry capacity to enable data and products to be disseminated

- capabilities, including four-dimensional data assimilation, to provide analyzed products

- global climate models encompassing all the components of the climate system, utilized in data assimilation and in providing ensemble predictions from the initial observed state

- a centre for overseeing and monitoring climate observations, their collection and processing, and tracking their quality: this centre should have the resources and influence to enable resolution of problems and be prominently involved in the consideration of observing systems established for purposes such as weather prediction, and in the choice and characteristics of instruments placed on satellites.

The JSC reviewed and discussed at length the exciting ideas and concepts put forward by Professor Shukla and Dr Trenberth. Particular note was taken of comments made by Dr S. Zebiak in his role as Chair of the CLIVAR Working Group on Seasonal-to-Interannual Prediction (WGSIP), and by Dr B. McAvaney on behalf of the Working Group on Coupled Modelling (WGCM). Dr Zebiak took the opportunity to outline the work being undertaken and the approach followed by WGSIP, which was aimed directly at improving the practical prediction of seasonal-to-interannual variability. The role of atmosphere-ocean interaction was currently at the heart of WGSIP studies. It was considered that there were significant benefits to be obtained by investigating interactions which were thought to contribute to seasonal-to-interannual predictability in an individual (and consecutive manner) rather than all the processes involved at once. For instance, WGSIP was aware of the results suggesting the important part played by atmosphere-land surface interactions in predictability at seasonal time-scales. This implied close contact with GEWEX and a scientist working in this area had been invited to join WGSIP which should lead to advances of understanding in this area. WGSIP had a preference to this type of approach to broadening its agenda instead of placing so many issues on the table at the same time that it might be difficult to focus on and improve understanding of the contribution to predictability (and how this could best be exploited) of particular factors.

Dr B. McAvaney reported that WGCM had fully recognized that it was strongly in the interests of WCRP to be seen to be encouraging work that would lead to the development of the practical side of climate prediction on seasonal, interannual and decadal timescales. It had been suggested that the proposal for a project on predictability and prediction in the WCRP could be accommodated by modifying the role of the existing WGSIP. However, it was stressed that this should not mean WGCM would be concerned only with the issue of anthropogenic climate change. WGCM dealt fundamentally with the development of coupled ocean-atmosphere models (although it was recognised that much of the development had been motivated by the need to make projections of anthropogenic climate change). In this regard, WGCM considered the full climate system, interacting with all the WCRP core projects as well as WGNE and WGSIP as appropriate. Strong co-operation was developing with IGBP/GAIM (including planning of a joint WGCM/GAIM workshop on Earth system modelling). Duplication of effort where, for example, a modified WGSIP would also look at the development of coupled models, should be avoided. Rather, attention would need to be given to investigating data requirements for seasonal to interdecadal predictions, and data assimilation and initialization aspects, although close liaison between WGSIP and WGCM (as there was already) would clearly be essential. WGCM had additionally noted that, as changes in the frequency and intensity of extreme events were potentially one of the most important manifestations of climate change, it must continue to assess and work on improving understanding of natural climate variability on all time scales.

Taking note of all comments and views expressed, the JSC agreed on the proposal for "A new banner for the WCRP - Predictability Assessment of the Climate System", having the aim of major steps forward in climate prediction. The foci of this activity, responding to the research priorities set at the Conference on the WCRP in 1997, would include the determination of the extent of useful skill in predicting variations in the climate system on time scales from weekly to decadal (or even centennial) and of the extent to which global models could be designed to reproduce correctly the probability distribution functions of sub-decadal climate variability, as well as the temporal and spatial modifications of these probability distribution functions in a changing climate (thus enabling possible regional manifestations of climate change to be inferred). The elaboration of data management and analysis systems and of predictive models, and the contribution to the development of climate observation systems would be another crucial element. The underlying theme and modus operandi would be increasing understanding through diagnosis of observational and model data, process studies and the creation and analysis of special data sets. Whilst aimed initially at the physical climate system, the predictability assessment would be gradually broadened to encompass the full physical-chemical-biological system with the need for increasingly strong collaboration with IGBP. The preliminary milestones suggested were the development by 2010 of prototype prediction systems for climate on time scales from weeks to a century, and testing and improvement of systems in the period 2010-2020. Emphasis would be given to demonstrating the importance of observed climate data, particularly those from the new satellites planned for launch in the period up to 2007, thereby providing a firm basis for requesting the continuation and enhancement of these satellite observations. The results would be expected to be directly beneficial to society and a major contribution to the planning of sustainable development. All WCRP projects would be involved.

The JSC was aware of concerns that more might be promised than could be delivered and that changes to the present structure and functioning of the WCRP would be likely. It should also be made clear that the predictability assessment would not divert attention from the WMO/CAS World Weather Research Programme planning of "The Observing System Research and Predictability Experiment" (THORPEX) (and its possible development as a "Second GARP Global Experiment") (see section 10.1.10) nor to step into the domain of activities of national meteorological services. Rather, the predictability assessment would need to draw on THORPEX and to involve fully the national meteorological services.

The JSC established a task force composed of Professor B. Hoskins (convener), Professor J. Shukla, and Dr J. Church to develop ideas and proposals for implementation of the WCRP predictability assessment, including consideration of the changes that might be needed in the organization of the WCRP. The task force would report to the next session of the JSC in March 2003, at which at least one full day would be set aside for discussion of this crucial prospective advance in the WCRP, review of the status of relevant research and the contributions expected from existing WCRP projects and activities, formulating decisions on the future strategy, and outlining a vision for WCRP after 2010. In order to gather the appropriate information and to indicate the areas where contributions would be made, all project groups were requested to discuss fully the new "banner" being proposed, with input to be given to the task force by 31 July 2002. Project groups were further asked to nominate representatives for inclusion in the deliberations of the task force.

3.2 Overall approach to data management in the WCRP

As noted above (section 2.4), several data management issues had been raised at the twenty-second session of the JSC (March 2001). To review questions related to data management in the different components of the climate system (atmosphere, ocean, cryosphere, land-surface) spanned by the WCRP, as well as a huge variety of model output data sets, the JSC recommended that leaders of WCRP data management groups and/or project office directors should begin a dialogue on the different project data and information management systems employed with a view to setting out overall guidelines for data management practises in the WCRP as a whole, and what might be needed at various timescales in the future.

The main conclusions so far were that WCRP could do more to advertise its data sets and that there was a role for WCRP in encouraging development of improved data transmission capabilities, data assembly, quality control and user interfaces. Regarding the need for, or desirability of, cross-WCRP standard formats and/or common data policies, there was a general view that overall prescriptions should not be made (although it was noted that WOCE has benefited from standard formats and that there have been complaints about the different formats of the reanalysis data sets). Further exchange of information on formats and data policies for WCRP projects was planned. It was also suggested that a "data" feature be added to the WCRP web site with links to project data information.

Apart from this dialogue, data management issues had come up in other connections in the WCRP (e.g. discussions by WGCM on developments in data formats and handling climate model data formats, see section 10.2.15; dealing with the increasingly voluminous remotely-sensed data sets, see section 2.4). In the latter respect, the implementation of CEOP would also be an excellent opportunity for WCRP to identify and define the type of summary data sets that would be most useful (see section 4.2.3). The reanalysis data sets required by individual WCRP projects also needed to be clarified. Regarding requirements for historical data, a proposal has also been made by Dr R. Jenne (NCAR) for a workshop on this topic.

In its review of this item, the JSC fully recognized that there were many different approaches in the WCRP to data management and handling, as well as varied data formats, in different projects, often designed to deal with specific research applications. Thus, it was clearly not possible or desirable at present to impose one overall programme-wide data management, formats and information system in the WCRP. The JSC urged, nevertheless, that the dialogue between WCRP projects in this area continue, and, in particular, that approaches, concerns and requirements for data delivery and management be documented. The whole situation also needed to be kept under review in the light of the rapid advances in the development of (distributed) data and information systems.

4. THE GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (GEWEX)

The main developments in GEWEX during the past year, including the principal recommendations from the fourteenth session of the GEWEX Scientific Steering Group (kindly hosted by ECMWF in Reading, UK, January 2002) were presented by Professor S. Sorooshian, Chair of the GEWEX Scientific Steering Group, Dr W. Rossow, Chair of the GEWEX Radiation Panel, and Dr P. Try, Director of the International GEWEX Project Office. The past year had been one of transition to the second phase of GEWEX based on the revised principles discussed at the twenty-second session of the JSC. These principles were now being taken into account in planning the activities in the three main thrusts of GEWEX: hydrology, radiation and modelling, and the important Co-ordinated Enhanced Observing Period (CEOP) initiative. Increased co-ordination was being seen between previously separate GEWEX activities and greater efforts were being made to foster appropriate interactions with other WCRP projects and modelling work. Consideration has also been given to the positioning of GEWEX in relation to other non-WCRP programmes or initiatives such as the CAS/WMO World Weather Research Programme, the water component of the World Climate Programme, and the IGOS Water Cycle theme (see section 2.4).

4.1 Transition from GEWEX Phase I to Phase II

The main achievements of the first phase of GEWEX were reviewed at the Fourth International GEWEX Science Conference held in Paris in September 2001, in which nearly 250 scientists from 20 countries participated. Among the many accomplishments noted were: the advances in understanding cloud processes, their representation in models and their role in the general circulation; ground hydrology and its coupling with the atmosphere; the interaction between the atmosphere and biosphere; the global water cycle and its sensitivity to climate change; the exploitation of the substantial data sets available from research satellites. Key results presented at the Conference were the suggestion that changed radiative fluxes in the atmosphere linked to anthropogenic effects could lead to an intensification of the global water cycle, the persistence over several decades of anomalies in the coupled atmosphere-ocean-land system, and that discrepancies in radiative cloud feedback processes and in water vapour simulations in models remained unresolved. Overall, the Conference demonstrated the rapid progress in improving the knowledge of the global energy and water cycle and its role in climate. A more detailed report on the Fourth International GEWEX Science Conference may be found in GEWEX News, 11, 4 (November 2001).

As well as producing many important scientific results, GEWEX has been successful in bringing together research workers from diverse disciplines to work on the common goal of understanding the global energy and water cycle, in fostering co-operation between the scientific community and space agencies, and in making available knowledge for water resource applications. A paper assessing the overall achievements of the first phase of GEWEX was in the course of preparation.

With regard to the orientation of the second phase of GEWEX, it was recalled that the overall guiding principles have been expressed as follows:

- 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.

Specifically, emphasis would be given to two complementary aspects:

- improving the observation, understanding, and representation of processes that produced precipitation in all phases, with the objective to improve precipitation forecasts and their applications for the management of water resources. Inter alia, this would require joint consideration by GEWEX projects of the critical aspects of observation strategies, data processing and modelling with respect to both precipitation prediction and applications, and the development of methods for assessing precipitation observation and prediction at an appropriate scale, compatible with satellite and model data. The assessment of skill of current models in precipitation forecasting at various space and time scales being undertaken by WGNE (see section 10.1.9) would provide valuable input in this regard;

- contributing to the work being undertaken throughout the WCRP on how the simulation of global precipitation statistics could be improved and how these statistics might vary as a consequence of climate variability or climate change. This would depend on a significant improvement in the simulation of the water cycle in climate models, in turn requiring the development of a new generation of parameterization schemes (e.g., involving the application of cloud-resolving models) and estimating the probability of distribution of various precipitation-producing systems associated with various dynamic modes of the global climate system.

The development of GEWEX activities was being oriented on the above lines e.g., the extension and refinement of the GEWEX global climatological data sets (see section 4.3) involving a better integration of satellite and other sources of data and exploitation of the many new sources of remotely-sensed information; the implementation of CEOP which should set new standards on international exchange of data and scientific products between agencies and research groups.

To reach the ambitious goals set in Phase II, close co-ordination was needed between GEWEX and a range of other activities. This included several interactions with CliC on precipitation and the hydrological cycle in cold regions, and with CLIVAR on the predictability and variability of monsoon systems. The GEWEX Radiation Panel was jointly organizing with WGCM a workshop on the crucial issue of cloud-climate feedback (see section 10.2.2). The co-operation between the GEWEX Modelling and Prediction Panel and WGNE continued to be reinforced, embracing particularly assistance from NWP centres in providing routine model analysis and forecast data required in CEOP. GEWEX and WWRP projects were complementary in many areas and GEWEX would certainly contribute to the hydrological component of the World Climate Programme (WCP-Water), particularly through the development of the Water Resources Applications Project (WRAP)(see section 4.2.2). GEWEX would play an important role in the WCRP/IGBP/IHDP joint projects (see section 2.2), particularly in that concerned with water where the hydrological community should take the lead. GEWEX was also closely involved in the development of the IGOS water cycle theme (see section 2.4). GEWEX, since its inception, had been a major user of remotely-sensed data and has formulated requirements for new and improved observations from space (which have served as a basis for several of the new research missions). GEWEX would continue to keep the planning and implementation of satellite missions under review to assess how well its own (and other WCRP) requirements were being met.

Finally, looking further ahead, the GEWEX Scientific Steering Group had suggested that it could be timely to consider preparation of a "Second GARP Global Experiment" (SGGE) adapted to climate research priorities, following on the First GARP Global Experiment in 1979. Advantage could be taken of the enormous progress in modelling the overall Earth System and of the wide range of new environmental satellites in the period 2005-2010. SGGE could be seen as a co-ordinated weather-climate experiment, building on the CEOP, THORPEX and GODAE initiatives. The GEWEX community would be ready to contribute strongly in the planning and preparation of such an activity.

The JSC was appreciative of the advances in GEWEX planning in the past year and the development of the specific concepts that would be studied in GEWEX Phase II. This and GEWEX projects in Phase I represented a wide-ranging contribution to WCRP activities as a whole. The JSC particularly looked forward to seeing the overall assessment of the achievements of the first phase of GEWEX in the next few months. With respect to the GEWEX discussion of a "SGGE", this was taken into account in the elaboration of the concept of the "predictability assessment of the climate system" and extensive range of supporting activities necessary (see section 3.1).

4.2 Hydrometeorology

The objective of the GEWEX hydrometeorology thrust, as currently expressed, was "to improve the capability to predict variations in water resources and soil moisture on seasonal and annual timescales as an element of WCRP's prediction goals for the climate system" and was thus central to GEWEX Phase II. The building blocks in the strategy have been a number of regional research initiatives leading towards global application. Five "continental-scale experiments" to investigate energy and water budgets over large river basin/drainage areas and to study physical processes that determined surface fluxes of energy and water over land had been implemented: the GEWEX Continental-scale International Project/GEWEX Americas Prediction Project (GCIP/GAPP) over the USA; the Baltic Sea Experiment (BALTEX); the McKenzie GEWEX Study (MAGS); the Large-scale Biosphere Atmosphere (LBA) experiment in Amazonia; and the GEWEX Asian Monsoon Experiment (GAME). These experiments have made substantial progress, and were now maturing further and being oriented to GEWEX Phase II, including being integrated into CEOP. An affiliated 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 initiated and should soon become part of a larger research investigation focussed on the African monsoon. A new continental-scale experiment for the Murray-Darling Basin has been proposed, and two other initiatives having strong links to CLIVAR were in planning: the North American Monsoon Experiment, NAME (as a component of GAPP); and the La Plata

Basin study. More detailed accounts of these activities, the development of the overarching CEOP, and other critical support tasks are given in the paragraphs below.

These extensive endeavours collectively brought together some five hundred scientists in studying water and energy fluxes and reservoirs over a range of continental areas. Each experiment entailed major efforts to acquire the observations necessary to characterise the regional hydrological cycle and to build up simulations with the appropriate atmospheric, land surface and hydrological models (either used separately or coupled, see section 4.2.2). The same successful strategy would be continued in the future, with the pursuit of the existing regional experiments, development of the co-ordinated approach by hydrological, land-surface and atmospheric scientists, and enhanced interaction between the experiments fostered by CEOP. A small number of new projects would be integrated into this strategy (such as the Murray-Darling Basin experiment and an African monsoon experiment). Overall, the hydrometeorological community would play a central role in extending the relationship and joint work between GEWEX and other water resource and application programmes.

Whilst acknowledging the progress that had been made, the JSC pointed out that many uncertainties remained in the behaviour of the hydrological cycle. Furthermore, closer co-operation between GEWEX and the WMO Hydrology and Water Resources Programme in assembling run-off and basin data sets could be valuable.

4.2.1 Progress in the continental-scale experiments

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. Several new types of data such as GPS water vapour column measurements, radar network and satellite cloud climatology products were collected. Water budgets over the entire Baltic area were available for limited periods and progress was being made in assembling the budgets for a full annual cycle. A comprehensive regional coupled atmosphere/land-surface/hydrology/ocean/sea-ice model was being developed and tested. A second phase of BALTEX for the period 2002-2005 was in preparation (as an integral part of CEOP), and would also include research on seasonal predictability and regional climate change scenarios.

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. In the first phase of GAME, a series of process studies in the main regions of interest in understanding the behaviour of the Asian monsoon and its role in the global energy and water cycle (a tropical monsoon region around the Bay of Bengal, the Tibetan plateau, a large river basin in China and part of Siberia) have been undertaken. Critical observational and monitoring networks have been established in each area, and co-ordinated sets of observational data and analyzed products assembled. Model studies have been initiated. The second phase of GAME, organized as a component of CEOP, has been planned in co-operation with CLIVAR (and would be known as the "CEOP Asia-Australia Monsoon Project", CAMP).

GEWEX Continental-scale International Experiment (GCIP)/GEWEX Americas Prediction Project (GAPP)

GCIP was the first 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. GCIP has now been completed and its overall accomplishments were being reviewed at a conference in New Orleans in May 2002. The data collected included a unique ensemble of high resolution precipitation (gauge and rain radar observations) and hydrological data as well as soil moisture and radiative flux measurements at selected sites. Three major results have been the closure of the water and energy budget over the Mississippi River Basin, the identification of the land surface processes important in forcing the atmosphere on timescales up to a few weeks (this has stimulated improvements in surface parameterization schemes and the assembly of a 1 km resolution land-surface data set), and the demonstration of the utility of precipitation forecasts in the management of water resources. GCIP has now evolved into GAPP which extended the GCIP approach to the western part of the USA. The two main objectives formulated for GAPP were to:

- develop and demonstrate a capability to make reliable monthly to seasonal predictions of precipitation and land-surface hydrologic variables through improved understanding and representation of land surface and related hydro-meteorological and boundary layer processes in climate prediction models;

- interpret and transfer the results of improved seasonal predictions for the optimal management of water resources.

GAPP would be a key component of CEOP with the establishment of four reference sites, the development of an operational land-surface assimilation scheme, and studies of the transferability of regional coupled atmospheric-hydrological models. GAPP would also contribute to the work on the North American monsoonal circulation and quantification of carbon fluxes over the North American sub-continent.

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 in land 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. A range of climate and hydrological modelling studies was now being undertaken making use of the global model (70 km resolution) of the Centro de Previsao de Tempo e Estudios Climaticos (CPTEC) of Brazil and the CPTEC (Eta) regional model at a resolution of 20 km. The closure of the water budget over the Amazon basin remained a priority. LBA would play an important role in CEOP with high resolution data available over Amazonia from a new series of field experiments. Among these was that focussed on the South American low-level jet being planned jointly with CLIVAR (see section 8.2.1) which would provide a better knowledge of the moisture transport between Amazonia and the La Plata river basin. A second international LBA Conference was scheduled for July 2002.

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, and improving the ability to assess changes in Canada's water resources that could arise from climate variability and human-induced climate change. The first phase of MAGS has been completed and a description of the overall scientific achievements, notably the importance of the comprehensive joint meteorological/hydrological data set compiled, and the progress in describing understanding, modelling and closing the energy and water cycle budgets in an Arctic continental basin, published in a scientific review article. MAGS has now embarked on a second five-year phase (2001-2005) focussing on the response of the energy and water cycles to climate variability and change, and applications of predictive capabilities to climate, water resource and environmental aspects in the MacKenzie basin and other high latitude regions.

Murray-Darling Basin Water Balance Project

Plans were being drawn up by the Australian Bureau of Meteorology and the University of Melbourne for a water balance project in the Murray-Darling Basin. The objectives were to:

- enhance the capability of the operational systems of the Bureau of Meteorology to provide accurate and reliable estimates of the real-time surface water budget across the Murray-Darling Basin;

- measure the spatial and temporal variability of soil moisture and temperature across one part of the basin;

- identify and reduce key limitations in the representation of soil moisture and temperature in Bureau of Meteorology atmospheric models;

- develop products for water authorities in the Murray-Darling Basin.

The project would involve a range of observational and modelling studies drawing on the hydrological expertise of the University of Melbourne, and the atmospheric modelling experience of the Bureau of Meteorology. The core of the observational programme would be detailed observations of soil moisture and temperature at 18 sites in the Murrumbidgee River Basin (a tributary of the Murray-Darling), providing a unique data set for the evaluation and development of numerical models.

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, with the objective of examining 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. As well as the installation of a hydrological network in Ouémé catchment area, an additional small river basin was being instrumented and a precipitation radar should be added in 2003. CATCH would now be a component of a much larger multi-scale African Monsoon Experiment that was being planned (see section 8.2.3) and which would involve a much wider community. Aspects of major interest were the reinforcement of the rawinsonde network during the period 2004-2005, and the data from the hydrometeorological network in the CATCH area up to 2010.

4.2.2 Supporting projects and activities

Water and Energy Balance Study (WEBS)

WEBS was a specific activity within the GEWEX hydrometeorology thrust aiming to quantify and characterise the water and energy budgets and reservoirs on a regional scale for each of the continental-scale experiments and for other areas. Significant progress was being made by using the available data in conjunction with global and regional models.

Water Resources Applications Project (WRAP)

The objective of WRAP was to foster and encourage the dialogue between the users of hydrometeorological data and predictions and the GEWEX research community involved in assembling the data and building global models. An initial workshop has been organized with new linkages being developed between the different communities, which should improve the application of GEWEX results. The hydrological and climatological communities, as represented in the water component of the World Climate Programme, appeared to be reacting positively to this effort.

Data management

Attention was being given to access to and distribution of the variety of often specialized data sets produced by the continental-scale experiments. A particular effort was the compilation of a first collective precipitation data set. This data management activity was also fundamental in the preparation of CEOP and would feed into the overall WCRP-wide discussion on this topic (see section 3.2).

Modelling

Large-scale hydrological modelling was being carried out as part of the continental-scale experiments, in several cases using coupled atmosphere/land-surface models. In BALTEX, an intercomparison of models has been undertaken. The transferability of models from one region to another was being tested, and global models validated over the various continental-scale experimental regions. Evaluation of models and their transferability would also be a specific activity in CEOP. Generally, the capabilities of and shortcomings in prediction of hydrological-related parameters over the continental-scale-experimental regions on time-scales from a few days up to interannual were being studied.

4.2.3 Co-ordinated Enhanced Observing Period (CEOP)

The overall goal of the GEWEX Co-ordinated Enhanced Observing Period (CEOP) was to understand the influence of continental hydro-climatological processes on the predictability of the global atmospheric circulation and changes in water resources, with a particular focus on heat source and sink regions that could drive/modify the climate system and anomalies. A wealth of data to enable testing of atmospheric model parameterizations would be provided. Synchronous common data sets from all the

GEWEX continental-scale studies, together with remotely-sensed environmental data sets, and global model fields would be collected for a period from 2001 to 2003.

Specifically, CEOP was designed to:

- document, understand better and improve the simulation and prediction of water and energy fluxes and reservoirs over land for water resource applications;

- document the seasonal march of the monsoon systems and understand better their physical driving mechanisms and their possible connection.

A database of in situ and remotely-sensed measurements would be created including those from a number of carefully selected reference stations closely linked to observing sites in the GEWEX continental-scale studies as well as model output. A pilot global hydro-climatological data set would be compiled to assess and improve the representation of water and energy cycle processes in global and regional models. Full details were available at **http://www.gewex.com/ceop.html**.

CEOP depended on close co-ordination with many other activities in WCRP, including especially CLIVAR for monsoon-related studies, and WGNE in interfacing with modelling centres in data assimilation, parameterization and forecast validation work, as well as considering model data sets needed to complement observations. The recognition of CEOP by the IGOS partners as the first element of the Integrated Global Water Cycle Observations Theme (see section 2.4) was definitely encouraging the direct participation of the environmental satellite operators in CEOP.

The JSC welcomed the refinements in the planning of CEOP and the steps towards the implementation of the project since its twenty-second session (March 2001) and looked forward to seeing concrete results. It was acknowledged that CEOP could be viewed as a major comprehensive global climate study and in that respect would be a significant contribution to the new WCRP banner on the predictability assessment of the climate system (see section 3.1). The JSC urged all WCRP projects/project groups to provide support to CEOP as appropriate. The JSC noted the important efforts of science and funding agencies in the implementation of CEOP and, in particular, expressed its appreciation of the leadership of Professor T. Koike and the major role of Japan.

4.3 Radiation and GEWEX global climatological data sets

In this thrust of GEWEX, studies of all important radiative processes, particularly the effects of clouds and aerosols, were being undertaken, and several global climatological data projects, based to a large extent on merging satellite data with in situ measurements, have been organized. Progress in understanding atmospheric radiation was kept under review (see section 4.3.1) and, in particular, an informal list of achievements in atmospheric radiation-related studies of the past twenty years, highlighting the contributions from GEWEX (i.e. the radiation projects) was being compiled. The outstanding problem was not just cloud/radiation interaction and the effect on three-dimensional radiative flux fields; a full assessment of clouds/radiation/dynamics interaction (which appeared to be essential in evaluating cloud-climate feedback) was now necessary. This would also lead into topics such as the three-dimensional coupling of radiation with the cloudy boundary-layer, turbulence and the land surface.

One of the primary goals of the global climatological data projects (see section 4.3.2) was to foster a systematic (longer-term) global record of atmospheric and surface parameters needed for diagnosing the co-variability of global energy and water budgets and the processes that played a role in this. Several data sets now extended to ten years or more. The aim was to cover a twenty-year period, and in the second phase of GEWEX, emphasis was being placed on advanced diagnosis, exploiting new satellite products, and identifying signatures of climate variability. A "standard" set of statistical and diagnostic analyses to be applied to all the GEWEX global data products (and possibly others) in order to characterise the variability of parameters in a common manner and thus enable a joint analysis should be defined. All this required major efforts on a combined interpretation and analysis of data and much closer interaction with users of the data and the modelling community. Additionally, the exploitation of new satellite data sets, involving the elaboration of practical multi-wavelength/multi-instrument analyses for application to very high volume data sets, needed substantial resources. However, support in these areas was, as noted in section 2.4, severely lacking, and the commitments that were necessary were reiterated by the JSC.

The activities in the radiation thrust of GEWEX were one of the main links with the space agencies and depended on the continuity of measurements from operational and polar orbiting satellites. In this regard, NOAA plans have been encouraged, and interaction with EUMETSAT was being enhanced. As a consequence of CEOP, there was increasing liaison between the radiation and hydrological communities, and, as noted earlier, the GEWEX Radiation Panel was collaborating with WGCM in considering how to make progress in studying radiative feedbacks in the climate system (see section 10.2.2).

Intercomparison of radiation codes in climate models (ICRCCM)

A study of parameterizations of cloud variability effects on short-wave scattering in radiative codes was nearing completion. Treatment of small-scale variability as "an independent column approximation" appeared to provide fairly accurate results. A more extensive set of test cases for long-wave computations with a full range of cloudiness variability has also now been compiled.

Sea Flux

The possibility of obtaining estimates of global ocean evaporation, the diurnal variation of sea surface skin temperature, and surface heat flux from satellite data at high-resolution space- and time-scales was being carefully explored. As well as drawing on satellite radiance measurements, the use of scatterometer and ocean altimetric data now offered the prospect of significant refinements to the type of algorithms that could be employed. Several wide-ranging comparisons of in situ data, satellite-derived parameters, flux data sets, NWP and reanalysis products as well as of flux algorithms had been organized. An important resource was an extensive web-based library of in situ data sets (including direct turbulent flux measurements, skin and bulk sea surface temperatures, wave information and vector winds) that had been assembled (see **http://paos. colorado.edu/~curryja/ocean/intercomparison-cg.html**).

Land Flux

A similar concept to that of Sea Flux to obtain refined, high-resolution estimates of heat and moisture fluxes over land was being developed. Comparisons of analysis methods, retrievals and products would be organized, a "global" analysis approach followed, and a global data set produced. This would be of vital service to the continental-scale experiments and CEOP.

Profiling clouds, precipitation and water vapour

A new effort was being undertaken to obtain atmospheric profiles of clouds, precipitable water, and water vapour as well as other radiatively important tropospheric constituents such as aerosols. This would require co-operation between various sites that had prepared atmospheric profile data sets over a period of several years, even if not continuously. The main source of basic data would be radar and lidar observations. Among issues that would be discussed were analysis methods, and common practices and data formats to facilitate wider use of these data sets.

International Satellite Cloud Climatology Project (ISCCP)

ISCCP has now completed more than eighteen years of data collection. Full details of the wide range of ISCCP cloud product data sets (from 30 km/three-hour to 300 km/monthly resolution) and up-to-date calibration information are posted on the ISCCP home page **http://isccp.giss.nasa.gov**. Recent research work, complemented by a specific analysis of ISCCP data, has pointed to a means of parameterizing the radiative effects of small-scale cloud variability in atmospheric circulation models. Work was also being undertaken to attempt to explain the slow variation in the global monthly-mean cover observed in the tropics.

International Satellite Land Surface Climatology Project (ISLSCP)

Progress was now being made in the production of the ISLSCP multi-disciplinary land surface/vegetation Initiative II climatology data sets thanks to funding provided by NASA's Hydrology Program. The data set, which was expected to be completed by the end of 2002, would comprise 382 key parameters on a uniform 0.5° x 0.5° grid spanning the ten-year period 1986-1995 (cf. the Initiative I data set with 159 parameters on a 1° x 1° grid for two years 1987-1988).

Global Aerosol Climatology Project

A monthly-mean aerosol record over the ocean only at a resolution of 300 km over an eleven-year period has been compiled, after the development of a two-channel retrieval approach. However, uncertainties in calibration of radiances cannot be resolved with current data. The time variations seen in the global aerosol thickness and average size appeared to be consistent with other observations of the evolution of stratospheric aerosols between volcanic events.

Surface Radiation Budget

A twelve-year radiative flux data set (1983-1995) inferred from remotely-sensed data at three-hourly intervals and spatial resolution of 100 km and including upwelling and downwelling short and long-wave fluxes at the surface and the top of the atmosphere was being produced by the NASA Langley Research Centre. This work continued to be complemented by the activity in the Baseline Surface Radiation Network which had the objective of observing surface short- and long-wave radiative fluxes at the highest attainable accuracy in a number of contrasting climatic regions. Data from 30 functioning sites in 19 countries were being collected at a central archive (the Swiss Federal Institute of Technology, Zurich) with data records up to seven years now available in some cases. Particular progress has been made in refining instrument calibration and measurement capabilities, and proposals have been made for standardizing observing procedures for aerosol optical data.

Earth Radiation Budget

A twenty-one year record of top-of-the-atmosphere radiative fluxes from the NIMBUS-7 ERB instrument, ERBE, ScaRab and CERES now existed. Despite overall questions concerning the continuity of this record, it appeared that a long-term variation in the tropical outward-going long-wave radiation was consistent with the change in cloud cover.

Global Precipitation Climatology Project (GPCP)

The GPCP data set had now been extended to cover a twenty-two year period (1979-2001)(pentad and monthly means on a 2.5° x 2.5° grid) and a four-year period (1997-2001)(daily estimates on a 1° x 1° grid). The preparation of an hourly product on a 1/2° grid was being considered. Data from the Tropical Rainfall Measuring Mission (TRMM) have offered a valuable possibility of validating and improving the GPCP retrieval algorithms. New microwave algorithms and procedures for using simultaneous data from several satellites were also being developed, and the means of implementing a "snowfall" product was being considered. On the research side, the issue of interannual variability of precipitation and possible variation linked to global change would be examined. A workshop on the "objective analysis of precipitation" had been proposed.

GEWEX Water Vapour Project (GvaP)

The initial GvaP pilot study provided a ten-year record of tropospheric water vapour (daily and monthly means at 300 km resolution). For the moment, GvaP was continuing as a study project organizing comparisons of existing water vapour data sets and assessing the potential of new algorithms and data becoming available.

Evaluation of global analyses of remotely-sensed data

An essential adjunct to the compilation of the various global climatological data sets, based on, as noted above, a range of satellite data sets, was studies of the accuracy of the methods and analyses employed. For example, ISCCP has undertaken careful algorithm intercomparisons and has drawn on a number of field studies such as FIRE, ICE, EUCREX. GPCP activities in this area have been largely incorporated into the TRMM efforts. The BSRN, referred to above, was particularly important in validating the surface radiation budget analyses.

4.4 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 regulated 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. An atmospheric boundary layer study was also now being undertaken. In view of the close relationship between the activities of the Modelling and Prediction Panel and those of WGNE, the two groups met jointly.

4.4.1 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 studies 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 had, of course, been tested in full climate simulations or in numerical weather prediction models and the organization of such activity was being considered. Attention was also being given to parameterization development, and assessing new treatments 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 under way were included in the GCSS Science and Implementation Plan (**http://www.gewex.com/gcss_sciplan.pdf)**. A general GCSS meeting was being planned in Canada in May 2002 (jointly with an ARM workshop) which would bring together all the scientists working on different cloud types and experts from the (large-scale) atmospheric modelling community.

4.4.2 Global Land-Atmosphere System Study (GLASS)

Progress was being made in the planning and implementation of GLASS which has been designed to encourage the development of a new generation of land-surface schemes for incorporation into general circulation models. As reported at the JSC session in March 2001, extensive intercomparisons of land-surface models ranging from local to global scales and from off-line experiments to fully coupled were being co-ordinated.

Recent specific local-scale/off-line intercomparisons (a continuation of activities initiated by the Project for Intercomparison of Land-surface Parameterization Schemes, PILPS) included a study of simulations of the surface hydrology in land-surface models in high latitudes. The key processes involved were the snow regime, turbulent fluxes in cold climates, and frozen soil and surface water storage. It was found that the main differences between the simulations were caused by uncertainties in the rate of sublimation from a snow-covered surface. Large differences in land-atmosphere sensible heat flux were also noted, a consequence of the decoupling of the atmosphere and surface in stable conditions. Another local-scale/off-line intercomparison in preparation was aimed at evaluating the ability of land-surface models to simulate carbon fluxes over a forested area (in The Netherlands) and to represent both the biophysical and biogeochemical processes involved, and to examine how well observed carbon sinks were captured. At a larger scale, experimentation was being planned to assess the performance of land-surface models in reproducing the discharge for a number of sub-basins in the Rhone Valley over several annual cycles (the "Rhone AGG" organized by Météo-France/CNRM as a contribution to GLASS). Questions to be investigated were the extent to which the sub-grid run-off and drainage parameterizations were scale dependent, how various aggregation methods employed compared, and the impact of grid resolution on simulated surface water exchange and snow-melt run-off.

Global scale/off-line experiments were being planned using the ISLSCP Initiative II dataset to check model representation of interannual variability over a ten-year period. The sensitivity to errors in the forcing data would be explored, whether land-surface models could be satisfactorily validated at the global scale with remotely-sensed data, the comparability of drying-out cycles in different models, and the simulation of carbon dioxide fluxes at the global scale.

Coupled, local-scale experiments were beginning to indicate the importance of coupling, in particular that the effects of feedback from the planetary boundary layer could be significant. At the global-scale, experimentation was being designed to assess benefits that could result from more realistic precipitation values in improving the behaviour of land-surface schemes and the simulated climate. The role of surface initial conditions was also being investigated based on a multi-model ensemble. Soil moisture was being initialized over a three-to-four month period using observed precipitation amounts, by when it was assumed that the model soil moisture would be realistic. In the integration phase, soil moistures would be free to evolve and diverge.

It was recognized that, overall, GLASS was advancing satisfactorily. Activities in the coupled, local-scale area needed to be enhanced as this would underpin interactions with GCSS in examining the effects of an improved land-surface treatment in cloud experiments, with the "GEWEX Atmospheric Boundary Layer Study" (GABLS)(see section 4.4.3) in searching for better ways of forcing land-surface schemes outside atmospheric models, and with data assimilation studies for appropriate refinements to land surface models.

4.4.3 GEWEX Atmospheric Boundary Layer Study (GABLS)

The twenty-second session of the JSC in March 2001 was informed of a proposal for a "GEWEX Atmospheric Boundary Layer Study" (GABLS). The principal objective would be to improve the representation of the atmospheric boundary layer in general circulation models, based on advancing the understanding of the relevant physical processes involved. GABLS should also provide a framework in which scientists working on boundary layer research issues could interact.

The initial focus of GABLS would be the treatment of the stable atmospheric boundary layer over land, for which understanding and parameterizations were limited (e.g. see reference to issue noted above concerning decoupling of the atmosphere and surface in stable conditions). Details of the work needed were being developed at a workshop at ECMWF, Reading, UK, in March 2002, in which process-oriented experts and large-scale modellers were being brought together.

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

Professors M. Geller and A. O'Neill, Co-chairs of the SPARC Scientific Steering Group, summarized the main recent developments in SPARC, including the principal items and recommendations from the ninth session of the SPARC Scientific Steering Group held in Honolulu, Hawaii, USA in December 2001. It was stressed that SPARC was very much a task-driven project directed to address specific current issues and to increase understanding of basic processes in turn leading to improved models and projections of the future. SPARC was well integrated with many other activities in WCRP and IGBP since only very few questions were limited to one component of the climate system (such as the stratosphere) alone. Particularly important and topical subjects being considered at present were chemistry-climate interactions, the dynamical coupling between the stratosphere and troposphere, and diagnosing and exploring stratospheric change.

5.1 Modelling stratospheric effects on climate

5.1.1 Intercomparison of stratospheric models

The primary goal of the "GCM Reality Intercomparison Project for SPARC", GRIPS, was to improve the representation of the stratosphere in coupled global climate models. In this respect, close co-operation with the Working Group on Coupled Modelling and the Working Group on Numerical Experimentation was maintained. As reported at the twenty-second session of the JSC, major efforts had been made in 2000 in collecting and summarizing the results of the first phase of GRIPS, an intercomparison of basic features of model stratospheric simulations. Findings had been published in the Bulletin of the American Meteorological Society and the Journal of Geophysical Research.

The past year had been one of consolidation. A number of activities within the first phase were being finalized (e.g. studies of the treatments of sudden warmings, tropospheric-stratospheric interactions). In the second phase of GRIPS (impacts of different parameterization schemes), tests of radiative codes were under way, preceding an investigation of gravity wave parameterizations. Studies of model response to formulations of mesospheric drag have been completed. The third phase of GRIPS was concerned with explaining the observed variability in the stratosphere taking into account natural variability and the forcing by changes in aerosol loading, solar radiation, and atmospheric concentrations of ozone and carbon dioxide. A few groups have begun the experimentation required (some in connection with the European projects "Solar Influence on Climate and the Environment" (SOLICE) and "Stratospheric Processes and their Impacts on Climate and the Environment" (EUROSPICE)).

A workshop of participants in GRIPS was being held in Japan in March 2002 to review the overall status of the project. The further development of the third phase of GRIPS would be considered in relationship with the integrated approach to modelling and data activities now planned within SPARC as a whole (see section 5.5) and to tropospheric-stratospheric coupling (see section 5.3.2).

5.1.2 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, 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 included upper-level radio-sonde winds from Singapore (as an indicator of the phase of the QBO) and statistics on tropopause height. Recently rocketsonde and lidar data have also been added, permitting the extension of the climatology of temperature and winds up to the middle mesosphere. These data sets could be accessed via the SPARC Data Centre (**http://www.sparc.sunysb.edu/**)(see section 5.7).

Comparisons of the various data sets have been carried out in order to identify biases, and parameters for which uncertainties are high. The comparison of the rocketsonde and lidar observations with global satellite data involved particular difficulties because of the sparse scattered nature of the former and the non-simultaneity of the records (most rocket series have been discontinued for many years). A technical report "SPARC Intercomparison of Middle Atmosphere Climatologies" summarizing the findings was being drafted and would be published as a SPARC Report in mid-2002. It was hoped that it might be possible to include data from the ECMWF Reanalysis Project (ERA-40) in the intercomparisons, but this would only be done if it did not delay the preparation of the report.

5.1.3 Stratospheric data assimilation

SPARC was fostering activities in this area to ensure that the advances in data assimilation techniques in many operational centres were exploited to obtain global quality-controlled, internally consistent data sets of the dynamic and chemical state of the stratosphere (as well as, where possible, the upper troposphere and mesosphere). The data sets would be especially designed to support SPARC-related studies of chemistry-climate interactions, with attention initially being given to making full use of the data becoming available from the ENVISAT and EOS/AURA satellites. A range of error statistics related to the utilisation and/or validation of instruments and for validation of models would also be produced.

The type of effort to be undertaken included comparisons of global stratospheric analysed data sets prepared by active groups, assembly of documentation at the SPARC Data Centre on data production methods and data quality, and organization of workshops to consider how the methodology of data assimilation in the stratosphere could be refined (e.g., to include new variables such as aerosol loadings). It was also the intention to draw on analysed data sets to prepare reports on particular aspects of interest (e.g., stratospheric water vapour and its evolution).

A small SPARC working group bringing together representatives from several of the active leading centres preparing stratospheric analyses has been formed to guide the work necessary. Close co-ordination and liaison would be maintained with WGNE.

5.2 Long term changes in the stratosphere

5.2.1 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 first phase has now been completed (with results having been reported at previous sessions of the JSC). A summary of the work was published in Reviews of Geophysics in February 2001, and the findings were also an important input to the IPCC Third Assessment Report. A full account of the activity and results was being prepared for publication as a SPARC Report in 2002 (with support from NOAA).

In the meantime, the temperature trend record continued to be updated. For the period 1979-2000, the earlier findings of a general cooling of the stratosphere were confirmed, but the significance was greater (this would be a particular contribution to the next WMO/UNEP Assessment in 2002). Additional progress has been made in the correction of inhomogeneities in radiosonde observations, and improved trend estimates have been obtained from rocket-sonde data. New model simulations of temperature trends using updated information on changes in species such as ozone and carbon dioxide have also been produced with reasonable agreement between model results and the trends inferred from observed data up to 0.5hPa.

As noted at the twenty-second session of the JSC, plans were being made to extend the temperature analyses to the upper stratosphere and mesosphere in collaboration with the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). This matter was considered at the Second Workshop on Long-term Temperature Changes and Trends in the Atmosphere in Prague, July 2001 (co-sponsored by SPARC). This set the scene for a workshop being held in Germany in May 2002 which would discuss the activities needed for a state-of-the-art assessment of upper stratospheric and mesospheric temperature trends. SPARC was contributing to the planning of this workshop, and SPARC experience in assessments of stratospheric temperature trends would be a sound basis for making progress.

5.2.2 Understanding ozone trends

The main activity in this area in the past year in which SPARC has been involved was a joint workshop organized by SPARC and the International Ozone Commission at the University of Maryland in March 2001, with the need to prepare for the WMO/UNEP Assessment in 2002 in mind. The workshop aimed to identify the major current issues concerning trends and to improve quantification of the contributions linked to, and uncertainties in, chemical and dynamic mechanisms, particularly in mid-latitudes. Attention was focussed on the dynamical influence on ozone trends. However, it was difficult to isolate separate dynamical forcings in terms of an ozone response. A comparison of statistical analyses including dynamical factors for certain baseline periods was being undertaken. With regard to Arctic ozone loss, a workshop was planned to be held in Germany in March 2002.

5.2.3 Stratospheric and upper tropospheric water vapour

The comprehensive SPARC Water Vapour Assessment (published as SPARC Report No. 2/WCRP-113) which reviewed in depth the concentration, distribution, variability and trends of water vapour in the stratosphere and upper troposphere has attracted wide interest and was being extensively quoted (there have been many requests to use figures from the report). As well as being presented at a range of meetings, the results were being used as a benchmark and background material. An offer has been made for publication commercially as a book, and this question was being considered.

5.2.4 SPARC aerosol assessment

It has long been recognized that aerosols in the upper troposphere/lower stratosphere played a significant role in climate by way of radiative effects and in stratospheric chemistry (particularly through the impact on ozone). The magnitude of the influence of aerosols was highly variable and consequently complicated identification of causes of stratospheric changes, anthropogenic or otherwise. Accounting accurately for the effects of aerosols was an essential step in understanding and modelling climate/chemistry interaction properly. SPARC was therefore planning a new initiative with the intention of providing a detailed assessment of the scientific understanding of upper tropospheric/lower stratospheric aerosols.

Important issues to be addressed included quantifying the non-volcanic background stratospheric aerosol and whether there was a trend in this, the variation of key aerosol properties (e.g., surface area, density), the representativeness of satellite-based climatologies, and how well non-volcanic gaseous precursors and models could predict observed aerosol properties. The goal was to produce a report in less than two years, which should be a landmark in its field as had been the water vapour assessment. The report was expected to comprise:

- a review of aerosol processes including those that controlled polar stratospheric clouds and cirrus near the tropopause, and nucleation at the tropical tropopause and in the post-eruption stratosphere

- a review of non-volcanic aerosol precursors

- a comprehensive climatology of the fundamental physical characteristics of aerosols, but also including important parameters such as effective radius: primarily satellite-based (SAGE/HALOE), in combination with in situ measurements for validation and identifying shortcomings

- assessment of trends in long-term primary measurements, including identification and comparison of background periods

- descriptions of modelling (background) stratospheric aerosols and comparison of model results, source gas measurements and aerosol observations.

Writing groups have been established and group leaders were being designated.

5.3 Stratospheric processes

5.3.1 Gravity wave processes and their parameterization

A particularly exciting development was the initiation of the Darwin Area Wave Experiment (DAWEX), involving scientists from Australia, Japan and the USA, designed to characterize the wave field in the middle atmosphere over northern Australia excited by intense diurnal convection in this area (known locally as "Hector"). This field experiment stemmed from discussions at the fourth session of the SPARC Scientific Steering Group five years previously (1996). Included were three five-day intensive observation periods (in October, November, December 2001) during which there were three-hourly radio-sonde observations from three north Australian locations. In addition, ground-based air-glow imagers provided by groups in Japan and the USA, radars to monitor winds in the mesosphere and lower thermosphere, and a Doppler radar (from the Australian Bureau of Meteorology) were deployed. The analysis of the data collected was just beginning and was expected to take the next two years (with a series of papers and an overview foreseen by the end of 2003). The findings and results would very much help in the preparation of the larger-scale campaign "Effects of Tropical Convection Experiment" (ETCE) in 2005 or later.

In the future, attention would also be given to a detailed review of existing data sets and encouraging appropriate new observational and modelling projects needed to characterize the spectrum of gravity-wave momentum fluxes, including their geographical and seasonal variations, and short-term intermittency. The aim would be to exploit available data and limited area model results to provide as much guidance as possible for formulating the specification of sources and saturation mechanisms in parameterization schemes (although the actual "engineering" aspects of gravity wave parameterization would be left to GRIPS). As steps in this process, it was firstly planned to convene a conference in 2003 (possibly as a Chapman Conference) at which outstanding questions in gravity-wave parameterization would be reviewed (this could be considered as a follow up to the successful workshop on gravity wave processes and their parameterization in global models held in Santa Fe in 1996). Secondly, a small specialized workshop would be organized in 2004 to assess critically the status of knowledge of the gravity wave spectrum and consider the practical implications for the parameterization of gravity wave processes.

5.3.2 Lower stratospheric/upper tropospheric processes

Activities under this heading in SPARC were concerned with the transition region between the stratosphere and troposphere. In this region, the separation in time and space of chemical, radiative and dynamical processes was not feasible because of the strong coupling that exists between them. The key characteristics of this part of the atmosphere were the very low temperatures, sharp gradients (especially in the vertical), and rapid variations of water vapour, ozone and other species. Understanding in an integrated manner the processes in which the various species were involved was essential in evaluating lower stratospheric/upper tropospheric interactions, the role of the stratosphere in climate, and in the projection of long-term changes in ozone.

The main event in the past year was the organization of a workshop on the tropopause in Germany in April 2001. The workshop brought together a diverse group of scientists (over 70 participants including many young scientists) to consider various aspects of the tropopause region - what it was, why it took the form it did, how it affected climate, and how it might change in the future. There were intensive discussions on the crucial interface between the stratosphere and troposphere, and key questions on the issue of chemistry/climate interactions were formulated. The largest uncertainties, as might be expected, were related to coupled processes. However, even the quantitative picture of tropical dehydration was still far from complete with the role of convection and microphysics still only partly understood. Coupled chemical-climate modelling of the tropopause region was still also in its infancy, although this was the region where one might expect the largest sensitivities. Renewed attention was being given to the concept of the "tropical tropopause layer" (the transition region between the troposphere and stratosphere in the tropical zone with the characteristics of both), especially because it was a chemically active region. The general view was that net stratosphere-to-troposphere exchange was controlled by stratospheric wave drag (mainly at the planetary wave scale). Two-way exchange occurred on synoptic and sub-synoptic scales bringing tropospheric air into the lowermost stratosphere, especially in the summer. It was noted that the seasonal cycle of ozone appeared to be linked to trends in tropopause height. A comprehensive review paper summarising the main conclusions and outstanding issues was being prepared which it was hoped would be a successor to the highly influential review paper of Holton et al, based on the findings of the SPARC/NATO workshop in Cambridge, UK in 1993 on stratosphere-troposphere exchange. At that time, the paradigm for global exchange was developed, but the focus was still very much on dynamics and transport. This now needed to be linked to climate, requiring the inclusion of radiation and chemistry in the conceptual framework. The review paper from the April 2001 workshop would thus be the basis for defining further research that would feed into joint SPARC/IGAC chemistry-climate activity (see section 5.4.2).

Another event of particular importance for SPARC activities in this area was the publication of a review paper on the atmospheric chemistry of small organic peroxy radicals (Tyndall et al, J. Geo. Res., 106, D11, 12157-12182, 2001). To increase the scope of the global models on which assessments of the human impact on climate and air pollution were based, it was essential that state-of-the-art representations of chemical mechanisms were included, and the referenced paper discussed the atmospheric reactions, rate coefficients and available kinetic and product data for some of the most abundant peroxy radicals (CH_3O_2, $C_2H_5O_2$, $CH_3C(O)O_2$, $CH_3C(O)CH_2O_2$). The information and data in the paper would be used in a NASA/JPL evaluation, and also by the International Union of Pure and Applied Chemistry (IUPAC) in their next update. Assistance provided in this respect by the SPARC Data Centre (see section 7) had been very valuable. Workshops have also been held in the framework of joint SPARC/IGAC activities on nitrogen oxides in the upper troposphere/lower stratosphere (Heidelberg, Germany, March 2001) and on laboratory studies of upper tropospheric/lower stratospheric processes (Breckenridge, CO, USA, July 2001).

5.4 Other scientific issues

5.4.1 Dynamical coupling of the stratosphere and troposphere

The apparent coupling between the stratosphere and troposphere as indicated by correlations in time series of the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) remained a subject of considerable interest and debate. One report showed evidence that, by selecting time series of AO amplitudes after strong stratospheric warmings, there seemed to be downward propagation of anomalies from the stratosphere to the troposphere implying that knowledge of the state of AO in the stratosphere could increase predictive skill in the troposphere. Other work has given a measure of support to this suggestion, but the potential improvement in predictive skill was small (although statistically significant). It was likely that very strong events dominated the statistical results, and ensemble modelling experiments were needed to understand causal connections and mechanisms. The SPARC Scientific Steering Group was ready, in collaboration with other interested groups (e.g. CLIVAR, ACSYS/CliC), to promote research on stratospheric-tropospheric coupling (e.g., such as that seen in the AO).

5.4.2 Chemistry-climate interaction

A significant proportion of both the IGAC and SPARC research agendas have their ultimate application in understanding chemistry-climate interactions. For instance, a central problem in stratosphere-climate interaction was to predict how polar stratospheric ozone would evolve in the future, taking account of increasing greenhouse gas concentrations and the decreasing "effective chlorine" (resulting from the actions of the Montreal Protocol and its subsequent amendments). Substantial differences existed between present model predictions, perhaps consequent to different projections of planetary wave transports in the future stratosphere. In the troposphere, a key issue was to assess the future greenhouse warming from troposphere ozone, methane, etc. In reality, predicting how the future vertical structure of atmospheric ozone throughout the trosposphere and stratosphere might change was necessary. Another problem was to investigate how the changing atmosphere might lead to changing upper troposphere-stratosphere water vapour concentrations. This could feed back to tropospheric-stratospheric chemistry, which in turn could affect tropospheric climate. Another vital factor to be considered was cloud microphysics in the upper troposphere/lower stratosphere because of the effect on radiative forcing of the troposphere.

To make progress in these coupled climate-chemistry problems would require active collaboration between SPARC and IGAC. As a first step it was proposed to convene a joint chemistry-climate workshop to plan an IGAC/SPARC "chemistry-climate" research agenda.

The JSC was particularly appreciative of the SPARC initiative in this area and the co-operation being fostered with IGAC. It was recognized that this could be a good starting point for an "Atmospheric Chemistry and Climate" initiative as referred to in section 2.2. The approach set out by SPARC offered many possibilities for future development and the involvement of other WCRP projects/groups as required, especially WGCM.

5.5 Development of SPARC scientific strategy

As noted at the twenty-second session of the JSC, SPARC studies of long-term changes in the stratosphere of temperature, ozone and water vapour had all now produced initial sets of results which had suggested that trends in one parameter were closely linked to the trends in the others, and that an increasingly integrated approach was required to understand stratopheric climate change. A new initiative "Understanding stratospheric climate change (1979-1998)" was accordingly being implemented, aiming to understand the observed trends of stratospheric temperature, ozone, and water vapour (also taking into account solar effects). A particular objective would be to elucidate upper tropospheric/lower stratospheric variability and its relationship to the overall climate system by building on and developing the modelling work carried out in the stratospheric temperature trends study and GRIPS, and the activities in stratospheric data assimilation. Strong interdisciplinary exchanges would also be encouraged.

Specifically the following questions would be taken up:

(i) Did the different observed variations provide a consistent picture of stratospheric climate variations, including the possibility of a trend over the past two decades, upon which shorter time scale variations were superposed?

(ii) Could 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 identification of the causes of these changes?

(iii) Did conditions and processes in the stratosphere have an effect on tropospheric climate down to the surface?

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 transient increases in temperature in the aftermath of the volcanisms), the 11-year cycle in solar irradiance. The investigation of the coupling of stratospheric and tropospheric modes was also a question of considerable interest (see section 5.4.1) and could be of significance for the behaviour of the overall climate system. 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 would be undertaken, including a set of simulations without any "forcing" in order to assess the role of the internal dynamical fluctuations of the modelled stratospheric climate system.

5.6 Interactions with other programmes and activities

SPARC maintained strong links and/or interacted widely as appropriate and necessary with a number of other groups/activities in WCRP (in particular WGNE and WGCM). Closer co-operation needed to be developed with CLIVAR and ACSYS/CliC in the study of the role and variability of the Arctic Oscillation. Outside WCRP, especially noteworthy was the proposed collaboration between SPARC and IGAC in coupled chemistry-climate problems (see section 5.4.2). Also important was the co-operation with SCOSTEP in the study of upper stratospheric/mesospheric temperature trends (see section 5.2.1): a joint workshop would be held in Germany in May 2002 to consider the activities needed. A close relationship was maintained with the WMO Global Atmosphere Watch (GAW) and it was agreed that the GAW seasonal ozone bulletins would be posted at the SPARC data centre. The question of measuring/specifying the intensity of the winter ozone hole in polar regions was raised, and a small joint SPARC/GAW group was proposed to define a series of key indicators. Interaction between the Network for Detection of Stratospheric Change and SPARC was also being reinforced. Liaison was maintained with COSPAR in considering how to take advantage of the expected launching in the next few years of numerous instruments that will contribute to SPARC (e.g., ENVISAT-GOMOS, MIPAS, SCIAMACHY, ADEOS-II/ILAS, HIRDLS, SAGE-III). A SPARC session was being arranged at the 34th COSPAR Scientific Assembly (being held jointly with the 2002 World Space Congress in Houston, Texas in October 2002).

5.7 The SPARC data centre

The SPARC Data Centre at the State University of New York at Stony Brook, supported by NASA, has continued to assemble key stratospheric data sets in a readily accessible form. Since its establishment in 1999, the number of data sets has grown rapidly, with many being available on line. Of principal interest were reference data sets based on UARS measurements and model analyses, and high-resolution temperature and wind observations from radio-sondes for 1998 (soon to be augmented by additional years by purchase from NOAA). Solar forcing and historic ozone data had also been acquired, as had data from the GRIPS model intercomparisons. In relation to the water vapour assessment (see section 5.2.3), a range of humidity mixing ratio observations from ground-based, airborne and satellite instruments had been archived. Recently added items include collections of rocketsonde data, and small organic peroxy radical data (see section 5.3.2). The website **http://www.sparc.sunysb.edu/** gave information on the full list of data sets available and on access and downloading.

5.8 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, a large number of reports and documents have been compiled in the past year. These included the SPARC Water Vapour Assessment and the proceedings of the SPARC 2000 General Assembly (produced as a CD-ROM). A new SPARC brochure and posters were edited for the Global Change Open Science Conference in July 2001.

5.9 Proposal for Third SPARC General Assembly

The success of, wide interest in, and large attendance at both the First and Second SPARC General Assemblies (respectively in Melbourne, Australia, December 1996, and Mar del Plata, Argentina, November 2000) have been reported to the JSC. The SPARC Scientific Steering Group was duly planning to arrange a Third Assembly and has agreed to accept a kind offer to host the event in Victoria, BC, Canada in 2004 (the exact dates proposed being 1-6 August).

6. AIR-SEA FLUXES

6.1 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 (WGASF) gave a final report on the activities that had been undertaken by the group. As noted at the twenty-second session of the JSC, WGASF had produced a comprehensive and authoritative assessment of the state of the art in regard to air-sea flux determination in 2000 (published in the WCRP report series, WCRP-112, Intercomparison and Validation of Ocean-Atmosphere Energy Flux fields, also available at **http://www.soc.soton.ac.uk/JRD/MET/WGASF/**). This report has proved to be very useful and has been widely appreciated in the interested scientific community.

WGASF subsequently organized a major workshop (Washington, DC, May 2001) bringing together the different scientific communities interested in air-sea fluxes to review the Working Group report and to consider what needed to be done in determining surface fluxes more accurately. The workshop was a considerable success with well over 100 participants from 15 countries. After initial keynote addresses (including a review of the WGASF report), sessions at the workshop were devoted to modelling and data assimilation, validation of flux products, flux fields inferred from remote sensing, and flux measurements and parameterizations. Break-out groups then took up the issues of how parameterizations could be refined and the measurements necessary, how flux estimates could be validated, and how flux products could be improved in the future. In the area of parameterizations and measurements, the case was made for an airflow distortion experiment involving suitable reference platforms and a research ship with sonic anemometers distributed around the vessel. A flux-profile study over the ocean, a radiation measurement comparison experiment, and coastal ocean studies in carefully chosen, contrasting regions conducted in a standard manner were also proposed. Regarding verification, strong encouragement was expressed for the WGNE "SURFA" project (comparing surface fluxes and near-surface fields from NWP centres with high quality observations, see section 10.1.5). The importance of developing error estimates for air-sea fluxes and near-surface fields from NWP was stressed, as well as the need to investigate new methods of direct precipitation measurement over the ocean and to expand and improve the on-line catalogue of air-sea flux data sets and their evaluation established by WGASF. Looking to the improvement of flux fields in the future, a combination of flux and meteorological products would certainly be required (this would depend on more timely delivery of flux products and including meta data with all flux data sets), detailed studies of error estimates should be undertaken as a means of quantifying and then reducing imbalances, and parameterizations valid over a wider range of environmental conditions (e.g. low and high winds) should be developed. The planned Global Precipitation Measurement mission was seen as providing an essential step in obtaining higher temporal and spatial resolution fields of atmospheric and ocean basic variables and air-sea fluxes. The full report of the workshop including all the main findings, conclusions and recommendations and extended abstracts of the presentations had been published as WCRP-115, Intercomparison and Validation of Ocean-Atmosphere Flux Fields (and could also be accessed via the web at **http://www.soc.soton.ac.uk/JRDMET/WGASF/workshop/report/html**).

WGASF (which was established as a limited-life group) formally came to the end of its mandate following the workshop in Washington in May 2001. In the attempt to evaluate existing flux fields, significant gaps in our knowledge were identified (e.g., the lack of closure for global and regional-scale energy balances, the large regional biases in flux components, details of seasonal and interannual variability of fluxes, inherent error characteristics). It was recalled that the JSC had already recognized at its twenty-second session that a new WCRP "air-sea interactions" group would need to be established. A principal task of such a group would be to keep under careful review issues related to air-sea interaction across the whole spectrum of WCRP activities.

The JSC reaffirmed the need for a continuing WCRP-level focus in this area and agreed that an appropriate group should be established. It was suggested that this group might also support the Surface Ocean-Lower Atmosphere Study (SOLAS)(see discussion of SOLAS and recommendation that WCRP should be a "co-sponsor" of SOLAS in section 6.2). This proposal would be discussed with the SOLAS Scientific Steering Group. If agreed, terms of reference and proposed membership would also be taken up with SOLAS.

6.2 Surface Ocean-Lower Atmosphere Study (SOLAS)

The JSC has been following with interest and contributing to the development of SOLAS planning for a number of years. At the twenty-second session of the Committee, the JSC agreed that WCRP should be involved in the further development of SOLAS and nominated two of its members (Dr K. Denman, Professor P. Schlosser) to be included in the (then proposed) SOLAS Scientific Steering Committee. The SOLAS Committee had duly been formally established and held its first session in December 2001. Dr Denman and Professor Schlosser outlined the further progress in SOLAS scientific planning.

It was recalled that the basic scientific focus of SOLAS was the interaction between the atmosphere, climate and marine biogeochemical processes. SOLAS was envisaged as a hypothesis-driven programme: hypotheses arising from critical issues related to global change would be posed and specific experiments and studies designed and conducted within SOLAS in order to test them. It was anticipated that, when the scientific mission, foci, and hypotheses were fully-elaborated, SOLAS should be of major interest to both the WCRP and IGBP. SOLAS was intended to build on the work of other projects such as IGAC, JGOFS 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 were to succeed.

A science plan for SOLAS had been drafted (including WCRP input): this had been presented at the twenty-second session of the JSC where it had been generally positively received (see report of twenty-second session of JSC in which the plan was summarized). The goal of SOLAS had 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". Three main foci had been defined: biogeochemical interactions and feedbacks between ocean and atmosphere; exchange processes at the air-sea interface and the role of transport and transformation in the atmospheric and oceanic boundary layers; air-sea flux of CO_2 and other long-lived radiatively active gases. Subsequently, SOLAS had officially been recognized as a new SCOR programme and IGBP had endorsed SOLAS after review.

The JSC considered the role that WCRP should play in SOLAS. In examining the latest version of the science plan, it was noted that some of the emphases earlier given to physical aspects appeared to have been somewhat diluted. Nevertheless, SOLAS could provide a satisfactory framework for studies of air-sea fluxes and gas exchange in WCRP. For example, fluxes of carbon dioxide would be an increasingly important issue for the WCRP. Furthermore, considerable merit was seen in organization of appropriate joint activities and experiments as well as in the work of the group needed for study of air-sea interactions (see section 6.1). It was also pointed out that the fundamental parameters in determining ocean-atmosphere exchanges (of energy, moisture, gases) were the ocean surface aerodynamic roughness and the surface wind speed which were key products of WCRP work. The JSC duly believed that WCRP should be a co-sponsor of SOLAS, together with IGBP and SCOR, but not a "principal" sponsor at the same level as the other two bodies. The JSC requested the Director of the WCRP to work out the formalities and details of a suitable co-sponsorship with the SCOR, IGBP and the SOLAS Scientific Steering Group with the guideline that WCRP interest would be focussed on the subset of activities directly relevant to WCRP. As noted in section 6.1, the issue of a joint group meeting WCRP and SOLAS needs in the area of air-sea interactions, including gas fluxes, should also be discussed.

7. WORLD OCEAN CIRCULATION EXPERIMENT (WOCE)

WOCE, the oldest of WCRP's projects, would formally conclude at the end of 2002. The presentation of WOCE at the 2002 session of the JSC was thus the last full account that would be given. The Co-chairs of the WOCE Scientific Steering Group, Professor P. Killworth and Dr W. Large, and Dr J. Gould, Director of the WOCE International Project Office, orchestrated a wide-ranging review of what WOCE had achieved since its inception in 1984, the progress made towards achieving the objectives as originally set out, what remained to be accomplished, and the lessons learnt that could be applicable to other WCRP projects, both current and future. Many highlights of WOCE have, naturally, been described more extensively at previous sessions of the JSC, including detailed accounts of the observational programme and the supporting technological advances in instrumentation, the contents of the WOCE data set, the landmark WOCE Conference in 1998 resulting in the publication of the outstanding book "Ocean Circulation and Climate", the analysis phase of WOCE, ocean model development, and the compilation of the WOCE bibliography.

7.1 Overview of WOCE

WOCE grew from a realisation in the late 1970s that the new generation of Earth-observing satellites presented the potential to measure the ocean circulation, wind fields and ocean surface properties globally. Thus, for the first time, the ocean circulation's role in climate could be addressed from a global perspective. Satellite observations would be only one part of the strategy to investigate this topic. The other elements would be in-situ observations and ocean circulation models, the resolution of which might be expected to improve to a level at which the oceanic mesoscale (that had been explored during the 1970s) could be resolved.

All the expected developments did indeed take place. The new generation of satellites performed beyond their design expectation both in terms of mission duration and data quality. The advent of accurate satellite altimetric measurements in the concluding years of WOCE was another vital step forward. The highest resolution global ocean circulation models changed from of order 2° in 1990 to 1/12 degree by 2002, although global runs at such high resolutions have only been integrated for periods of two to five years at present.

The WOCE in situ observational strategy was founded primarily on techniques that already existed in the late 1980s when WOCE was being planned. A main exception was the use in WOCE of a global network of neutrally buoyant floats designed to provide a subsurface reference level velocity field. This was a major technological advance stimulated by WOCE. These Autonomous Lagrangian Circulation Explorer (ALACE) floats were further developed during WOCE to provide CTD profiles and have now become the basis of the global ARGO array (see section 2.3). WOCE's observational capability also benefited greatly from the introduction of new and improved technologies (e.g., the global positioning system, ADCPs).

The observations ran from 1990 to 1997. (This was extended from the originally-planned 1990-1995 period subsequent to the delay in satellite launches). WOCE then entered its Analysis, Interpretation, Modelling and Synthesis (AIMS) phase marked by a number of regional and subject-based workshops and the publication of many papers based on WOCE modelling and observations.

An obvious and unique end-product of WOCE was the unprecedented in-situ data set describing the state of the interior of the global ocean in the 1990s. This had been available to researchers since 1998 and would appear in a final form in 2002 as the third version of the WOCE data set on CD-ROMs. The hydrographic programme data set would provide the baseline against which future and past changes in the ocean could be assessed and, as well as being an integral part of the data set, would be published over the next two years as a series of four Atlas volumes (electronic and hard copy).

WOCE was made up of a number of individual national efforts contributing towards the fulfilment of an internationally-agreed implementation plan. Some countries set themselves specific national objectives that were not necessarily identical with the international objectives. WOCE collaboration was conducted largely at an international rather than an intergovernmental level and this provided substantial freedom. An Intergovernmental WOCE Panel was formed following the 1988 WOCE international conference at which national commitments were made. The Panel was instrumental in helping to ensure that commitments were fulfilled. Notable throughout was the enthusiasm of the oceanographic science community and the support of funding agencies.

In summary, WOCE, 1984-2002, was a revolution in our ability to measure, model and understand the ocean circulation and its role in climate.

7.2 Progress towards WOCE scientific objectives

The WOCE objectives were defined in the Science and Implementation Plans as follows:

Goal 1: To develop models useful for predicting climate change and to collect the data necessary to test them

Within this first goal the specific objectives were:

To determine and understand on a global basis the following aspects of the world ocean circulation and their relation to climate:

(i) The large-scale fluxes of heat and fresh water, their divergences over 5 years, and their annual and interannual variability.

(ii) The dynamical balance of the world ocean circulation and its response to surface fluxes.

(iii) Components of ocean variability on scales of months to years and thousands of kilometres upwards, and the statistics on smaller scales.

(iv) The rates and nature of the formation, ventilation and circulation of water masses that influenced the climate system on time scales from ten to one hundred years.

Goal 2: To determine the representativeness of the specific WOCE data sets for the long-term behaviour of the ocean, and to find methods for determining long-term changes in the ocean circulation

Within the second goal the specific objectives were:

(i) To determine the representativeness of specific WOCE data sets.

(ii) To identify those oceanographic parameters, indices and fields essential for continuing measurements in a climate observing system on decadal time scales.

(iii) To develop cost-effective techniques suitable for deploying in a climate observing system.

The short papers contained in Annex C reflected the assessment of the WOCE Scientific Steering Group of the progress made towards these objectives, summarizing the status in the particular area of oceanography at the time of WOCE planning, the present situation, the advances attributable to WOCE, and the continuing or further actions now needed. The specific topics covered were:

- The large-scale fluxes of heat and fresh water, their divergences over 5 years and their annual and interannual variability

- Large scale air-sea fluxes: climatologies, uncertainties and biases

- Water mass formation and circulation

- The variability and representativeness of WOCE observations

- Cost-effective monitoring

- Developments and issues in climate modelling

Additionally, the WOCE AIMS phase included a number of workshops (as reported at previous sessions of the JSC) relating to the regional synthesis of WOCE results and aspects relevant to WOCE's scientific objectives. The results presented at and conclusions from these workshops (as published by the

WOCE International Project Office or, in some cases, special journal editions) complemented the papers in Annex C (see appropriate references in Annex C).

7.3 The overall success of WOCE and the legacy of the project

The five-year AIMS phase (1998-2002) following the WOCE observational period has been essential in crystalising the overall success of WOCE and in demonstrating the progress made. The WOCE Scientific Steering Group expressed the view that a post-observation analysis phase such as AIMS in WOCE should be a feature of all WCRP projects, as should a formal end-date that encouraged an assessment of progress that had been made and, if appropriate, transition to new activities or follow-up actions. One of the significant marks of success of WOCE was that it left the oceanographic/climate research community in a situation in which scientific advances could continue to be made without the need for an extensive formal programme structure at least for the time being.

As noted above, WOCE coincided with (and helped stimulate) a revolution in physical oceanographic measurements and largely fulfilled the goal of understanding quantitatively the role of the oceans in the Earth's climate system. This came about primarily through reductions of uncertainty in the knowledge of the ocean's circulation as a result of the collection and analysis of the WOCE data set and through higher resolution model runs, rather than the development of new paradigms. Further progress would undoubtedly continue to be made after the end of the project. The particular tasks of making a new determination of ocean heat and freshwater transports and reconciling the divergences of these with the best available estimates of air-sea fluxes was yet to be completed: this awaited the finalization of the WOCE global synthesis and the higher resolution analysis of the ocean state, as well as the further refinement of air-sea flux estimates. However, water mass inventories have already improved greatly from the wide use of WOCE transient tracer measurements.

Much of WOCE planning was based on the premise of a slowly varying ocean circulation. Nevertheless, considerable progress was also made towards the second main goal of WOCE in documenting ocean variability and establishing new measurement techniques that could be employed in extending the record of variability. This legacy provided a springboard for CLIVAR studies in this area and for implementing GOOS (see section 2.3).

In addition to the important legacy of the WOCE data set, the documentation of the scientific output of the project in the WOCE bibliography (compiled by the WOCE International Project Office) has been extremely valuable. At the time of the JSC session, this showed that there were 1600 papers in refereed journals that could have been considered to have stemmed directly from data collected in WOCE and WOCE-related research. The book "Ocean Circulation and Climate", based on the 1998 WOCE Conference, has also been recognized as an outstanding record of the advances made in oceanographic science during the 1990s.

WOCE could thus be viewed as, by far, the biggest and most successful global ocean programme to date and it had, during the past decade, provided a global umbrella under which a high proportion of physical oceanographic research had been carried out. Not all of these activities have been directly related to the role of the ocean in the coupled climate system. They have included detailed observational and modelling studies of processes that were perceived as being poorly represented in ocean models or poorly understood. WOCE was the driving force behind new and enhanced funding for marine sciences in many countries and provided an underlying rationale for building new research vessels with enhanced capabilities (endurance and size of the scientific team) needed to occupy the trans-ocean sections demanded by WOCE, as well as refitting a number of other vessels. The requirements of the WOCE hydrographic programme also provided a motivation to develop new techniques that resulted in analyses of samples being carrried out more quickly at sea. WOCE encouraged the participation, often for the first time, of a number of countries in a global-scale oceanographic project (notably Spain, Portugal, the Nordic Countries, and countries in S. America).

The success of WOCE came through many contributions - from those who conceived the idea, those who carried out the detailed planning, those who carried out the research, and those who administered the project. WOCE was clearly a prime example of clarity of planning, efficiency of execution, and the immediate scientific (and societal) value of the data collected and research undertaken.

7.4 Climate and ocean science following the end of WOCE

The JSC expressed deep appreciation for the presentations and reviews by WOCE representatives and congratulated the WOCE Scientific Steering Group for bringing WOCE successfully to its closing phases. It was noted that the final major WOCE event would be the Conference "WOCE and beyond: achievements of the World Ocean Circulation Experiment" in the USA in November 2002.

Regarding ocean science in the post-WOCE era, CLIVAR appeared to be the natural successor to WOCE and to the earlier WCRP Tropical Ocean-Global Atmosphere (TOGA) project. The JSC thus formally agreed that the WOCE objective of understanding the role of ocean in climate and long-term ocean variability should be pursued by CLIVAR (although it was recognized that the broad scope of CLIVAR did not provide the same focus for ocean research as that which came from WOCE). The JSC requested the CLIVAR Scientific Steering Group, in conjunction with GOOS, to examine the requirements for long-term ocean observations, building on the recommendations of the Conference on the Ocean Observing System for Climate in October 1999. Action needed to be taken to ensure that WOCE data sets were archived at the appropriate centres. It was foreseen that WOCE data management elements and technology development would become the responsibility of GCOS/GOOS. Specific ocean process studies needed (e.g., the spatial and temporal distribution of mixing in the deep ocean; processes controlling flows through abyssal channels and mixing and entrainment downstream of oceanic sills) should be considered by the Working Group on Ocean Model Development (see section 10.2.7), perhaps with a mechanism for setting up "climate process teams". The JSC stressed the importance of maintaining the WOCE bibliography (to be taken over by the International CLIVAR Project Office) and of publishing the WOCE atlases, the final WOCE Newsletter, the comprehensive field programme survey, and the proceedings of the Conference "WOCE and beyond".

Another key issue was the provision of an international co-ordination mechanism for research on the physics of the ocean not motivated by climate considerations. SCOR, a co-sponsor of WOCE, had a significant role in this respect, but during the 1990s, perhaps as a consequence of the dominant position of WOCE in influencing ocean physics, had focussed more on activities relating to ocean biogeochemistry and the carbon cycle. Other mechanisms might be found through IOC or through the International Association of Physical Sciences of the Ocean (IAPSO).

8. 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. There had been notable progress in the implementation of the project since the twenty-second session of the JSC, particularly in the area of observational activities. A number of cross-cutting themes were emerging, and increasing interaction of CLIVAR with other projects within and external to WCRP was required.

8.1 Ocean observations

8.1.1 Global implementation issues

The global oversight of ocean observations required for CLIVAR was the responsibility of the CLIVAR Ocean Observations Panel which worked closely with the WCRP/GCOS/GOOS Ocean Observations Panel for Climate (see section 2.3). There were also overlaps with activities being undertaken by the WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM). The JSC recalled the recommendation made in considering agenda item 2.3 that attention needed to be given to the best way of providing oversight/co-ordination of sustained global ocean observations in the face of the proliferation of groups/activities with an interest in this area.

Several topics with regard to global ocean observations (e.g. ARGO, tropical moored arrays) were discussed in section 2.3. On its side, CLIVAR has particularly pursued issues concerning the implementation of the new high density/high frequency XBT network, urging that designated zonal sections in the southern hemisphere to close the Indian and South Oceans be supported. CLIVAR has also urged that the effectiveness of aspects of data quality control and archiving systems be reviewed.

CLIVAR has fully endorsed the requirements for full depth, high quality deep hydrographic measurements for climate change detection as set out in an informal report "The need for continuing global deep ocean surveys" (prepared on behalf of the CLIVAR Southern Ocean Panel and the US Ocean Carbon and Hydrography Panel). The International CLIVAR Project Office has been documenting commitments to the reoccupations of WOCE sections over the coming decade (approximately two-thirds) and has also initiated a review of the operating procedures for high quality hydrographic measurements, which is being linked to a similar exercise being undertaken in the USA for ocean carbon measurements. Whilst CLIVAR's primary interest is the assessment of decadal changes in physical (and chemical) water mass properties and distributions, and the determination of heat and freshwater transports, the sections required to achieve these objectives would also provide an opportunity for carbon measurements. The synergy of CLIVAR/carbon measurements would be significant in the framework of the Joint WCRP/IGBP/IHDP Global Carbon Project (see section 2.2) and follow on the productive collaboration between WOCE and the IGBP Joint Global Ocean Flux Study (JGOFS) in hydrographic and ocean carbon measurements. As noted in section 2.3, a pressing issue was to oversee and to link/co-ordinate these type of ocean observations effectively across the various projects and scientific communities active in this area.

The equatorial moored buoy arrays were an essential element of CLIVAR's global observational strategy. In particular, the TAO/TRITON array in the Pacific made a fundamental contribution to climate research and forecasting on seasonal-to-interannual timescales. Resources for the network (funding, ship time, personnel) appeared stable, but, as noted in section 2.3, vandalism by fishing fleets continued to have adverse effects, particularly on the eastern and western margins of the array. Thought was being given to introducing new technology to enhance system performance where appropriate and improve instrumental accuracy. Steps were also being taken to ensure that the TAO/TRITON array was fully integrated with other elements of the global ocean observing and global climate observing systems. In the Atlantic, the same technology (ATLAS moorings) and data management/handling schemes were used for the Pilot Research Array in the Tropical Atlantic (PIRATA) in place since 1997, supported by Brazil, France and the USA. Many research groups used PIRATA data to study the phenomenology of the tropical Atlantic on the regional climate. Availability of ship time to maintain PIRATA was a concern (Brazil and France have ensured servicing of the buoys approximately once per year) and vandalism had adverse effects. Brazil, France and the USA recently agreed on a five-year consolidation phase for PIRATA, laying out the common objective and shared responsibilities for maintenance of the array. Extensions northwestward and southeastward of PIRATA were still being considered, but as yet no funding possibilities had emerged. The situation in the Indian Ocean was less encouraging, although there were several related scientific initiatives for developing a moored array in support of climate. These included two JAMSTEC TRITON buoys and those of the Indian National Data Buoy Programme in the Arabian Sea, Bay of Bengal and along the equator. As in the Pacific and Atlantic Oceans, there was evidence of vandalism. Steps to build up the Indian Ocean array have been proposed by South Africa in collaboration with neighbouring countries, and by various US research and government groups.

Large amounts of ocean data vital to CLIVAR science would be contributed by satellites. In this respect, continuity of altimetric, wind and surface temperature measurements looked promising for the current decade. The JASON-1 altimetric satellite was launched in December 2001 in an orbit identical to that of TOPEX/POSEIDON. Following extensive lobbying (including from CLIVAR), it was now expected that TOPEX/POSEIDON would continue to report until 2003. In conjunction with JASON-1, ERS-2 (launched in 1995) and ENVISAT (launched in March 2002) would provide an unprecedented coverage of altimetric data. Heat and volume transports in western boundary currents in all ocean basins were also essential for CLIVAR and encouraging results based on altimetric data in conjunction with high density XBT sections were being obtained.

In respect to ocean-atmosphere fluxes, CLIVAR has strongly endorsed the need for surface reference sites as proposed in the report of the JSC/SCOR Working Group on Air Sea Fluxes (WCRP-112, Intercomparison and Validation of Ocean-Atmosphere Energy Flux Fields)(see also section 6.1). Further, CLIVAR was duly encouraging the WGNE evaluation and intercomparison of global surface flux products (over ocean and land) from the operational analyses of the main NWP centres (the "SURFA" project - see section 10.1.5) with data from such surface reference sites.

The concerns voiced at the twenty-second session of the JSC by Dr N. Smith on the shortcomings in data and information management for ocean and marine observations (see section 2.5, Annual Review of the World Climate Research Programme and Report of Twenty-second Session of the Joint Scientific Committee, WMO/TD-No. 1096, November 2001) were reiterated, especially the lack of telemetric capacity. CLIVAR fully supported the proposal of Dr Smith to escalate research into improved data transmission and handling systems for operational oceanography and ocean research (including that to be undertaken in CLIVAR). On the complementary issue of the assimilation of ocean data that were collected, progress was being made but no scheme was as yet sufficiently mature to exploit all available observations. In the light of current capabilities, results from observing system simulation and observing system experiments for the oceans needed to be interpreted with care. There was also a definite requirement for ocean climate reanalyses (as distinct from the near real-time "operational" analyses envisaged in the Global Ocean Data Assimilation Experiment - see section 2.3).

8.1.2 The major ocean basins

Atlantic

The Atlantic thermohaline circulation appeared to have an important role in climate at decadal and longer timescales, in particular as acting as a potential trigger of rapid anthropogenic-related climate changes and influencing South American climate variability. The specific meridional configuration of the tropical Atlantic basin, bordered by two land masses with complex coastlines favoured a strong seasonal cycle which consequently interacted with lower frequency variability. Two main scientific thrusts would be followed:

- investigation of the regional three-way coupling between atmosphere, ocean and land surface;

- investigation of the regional links between the seasonal mean evolution of the background state and its variations on interannual to decadal timescales.

These would be supported by appropriate analysis and modelling studies, including regional coupled modelling to explore the effects of atmospheric teleconnections and their interaction with local processes. Another basic aspect was the link between the upper tropical Atlantic, the deeper ocean, and other ocean basins.

The meridional overturning circulation in the Atlantic was another topic beginning to receive active consideration. Discussions had been initiated with WGCM on whether modelling work could aid improved understanding of the role of the meridional overturning circulation in climate tropical Atlantic variability (see section 10.2.10).

In the South Atlantic, there were only sparse observations and no process studies at the basin scale. A workshop was being planned jointly by CLIVAR and the Ocean Observations Panel on Climate to review climate-related issues in the South Atlantic and to consider how to entrain the resources necessary for a sustained observational programme.

Southern Ocean

The Southern Ocean was a fundamental element of the global ocean circulation and global climate system. There was considerable interest and activity in this area, and there were full or partial commitments to almost all the Southern Ocean studies included in the CLIVAR initial implementation plan. Attention was further being given to defining required basic process studies such as water mass transformation in the southeast Pacific, and exchange mechanisms across the Antarctic slope front. It also remained to find resources to establish time series sites in the Southern Ocean that would contribute to a number of science areas (e.g., air-sea interaction and reference sites for air-sea fluxes, water mass formation, the carbon cycle, documentation of multi-annual variability). Full implementation of XBT lines to supplement the infrequent hydrographic sections across the entrances to the other oceans (South Atlantic, South Indian, and south of Africa) was additionally required. The determination of seasonal and interannual changes in sea-ice volume in the Southern Ocean was another challenge (this would be taken up jointly with CliC). The interconnections between the Southern Ocean and Atlantic, Indian and Pacific Oceans necessarily meant close collaboration with CLIVAR studies in these basins.

Pacific

With the availability of TAO/TRITON data, and ARGO coverage of the North and equatorial Pacific, the Pacific basin was at a more advanced level of implementation than other basins (although there was a serious shortfall in expected ARGO deployments in the South Pacific). Commitments had also been made to repeat many (WOCE) hydrographic sections in the North and South Pacific. Various supporting process studies were under way or in the planning phase. These included the East Pacific Investigation of Climate (EPIC) which was already producing interesting results on the interaction between the ocean and atmospheric boundary layer, the Kuroshio Extension System Study (KESS), the Observing System Research and Predictability Experiment (THORPEX, see section 10.1.10), and the US CLIVAR Pacific Basin Extended Climate Study (PBECS), a long-term investigation to test and improve dynamical models of ocean processes that might be involved in climate variability. In regard to atmospheric variability, the vulnerability of the operational radiosonde network over the Pacific was a matter of concern.

In meeting the many outstanding scientific challenges, contributions from the Working Group on Seasonal-to-Interannual Prediction (WGSIP, see section 8.3) were seen as important in increasing understanding of the mechanisms underlying Pacific variability (particularly ENSO), and work was also needed to explore the link between phenomena on seasonal-to-interannual timescales and lower frequency ocean and atmosphere variability. Other challenges included deeper insight into the factors controlling decadal variability and the implementation of additional observations that might be needed, and into the relationship between natural variability and human-induced climate change.

As had the Asian-Australian monsoon panel (see section 8.2.2), it was suggested that there could be benefits from establishing an intergovernmental resource board to help in the identification of support for the type of sustained observational programmes necessary (see section 8.7 for JSC discussion of this issue).

8.2 Studies of monsoonal and regional climate variability

8.2.1 The Variability of the American Monsoon System (VAMOS)

The implementation of VAMOS was in full swing with interest being shown by scientists throughout the Americas. VAMOS comprised a number of specific activities, which were at different stages of advancement. The two main foci of VAMOS internationally co-ordinated efforts were the Monsoon Experiment in South America (MESA) and the North American Monsoon Experiment (NAME).

MESA was organized in three stages, the first a study of the moisture corridor east of the Andes and participation in EPIC (see section 8.1.2). The former topic was part of the South American Low Level Jet (SALLJ) programme, a broader initiative concerned with American low-level jets. Among the hypotheses being explored in the SALLJ field experiment were that: the water vapour transport in the moisture corridor east of the Andes (by low level jets) was a key component in the water balance and exchanges between the Amazon and La Plata basins; low level jets had variability on diurnal, synoptic, intraseasonal and interannual timescales influenced by ENSO, sea surface temperature anomalies in the tropical and sub-tropical Atlantic, and by land surface conditions. The second stage of MESA would, on one hand, take up the climatology and hydrology of the La Plata basin (jointly with GEWEX, section 4.2) and, on the other, pursue "VAMOS EPIC", extending the basic EPIC activities to include data analysis, monitoring, modelling and pilot observational studies of climate variability in the eastern Pacific from USA to the Chilean coast. The third stage, towards the end of CLIVAR, would have the goal of consolidating the preceding activities into a comprehensive monitoring and scientific capability for the Americas.

NAME was expected to involve a field campaign and a range of supporting modelling and diagnostic activities, requiring the establishment of a number of international partnerships. A science and implementation plan has been drafted (and may be consulted at **http://www.cpc.ncep.noaa.gov/products/precip/monsoon/NAME.html**). The NAME field campaign should take place in 2004.

8.2.2 Asian-Australian monsoon

Current evidence, based on modelling and diagnostic studies, suggested that the evolution of the annual cycle and interannual variability of the monsoon was modulated by coupled ocean-atmosphere interactions, explaining to a degree why the monsoon exhibited relatively small year-to-year variability. Nevertheless, there existed a number of outstanding scientific questions such as the role of the Indian Ocean zonal dipole mode, the relationship of the interannual (and decadal) variability of the Asian and Australian monsoons with the phase and strength of ENSO, and the processes governing the precise onset date of Asian/Australian monsoons and their intraseasonal variability. The issue of possible changes in monsoon intensity linked to global climate change was also becoming increasingly important.

There were significant difficulties in obtaining both the real-time and historical data sets needed from nations abutting the Indian Ocean and the marginal seas. An example was the daily rainfall record for the Indian sub-continent which existed from 1900-1970 but which was not available to the research community. With regard to the Indian Ocean, the implementation of ARGO should provide a good coverage of the northern part of the ocean by 2003 and the possible build-up of an Indian Ocean moored buoy array (see section 8.1.1) should also help. Various existing and planned process studies and field experiments were also of relevance to understanding the Asian-Australian monsoon including the South China Sea Monsoon Experiment (SCSMEX), the GEWEX Co-ordinated Enhanced Observing Period (CEOP) especially the CEOP Asian-Australian Monsoon Project (CAMP) (see sections 4.2.2, 4.2.3), the Joint Air-Sea Interaction Experiment (JASMINE) which furnished compelling evidence of the role of air-sea interaction in monsoon intraseasonal variability, the Bay of Bengal Monsoon Experiment (BOBMEX), and the Arabian Sea Monsoon Experiment (ARMEX).

It was a matter of concern that model systematic errors were still a barrier to progress in seasonal and climate change prediction in monsoon regions. Marked shortcomings were the poor simulation of precipitation over the maritime continent, overly strong and variable Indian monsoonal circulation, and the inadequate representation of the intra-seasonal oscillation. The JSC pointed out that the principal modelling groups in the WCRP (WGNE, WGCM) were responsible for defining the overall WCRP modelling strategy. They were well aware of this type of problem and, as reported in section 10, were making steady progress in improving deterministic predictions and climate simulations. Information on model systematic errors that could be provided from Asian-Australian modelling diagnostic studies to WGNE and WGCM would evidently be appreciated.

Given the strong scientific, economic and social justification for building up observational systems in the Indian Ocean region and the process studies being undertaken or planned, it was proposed that consideration be given to the establishment of a "CLIVAR Intergovernmental Panel for the Asian-Australian monsoon region" (see section 8.7 for JSC discussion of this proposal).

8.2.3 African climate variability

Considerable groundwork was still required before a comprehensive research programme into the variability of the African climate system and supporting observational programmes could be fully implemented. Activities were under way although there were marked regional differences in progress. Two major limitations were the difficulty of finding resources for developing the observational network and of establishing working collaborations with local scientists.

The most intensive efforts at present were being made in West Africa, led principally by the French scientific community, but with significant contributions from Germany, UK and USA. A multi-scale African Monsoon Experiment was being planned and covering aspects such as hydrology, chemistry, agriculture and health (and would build on the Coupling of the Tropical Atmosphere and Hydrological Cycle, CATCH, experiment; see section 4.2.1). Enhanced observations would be made along two north-south transects with the foci of interest to CLIVAR being the seasonal march of the ITCZ and associated dynamical features such as the African easterly jet. A zonal transect has also been proposed in order to observe easterly waves. A long-term observing period would be complemented by a data-rescue activity and attempts to put in place new and sustained observations from 2002 onwards.

The planned southeastward extension of PIRATA in the Atlantic Ocean and the development of an array in the Indian Ocean (see section 8.1.1) were evidently of major direct interest to African climate variability studies.

8.3 Modelling activities in support of CLIVAR

Modelling activities of interest to and in support of CLIVAR were led by the joint JSC/CLIVAR Working Group on Coupled Modelling (WGCM), the joint WGCM/WOCE Working Group on Ocean Model Development and the (CLIVAR) Working Group on Seasonal-to-Interannual Prediction (WGSIP). The work of WGCM is described in detail in section 10.2 (including also that of the Working Group on Ocean Model Development in section 10.2.7). CLIVAR naturally had a key interest in WGCM initiatives, in particular the ability of coupled climate models to reproduce the natural variability of climate (in both the atmosphere and ocean) as well as the response of the coupled system to anthropogenic influences.

As regards the work in the area of seasonal-to-interannual prediction led by WGSIP, a number of activities that had been initiated a few years ago had now come to a conclusion including the ENSO Simulation Intercomparison Project (ENSIP) and the Study of Tropical Oceans in Coupled Models (STOIC)(results published in Climate Dynamics in 2001), as well as the assessment of the current status of ENSO forecast skill (published electronically by the International CLIVAR Project Office). As part of the ongoing Seasonal Prediction Model Intercomparison Project, a supporting "historical forecast project" had been organized aiming to investigate the actual forecast skill that could be obtained out to a season ahead using current model-based objective methods. A hindcast data set would be produced that could be used to demonstrate the current level of skill of forecasts up to a season ahead for a range of variables, and to support the development and application of probability forecasting, ensemble and "super-ensemble" methods.

Increasing attention was now also being given to downscaling and regional climate modelling. In this context, the review of the ad hoc panel on regional climate modelling session (see section 10.3) had been welcomed and the recommendations endorsed, including specifically the proposal for a workshop on regional climate modelling. In the future, WGSIP agreed that it should explore the possibilities for a tropical downscaling ("big brother") experiment.

The priorities for real-time and delayed-mode observations for seasonal-to-interannual prediction and requirements for process studies were also being considered. The various prediction techniques (statistical, atmospheric models, fully coupled ocean-atmosphere models) had different needs for initialisation and verification. Complex model-based systems had the greatest potential for exploiting the full range of different types of observational data, but were the most demanding in this respect: thus the current assessment was oriented towards satisfying the requirements of these models (which were thought to offer the greatest promise in the long term for improved seasonal predictions).

Although existing and planned observational systems met many of the needs, gaps were evident particularly in the area of historical and delayed-mode data used in hindcast studies, and the verification and refinement of models. Necessary atmospheric data (for the initialisation of the ocean component) included global fields of surface momentum and heat fluxes. These had to be inferred from remotely-sensed data and operational NWP systems. Although the quality of available fields was improving (e.g. as result of the work of WGNE and of the JSC/SCOR Working Group on Air-Sea Fluxes, see section 6), homogeneity over periods of a year or longer remained a problem. Precipitation fields were also crucial as forcing for salinity variations. The sea surface temperature field was essential. Uncertainties in these were currently large enough to have a significant impact in, for example, forecasts of ENSO events. Careful distinction between skin and bulk temperatures was required. High quality integrated products from an optimal analysis scheme exploiting all data sources were vital.

It was anticipated that data from the ARGO system would provide a clear large-scale view of the upper ocean and resolve most of the low frequency signals important for seasonal prediction. Altimetric measurements were a good constraint for ocean models, complementing in situ ARGO data. Tropical moored buoy arrays were absolutely critical in view of the complex, fine-scale and relatively fast evolving structures in the equatorial zone. The TAO/TRITON array gave an adequate overview of the state of the equatorial Pacific, but finer vertical resolution (and salinity data) would enable more accurate estimation of pressure gradients for assimilation into ocean models. The equatorial Pacific was of primary importance for making seasonal predictions, and the relatively modest enhancements needed appeared likely to be very worthwhile. The equatorial Atlantic was not as well observed and did not meet the requirements for model initialisation: this could undermine studies of equatorial Atlantic variability and its role in seasonal climate variability for many years to come. In the Indian Ocean, the observational requirements were not as yet clear, partly at least as a consequence of the lack of routine observations of adequate quality, past and present. There was a basic lack of understanding of the basic dynamics of variability in the Indian Ocean, and insufficient attention was being given to this in current prediction efforts (although several studies have pointed to the important role of Indian Ocean sea surface temperature in many areas of Africa, Asia and Australia). Other ocean data that might be needed were special observations in some regions (e.g. for western boundary currents, straits, sills, as these areas were not particularly well-handled in global models). Salinity has been shown to be important for some periods and locations (ARGO data should give an adequate broad-scale view of the distribution of salinity, but surface salinity observations and equatorial moorings might be needed to complete the picture). There was evidence that the velocity field in the equatorial oceans was important, but available data of this type were not yet being assimilated. Overall, for the oceans, optimal data requirements could not be specified exactly at present. The impact of ocean observations on seasonal predictions was very dependent on models and assimilation schemes, the latter being expected to improve substantially over the next decade or so. Land surface and sea-ice conditions could also result in climate anomalies at least locally on seasonal time scales, and appropriate specification of these conditions (and vegetation cover) was likely to be required.

A key step in improving current capabilities of seasonal-to-interannual prediction and in using data to refine models was enhanced co-ordination between modellers and observationalists. An end-to-end joint initiative aimed at making progress in model simulations of the equatorial zone, particularly including improved physical parameterizations of key processes, could be highly valuable and worthwhile.

In the area of seasonal-to-interannual prediction, highlights of developments at the various active centres, and other relevant initiatives were kept under review. In particular, a variety of approaches to assimilation (optimum interpolation, 3DVAR, Kalman filtering, 4DVAR) using several different ocean models was being evaluated. Early results with 4DVAR obtained at the Laboratoire d'Océanographie Dynamique et Climatologie were encouraging in the manner available data were assimilated and in the fit to current and independent data. Initial findings in both the European "DEMETER" project (aimed at developing a multi-model ensemble prediction system for seasonal-to-interannual prediction) and the International Research Institute/Arctic Regional Climate project have reaffirmed the strong sensitivity of prediction skills to season, in the sense that forecasts initialized in the early part of the year are inferior to those begun in the later part (at least in the northern hemisphere). Generally, multi-model ensembles (or "super-ensembles") were being increasingly investigated or employed for seasonal prediction in the light of evidence from some centres showing advantages in skill of such ensembles. It was planned to sponsor or organize a workshop on this topic in the near future. In other work, the use of singular vectors in diagnosing forecast reliability and improving the methodology of ensemble prediction was being studied. A noteworthy finding in this respect was that structures in the ocean thermocline were much more robust than those of most other components of the coupled system, especially, for example, sea surface temperature.

8.4 CLIVAR links to other programmes

The scope of CLIVAR was very large by any standards and there were links and intersections with most other projects in the WCRP and many activities external to WCRP. In addition to those referred to in sections 8.1 to 8.3, the interactions of CLIVAR with the IGBP Past Global Changes (PAGES) project were especially important. The opportunity to discuss joint PAGES/CLIVAR-related activities had been taken at the IGBP/IHDP/WCRP Global Change Open Science Conference (Amsterdam, July 2001, see section 2.1), in particular the development of the proposal for a Global Palaeoclimate Observing System (GPOS) (see section 2.3). As noted by the JSC in its earlier discussion, GPOS data had considerable potential for CLIVAR studies of long-term variability.

It was also recalled that CLIVAR co-sponsored with the WMO Commission on Climatology a working group on climate change detection which, as reported at the twenty-second session of the JSC, had carried out valuable work on the development and verification of climate change indices (this had fed into the IPCC Third Assessment Report). The WMO Commission for Climatology, following its quadrennial session in November 2001, had changed its organizational structure and had moved to so-called "Open Programme Area Groups". One of these was concerned with the monitoring and analysis of climate variability and change and included an "Expert Team on Climate Change Detection, Monitoring and Indices (in co-ordination with CLIVAR)". The primary term of reference was to continue to "develop and publicize indices and indicators of climate change and variability with particular emphasis on the creation of indices of daily to seasonal extremes covering the global land-surface using standardized software packages". It was foreseen that the work of the group would be linked with that of WGCM. The past successful strategy of holding regional workshops in order to entrain the active participation of local climate scientists and meteorological agencies would be maintained (the next meeting planned was in South America).

8.5 CLIVAR infrastructure

Data system

CLIVAR was continuing to consider the strategy for an appropriate data management system capable of delivering ocean and atmospheric data and products to the research community in a straightforward and timely manner. CLIVAR panels and working groups have been asked to designate representatives to identify the data sets needed and to highlight any outstanding data issues.

Regarding the different types of data and products with which CLIVAR needed to work, those from the atmosphere were mainly effectively dealt with by operational agencies (including national meteorological services, space agencies, specialized data centres) and little needed to be done by CLIVAR. Also, delivery of ocean data in real time via the GTS was expanding under the aegis of GOOS/GCOS. It was considered that delayed-mode, high quality (research) ocean data of the type collected in WOCE were most appropriately handled through continuation of the WOCE structure of data assembly centres, each managing and providing quality control for a single data stream (e.g., hydrography, current meters, drifters). CLIVAR would work in conjunction with GCOS and GOOS in this respect. Another potential approach that has emerged was that operational and research (or WOCE) data centres relayed information to regional and process study centres where products and integrated data sets could be prepared. It was recognized that the role of the International CLIVAR Project Office in the overall CLIVAR data system in compiling a comprehensive central inventory of all CLIVAR-relevant observations, both global and regional, was of paramount importance, but this had major resource implications.

Several of these data issues went beyond CLIVAR alone, and in some cases, cut across other WCRP projects. This again underlined the importance of the continuing dialogue between WCRP projects in this area as had been recommended by the JSC aimed at programme-wide action in developing the appropriate approach to data management and information systems in the WCRP (see section 3.2).

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 United Kingdom whilst, following renegotiation, USA support that was previously used to meet the costs of the "CLIVAR Chief Scientist" had enabled two new staff members with expertise in the areas of monsoons, climate extremes, ENSO and ocean biogeochemistry to be recruited. The International CLIVAR Project Office continued to benefit from the services of a staff member working at the Institut für Meereskunde in Kiel (funded by Germany and Canada). As well as servicing a range of CLIVAR meetings, and production of documents and reports, the development and maintenance of a high quality web site together with a searchable data base of CLIVAR projects and current gallery of images reflecting CLIVAR research activities was, and would remain, a high priority. As CLIVAR grew in complexity, the web-based CLIVAR tracking project, a data base of information concerning CLIVAR implementation, would evidently become an increasingly valuable resource. Another specific task in the past year was the preparation of a new CLIVAR brochure, particularly for the IGBP/IHDP/WCRP Global Change Open Science Conference in July 2001.

The Director of the International CLIVAR Project Office, Dr J. Gould, would be retiring in September 2002. Following a normal search and recruitment process, Dr H. Cattle (at the time of the JSC session, Chair of the ACSYS/CliC Scientific Steering Group and present at the session in this capacity) had been invited to take up the position of Director of the Office. The JSC wished Dr Cattle success in his new role.

8.6 Organization of CLIVAR Science Conference

The JSC endorsed the proposal for the organization of a major CLIVAR Science Conference in Baltimore, MD, USA in June 2004. The Conference organizing committee would be chaired by Professor L. Bengtsson.

8.7 Resource issues

Whilst progress had been made in the implementation of CLIVAR over the past year, lack of support for the required activities in several regions of the world was an increasing difficulty. The attention of the JSC was drawn to the case of CLIVAR initiatives in South America. The Director of the WCRP was duly requested to prepare a circular letter that could be sent from WMO under the signature of the Secretary-General of WMO to South American National Meteorological and Hydrological Services describing relevant WCRP/CLIVAR(VAMOS) activities to encourage interest and involvement. This would also serve to increase the awareness of meteorological and hydrological services of these activities, their timeliness, and the benefits that would be achieved, as well as advertising the link (through CLIVAR) to WCRP as the parent programme (and hence to WMO itself and the other sponsoring organizations). Generally, the need to search vigorously for additional funding mechanisms (e.g. non-governmental) to enable CLIVAR initiatives to advance was strongly stressed: the Directors of the WCRP and of the CLIVAR Project Office were asked to make a concerted effort in this regard, drawing on the good offices of JSC members in their home countries to assist in making appropriate contacts.

The JSC discussed the possibility of establishing an intergovernmental panel or resource mechanism for CLIVAR (and/or components of CLIVAR as had been explicitly mentioned in the consideration of activities required in the Pacific Basin, see section 8.1.2, and in the studies of the Asian-Australian monsoon, see section 8.2.2) as a means of helping in the identification of the necessary resources/support and providing a framework for commitments and international implementation. The potential value of such a panel or mechanism had to be weighed against the disadvantages of the heavy overhead involved in setting up and organizing the meetings needed and the difficulty of managing this type of body. Moreover, it was noted that recent discussions of a similar question in relation to GCOS have indicated that there was considerable reluctance to establish intergovernmental mechanisms. The possible role of a body such as the International Group of Funding Agencies for Global Change Research (IGFA) should be examined.

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

Dr H. Cattle, Chair of the ACSYS/CliC Scientific Steering Group, Dr I. Allison, one of the Vice-chairs of the group and Dr C. Dick, Director of the International ACSYS/CliC Project Office, reviewed the main developments in ACSYS and CliC during the past year. It was recalled that ACSYS had commenced its main observational phase on 1 January 1994 and would formally draw to a close at the end of 2003. CliC had been endorsed as a WCRP project by the JSC in March 2000 as a broader programme of cryospheric research, building on the foundation of ACSYS. The basic approach adopted by the ACSYS/CliC Scientific Steering Group for the transition from ACSYS to CliC had been endorsed by the JSC at its session in March 2001. Against this background, the overall guiding priorities in the past year had been:

- conclusion of ACSYS observational programmes and related studies and ensuring that important ACSYS activities needed for CliC (and the WCRP as a whole) were continued under CliC, summarising results and achievements (this would be in part the role of a final ACSYS Science Conference that was being organized), making data sets available on CD-ROM;

- formulation of CliC observational and modelling activities;

- seeking national commitments to CliC goals (by wide dissemination and discussion of the initial CliC implementation plans, leading to a CliC Commitments Conference);

- strengthening links and co-ordination of CliC activities with other WCRP projects and relevant research observational programmes outside WCRP as necessary.

9.1 Main progress in and results from ACSYS/CliC studies

Arctic Ocean circulation

Data needed to quantify the exchanges of water mass between the North Atlantic and Arctic Oceans continued to be assembled from various national, European, and other international initiatives. In particular, a section across the Fram Strait (by the German polar research vessel POLARSTERN) was carried out during 2001. A long-term time series of measurements of inflows and outflows between the Arctic Ocean and the peripheral sub-polar seas would be provided by the Arctic/Subarctic Ocean Flux Array (proposals submitted for funding by the European Union).

Attention also continued to be paid to the Canadian Arctic Archipelago, including a hydrographic survey in the Nares Strait (between Ellesmere Island and Greenland), a major flow channel between the North Atlantic and Arctic Oceans. This was complemented by a section across the Smith Sound in 1997 and one further north across the Kennedy Channel. Current meter moorings were deployed in the Barrow Strait in the Lancaster Sound. These measurements would all contribute to quantifying the flow through the Canadian Arctic Archipelago.

Collaborative Canadian-Japanese-US studies were pursued in the Bering-Chukchi-Beaufort Seas and western Canadian Arctic Archipelago. Furthermore, major new fieldwork had been undertaken to investigate shelf-basin interactions in the Beaufort Sea, and the influence of Mendeleyev Ridge and Chukchi borderland on the Arctic Ocean circulation.

An (ACSYS/CliC) workshop was being planned (June 2002) to highlight the observed features of the Arctic Ocean circulation, present model results, and consider comparison with observations and the best means of validation, and explore the most effective design of observing systems for the circulation of the Arctic Ocean.

Arctic sea ice

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 addition to moorings in the Fram Strait from prior to 1990, the thickness of sea ice and seasonal changes have been monitored at three sites in the Beaufort Sea for more than eleven years. A mooring at the north pole was established by the USA in 2001. 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. Estimates of the thin ice fraction from Radarsat were now provided on a semi-operational basis. A cryospheric monitoring project initiated by Canada in 2001 would also contribute sea-ice data, namely weekly measurements of land-fast ice and snow thickness at Arctic coastal stations, and of the thickness of pack ice from a mooring in the Canada basin. Regarding historical data, a US/Russia joint sea-ice atlas for 1950-1994 was released on CD-ROM, and the Canadian Ice Service made available its ice charts for the Canadian Arctic for 1958-1967, and for the Hudson Bay and the east coast of Canada for 1956-1967 (also on CD-ROM). However, putting the data sources together, only a rudimentary knowledge of total ice volume in the central Arctic would be obtained. Unresolved uncertainties were a consequence of the poor spatial-temporal coverage, and lack of information on observational errors.

Sea-ice motion was another key parameter. The International Arctic Buoy Programme (IABP) was the principal source of data in this respect, although Radarsat products were available for the 1996-1997 and 1997-1998 winters. Under optimum tracking conditions, the Radarsat ice-motion vectors were as accurate as those from buoys. However, less-than-optimum conditions were frequent in the northern hemisphere summer (at the edge of image swaths, within a few hundred kilometres of coastlines, or other areas where deformation was large). The irregular timing and long intervals (3-7 days) between Radarsat observations also posed difficulties in interpretation. Overall, there remained a critical need for observations of sea-ice motion particularly in the seasonal ice zone and marginal seas that was not being met by the IAPB or Radarsat products.

Research into ocean-ice-atmosphere interactions was also essential in understanding the processes involved in the adjustment of Arctic sea ice 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. Sub-surface sea-ice process studies were additionally needed in understanding the evolution of the thickness of sea-ice. Fieldwork in this respect was being conducted in the Beaufort Sea, but observations of thick ridged ice to test ridging theory remained a gap.

It was noted that ACSYS/CliC was fully involved in the topical and controversial discussion of the apparent thinning of sea ice in the Arctic. The ACSYS/CliC Observation Products Panel, following a request from the Arctic Ocean Science Board, was assessing and preparing a report on the current state of knowledge on sea-ice thickness in the Arctic (being presented at the Arctic Ocean Science Board meeting in April 2002). There was a growing consensus that changes in Arctic ice during the 1990s had been driven primarily by changes in the atmospheric circulation (e.g. the unprecedented retreat of ice from the Alaska coast in 1998 had been influenced by the 1997-1998 El Niño). Recent research had also pointed to the role of interdecadal atmospheric oscillations on sea-ice export from the Arctic Ocean.

To assist further in the evaluation of sea-ice thickness measurements, an expert meeting on the quality control of ice-profiling (or upward-looking) sonar data was being convened in July 2002. Other relevant events were an open workshop on sea-ice extent and the global climate system, and an open "mini-conference" on long-term variability of the Barents Sea Region, being held consecutively in Toulouse, France in April 2002.

The Arctic atmosphere

Studies of the Arctic atmosphere depended largely on the ECMWF and NCEP/NCAR reanalyses (see section 10.1.8). The preparation of the forty-year ECMWF reanalysis (ERA-40) 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). However, of particular concern was a cold bias seen in the lower tropospheric temperature in the Arctic in the initial ERA-40 production, probably in turn resulting in anomalously high precipitation totals in the same area. The cause was identified as deficiencies in the assimilation of HIRS data over sea ice, and the problem was being rectified. This was a very valuable consequence of the interaction of ACSYS/CliC with ECMWF in the ERA-40 initiative.

The Arctic hydrological cycle

The main activities under this heading were the compilation of an Arctic hydrological data base and the development of Arctic hydrological modelling (both in collaboration with GEWEX as appropriate). In respect to the former, an Arctic precipitation data archive has been organized on behalf of ACSYS/CliC by the Global Precipitation Climatology Centre at Deutscher Wetterdienst in Offenbach, Germany. Recent improvements made included the correction of systematic errors in synoptic precipitation observations taking account of the phase of the precipitation, development of a technique using snow-depth data to refine the climatological analysis of solid-state precipitation, and preparation of a more accurate large-scale precipitation climatology for the Arctic catchment area. Advantage would also be taken of the compilation of a comprehensive climatological database of precipitation, snow cover, surface air temperature and mean sea level pressure for the period 1890-2000 (in support of CLIVAR).

An Arctic run-off data base continued to be maintained by the Global Run-off Data Centre (GRDC) in Koblenz, Germany. This comprised measurements from a total of approximately 2000 run-off stations (200 on a daily basis, the remainder monthly) (see **http://www.bafg.de/grde.htm**). A "Pan-Arctic" run-off data base (including 1600 monthly mean data sets from the territory of the former Soviet Union and daily discharge data from 56 stations in the Russian Arctic) was available at the University of New Hampshire, USA (see **http://www.r-arcticnet.sr.unh.edu**).

Data and information management

An ACSYS data and information service was maintained by the International ACSYS/CliC Project Office. In the past year, efforts have been made to establish a comprehensive reference list of national and international projects, archive sites, and institutions relevant to ACSYS (see **http://www.npolar.no/oelke/adis.html**). The work to support this data and information service and to extend its capabilities for CliC was a significant demand on the very limited resources of the ACSYS/CliC Project Office (see section 9.5), and the lack of core funding for this type of activity was a serious concern. Attempts were being made to try and find additional resources.

As ACSYS approached its final stages, attention was being given to how best to advertise and make available ACSYS data sets and the essential complementary meta-data. Data sets that would represent the "legacy" of ACSYS were being identified.

Another relevant development was that a new "Sea-Ice Products" web page has been set up by the US National Snow and Ice Data Centre (**http://nsidc.org**), offering references to data sets from passive microwave, visible and infrared satellite sensors, sea-ice charts, ice-draft measurements from submarines, information on snow cover and its extent, and other data. Within the Russian Federation, steps were being taken to make important snow data sets available to the polar research community, as well as facilitating access to historical Arctic ice charts (co-ordinated with the International Arctic Research Centre).

Modelling activities

The activities being undertaken were being extended to meet the wider requirements of CliC, including coupled ice-ocean modelling in the Southern Ocean. An issue in this respect was the lack of suitable sea-ice thickness data for model evaluation. Among other topics being taken up were the representation of vertical mixing in the ocean, the parameterization of ocean/ice-shelf interactions, tidal effects and the role of coastal polynyas. Enhanced collaboration would be fostered between interested research groups. There would also be close interaction with the Ocean Model Intercomparison Project, being organized by the Working Group on Ocean Model Development (see section 10.2.7). This could particularly involve assessment of the treatment of ice-ocean interactions under high latitude shelves. The importance of ocean models representing an open Bering Strait and of including contemporary sea-ice dynamics formulations would also be stressed. Furthermore, close co-ordination between the Ocean Model Intercomparison Project and Arctic Ocean Model Intercomparison Project would be useful.

Following conclusion of the European Ice Sheet Model Intercomparison (EISMINT), consideration was being given to a follow-on activity. This would be aimed at advancing knowledge of climatically important ice-sheet processes and improvements in their representation in climate models.

Observation products

The data and further cryospheric observations required to support ACSYS/CliC modelling activities, particularly those relevant to the southern hemisphere, were being reviewed. Data relating to sea-ice cover, motion, thickness, snow cover on sea ice, ice shelves and their movement and the Antarctic atmosphere, and available in situ observations were sparse and not adequate for model validation. Remotely-sensed data from visible and microwave satellite-borne sensors did offer sufficient spatial and temporal coverage over the Southern Ocean and Antarctica for at least a preliminary validation of model results. Moreover, space-borne radar and laser altimeter methods to estimate ice thickness in the Southern Ocean were under development with the potential to provide the data needed for model verification.

Interesting findings were reported to the JSC regarding ice concentrations derived from passive microwave data for the period 1978-2000: a small positive trend in ice extent over the Southern Ocean was apparent, consistent with the slight Antarctic continental cooling observed in the same period. This was in striking contrast to the negative trend in Arctic sea-ice cover. However, the Antarctic peninsula had warmed by more than 2K since 1940 with a retreat of the ice shelf over the last century (notably the spectacular collapse of the Prince Gustav and parts of the Larsen ice shelves as documented by satellite observations).

9.2 WCRP Antarctic research

The 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 in 1995 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. The area covered was south of 55°S, encompassing the Southern Ocean and Antarctic marginal seas within the maximum seasonal sea-ice extent. Participants in the programme, with support from WMO and WCRP, have resolved to continue this self-sustaining initiative of the WCRP and the WMO/IOC Data Buoy Co-operation Panel.

Details of the programme were available on the web site **http://www.ipab.aq**. Synoptic data from the buoys reporting in real time on the GTS were archived at the Marine Environmental Data Service, Canada (as the responsible National Oceanographic Data Centre for drifting buoy data). The IPAB co-ordinating office (now located at the Scott Polar Research Institute, Cambridge, UK) also maintained a research data base for all buoys, including those not reporting via the GTS and those reporting location only. There was a relatively slow rate of deployment of IPAB buoys in recent years. It was thus encouraging that the number of buoys deployed in 2001 rose to nineteen - three in the Weddell Sea, four East Antarctica, and twelve in the area between 170°E and 60°W (the Bellinghauser, Amundsen and Ross Seas). In October 2001, the total number of active buoys amounted to twenty-five, twenty-one of which were equipped with an air pressure sensor and nineteen reported data via the GTS. Taking account of stated intents, the number of instruments could be expected to be slightly higher in the coming years. The data collected were used operationally by National Meteorological Services and in support of a wide variety of studies of the Antarctic sea-ice zone and for validation of sea-ice motion estimates inferred from remotely-sensed data. The buoy data have demonstrated clearly the highly dynamic nature of Antarctic sea ice and also that ice drift was on average divergent over much of the Antarctic sea-ice zone. This drift and deformation played a major role in determining the ice-thickness distribution.

Despite the value of the high-latitude southern hemisphere buoy data in meteorological analyses and 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. The possibility of approaching the WMO Commission for Basic Systems and the WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology with a request further to promote support of IPAB was now being considered.

Antarctic sea-ice thickness project

The participating institutions in this initiative which began in 1990 were the Alfred Wegener Institute for Polar and Marine Research (Germany), the Antarctic Co-operative Research Centre (Australia), the Norwegian Polar Institute, and the Woods Hole Oceanographic Institution (USA). Since the inception of the project, forty-three moorings with upward-looking sonars have been deployed, providing twenty-five records of ice thickness over varying time periods. Ten moorings equipped with upward-looking sonars were active at the beginning of February 2002 with plans in hand to recover four of those. Loss of moorings to icebergs, and of records because of shortage of memory or power failure, remained problems. More detailed information on the project's activities and results was available at **http://www.awi-bremerhaven.de/Research/IntCoop/Oce/ansitp.html**.

Every mooring record collected was of considerable importance, providing unique information on ice draughts in the neighbourhood of Antarctica. The data were also likely to be indispensable in calibrating remotely-sensed estimates, and co-operation with satellite data groups developing sea-ice thickness products was being strengthened (in line with CliC plans to become involved in the announcement of opportunity for CryoSat validation).

9.3 Development of CliC

CliC Implementation Plan and Commitments Conference

The initial implementation plan for CliC was being developed from the CliC Science and Co-ordination Plan reviewed at the twenty-first session of the JSC (March 2000) (the Science and Co-ordination plan was finalized, printed and distributed as WCRP-114, WMO/TD No. 1053 in 2001). For the implementation plan, a drafting group had been specially constituted, with the overall work being co-ordinated by the International ACSYS/CliC Project Office. As discussed at the twenty-second session of the

JSC (March 2001), most ACSYS activities would need to be continued in CliC in one form or another and this featured in the plan. The draft of the implementation plan would be available by May 2002 (posted on the CliC web page). Comments would be invited from all those having an interest in the subject matter and in the CliC project. It was recognized that, for the success of CliC as a whole, it was very important to ensure the support of the plan by potential participant countries, organizations and scientists, and thus all comments would be collected, reviewed and reflected in the implementation plan. A CliC "Commitments" Conference would then be organized (probably in 2004 in Geneva) with the "stability of the global cryosphere/climate system" as a particular theme. Much work was necessary leading up to the Conference in promoting CliC objectives and in attracting the interest of relevant national research agencies. Support from JSC members would be especially important in ensuring that CliC did receive the backing in terms of resources that was needed.

Building contributions to CliC

As with other WCRP projects, it was recognized that establishing national CliC committees would provide an efficient mechanism for increasing awareness of CliC, channelling support, and ensuring that CliC itself was informed of and responsive to national priorities in cryospheric research. The formation of national committees and/or national or regional groupings was therefore being strongly encouraged. It was noted that China had already set up a national CliC committee (under the chairmanship of Professor Qin Da He, a member of the CliC Scientific Steering Group and Permanent Representative of China to WMO).

Two other meetings had recently taken place that would help in strengthening national and/or regional contributions to CliC. Firstly, an ad hoc meeting on a USA programme on the Climate and Cryosphere was held in Washington, DC in January 2002 (convened by the US Polar Research Board and Climate Research Committee). The issue of whether and how to initiate a US CliC programme analogous to that on CLIVAR was taken up. North American participants in the CliC Scientific Steering Group and other CliC working groups/panels would prepare a summary and recommendations for submission to potential USA agency sponsors. In the meantime, it was seen that the US Study of Environmental Arctic Change (SEARCH) programme could make a key contribution to CliC. A draft memorandum of understanding between CliC and SEARCH has been prepared and was being reviewed.

Secondly, an "Asia CliC meeting" took place in Japan in February 2002 (organized by the Institute of Low Temperature Science, Hokkaido University/Japan Frontier Research Programme for Global Change, the China Meteorological Administration, and the Institute of Geography of the Russian Academy of Sciences) with participants from China, Japan, Mongolia, Nepal and the Russian Federation. The priorities and issues for cryospheric research in Asia in relation to climate studies, national plans, and areas of possible co-operation were reviewed. The discussions were successful in creating an awareness of CliC among the participating countries and might thus serve as a catalyst for CliC in Asia. Efforts would be made to advance CliC activities in the respective countries and contact would be established with other countries in central Asia that could be interested in CliC. An inventory of CliC-related data sets would be compiled, national focal points nominated, an Asia CliC plan developed, and contributions put forward for updating the CliC Science and Co-ordination, and implementation plans.

Organization of similar meetings in other regions would clearly be beneficial, although the main support (including finance) would have to be provided regionally or nationally.

Linkages to other programmes/activities

There were extensive areas of common interest between CliC and CLIVAR including, in the Southern Ocean, interaction of sea-ice and ice shelves with the ocean circulation, and co-ordination of observing programmes and experiments. Data from IPAB (see section 9.2) would clearly be of value to CLIVAR. There was also scope for co-operation in Arctic activities (particularly with CLIVAR Atlantic studies), for example, in the promotion of repeat hydrographic sections, co-ordination of various observing programmes, including the International Arctic Buoy Programme, and the assessment of exchanges of water mass between the Arctic and Atlantic Oceans.

Among CliC/GEWEX interactions was the contribution to CEOP being made by CliC which, in return, would draw on the cryosphere-related elements of GAME, MAGS and BALTEX. Another important joint activity was a workshop on cold region precipitation being held in Alaska in June 2002 (also being sponsored by GCOS). The workshop would review the current status of measuring solid precipitation in cold climate regions and put forward recommendations for determining precipitation over a range of time and space scales for climatological and hydrological analyses and regional water budgets. CliC and GEWEX were also moving forward jointly on promoting the development of an Arctic HYCOS as a component of the World Hydrological Cycle Observing System (WHYCOS) being fostered by the WMO Hydrology and Water Resources Programme. CliC interest lay particularly in the significant role of Arctic river run-off in the circulation of the Arctic Ocean and changes in ice cover.

Links to programmes/activities outside WCRP included those to:

- the Global Terrestrial Observing System networks on glaciers, permafrost, mountains and hydrology

- the study of the Mass Balance of Arctic Glaciers and Ice sheets in relation to Climate and Sea-level changes (MAGICS)

- the Global Land Ice Measurement from Space (GLIMS) initiative

- the Global Change and Antarctic (GLOCHANT) programme of the Scientific Committee on Atmospheric Research (SCAR), in particular the component concerned with Antarctic Sea-ice Processes and Climate (ASPeCT)

- the IUGG International Commission on Snow and Ice (consideration was being given to forming a joint CliC/ICSI partnership for the observation of global snow and ice, analogous to the Partnership for Global Ocean Observations)

- IGBP/PAGES on ice sheets

Proposed sponsorship by the Scientific Committee on Antarctic Research (SCAR)

A proposal had been made by SCAR for co-sponsoring CliC jointly with WCRP. The SCAR wished particularly to nominate a number of members on the ACSYS/CliC Scientific Steering Group. The principle of SCAR involvement was welcomed by the JSC but it was recommended that there be detailed and careful discussions on the terms of the association of SCAR with CliC, the possible appointment of members on the ACSYS/CliC Scientific Steering Group by SCAR, the funding/support that would be provided and potential advantages for WCRP, and related aspects.

9.4 Synthesis of ACSYS results and celebration of ACSYS achievements

A final ACSYS Conference was being planned for 2003 with the intention of summarising ACSYS results and achievements and highlighting the progress made in understanding the Arctic climate system.

9.5 The International ACSYS/CliC Project Office

The International ACSYS/CliC Project Office continued with its basic tasks of co-ordination of national commitments of resources and logistic support for the implementation of ACSYS and CliC, developing a data management and information system, and assisting in the organization of ACSYS/CliC meetings and workshops. In addition, as well as maintaining the ACSYS and CliC websites, a new newsletter "Ice and Climate News" (two issues so far) has been prepared, and other publications assembled. The format of the newsletter had been revised from its (ACSYS) predecessor, and positive feedback had been received from a number of readers. The major contribution of the Norwegian Polar Institute in continuing to host and provide the main support for the operation of the ACSYS/CliC Project Office was gratefully acknowledged, as was the valuable assistance from the Norwegian Science Council and the Japanese Marine Science and Technology Agency (JAMSTEC).

However, with the range of activities being undertaken, the resources of the ACSYS/CliC Project Office were now severely stretched. In particular, as noted in section 9.1, lack of funding and manpower to support the ACSYS/CliC data and information service was a serious concern. JSC members were asked urgently to seek out possibilities in their home countries for suitable secondments of staff and financial contributions to the International ACSYS/CliC Project Office.

10. CLIMATE MODELLING

The fundamental unifying and integrating theme in the WCRP was the development of comprehensive global models of the full climate system, pulling together and building on the results provided by the other supporting discipline-oriented WCRP projects. Such models were the fundamental tool for understanding and predicting natural climate variations and establishing projections of climate change. Activities in this area in the WCRP were centred round two main groups: the CAS/JSC Working Group on Numerical Experimentation (WGNE) and the (WCRP) Working Group on Coupled Modelling. The Chairman of WGNE, Dr K. Puri, summarized activities being undertaken under WGNE auspices concerned with the development of the atmospheric component of climate models, including a number of model intercomparison projects, the evaluation and intercomparison of surface flux fields produced operationally by NWP centres, reanalyses, and NWP topics of interest such as verification and comparison of precipitation forecasts and developments in ensemble prediction (section 10.1). On behalf of WGCM, Dr B. McAvaney reported on the wide range of WGCM initiatives, notably the Coupled Model Intercomparison Project and organization of carbon-cycle experimentation (jointly with IGBP/GAIM) that were leading to steady progress in the development of fully coupled atmosphere/ocean/land/cryosphere models fundamental to WCRP (section 10.2). Comments by WGCM on the proposal to initiate a major new project in the WCRP on prediction and predictability were noted in section 3.1. The report of the joint WGNE/WGCM ad hoc panel, reviewing the state of the art in regional climate modelling and identifying outstanding questions, was also presented (section 10.3).

10.1 Atmospheric modelling activities in support of WCRP

10.1.1 Organization of WGNE work

In view of their joint role at the core of climate modelling in the WCRP, close co-ordination was maintained between WGNE and WGCM. WGNE also worked in conjunction with GEWEX in the development of atmospheric model parameterizations and, in this respect, WGNE sessions were held jointly with the "GEWEX Modelling and Prediction Panel". Furthermore, liaison was maintained with the SPARC "GRIPS" project (focussed on the intercomparison of model stratospheric simulations) (see section 5.1.1) and with the new SPARC initiative on stratospheric data assimilation (see section 5.1.3).

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. A particularly strong area of collaboration was in the planning and development of The Observing System Research and Predictability Experiment (THORPEX).

10.1.2 Model intercomparison projects

A key element in meeting the WGNE basic objective to identify errors in atmospheric models, their causes, and how they could 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, based on a community standard control experiment simulating the period 1979-1996, was now reaching the end of its second phase (AMIP-II). Twenty-three modelling groups had submitted simulations and much of the data from these runs were available for a wide range of diagnostic sub-projects. A few further groups might provide integrations before the end of the year, the time limit recommended by WGNE for the current phase of AMIP. In addition to the standard runs, ensembles and runs at varying horizontal resolutions were being archived for specific research sub-projects. Climatological comparisons were available for nearly every standard AMIP model output field, and probably represented the most comprehensive source of the climatologies of atmospheric circulation models. AMIP research was structured round a series of diagnostic sub-projects and a clear view of how models have evolved since AMIP began nearly a decade ago has emerged. Overall, there has been a general improvement both in terms of the "median" model as well as for many of the individual models. The simulation of interannual variability and performance in specific geographical regions, as measured by global climatological statistics, also appeared to be more realistic. Regular updates of the overall status of AMIP, model integrations, diagnostic subprojects were posted on the AMIP home page **http://www-pcmdi.llnl.gov/amip**.

On the technical side, PCMDI had now completed an open source software system which enabled much more efficient management of the voluminous AMIP data sets. An automatic system has been put in place to organize the simulations, perform extensive quality control, and make the data accessible (via FTP) to interested users. Most importantly, modellers could now access a "quick-look" summary of the performance of submitted runs, thus enabling PCMDI to turn towards developing increasingly advanced model diagnostics.

In reviewing AMIP, it was noted that the project had become a well-defined experimental protocol for testing global atmospheric circulation models. However, although useful, model intercomparison by itself left many questions unanswered. Thus, the "I" in AMIP might now also stand for "Infrastructure" in view of the powerful capabilities PCMDI had built for handling model integrations, and so effectively facilitating the diagnosis and display of many characteristics of the results. The co-ordination with the Coupled Model Intercomparison Project (CMIP) (see section 10.2.3) was being increased, in particular to encourage the preparation of an AMIP simulation using the atmospheric component of coupled models, as has been recommended by WGNE. A second international AMIP conference would be held in November 2002, and would highlight the results from the AMIP-II diagnostic sub-projects and provide an opportunity for activity reports from the participating modelling groups.

Looking beyond the conference, WGNE strongly supported the continuation of AMIP as an experimental protocol providing an independent evaluation of atmospheric models and facilitating increasingly advanced diagnostic research. It was considered that AMIP should evolve from a "snapshot" exercise (such as AMIP-I and AMIP-II had been) into an ongoing activity, with modelling groups submitting updated runs with new versions of their models every few years (at a time of their choosing) and that a centralized library of these simulations (including a model median) should be maintained as a gauge of progress in atmospheric modelling. A number of other suggestions were put forward to be taken into account in drawing up a blueprint for the future of AMIP and in planning the AMIP conference in November 2002.

The JSC fully recognized the importance of AMIP and the infrastructure that had been set up. The value of continuing the project was strongly stressed, but it was considered that more emphasis should be given to an observational component, verifying simulations against available relevant data sets rather than simply an intercomparison of model results. It was seen that the "SURFA" project (see section 10.1.5) represented a significant step in this direction.

"Transpose" AMIP

In operational NWP, models used for forecasting and data assimilation were tested against reality routinely, sometimes several times a day. The requirement to provide as accurate analyses and forecasts as possible was a powerful stimulus to careful refinements of the parameterization of physical processes in operational models. It appeared unlikely in general that use of an atmospheric climate model (at the type of resolutions typically employed) in an operational system would approach the level of skill and realism of a state-of-the-art NWP model. The question was how to obtain the benefits conferred by application of a model operationally in forecasting and assimilation for developing the parameterizations in climate models. The basic idea of a "transpose" AMIP (or a similar exercise "Analysis of Tendency Errors" being considered by PCMDI) was to examine how well climate models predicted the detailed evolution of the atmosphere at the spatial scales resolved by these models, and to explore whether errors occurring in short-range forecasts (six hours up to a few days) with climate models might suggest how the physical parameterizations could be improved. How best to take advantage of field programme data (e.g., from the Atmospheric Radiation Measurement programme, ARM) to refine models and the possible relationship between initial (forecast) errors and long-term systematic errors were other key aspects. Forecasts from operational analyses and/or reanalyses using (atmospheric) climate models needed to be prepared and compared (on a climate scale) with verifying analyses in regions with adequate data (so that the background operational model forecast did not dominate the analysis).

The initialization and spin-up of forecasts were likely to be critical aspects. The basic approach would be to map the climate scales as represented in the analyses onto the climate model grid. In principle, such a mapping of atmospheric variables of state was straightforward except insofar as changes in orography and the vertical co-ordinate system were required. The handling of other physical parameters which have a time history (e.g., cloud water) was less obvious, but might be possible if details of the parameterizations in both the climate model and analysis model were known. Land-surface variables were even more problematic in face of the difficulties of mapping discrete/discontinuous variables, different representations of land surfaces in different models, and the lack of a uniform definition of land-surface variables. It would be necessary to spin up the land surface variables and possibly certain other key variables in atmospheric parameterizations for a period of a few months. In the case of the former, a start would be made from a land model climatology with attention given to achieving appropriate values for those variables affecting surface fluxes (deep, slowly evolving soil layers near to climatology would probably not present a problem). During this process, either the atmospheric state could be updated with analyses periodically (e.g., daily), or a term added to the model variables to relax the predicted state towards the analysis.

A project on these lines was being developed and appropriate contacts would be taken with potential participants in discussing how to proceed. Advantage would also be taken of the experience in the Global Land-Atmosphere System Study (GLASS) (see section 4.2) where the planning of global scale interactive integrations had faced similar difficulties in the initialisation of land surface and soil variables.

Snow Models Intercomparison Project (SNOWMIP)

SNOWMIP was being undertaken by Météo-France (Centre National de Recherches Météorologiques, Centre d'Etudes de la Neige, CNRM/CEN) under the auspices of WGNE and the International Snow and Ice Commission (ICSI) of the International Association of Hydrological Sciences. Liaison was also maintained with the Global Land-Atmosphere System Study (GLASS). The project was aimed at intercomparing and evaluating the variety of snow models that have been developed for applications ranging from climate modelling, hydrological simulations, snow stability and avalanche forecasting. The basic approach was the point validation of the simulation of several properties of the snow-mantle (snow depth, snow water equivalent, snow temperature profile, and in some cases the fine scale characteristics of the snow). Initial conditions and forcing data from four sites at various altitudes (Col de Porte, France; Weissflujoch, Switzerland; Sleepers River, Appalachians, USA; Goose Bay, Canada) were supplied to participating groups at the end of 2000. The snow models could also be run coupled with underlying soil models rather than with the prescribed heat fluxes from the ground. Twenty different groups have submitted simulations from twenty-four snow models, with preliminary results being discussed at the IAMAS Scientific Assembly (Innsbruck, Austria, July 2001). A large scatter in results from different models was apparent and further detailed analysis was being undertaken. However, there was little difference in using an underlying soil model or prescribed heat flux (the heat flux from the ground was very small anyway). More information was available at **http://www.cnrm.meteo.fr/snowmip/**.

Comparisons of stratospheric analyses and predictive skill in the stratosphere

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 have significantly increased the vertical extent and resolution of their models and associated data assimilation and predictions in the stratosphere and into the mesosphere. WGNE was thus undertaking a new intercomparison of stratospheric analyses, to be followed by an assessment of model predictive skill in the stratosphere. Interested groups were being invited to submit analyses for the period January-February 2000. Subsequently, centres would be asked for forecasts (based on their own analyses) to at least ten days, and, preferably up to twenty days in order to be able to assess the limit of useful predictability in the stratosphere. Fields at daily intervals of u, v, z, T, RH on pressure levels (1000, 850, 500, 200, 100, 70, 50, 30, 10, 1 hPa) on a 2.5° x 2.5° latitude/longitude grid, as well as sea-level pressure and isentropic potential vorticity at 500K, would be collected. Comparisons would be made with UKMO analyses (in pressure co-ordinates). This work closely complemented that carried out in SPARC "GRIPS" and data assimilation studies.

International Climate of the Twentieth Century Project (C20C)

The objective of the International Climate of the Twentieth Century Project, developed under the leadership of the Center for Ocean-Land Atmosphere Studies (COLA) and the UK Met 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 has involved carrying out "classic" C20C/extended AMIP-type runs using the observed sea surface temperature and sea ice as the lower boundary conditions (the HadISST 1.1 analyses provided by the Hadley Centre) for the period 1949-1997, with a minimum ensemble size of four members. Some participating institutions began the experiments from an earlier date (HadISST 1.1 extended back to 1871). A small common set of diagnostics has been saved from the 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.

A second (optional) ensemble of experiments was being planned with specified values of most of the known external forcings, both natural and anthropogenic (again ensembles of at least four members starting from 1871 or 1949). A third set of experiments (also optional) was being designed to explore the role of the land surface in recent climate change and variability, particularly at the regional scale, probably beginning from 1970.

10.1.3 Standard climate model diagnostics

The WGNE standard diagnostics of mean climate had now been in use for a number of years and, in particular, were the basis for the "quick-look" diagnostics for AMIP simulations computed by PCMDI (see section 10.1.2). (The list of these standard diagnostics was available at **http://www.pcmdi.llnl.gov/amip/OUTPUT/WGNEDIAGS/wgnediags.html**.)

The diagnostics of mean climate included certain variance and eddy statistics, but additional parameters to describe large-scale climate variability at a range of frequencies were needed. Over the past two years, attention had thus been given to preparing a list of "WGNE standard diagnostics of variability". For the present, these were focussed on summarising the variability simulated in the troposphere of atmospheric climate models. The diagnostics being considered should already have been used and demonstrated (with examples from a specific model), easily computed (perhaps with code supplied), and stable (in the sense of not being strongly influenced by natural variability so that representative values could be obtained from a single AMIP simulation without ensembles being required). The proposed list of variability or phenomenological diagnostics included those related to intraseasonal variability, the Madden-Julian Oscillation, ENSO, blocking, wavenumber-frequency power spectra, precipitation rates, the seasonal cycle, and atmospheric angular momentum.

10.1.4 Developments in numerical approximations

The range of approaches being followed in numerical approximations for integrating partial differential equations on a sphere, and the types of grids being tried, were well illustrated by the scope of presentations at the 2001 Workshop on the Solution of Partial Differential Equations on the Sphere in Canada, May 2001. Examples included, for the shallow water equations, techniques for using icosahedral, cubed sphere, and spherical grids. Likewise for baroclinic systems, to which much more attention was now being given, methods using icosahedral, cubed sphere, spherical grids with variable resolution, and adaptive meshes were described. In the vertical, although an example of the application of finite elements was presented, traditional "sigma" co-ordinates were still very much in use. Additional studies in this area (e.g., to take advantage of isentropic co-ordinates) were now definitely needed. The problem of representation of the "pressure gradient" term also remained somewhat neglected.

Specific consideration was also being given to the development of new methods for application in climate models, and for simulation of atmospheric transport (e.g., of aerosols, trace chemicals) where local conservation and preservation of the shape of distributions were essential. Energy conservation in climate models was of particular importance. In practice, conservation of better than 0.1 Wm^{-2} was needed, whereas schemes with non-linear intrinsic diffusion (e.g., Lin-Rood, monotonic semi-Lagrangian) could lose energy at a rate of 1.5 Wm^{-2}, as could explicit diffusion schemes. This loss should be converted to heat, but this might not be the correct approach. This was still a basic uncertainty in model formulation that must be kept in mind.

There was considerable continuing activity in this area with various workshops in the course of the coming year that should bring together the atmospheric modelling and the computer science communities, but these links needed to be reinforced. The numerical representation of orography and transport modelling remained particular issues which WGNE intended to follow. Another important component of activities in this area was the development of tests of the various numerical schemes/grids in a baroclinic system before introduction into complete models where complex feedbacks could obscure effects of new schemes. In this respect, two new baroclinic tests have been devised, firstly a polar vortex test including complex dynamical features (a primary potential vorticity tongue and secondary instability causing roll-up into five sub-vortices) and, secondly, the simulation of a growing baroclinically unstable wave.

As well as these tests, the interactions of physics parameterizations with each other and with the dynamics needed to be examined. 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, with considerable potential to understand the performance and effects of different dynamical cores and different representations of physical processes. For example, at NCAR, aqua-plant simulations with Eulerian and semi-Lagrangian dynamical cores coupled to the CCM3 parameterization suite produced very different zonal average precipitation patterns. Analysis showed that the contrasting structures were caused primarily by the different timestep in each core and the effect on the parameterizations rather than by different truncation errors introduced by the dynamical cores themselves. When the cores were configured to use the same time step, and same three time-level formulation and spectral truncation, similar precipitation fields were produced.

Aqua-planet experiments had wide application in testing basic model numerics and parameterizations in the way described above and WGNE was duly following up a proposal for an "aqua-planet intercomparison project". This would be led by the University of Reading together with NCAR and PCMDI. The objective would not just be to assess current model behaviour and to identify differences, but to establish a framework to pursue and undertake research into the differences. An experimental design has been developed and a list of diagnostics to be computed and compared was being considered.

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

Work continued on the updated 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 to be provided from routine operational analyses to meet the 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 (see section 2.3), also had requirements for high quality global real-time products. Moreover, the intercomparison of land-surface fluxes was of importance in the context of the Global Land Atmosphere System Study (GLASS) (see section 4.4.2).

In an initial pilot study, eleven operational NWP centres were invited to submit global fields (for 1999) of a number of various surface products and related parameters at various time intervals to PCMDI. Several groups provided the requested fields, but it was apparent that extracting historical data presented a number of difficulties. Because of this and since the real interest lay in the performance of current operational systems, a "near real-time" approach for collecting data was being adopted, with a near real-time link being established with interested centres. The primary objective would be to make the data collection from the centres and the handling of the data at PCMDI as easy and efficient as possible and "real-time" data were now being received by PCMDI from NCEP and ECMWF. Efforts were being made to extend this to other operational centres. At the same time, steps were being taken to have available relevant oceanographic data (e.g., from the TAO/Triton array) for comparing with and validating model-based estimates of surface fluxes.

High priority was being given to advancing "SURFA" in which the atmospheric and coupled modelling communities and oceanographers all had very strong interest, and which was a good opportunity for real progress jointly in estimating and determining surface fluxes.

10.1.6 Atmospheric model parameterizations and Co-ordinated Enhanced Observing Period (CEOP)

The GEWEX "modelling and prediction" thrust, with which WGNE worked in close association, was devoting efforts to the refinement of atmospheric model parameterizations, notably those of cloud and radiation, and land surface processes and soil moisture (see section 4.4.2).

WGNE has been actively encouraging modelling centres to participate as appropriate in CEOP (see section 4.2.3), to contribute data required, to consider how to take advantage of opportunities for validation of model products, and supporting experimentation. In particular, the main operational NWP centres had been invited to supply an extensive range of model gridded output in a specific format in support of CEOP. Most of the centres represented on WGNE were in principle ready to assist but raised questions concerning the complexity and long-term nature of the request, how the model data would be used in practice, and how CEOP would be useful. The point was reiterated that potential benefits of CEOP could be fully exploited by operational centres only if the data collected were available in real time. WGNE was ready to give advice to CEOP so that it could better serve NWP centres.

10.1.7 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, but the funding needed to conduct the exercise has not so far been secured.

10.1.8 Reanalyses

As noted in section 2.1, WGNE has long had the responsibility and leadership in WCRP for fostering the atmospheric reanalyses so important for many WCRP activities. Not only has WGNE maintained a continuous assessment of the technical aspects of the reanalyses and the quality of the products, the group has led the organization of two major international (WCRP) conferences on reanalyses in 1997 and 1999. The JSC strongly encouraged WGNE to continue its very successful work in this area. The latest status of reanalysis activities is summarized below.

ECMWF

The ambitious and comprehensive 40-year reanalysis project at ECMWF (ERA-40), with support from the European Union, was progressing well. The assembly of a merged data set of conventional observations carried out in collaboration with NCEP and NCAR was complete. A surprisingly large amount of extra data was available compared to the earlier 15-year reanalysis (ERA-15), with, in particular, a significant increase in the number of radiosonde and pilot wind soundings from the NCEP data base. Discussions were also in hand with EUMETSAT regarding the reprocessing of wind products from METEOSAT-2. The reanalysis itself was being undertaken in three streams covering the periods 1987-2001 when TOVS, SSM/I, ERS, ATOVS and CMW data were available, 1972-1988 with VTPR, TOVS and CMW data, and 1957-72 (the pre-satellite era), using a 60-level, T159 forecast model coupled with an ocean-wave model. At the time of the JSC session, nearly seven years of analysis starting from September 1986 had been prepared. Two years of analysis from July 1957 and one year from January 1972 had also been completed, with VTPR radiance data being successfully assimilated towards the end of the latter period. However, serious deficiencies in the analysed hydrological cycle were noted. These were traced to an error in encoding some of the SYNOP data for the period, and problems with the time assignment of certain radiosonde data used in the assimilations in both the 1950s and 1970s were also detected. Corrected data sets were prepared and production recommenced.

Tests of the assimilation of SBUV and TOMS ozone data have proceeded in parallel, and have given satisfactory results. SBUV and TOMS assimilation was thus added to the production system from January 1991 onwards. Ozone analyses for 1989 and 1990 would be produced off-line. In this connection, the ERA-40 experience has been invaluable in the development of operational assimilation of ozone at ECMWF.

A number of assessments of the ERA-40 analyses for the late 1980s and early 1990s have been made by the partners in the project (from ECMWF Member States and NCAR). In almost all respects, the quality of the ERA-40 analyses appeared to be superior to that of the ERA-15 analyses. The validation studies have identified some deficiencies; the extent of these in the longer time series of analyses that were gradually emerging as production progresses would be carefully assessed.

Comprehensive information on ERA-40, including the current status of production and archiving and monitoring plots could be consulted via **http://wms.ecmwf.int/research/era**.

NCEP

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 fifty-four years. The recent period March 1997-September 2001 has been reanalysed to correct for a modification in the processing of TOVS data. The reanalyses distributed through NCAR, CDC and NCDC were readily available either electronically or on CD-ROM. A joint NCEP/DOE reanalysis (NCEP-2) for the period 1979-1999 has also been produced (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 improved diagnostic outputs. In particular, hourly fields were provided to support the compilation of the International Satellite Land-Surface Climatology Initiative II data set. An additional initiative was the preparation of a regional reanalysis over the USA for the period 1982-2003 (perhaps 1979-2003). This should provide a long-term consistent data set for the North American domain, superior to the global reanalysis in both resolution and accuracy. The regional reanalysis would be based on the Eta model (and the Eta data assimilation system) (with the global reanalysis used as boundary conditions). Important features would be direct assimilation of radiances and assimilation of precipitation (over the USA), as well as recent Eta model developments (refined convective and land-surface parameterizations). A range of data (including all those used in the global reanalysis, various precipitation data sets, TOVS-1B radiances for certain periods, profiler measurements, and lake surface data) has been assembled and some pilot runs carried out. Considerable improvements were apparent in the monthly precipitation fields produced over the contiguous USA, especially in runs where precipitation was assimilated. However, some unrealistically intense episodic precipitation events occurred in the summer period in locations off the Mexican coast (now remedied). The fit to the geopotential heights (as observed by radio-sondes) was also notably better than that of the global reanalysis.

Japan Meteorological Agency (JMA)

An exciting development was the planning of a 25-year reanalysis by JMA (JRA-25) for the period 1979-2004. This would form the basis for a dynamical seasonal prediction project and global warming study, for advanced operational climate monitoring services at JMA, and for various activities in climate-system studies. The reanalysis was a five-year joint initiative of JMA, which was providing the data assimilation expertise and forecast system, and the Central Research Institute of the Electric Power Industry, a private foundation, furnishing the computer resources. A 3DVAR system (operational since September 2001) with a model of resolution of at least T106 and 40 levels in the vertical would be employed. As well as data archived at JMA from 1975 to the present, the NCEP/NCAR data set used in the NCEP reanalysis and the merged ECMWF/NCEP data sets in ERA-40, a range of satellite observations (including reprocessed GMS cloud motion wind data) would be assimilated. The project was expected to be completed by 2005, with the products available to scientific groups contributing to the evaluation of the reanalyses and who provided feedback on improvements that could be made.

10.1.9 Verification and comparison of precipitation forecasts

BMRC has been verifying twenty-four and forty-eight hour quantitative precipitation forecasts from eleven operational NWP models for a five-year period against rain gauge observations over Australia, Germany and the USA to obtain a comprehensive view of the skill in predicting the occurrence and amount of daily precipitation. It had been found that quantitative precipitation forecasts had greater skill in mid-latitudes than the tropics where the performance was only marginally better than persistence. The best agreement among models, as well as the greatest ability in discriminating rain areas, occurred for a low rain threshold of 1-2 mm/day. In contrast, the skill for forecasting rain amounts greater than 20 mm/day was generally low, pointing to the difficulty in predicting precisely where and when heavy precipitation may occur. Location errors for rain systems, determined using pattern matching with observations, were typically about 100 km for twenty-four hour forecasts with smaller errors for the heaviest rain systems.

Overall quantitative precipitation forecasts did not appear to have improved significantly over the four to five year period examined. Certainly, as new model versions were introduced, the skill in the various aspects of precipitation forecasting assessed changed - but not always for the better. This finding underlined the complexity of juggling improved model numerical and physical parameterizations. Unless the accurate prediction of rainfall was made a top priority by NWP centres, only slow advances could be expected in the skill of model precipitation forecasts.

This work was being written up for publication. Several other centres represented on WGNE (in particular, NCEP and DWD) were pursuing activities in this area, and WGNE was prominently involved in the organization of the International Conference on Quantitative Precipitation Forecasts being held in Reading, UK in September 2002.

10.1.10 THORPEX

The Observing System Research and Predictability Experiment (THORPEX) was being undertaken as a "Research and Development Programme" of the CAS World Weather Research Programme (WWRP) in collaboration with WGNE for numerical experimentation. The themes proposed were of major interest to WGNE, and the studies of predictability and observing system issues being taken up would have benefits throughout the WCRP. THORPEX was particularly targeted on the outstanding challenge of the skilful prediction of high impact weather associated primarily with synoptic-scale systems which often contained significant embedded mesoscale features. Activities would include:

- observing system experiments with real and "virtual" observations to determine optimal observing and data assimilation strategies for improved predictions of high impact weather;

- diagnostic studies of life-cycles of high impact weather systems;

- establishing the relative importance of errors in models and initial conditions on forecasts;

- assessing the potential of advanced ensemble prediction systems to indicate the probability of high impact weather events;

- identifying regions where new observations (in situ or remotely-sensed) would have the greatest impact;

- an ambitious field campaign testing possible enhancements to the operational observing system and providing guidance for the design of permanent and targeted components of the observing system;

- regional field tests to study specific predictability issues and new observing systems;

- determining economic and societal benefits of improved forecasts of high impact weather.

The JSC welcomed the development of THORPEX as a collaborative WWRP/WGNE experiment. It was noted that the next step would be the preparation of a focussed science plan, laying out a schedule of activities and resource requirements. To oversee the preparation of the plan and its implementation, an international science committee would be established, to be supported later by an international management committee to secure and guide the use of resources (WGNE would take part in these committees). Questions had been raised on the capacity of atmospheric/meteorological research communities to carry out THORPEX as described, and whether it would be possible to conduct the proposed rapid sequence of field programmes in several distinct geographical regions. Thus, bearing in mind the primary goal of forecasting cyclones originating over the ocean and remote continental regions taking advantage of new technologies, targeted observations, and advanced data assimilation methods, THORPEX would initially focus on the North Pacific region, and observing/analysing developing mid-latitude baroclinic waves. This could have an immediate impact on short-range forecasts in North America and medium-range forecasts in Europe. Subsequently, an area for attention should be the western Pacific, to explore tropical cyclone track prediction. The importance of collaboration with the World Weather Watch and other projects requiring sustained observations in remote regions (such as CLIVAR-Pacific) was stressed.

10.2 Progress in coupled modelling

WGCM endeavoured to maintain a broad overview of modelling activities in the WCRP in its basic task of building up comprehensive climate models, and reviewed carefully work in hand by the JSC/CAS Working Group on Numerical Experimentation (WGNE), the CLIVAR Working Group on Seasonal-to-Interannual Prediction (WGSIP), and modelling-related work studies of Stratospheric Processes and their Role in Climate (SPARC) and in the Arctic Climate System Study (ACSYS)/Climate and the Cryosphere (CliC) project.

10.2.1 Outstanding issues in the development of coupled models

Drawing from the list of uncertainties and priorities listed in the IPCC Third Assessment Report and from the experience of the members of WGCM (representing the main coupled modelling groups), the following items were set down as requiring urgent study and investigation:

- improved methods of quantifying uncertainties in climate projections and scenarios, including development and exploration of ensembles of climate simulations

- increased understanding of the interaction between climate change and natural climate variability

- the initialization of coupled models

- the reduction of persistent systematic errors in cloud simulations, sea surface temperature etc.

- the variations in past climate as a tool in understanding the response to climate forcing factors

- the reasons for different responses in different models

- improved knowledge of cloud/climate forcing and the direct/indirect effect of aerosols (including refined methodologies for refining the analysis of feedback processes)

- improved simulation of regional climate and extreme events

WGCM was directly addressing many of the issues through the specific initiatives being undertaken (see descriptions below).

10.2.2 Cloud/climate feedback

Despite a decade of intense research on the role of water vapour and clouds in climate change, it was concluded in the IPCC Third Assessment Report that the sign of net cloud feedback was still a matter of uncertainty, and various models exhibited a large spread. The report recommended that further work was needed to "understand and characterise more completely the dominant processes and feedbacks (e.g., from clouds and sea ice) in the atmosphere". In view of the critical nature of this problem and its complexity, special presentations were given to the JSC jointly by Dr W. Rossow, Chair of the GEWEX Radiation Panel, and Dr B. McAvaney on behalf of WGCM.

As emphasized by Dr Rossow, current literature on understanding climate feedbacks strongly indicated the need for new approaches to this long-standing problem. In particular, continued use of analysis methods that were conceptually linear was likely to be inadequate given the complex coupling of energy and water cycles in clouds. As a first step, the GEWEX Radiation Panel was proposing the organization of a workshop with the objectives of evaluating current analysis methods for analysing feedbacks and results, identifying the main questions and issues, examining analysis methods from other disciplines and selecting new methods that could be investigated further for application in the climate area. The workshop would set out to specify what needed to be known about climate as a non-linear dynamical system in order to predict the response to changed forcing, and what needed to be known about climate dynamics to understand natural variability, to consider how climate response should be "measured", and how feedbacks might be inferred from observed variability. The type of analysis methods that could be used include multi-variate dynamic statistical composites, diagnosis of energy and water exchanges between the different components of the climate system and within the atmosphere and ocean, and advanced statistical techniques (e.g. neural networks) to point towards multi-variate non-linear relationships and their state dependence. WGCM was represented on the organizing committee for the workshop.

The JSC strongly supported the co-operation between the GEWEX Radiation Panel and WGCM in tackling this difficult issue and agreed that new methods for analyzing non-linear feedbacks needed urgently to be explored. The plans for organization of an appropriate workshop were greatly welcomed.

At the same time, WGCM was encouraging other work aimed at assessing cloud feedback, including improved methods of evaluating model clouds against satellite data, and techniques to separate dynamically and non-dynamically forced cloud changes: this could point to aspects of cloud variation which might be useful proxies for cloud feedbacks in a changed climate. In particular, cloud variations had been stratified by regional anomalies in sea surface temperature and vertical velocity. By then stratifying cloud response in a climate change simulation according to changes in sea surface temperature anomalies, vertical velocity, cloud characteristics etc., a strong parallel in the cloud response to present day spatio-temporal sea surface temperature variability was being found. It was noted that this technique had also pointed the way to changes in physical parameterizations at the UK Met Office Hadley Centre. A new European project was also being undertaken with the goal of reducing uncertainty in cloud feedbacks in which a range of diagnostic comparisons of models with observations were planned to provide as stringent a test as possible and to highlight deficiencies. Proxy methods for assessing cloud feedback would be developed. The diagnostics could then be used to prioritise model errors in terms of the processes most important for climate change, and a hierarchy of models (coupled, atmospheric, single-column, cloud-resolving) exploited to test the limitations of physical parameterizations. WGCM was also continuing its climate sensitivity studies, now being focussed on a systematic intercomparison of cloud feedbacks (see section 10.2.4).

10.2.3 Coupled Model Intercomparison Project (CMIP)

CMIP continued to be one of the most important and long-standing initiatives of WGCM, having been started in 1995. There were now three components: CMIP1 to collect and document features of global coupled model simulations of present-day climate (control-runs); CMIP2 to document features of control runs and climate sensitivity experiments with CO_2 increasing at 1% per year; CMIP2+, as CMIP2, but many extra fields and data, monthly means and some daily data were being collected. The range of extra fields at higher temporal resolution being assembled in CMIP2+ (compared to the limited fields, time-averaged blocks, monthly mean time series in CMIP1 and CMIP2) was enabling in-depth study of many additional aspects of coupled model simulations (e.g. feedback mechanisms, ocean processes, why different models had different responses, higher frequency phenomena).

In CMIP1, data from the control runs of twenty-one global coupled models from nine countries (representing virtually every group in the world with a functioning coupled model) have been collected and archived at PCMDI. About half of these used some form of flux adjustment. In CMIP2, data from climate change experiments with eighteen global coupled models have been assembled (from eight countries). For CMIP2+, data from five models (daily data from four) were available so far, with at least four further groups preparing data for submission. The organization of these data, especially for CMIP2+, has been a major task for PCMDI. The acquisition of CMIP2+ data has boosted the original volume by two or three orders of magnitude, and it was now approaching one Tbyte.

Using these various databases, many diagnostic sub-projects were under way or were being initiated. In the case of CMIP1, there were ten sub-projects (dating from 1997 and 1998), of which six have led to at least one published paper. There was much activity surrounding the CMIP2 database, with twenty-one sub-projects having been initiated and proposals still continuing to be submitted: nine of these have provided material/results for at least one publication. Even though the announcement for CMIP2+ projects was only made in August 2001, thirteen sub-projects have already been proposed, showing the interest of the community in the much greater range of data that was available. Among the topics being taken up were the representation of the Madden-Julian Oscillation and intraseasonal variability in coupled models, the coupling between changes in the hydrological and energy budgets, studies of monsoon predictability, decadal climate variability in climate change scenarios, the trend of El Niño following global warming, air-sea interaction in the tropical Atlantic, and the stationary wave response to climate (some of these were continuations or developments of CMIP2 sub-projects). (A complete list of CMIP diagnostic sub-projects could be consulted at **http://www-pcmdi.llnl.gov/cmip/**). As well as the publications by individual authors of sub-project results, referred to above, the IPCC Third Assessment Report drew substantially on several CMIP sub-projects, and included an analysis of CMIP models.

CMIP1 was now being wound down and no further integrations would be accepted. Nevertheless, the CMIP1 data (although several of the integrations were now fairly old) would remain archived. It was considered that it would be timely to hold another CMIP workshop in late 2003 (the last workshop was held in 1998). This would appear to be a suitable time to conclude CMIP2 and CMIP2+ (data submission to be completed by October 2002). In the meantime, the ocean community would be strongly encouraged to exploit the CMIP2+ database for assessing the performance of the ocean component of coupled models as the ocean model data became available.

Subsequently, a new phase of CMIP, again in the form of a specified standard experiment, would be undertaken. The detailed plans for this next phase (experimental protocol, standard model output data sets to be collected) would be reviewed at the next session of WGCM, but basically another transient experiment with CO_2 increasing at 1% per year was envisaged. The objective would be to collect model simulations by 2004 (which could be also used in the next IPCC assessment, anticipated in the 2005-2006 timeframe). The importance of linking and co-ordinating the new CMIP effort with the Atmospheric Model Intercomparison Project (AMIP) and an "Ocean Model Intercomparison Project" (see section 10.2.7) was recognized. In particular, the atmospheric component of the model used in CMIP should be run in the new phase of AMIP now also being considered (see section 10.1.2). Additionally, the principal CMIP integration would be supplemented by separate co-ordinated "sensitivity" experiments (e.g. to study the effects of "water hosing", see section 10.2.10, and the factors affecting the variability of the thermo-haline circulation). The details of these experiments were being worked out.

10.2.4 Intercomparison of cloud feedbacks in models

WGCM has undertaken in recent years an initiative entitled "idealized sensitivity experiments" involving intercomparisons of results from equilibrium doubled CO_2 experiments, in which the atmosphere was coupled to a slab ocean, thus not involving the complexity of the ocean response. This work has shown significant differences in inferred cloud forcings and changes in top-of-the atmosphere fluxes in different models (and had been drawn upon in the IPCC Third Assessment Report).

The scientific community had expressed considerable interest in continuing this study and various means for diagnosing feedbacks. Consideration was thus being given to a proposal for systematic intercomparison of cloud feedbacks in climate models (in addition to the co-operative activities with the GEWEX Radiation Panel outlined in section 10.2.2) in the approach to understanding climate feedbacks. The specific study of cloud feedbacks raised various issues, requiring use of the current generation of climate models and cloud resolving models and taking advantage of available observational data. Among the broad questions to be taken up were to examine how well current climate models simulated the distribution and behaviour of clouds, the relationship between feedbacks on different timescales (seasonal and longer), the reasons for the wide range in climate and hydrological sensitivities in models, and the extent to which processes producing feedbacks in cloud resolving models resembled those in climate models. This initiative would also provide an updated assessment of the strength of cloud feedback represented in models, and an evaluation of the performance of climate models in simulating the aspects of cloud important in cloud feedback. This should be an important contribution to the IPCC call to "characterise more completely the dominant processes in cloud feedback".

Two main thrusts were envisaged, the first an investigation of the characteristics of the clouds as simulated in models compared to ISCCP data. This required clouds to be diagnosed in models in a manner that was consistent with ISCCP algorithms. The study of cloud behaviour in different dynamical regimes across a range of climate models as compared to the behaviour of ISCCP clouds in the dynamical regimes determined from reanalyses should serve in categorising the potential for climate models to produce realistic cloud feedbacks. Appropriate links would also be made to AMIP and CMIP.

The second thrust would involve two types of systematic model experiments. "Classic" fixed season ±2K sea surface temperature perturbation experiments (i.e. forcing of an atmosphere-only model) were intended to provide historical comparison with the intercomparisons conducted by Cess and collaborators several years ago. Experiments with a slab ocean (with 1 x CO_2 and 2 x CO_2) were now becoming the standard, and the behaviour of model clouds in different dynamical regimes in the "control" climate would be compared with observations in the same manner as in the first thrust of this proposal, as well as being linked to AMIP and CMIP. Additionally, it was planned to establish active collaboration with the GEWEX Cloud System Study to organize a range of "cloud feedback" experiments with cloud resolving models.

Detailed plans for the work and diagnostic studies involved have been drawn up and would be discussed with modelling centres/groups interested in participating.

10.2.5 Forcing scenarios

Many centres have undertaken and continued to undertake runs using the emission scenarios proposed by IPCC; however, the uncertainties in external forcing were one of the major factors limiting confidence in climate projections. The largest uncertainty was in the indirect (aerosol) forcing. Knowledge of variations in the magnitude and phase of solar forcing was also inadequate.

10.2.6 Initialization of coupled models

There has been no new major breakthrough in this area, and many modelling groups were still undertaking long laborious spin-up integrations, demanding in computer resources because of the lengthy time-scales involved. A technique involving use of air-sea fluxes computed in an adjoint model was being explored at GFDL. Several groups had used an "observed" initial three-dimensional ocean state, in particular that compiled by Levitus. This had the advantage of requiring considerably less computer time, and the initial coupled model state was near to that observed. On the other hand, the ocean initial state might not be in balance (because of deficiencies in data and their analysis and/or since the present climate was changing). Also, when the initial conditions for ocean and atmosphere were not obtained in coupled mode (i.e. by a sufficiently long coupled integration), there was potential for shock when the individual components were brought together.

WGCM was continuing to keep this topic under close review: it was foreseen that the problem would gradually be alleviated in time by increases in available computing power and resources.

10.2.7 Ocean model development

The joint WGCM/WOCE Working Group on Ocean Model Development devoted attention to a number of questions on the performance of ocean models and to the refinement of the ocean component of coupled models. A main item of discussion at the second session of the group (Santa Fe, NM, March 2001) was the impact of higher resolution in the ocean component of global coupled models. A clear tendency towards resolutions of about 0.5-1.0° was noted, apparently motivated by general recognition of the need for a more realistic representation of topographic features such as passages, equatorial ocean dynamics, and aspects of high latitude water mass formation.

One of the main results from the 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. More confidence was now felt in ocean forcing data sets, and, in particular, forcing from a global flux data set based on refined ECMWF reanalysis products would be used. 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, and the questions involved were being discussed with ACSYS/CliC NEG (see section 9.1). OMIP would be arranged so as to be complementary with the next phase of CMIP in 2004 (see section 10.2.3).

Very few CMIP diagnostic projects have so far been concerned with the characteristics of ocean simulations, and the initiation of such projects by ocean scientists was strongly encouraged. The extra availability of data in CMIP2+ should permit a far greater range of revealing projects (see section 10.2.3).

In view of the formal conclusion of WOCE at the end of 2002, the position of the (WGCM/WOCE) Working Group on Ocean Model Development in the WCRP framework needed to be considered. As emphasized in the WOCE presentation on "Developments and Issues in Ocean Climate Modelling" (see Appendix C), there was a strong continuing role for a Working Group on Ocean Model Development. The view was expressed that its importance was such that it should be reconstituted as a WCRP working group at the same level as WGCM or WGNE reporting directly to the JSC.

10.2.8 Detection and attribution of climate change

The JSC was briefed on the range of outstanding issues in the quest to detect and attribute climate change. The method generally considered the most rigorous and powerful for this purpose was the multiple regression technique, "optimal fingerprint detection" (as described in the IPCC WG1 Third Assessment Report, Ch. 12, section 12.4.3). The method required ideally ensembles of simulations of twentieth century climate with individual forcing agents to provide "fingerprints", and very long (multi-centennial or even millenial) control simulations to assess internal climate variability. Several groups have used this approach, with strong indications of anthropogenic influences on surface temperature being found: the results from different groups were consistent and inter-implementation differences small. The technique could also be employed to scale simulations of the twenty-first century to infer predictions or mean temperature change relative to twentieth century observations and to estimate key parameters such as climate sensitivity, ocean heat uptake and sulphate aerosol forcing.

Uncertainty remained in the model-derived estimates of internal climate variability, which could not be fully validated with observed variability over the required timescales (of several decades to centuries). Reconstructions of temperature variations over the recent centuries from palaeoclimatic data were becoming increasingly important in this context. However, the influence of natural climate forcing on the palaeoclimatic record appeared to be considerable. Thus an essential step in verifying model performance and the simulated internal (or natural) variability would be model integrations over the appropriate period with the appropriate (reconstructed) natural forcing.

Optimal detection methods also tended to be sensitive to the model employed to derive fingerprints. This could be partly alleviated by using fingerprints averaged from several model simulations. Estimates of model error covariance (required for a comprehensive assessment of model uncertainty) depended on the availability of a range of simulations with varying parameters. Another key issue in increasing confidence in climate models was to understand better the different trends in surface and lower tropospheric temperature.

Attention was now turning to identifying signals of anthropogenic climate change in other parameters that are relevant socio-economically such as precipitation, models of climate variability, or climate extremes. Assessment of changes on a continental scale instead or in addition to global scale would be another means of verifying model simulations in mode detail as well as the quality of the fields produced to drive regional or impact models. Such efforts were already starting with promising first results.

10.2.9 Palaeo-climatic modelling

Although the first phase of the Palaeoclimate Modelling Intercomparison Project (PMIP) had been formally completed, a number of groups were producing updated simulations of the climates of the mid-Holocene (6000BP) and the Last Glacial Maximum (21000BP) using the standard forcing (ice sheet limits, atmospheric carbon dioxide, insolation) specified for PMIP experiments. In particular, a number of simulations of the Last Glacial Maximum had now been carried out with coupled ocean-atmosphere models (including those of the Hadley Centre, the Meteorological Research Institute of Japan, and the NCAR/CSM). However, the models still did not generally show cold enough temperatures over western Europe: this appeared to be linked to an inadequate representation of the effect of the feedback associated with vegetation changes.

New impetus should be given to PMIP following the initiation of the European Union project "Model and Observations to Test clImate Feedbacks" (MOTIF). Participating (European) modelling groups would undertake PMIP-like integrations with coupled ocean-atmosphere, and coupled ocean-atmosphere-vegetation models for 6000BP and 21000BP. The future plans for PMIP itself would be discussed at a workshop in July 2002, and it was likely that experimentation with coupled ocean-atmosphere-vegetation models for 6000BP and 21000BP would be proposed. Other time periods were also of interest, namely the early-Holocene (11000BP) and the inception of the Ice Age at the end of the last interglacial.

10.2.10 Coupled ocean-atmosphere variability and predictability

The JSC at its twenty-second session advised that attention should continue to be given to simulations of decadal variability in coupled models. It was also noted that a critical question in CLIVAR was the need for a better understanding of the role of the Atlantic thermohaline circulation (or meridional overturning circulation) in climate variability and change and, in particular, in tropical Atlantic variability. CLIVAR had suggested that modelling work could aid improved understanding, and provide guidance for framing observational programmes seeking to study and monitor the meridional overturning circulation. Among outstanding questions were the magnitude and space-time structure of the meridional overturning circulation, the upper ocean and sea surface response to variability and change of this circulation and, in turn, the climate response, and the predictability of these changes and their impact. Detailed analyses of the behaviour (natural variability, greenhouse gas response, climate impacts) as simulated would be valuable. In addition, co-ordinated experiments (e.g. designed to show the sensitivity to perturbed initial conditions and/or surface fluxes) could be helpful in elucidating the physical processes and mechanisms involved.

Decadal climate variability had been the subject of a workshop in January 2001 in Hawaii. The findings agreed well with those from the Workshop on Decadal Predictability, organized by WGCM in October 2000, namely that there was some slender evidence for limited predictability in the oceans at decadal timescales, but little over continental regions. Oceanic heat content changes demonstrated long-term trends and decadal variability. Climate models were being used to interpret multi-century proxy records, complemented by studies on the dynamics of simulated variability. An AGU Chapman Conference on the North Atlantic Oscillation in November 2000 had produced suggestions of the potential role of the tropics in affecting decadal and longer-term swings in the North Atlantic Oscillation index. Long reconstructions of the North Atlantic Oscillation Index had been presented, and temporal shifts in the North Atlantic Oscillation noted. The question of the predictability of swings on seasonal and longer time scales had been raised, as well as the relationship between NAO dynamics and the stratosphere (as also referred to by SPARC, see section 5.4.1).

The main challenges and priorities in decadal to multi-decadal variability and predictability were to augment the observational record better to define the characteristics of the variability, to diagnose the mechanisms of simulated variability, to investigate further predictability at these time scales and, particularly, whether there might be any predictability over continents, and to try and assess the interaction between decadal variability and anthropogenic climate change. More specifically, questions that needed to be answered were the extent of air-sea coupling in decadal variability, the relative roles of the tropics and extra-tropics, the role of high latitudes, space-time structure of decadal variability (to be deduced from observations), and the parts played by vegetation and external forcings. With regard to decadal predictability, open issues were the contribution from internal predictability, the predictability of changes at decadal time scales in the statistics of interannual variability, and the definition of an appropriate initial state and initialisation.

The main WGCM contribution to progress in this area would be through CMIP2+, in which much more ocean data were available (see section 10.2.3). Interested groups have been urged to organize appropriate diagnostic sub-projects aimed at such questions as detailed analyses and comparisons of the magnitude and space-time structure of the meridional overturning circulation (as simulated in coupled models) and other aspects as referred to above. The possibility or organizing co-ordinated "sensitivity" experiments to improve understanding of some of the processes involved was also being examined. These might include changes in initial conditions, perturbations in salinities, and/or perturbed surface experiments (partial coupling). These would be undertaken as a complement to the next principal CMIP integration (see section 10.2.3), and details of the experimental protocol were being worked out. Regarding the use of model studies as a guide to observational programmes, caution was essential. However, this could become a more valid approach in the future as model resolutions increased and ocean simulations improved.

10.2.11 Carbon-cycle modelling

WGCM was co-operating with the Global Analysis, Integration and Modelling (GAIM) element of IGBP in the planning of the "Coupled Carbon Cycle Climate Model Intercomparison Project" (C4MIP). This would basically be organized on the same lines as the other main WCRP model intercomparison projects, CMIP and AMIP, with standard co-ordinated experimentation being proposed. In the first phase, interested groups were being invited to undertake a historical land-atmosphere experiment with global models having full coupling between radiation, biogeochemical cycles and carbon dioxide with specified sea surface temperature forcing, carbon dioxide emissions, and land-use change. Key diagnostics would include the model-predicted carbon dioxide fluxes and concentrations. The detailed experimental protocol was being defined and a workshop bringing together representatives of interested groups would be organized in the coming months.

In the meantime, several groups were already carrying out various climate-carbon studies. Among results noted were those from experiments at the Hadley Centre and at the Institute Pierre-Simon Laplace (IPSL) with coupled physical ocean-atmosphere models including ocean and land carbon cycles. Both used historical carbon dioxide emissions (from burning fossil fuels and deforestation) for the period 1860-1995, but with slightly different emission scenarios for the period 1995-2000 (Hadley Centre: IPCC IS92A; IPSL: IPCC SRES-A2). Sinks were different because of contrasting treatment of the terrestrial biosphere (the Hadley Centre model included dynamic vegetation whereas IPSL did not). Nevertheless, there was agreement in the experiments that the climate-carbon cycle was positive, mainly as a consequence of the negative climate impact on the biosphere, the feedback being much larger in the Hadley Centre model. Key uncertainties in the results were, over land, the vegetation and soil response to changing atmospheric concentrations of carbon dioxide and warming/drying, and over the ocean, the geochemical uptake (e.g. by the Southern Ocean circulation).

Looking to the future, increasing co-operation between WGCM and GAIM was foreseen in the task of developing the comprehensive Earth system models required, bringing together the hitherto largely separate work of the two groups. To this end, it was planned that the next session of the two groups would be held jointly, and that a joint workshop on Earth system modelling could be organized (possibly in April 2003 in conjunction with the European Geophysical Society Annual Assembly).

10.2.12 Simulations of climate of the twentieth century

WGCM had again reviewed the issue of trying to organize standardized simulations of the climate of the twentieth century. Such integrations were plainly of much interest and have been or were being carried out by many centres. However, numerous forcing scenarios were being employed and there was no general agreement on forcing data sets. (In many cases, the forcing was not accurately known especially for indirect forcing). The situation was becoming more complicated as centres introduced their own model carbon and sulphur cycles.

It would be difficult to regiment these integrations, but, nonetheless, it was considered important to assemble the twentieth century runs that had been made, together with a detailed specification of the forcings that had been used. Such a database would be valuable for detection and attribution studies and for model validation. Simulations with one specific forcing only would be of particular interest, as would runs with other forcings such as that linked to land use change. PCMDI expressed its willingness to act as the centre for collecting the data, and to offer its extensive software in support of diagnostic sub-projects drawing on the database. A detailed list of model output to be archived from twentieth century climate simulations together with a complementary list of forcing fields and the form in which they should be collected would be compiled. Care would be taken not to duplicate work already undertaken in this area by others, notably the IPCC Data Distribution Centre which was also archiving data from twentieth or twenty-first century coupled model simulations. However, the forcing and response data held by the IPCC Data Distribution Centre were not likely to be extensive enough for the type of in-depth studies in which WGCM would be interested (see also section 10.2.16 below on the role of IPCC Data Distribution Centre).

10.2.13 Long-term climate integrations

WGCM was encouraging modelling groups to consider if possible long (control) integrations for an extended period (e.g. 1000 years). These integrations, which should use pre-industrial forcing, would provide a valuable reference and control for CMIP and the 6000 year BP PMIP simulations, as well as a good basis for assessing (model-simulated) internal or natural variability. Comparisons with proxy data would be possible. However, interpretation of the latter was not straightforward and careful consideration needed to be given to the range of parameters to be collected from the model integrations to describe the simulated low-frequency patterns adequately and to be able to compare with proxy indices. When such runs were made, as with the climate of the twentieth century simulations, the forcing used should be carefully archived along with the model results.

10.2.14 Use of advanced numerical techniques in climate model simulations

At its twenty-second session, the JSC invited WGCM to comment on the feasibility of/questions related to the use of numerical techniques (e.g. linear grids, semi-Lagrangian techniques) that have been developed for use in NWP and which potentially might also offer advances in integration speeds in climate modelling applications. WGCM pointed out that, firstly, the use of semi-Lagrangian schemes did not offer a similar gain in integration speed in climate models as compared to NWP because of the considerably coarser resolution of the former. Climate models depended fundamentally on a satisfactory treatment of the physics, and it was known that problems could arise if too long a timestep were used (e.g. see section 10.1.4). Secondly, conservation, particularly of energy, was of the utmost importance in the integration of climate models. Again, as noted by WGNE, schemes with non-linear intrinsic diffusion could lose energy at an unacceptably high rate (as could also explicit diffusion schemes). Thirdly, potential gains in efficiency in integrating the dynamical core were relatively small when weighted against the importance of the number of levels in the vertical, and greater complexity of the physics in climate models compared to the dynamics. Nevertheless, the issue was not being ignored by the climate modelling community, and techniques such as semi-Lagrangian, semi-implicit timestepping, and staggered grids were finding their way into climate models especially when they had been well tested in operational models and had demonstrated the required properties. (A good example was at the Hadley Centre where the next version of the model would include the "new dynamics" developed for the Met Office NWP model).

10.2.15 Developments in data formats and handling climate model data sets

Long runs with coupled models generated extremely large volumes of data. As well as working with basic modelling problems, the climate research community had also to consider formats for the efficient handling and exchange of these large volumes of data, and how the data should be managed.

In respect to the former topic, a number of centres (including the Hadley Centre, NCAR, PCMDI) have developed the "NetCDF/CF" format for climate data, aimed to achieve easier data exchange, definition of climate meta data, and to serve as a possible archive format. The NetCDF format itself, developed by Unidata, has been commonly used for some time, and was freely available and portable. NetCDF files were binary and machine-independent, utilities existed for translation from binary to plain data, and a library was available to read and write NetCDF files, with interfaces in many programming languages. The files contained variables, dimensions and attributions, and NetCDF conventions defined how to use these: the format was highly suitable for a self-describing logical data format. The NetCDF/CF convention was intended for use with atmospheric, surface and oceanographic climate and forecast data and was particularly designed with model-generated data in mind. NetCDF/CF extended the Co-operative Ocean/Atmosphere Research Data Service (COARDS) (the NOAA/university co-operative for sharing and distributing global atmospheric and oceanographic data sets) by establishing standard names for identification of variables, offering facilities such as specification of boundary co-ordinates, grids other than latitude-longitude, and indications of statistical reduction, and a number of other features. PCMDI has adopted NetCDF/CF and it was also being used by the European infrastructure project "Programme for Integrated Earth System Modelling" (PRISM) (this had the objective of developing a flexible model structure with interchangeable model components with standard interfaces and a universal coupler).

The important potential value of NetCDF/CF as an exchange format between centres involved in climate research, especially the feature of including/specifying climate meta-data was fully recognised. However, it was pointed out that, in the data processing industry, new standards were rapidly being defined (in particular "W3C"). Contact should be made with the W3C standards group to explore inclusion of NetCDF/CF. Generally, the JSC was of the view that careful consideration was needed of the definition of and formats for standardized exchanges of meta-data, and this question could perhaps be taken up in conjunction with the comprehensive consideration of WCRP data management and information systems (see section 3.2).

The issue of centralized versus distributed data sets was also raised. In the case of the former, data were held at one central location/institution (PCMDI was an excellent example of such a centre), with the advantages of being able to obtain all data from one site and assured data quality. However, this meant the data handling fell on one group which could be faced with having to deal with very large data volumes: also the data were separated from the providers. In contrast, a distributed data system was internet-based, and data and services were provided by individual institutions using a common framework (e.g. the NOAA Operational Archive and Distribution System which allowed access to model data via the Internet, and users to perform simple analyses without moving raw data). There was a close tie between the data providers and users, easy automation of tasks (downloading data, mapping, etc.), and the data management load was distributed. There could, however, be weakness in the overall data consistency and data quality between different stations.

Distributed data techniques clearly appeared to be the way of the future, but there was a need for oversight, co-ordination in areas such as definition of standards, formats, types, the exchangeability of data, a reference system to indicate the availability of data, and user help.

10.2.16 IPCC Data Distribution Centre

The IPCC Data Distribution Centre (DDC) (at the Max-Planck Institute in Hamburg) collected results of SRES-forced climate experiments which were then available for use by the climate impacts community and groups in developing countries. Although guidelines have been set down for sets of results submitted to the DDC, there was not the same scientific discrimination as for the CMIP database which included results from more closely defined experiments. Reference was made to the issue of the connection with the climate impacts community, and whether it would be better that a direct relationship with WCRP/WGCM was fostered. It could therefore be valuable that WCRP and/or WGCM were more closely associated with the DDC and also that PCMDI could have a role in this regard. However, the DDC did hold a lot of data (population growth figures, emission scenarios etc.) which were outside the current remit of WCRP.

The JSC considered that the DDC and CMIP data bases needed to be maintained separately in view of their different roles and purposes. In particular, the CMIP data base had to be designed to serve the scientific modelling community and to understand why different models gave different results and had different climate sensitivities. Nevertheless, the WCRP should certainly be fully aware of DDC activities, with close interaction and co-operation as necessary.

10.3 Regional climate modelling

Following the reviews carried out by WGNE and WGCM in respect to regional climate modelling at their respective 1999 sessions, 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 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, and the predictability/reproducibility of smaller scales simulated in regional climate models). An advanced draft of the report "Atmospheric regional climate models: a multiple purpose tool" prepared by the panel (R. Laprise, University of Québec, Montréal, Canada: convener; R. Jones, Hadley Centre, UK; B. Kirtman, COLA, USA; H. von Sotrch, GKSS Research Centre, Germany; W. Wergen, Deutscher Wetterdienst, Germany) was presented to the JSC.

The report pointed out that dynamical atmospheric regional climate models (RCMs) had matured over the past decade and now allowed (and were used in) a very wide spectrum of applications. At horizontal scales of 300km and larger, simulations were consistent with the nesting (driving) data. At fine spatial and temporal scales, the RCM-simulated patterns of important surface variables, such as precipitation and winds, often had demonstrable skill. However, grid spacing was currently often constrained by computing resources to typically about 50km, which limited the amount of detail available at the finest scales. Future increases in computer power and applications of multiple nesting techniques would be likely to allow increases in resolution to grid spacing of order of 1km (this would require the use of fully non-hydrostatic models and scale-dependent parameterizations).

It was recognised that RCMs had deficiencies and improvements were required. The sensitivity of RCM-simulated results to computational domain size, to the jump in resolution between the nesting data and the RCM, to errors or deficiencies of nesting data, and to nesting techniques, needed further investigation. Moreover, the added value provided by regional modelling should be assessed relative to simpler statistical post-processing of coarse-grid data. An assessment of the performance of an RCM required climate data on much finer spatial and temporal scales than traditionally used for validating global models. In some regions such data were available but not necessarily easily accessible, and appropriate gridded analyses have not been prepared. Where such data were not available, methods of validation other than comparison with standard climatological variables ought to be developed or applied. The performance of different RCMs should be compared both in their simulation of current climate and in their use as a dynamical downscaling tool to provide high-resolution climate-change information. This was necessary both to guide future developments in regional climate modelling and to contribute to the assessment of uncertainty in regional climate simulations and projections.

The ad hoc panel reiterated that the final quality of the results from a nested RCM depended on the realism of the large scales simulated by the driving general circulation model. The reduction of errors, systematic or otherwise, in general circulation models must therefore remain a priority for climate modellers.

The various recommendations made by the Panel included the following points:

(i) **Obviously, all numerical models suffered from various defects and were a reduced image of a considerably more complex reality. In this sense, all models should be made more realistic in very many different ways, but the process of improving models should be guided by the needs of the specific applications.**

(ii) An international RCM workshop should be organised bringing together, not only RCM modellers, but also global climate modellers, diagnosticians and dynamicists, users of RCM results, research managers and funding agencies, with the theme "the added value of regional climate model simulations" in many applications. The Panel suggested holding the workshop during 2003 in the Southern Hemisphere, possibly in Buenos Aires, Argentina, where there was growing community of scientists who could contribute to the essential local arrangements.

(iii) The assessment of RCM climate simulations continued to be hampered by the lack of high-resolution observed gridded climate data over many regions of the globe. Regional data re-analysis projects using observations from national archives should be encouraged.

(iv) Long, multi-decadal RCM simulations nested within an ocean-atmosphere model and forced by observed SST could be made to assess RCM skill in reproducing fine-scale features associated with large-scale year-to-year anomalies. This would constitute a "Regional (climate) Model Intercomparison Project", RMIP, analogous to AMIP. The recently-completed European project MERCURE has delivered such simulations for the European region using three RCMs and could act as a model for such an exercise.

(v) When intended for climate-change projections, the RCM should be validated in different climate regimes in order to establish their general applicability. It would be valuable to organize a co-ordinated international modelling effort to nest a number of global model-simulated data sets over a few regions. This would be a major undertaking requiring strong international support and convincing funding agencies of the importance of such a project. The new European project Prediction of Regional scenarios and Uncertainty for Defining European Climate-change risks and Effects" (PRUDENCE) which would compare simulations and climate change over Europe from several general circulation models and RCMS could be an important component of such a project.

Both WGNE and WGCM had reviewed the report. WGNE agreed with most of the points made, including the proposal for an international RCM workshop in the next 1-2 years and saw merit in a regional climate model intercomparison project if an appropriate exercise could be designed. It was suggested that the report could also include or expand discussion of the following points:

- the risk of "blind application" of a regional climate model and the need to educate less experienced users of models and the data produced, in particular advice on the limitations of regional climate model results consequent to the shortcomings in skill of the simulations of the forcing general circulation in representing large-scale circulation features (oscillations, seasonal variability)

- the differing vertical resolution between a regional climate model and the driving general circulation model, and the interpolation (in the vertical) from the outer grid and nested grid

- the role of regional climate models in testing and paving the way for the next generation of high resolution general circulation models and testing model parameterizations (e.g. land-surface schemes)

- the importance of checking conservation properties

- the need to test the regional climate model physics in different "climates"/geographical regions

- comparison of model results with a statistical down-scaling approach

WGCM, in its turn, appreciated the wide-ranging review of regional climate modelling that had been produced. Agreement was expressed with several of the points made by WGNE. The importance of assessing the added value provided by a regional climate model simulation compared with a statistical down-scaling approach was particularly stressed. WGCM also concurred with the proposals for a regional (climate) model intercomparison and for an international regional climate modelling workshop. In respect to the former of these items, WGCM pointed out that a regional model intercomparison should include tests with reanalyses as boundary conditions to verify the ability of regional climate models to simulate the present climate in various distinctive climatological regions of the world.

It was expected that the ad hoc panel would take note of these various points in the preparation of an appropriately revised report. This would then be produced as a WCRP technical document, as well as a suitably edited version perhaps being submitted for publication in, for example, the Bulletin of the American Meteorological Society.

The JSC expressed its appreciation of the work of the group under the leadership of Dr R. Laprise. The JSC considered that the WCRP (through WGNE and WGCM) should keep the topic of regional climate modelling under careful review both to monitor progress and to ensure that all users of "off-the-shelf" RCMs were aware of potential pitfalls. The ad hoc WGNE/WGCM panel was thus invited to continue its work, and, in particular to take up the organization of an international RCM workshop in the next 1-2 years to consider the use of RCMs in various applications, and to plan, as far as feasible, a co-ordinated assessment of RCM skill in reproducing fine-scale regional features that might be associated with large-scale year-to-year anomalies in the global circulation.

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. In particular, the appointments of the Officers of the Committee were considered. The Chairman (Professor P. Lemke), vice-Chairman (Professor B. Hoskins), and two Officers (Dr J. Church, Professor Y. Ding) were unanimously re-elected for a further two-year period (1 April 2002-31 March 2004). The third Officer position, which would be left vacant by Professor A. Sumi stepping down from the JSC at the end of 2002, would be taken up at the next session of the JSC (March 2004) when the new membership of the Committee as a whole was confirmed.

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 appointment or nominated new members as appropriate. Affiliations/contact information for members of these groups may be found via the WCRP web page at http**://www.wmo.ch/web/wcrp/committees.htm.**

JSC/CAS Working Group on Numerical Experimentation (WGNE)

Membership of the WGNE was determined by consultation between the Chairman of the JSC and the President of CAS. The terms of ten of the eleven members of the group were expiring. Three members, Drs H. Ritchie, T. Tsuyuki, and W. Wergen were now leaving WGNE. Drs. J.-G. Côté (Meteorological Service of Canada), D. Majewski (Deutscher Wetterdienst), and K. Saito (Japan Meteorological Agency) were being invited to take up the vacant positions (for initial terms of four years). The terms of the Chair of WGNE, Dr K. Puri, and those of Drs P. Bougeault, Chen Dehui, S. Lord, A. Lorenc, M. Miller and D. Williamson were being extended for a further two years. The composition of WGNE has thus now become:

Membership	Expiry of appointment

K. Puri (Chair)	31 December	2003
P. Bougeault	"	2003
J.-G. Côté	"	2003
Chen Dehui	"	2003
V. Kattsov	"	2003
S. Lord	"	2003
A. Lorenc	"	2003
D. Majewski	"	2005
M. Miller	"	2003
K. Saito	"	2005
D. Williamson	"	2003

JSC/CLIVAR Working Group on Coupled Modelling (WGCM)

The terms of the Chair of WGCM and of several members expired on 31 December 2001. The JSC agreed that the term of the Chair, Dr J. Mitchell, and those of Drs H. Le Treut, B. McAvaney, G. Meehl, A. Noda and D. Webb should be extended by two years. Dr P. Braconnot (CEA-CNRS, France) would be invited to join the working group for an initial term of four years in place of Dr S. Joussaume who was now stepping down from membership. Further, it was agreed that Dr A. Hirst (CSIRO, Australia) should also be invited to become a member. The group was thus now constituted as follows:

Membership	Expiry of appointment	
J. Mitchell (Chair)	31 December	2003
C. Boening	"	2002
P. Braconnot	"	2005
T. Delworth	"	2003
G. Hegerl	"	2002
A. Hirst	"	2005
M. Latif	"	2004
H. Le Treut	"	2003
B. McAvaney	"	2003
G. Meehl	"	2003
A. Noda	"	2003
A. Weaver	"	2003
D. Webb	"	2003

WOCE Scientific Steering Group

The membership of the WOCE Scientific Steering Group would continue unchanged until the formal end of WOCE at the end of 2002, when the group would be dissolved.

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 2002 were agreed in advance by the Chairman of the JSC on behalf of the Committee. In that context, Professor J. Willebrand's term as a Co-chair of the CLIVAR Scientific Steering Group was extended by two years. Two other members whose terms expired on 31 December 2001 (Drs J. Jouzel, D. Martinson) were now leaving the group. Dr T. Stocker (University of Bern, Switzerland) was being invited to accept membership for an initial term of three years.

(A further nomination to the CLIVAR Scientific Steering Group was pending). The composition of the group was thus:

Membership	Expiry of appointment	
A. Busalacchi (Co-chair)	31 December	2002
J. Willebrand (Co-chair)	"	2003
T. Palmer	"	2002
P.L. da Silva Dias	"	2003
I. Simmonds	"	2003
T. Stocker	"	2004
M. Suarez	"	2003
K. Takeuchi	"	2003
K. Trenberth	"	2002
R. Weller	"	2002
G. Wu	"	2002
F. Zwiers	"	2002

ACSYS/CliC Scientific Steering Group

The terms of the Chair of the ACSYS/CliC Scientific Steering Group, Dr H. Cattle, of the Vice-chairs, Drs I. Allison and R. Barry and of members, Drs T. Fichefet and Dr B. Goodison, which expired on 31 December 2001, were all extended by two years. It would be necessary to appoint a new chair of the group later in 2002 when Dr H. Cattle took up his new position as Director of the International ACSYS/CliC Project Office (see section 8.5). The Chairman of the JSC was asked to act on behalf of the JSC in the nomination and appointment of a new Chair of the ACSYS/CliC Scientific Steering Group at the appropriate time. Until then, the membership of the group was :

Membership	Expiry of appointment	
H. Cattle	31 December	2003
I. Allison (Vice-chair)	"	2003
R. Barry (Vice-chair)	"	2003
M. Burgess	"	2004
M. Drinkwater	"	2004
E. Fahrbach	"	2002
T. Fichefet	"	2003
B. Goodison	"	2003
V. Kotlyakov	"	2004
T. Ohata	"	2004
Qin Da He	"	2004
H. Zwally	"	2004

GEWEX Scientific Steering Group

No changes were due to be made and the composition remained:

Membership	Expiry of appointment	
S. Sorooshian	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

SPARC Scientific Steering Group

No changes were due to be made and the composition remained:

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 formally came to an end following the Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux Fields in May 2001 (see section 6). The JSC expressed its appreciation for the excellent work carried out by the group under the leadership of its Co-chairs, Drs S. Gulev (Shirshov Institute of Oceanology, Russian Federation and Dr P.K. Taylor (Southampton Oceanography Centre, UK).

It was recalled that a new "air-sea interactions" group should be established to examine issues related to air-sea interaction across the whole spectrum of WCRP activities, and also if possible, to support SOLAS (as a joint group with SOLAS). Following required discussions with SOLAS on this matter, the Chairman of the JSC was asked to act on behalf of the Committee in the formal establishment and nomination of members of an appropriate group.

WCRP/GCOS/GOOS Ocean Observations Panel for Climate

The nomination of the new Chair (Dr E. Harrison, NOAA Pacific Marine and Environment Laboratory) in place of Dr N. Smith, who (as noted in section 2.3) was now standing down, was endorsed. The membership of the panel, jointly sponsored by the JSC and Joint Scientific and Technical Committees for GCOS and GOOS was now:

- E. Harrison, NOAA Pacific Marine and Environment Laboratory, Seattle, USA (Chair)
- E. Campos, Instituto Oceanografico, University of Sao Paolo, Brazil
- T. Dickey, Ocean Physics Laboratory, University of California, Santa Barbara, 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

The membership of this group, jointly sponsored by WCRP and GCOS remained as:

- M. Manton, Bureau of Meteorology Research Centre, Melbourne, Australia (Chair)

- P. Arkin, University of Maryland, 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

The JSC urged that, when possible, the overall geographical representation on the panel be extended by inclusion of an appropriate expert or experts from China and/or the Russian Federation.

11.3 Publications

The following reports were produced under WCRP auspices in various series between the twenty-second and twenty-third sessions of the JSC:

WCRP Report Series

WCRP-115 Intercomparison and Validation of Ocean-atmosphere Flux Fields (Proceedings of WCRP/SCOR workshop, Potomac, MD, USA, 21-24 May 2001) (WMO/TD-No. 1083)

Informal WCRP reports and documents

8/2001 Arctic Climate System Study (ACSYS) and Climate and Cryosphere (CliC) Project (Report of first session of Scientific Steering Group, Kiel, Germany, 23-27 October 2000)

9/2001 JSC/CAS Working Group on Numerical Experimentation (WGNE) (Report of sixteenth session, Melbourne, Australia, 23-27 October 2000)

10/2001 CLIVAR Variability of the African Climate System (VACS) (Report of first session of panel, Nairobi, Kenya, 29-31 January 2001) (also ICPO Report No. 46)

11/2001 CLIVAR Scientific Steering Group (Report of ninth session, Honolulu, Hawaii, USA, 2-5 May 2000) (also ICPO Report No. 43)

12/2001 CLIVAR Pacific Implementation (Report of workshop, Honolulu, Hawaii, 5-8 February 2001) (also ICPO Report No. 51)

13/2001 CLIVAR Variability of the American Monsoon System (VAMOS) (Report of fourth session of panel, Montevideo, Uruguay, 26-30 March 2001) (also ICPO Report No. 49)

14/2001 Arctic Climate System Study (ACSYS) (Report of second session of observation products panel, Geneva, Switzerland, 4-7 October 2001)

15/2001 Arctic Climate System Study (ACSYS) and Global Energy and Water Cycle Experiment (GEWEX) (Report of workshop on Arctic hydrological model intercomparison, Seattle, WA, USA, 18-20 March 2001)

16/2001 Stratospheric Processes and their Role in Climate (SPARC) (Report of eighth session of Scientific Steering Group, Buenos Aires, Argentina, 13-16 November 2000)

17/2001 Baseline Surface Radiation Network (BSRN) (Report of sixth session of science and review workshop, Melbourne, Australia, 1-5 May 2000)

18/2001 Global Energy and Water Cycle Experiment (GEWEX) (Report of thirteenth session of Scientific Steering Group, Barcelona, Spain, 29 January - 2 February 2001)

19/2001 Global Energy and Water Cycle Experiment (GEWEX) (Report of ninth session of Panel on Cloud System Study, Tokyo, Japan, 29 November - 1 December 2000)

20/2001 PAGES/CLIVAR Working Group (Minutes of the second meeting, Amsterdam, The Netherlands, 14 July 2001) (also ICPO Report No. 54)

21/2001 CLIVAR Ocean Observations (Report of the first session of panel, Hobart, Tasmania, Australia, 27-30 March 2001) (also ICPO Report No. 59)

22/2001 CLIVAR Working Group on Seasonal-to-Interannual Prediction (Report of fifth session, Buenos Aires, Argentina, 1-3 November 2000) (also ICPO Report No. 50)

23/2001 CLIVAR Working Group on Seasonal-to-Interannual Prediction (Report on current status of ENSO forecast skill, ed. B. Kirtman et al) (also ICPO Report No. 56) (only available electronically: **http://www.clivar.org/publications/wg_reports/wgsip/ nino3/report.htm)**

24/2001 Global Energy and Water Cycle Experiment (GEWEX) (Report of fifteenth session of the Working Group on Data Management for the Global Precipitation Climatology Project, Bologna, Italy, 14-17 May 2001)

25/2001 GOOS-GCOS-WCRP Ocean Observations Panel for Climate (Report of fifth session, Bergen, Norway, 20-23 June 2000) (also GOOS Report No. 98, GCOS Report No. 69)

26/2001 GOOS-GCOS-WCRP Ocean Observations Panel for Climate (Report of sixth session, Melbourne, Australia, 2-5 April 2001) (also GOOS Report No. 113, GCOS Report No. 70)

1/2002 CLIVAR Asian-Australian Monsoon Panel (Report of fourth session, Reading, UK, 29-31 August 2001) (also ICPO Report No. 57)

2/2002 CLIVAR Atlantic Implementation Panel (Report of third session, Paris, France, 7-8 September 2001) (also ICPO Report No. 58)

Special WCRP Reports

- 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) (WMO/TD-No. 1096)

CAS/JSC Working Group on Numerical Experimentation Report Series

No. 31 Research Activities in Atmospheric and Oceanic Modelling (edited by H. Ritchie) (WMO/TD-No. 1064)

Others (including reports produced by project offices)

- World Ocean Circulation Experiment (WOCE) (Report of twenty-seventh session of Scientific Steering Group, Fukuoka, Japan, 21-22 October 2000) (WOCE Report No. 172/2001)

- World Ocean Circulation Experiment (WOCE) (Report of fourteenth session of Data Products Committee, Silver Spring, MD, USA, 27-29 March 2001) (WOCE Report No. 173/2001)

- World Ocean Circulation Experiment (WOCE) (Report of the WOCE/JGOFS Ocean Transport Workshop, Southampton, UK, 25-29 June 2001) (WOCE Report No. 174/2001)

- World Ocean Circulation Experiment (WOCE) (CLIVAR Report of the workshop on representativeness and variability, Fukuoka, Japan, 17-20 October 2000) (WOCE Report No. 175/2001) (also ICPO Report No. 55)

- Global Energy and Water Cycle Experiment (GEWEX) (Co-ordinated Enhanced Observing Period (CEOP) - Implementation Plan) (May 2001) (International GEWEX Project Office Publication Series No. 36)

Most of the reports produced by the International CLIVAR Project Office also had a WCRP Informal Report number and have been included in the list of those reports. Other reports/documents available were listed on and accessible through the WCRP Home Page: **http://www.wmo.ch/web/wcrp/otherwcrpreports.htm**

11.4 WCRP resources

A summary of the proposed programme to be supported by the Joint Climate Research Fund (JCRF) for the Fourteenth WMO Financial Period (2004-2007) was presented to the JSC. This proposal was subject to review initially by the WMO Executive Council at its session in June 2002, and later by the Fourteenth World Meteorological Congress in May 2003 and the executive bodies of IOC and ICSU. The sum available for WCRP activities was sharply lower for the period 2004-2007 than for 2000-2003 (less than CHF 4.6M compared to about 6.0M). This would mean a significant reduction in the number of project meetings/activities that could be supported in the period 2004-2007 from the JCRF, especially for GEWEX and CLIVAR. It was also noted that the number of positions in the Joint Planning Staff was expected to be maintained at the current level. Thus, no relief could be foreseen in the pressure of work on the Joint Planning Staff which would continue to be very seriously overstretched.

In view of the pressure on resources, and the decrease in available funds in the period 2004-2007, JSC members were called on, as part of their primary duty as advocates of the WCRP in their home countries, to pursue actively and vigorously all means of finding additional support and funding for the WCRP, the operation of the Joint Planning Staff for the WCRP and the various Project Offices. Furthermore, JSC members were invited 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 to be made to the relevant national scientific council or body in members' countries).

12. DATE AND PLACE OF TWENTY-FOURTH SESSION OF THE JSC

The JSC gratefully accepted the kind invitation put forward by the Vice-chair, Professor B. Hoskins, to host the twenty-fourth session of the Committee in Reading, UK from 17 to 22 March 2003.

13. CLOSURE OF 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, especially the exciting concept of the new WCRP banner "Predictability Assessment of the Climate System". The Chairman also acknowledged the very interesting scientific presentations that had been given to the Committee by Dr S. Rintoul on the "Southern Oceans and Climate - Lessons from WOCE and Prospects for CLIVAR" and by Dr N. Nicholls on "DIAGNOSE: a system for real-time monitoring of climate variations and the diagnosis of their causes and impacts".

The Chairman paid special tribute to three participants who had been long involved in WCRP activities and in supporting the JSC who were now retiring from their positions. Firstly, he referred to the outstanding service of Dr A. Alexiou who had represented IOC at the JSC sessions for many years and was such a valuable and effective point of contact between the WCRP and IOC in dealing with the various questions that arose. Secondly, he noted the remarkable contributions of Dr J. Gould, Director of the International WOCE Project Office as well as for the past three years Director of the International CLIVAR Project Office, in carrying forward WOCE to its now almost final stage and in the firm steps taken towards the implementation of CLIVAR. Dr Gould always also participated in JSC sessions in a highly effective manner. Thirdly, he thanked Mr R. Newson, Director of Climate Modelling in the WCRP, for his work in supporting the JSC and many other activities in the WCRP over many years. One of Mr Newson's strengths was that he constantly stressed the need to view the goals of, and results from, the WCRP component activities in the context of the overall coherence, integrity and interest of the WCRP as a whole.

Finally, the Chairman reiterated sincere gratitude to Dr J. Church and all who had worked with him for the memorable arrangements that had been made for the JSC session, the excellent facilities, and generous hospitality. He asked that the appreciation of the JSC be relayed to all involved.

The twenty-third session of the WMO/ICSU/IOC Joint Scientific Committee for the WCRP was closed at 13.45 hours on 22 March 2002.