WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR ATMOSPHERIC SCIENCES

THIRTEENTH SESSION

OSLO, 12–20 FEBRUARY 2002

ABRIDGED FINAL REPORT WITH RESOLUTIONS AND RECOMMENDATIONS

WMO-No. 941

Secretariat of the World Meteorological Organization - Geneva - Switzerland

REPORTS OF RECENT WMO SESSIONS

Congress and Executive Council

883 — **Executive Council**. Fiftieth session, Geneva, 16–26 June 1998.
902 — **Thirteenth World Meteorological Congress**. Geneva, 4–26 May 1999.
903 — **Executive Council**. Fifty-first session, Geneva, 27–29 May 1999.
915 — **Executive Council**. Fifty-second session, Geneva, 16–26 May 2000.
929 — **Executive Council**. Fifty-third session, Geneva, 5–15 June 2001.
932 — **Thirteenth World Meteorological Congress**. Proceedings, Geneva, 4–26 May 1999.

Regional associations

882 — **Regional Association VI** (Europe). Twelfth session, Tel Aviv, 18–27 May 1998.
890 — **Regional Association V** (South–West Pacific). Twelfth session, Denpasar, 14–22 September 1998.
891 — **Regional Association I** (Africa). Twelfth session, Arusha, 14–23 October 1998.
924 — **Regional Association II** (Asia). Twelfth session, Seoul, 19–27 September 2000.
927 — **Regional Association IV** (North and Central America). Thirteenth session, Maracay, 28 March–6 April 2001.
934 — **Regional Association III** (South America). Thirteenth session, Quito, 19–26 September 2001.

Technical commissions

879 — **Commission for Atmospheric Sciences**. Twelfth session, Skopje, 23 February–4 March 1998.
881 — **Commission for Instruments and Methods of Observation**. Twelfth session, Casablanca, 4–12 May 1998.
893 — **Commission for Basic Systems**. Extraordinary session, Karlsruhe, 30 September–9 October 1998.
899 — **Commission for Aeronautical Meteorology**. Eleventh session, Geneva, 2–11 March 1999.
900 — **Commission for Agricultural Meteorology**. Twelfth session, Accra, 18–26 February 1999.
921 — **Commission for Hydrology**. Eleventh session, Abuja, 6–16 November 2000.
923 — **Commission for Basic Systems**. Twelfth session, Geneva, 29 November–8 December 2000.
931 — **Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology**. First session, Akureyri, 19–29 June 2001.
938 — **Commission for Climatology**. Thirteenth session, Geneva, 21–30 November 2001.

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NOTE

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GENERAL SUMMARY OF THE WORK OF THE SESSION

1. **OPENING OF THE SESSION** (agenda item 1)

1.1 The thirteenth session of the Commission for Atmospheric Sciences (CAS) was held in the Radisson SAS Scandinavia Hotel in Oslo, from 12 to 20 February 2002, at the kind invitation of the Government of Norway. The session was attended by 82 delegates representing 42 Members and two international organizations. The list of participants appears in Appendix A to this report.

1.2 The president of the Commission, Mr A. Eliassen, formally declared the session open at 10 a.m. on Tuesday, 12 February 2002. Mr Eliassen thanked all those individuals who had made positive contributions to the work of the Commission during the intersessional period, especially the chairpersons of the working groups, the rapporteurs and the individual CAS members and the Secretariat of WMO. He expressed his appreciation to the Norwegian Government and the city of Oslo for providing the facilities for the meeting. Mr Eliassen noted that the various branches of meteorology, atmospheric chemists and, increasingly, social scientists were now working more closely together and that CAS could contribute to that integration process. The short distance from advanced research into useful applications which contributed to the safety, well-being and prosperity of societies made the work of CAS important and interesting. That feature was particularly evident in the work of the WWRP. With respect to atmospheric composition monitoring, Mr Eliassen was pleased that the GAW activities of the Commission had matured since the twelfth session and was now providing important information to environmental conventions as well as basic input for studies on atmospheric chemistry, physics and climate. Mr Eliassen concluded by looking forward to discussions at the session which would move CAS to a body looked upon to provide scientific answers that improved the range of services supplied by meteorological institutes around the world.

1.3 On behalf of the Government of Norway, H.E. Mr T. Fevolden, Secretary-General of the Ministry of Education and Research, warmly welcomed the participants to Norway for the thirteenth session of CAS. H.E. Mr Fevolden noted that Norway had a particular place in the history of meteorology. First, with Mr Bjerknes and the founding fathers, who created the famous Bergen school of meteorology. Later, Messrs Fjørtoft and Eliassen who played important roles in the development of modern meteorology with their pioneer work in NWP. It was a great honour to host a meeting of CAS in the homeland of those pioneers and a pleasure to meet so many eminent scientists from all parts of the world. Since the atmosphere knew no political frontiers, worldwide cooperation in understanding its behaviour was the only sensible way ahead. WMO was, H.E. Mr Fevolden remarked, an excellent example of how scientific efforts could be coordinated for the common good of mankind. The meteorology-related challenges facing society around the world were numerous. H.E. Mr Fevolden was pleased to see that those issues were to be discussed at the session. The results would be of fundamental importance to the progress and improvements in National Meteorological Services. Meteorology had always played a vital role in the everyday life of people in Norway. For centuries, reliable weather forecasts had often been a matter of life or death, especially for people living along the weather-exposed coast and making their living from the sea. Reliable weather forecasts were of no less importance in our modern society. H.E. Mr Fevolden pointed out that every winter the coast of Norway was subject to severe storms, sometimes with heavy economic and human losses. Other parts of the world were even more exposed to severe weather events, threatening the well-being of the citizens, the economy of the countries and an indefinite number of human lives. H.E. Mr Fevolden noted, however, that it was difficult, and perhaps impossible, to quantify the benefit of meteorological information, but there was no doubt that the benefit factor was high.

1.4 Mr Per Ditlef-Simonsen, the Mayor of the city of Oslo, expressed the honour of the people of Oslo for the Commission choosing to hold its session in their city. He indicated that Oslo was subject to difficult meteorological conditions on occasion, particularly regarding severe cold and air quality problems. Mr Ditlef-Simonsen drew an analogy with respect to how his city had successfully integrated peoples from all over the world into Norwegian society and the impressive results that the city had made in addressing its environmental problems. He said that an inclusive approach had been key to both those successes, involving all stakeholders at each stage. He cited an example of an environmental success story which had witnessed the sea that had been heavily polluted 20 years ago returned to its pristine state. Mr Ditlef-Simonsen concluded by wishing the participants a pleasant stay in his city.

1.5 The Secretary-General of WMO, Professor G.O.P. Obasi, greeted the participants and expressed his sincere thanks to the Government of Norway for the invitation to hold the session of CAS in Oslo and for providing such excellent facilities. Professor Obasi acknowledged the work done by the president of the Commission, Mr A. Eliassen and the vice-president, Mr Yan Hong in overseeing the affairs of the Commission since its last session in Skopje. The Secretary-General identified some key issues that should be considered by the Commission:

(*a*) GAW had matured in recent years into an internationally recognized programme providing high quality atmospheric composition information. CAS was urged to consider undertaking additional scientific assessments on, for example, carbon dioxide and, perhaps, other greenhouse gases in addition to the existing quadrennial assessments of stratospheric ozone. With regard to the urban component of GAW, the Secretary-General invited the Commission to develop the necessary framework for the involvement of NMHSs in such activities;

(*b*) The Programme on Physics and Chemistry of Clouds and Weather Modification Research provided Members with sound scientific advice on the efficacy of various weather modification techniques. The Commission was invited to assist Members, particularly those in the Mediterranean region who were embarking on a project, to examine the potential for precipitation enhancement;

(*c*) NWP activities continued to make steady progress, especially in the short to medium ranges. CAS was encouraged to give attention to the needs of Member countries in the use of NWP products from advanced centres and in the development of national and regional NWP capabilities for purposes of warnings and socio-economic planning;

(*d*) The TMRP was of importance not only to those countries in the tropics, but also to those of higher latitudes. It dealt with improving understanding of the phenomenon of droughts, tropical cyclones and monsoons. CAS was urged to give priority attention to developing country NMHSs to improve their capabilities in dealing with those matters.

The Secretary-General mentioned other important issues that the delegates should consider, such as the international exchange of data, input into the development of the Sixth WMO Long-term Plan and the enhanced engagement of developing countries in the activities of the Commission. He concluded by wishing the delegates a fruitful session and a pleasant stay in Oslo.

2. ORGANIZATION OF THE SESSION (agenda item 2)

2.1 CONSIDERATION OF THE REPORT ON CREDENTIALS (agenda item 2.1)

The representative of the Secretary-General reported to the Commission on the status of the credentials received. In accordance with General Regulation 22, the Commission agreed to accept the credentials of the delegates named in the list prepared by the representative of the Secretary-General. It was considered unnecessary to establish a Credentials Committee.

2.2 ADOPTION OF THE AGENDA (agenda item 2.2)

The Commission adopted the agenda, which is reproduced in Appendix B to this report.

2.3 ESTABLISHMENT OF COMMITTEES (agenda item 2.3)

NOMINATION COMMITTEE

2.3.1 In accordance with General Regulation 24, a Nomination Committee was established consisting of Messrs P. G. Price (Australia), chairperson, A. Quinet (Belgium) and E. Kambueza (Namibia).

COORDINATION COMMITTEE

2.3.2 In accordance with General Regulation 28, a Coordination Committee was set up composed of the president, the chairpersons of the two working committees, the representative of the Secretary-General and the Conference Officer.

WORKING COMMITTEES

2.3.3 Two working committees were set up to examine in detail specific agenda items:

(*a*) Committee A to deal with agenda items 5.1 (on the issue of WWRP), 5.2 and 6. Mr A. V. Frolov (Russian Federation) served as chairperson;

(*b*) Committee B to deal with agenda items 3.1, 4, 5.1 (on the issue of middle-atmosphere studies) and 7. Mr M. Béland (Canada) served as chairperson.

The Commission agreed to discuss agenda items 3, 8, 9, 10 and 11 as a Committee of the Whole.

COMMITTEE FOR COORDINATING PROPOSALS FOR RAPPORTEURS AND MEMBERSHIP OF WORKING GROUPS

2.3.4 A committee for coordinating proposals for rapporteurs and membership of working groups was established consisting of the president, representatives of China, the Islamic Republic of Iran, South Africa, the United Kingdom and the United States, and the representative of the Secretary-General.

2.4 OTHER ORGANIZATIONAL MATTERS (agenda item 2.4)

Under the present agenda item, the Commission decided on its working hours. The Commission agreed that the decisions arrived at for each agenda item would be recorded in the general summary of the work of the session.

3. REPORT OF THE PRESIDENT OF THE COMMISSION (agenda item 3)

3.0.1 The president of the Commission, Mr A. Eliassen (Norway), presented an overview of the Commission's main activities and developments since its last session drawing attention to the very substantial progress in areas such as GAW, WWRP, TMRP and the Programme on Physics and Chemistry of Clouds and Weather Modification Research. The president furthermore highlighted the key role of CAS in the transfer of science advances into applications and operations and in addressing the difficult question of the links between science, applications and socio-economic aspects. That would require more sophisticated products, for example probabilistic forecasts, as well as better interaction with the user community to determine their needs. The president also emphasized the increasing importance of extrabudgetary resources in support of the activities of the Commission. New alliances with university sectors, users and WMO Members' national programmes would be necessary in order to maintain and enhance future progress.

3.0.2 The president informed the Commission that the fifty-second session of the Executive Council in 2000 had requested CAS to prepare a draft WMO policy statement on the scientific basis for, and limitations of, weather and climate forecasting. That matter was further discussed under agenda item 8.

3.0.3 The Commission responded by expressing its appreciation to the president of CAS for both his informative report and for his considerable contributions to WMO and its Atmospheric Research and Environment Programme.

3.0.4 The Commission also indicated its satisfaction with the progress being achieved with its programmes in general and, in particular, the manner in which the WWRP, GAW and the GURME project were developing. With respect to GAW, the Commission expressed its gratitude to a number of countries for their substantial contributions to training and other important operational functions of the system. The Commission was also fully supportive of the initiative to engage the satellite operators in developing an integrated approach to observing the atmosphere, within the framework of IGOS.

3.0.5 The Commission agreed with the sentiments expressed by the president that its programmes, while supporting key thrusts of the Organization, would benefit from strengthening links with the broader scientific community and potential users, particularly from the perspective of fostering two-way exchanges to enhance appreciation of user requirements and to obtain user input. The Commission also endorsed continuing efforts to include a capacity transfer component or objective in many of its activities. The long-term benefits of those enhanced initiatives for NMHSs with respect to weather prediction services, tropical meteorology understanding, and the functioning of GAW would be considerable.

3.0.6 The proposed new terms of reference were discussed at some length. The Commission agreed that they should reflect the important contributions made by GAW to a number of international environmental conventions as well as the need to enhance capacity transfers, particularly in GAW, WWRP and TMRP. The new proposed terms of reference for the Commission appeared in Annex I to this report and would be submitted to the Executive Council and Congress for approval.

3.0.7 Noting the valuable work carried out by the CAS Advisory Working Group, the Commission agreed that the group should be re-established and consequently adopted Resolution 1 (CAS-XIII).

3.1 SUPPORT TO OZONE AND OTHER ENVIRONMENT-ORIENTED CONVENTIONS (agenda item 3.1)

3.1.1 With regard to WMO support to a number of environmental conventions, the Commission noted that WMO's GAW programme continued to provide fundamental information underpinning assessments of the measures agreed by Governments to address stratospheric ozone destruction (Vienna Convention and Montreal Protocol and subsequent amendments), long-range transport of pollution in Europe (Convention on Long-range Transboundary Air Pollution), environmental impacts of persistent organic pollutants (Stockholm Convention) and the build up of greenhouse gases (notably carbon dioxide and methane) in the atmosphere (UNFCCC and Kyoto Protocol).

3.1.2 With respect to ozone destruction, the Commission noted with satisfaction that GAW had continued to assign high priority to maintaining the integrity of the global ground-based ozone measurement network through a combination of regular intercomparisons of Dobson spectrophotometers, through comparisons of various types of ozonesondes, through quadrennial ozone assessments and through the excellent work of the World Ozone and Ultraviolet Data Centre. It commended GAW for its initiative to organize the first ever Dobson intercomparisons held in South America and Africa for instruments resident in those regions. The Commission strongly supported the notion of staging regular WMO Dobson intercomparisons in different WMO Regions. In addition, the Commission strongly supported the continued WMO participation in the periodic assessments of the state of the ozone layer and the issuing of periodic bulletins on seasonal polar ozone losses.

3.1.3 In view of the positive and increasing contribution to global ozone measurements resulting from the introduction of more than 100 Brewer spectrophotometers around the world, the Commission commended GAW for sponsoring biennial meetings of Brewer operators. Such meetings were essential to increase the flow of ozone data into the World Ozone and Ultraviolet Data Centre. The Commission welcomed actions by the Secretariat that would bring together both the Dobson and Brewer instrument communities to integrate better their calibration procedures and noted the need to conduct regular intercomparisons between Brewer and Dobson instruments.

3.1.4 The Commission recognized the paucity of information on the vertical distribution of ozone from tropical and subtropical areas of the world without which a complete understanding of the physics, chemistry and transport processes of atmospheric ozone remained difficult. It therefore recommended that WMO GAW explore options to increase the number of ozonesonde stations in those data-sparse areas. The Commission was, therefore, pleased to be informed that the Hong Kong Observatory was planning to increase the number of ozonesonde flights from once a month to weekly, and that weekly ozonesonde flights from Macquarie Island (54°S, 159°E) were to be operational in Australia's Basic Observing System. The Commission was also pleased that a set of standard operating procedures had been developed for ozonesondes and were currently being finalized, thus facilitating interpretation of ozone data from the various types of sonde.

3.1.5 With respect to the UNFCCC and the work of the IPCC, the Commission emphasized the important atmospheric information on greenhouse gas trends from the GAW Global and Regional Stations for conducting

assessments and climate projections and for identifying mitigation/adaptation strategies. It was noted that the six GAW Global Stations recently established in developing countries continued to need assistance if they were to reach their full capacity to contribute to our understanding of climate change. That information would be viewed as crucial when implementing the Kyoto Protocol. The Commission regretted, however, that the contribution of GAW to those international mechanisms was not sufficiently recognized. It requested CAS through its Working Group on Environmental Pollution and Atmospheric Chemistry to develop a communication strategy to increase the international visibility and standing of GAW.

3.1.6 The Commission was strongly supportive of the links that had been established between EMEP and GAW. It noted with satisfaction that GAW had been invited to co-chair the EMEP Task Force on Measurements and Modelling. The Commission informed that EMEP was beginning a major project to assess the implementation of the European Convention on Long-range Transboundary Air Pollution over the last 20 years and recommended that GAW take an active role in that initiative.

3.1.7 In connection with the cooperation of WMO with the Barcelona Convention for the Protection of the Mediterranean against Pollution, the Commission acknowledged with satisfaction the valuable contribution of GAW to the Convention's MED POL Programme as it related to monitoring, modelling and assessment of pollution of the Mediterranean Sea from land-based sources through the atmosphere. Of particular importance were the assessments of the atmospheric inputs of heavy metals, including mercury, and persistent organic pollutants, which entered the marine environment mainly through the atmosphere together with a manual for monitoring atmospheric deposition, prepared under the leadership of GAW. The Commission invited all the WMO Members in the Mediterranean region to participate actively in corresponding MED POL activities coordinated by GAW.

4. GLOBAL ATMOSPHERE WATCH (agenda item 4)

4.1 ENVIRONMENTAL POLLUTION AND ATMOSPHERIC CHEMISTRY (agenda item 4.1)

4.1.1 The Commission noted with appreciation the comprehensive report presented by the chairperson of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Mr O. Hov (Norway), with regard to the state, further development and objectives of the GAW programme and other WMO environment-related activities. It commended the Working Group for providing valuable guidance to GAW and for its efforts in increasing the visibility of WMO environment-related activities, and recommended that the Executive Council Panel of Experts/CAS Working Group be re-established and that the Executive Council give favourable consideration to the proposed composition and terms of reference. The Commission, accordingly, adopted Recommendation 1 (CAS-XIII).

4.1.2 The Commission fully supported the Strategy for the implementation of the GAW programme (2001–2007) prepared by the Secretariat with the help of a number of atmospheric chemistry experts and thoroughly reviewed and endorsed by the working group. It also supported the proposed GAW strategic goals and implementation strategies as related to the programme as a whole, as well as to its individual measurement parameters, quality assurance, data management and application and other major activities with particular focus on the following core activities in 2001–2004:

(*a*) Stabilization of operations at the present stations;
(*b*) Continuation of capacity building efforts through twinning, workshops and other activities;
(*c*) Completion of the quality assurance/quality control system for the measured parameters;
(*d*) Provision of easy access to the data and promotion of data applications for modelling and scientific assessments, in order to expand the user base;
(*e*) Extension of measurements in regions with insufficient coverage, especially in the tropics, the southern hemisphere and in continental areas, first through strengthened links with existing regional networks;
(*f*) Evolution of GAW into a three-dimensional global observation network through close contact first of all between the surface-based and satellite observations;
(*g*) Building data analysis capabilities at central GAW facilities in cooperation with the rest of the research community.

4.1.3 The Commission stressed the importance of the new GAW strategy for further development of the programme and urged all the GAW partners to implement that strategy as fully as possible. The need to ensure adequate human and financial resources in order to maintain and enhance GAW's operational infrastructure was especially emphasized. The Commission urged its working group, the SAGs, the GAW central facilities as well as individual scientists and institutions participating in GAW, to initiate and support the joint twinning activities and cooperation with those who needed assistance to maintain existing, and to restore inactive, GAW stations.

4.1.4 In considering the implementation of GAW since its previous session, the Commission was satisfied with the continued progress in that important WMO activity which had acquired ever greater significance as the world community was becoming increasingly concerned about the present and future state of the environment. In that regard, the Commission recognized the important role played by the GAW SAGs which were established in accordance with the first GAW strategic plan approved by CAS-XII for such measurement parameters as ultraviolet radiation, aerosols, ozone, precipitation chemistry and deposition, greenhouse gases and urban environment. It was recommended that the SAG on reactive gases (carbon monoxide, volatile organic compounds, nitrogen oxides and sulphur dioxide) also be established as soon as possible, with the participation of satellite experts. The

Commission also acknowledged the useful services provided by the GAW Quality Assurance/Science Activity Centres and agreed with the recommendation of the Working Group that responsibilities of those centres should be shifted, where feasible, from regional quality assurance for all parameters to global quality assurance for individual (or groups of) parameters.

4.1.5 The Commission welcomed the active participation of WMO in the multi-agency IGOS as an effective way to integrate the major satellite and ground-based systems so as to provide highly accurate global observation of the atmosphere, oceans, cryosphere and land. In that regard, it expressed satisfaction with the *WMO/CEOS Report on a Strategy for Integrating Satellite and Ground-based Observations of Ozone* (GAW Report No. 140, WMO/TD-No. 1046) prepared by WMO and CEOS. The further participation of GAW in, and contributions to, IGOS was recommended, in particular with regard to the developing IGOS Theme on Integrated Global Atmospheric Chemistry Observations. It was also recommended that the satellite community share responsibility and resources with the GAW programme in maintaining high quality measurements over the long-term.

4.1.6 With regard to GAW data handling and use, the Commission supported the opinion of its Working Group that the GAW WDCs should continue providing free, unrestricted and user-friendly access to their data for scientific purposes. The Commission endorsed the statement of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, made at its seventh session in April 2001, that "the user of such data accepts that an offer of co-authorship will be made through personal contact with the data providers or owners whenever substantial use is made of their data. In all cases, an acknowledgement must be made to the data providers or owners and to the data centre when these data are used within a publication." In order for wider use to be made of GAW data, there was a need to establish closer contacts with potential data users, to inform them on the availability of, and access to, the data, to identify their needs for data that might be provided by GAW, to initiate and coordinate the preparation of scientific assessments and development of models, and to promote the use of GAW data for dealing both with global and specific regional and, even, national environmental problems.

4.1.7 The Commission shared the concern of its Working Group with respect to the need for regular calibration of the instruments measuring infrared radiation and requested *MétéoSuisse* to consider the possibility of establishing an infrared calibration centre and to initiate relevant activities in 2002–2003 in the World Radiation Centre in Davos, Switzerland. The Commission proposed that related steps to define and formulate the needs and operational procedures for such an infrared centre be undertaken by the responsible bodies of WMO, such as by CIMO, in cooperation with the World Radiation Centre and in consultation with the CAS Working Group on Environmental Pollution and Atmospheric Chemistry. The Commission noted that the SAG for ultraviolet had been active in reviewing ultraviolet measuring instruments. In view of the public and scientific interest in ultraviolet levels, CAS recognized the need to establish Regional/World Calibration Centres. It requested the SAG for ultraviolet to investigate that matter further.

4.1.8 Satisfaction was expressed by the Commission in connection with the close cooperation of GAW with the atmospheric sciences and environment protection communities, both within and beyond NMHSs, including many international, regional and national oganizations and programmes such as IGAC, IAMAS, EMEP, EANET, GESAMP, CEOS, UNEP, WHO and others. The need for close cooperation and coordination of international activities was particularly stressed for addressing emerging environmental issues and for ensuring the leading role of WMO in those environmental problems where the atmosphere played an important role.

STATUS OF THE GAW SYSTEM

4.1.9 The Commission expressed its satisfaction with the development of GAW, which continued to mature both internally and externally, in particular with regard to the network of GAW stations, and agreed that added weight be given to the work of regional stations to address urgent regional or even national environmental issues. The Commission welcomed the initiation of the GAW Station Information System which would provide up-to-date information about operation of the GAW stations and their data and expressed appreciation to *MétéoSuisse* and the Japan Meteorological Agency for their support to that development.

4.1.10 With respect to the full functioning of the new GAW stations in developing countries, established through the WMO/GEF projects — Global Monitoring of Greenhouse Gases including Ozone, and Monitoring of Ozone and UV-B in the Southern Cone Countries of South America — the Commission recognized that in order to assure long-term operations at those stations both the Secretariat and Members with the requisite expertise and those developed countries hosting global stations and calibration centres would need to continue to cooperate and provide assistance to those stations.

4.1.11 The Commission was informed about the Seventh Session of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry and the GAW 2001 Workshop organized by the Secretariat in Geneva in April 2001. For the first time since GAW was established more than 10 years ago, representatives of some GAW global stations, Quality Assurance/Science Activity Centres, World Calibration Centres and some collaborating programmes as well as managers of the GAW WDCs and chairpersons of SAGs were able to discuss the major issues related to the functioning of the whole GAW system. The Commission agreed that such meetings were of benefit for GAW and that, should resources allow, they should be held on a more regular basis in the future.

4.1.12 With regard to the six GAW WDCs, the Commission noted that most of those centres were conducting their operations in a satisfactory manner but expressed its concern that some centres required additional resources to become fully operational. In that connection, CAS appreciated the offer of the Japan Meteorological Agency to consider positively including surface ozone data at the WDC for greenhouse gases. The Commission commended those countries and organizations which hosted the WDCs (Canada, the European Commission, Japan, Norway, Russia and the United States) and thus assumed the costs of their operations. The WDCs were urged to continue their efforts with respect to coordinating and harmonizing their work, developing comprehensive databases, quality assurance and Internet-based data submission procedures and ensuring easy access and better use and application of GAW data. Concern was expressed that data reporting from many GAW stations was insufficient and all WMO Members operating GAW stations were called upon to ensure that the data from their stations were regularly submitted to WDCs in accordance with the established procedures.

4.1.13 The significant efforts of GAW towards improving the quality of measurements were acknowledged by the Commission. It reiterated that quality assurance should remain one of the most important tasks for GAW to continue to succeed and to be recognized as the leading international programme providing reliable data and information on the state of the atmospheric environment. The Commission appreciated the work of the GAW Calibration Centres and the activities of the SAGs for ultraviolet, ozone, aerosol and urban environment in developing relevant quality assurance documents, and invited other SAGs to strengthen their efforts in that direction. It was recommended that calibration, instrument intercomparisons and laboratory performance audits should continue on a regular basis and encompass as many GAW stations as possible. Satisfaction was expressed with regard to the publication of an updated GAW measurements guide.

4.1.14 The Commission emphasized that the training and education needs in developing countries should continue to be a high priority for the GAW programme. In that connection, many GAW centres and collaborating national organizations were commended for their substantial efforts in providing training to GAW station personnel from developing countries. Particular appreciation was expressed to the State Government of Bavaria (Germany) for establishing the GAW Training and Education Centre and to the Czech Republic for conducting annual training for Dobson spectrophotometers at the Solar and Ozone Observatory.

4.1.15 The Commission noted with satisfaction the substantial improvements in communication among all the GAW partners and in the coordination of GAW activities. Examples included the nomination of GAW focal points in participating countries, the preparation and distribution (every four months) of the GAW Information Sheets, the provision of GAW-related information and communication over the Internet and the development of a pilot GAW Web site. The complex, international and multilayered nature of GAW operations, with its need for frequent and effective communication, dictated that a Web-based facility be employed as a primary and central tool for managing and coordinating GAW activities, disseminating relevant information and two-way communication.

4.1.16 The Commission acknowledged the leading role of WMO in preparing and distributing biweekly bulletins on the state of the ozone layer over Antarctica during August-December each year and in preparing (by the WMO Ozone Mapping Centre, Greece) and distributing through the Internet the northern hemisphere daily ozone maps for the winter/spring periods. WMO was also active in international efforts to prepare regular scientific assessments of ozone depletion, the most recent being issued in 1998 with the next in the series expected later in 2002. The Commission requested that those activities be continued and appealed to all Members to provide the necessary support. In addition, CAS recalled that the new 2001–2007 strategy for GAW made explicit mention of the need to expand the use of GAW data for, inter alia, scientific assessments. The Commission, therefore, agreed with the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry that GAW, working with other programmes and agencies, should initiate scientific assessments additional to the quadrennial ozone assessments, perhaps for some of the greenhouse gases. An increased international awareness of the GAW programme was judged as a secondary benefit of conducting further assessments.

4.1.17 Satisfaction was expressed by the Commission with regard to the GAW assistance and advice provided to address urgent environmental problems such as transboundary smoke and haze in South-East Asia, long-range atmospheric transport and deposition of persistent organic pollutants and heavy metals, as well as acid deposition in east Asia. Further GAW cooperation with those activities was strongly recommended.

4.1.18 The Commission was pleased to note the active participation of WMO in the work of GESAMP directed at assessing the state of the marine environment. It was recommended that WMO should continue participating in relevant international activities related to the atmospheric input of pollutants into the sea and the effects of global changes and other atmosphere-related processes on the marine environment.

4.1.19 The Commission requested its president — in consultation with the Advisory Working Group, the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry and the Secretariat — to work towards establishing a mechanism to assist the work of the Panel through promotion of GAW, seeking resources and facilitating broad international cooperation.

4.1.20 By way of conclusion, the Commission expressed deep appreciation to all WMO Members operating GAW stations, who actively participated in GAW

activities and to ensure the functioning of the GAW central facilities such as WDCs, Quality Assurance/Science Activity Centres, Calibration Centres and training centres. It urged their continued and, if possible, enhanced support and contributions to GAW so that it might continue to provide quality atmospheric composition information to both Governments and the scientific community.

4.2 **URBAN ENVIRONMENT** (agenda item 4.2)

4.2.1 The Commission noted with appreciation the activities carried out under the GURME project, endorsed by the WMO Executive Council in 1998 following a recommendation from CAS-XII.

4.2.2 Specifically, the GURME project was developed in response to the recognition that NMHSs had a critical role to play in the study and management of urban environments, in part because the NMHSs were in possession of information and capabilities that were essential to the forecasting of urban air pollution and the evaluation of the effects of different emission control strategies. GURME activities were designed to enhance the capabilities of NMHSs with the meteorological and related aspects of urban pollution through coordination and selected new endeavours.

4.2.3 The Commission was informed that two Workshops on Urban Environment had been convened (Beijing, November 1999 and Moscow, December 1999) to determine the requirements of Member countries in order that they might assume a leadership role in managing urban pollution.

4.2.4 The Commission reviewed the recommendations from those Workshops and more recent developments, and was in agreement that the future development of GURME should focus on:

(*a*) Assisting NMHSs in providing air quality services by illustrating and promoting the linkages between meteorology and air quality; by building awareness with end-users (customers) through applications related to compliance, trend analysis and industrial/city planning; and by providing opportunities for twinning and facilitating expert assistance;

(*b*) Assisting NMHSs in developing urban-environmental forecasting capabilities by providing guidelines on available models, by conducting intercomparisons and by facilitating training activities;

(*c*) Assessing appropriate urban measurements that supported urban forecasting by better defining meteorological and air quality measurements (including contemporary techniques to obtain vertical structure, i.e. wind and temperature profilers, meteorological towers and satellite products); by assisting in quality assurance/quality control analysis, intercalibrations and by extending those efforts to include key meteorological parameters;

(*d*) Promoting the use of passive samplers to augment chemical measurements in urban environments, to aid in-site selection, and to provide added spatial resolution in support of model evaluation;

(*e*) Expanding and publicizing its use of the Internet. That could include a catalogue of appropriate measurement and modelling techniques, with examples of successes, failures and applications for new measurement techniques and models, and as a forum to exchange information on a variety of issues. Other uses of the Internet could be to create or to link to common databases while avoiding unnecessary duplication with existing databases;

(*f*) Improving linkages with national/regional/international programmes (e.g. environmental agencies, municipalities, the IGAC project, etc.) in addition to other WMO Programmes and to WHO;

(*g*) Facilitating NMHS' initiatives related to urban environments through twinning relationships and by pursuing additional funding channels (e.g. such as the Asian Development Bank and the World Bank, through such programmes as their Clean Air Initiative).

4.2.5 The Commission was pleased to learn that as a direct consequence of those Workshops and their recommendations, the first WMO/GAW GURME Air Quality Forecasting Workshop was held in Kuching, Malaysia, in August 2000.

4.2.6 The Commission noted that the objectives of that Workshop were:

(*a*) To familiarize the participants with the different options for urban forecasting;

(*b*) To present a spectrum of forecasting tools and to discuss appropriate uses (including examples of model applications and their limitations and technical and data support requirements);

(*c*) To help NMHSs in their deliberations on what role to undertake in urban forecasting and in identifying suitable systems for use in support of their activities.

4.2.7 The Commission was aware that Member countries considered GURME to be an important undertaking by WMO in that it provided an international framework for air pollution modelling and other urban environmental issues. The Commission agreed with the Executive Council that future workshops under the GURME umbrella should focus on training and technology transfer aspects where participants were first introduced to the limitation of models and to which applications they could be used. The use of local and regional information combined with practical exercises were judged as important parts of the training. The Commission was pleased that a second forecasting workshop would be held later in 2002 in Mexico, with support from NOAA.

4.2.8 The Commission was pleased that in the short time since WMO endorsed GURME as a project within GAW, it had approved a number of pilot projects operating within its framework. The Beijing and Moscow projects were city-wide initiatives dealing with monitoring systems, modelling activities and meteorological/environmental activities. In the case of Beijing, those activities were focused on air quality issues while the Moscow project would ultimately integrate urban

pollution matters into the wider issue of sustainable development. The Commission noted the good progress evident in both projects and requested the SAG for GURME to enhance its interaction with the organizers of those pilot projects to provide international expertise to maintain their momentum. The third project on passive samplers aimed to establish a monitoring network of those instruments in background, regional and urban settings. The Commission urged those agencies responsible for those passive sampling networks to deposit their data in the appropriate GAW WDCs for use by the wider scientific community.

4.2.9 The Commission reviewed the Strategic Plan for GURME developed by its SAG and fully supported the implementation strategy consisting of:

(*a*) Task 1 — To produce GURME guidelines to enable NMHSs to take full advantage of GURME;
(*b*) Task 2 — To establish a GURME Web site to be used as the main communication vehicle for GURME activities;
(*c*) Task 3 — To conduct regional workshops focused on ways and means of developing urban environmental forecasting capabilities;
(*d*) Task 4 — To develop new, and promote, established GURME pilot projects to illustrate the spectrum of NMHSs urban-related activities and opportunities for cooperation with environmental agencies;
(*e*) Task 5 — To tie into related/complementary activities within WMO (e.g. WCP, CIMO) by collaborating on common topics and/or by collocating a project;
(*f*) Task 6 — To foster and continue close cooperation with WMO on the meteorological, measurement and health aspects of urban environments;
(*g*) Task 7 — To develop a strategy for addressing advice and guidance to NMHSs on measurements; and
(*h*) Task 8 — To continue evaluation of the passive sampler method, expand the number of sites and publish the observational data.

4.2.10 The Commission recalled that, at its twelfth session, it had identified the value of a database of results from relevant campaigns relating to transport and dispersion of atmospheric pollutants for use by the modelling community to conduct sensitivity and verification studies. The Commission learned with interest that Australia and the United States had developed a prototype database on three CD-ROMS. The data and related documentation, which had already been provided to each of the Regional Specialized Meteorological Centres for Emergency Response, could be reviewed on the Web site of the United States's Air Resources Laboratory.

4.3 CONTRIBUTION TO THE GLOBAL CLIMATE OBSERVING SYSTEM (agenda item 4.3)

4.3.1 The Commission noted that GCOS had been extended substantially by the revised 1998 Memorandum of Understanding which emphasized issues of implementation of the GCOS networks, and by the decisions of the fifth session of the Conference of the Parties to the UNFCCC. GCOS had therefore increased its focus on: (*a*) implementing and further planning of the GCOS networks and cooperation with its global observing system partners (including GAW) and other participants in IGOS; and (*b*) interactions with its sponsors and the UNFCCC. A GCOS Implementation Strategy, endorsed by the GCOS Steering Committee at its ninth session in September 2000, defined a way forward in building a multi-domain global observing system for climate and stressed close cooperation with existing operational and research observation networks.

4.3.2 The Commission noted that in Resolution 3 (EC-LII) — Global Climate Observing System, the Executive requested the presidents of technical commissions, in particular CAS, CBS, CCl and JCOMM, to strengthen the cooperation between GCOS and their respective technical commissions. The Commission fully supported that initiative and recalled Resolution 13 (Cg-XI) — Atmospheric Research and Environment Programme, contending that GAW would be a major contributor to GCOS as recommended by the Second World Climate Conference. It urged that the links and cooperation between GAW and GCOS be strengthened through the efforts of their respective Secretariats and Panels and the Members concerned.

4.3.3 The Commission recognized the importance of the decisions of the fifth session of the Conference of the Parties to the UNFCCC regarding meteorological and hydrological observing systems. It requested Members to participate, as needed, in the preparation of the second *Report on the Adequacy of the Global Climate Observing Systems to the UNFCCC*, which was being organized and guided by GCOS, in order to ensure that appropriate consideration was given to GAW and related issues in that *Report*.

4.3.4 The Commission welcomed the regional approach being taken by GCOS for identifying and seeking to address deficiencies in the observing networks for climate. It recalled in particular the recently-completed project funded by the GEF that established six new GAW stations in developing countries and requested that the needs and priorities of GAW be reflected in the development of the Regional Action Plans which would result from the GCOS regional workshops.

5. WEATHER PREDICTION AND TROPICAL METEOROLOGY RESEARCH (agenda item 5)

5.1 WORLD WEATHER RESEARCH PROGRAMME (agenda item 5.1)

5.1.1 The Commission noted with appreciation the report of the chairperson of the CAS Science Steering Committee for the WWRP, Mr R. Carbone (United States) highlighting the developments of WWRP. CAS commended the considerable work accomplished by the Science Steering Committee since its initial establishment at the twelfth session to implement the WWRP. The WWRP had successfully provided a focus for activities of the Commission and had added a positive international dimension to some national projects.

5.1.2 The Commission noted with satisfaction the success of the Third WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography (Quebec City, Canada, June 1999), the International Workshop on Long-range Forecasting and its Applications (Cairo, Egypt, January 2000), the Training Workshop on Nowcasting (Sydney, Australia, October/November 2000) and the WWRP Workshop on Verification of Quantitative Precipitation Forecasts (Prague, Czech Republic, May 2001). To promote the applications of improved and cost-effective forecasting techniques to all Members, the Commission encouraged the holding of similar workshops and training courses in the future. In particular, the active participation in the International Conference on Quantitative Precipitation Forecasts (Reading, United Kingdom, September 2002) by Members was encouraged.

PROJECTS IN PROGRESS

5.1.3 The Commission noted that intense weather over major mountain ranges, such as the European Alps, brought a high cost to society in the form of floods, windstorms and threats to aviation. The Mesoscale Alpine Programme was a measured response of the international atmospheric and hydrologic community to the challenge of improving the understanding and prediction of intense weather in mountainous areas. The Commission was impressed by the quality and quantity of datasets that had been obtained from the Mesoscale Alpine Programme Special Observing Period (7 September to 15 November 1999) as well as by the efforts to make those data accessible. The Commission encouraged the Mesoscale Alpine Programme to continue its efforts to integrate research related to societal impacts and forecast value.

5.1.4 The Commission was pleased with the success of the Sydney 2000 Forecast Demonstration Project. It brought together developers, forecasters and end-users working on common problems in an operational setting. The project, consistent with its aims, demonstrated that advanced nowcast systems were robust and transferable to a new location and could be used successfully in an operational environment. The project showed that international collaboration could be focused on local problems of significant economic and societal impacts that were repeatedly experienced in major cities worldwide.

5.1.5 The Commission was impressed at the progress of the Aircraft In-Flight Icing Project, which played an important role in coordinating and consolidating numerous national and regional efforts related to understanding icing conditions in water and mixed-phase clouds. Those efforts were focused on regional climatologies of freezing precipitation and upper-air conditions; the development of in situ instrumentation and acquisition of microphysical data in icing conditions; the interpretation and use of remote sensing data; and numerical model representations and predictions of icing. The Project involved all sectors of the aviation industry and users of icing forecast information.

5.1.6 The Commission noted with satisfaction the cooperation that existed between WWRP and TMRP in developing the International Tropical Cyclone Landfall Programme, which would contribute to improving further safety and to reducing the economic losses of tropical cyclone affected countries.

5.1.7 The Commission strongly encouraged the continued development of THORPEX aimed at demonstrating that additional high quality observations in critical areas of extratropical and subtropical oceans could improve the performance of one to 10-day numerical weather forecasts. The Commission noted that the Japan Meteorological Agency was studying the feasibility of establishing a THORPEX experiment in the nort-west Pacific with the goal of improving forecasts of typhoon tracks. The Commission encouraged coordination among those countries affected by typhoons in that initiative.

5.1.8 The Commission fully supported the science plan for the first phase of the Mediterranean Experiment on Cyclones that Produce High Impact Weather in the Mediterranean. That plan had specified the need to address, in the first instance, deficiencies in existing meteorological information, cases where high impact weather was poorly forecast and identification of sensitive areas and research on improved forecasting techniques.

DEVELOPING PROJECTS

5.1.9 The Commission welcomed the proposals to develop further potential new WWRP research and development projects and forecast demonstration projects that addressed warm season rainfall and flooding, sand and dust storms, urban environment and flooding, and the Athens 2004 Olympic Games. The Commission noted that in many parts of the world mesoscale convective systems were known to have lifetimes up to 24 hours, indicative of a dynamic upscaling from ordinary forms of convection. The goals of the proposed Warm Season Rainfall and Flooding Project were to increase markedly the skill of quantitative precipitation forecasts in the warm season over continents and to demonstrate the benefits of improved quantitative precipitation forecast information. Furthermore, in view of the heavy loss of life in some urban areas due to heavy rainfall events, CAS fully supported the developing project on Urban Environment Flooding, possibly in Sao Paulo, Brazil. The Commission was strongly supportive of the proposed Athens 2004 Forecast Demonstration Project which was being planned as an advanced version of the Sydney 2000 Forecast Demonstration Project. Three components were under consideration: (*a*) a set of limited area models for NWP at 1–3 km resolution for local winds and temperatures; (*b*) air quality forecasts based on the predictions of (*a*) plus the inclusion of pollution source data and models; and (*c*) nowcasting by means of expert systems of convective storms, local winds, and precipitation amount and type. With the potential importance of those projects to society, the Commission requested the WWRP Science Steering Committee to pursue

vigorously its efforts to coordinate and facilitate those potential WWRP projects. The Commission was informed that the China Meteorological Administration had initiated an action plan of the meteorological services to be provided at the Beijing 2008 Olympic Games including the build-up of new observation networks, the development of high resolution mesoscale models and the application of super-ensemble technology. The Commission also noted the proposal regarding a possible WWRP Beijing 2008 Forecast Demonstration Project, which would integrate urban environment with nowcasting services. In view of the success of the Sydney 2000 Forecast Demonstration Project and the progress of the Athens 2004 Forecast Demonstration Project, the Commission encouraged the China Meteorological Administration to prepare a formal proposal for consideration at the next session of the WWRP Science Steering Committee. The Commission urged the WWRP Science Steering Committee and others to provide advice and support to that development.

FUTURE DIRECTIONS

5.1.10 The Commission considered that the WWRP Science Steering Committee had worked diligently to formulate a programme with vigorous elements of meteorological research and development, advanced forecast demonstrations, verification, impacts research and training. That progress had been accomplished mainly through initiatives of the Science Steering Committee membership and ad hoc funding.

5.1.11 During the next four years it was essential that the programme of activities achieve a mature state, with a relatively small number of high priority projects advocated, guided and supported through critical review and publication. The Commission agreed that the number of programmes did not need to be increased but rather a greater coherence and critical mass of effort should be achieved through international collaboration and coordination. More systematic and integrated procedures should be developed to obtain funds for the conduct of those activities at a level that could be sustained for a period of years. Those considerations were especially germane to the conduct of THORPEX, within which the major NWP centres of the world would require augmented observational, computational and human resources to facilitate accelerated research and verification efforts. In order to facilitate international coordination and funding of THORPEX, the WWRP should establish an ICSC. The membership of the ICSC would be drawn from countries that contributed to THORPEX. The International Scientific Steering Committee of THORPEX would continue to develop the scientific scope of the programme and would be overseen by the ICSC.

5.1.12 The WWRP must also develop more effective mechanisms to attract unsolicited proposals for worthy projects and to engage more thoroughly developing country participants at the forefront of research and demonstration. In addition, CAS urged that greater emphasis should be placed on the use of operational data in WWRP research together with specialized or advanced numerical models. The Tropical Cyclone Landfall, THORPEX and the developing Warm Season Projects offered the potential to achieve major advances in forecast skill for problems with widespread global application. With respect to a possible WWRP Sand and Dust Storm Project, the Commission agreed that those phenomena could result in serious socio-economic dislocation in many arid and semi-arid regions of the world. It therefore encouraged the organization of a workshop to develop the scientific plan for consideration by the WWRP Science Steering Committee.

5.1.13 The Commission commended the work of the Egyptian Meteorological Authority and the World Laboratory Mediterranean Research Centre for conducting annual training courses for Arab and African countries in the field of NWP and encouraged continuation of those courses to enhance the forecasting of severe weather events in those countries.

5.1.14 The Commission decided that the activities of the Science Steering Committee for the WWRP should be continued and adopted Resolution 2 (CAS-XIII).

MIDDLE-ATMOSPHERE STUDIES

5.1.15 The Commission noted with appreciation the report of the Rapporteur on Middle-atmosphere Studies. The report emphasized important recent developments in large NWP centres as seen in WGNE reviews of their activities. The trend was towards raising the tops of the models together with higher vertical resolution and improved parameterization of physical processes such as radiation and gravity wave drag. As a consequence, the overall representation of stratospheric circulation had very significantly improved, facilitating the assimilation of stratospheric observations by satellites. In that regard, CAS recognized the importance of WGNE stratospheric intercomparison studies showing promising five-day predictions but quite rapid error growth beyond that range. That had been complemented by studies of stratospheric climate simulation organized by the WCRP project on SPARC, which showed a wide range of skills and a high sensitivity to the model's radiation code. The Commission was particularly pleased by the strong cooperation that existed between programmes demonstrated in those activities.

5.1.16 The Commission acknowledged the considerable progress that had resulted in reduced emissions of known ozone-damaging trace gases. However, not only would emissions of old ozone-depleting substances continue for some time through, for example, leakage from refrigeration systems, but current replacement gases had a considerable ozone damaging potential, particularly when containing bromine. Thus, the monitoring of the ozone layer by sondes, lidar, total ozone measurement instruments and satellites must be continued. In addition, the Commission stressed that climate change was expected to interact with, and potentially delay, the recovery of the ozone layer by decades with associated influences on atmospheric circulation.

5.1.17 The Commission noted the importance of the stratosphere-troposphere links for significant weather and climate events such as the strong statistical connection between the stratospheric cyclonic winter vortex anomaly and tropospheric circulation over the North Atlantic, as well as stratospheric, tropospheric interactions in cases of severe precipitation in the Alps, as shown within the Mesoscale Alpine Project.

5.1.18 The Commission shared the concern expressed by the rapporteur on the decreasing number of radiosondes reaching high in the stratosphere which could only be compensated for by remote-sensing observations from new operational and research satellites, combined with the use of advanced variational data-assimilation techniques.

5.1.19 For future activities connected with middle atmospheric studies, the Commission endorsed the following recommendations:

(*a*) To support the WGNE project on the intercomparison of model stratospheric analyses and model predictive skill in the stratosphere;

(*b*) To encourage further research studies to improve understanding of the mechanism linking the stratosphere circulation anomalies with anomalies in the (North) Atlantic Oscillation;

(*c*) To encourage further research studies relating high impact weather events to tropopause folds, incident upper-tropospheric potential vorticity anomalies and tropospheric intrusions of stratospheric phenomena, as suggested by the Mesoscale Alpine Project;

(*d*) To endorse the stratospheric data assimilation initiative coordinated by SPARC and WGNE;

(*e*) To continue the WMO STRATALERT and GEOALERT/STRATWARM arrangements. Daily messages containing the 10 hPa circulation description for the northern hemisphere were prepared by the Free University of Berlin and transmitted via the WWW Global Telecommunication System;

(*f*) To encourage further research studies of long-term variability of temperature and other parameters in the stratosphere and mesosphere.

5.1.20 In order to avoid duplication with existing WMO-related groups who were concerned with middle-atmosphere studies, the Commission decided that it should remain informed on progress in middle-atmospheric research through SPARC and the CAS/JSC Working Group on Numerical Experimentation. The Commission therefore decided not to re-appoint an individual rapporteur on middle-atmosphere studies.

5.2 TROPICAL METEOROLOGY RESEARCH (agenda item 5.2)

5.2.1 The Commission noted with appreciation the report of the chairperson of the CAS Working Group on Tropical Meteorology Research, Mr G. Holland (Australia), and commended the work accomplished by the Working Group since its re-establishment by CAS-XII to implement the TMRP.

5.2.2 The Commission reviewed the activities of TMRP Project TC1 (Tropical cyclone motion and intensity) and noted that the series of International Workshops on Tropical Cyclones had provided an excellent forum for interaction between researchers and forecasters, particularly as they had resulted in the publication of two textbooks and a forecast guide. The Commission was also pleased to note recent developments in unmanned aerial vehicle technologies under the programme which should provide valuable observations for tropical cyclone forecasting. The Commission noted the successful outcome of the fourth WMO/ICSU International Workshop on Tropical Cyclones (IWTC-IV) held in Haikou, China in April 1998 and that arrangements were well advanced for holding IWTC-V in Cairns, Australia in December 2002, at which the essential global and forecaster-researcher character of the IWTC series would be maintained. In that connection, the Commission noted with satisfaction the establishment of the new International Committee (chaired by Mr R. L. Elsberry (United States)) which would be responsible for the organization of IWTC-V. The Commission noted that the IWTC series had now existed for over 15 years. It therefore suggested that the Advisory Working Group should arrange for an independent review of the series to ensure that it continued to provide a high standard of support to WMO Members.

5.2.3 The Commission noted the initiative of the Japan Meteorological Agency, at the request of the ESCAP/WMO Typhoon Committee, to establish a Web site displaying typhoon track forecasts by various NWP models. In view of the responsibilities of Members regarding the protection of life and property, the Commission encouraged the distribution in real time of tropical cyclone tracks, i.e. position, intensity, gridded prognostic fields and other environmental information, including results of the ensemble prediction system by all modelling centres. The Commission also noted that the Hong Kong Observatory had been tasked by WMO to develop a pilot Web site on forecasts and warnings of tropical cyclones in the western North Pacific issued by NMHSs in the region, and that the address of the site was http://typhoon.worldweather.org.

5.2.4 The Commission was informed that *Météo France* had created a research team on tropical cyclones at the Regional Centre for Forecasting for the Indian Ocean (La Réunion). In addition, the community of atmospheric scientists in France was developing an ambitious programme of research into the west African monsoon which had generated interest in both Europe and North America. That programme would address the following topics:

(*a*) Interannual variability of the west African monsoon and its causes;

(*b*) The convective cloud systems — their dynamics and links to the easterly waves;

(*c*) The transport of chemical species between the surface and the tropopause by convective cloud systems;

(*d*) The hydrology of large African rivers;
(*e*) The optimal use of satellite data over west Africa.

Countries in sub-Saharan Africa had expressed much interest in that initiative and were strongly represented at a workshop presently taking place in Niamey, Niger, to develop further the research plan. The Commission strongly urged all interested NMHSs and the African academic community to participate in that programme.

5.2.5 The Commission noted that quadrennial updates of the Statement on the assessment of tropical cyclones and global climate change were scheduled in conjunction with future IWTCs. Further work was encouraged on climate change aspects of tropical cyclone and other severe weather systems.

5.2.6 The Commission recognized that great challenges existed for improving the prediction of tropical cyclone landfall and welcomed the close collaboration that existed between the WWRP and the TMRP in that initiative. In that regard, the Commission considered that that collaboration should focus on research related to the genesis, track, intensity and landfall hazard prediction. In particular, technologies for targeted observations over upstream oceanic regions might improve prediction performance substantially. In an effort to expand the international expertise available for tropical cyclone forecasting studies, the Commission urged interested Members to participate in the United States programme studying hurricane structure, motion and amplification and similar activities being conducted in Australia; China; Hong Kong, China; Japan and the Republic of Korea in the western Pacific region.

5.2.7 The Commission was pleased to note the success of the First South China Sea Monsoon Experiment (1998) conducted under the auspices of TMRP Project MI (Research initiatives on the east Asian monsoon), which provided a better understanding of the key physical processes for the onset, maintenance and variability of the monsoon over south-east Asia and southern China leading to improved predictions. The Commission urged that Members consider participating in the second phase of the Experiment.

5.2.8 The Commission was pleased with the excellent role of the Monsoon Activity Centres in New Delhi, Nairobi and Kuala Lumpur in support of TMRP Project M2 (Long-term Asian/African monsoon studies) and endorsed the recommendations of the CAS Working Group on Tropical Meteorology Research that those Centres should also serve as dissemination and coordination centres for NWP products relevant to monsoon forecasting as well as data centres for ENSO and interannual variability studies in the region. The Commission requested the Working Group on Tropical Meteorology Research to provide the necessary guidance and technical assistance to those Centres with their increased responsibilities.

5.2.9 The Commission endorsed a recommendation of the Second International Workshop on Monsoon Studies (IWM-II) (New Delhi, March 2001) that an ongoing Web-based training document be developed and maintained by WMO. The purpose would be to update forecasters in developments in the science of direct relevance to monsoon forecasting. That project would use the Regional Training Workshops and the IWM series to develop documents and information for use on the Web site.

5.2.10 The Commission noted with satisfaction the progress of TMRP Project M3 (American monsoon studies), which provided support for American monsoon studies, in coordination with the relevant CLIVAR/GOALS components of the WMO/ICSU WCRP.

5.2.11 Concerning TMRP Project AZ1 (Tropical droughts and related rain-producing systems, including the ITCZ), the Commission noted that the current project was in need of new directions. Consequently, the Commission approved the decision made by the Working Group on Tropical Meteorology Research to establish a new steering committee, with Mr R. Okoola (Kenya) as chairperson, to coordinate the future activities.

5.2.12 The Commission highly commended the work of the Steering Committee chaired by Mr T. N. Krishnamurti (United States) for TMRP Project LAM1 (Application of limited-area modelling to tropical countries) for its continued strong involvement on the development and conduct of training workshops.

5.2.13 Having recognized the continuing need for a source of expert advice on relevant areas of the TMRP during the next four years, the Commission decided to re-establish the Working Group on Tropical Meteorology Research and adopted Resolution 3 (CAS-XIII).

5.3 OTHER ACTIVITIES RELATED TO WEATHER PREDICTION (agenda item 5.3)

ACTIVITIES OF THE CAS/JSC WORKING GROUP ON NUMERICAL EXPERIMENTATION

5.3.1 The Commission noted with appreciation the report of the chairperson of the CAS/JSC WGNE, Mr K. Puri (Australia), highlighting the many important activities of the Working Group. CAS was particularly pleased by the fundamental role played by WGNE as the numerical experiment group for all relevant CAS activities. CAS further emphasized the essential cooperation, through WGNE, between CAS NWP activities and the climate modelling efforts of the WCRP.

STUDIES AND COMPARISONS OF ATMOSPHERIC MODELS

5.3.2 Important activities of the WGNE were to maintain a watching brief on model development, to facilitate studies to identify systematic errors in their outputs and to organize model intercomparisons. A significant workshop organized by WGNE and the Australian Bureau of Meteorology Research Centre on Systematic Errors in Atmospheric Models (Melbourne, October 2000) brought together all the world's active modelling groups to review recent developments. The Commission noted that there had been a marked decrease in errors in the short- to medium-range but that errors were still evident in the longer range forecasts.

5.3.3 The Commission welcomed the continuation of the long-running Atmospheric Model Intercomparison

Project which was now in its second phase. Like phase I, it was a community standard-control experiment (January 1979–March 1996) conducted in conjunction with careful specific analyses of various aspects of the simulations. Nineteen modelling groups were currently taking part. The Commission congratulated the Lawrence Livermore National Laboratory and the United States Department of Energy's Programme for Climate Model Diagnosis and Intercomparison for their continued support, which had included making the data available to interested users via Internet.

5.3.4 CAS was satisfied with the role played by WGNE in evaluating and intercomparing process representation within models and the corresponding model-derived estimates, for example, of precipitation, snow cover and surface fluxes. Furthermore, CAS was convinced that a better representation in models of surface fluxes over both the ocean and land would contribute to the improvement of long-range forecasting and encouraged WGNE to pursue further its activities in that domain.

PARAMETERIZATION OF PHYSICAL PROCESSES

5.3.5 The Commission noted with interest the WGNE's activities with respect to parameterization of physical processes for use in models. Those activities were being carried forward in close cooperation with the GEWEX Modelling and Prediction Panel. Through the GEWEX Cloud System Study, Global Land-Atmosphere Study and the GEWEX Atmospheric Boundary-layer Study, the GEWEX Modelling and Prediction Panel and WGNE were stimulating developments in parameterization concerning clouds systems, a new generation of land surface schemes and the atmospheric boundary layer. The Commission was encouraged by those initiatives and urged intercomparisons of the various studies so as to move towards standard methods, where applicable.

DATA ASSIMILATION AND ANALYSIS

5.3.6 The Commission was pleased that funding from the European Commission had allowed ECMWF to embark on its 40-year re-analysis project. In the first year of experimental production (September 1986–August 1987) using a 60-level T159 forecast model coupled with an ocean wave model, a spin-up production of a first stream 1987–2001 had begun. Special attention had been paid to the assimilation of the satellite radiance data, with the operational system being modified to include raw radiances from the HIRS and SSU instruments that had flown (with MSU instruments) on TOVS satellites since 1978. More generally, there had been significant technical development of the assimilation system to meet the needs of the 40-year re-analysis project and many of the earlier deficiencies had been rectified. The Commission was also pleased to note the establishment in several countries of centres for the assimilation of satellite data. Those included the NASA/NOAA Joint Center for Satellite Data Assimilation in the United States, the Joint Center for Satellite Data Assimilation and NWP Innovation in China and the Data Assimilation Research Centre at the University of Reading, United Kingdom. The aim of those Centres was to address the current and future challenges of optimizing the assimilation of operational and research satellite data with increasing temporal, spatial and spectral resolution. Already the tropical rainfall measuring mission, Quikscat and the European remote-sensing satellite data were being assimilated into operational models at various forecast centres. Also, work on the use of the advanced infrared sounder and the infrared advanced sounding interferometer was proceeding at NCEP, ECMWF, the United Kingdom Meteorological Office, *Météo France* and the Canadian Meteorological Center.

5.3.7 The original NCEP/NCAR re-analysis from 1948 was continuing to be carried forward to the present in a quasi-operational manner (two days after data time) and had now been extended to a total period of nearly 53 years. Regarding further re-analysis activities, a joint NCEP/Department of Energy re-analysis (NCEP-2) for the period 1979–1999 had now been completed. That was based on an updated forecast model and data assimilation with corrections for many of the problems seen in the original NCEP/NCAR re-analysis, and also provided improved diagnostic outputs. A regional re-analysis over the United States was also being prepared for the period 1979–2003, using a 32-km resolution, 45-layer model. The expectation was that the regional re-analysis would offer a superior product for the North American subcontinent taking advantage of the intrinsic ability of regional models to offer more detailed results for domains of interest other than global models, as well as for exploiting boundary conditions provided by the existing global re-analysis to drive a regional system.

5.3.8 The Commission noted with interest that the Japan Meteorological Agency has initiated JRA-25, a re-analysis project which covered 25 years from 1979 to 2004. The Japan Meteorological Agency was going to establish a JRA-25 data assessment group, the membership of which would be open to the international meteorological community. The Commission supported that effort as it would beneficially impact the work of the CAS TMRP and WWRP focusing as it would on the behaviour of the Asian monsoon and tropical cyclones.

NUMERICAL WEATHER PREDICTION TOPICS

5.3.9 The Commission strongly encouraged the active participation of WGNE in the planning and implementation of THORPEX as theoretical and numerical research was fundamental to the project's success. Further information on THORPEX and other WWRP projects could be found under agenda item 5.1.

5.3.10 With respect to the performance of the main global operational forecasting models, the WGNE routinely reviewed the skill from a number of main operational centres in terms of verification scores. The Commission was interested to learn that despite distinct increases in skill in the northern and southern hemispheres in recent years, it was disappointing that that was not matched in tropical regions. The Commission, recognizing a requirement to provide measures of model performance for

predicting weather elements and severe weather events, requested the WGNE to prepare a position paper on model verification. Measures of model performance should include information on assessment of track accuracies of hurricanes and typhoons and their intensity.

5.3.11 The Commission noted that the Japan Meteorological Agency was extending the intercomparison of forecasts of typhoon tracks by global models to the north-eastern Pacific. That would mean that the intercomparison now covered tropical cyclones over all oceans in the northern hemisphere. Further extension into the south Pacific and Indian Ocean was planned. Those intercomparisons had shown gradual improvements on the forecasts of cyclone tracks and intensities over recent years.

5.3.12 The WGNE initiative to intercompare and verify precipitation forecasts against surface station in data-rich areas had shown no clear trend in improved skill over the past number of years. The Commission looked forward to a report documenting results from the centres carrying out that work.

5.3.13 The use of ensembles to give an idea of the likely spread of predictions, to provide a basis of the probability of different results occurring, and to compute ensemble means which might have more skill was now very much a cornerstone of forecasting or climate projections on all timescales. Recent years had seen remarkable progress in the application and use of ensemble prediction systems underpinned by rapid advances in the provision of singular vectors, initial perturbed states, etc. The WGNE therefore had decided to include ensemble prediction as a regular discussion item at its sessions. That commenced at the sixteenth session (Melbourne, October 2000) where WGNE reviewed the status of work in that area.

5.3.14 The Commission noted with satisfaction the many developments in ensemble prediction systems at most large NWP centres leading to various techniques and approaches. The Commission emphasized the critical importance of those activities and, in particular, the need for probability distribution in cases of forecasting extreme events and the important role of the user decision process for optimum use of the product in a socio-economic context.

5.3.15 The Commission supported continuation of the annual WCRP/WMO publication entitled *Research Activities in Atmospheric and Oceanic Modelling* (Report No. 30, WMO/TD-No. 987), kindly prepared by the Meteorological Service of Canada. The Commission was pleased that possibilities for electronic submission of contributions and that final publication were now a reality.

6. PHYSICS AND CHEMISTRY OF CLOUDS AND WEATHER MODIFICATION RESEARCH (agenda item 6)

6.1 The Commission noted with appreciation the informative report presented by the chairperson of the Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research, Mr J.-P. Chalon (France). In view of the continuing interest of many Member countries in the areas for hail suppression and precipitation enhancement, as well as for improved parameterizations of cloud processes in weather forecasting models and for a better understanding of the behaviour of clouds in climate, the Commission recommended that the joint Executive Council Panel of Experts/CAS Working Group be re-established and that the Executive Council give favourable consideration to its composition and responsibilities. Accordingly, the Commission adopted Recommendation 2 (CAS-XIII).

6.2 At its twentieth session held in Geneva, 20–24 November 2000, the Executive Council Panel of Experts/CAS Working Group reviewed the latest scientific developments of interest to Member States in the following areas:

(*a*) Mixed-phase cloud precipitation enhancement;
(*b*) Warm cloud precipitation enhancement;
(*c*) Fog dissipation and other fog-related activities;
(*d*) Hail suppression: trends and perspectives;
(*e*) Clouds and atmospheric electricity;
(*f*) Role of clouds in climate, the anthropogenic modification of cloud structure and the development of precipitation processes in clouds;
(*g*) The impacts of clouds and precipitation on icing;
(*h*) The role of clouds in atmospheric chemistry;
(*i*) Cloud modelling;
(*j*) Recent developments in radar and airborne particle probes.

6.3 With respect to (*a*) above, the Commission noted that mixed-phase cloud systems produced a large proportion of the global precipitation and continued to be the focus of much of the operational enhancement activity conducted by Governments and the private sector. Snow pack and rainfall augmentation had been shown to be possible for orographic systems and there was evidence of changes in precipitation from individuals clouds. Recent results from hygroscopic flare experiments on individual clouds in South Africa and Mexico were especially noteworthy. The Commission recommended that further research be undertaken to determine the scientific transferability of results from individual cloud systems to their larger counterparts and the interactions between cloud dynamics and microphysics under the impact of seeding.

6.4 Regarding (*c*) above, the Commission noted the positive results of the Russian-Italian project on fog dissipation on highways in the northern part of Italy. An automatic supercooled fog dispersing system was now in operational use. Electrostatic and thermal full-scale models of warm fog dispersal units were being tested in the field.

6.5 The Commission considered the latest developments with regard to hail suppression techniques in view of the relatively large number of countries where such activities were routinely conducted. It noted that concepts for hail suppression had not changed a great deal over recent years and that claims of success varied over a wide range. The Commission, however, agreed with the view of the Executive Council Panel of

Experts/CAS Working Group that such claims remained unsubstantiated as there were no internationally-agreed scientific methods for evaluating the efficacy of hail suppression activities, due in part to the extreme natural variability of hailfall.

6.6 The quality of numerical models used for weather forecasting or climate prediction, as well as the quality and efficiency of rain enhancement and hail suppression projects were still strongly limited by the incomplete understanding of cloud behaviour. To allow progress in those fields, the Commission recommended that further research be undertaken, in particular, on the mechanisms that lead to small and mesoscale cloud system organization and on those that lead from cloud formation to precipitation development. Theoretical and laboratory studies were encouraged as well as field experiments and numerical simulations. The Commission recommended that enhanced cooperation was required in order to benefit from existing experience and available tools.

6.7 The Commission noted with satisfaction that the Executive Council Panel of Experts/CAS Working Group had reviewed and updated both the WMO Statement on the status of weather modification and the Guidelines for advice and assistance related to the planning of weather modification activities, which appeared in the *Report of the Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research* (WMP Report Series No. 36, WMO/TD-No. 1059). Those two documents were subject to revisions by the fifty-third session of the Executive Council and, in view of the interest of many WMO Members in that matter, had been sent to all Member countries. CAS agreed with the tone of the Statement with respect to the various aspects of weather modification. It was also pleased that a section on inadvertent modification had been included in the Statement as called for by the seventh WMO Scientific Conference on Weather Modification held in Chiang Mai, Thailand on 17–22 February 1999.

6.8 The Commission was pleased that that Conference once again generated much international interest with more than 200 scientists from 33 countries representing all WMO regional associations taking part. Three volumes of preprints had been published by WMO which included the list of participants, opening addresses by high ranking officials from Thailand and the Secretariat and a summary and conclusions of the Conference. The Executive Council Panel of Experts/CAS Working Group recommended that an eighth conference be organized, possibly in 2003, to bring to a wide audience advances in technologies and computers that allowed dramatic improvements in cloud observational capabilities and more complex modelling of clouds and mesoscale processes. The Commission agreed that such advances should lead to better understanding of precipitation processes, both natural and from seeding experiments.

6.9 The Commission noted with interest the outcome of the WMO International Workshop on Hygroscopic Seeding: Experimental Results, Physical Processes and Research Needs, organized by WMO, NCAR and the Mexican State of Durango in Mazatlán, Mexico in November/December 1999, which had evaluated the intriguing results obtained through hygroscopic seeding at the base of clouds in Mexico, South Africa and Thailand. The Workshop was unable to explain fully the processes at play in the seeded clouds, since the effects noted up to an hour after seeding were unexpected, for example. CAS was supportive of the strategy developed by the Workshop to elucidate further the scientific questions associated with those hygroscopic seeding results including an in-depth review of past experiments, theoretical studies, laboratory studies, numerical simulations and, possibly, large field experiments. The Commission urged WMO to support that initiative to the extent possible. With respect to capacity transfer, the Commission requested the Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research to enhance its activities on technical exchanges and to organize workshops to enhance the capabilities of developing countries. In that regard, the initiative of Morocco to offer theoretical and operational courses in weather modification was noted by the Commission. The Commission also noted that the Russian Federation used stratospheric and tropospheric aircraft laboratories as well as unique cloud and aerosol chambers of the Institute of Experimental Meteorology to improve understanding of cloud physics, including water vapour transport issues and the efficiency of hygroscopic re-agents. The Commission requested the Executive Council Panel of Experts/CAS Working Group to consider whether those advanced facilities could be used for international research efforts into cloud physics.

6.10 As regarded the European initiative to examine the possibilities of precipitation enhancement in the Mediterranean basin, the Commission recognized the potentially important contribution that any increase in precipitation could make to the region's water resources. It welcomed the incremental approach being advanced by the partners in the project through which a suitable infrastructure to determine the area's precipitation enhancement potential was being put in place. That infrastructure included establishing cloud, climatological and other databases on training requirements and scientific questions requiring attention. The Commission urged it members and WMO to play an active role in that long-term project.

6.11 The Commission noted that the WMO Secretariat had issued Registers of National Weather Modification Projects for the years 1997–2000 since its last session. The number of countries engaged in weather modification activities, primarily hail suppression and precipitation enhancement, remained at around 30 comprising a total of 75 distinct projects. Those numbers had shown no clear trend over many years. The Commission recommended that the annual Register be continued in light of expected water stresses faced by increasing numbers of people in the coming decades.

6.12 The Commission noted that many WMO Members were conducting operational weather modification activities concerning precipitation enhancement and hail suppression. It stressed the need for the operators of such programmes to conduct rigourous analyses of the results for international peer review.

7. CLIMATE RESEARCH (agenda item 7)

7.1 STRATEGY AND ACTIVITIES OF THE WORLD CLIMATE RESEARCH PROGRAMME (agenda item 7.1)

7.1.1 The Commission noted with interest the report on the activities of the WCRP, jointly undertaken by WMO, IOC and ICSU. The principal aim of the WCRP was to develop the fundamental scientific understanding of the physical climate system needed to predict global and regional climate variations on all timescales, including those resulting from the effect of man's influence on climate. The Commission provided input to the planning and development of WCRP through the participation of a nominated representative in the annual sessions of the WMO/ICSU/IOC JSC which formulated the overall scientific goals for the WCRP. That representative briefed JSC on the relevant activities being conducted under the auspices of the Commission.

7.1.2 In reviewing the various WCRP core projects, the Commission recognized that activities in GEWEX could substantially contribute to the advancement of the WWRP. GEWEX had promoted a number of regional experiments aimed at studying energy and water budgets on the scale of continents. Those included the GEWEX Continental-scale International Project over the Mississippi river basin, the Baltic Sea Experiment, the GEWEX Asian Monsoon Experiment, the MacKenzie Basin GEWEX Study, and the Large-scale Biosphere-atmosphere Experiment in the Amazon. The first of those, the GEWEX Continental-scale International Project, was now beginning to evolve into the GEWEX Americas Prediction Project, which would place additional emphasis on understanding how land surfaces could influence climate and predictability. Steps were also being taken in the organization of an investigation of the coupling of the tropical atmosphere and hydrological cycle in the Sahel region of West Africa. A Coordinated Enhanced Observing Period was being implemented from 2001 to 2003 in which common datasets from all the GEWEX regional studies were being collected, thus offering the prospect of assessing the influence of continental heat and moisture sources and sinks on the global climate system and its anomalies. The Commission was also informed that GEWEX had continued to build up a number of basic climatological datasets combining conventional (in situ) measurements, remotely-sensed data and operational meteorological analyses. Among those were the International Satellite Cloud Climatology Project, the Global Precipitation Climatology Project and the GEWEX Water Vapour Project. The Commission was impressed at the wide-ranging activities in GEWEX and encouraged collaboration between the WWRP and GEWEX in the development of the Water Vapour Project, in the planning of the GEWEX Americas Prediction Project, and in improving understanding of the role of orography in cloud and precipitation processes.

7.1.3 The Commission welcomed the synergy between the WCRP study of SPARC and GAW which provided many measurements of environmental parameters and atmospheric composition that underpinned SPARC investigations. The latter had included an assessment of stratospheric temperature trends and study of the reasons for changes in the vertical distribution of ozone. A comprehensive assessment of the concentration, distribution and variability (long-term changes or trends of water vapour in the upper troposphere and lower stratosphere) had also recently been completed. Findings confirmed an upward trend in water vapour in those regions of the atmosphere. Present observations were inadequate to answer several fundamental questions on the influence of upper tropospheric/lower stratospheric water vapour on climate, and additional efforts to improve the monitoring of water vapour were required. Together those investigations had shown that changes in temperature, ozone and water vapour were linked and that, increasingly, an integrated approach to studying changes in stratospheric parameters was essential.

7.1.4 The Commission was impressed by the progress made in the implementation of the WCRP/CLIVAR in the following areas:

(*a*) Implementation of national components of the project;
(*b*) Seasonal prediction capability;
(*c*) Implementation of in situ observing systems and use of satellite data;
(*d*) Regional studies, in particular the Asian/Australian monsoon studies;
(*e*) Variability of the American Monsoon System;
(*f*) African climate variability.

The Commission noted also the important contribution of the scientific community to the IPCC evaluation process of its Science Working Group. The Commission emphasized the need for coordination between WCRP initiatives and work in the TMRP in order to encourage, at the regional level, collaborative research activities on those subjects and to disseminate the benefits from knowledge, methodologies and experiences.

7.1.5 The Commission noted the establishment of a new WCRP Study of the Climate and Cryosphere, which would be a coordinated investigation of the role of all components of the cryosphere in the global climate system. The main scientific themes were the effect of climate change on seasonal snow cover, permafrost, land- and sea-ice, the contribution of ablation of land-ice to sea-level rise, and whether changes in the cryosphere could lead to irreversible changes in climate.

7.1.6 The Commission appreciated the substantial achievement of WOCE in greatly expanding knowledge of the structure of the deep ocean circulation and the role of the ocean in the climate system. WOCE had also stimulated major technological advances in the methods of observing and collecting oceanographic data (e.g. automated floats and satellite sensors for precise ocean

topography). WOCE was now in its final phase of synthesizing the measurements gathered during the field programme 1990–1997 into a dynamically consistent view of the ocean circulation in the 1990s, a task which was expected to be completed in 2002.

7.1.7 The Commission observed that the unifying theme running through WCRP was the development of comprehensive global models of the full climate system, building on scientific and technical advances in the other main WCRP projects. Those models were the fundamental tool for understanding and predicting natural climate variations and for providing reliable estimates of anthropogenic climate change. Activities in that area were centred around two main groups: the joint CAS/JSC WGNE and the WCRP WGCM. The activities of WGNE, concerned with the development of the atmospheric component of climate models and the closely related atmospheric models used for numerical weather prediction in support of both WCRP and CAS weather prediction research, were reviewed by the Commission under agenda item 5.3. The Commission reiterated the important role of WGNE in providing feedback from WCRP results into improvements in operational predictions and in acting as the interface between the WCRP and the WWRP. The WGCM had the task of overseeing the development of fully coupled atmosphere/ocean/land/cryosphere models to study climate variations on timescales from several years to a century and to provide projections of anthropogenic climate change.

7.2 **CLIMATE ACTIVITY INTERACTIONS** (agenda item 7.2)

7.2.1 The Commission noted that the thirteenth session of CCl had been held in Geneva in November 2001. It noted, in particular, the number of areas of common or overlapping interest, especially with respect to seasonal to interannual climate prediction or long-range forecasting, the increasing use of ensemble methods in numerical forecasting, the use of limited area modelling techniques and a range of issues relating to urban environments.

7.2.2 The Commission was especially pleased with the fruitful areas of interaction with the CLIPS project on developing suitable verification methods for longer-range predictions. The Commission was also pleased to note the success of the International Workshop on Applications of Long-range Forecasting and its Applications, that was arranged jointly with the WMO Atmospheric Research and Environment Programme, in Cairo in January 2000. The Commission noted that issues relating to the infrastructure for seasonal to interannual climate prediction currently lay within the remit of the Intercommission Task Team on Regional Climate Centres and had been managed by CCl in coordination with CAS, CBS and CAgM. It expressed its appreciation to the president for facilitating the continuing involvement of the Commission in that important area of investigation.

7.2.3 The Commission noted the growing interest in improving urban environments, given the ongoing drift of populations into large urban complexes. It was informed, in that regard, of the development of the Showcase Projects on Heat/Health Warning Systems directed at minimizing the especially deleterious effects of extended periods of high temperature in urban settings. The Commission agreed that there would be opportunities for further synergistic collaboration with CCl on urban climatology and environments. It therefore requested the president, in collaboration with the president of CCl and the Secretary-General, to ensure an optimum set of arrangements for that collaboration.

8. **OTHER RESEARCH ACTIVITIES** (agenda item 8)

8.1 With respect to the Executive Council request for a policy statement on weather forecasting and climate projections, the Commission warmly congratulated the CAS Science Steering Committee for the WWRP, the CAS/JSC WGNE and the appropriate bodies of the WCRP for collaborating successfully in the preparation of a possible WMO statement on the scientific basis for, and limitations of, weather forecasting and climate projections. The Commission noted that the statement was primarily intended to assist NMHSs in their dealings with Governments, the media, the general public and users.

8.2 The Commission expressed its sincere appreciation to the ad hoc drafting group, established during the session, for refining the text to distinguish clearly between weather forecasting, the prediction of climate anomalies and climate projections. That distinction was based on consideration of the input needed to produce forecast/projections, as well as the different nature of the outputs themselves. The Commission believed that the Statement clarified the issue, based on the current body of scientific knowledge on those topics. The Statement would need to be periodically revised as the techniques and scientific knowledge improved.

8.3 The draft WMO Statement on the scientific basis for, and limitations of, weather forecasting and climate projections as approved by CAS is reproduced in Annex II to this report.

9. **SCIENTIFIC LECTURES** (agenda item 9)

The following four lectures were presented during the session:

(*a*) Weather impacts, forecasts and policy (Dr R. Pielke, Jr., University of Colorado, United States);

(*b*) Skill of weather prediction in the twenty-first century (Dr A. Thorpe, NERC Centres for Atmospheric Science, United Kingdom);

(*c*) Ensemble prediction from days to decades (Dr T. Palmer, ECMWF, United Kingdom);

(*d*) The exploitation of data from the GAW observational network and possible future directions of GAW (Dr U. Baltensperger, Paul Scherrer Institute, Switzerland).

Those lectures were of very high quality and greatly facilitated the discussions of agenda items 5.1, 5.2, 3.1 and 4.

10. WMO LONG-TERM PLANNING (agenda item 10)

FIFTH WMO LONG-TERM PLAN

10.1 The Commission noted the adoption by Thirteenth Congress of the 5LTP covering the period 2000–2009. It further noted that the technical commissions, among others, were requested to adhere to the policies and strategies set forth in the Plan and to organize their activities to achieve the main long-term objectives as defined in it.

10.2 The Commission took note of the fact that the monitoring and evaluation of the first four years (2000–2003) of the 5LTP would be undertaken and that an assessment of its implementation would be considered by the fifty-fourth session of the Executive Council and subsequently by Fourteenth Congress based on Resolution 12 (EC-LIII) — Guidelines for monitoring and evaluation of the implementation of the Fifth WMO Long-term Plan. The Commission requested its president to ensure the provision of the relevant contribution expected from CAS in the pertinent evaluation process.

PREPARATION OF THE SIXTH WMO LONG-TERM PLAN

10.3 The Commission recalled that Thirteenth Congress had decided that the 6LTP should be prepared. In so doing, Thirteenth Congress requested the technical commissions to lead the formulation of all scientific and technical aspects of WMO Programmes and activities falling within their respective responsibilities.

10.4 The Commission also recalled that the Executive Council established its Working Group on Long-term Planning to assist it in connection with long-term planning and the Task Team on WMO Structure, and that both groups had a second session conjointly from 12 to 16 March 2001. The fifty-third session of the Executive Council (June 2001) considered the report of the joint session.

10.5 The Commission noted that the vice-president of CAS had attended meetings in conjunction with the Meeting of the Presidents of Technical Commissions in October 2000 and October 2001 which reviewed draft proposals by the Executive Council Working Group on Long-term Planning relating to the draft 6LTP and provided further input.

10.6 The Commission noted the decisions of the fifty-third session of the Executive Council regarding the drafting of the 6LTP. The Council had adopted the WMO vision, a set of desired outcomes and a set of strategies and associated strategic goals which provided the framework for the formulation of the full draft of the 6LTP. The Council noted that it would be helpful to take into consideration the views of the entire international meteorological and hydrological community on those matters and agreed that the leadership role of WMO in providing expertise and in promoting international cooperation in relevant fields was a key element of the WMO vision. The Commission was informed that the WMO vision was formulated:

> To provide world leadership in expertise and international cooperation in weather, climate, hydrology and water resources, and related environmental issues, and thereby to contribute to the safety and well being of people throughout the world and to the economic benefit of all nations.

10.7 The Commission noted that the Council had agreed on the set of six desired outcomes: (*a*) improved protection of life and property; (*b*) increased safety on land, at sea and in the air; (*c*) enhanced quality of life; (*d*) sustainable economic growth; (*e*) protection of the environment; and (*f*) enhanced WMO effectiveness. It noted the objective of identifying the desired outcomes so that the 6LTP would be more strategic and outward-looking. The Commission endorsed the nine strategies with the associated strategic goals, as adopted by the Council, to meet the evolving global needs for expert advice and services pertinent to weather, water, climate and the natural environment.

10.8 The Commission recalled that the Council had agreed that the present programme structure should be used as a basis for further developing the 6LTP and the programme and budget for the fourteenth financial period. The Council had recognized the importance of identifying lead responsibility for ensuring the carrying out (and/or coordination) of each of the programmes, as well as the strategies and associated strategic goals. The Council had also agreed that the major Programmes and component programmes thereof should be presented in the 6LTP, using a programme layout which included the purposes of the Programme and how they supported the 6LTP strategies and associated goals.

10.9 The Commission endorsed the sense of the Council that the vision, desired outcomes, strategies and associated goals, as well as the programme structure of the 6LTP, would serve as a clear basis for the programme and budget. The achievement of expected results defined in the programme and budget would contribute to the realization of the strategies and associated goals of the 6LTP. Those established the meaningful link between the 6LTP and the programme and budget.

10.10 The Commission further noted that the Council decided that four key areas should receive greater emphasis: (*a*) protection of life and property, especially disaster prevention and mitigation; (*b*) climate change and its impacts; (*c*) provision of services for the socio-economic benefits of people; and (*d*) hydrology and water resources.

10.11 In that connection, the Commission wished to emphasize that the present orientation and priorities of its activities would significantly contribute to the WMO vision, desired outcomes, strategies and associated goals. Furthermore, the Commission stressed the role of the WWRP in addressing aspects of the socio-economic consequences of high impact weather as well as its activities with respect to improved forecast technologies, thus assisting WMO Members to meet their responsibilities regarding the protection of life and property. In addition, the contribution of GAW to the protection of the environment, on scales from local to global, was also highlighted.

10.12 The Commission recognized that it had a role to play in the preparation and implementation of the

6LTP as well as in its monitoring and evaluation. In that regard, the Commission requested the president of CAS, working with other members of the Advisory Working Group, to provide strong input with respect to CAS programme priorities and initiatives to meetings of the Executive Council Working Group on Long-term Planning. That input should include information on the expected outcomes and benefits resulting from CAS actions. It noted that the approved Strategy for the implementation of the GAW (2001–2007) would provide important input for that CAS programme to the 6LTP.

WMO STRUCTURE

10.13 The Commission noted the views of the fifty-third session of the Executive Council, concerning the review of the WMO structure. The Commission further noted that Thirteenth Congress had endorsed a number of measures to encourage and promote overall participation in, and cooperation among, the technical commissions and regional associations, and requested the presidents of technical commissions, among others, to implement them, as appropriate, within available resources.

10.14 The Commission noted, in particular, that the Council had requested its Task Team on WMO Structure to study further a number of areas, including the role and functions of technical commissions and regional associations; further streamlining of the work and session of the Executive Council; Executive Council subsidiary bodies; and the WMO Bureau. The Commission requested its president to work with the presidents of other technical commissions and of regional associations to consider the relevant issues and to make recommendations, and to assure that the Commission's concerns were conveyed in future meetings of relevant task teams and working groups of the Executive Council.

GENERAL CONSIDERATION

10.15 The Commission recalled that the Council recognized that the collaboration between technical commissions and regional associations should be improved. Particular attention was given to ensuring that the intersessional activities were effectively carried out. In that connection, the Commission emphasized that its participation and contribution in the long-term planning process during the intersessional period was a matter of utmost importance and requested its president to ensure that appropriate actions were taken in that regard.

11. REVIEW OF PREVIOUS RESOLUTIONS AND RECOMMENDATIONS OF THE COMMISSION AND OF RELEVANT EXECUTIVE COUNCIL RESOLUTIONS (agenda item 11)

11.1 The Commission reviewed the resolutions and recommendations adopted at its previous session which were still in force as well as those of the Executive Council relating to CAS activities. Accordingly, the decisions of the present session were recorded in Resolution 4 (CAS-XIII) and in Recommendation 3 (CAS-XIII).

11.2 The Commission noted that Executive Council Resolutions 11 (EC-XXIX) and 7 (EC-XXXIX), both dealing with atmospheric ozone, contained overlapping content. It therefore requested the Secretariat, working with the Advisory Working Group and taking into account the GAW strategy plan for 2001–2007 to develop a consolidated draft Executive Council resolution on that matter. The resolution should be presented to the Executive Council in 2003.

12. ELECTION OF OFFICERS (agenda item 12)

The Commission unanimously re-elected Mr A. Eliassen (Norway) as president of the Commission and elected Mr A. V. Frolov (Russian Federation) as vice-president. The newly elected officers accepted with pleasure to serve the Commission until its fourteenth session.

13. NOMINATION OF MEMBERS OF WORKING GROUPS (agenda item 13)

13.1 The Commission established working groups (two of which were expected to be asked to fulfil the joint functions of Executive Council Panel of Experts/CAS Working Groups) and appointed rapporteurs to carry out its work between the thirteenth and fourteenth sessions:

(*a*) Advisory Working Group of the Commission for Atmospheric Sciences;
(*b*) Executive Council Panel of Experts/Working Group on Environmental Pollution and Atmospheric Chemistry;
(*c*) Science Steering Committee for the WWRP;
(*d*) Working Group on Tropical Meteorology Research;
(*e*) Executive Council Panel of Experts/Working Group on Physics and Chemistry of Clouds and Weather Modification Research.

13.2 The Commission established the membership of the working groups, recommended membership for the joint Executive Council Panels of Experts/CAS Working Groups and appointed rapporteurs as indicated in the relevant resolutions of the session.

13.3 Between sessions of the Commission, and notwithstanding General Regulation 33, the president was authorized to make any necessary changes in the composition of the working groups, including the appointment of new chairpersons and designation of suitable experts to participate in the work of the relevant working groups.

13.4 The Commission expressed its appreciation to the committee for coordinating proposals for rapporteurs and membership of working groups for the excellent manner in which it had completed its difficult task.

14. DATE AND PLACE OF THE FOURTEENTH SESSION (agenda item 14)

The Commission noted with appreciation that the delegates from Morocco, South Africa and Turkey

had, on behalf of their Governments, extended invitations to WMO to host the fourteenth session of CAS, to be held in the year 2006. The Commission also noted that the date and place of its fourteenth session would be determined in accordance with General Regulation 186.

15. **CLOSURE OF THE SESSION** (agenda item 15)

15.1 In his closing address, the president of the Commission thanked all those who had contributed to the successful completion of the work of the session, in particular, the chairpersons of the working committees, the chairperson of the Nomination Committee, the Committee for the Selection of Working Group Members and Rapporteurs, the drafting group on the Statement on the scientific basis for, and limitations of, on weather forecasting and climate projections, delegates, as well as the staff of both the WMO and the local Secretariats, including the interpreters, translators and those producing the documents behind the scenes. He congratulated the newly elected vice-president, and wished him and all the elected working group members and rapporteurs, a successful and fruitful intersessional period as they started to consider all the challenging issues facing the Commission.

15.2 The thirteenth session of the Commission for Atmospheric Sciences closed at 10.45 a.m. on 20 February 2002.

RESOLUTIONS ADOPTED BY THE SESSION

RESOLUTION 1 (CAS-XIII)

ADVISORY WORKING GROUP OF THE COMMISSION FOR ATMOSPHERIC SCIENCES

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING:

(1) The views of the Sixth World Meteorological Congress on retaining the system of advisory bodies to provide advice to presidents of technical commissions,

(2) The future policies, strategy, objectives and outline plans of CAS adopted by the Thirteenth World Meteorological Congress,

CONSIDERING:

(1) The importance attached to the role of CAS in directing attention to outstanding research problems and in facilitating the distribution of scientific knowledge,

(2) That the Executive Council has requested the Commission to exercise a coordinating role for WMO research programmes,

DECIDES:

(1) To re-establish the Advisory Working Group of CAS with the following terms of reference:

(*a*) To assist the president of the Commission in providing advice on urgent matters which cannot be dealt with by regular working groups or by correspondence among members of the Commission;

(*b*) To advise on, and to assist the president in, reviewing the progress of the work, in particular of working groups and rapporteurs, in organizing conferences, symposia and meetings of experts and in planning the future programme of the Commission;

(*c*) To respond quickly and effectively concerning any project which the Commission might be invited to undertake;

(*d*) To assist the president in maintaining a review of the research activities within WMO and of interest to the Organization and in formulating the relevant parts of the WMO Long-term Plans;

(*e*) To maintain overall responsibility for ensuring the transfer of research results, techniques and information between Members in the fields of atmospheric and related sciences, including environmental aspects;

(2) That the composition of the Advisory Working Group should be as follows:

Mr A. Eliassen (Norway), president of CAS;
Mr A. V. Frolov (Russian Federation), vice-president of CAS;
Mr M. Majodina (South Africa);
Mr L. W. Uccellini (United States);
Mr M. Béland (Canada);
Mr Zheng Guoguang (China);

(3) To authorize the president to call on other experts, keeping in mind General Regulation 34, to participate in any particular task when he feels that such additional assistance is necessary;

REQUESTS the president to report to the Commission on the activities of the Advisory Working Group not later than six months before the fourteenth session of the Commission.

RESOLUTION 2 (CAS-XIII)

SCIENCE STEERING COMMITTEE FOR THE WORLD WEATHER RESEARCH PROGRAMME

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING:

(1) The report by the chairperson of the Science Steering Committee for the World Weather Research Programme,

(2) General summary paragraphs 3.3.0.8 and 3.3.3.1 to 3.3.3.7 of the *Abridged Final Report with Resolutions of the Thirteenth World Meteorological Congress* (WMO-No. 902),

(3) General summary paragraphs 5.3.1 to 5.3.6 of the *Abridged Final Report with Resolutions of the Fifty-second session of the Executive Council* (WMO-No. 915),

(4) General summary paragraphs 5.4.1 to 5.4.4 of the *Abridged Final Report with Resolutions of the Fifty-third session of the Executive Council* (WMO-No. 929),

(5) The report of the tenth session of the CAS Advisory Working Group,

CONSIDERING:

(1) The demand for a formal international programme to promote a concerted new effort on the weather prediction problem, with emphasis on high impact weather, to the benefit of all members,

(2) The demand for a formal international programme to energize national resource commitments to regional research initiatives and to research problems common to many countries,

(3) The need to broaden the basis of the specialized observation support available for relevant research studies,

(4) The need to enhance the prospects of increased funding support from external groups,

(5) The need to facilitate aspects of technology transfer,

DECIDES:

(1) To pursue the implementation of the WWRP;

(2) To re-establish a Science Steering Committee for the WWRP as a CAS Working Group, with the following terms of reference:

(*a*) To promote, organize and/or endorse research projects including, where necessary, field experiments to develop understanding of weather processes and improve forecasting techniques;

(*b*) To review and assess the development of all elements of the WWRP, including demonstration forecast evaluation methods, formulate recommendations to guide further actions and report periodically on the progress of the programme to the president of CAS;

(*c*) To facilitate the exchange of information among scientists participating in the programme and relevant scientific institutions and agencies at the national and international levels;

(*d*) To promote actively the applications of improvements in weather forecasting capability through forecast demonstration projects and the sponsoring of technical workshops and conferences;

(*e*) To supervise the process of individual evaluation and quality assessment of each "pre-operational" type project (in particular of each demonstration project) and to validate its conclusions, in light of the state of the art;

(*f*) To collaborate with CBS, the CAS Working Group on Tropical Meteorology Research and the Executive Council Panel of Experts/CAS Working Groups on Physics and Chemistry of Clouds and Weather Modification Research, and on Environmental Pollution and Atmospheric Chemistry, in considering questions in weather prediction that span all timescales;

(*g*) To collaborate with the CAS/JSC Working Group on Numerical Experimentation in considering developments in atmospheric models;

(*h*) To prepare for the next session of the Commission a report on the progress in weather prediction research;

(3) To invite the following individuals to serve on the Committee:

(*a*) Mr R. E. Carbone (United States), chairperson;

(*b*) Mr G. Isaac (Canada), Rapporteur on Physical Processes;

(*c*) Ms R. Brozkova (Czech Republic), Rapporteur on Forecast Verification Techniques and Validation;

(*d*) Mr P. Bougeault (France), Rapporteur on Data Assimilation and Modelling;

(*e*) Messrs K. Browning (United Kingdom) and T. Keenan (Australia), Rapporteurs on Nowcasting and Integrated Forecast Systems;

(*f*) Mr Tang Xu (China), Rapporteur on Tropical Meteorology;

(*g*) Mr T. Tsuyuki (Japan), Rapporteur on Long-range Weather Prediction;

(*h*) Mr R. Pielke (United States), Rapporteur on Social and Economic Effects;

(*i*) Mr E. Poolman (South Africa), Rapporteur on Forecast Technology Transfer — Application to Members;

(4) To invite CBS to nominate a representative to liaise with, and to participate in, the work of the Committee, serving as a Rapporteur on Observation Systems (including remote sensing from earth, air and space);

(5) To invite IAMAS to nominate a representative to liaise with, and to participate in, the work of the committee;

(6) To invite the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, in the context of its Initiative on Urban Environment, to liaise with, and to participate in, the work of the Committee concerning the conduct of research and development projects and forecast demonstration projects in urban areas;

(7) To request the chairperson of the Committee to submit a final report to the president of CAS not later than six months before the fourteenth session of the Commission.

RESOLUTION 3 (CAS-XIII)

WORKING GROUP ON TROPICAL METEOROLOGY RESEARCH

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING:

(1) The report of the tenth session of the CAS Advisory Working Group,

(2) The report by the chairperson of the Working Group on Tropical Meteorology Research,

(3) The *Abridged Final Report with Resolutions of the Thirteenth World Meteorological Congress* (WMO-No. 902),

CONSIDERING:

(1) The potential for disaster reduction and economic benefit to be derived from increasing research of tropical atmospheric processes directed towards improved weather prediction capabilities,

(2) The need to assist coordination of research efforts in tropical and subtropical meteorology of all countries involved,

(3) The likelihood of significant developments in the scientific aspects of tropical meteorology, particularly those resulting from data obtained by advanced observing methods and prediction models over the next few years,

(4) The renewed recognition of the influence of tropical atmospheric processes for the improvement of medium- and long-range forecasts on the globe,

DECIDES:

(1) To re-establish the Working Group on Tropical Meteorology Research with members serving as rapporteurs for specifically defined areas with the following overall terms of reference:

   (*a*) To monitor the implementation of existing priority projects within the WMO TMRP and to develop further other appropriate research projects as the need arises, under the following main programme components:

      (i) Tropical cyclones;

      (ii) Monsoon studies (on regional and global scales);

      (iii) Tropical drought and rain-producing systems;

      (iv) Limited-area modelling in the tropics;

      (v) Interaction between tropical and mid-latitude weather systems;

      (vi) Tropical meteorology and climate;

   (*b*) To provide scientific advice to the Secretary-General and the president of CAS, as necessary, on the implementation and development of the main TMRP components;

   (*c*) To identify those research initiatives which, if taken by Meteorological Services in tropical countries, generally including collaboration with other groups in universities or research institutes, are likely to lead to social and economic benefits, particularly in agriculture, water resources management and weather-related disaster reduction;

   (*d*) To keep under continuous review developments in research aspects of the WMO TCP by maintaining close liaison with TCP regional bodies and to facilitate coordination of research at the regional level;

   (*e*) To prepare for the next session of the Commission a report on the progress in tropical meteorology;

   (*f*) To follow the progress of the CLIVAR and GOALS components of the WMO/ICSU WCRP on the monsoon, as well as of the GEWEX Asian Monsoon Experiment and the South China Sea Monsoon Experiment;

   (*g*) To keep in contact, through the Secretariat, with various WMO regional and other groups dealing with tropical meteorology research (particularly the WWRP);

(2) To invite the following individuals to serve as rapporteurs:

   (*a*) Mr R. Elsberry (United States), Rapporteur on Tropical Cyclone Prediction Research;

   (*b*) Ms A. Grimm (Brazil) and Mr S. R. Kalsi (India), Rapporteurs on Monsoon Prediction Research;

   (*c*) Mr R. Okoola (Kenya), Rapporteur on Tropical Droughts and Rain-producing Systems;

   (*d*) Messrs Chen Lianshou (China) and V. Tunegolovets (Russian Federation), Rapporteurs on Interaction between Tropical and Mid-latitude Weather Systems;

   (*e*) Messrs K. Saito (Japan) and A. E. Youssef (Egypt), Rapporteurs on Tropical Limited-area Weather Prediction Modelling and Operational Use of NWP Products;

   (*f*) Mr J. McBride (Australia), Rapporteur on Climate Change Aspects of Tropical Weather Systems;

   and to appoint Mr Chen Lianshou as chairperson;

(3) To request the chairperson of the Working Group to submit periodical reports, as necessary, and a formal report to the president of CAS not later than six months before the fourteenth session of the Commission.

RESOLUTION 4 (CAS-XIII)

REVIEW OF THE RESOLUTIONS AND RECOMMENDATIONS OF THE COMMISSION FOR ATMOSPHERIC SCIENCES

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING:

(1) General Regulation 190 concerning the review of previous resolutions and recommendations of the Commission,

(2) The action taken by the competent bodies on the resolutions and recommendations of its previous sessions,

DECIDES:

(1) To keep in force Resolution 5 (CAS-XII);

(2) Not to keep in force the other resolutions adopted before its thirteenth session.

NOTE: This resolution replaces Resolution 6 (CAS-XII), which is no longer in force.

RECOMMENDATIONS ADOPTED BY THE SESSION

RECOMMENDATION 1 (CAS-XIII)

TERMS OF REFERENCE AND THE COMMISSION REPRESENTATION IN THE PROPOSED RE-ESTABLISHMENT OF THE EXECUTIVE COUNCIL PANEL OF EXPERTS/CAS WORKING GROUP ON ENVIRONMENTAL POLLUTION AND ATMOSPHERIC CHEMISTRY

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING:

(1) Resolution 7 (EC-L) — Re-establishment of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry,

(2) General Regulation 179, Annex III: Structure and terms of reference of technical commissions,

(3) General summary paragraphs 3.3.2.1 to 3.3.2.8 of the *Abridged Final Report with Resolutions of the Thirteenth World Meteorological Congress* (WMO-No. 902),

(4) Resolution 10 (Cg-XIII) — Atmospheric Research and Environment Programme,

(5) The *Fifth WMO Long-term Plan 2000–2009* (WMO-No. 908), paragraphs 6.3.7 to 6.3.9 and relevant sections of the draft Sixth WMO Long-term Plan,

CONSIDERING:

(1) The need, as re-affirmed by Thirteenth Congress, for WMO to provide, within the United Nations system, an informed, authoritative and effective scientific voice on the state and behaviour of the atmosphere and climate of our planet,

(2) That WMO is highly suited to undertake the tasks of long-term monitoring of global atmospheric composition and related physical characteristics including the preparation of related scientific assessments, and that through the implementation of GAW the involvement of WMO in such activities has increased substantially,

(3) That WMO, as stated by Thirteenth Congress, plays a leading role in international efforts to monitor and protect the environment and continues to support the implementation of relevant environment protection conventions,

(4) That a focal point to coordinate all WMO activities in the fields of environmental pollution and atmospheric chemistry is needed,

RECOGNIZING the responsibility of CAS as the lead Commission in this field,

RECOMMENDS to re-establish the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry with the following terms of reference:

(1) To serve as the advisory body to the Executive Council and the president of CAS for all WMO activities in the fields of atmospheric chemistry and environmental pollution;

(2) To act as the focal point for GAW and to provide scientific guidance on further development of the programme including adequate global coverage, the need for near-real-time and three-dimensional observations, completion of a quality assurance/quality control system, improved access to, and use of, data and better communications between different GAW components and user;

(3) To serve as an advisory panel for GAW SAGs, WDCs and Quality Assurance/Science Activity Centres;

(4) To keep informed of, and review scientific developments in, the fields of environmental pollution and atmospheric chemistry, including the interrelationships between changes in atmospheric composition, global and regional climate and other aspects of the Earth system, and perturbations to the natural cycles of chemical species in the atmosphere/ocean/biosphere system;

(5) To recommend to the Executive Council, in consultation with the president of CAS, actions that WMO should take to promote, initiate, facilitate or set priorities for research and monitoring activities in the above areas with special attention to:

(*a*) Long-term observations of background atmospheric composition and air pollution, including greenhouse gases, ozone, other reactive gases, radiation and optical depth, aerosol particle characteristics, precipitation composition and related parameters;

(*b*) The high quality and timeliness of data from the monitoring network and development of a functional system for real-time or quasi-real-time measurements;

(*c*) The transport, transformation and deposition of air pollutants on all space and timescales;

(*d*) The air/sea and air/land/sea exchanges of atmospheric constituents;

(*e*) User-friendly access to the data and fuller application of data for modelling and scientific assessments on the existing and

emerging environmental issues both of global and regional importance;

(*f*) Effective cooperation with other relevant programmes and organizations;

(6) To promote, guide and review the implementation of the GAW programme taking into account the Strategy for the Implementation of the GAW programme for 2001–2007;

(7) To review and guide the implementation of the GURME project and to provide relevant advice to Members' Meteorological and Hydrometeorological Services;

(8) To collaborate, as appropriate, in the work of relevant working groups and rapporteurs;

(9) To promote capacity building activities including training and twinning;

(10) To keep informed of the work of other relevant international organizations and programmes and to advise the Executive Council and the president of CAS of these activities on the policy implications for WMO and on appropriate coordination and collaboration measures;

RECOMMENDS FURTHER:

(1) That the membership of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry be as follows:

(*a*) Mr W. Kimani (Kenya), Rapporteur on Changes in Atmospheric Composition on a Long-term Basis;

(*b*) Messrs Xu Xiangde (China) and B. Hicks (United States), Rapporteurs on the Urban Atmospheric Environment;

(*c*) Mr Y. Tsaturov (Russian Federation), Rapporteur on Atmospheric Transport and Deposition of Pollutants including Modelling;

(*d*) Mr H. Matsueda (Japan), Rapporteur on Greenhouse Gases including their Effects on Climate Change;

(*e*) Mr E. A. Piacentini (Argentina), Rapporteur on Atmospheric Ozone and Ultraviolet Radiation;

(*f*) Mr J. Gras (Australia), Rapporteur on Aerosols;

(*g*) Ms R. Simeva (The Former Yugoslav Republic of Macedonia), Rapporteur on Reactive Gases;

(*h*) Mr S. Penkett (United Kingdom), Rapporteur on Atmospheric Chemical System Modelling;

(*i*) Mr M. Bittner (Germany), Rapporteur on Satellite Measurements of Atmospheric Constituents;

(*j*) Mr G. Müller (Switzerland), Rapporteur on Strategic Planning and Implementation of GAW;

and to appoint Mr O. Hov (Norway), as chairperson and coordinator of the work of the individual rapporteurs;

(2) To request the chairperson of the Executive Council Panel of Experts/CAS Working Group to keep the president of CAS informed of significant developments in atmospheric environment-related activities and to submit reports on atmospheric environment research to the president of CAS at his request and a final report not later than six months before the fourteenth session of the Commission.

RECOMMENDATION 2 (CAS-XIII)

TERMS OF REFERENCE AND RE-ESTABLISHMENT OF THE EXECUTIVE COUNCIL PANEL OF EXPERTS/CAS WORKING GROUP ON PHYSICS AND CHEMISTRY OF CLOUDS AND WEATHER MODIFICATION RESEARCH

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING:

(1) Resolution 10 (Cg-XIII) — Atmospheric Research and Environment Programme,

(2) Resolution 8 (EC-L) — Re-establishment of the Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research,

(3) The *Fifth WMO Long-term Plan 2000–2009* (WMO-No. 908), paragraphs 6.3.16 to 6.3.19,

CONSIDERING:

(1) The importance of cloud physics and chemistry with regard to weather forecasting, from the very-short range to the long range,

(2) The importance of cloud physics and chemistry with regard to climate change issues, particularly in parameterizations in climate modelling,

(3) The importance of cloud physics and chemistry with regard to the transport, deposition and transformation of atmospheric pollutants,

(4) The importance, reaffirmed by WMO Congress, of providing a clear answer as to the possibility and limitations regarding intentional weather modification,

(5) The need to assess the benefits of scientifically-based cloud seeding to the planning and management of water resources and agriculture and related activities as well as to ensure authoritative advice on weather modification, with particular regard to precipitation enhancement and hail suppression,

RECOGNIZING the responsibility of CAS in this field,

RECOMMENDS that the Executive Council re-establishes a joint group with the title Executive Council Panel of

Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research with the following terms of reference:

(1) To keep under review relevant research and advise the Executive Council, CAS and, as appropriate, other WMO bodies on urgent problems requiring attention relating to physics and chemistry of clouds and weather modification research;
(2) To keep under review the role of clouds in the transport, transformation and deposition of various pollutants, including especially nuclear pollution, in the process of their dispersion and long-range transport;
(3) To keep under review the role of cloud and fog processes in both weather and climate prediction/simulation research, interactions with vegetation, especially at high altitudes, and in the collection of water for human use;
(4) To arrange the preparation of reviews and summaries of field experiments related to cloud physics and chemistry, of cloud-seeding experiments as well as the dispersion of fog for wide distribution to Members;
(5) To provide advice and assistance, in particular the manner and means of transferring competence for planning scientific experiments and scientific meetings organized, coordinated or sponsored by WMO in the above-mentioned fields;
(6) To draft and review WMO documents on the status of weather modification and guidelines for advice to Members and propose revisions to these documents where necessary;

RECOMMENDS FURTHER that:

(1) The membership of the Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research be as follows:
   (*a*) Mr D. Terblanche (South Africa), Rapporteur on Mixed Phase Cloud Precipitation Enhancement;
   (*b*) Messrs F. Prodi (Italy) and L. Grana (Morocco), Rapporteurs on Warm Cloud Precipitation Enhancement;
   (*c*) Mr J.-P. Chalon (France), Rapporteur on Fog Dissipation;
   (*d*) Messrs V. Stasenko (Russian Federation) and Liu Qijun (China), Rapporteurs on Other Aspects of Weather Modification including Hail Suppression and Anthropogenic Modification of Clouds and its Repercussions;
   (*e*) Messrs P. Jonas (United Kingdom) and B. Ryan (Australia), Rapporteurs on Fundamental Cloud Physics and Chemistry;
   (*f*) Ms S. Javanmard (Islamic Republic of Iran), Rapporteur on Cloud Physics Application (Radiative Properties of Clouds, Climatology);
   (*g*) Mr Z. Levin (Israel), Rapporteur on Cloud Modelling and Cloud Electricity;
   (*h*) Mr B. Foote (United States), Rapporteur on Radar and Other Instrumentation;

   of whom the Executive Council may wish to consider Mr J.-P. Chalon, as chairperson and coordinator of the work of the individual rapporteurs;
(2) IAMAS be invited to designate a representative to liaise and participate in the work of the Working Group;
(3) The chairperson keep in close contact with the chairperson of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry to discuss issues of common interest;
(4) The group of experts collaborate with the CAS Science Steering Committee for the WWRP;
(5) The chairperson be requested to submit progress reports to the Executive Council and to the president of CAS, as needed, and to submit a final report not later than six months before the fourteenth session of the Commission.

RECOMMENDATION 3 (CAS-XIII)

REVIEW OF THE RESOLUTIONS OF THE EXECUTIVE COUNCIL RELEVANT TO THE FIELDS OF RESPONSIBILITY OF THE COMMISSION FOR ATMOSPHERIC SCIENCES

THE COMMISSION FOR ATMOSPHERIC SCIENCES,

NOTING with satisfaction the action taken on its previous recommendations by the Executive Council,

CONSIDERING:

(1) That some of these recommendations have become redundant in the meantime,
(2) That the substance of some of its previous recommendations has been included in recommendations of the thirteenth session,

RECOMMENDS:

(1) That the following Executive Council resolutions be no longer considered necessary:
5 (EC-XXXIX) and 6 (EC-L), 7 (EC-L) and 8 (EC-L);
(2) That the following Executive Council resolutions be maintained in force:
11 (EC-XXIX), 18 (EC-XXXIV) and 7(EC-XXXIX).

NOTE: This recommendation replaces Recommendation 3 (CAS-XII), which is no longer in force.

ANNEXES

ANNEX I

Annex to paragraph 3.0.6 of the general summary

DRAFT TERMS OF REFERENCE OF THE COMMISSION FOR ATMOSPHERIC SCIENCES

The Commission shall be responsible for matters relating to:

(*a*) Research in atmospheric and related sciences to advance the understanding of atmospheric processes and support the following:
  (i) Weather prediction for timescales from very-short to long range and space-scales from local to global, with emphasis on forecasting high impact events associated with serious consequences for populations and economies;
  (ii) Atmospheric composition and air pollution, including studies of transport, transformation and deposition of air pollutants and related monitoring;
  (iii) Physics and chemistry of clouds, particularly in support of weather prediction and atmospheric chemistry and for weather modification with emphasis on the underlying processes and the development of rigorous evaluation procedures;
  (iv) Tropical meteorology, studies of processes and phenomena of particular relevance to low latitudes and their influence beyond;
  (v) Climate studies, noting the central role of the WCRP for improved understanding of climate, the Commission will contribute expertise, especially in the above research areas, including the application of relevant research advances;

(*b*) Coordination of the operation and further development of GAW, including the setting of relevant network standards and procedures, the monitoring performance and for maintaining liaison with other international programmes engaged in environmental monitoring, especially GCOS;

(*c*) The formulation of requirements for observations and for the storage, retrieval and exchange of raw and/or processed data for research purposes;

(*d*) Scientific assessment of technical meteorological procedures including verification techniques;

(*e*) The coordination of the international aspects of the Commission's activities with relevant scientific bodies and those concerned with disaster mitigation;

(*f*) Standardization of functions, constants, terminology and bibliographic practices applicable to atmospheric sciences;

(*g*) Support to international environmental and climate conventions through regular scientific analysis and assessments relevant to its activity;

(*h*) Determination of the requirements of WMO Members and the transfer of knowledge, technologies and advice to them concerning atmospheric science issues;

(*i*) Support for research on the policy, social and economic impacts of advances in the understanding of atmospheric sciences.

ANNEX II

Annex to paragraph 8.3 of the general summary

WMO STATEMENT ON THE SCIENTIFIC BASIS FOR, AND LIMITATIONS OF, WEATHER FORECASTING AND CLIMATE PROJECTIONS

1. Introduction

1.1 Tens of millions of weather forecasts are issued annually by NMHSs. It requires comprehensive and well maintained meteorological networks, standardization and coordination of exchange of data and products at rapid rates by WMO, and development and application of new observational and modelling techniques and continued development of meteorological science. This body of experience, coupled with a robust set of metrics for assessing accuracy means that, in many cases, uncertainty in weather forecasts is well known, and in many cases well understood. For example, improved prediction of the track of tropical cyclones has protected numerous lives and properties in all basins threatened

by these storms. Nevertheless, track forecasts still need improvement and tropical cyclone intensity predictions still possess a large degree of uncertainty.

1.2 Over the past few decades, the impact of improved observational capability, increased scientific understanding and more sophisticated and skilful numerical models, and other forecasting tools has gradually changed the public perception of weather forecasting from one in which the community assumed that the forecasts would often be wrong, to one in which they are expected to be right. Indeed, three-day forecasts for surface pressure are as good as one day forecasts 20 years ago, which is a great scientific achievement. This improvement is continuing into the twenty-first century, perhaps at an even more rapid pace.

1.3 Notwithstanding these successes, some uncertainty in forecasts remains and 100 per cent success will never be achieved. There is the risk however, that the public will come to expect that forecasts should always be right; and when they are wrong, it must be the result of incompetence, negligence or some other culpable form of system failure. What should be better understood is that with present (and any foreseeable) future states of the science, some meteorological phenomena will remain inherently unpredictable, and the more extreme the phenomena, the more likely that this will be so.

1.4 This document has been prepared by experts from within the WMO's Atmospheric Research and Environment Programme to reflect the current state of the science of weather forecasting and climate projections. The contents may be of broad interest to scientists, users of weather forecasts, funding agencies and policy makers. However, the intent of this Statement is to celebrate the achievements while documenting the reasons for uncertainties in weather forecasting and climate projections and while explaining how forecasting methods are designed to minimize and quantify uncertainty. It is expected that this will contribute to a mutual understanding between the science and use community, allowing for improved understanding of this shared challenge.

2. The science of weather forecasting

Dynamical and physical processes within the atmosphere, and interactions with the surroundings (e.g. land, ocean, and ice surfaces), determine the evolution of the atmosphere and, hence, the weather. Scientifically-based weather forecasts are possible if the processes are well enough understood and if the current state of the atmosphere is well known enough, for predictions to be made of future states. Weather forecasts are prepared using a largely systematic approach, involving observation and data assimilation, process understanding, prediction and dissemination. Each of these components has, and will continue, to benefit from advances in science and technology.

2.1 Observations and data assimilation

2.1.1 Over the past few decades, substantial advances in science have resulted in improved and more efficient methods for making and collecting timely observations, from a wide variety of sources including radar and satellites. Using these observations in scientifically-based methods has caused the quality of weather forecasts to increase dramatically, so that people around the world have come to rely on weather forecasts as a valued input to many decision-making processes.

2.1.2 Computer-generated predictions are initialized from a description of the atmospheric state built from past and current observations in a process called data assimilation, which uses the NWP model (see paragraph 2.3.2) to summarize and carry forward in time information from past observations. Data assimilation is very effective at using the incomplete coverage of observations from various sources to build a coherent estimate of the atmospheric state. But, like the forecast, it relies on the NWP model and cannot easily use observations of scales and processes not represented by the model.

2.1.3 The international scientific community is emphasizing the still very poorly observed areas as being a limiting factor in the quality of some forecasts. As a consequence, there is a continued need for improved observation systems and methods to assimilate these into NWP models.

2.2 Understanding of the atmosphere: inherent limitations to predictability

2.2.1 The scientific understanding of physical processes has made considerable progress through a variety of research activities, including field experiments, theoretical work and numerical simulation. However, atmospheric processes are inherently non-linear and not all physical processes can be understood or represented in NWP models. For instance, the wide variety of possible cloud water and ice particles must be highly simplified, as are small cumulus clouds that can lead to rain showers. Continued research effort using expected improvements in computer technology and physical measurements will enable these approximations to be improved. Even then, it will still not be possible to represent all atmospheric motions and processes.

2.2.2 There is a wide spectrum of patterns of atmospheric motion, from the planetary scale down to local turbulence. Some are unstable and are arranged so that flow is amplified using, for example, energy from heating and condensation of moisture. This property of the atmosphere means that small uncertainties about the state of the atmosphere will also grow, so that eventually the unstable patterns cannot be precisely forecast. How quickly this happens depends on the type and size of the motion. For convective motions such as thunderstorms, the limit is of the order of hours, while for large scales of motion it is of the order of two weeks.

2.3 Weather prediction

2.3.1 *Nowcasting*: Forecasts extending from 0 out to 6 to 12 hours are based upon a more observations-intensive approach and are referred to as nowcasts. Traditionally, nowcasting has focused on the analysis and extrapolation of observed meteorological fields, with a special emphasis

on mesoscale fields of clouds and precipitation derived from satellite and radar. Nowcast products are especially valuable in the case of small-scale hazardous weather phenomena associated with severe convection and intense cyclones. In the case of tropical cyclones, nowcasting is an important detection and subsequent short-term prediction approach that provides forecast value beyond 24 hours in some cases. However, the time rate of change of phenomena such as severe convection is such that the simple extrapolation of significant features leads to a product that deteriorates rapidly with time — even on timescales of the order of one hour. Thus, methods are being developed that combine extrapolation techniques with NWP, both through a blending of the two products and through the improved assimilation of detailed mesoscale observations. These are inherently difficult tasks and, although accuracy and specificity will improve over coming years, these products will always involve uncertainty regarding the specific location, timing and severity of weather events such as thunder and hail storms, tornadoes and downbursts.

2.3.2 *Numerical weather prediction*: Forecasts for lead times in excess of several hours are essentially based almost entirely on NWP. In fact, much of the improvement in the skill of weather forecasts over the past 20 years can be attributed to NWP computer models, which are constructed using the equations governing the dynamical and physical evolution of the atmosphere. NWP models represent the atmosphere on a three-dimensional grid, while typical operational systems in 2001 use a horizontal spacing of 50–100 km for large-scale forecasting and five to 40 km for limited area forecasting at the mesoscale. This will improve as more powerful computers become available.

Only weather systems with a size several times the grid spacing can be accurately predicted, so phenomena on smaller scales must be represented in an approximate way using statistical and other techniques. These limitations in NWP models particularly affect detailed forecasts of local weather elements, such as cloud and fog and extremes such as intense precipitation and peak gusts. They also contribute to the uncertainties that can grow chaotically, ultimately limiting predictability.

2.3.3 *Ensemble prediction*: Uncertainty always exists — even in our knowledge of the current state of the atmosphere. It grows chaotically in time, with much of the new information introduced at the beginning no longer adding value, until only climatological information remains. The rate of growth of this uncertainty is difficult to estimate since it depends upon the three-dimensional structure of the atmospheric flow. The solution is to execute a group of forecasts — an ensemble — from a range of modestly different initial conditions and/or a collection of NWP models with different, but equally plausible, approximations. If the ensemble is well designed, its forecasts will span the range of likely outcomes, providing a range of patterns where uncertainties may grow. From this set of forecasts, information on probabilities can be derived automatically, tailored to users' needs.

Forecast ensembles are subject to the limitations of NWP discussed earlier. Additionally, since the group of forecasts are being computed simultaneously, less computer power is available for each forecast. This requires grid spacings to be increased, making it more difficult to represent some severe weather events of smaller horizontal scale. Together with the limited number of forecasts in an ensemble, this makes it harder to estimate probabilities of very extreme and rare events directly from the ensemble. Moreover it is not possible to modify the NWP models used to sample properly modelling errors, so sometimes all models will make similar errors.

2.3.4 *Operational meteorologist*: There remains a critical role for the human forecaster in interpreting the output and in reconciling sometimes seemingly conflicting information from different sources. This role is especially important in situations of locally severe weather. Although vigorous efforts are being made to provide forecasters with good quality systems such as interactive workstations for displaying and manipulating the basic information, they still have to cope with vast amounts of information and make judgements within severe time constraints. Furthermore, forecasters are challenged to keep up to date with the latest scientific advances.

3. Prediction at seasonal to interannual timescales

3.1 Beyond two weeks, weekly average predictions of detailed weather have very low skill, but forecasts of one-month averages, using NWP with predicted sea-surface temperature anomalies, still have significant skill for some regions and seasons to a range of a few months.

3.2 At the seasonal timescale, detailed forecasts of weather events or sequences of weather patterns are not possible. As mentioned above, the chaotic nature of the atmosphere sets a fundamental limit of the order of two weeks for such deterministic predictions, associated with the rapid growth of initial condition errors arising from imperfect and incomplete observations. None the less, in a limited sense, some predictability of temperature and precipitation anomalies has been shown to exist at longer lead times out to a few seasons. This comes about because of interactions between the atmosphere, the oceans, and the land surface, which become important at seasonal timescales.

3.3 The intrinsic timescales of variability for both the land surface and the oceans are long compared to that of the atmosphere, due in part to relatively large thermal inertia. Ocean waves and currents are slow in comparison to their atmospheric counterparts, due to the large differences in density structure. To the extent that the atmosphere is connected to the ocean and land surface conditions, then, a degree of predictability may be imparted to the atmosphere at seasonal timescales. Such coupling is known to exist particularly in the tropics, where patterns of atmospheric convection ultimately important to global scale weather patterns are quite closely tied to variations in ocean surface temperature. The

most important example of this coupling is found in the ENSO phenomenon, which produces large swings in global climate at intervals ranging from two to seven years.

3.4 The nature of the predictability at seasonal timescales must be understood in probabilistic terms. It is not the exact sequence of weather that has predictability at long lead times (a season or more), but rather some aspects of the statistics of the weather — for example, the mean or variance of temperature/precipitation over a season — that has potential predictability. Though the weather on any given day is entirely uncertain at long lead times, the persistent influence of the slowly evolving surface conditions may change the odds for a particular type of weather occurring on that day. In rough analogy to the process of throwing dice, the subtle but systematic influence of the boundary forcing can be likened to throwing dice that are "loaded". On any given throw, we cannot foretell the outcome, yet after many throws the biased dice will favour a particular outcome over others. This is the sort of limited predictability that characterizes seasonal prediction.

3.5 Currently, seasonal predictions are made using both statistical schemes and dynamical models. The statistical approach seeks to find recurring patterns in climate associated with a predictor field such as sea-surface temperature. Such models have demonstrated skill in forecasting *El Niño* and some of its global climate impacts. The basic tools for dynamical prediction are coupled models — models that include both the atmosphere and the other media of importance, particularly the oceans. Such models are initialized using available observations and integrated forward in time to produce a seasonal prediction. The issue of uncertainty is handled using an ensemble approach, where the climate model is run many times with slightly different initial conditions (within the range of observation errors or sampling errors). From this, a distribution of results is obtained, whereupon statistics of the climate can be estimated. Recently, encouraging results have been obtained from ensemble outputs of more than one model being combined.

3.6 There are several limitations attending current predictions. Most coupled models (and to a lesser extent uncoupled models) exhibit some serious systematic errors that inevitably reduce forecast skill. Data availability is a limitation for both statistical models and for dynamical models. In the latter case, very limited information is available for much of the global oceans and for the land surface conditions. Also, current initialization methods do not account properly for systematic model errors, further limiting forecast performance. A final set of limitations arises for practical reasons. Due to resource requirements, most seasonal predictions cannot be done at resolutions comparable to weather prediction. Furthermore, rather small ensemble sizes (of the order of 10) are used for some models, certainly less than is optimal for generating robust probabilistic forecasts. Current research is addressing the potential for regional "downscaling" of climate forecasts by various means and the possibilities for more detailed probabilistic climate information from expanded ensembles of one or more models.

3.7 Possible use of seasonal forecasts is currently being explored in various contexts. In each case, effective use will require careful attention to the issue of uncertainty inherent in seasonal forecasts. Future advancements can be expected to improve the estimates of uncertainty associated with forecasts, thus allowing better use of forecast products.

4. Projection of future climate

4.1 As explained above, based on the current observed state of the atmosphere, weather prediction can provide detailed location and time-specific weather information on timescales of the order of two weeks. Some predictability of temperature and precipitation anomalies has been shown to exist at longer lead times out to a few seasons. This comes about because of interactions between the atmosphere, the oceans, and the land surface, which become important at seasonal timescales. At longer timescales, the current observed state of the atmosphere and even those large-scale anomalies which provide predictive skill at seasonal to interannual timescales are no longer able to do so due to the fundamental chaotic nature of the Earth-atmosphere system. However, long-term changes in the Earth-atmosphere system at climate timescales (decades to centuries) are dependent on factors which change the balance of incoming and outgoing energy in the Earth-atmosphere system. These factors can be natural (e.g. changes in solar output or volcanoes) or human induced (e.g. increased greenhouse gases). Because simulations of possible future climate states are dependent on prescribed scenarios of these factors they are more accurately referred to as "projections" not "predictions" or "forecasts".

4.2 In order to perform climate projections, physically-based climate models are required in order to represent the delicate feedbacks which are crucial on climate timescales. Physical processes and feedbacks that are not important at NWP or even at the timescales of seasonal prediction become crucial when attempting to simulate climate over long periods, e.g. cloud-radiation interaction and feedback, water vapour feedback (and correctly modelling long-term trends in water vapour), ocean dynamics and processes (in particular an accurate representation of the thermohaline circulation). The treatments of these key features are adequate to reproduce many aspects of climate realistically though there remain many uncertainties associated with clouds and aerosols and their radiative effects, and many ocean processes. Nevertheless, there is reasonable confidence that state-of-the-art climate models do provide useful projections of future climate change. This confidence is based on the demonstrated performance of models on a range of space timescales.

4.3 Notably, the understanding of key climate processes and their representation in models (such as the inclusion of sea-ice dynamics and more realistic ocean heat transport) has improved in the past few years. Many

models now give satisfactory simulations of climate without the need for non-physical adjustments of heat and water fluxes at the ocean-atmosphere interface used in earlier models. Moreover, simulations that include estimates of natural and anthropogenic forcing are well able to reproduce observed large-scale changes in surface temperature over the twentieth century. This large-scale consistency between models and observations lends confidence in the estimates of warming rates projected over the next century. The simulations of observed natural variability (e.g. ENSO, monsoon circulations, the North Atlantic Oscillation) have also improved.

4.4 On the other hand, systematic errors are still all too apparent, e.g. in simulated temperature distributions in different regions of the world or in different parts of the atmosphere, in precipitation fields, clouds (in particular marine stratus). One of the factors that limits confidence in climate projections is the uncertainties in external forcing (e.g. in predicting future atmospheric concentrations of carbon dioxide and other greenhouse gases, and aerosol loadings).

4.5 As with NWP and seasonal forecasts, ensembles of climate projections are also extremely important. Ensembles enable the magnitude and effects of natural climate variability to be gauged and affect its impact on future projections, and thereby permit any significant climate change signal to be picked out more clearly statistically (the magnitude of natural climate variability will be comparable with that of climate change for the next few decades).

5. Dissemination to end-users

5.1 The weather forecasts have to be communicated to a vast array of users such as emergency managers, air traffic controllers, flood forecasters, public event managers, etc. in a timely and user-applicable form. This in itself poses another major challenge that is increasingly benefiting from advances in information technology. Predictions at seasonal to interannual timescales and climate projections are also being used by an increasingly wide range of users.

5.2 The value of forecasts to decision makers is greatly enhanced if the inherent uncertainty can be quantified. This is particularly true of severe weather, which can cause such damage to property and loss of life that precautions may be well advised even if the event is unlikely, but possible. Probabilities are a natural way of expressing uncertainty. A range of possible outcomes can be described with associated probabilities and users can then make informed decisions allowing for their particular costs and risks.

5.3 Forecasts expressed as probabilities, or ensembles, contain much more information than deterministic forecasts, and it is difficult to convey it all to users. Broadcast forecasts can only give a broad picture of the most likely outcome, with perhaps some idea of important risks. Each user's decision may be based on the probabilities of a few specific occurrences. What these are, and the probability thresholds for acting on the forecasts, will differ. So for important user decisions it is necessary to apply their particular criteria to the detailed forecast information.

6. Conclusions

6.1 The skill in weather forecasting has advanced substantially since the middle of the twentieth century, largely supported by the advancement of computing, observation and telecommunications systems, along with the development of NWP models and the associated data-assimilation techniques. This has been greatly facilitated because of the vast experience of both forecasters and decision makers in producing and in using forecast products. Nevertheless, each component within the science and technology of weather forecasting and climate projection has its own uncertainties. Some of these are associated with a lack of a complete understanding of, or an inherent limitation of, the predictability of highly complex processes. Others are linked still to the need for further advances in observing or computing technology, or to an inadequate transfer between research and operations. Finally, one cannot underestimate the importance of properly communicated weather forecasts to well-educated users.

6.2 Without a doubt, significant benefits will result from continued attention to scientific research and the transfer of knowledge gained from this work into the practice of forecasting. Furthermore, a recognition of the limitations of weather forecasts and climate projections, and when possible, an estimate of the degree of uncertainty, will result in the improved use of forecasts and other weather information by decision makers. Ultimately the objective is for the scientific and user communities to work better together, realizing even greater benefits.

APPENDIX A

LIST OF PERSONS ATTENDING THE SESSION

A. Officers of the session

A. Eliassen — President

B. Representatives of WMO Members

Member	*Name*	*Capacity*
Australia	W. K. Downey	Principal delegate
	G. W. Paltridge	Delegate
	P. G. Price	Delegate
Austria	C. Kress	Principal delegate
Belgium	A. Quinet	Principal delegate
Burkina Faso	I. Traore	Principal delegate
	N. F. Ouattara	Alternate
Canada	M. Béland	Principal delegate
	J. Abraham	Delegate
	K. Puckett	Delegate
China	Zheng Guoguang	Principal delegate
	Chen Zhenlin	Delegate
	Tang Xu	Delegate
	Zhang Renhe	Delegate
Croatia	B. Ivancan-Picek	Principal delegate
Denmark	B. Machenhauer	Principal delegate
Egypt	A. El Sayed Youssef	Principal delegate
Finland	H. Järvinen	Principal delegate
France	G. De Moor	Principal delegate
	P. Bougeault	Delegate
	J.-P. Chalon	Delegate
Germany	G. Adrian	Principal delegate
	P. Winkler	Delegate
Ghana	V. Antwi	Principal delegate
Hong Kong, China	K. H. Yeung	Principal delegate
Hungary	T. Práger	Principal delegate
Iceland	S. Jonsson	Principal delegate
India	A. K. Kamra	Principal delegate
	S. Utagar	Delegate
Islamic Republic of Iran	A. M. Noorian	Principal delegate
	S. A. Rezvani	Delegate
Israel	I. Setter	Principal delegate
Italy	G. Daddario	Principal delegate
Japan	N. Sato	Principal delegate
	Y. Makino	Alternate
Malaysia	Yap Kok Seng	Principal delegate
Morocco	L. Grana	Principal delegate
Namibia	E. Kambueza	Principal delegate
Netherlands	J. Alderliesten	Principal delegate
Nigeria	N. O. Nnoli	Principal delegate
	I. D. Nnodu	Alternate
Norway	A. Eliassen	Principal delegate
	T. E. Nordeng	Alternate
	A. Bratseth	Delegate
	E. Forland	Delegate
	O. Hov	Delegate
	T. Iversen	Delegate
	J. E. Kristjansson	Delegate
	K. H. Midtbo	Delegate
Poland	Z. Litynska (Ms)	Principal delegate
	J. Bartnicki	Adviser
Portugal	R. A. da Costa Carvalho	Principal delegate
Republic of Korea	Cho Joo-young	Principal delegate
	Park Jeong-gyoo	Alternate
Russian Federation	A. V. Frolov	Principal delegate
	A. A. Chernikov	Delegate
	A. V. Konoplev	Delegate
Slovakia	D. Závodský	Principal delegate
South Africa	B. Parker	Principal delegate
Spain	R. Diaz-Pabón (Ms)	Principal delegate
	J. Ramón de Grado	Alternate
Sweden	E. Liljas	Principal delegate
Switzerland	P. Binder	Principal delegate
	G. Müller	Alternate
The former Yugoslav Republic of Macedonia	R. Simeva (Ms)	Principal delegate
	A. Karanfilovski	Delegate
Turkey	H. Y. Özalp	Principal delegate
United Kingdom of Great Britain and Northern Ireland	P. Mason	Principal delegate
	R. A. Cox	Alternate
	D. Griggs	Alternate
	A. Thorpe	Delegate
United Republic of Tanzania	N. D. Pyuzza	Principal delegate
	D. G. Rutashobya	Delegate
United States of America	D. P. Rogers	Principal delegate
	L. W. Uccellini	Alternate

Member	*Name*	*Capacity*
United States of America (*contd.*)	J. L. Moyers	Delegate
	Pai-Yei Whung (Ms)	Delegate
	R. E. Carbone	Advisor
	J. M. Miller	Advisor
Viet Nam	Tran Duy Binh	Principal delegate

C. INVITED EXPERT

Chairperson of the Working Group on Numerical Experimentation	K. Puri

D. REPRESENTATIVES OF INTERNATIONAL ORGANIZATIONS

Organization	*Name*
European Centre for Medium-range Weather Forecasts (ECMWF)	T. Palmer
General Organization of Remote Sensing (GORS)	H. Ibrahim

Organization	*Name*

E. LECTURERS

Paul Scherrer Institut, Switzerland	U. Baltensperger
European Centre for Medium-range Weather Forecasts, United Kingdom	T. Palmer
University of Colorado, United States	R. Pielke
National Environment Research Council Centres for Atmospheric Science, United Kingdom	A. Thorpe

F. WMO SECRETARIAT

G. O. P. Obasi	Secretary-General
F. Delsol	Director, Atmospheric Research and Environment Programme
A. Soudine	Senior Scientific Officer, AREP
Z. Lei	Senior Scientific Officer, AREP
M. Malone	WMO Consultant, AREP
M. Peeters	Conference Officer

APPENDIX B

AGENDA

	Agenda item	*Document Nos.*	*PINK Nos. and person submitting*	*Resolutions and recommendations adopted*
1.	OPENING OF THE SESSION		1, president of CAS	
2.	ORGANIZATION OF THE SESSION		2, president of CAS	
2.1	Consideration of the report on credentials			
2.2	Adoption of the agenda	2.2(1); 2.2(2)		
2.3	Establishment of committees			
2.4	Other organizational matters			
3.	REPORT OF THE PRESIDENT OF THE COMMISSION	3	3, chairperson, Committee of the Whole	Res. 1
3.1	Support to ozone and other environment-oriented conventions	3.1	3.1, chairperson, Committee B	
4.	GLOBAL ATMOSPHERE WATCH			
4.1	Environmental pollution and atmospheric chemistry	4.1(1); 4.1(2)	4.1(1), chairperson, Committee B 4.1(2), chairperson, Committee B	Rec. 1
4.2	Urban environment	4.2	4.2, chairperson, Committee B	
4.3	Contribution to the Global Climate Observing System	4.3	4.3, chairperson, Committee B	
5.	WEATHER PREDICTION AND TROPICAL METEOROLOGY RESEARCH			
5.1	World Weather Research Programme	5.1(1); 5.1(2)	5.1(1), chairperson, Committee A 5.1(2), chairperson, Committee B	Res. 2
5.2	Tropical meteorology research	5.2	5.2, chairperson, Committee A	Res. 3
5.3	Other activities related to weather prediction	5.3	5.3, chairperson, Committee B	
6.	PHYSICS AND CHEMISTRY OF CLOUDS AND WEATHER MODIFICATION RESEARCH	6	6, chairperson, Committee A	Rec. 2
7.	CLIMATE RESEARCH			
7.1	Strategy and activities of the World Climate Research Programme	7.1	7.1, chairperson, Committee B	
7.2	Climate activity interactions	7.2	7.2, chairperson, Committee B	
8.	OTHER RESEARCH ACTIVITIES	8; 8, REV.	8, chairperson, Committee of the Whole	
9.	SCIENTIFIC LECTURES		9, chairperson, Committee of the Whole	
10.	WMO LONG-TERM PLANNING	10	10, chairperson, Committee of the Whole	
11.	REVIEW OF PREVIOUS RESOLUTIONS AND RECOMMENDATIONS OF THE COMMISSION AND OF RELEVANT EXECUTIVE COUNCIL RESOLUTIONS	11	11, chairperson, Committee of the Whole	Res. 4; Rec. 3

Agenda item	*Document Nos.*	*PINK Nos. and person submitting*	*Resolutions and recommendations adopted*
12. ELECTION OF OFFICERS		12, chairperson, Nomination Committee 12(2), chairperson, Committee of the Whole	
13. NOMINATION OF MEMBERS OF WORKING GROUPS		13, president of CAS	
14. DATE AND PLACE OF THE FOURTEENTH SESSION		14 and 15, president of CAS	
15. CLOSURE OF THE SESSION		14 and 15, president of CAS	

APPENDIX C

LIST OF ABBREVIATIONS

AIRS	Advanced infrared sounder
CAgM	Commission for Agricultural Meteorology
CAS	Commission for Atmospheric Sciences
CBS	Commission for Basic Systems
CCl	Commission for Climatology
CEOS	Committee on Earth Observation Satellites
CIMO	Commission for Instruments and Methods of Observation
CLIPS	Climate Information and Prediction Services
CLIVAR	Climate Variability and Predictability
CLIWOC	Climate of the World Oceans
EANET	Acid Deposition Monitoring Network in East Asia
ECMWF	European Centre for Medium-range Weather Forecasts
EMEP	Cooperative Programme for the Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
ENSO	*El Niño*/Southern Oscillation
ESCAP	Economic and Social Commission for Asia and the Pacific
5LTP	Fifth WMO Long-term Plan
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GEWEX	Global Energy and Water Cycle Experiment
GOALS	Global Ocean-Atmosphere-Land System
GORS	General Organization of Remote Sensing
GTS	Global Telecommunication System
GURME	GAW Urban Research Meteorological Environment
HIRS	High Resolution Infrared Sounder
IAMAS	International Association of Meteorology and Atmospheric Sciences
ICSC	International Core Steering Committee
ICSU	International Council for Science
IGAC	International Global Atmospheric Chemistry Programme
IGOS	Integrated Global Observing Strategy
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergence Zone
IWM	International Workshop on Monsoon Studies
IWTC	International Workshop on Tropical Cyclones
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JSC	Joint Scientific Committee
MED POL	Mediterranean Pollution Monitoring Programme
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NERC	National Environment Research Council
NMHS	National Meteorological and Hydrological Service

NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
6LTP	Sixth WMO Long-term Plan
SAG	Scientific Advisory Group
SPARC	Stratospheric Processes and their Role in Climate
SSU	Stratospheric Sounding Unit
TCP	Tropical Cyclone Programme
THORPEX	The Hemispheric Observing System Research and Predictability Experiment
TIROS	Television Infrared Observation Satellite
TMRP	Tropical Meteorology Research Programme
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UV-B	Ultraviolet-B
WCRP	World Climate Research Programme
WCP	World Climate Programme
WDC	World Data Centre
WGCM	Working Group on Coupled Modelling
WGNE	Working Group on Numerical Experimentation
WHO	World Health Organization
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWRP	World Weather Research Programme
WWW	World Weather Watch