OUTLINE PLAN AND BASIS
FOR THE
WORLD CLIMATE PROGRAMME
1980-1983

1980

WMO - No. 540

Secretariat of the World Meteorological Organization - Geneva - Switzerland
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(Annex to Resolution 29(Cg–VIII))

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**Agreement between the World Meteorological Organization and the International Council of Scientific Unions on the World Climate Research Programme**

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**The Declaration of the World Climate Conference**

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FOREWORD

The Executive Committee, at its twenty-sixth session (April/May 1974), considered that it was important for WMO to take the lead in promoting studies of climatic changes and their impacts on the natural environment of mankind and on world food production. With this in mind the Committee decided to establish a Panel of Experts on Climatic Change which would, inter alia, review WMO activities related to climatic changes and make recommendations on any additional steps necessary to integrate these activities into a coherent programme. The panel was requested to prepare a report for consideration by Seventh Congress.

The Seventh World Meteorological Congress (April/May 1975) therefore decided (Resolution 25(Cg-VII)) that WMO should undertake, with the co-operation of other international bodies concerned, the necessary co-ordination leading to the planning and execution of an integrated international effort on climate change. The Panel of Experts on Climatic Change was subsequently re-established by the twenty-seventh session (1975) of the Executive Committee, with revised terms of reference and membership.

The growing worldwide concern about the possibility of irreversible changes taking place in the natural environment was reflected in the reports presented by the panel to the Executive Committee and in the Committee’s decision at its twenty-ninth session (1977) to request the Secretary-General to make specific proposals in respect of the establishment, within WMO, of a World Climate Programme (WCP). At the same time it was decided to convene a high-level scientific and technical World Climate Conference (WCC) early in 1979, to be attended by meteorologists and experts from all the climate-sensitive branches of the national economy, including agriculture, energy, water resources, fisheries and health. The main purposes of the Conference were to review knowledge of climatic change and variability, due to both natural and anthropogenic causes, and to assess possible future climatic changes and variability and their implications for human activities.

The Conference, which was held in February 1979, was highly successful. The discussions at the WCC were organized to follow the structure of the tentative World Climate Programme, which was to be presented to Eighth Congress, and working groups were set up to study questions related to the proposed component programmes of the WCP. A very important outcome of the WCC was the adoption of “The Declaration of the World Climate Conference” which was based on supporting documents proposed by the working groups of the Conference.

The Eighth World Meteorological Congress, meeting in Geneva in April/May 1979, subsequently agreed that the Organization should establish a major programme entitled “World Climate Programme” and adopted Resolution 29(Cg-VIII) — World Climate Programme. Congress agreed that this Programme should comprise the following components:

- Climate Data Programme (CDP);
- Climate Applications Programme (CAP);
- Climate Impact Study Programme (CIP);
- Climate Change and Variability Research Programme (CRP) (also referred to as the World Climate Research Programme).
When discussing the plans for the WCP, Congress agreed that the reports of the WCC working groups should form the basis for the planning and implementation of the Programme and they were therefore included in the annex to the above-mentioned resolution.

The decisions taken by Eighth Congress with regard to the Climate Impact Study Programme and the World Climate Research Programme are particularly noteworthy. Congress welcomed an offer made by the UNEP Governing Council to assume responsibility for the implementation of the Climate Impact Study Programme under the overall co-ordination of WMO and requested the Secretary-General to negotiate with UNEP the conditions under which this could be arranged. A number of proposals have already been formulated in respect of this component of WCP.

As regards the Climate Research Programme, Congress approved the text of a new WMO/ICSU Agreement on the World Climate Research Programme whereby the overall supervision and co-ordination of this component of the WCP would be carried out jointly by WMO and ICSU. This Agreement also incorporates the Second GARP Objective and is indeed a logical follow-up to the highly successful activities undertaken under the GARP Agreement.

The present publication constitutes "The outline plan and basis for the world climate programme". It includes the resolution adopted by Congress on the WCP, together with its annex, the Agreement between WMO and ICSU on the World Climate Research Programme and the Declaration of the World Climate Conference, and thus will form the basis of further action to be taken to bring this important Programme to fruition.

In conclusion, it would be appropriate to mention that the World Climate Programme plan is the result of many years' intensive planning carried out in collaboration with Members of the Organization, many United Nations bodies and specialized agencies, in particular FAO, Unesco, WHO, IFAD and UNEP as well as intergovernmental and non-governmental bodies such as ICSU and IIASA. The efforts of many individual experts have also ensured that the plan is as comprehensive as the subject, which has ramifications in almost every aspect of daily life. The implementation of the plan will now require even closer co-operation and collaboration between Member countries, many international organizations and the WMO Secretariat to ensure its success.

D. A. DAVIES
Secretary-General
RESOLUTION ADOPTED BY EIGHTH CONGRESS

29(Cg-VIII)—World Climate Programme

THE CONGRESS,

NOTING:

(1) The decisions relating to climatic change of the second session of the Governing Council of the United Nations Environment Programme (1974),

(2) The request to WMO to undertake studies in the field of climatic change, made at the sixth special session of the United Nations General Assembly (1974),

(3) That Resolution XVI of the United Nations World Food Conference (1974), which has been endorsed by the General Assembly of the United Nations, requests WMO to encourage investigations leading to a better understanding of the causes of climatic change,


(5) Resolution 25(Cg-VII) — Climatic change (1975),

(6) Part C of Annex X to the abridged report of EC-XXVIII — Integrated international effort related to studies of climatic change (1976),

(7) Resolution 12(EC-XXVIII) — Climatic change (1976),


(9) Resolution 19(EC-XXX) — World Climate Programme (1978),

(10) Resolution E/RES/1978/45 — World Climate Programme, adopted by the second regular session (1978) of the Economic and Social Council,

(11) The results of the World Climate Conference organized by WMO in Geneva, in February 1979, and especially the Conference Declaration,

(12) The resolution of the seventh session of the UNEP Governing Council concerning the Climate Impact Study Programme of WCP,
RECOGNIZING:

(1) That the climate of a geographical area or of the world as a whole is the result of a delicate and ever-changing balance of forces involving the sun, the atmosphere, the oceans, the land, the ice and snow of the polar regions, the deserts and the system of all living things,

(2) That changes in this balance and the resulting climate can occur on time-scales ranging from inter-annual variations to more gradual climate changes occurring over decades, centuries and millennia,

(3) That climatic variations and change have serious implications for mankind in connexion with a wide range of activities, notably world food production,

(4) That man's activities are likely to have an increasing influence on global climate,

(5) That more research is urgently required, in order to achieve a better understanding of climate change and variability, with the aim of developing a capability for climatic prediction,

(6) That such research is multi-disciplinary and calls for the collaboration of other international bodies with WMO,

(7) That the Declaration of the World Climate Conference calls upon all nations to give strongest support to the World Climate Programme of the World Meteorological Organization,

(8) That there is an immediate need for nations to utilize existing knowledge of climate and climatic variations in the planning of social and economic development,

(9) That, in the developing nations, there is a special need to acquire the ability to obtain better climate data and to apply them effectively for their own purposes,

(10) That the World Climate Programme should be used only for peaceful purposes, due account being taken of the national sovereignty and security of States, in accordance with the provisions of the Charter of the United Nations and the spirit and traditions of the World Meteorological Organization,

CONSIDERING:

(1) That many Members and scientific institutes are pursuing major research programmes in the field of climatic change and inter-annual variation,

(2) That a number of activities relating to climatic changes are already being undertaken by various WMO technical commissions and within the framework of GARP,

(3) That WMO must take a lead in promoting the World Climate Programme,

DECIDES:

(1) To establish a WMO programme, entitled the World Climate Programme (WCP);

(2) That the World Climate Programme should have the following four components:
   — Climate Data Programme (CDP);
   — Climate Applications Programme (CAP);
— Climate Impact Study Programme (CIP);
— Climate Change and Variability Research Programme (CRP);

(3) To utilize the material contained in the annex to this resolution as the basis for the planning and implementation of this new major programme;

URGES all Members to co-operate in the World Climate Programme by intensifying their national efforts in all components;

REQUESTS the Executive Committee:

(1) To consider, as and when necessary, the establishment of an overall co-ordinating mechanism for the WCP;

(2) To entrust the task of close co-ordination of the WCP programmes on data and applications and the review of the progress in the other components of the WCP to the Scientific and Technical Advisory Committee referred to under agenda item 2.2;

(3) To establish and operate jointly with ICSU the corresponding committee which shall be responsible for the close co-ordination of the Climate Change and Variability Research Programme, in accordance with the provisions of this resolution;

REQUESTS:

(1) The presidents of the WMO regional associations to give particular attention to regional aspects of WCP;

(2) The presidents of technical commissions to study and promote those aspects of WCP activities which fall within the area of their competence and responsibility;

REQUESTS the Secretary-General:

(1) To bring this resolution to the attention of all concerned;

(2) To invite collaboration of other appropriate bodies of the United Nations family, in particular IFAD, FAO, Unesco, WHO and UNEP, as well as ICSU and IIASA and other international bodies concerned with climatic changes and their effects, and to promote effective co-ordination among them;

(3) To negotiate with UNEP the conditions under which UNEP could assume responsibility for the implementation of the Climate Impact Study Programme (CIP) of WCP subject to the principles adopted by the Congress of WMO and the Governing Council of UNEP;

(4) To report to Ninth Congress on the progress achieved and to submit proposals for the future.
OUTLINE PLAN AND BASIS FOR THE WORLD CLIMATE PROGRAMME 1980–1983

(Annex to Resolution 29(Cg-VIII))
PART I

SUMMARY

Climate defines a part of the natural environment in which man has evolved and now exists. Climate can foster human activities or hinder them. The variability of climate can be beneficial or it can be violent and disastrous. No one can deny that climate can be a problem with severe impacts. The Sahelian drought triggered disasters in parts of Africa, and floods in the Ganges plain have inflicted untold loss and suffering on the peoples of India and Bangladesh. In two successive years, unusually severe winter conditions led parts of North America to experience considerable economic disruption. Locusts, which are highly sensitive to climate, are on the move again in many parts of the semi-arid regions of Africa.

These events have produced a striking and rapidly growing realization by socio-economic planners, as well as by the general public, of the dependence of national economies and welfare on climatic fluctuations. Furthermore, the recognition of the important role to be played by the application of climatic knowledge in planning national socio-economic development has created the need for more effective international action in this field. This need has been expressed by a number of major intergovernmental meetings organized by the United Nations, such as the Conference on the Environment (Stockholm, 1972), the World Food Conference (Rome, 1974), the Conference on Human Settlements (Vancouver, 1976), the Water Conference (Mar del Plata, 1977), and the Conference on Desertification (Nairobi, 1977). The proposed WMO World Climate Programme (WCP) would represent a major contribution in response to the needs expressed by the nations through these conferences.

Climate has always been an important element of man's environment. Why, then, is a new international initiative such as the World Climate Programme needed at this point in history? A number of reasons come to mind:

- The growing world population and rising standards of living make increasing demands upon the finite resources of the environment. The role of climate as a natural resource and the effects of climate variations are therefore magnified.
- Man's activities themselves may alter climate. It is therefore necessary to learn how to avoid undesirable effects or to plan to live with them if they prove to be unavoidable.
- Study of past climates has shown that climate changes and variations occur on all time and space scales. Therefore, it is not unlikely that significant natural variations could occur within the time horizon of human planning.
- Now tools have been acquired for advancing our knowledge of climate and its relationships with human society. Among these may be mentioned the new techniques permitting global observation of the atmosphere, land and oceans, as well as new technology for collecting, transmitting, processing and interpreting such data. These technological advances have been accompanied by equally impressive advances in theoretical understanding and ability to develop models of the climate system that simulate its behaviour.

In February 1979 the World Meteorological Organization convened a World Climate Conference (WCC) — A Conference of Experts on Climate and Mankind — in which more than 350 experts from many nations and international organizations participated. These experts represented the many scientific
disciplines concerned with climate and numerous fields of human activity which are climate-sensitive. During the first week of the conference 24 overview papers on various climate topics were presented by outstanding scientists. The presentation of papers was followed by extensive discussions which were summarized during the last day of the first week.

During the second week of the conference some 120 invited experts divided into four working groups studied questions related to the components of the World Climate Programme, namely climate data, climate applications, climate impact study, and climatic change and variability research. The results of the deliberations of these groups of scientists are reproduced in Part II of this document.

When discussing the plans for the World Climate Programme, Congress agreed that Part II of this document should be used as the basic material for the planning and implementation of the WCP. It is for this reason that this material is reproduced here as the annex to Resolution 29(Cg–VIII). For ease of reference a summary of Part II is provided in the following paragraphs.

It should be mentioned here that the conference decided to establish a special working group to deal with the subject of the influence of society on climate change and variability (see Part II). This topic, although not identified explicitly as one of the components of the WCP, nevertheless cuts across all the WCP programmes and as such is of great importance in the plan for the WCP.

Climate Data Programme

The purpose of this component of the WCP is to improve the availability of reliable data for the purposes of the WCP. It is proposed that participating nations, WMO, and other international bodies include the following tasks in their priority programmes, as appropriate:

(a) To locate and assemble instrumental observations made during the last 100 years or more, examine the data for quality and consistency, and ensure that these data are readily available for both manual and computer processing;

(b) To establish, maintain and improve the network of climatological stations;

(c) To establish, maintain and improve the network of observations over the oceans;

(d) To establish, maintain and improve networks of hydrological stations;

(e) To establish a commonly agreed data-management plan and promote data exchanges;

(f) To collate, organize and process climatological data into readily usable formats;

(g) To undertake a survey of sources of meteorological, hydrological, oceanographic, paleo-climatic, geophysical, ecological and socio-economic data and establish a referral system on data sources;

(h) To promote the development of new observing technology and, in particular, space technology applicable to climate monitoring on a global scale.

Particular consideration must be given to developing countries by providing assistance for implementing the above priority tasks.

The success of applications, climate impact studies, and climate research depends upon the development of a vast and diverse data base including:

(a) Meteorological, oceanographic, hydrological and geophysical data;

(b) Biological and ecological data;

(c) Sociological and economic data.
The primary goal of international co-operation on climate is the acquisition of the type (a) data referred to above that are necessary for documenting the present world climates and climatic evolutions.

A second goal is to stimulate the acquisition of the remaining elements of the data base (types (b) and (c) above), some of which are beyond the resources and competence of WMO, through the co-ordination of national and regional efforts with the appropriate specialized international bodies.

Highest priority should be given to the extension and improvement of existing climatological networks on the one hand, and the development of an internationally agreed, compatible data system on the other. With respect to the first point, particular attention must be given to increasing satellite data and to extending ground-level observations, including those concerning the radiation and hydrological balance, and making world-wide oceanographic observations. With regard to the second point, greatest attention should be given to developing compatible procedures and formats for timely collection, quality control, archiving, and exchange of climatological data in order to document the world-wide climate, to allow early assessments of significant deviations from the current global climate, and to ensure the availability of climate data to other users.

**Climate Applications Programme**

In many parts of the world, there is sufficient information to provide applied climate services. These are invaluable for planning social and economic development and for day-to-day management decisions. Through the application of climate information, planners and operators can reduce the vulnerability of society to climatic extremes. However, only a start has been made; data and expertise are generally lacking in developing countries, while, everywhere, effective methodologies for use in climate-related problems need yet to be developed.

Although a wide variety of planning and operational activities are sensitive to climate, the most sensitive are food production, water resources, energy and the very important sector of human settlements and health. In serving each of these applications, climatologists must work with agriculturalists, engineers, etc., as well as with others within national weather services — data specialists, researchers, etc. Only cooperative efforts can make the goals of the WCP attainable.

Specific goals of the Climate Applications Programme are to enlighten people and policy-makers of the value of applying climate knowledge to socio-economic problems and to ensure that this knowledge is available. Action plans must therefore include programmes to assist national Meteorological and Hydrological Services to:

(a) Increase the awareness of users of the potential benefits to be gained through the use of climate information;

(b) Improve capabilities to provide and disseminate this information;

(c) Facilitate training in nationally significant climate applications.

Other action plans, on a global scale, must include programmes to develop new methodologies for the application of climate data in the food, water, energy and health sectors. Finally, programmes must be set up to assist developing countries to participate fully in the WCP through training and the transfer of appropriate methodologies.

**Impact Study Programme**

The ultimate objective of the Impact Study Programme should be to bring to light the importance of climatic considerations in the formulation of rational policy alternatives. In areas of the world charac-
terized by differing natural environmental conditions, social structures or economic systems and levels of development, there can be different interactions and responses to climatic variability. The basic studies should aim at an integration of climatic, ecological and socio-economic factors entering into complex problems of vital importance for society, such as availability of water, food, health conditions, energy resources, etc. The following objectives should be given special attention:

(a) Improving our knowledge of the impact of climatic variability and change in terms of the specific primary responses of natural and human systems (such as agriculture, water resources, energy, ocean resources and fisheries, transportation, human health, land use, ecology and environment, etc.);

(b) Developing our knowledge and awareness of the interactive relations between climatic variability and change and human socio-economic activities;

(c) Improving the methodology employed (e.g. case studies and models) so as to deepen the understanding and improve the simulation of the interactions among climatic, environmental and socio-economic factors;

(d) Determining the characteristics of human societies at different levels of development and in different natural environments which make them either especially vulnerable or especially resilient to climatic variability and change and which also permit them to take advantage of the opportunities offered by such changes.

The approaches and methods to be used in climatic impact analyses must be selected with a view to effectiveness, time and resource constraints, consistency, compatibility, comparability and credibility of results. They must also allow for periodic review and evaluation and take full recognition of the many disciplines that must be involved if the programme objectives are to be met.

**World Climate Research Programme**

Our social and economic life is vulnerable to periods of climate stress. Human activity may itself influence local, regional and global climate. These are problems which the international community should address through the Climate Research Programme which will attempt to determine why, how and where climate changes and variations occur, and thereby attempt prediction of their future occurrence.

The major objectives of the World Climate Research Programme should be to determine:

- To what extent climate can be predicted;
- The extent of man's influence on climate.

To achieve these objectives it is necessary:

(a) To improve our knowledge of global and regional climates and their temporal variations, and our understanding of the responsible mechanisms;

(b) To assess the evidence for significant trends in global and regional climates;

(c) To develop and improve physical-mathematical models capable of simulating, and assessing the predictability of, the climate system over a range of space and time scales;

(d) To investigate the sensitivity of climate to possible natural and man-made stimuli and to estimate the changes in climate likely to result from specific disturbing influences.
PART II

THE BASIS FOR THE WORLD CLIMATE PROGRAMME

1. CLIMATE DATA

1.1 Introduction

The success of climatic applications, impact studies and research will depend on the development of an adequate, reliable data base.

Climate-related data are required in order to describe, understand and predict both the behaviour of the climatic system itself, including man's impact on climate, and the relationship of climate to other aspects of the natural world and human society. Data programmes must therefore be integrally designed with the programmes for applications, the study of impacts and research. The data base should contain conventional climate data as well as data on climate-related events, and should consist of both conventional climatological data and climate-related geophysical, biological and socio-economic data.

Data are essential for national and world climate programmes, and maximum use should be made of existing facilities such as the World Weather Watch (WWW) and other climate observational and monitoring networks.

1.2 Objectives of climate monitoring and data collection

The establishment of climate monitoring and climate data-collection services is necessary for:

(a) Application of climate data in human activities;
(b) Assessment of the current global climate condition;
(c) Scientific research on climate change, climate variability and climate change prediction;
(d) Study of the impacts of climate variability and changes on human activities.

Different data bases are required to fulfil the above objectives. While the fulfilment of objectives with respect to (b), (c) and partly (d) requires global data, the fulfilment of item (a) requires additional data of national and regional scope. Evidently data bases will overlap. However, the data base for monitoring of climate will serve as a reference set for the climate impact studies and application programmes. The representativeness and resolution of data are determined by the natural variability of the parameters being observed and by procedures for averaging the data. The data should meet the requirements for the development and testing of models of the general circulation of the atmosphere and oceans and of climate models, and the needs for various applications.
1.3 Climate monitoring

Monitoring of the climate is needed for an understanding of natural climatic change and variability in both space and time and of climate interactions with the biosphere and human activities. In the latter context it contributes information on the important environmental questions concerning possible effects of human activities on the climatic system.

1.3.1 Types of data

For climate monitoring the following types of data are required:

1.3.1.1 Primary data

(a) Surface data from synoptic, climatological and specialized stations (such as radiation stations);
(b) Upper-air data;
(c) Data on atmospheric composition and aerosols;
(d) Oceanographic data, including sea-ice data;
(e) Hydrological data, including snow and ice data.

1.3.1.2 Other geophysical data

(a) Radiation balance at the boundaries of the atmosphere;
(b) Measurement of the solar constant;
(c) Data on stratospheric dust load;
(d) Geomorphological data.

1.3.1.3 Oceanic data

Air-sea interactions are of great importance in determining climate. Therefore, the first priority should be given to the establishment of monitoring systems in those oceanic regions where the interactions take place most actively.

1.3.2 Current climate-monitoring systems

The following kinds of monitoring activity are already being carried out with in the framework of WMO:

(a) World Weather Watch;
(b) World radiation network;
(c) Networks of climatological stations;
(d) Marine climatological networks;
(e) World ozone network;
(f) Background Air-pollution Monitoring Network;
(g) Integrated Global Ocean Station System (IOC/WMO IGOSS).

So far none of the above systems is providing adequate data coverage over the oceans, which occupy three-quarters of the Earth’s surface. This point is covered specifically in section 3.2.2. In addition, data needs and technology (such as satellites) are constantly evolving so that there is always a requirement for reviews of observing programmes, such as will be carried out using data collected during the Global Weather Experiment (FGGE). Further efforts are required for improving satellite observing techniques which, in addition to environmental space observation systems already developed, can be applied to the problem of climate monitoring on a global scale.

1.3.2.1 The design of climate-monitoring systems

For purposes of observing the weather, WMO initiated and co-ordinates the development of what is probably the largest and most effective environmental monitoring system in the world, namely the World Weather Watch. Although many of the components of this system have been optimized for operational weather-forecasting purposes, it already provides an adequate base for many climate-related activities. However, some data (e.g. radiation data) are not provided with sufficient accuracy and density and their observation must be improved.

An essential part of the climate-monitoring system is the network of climatological stations, in particular reference climatological stations. For homogeneity of the data, it is necessary to do more to improve a global network consisting of various types of climatological station as defined in the WMO Technical Regulations. Each type of climatological station should be located in such a way that the influence of local meteorological processes (including those modified by human activities) is suppressed as far as possible. Siting criteria would need to be specified for each type of station, and existing stations that meet the criteria would need to be identified. The criteria for reference climatological stations need not be the same as for air-chemistry monitoring systems.

1.3.2.2 Oceanic observations

It is recognized that a major issue in the process of understanding climate and eventually forecasting climate variations is the problem of the global ocean dynamics. It is essential that the help of the oceanographic community be enlisted to promote the appropriate observational and research programmes on the overall ocean circulation dynamics.

It is also recognized, on the other hand, that air-sea interaction involving the upper layer of the oceans is basic in determining the inter-annual variability and short time-scale climatic variations. Urgent action must be taken to apply the resources of the oceanographic and meteorological communities to establishing extensive and regular measurements of the upper layer of the global oceans down to the seasonal thermocline. For this purpose, it is recommended that an internationally co-ordinated, composite observation system be developed with the following components:

(a) Ocean Weather Stations (as primary reference climatological stations);
(b) Mobile ships (voluntary observing ship stations);
(c) Research vessels;
(d) Satellites;
(e) Ocean buoys (anchored and drifting).
1.3.2.3  *Multi-media monitoring stations*

Proposals have been made for pilot multi-media global environmental monitoring projects which would include monitoring of the atmosphere, the pedosphere, and elements of the biosphere at background monitoring stations. In addition to being cost-effective, such stations would be useful in studies of the biogeochemical cycling of trace substances (particularly carbon, sulphur and nitrogen) and in studies of biospheric response to natural and anthropogenic impacts, including climatic stress.

1.4  *Data needs for research, applications, and impact studies*

1.4.1  **DATA NEEDS FOR CLIMATOLOGICAL APPLICATIONS**

The scientific basis for applied climatology is well developed, and the data needs are reasonably well defined. (The important work of the WMO Commission for Special Applications of Meteorology and Climatology and of its predecessor should be mentioned.)

The data needs for different applications should be discussed and agreed upon between the services which provide data and the users. In addition, the design principles of climatological networks need to be improved.

It should be stressed that the field of applied climatology is continually evolving, presenting new challenges and opportunities. Data needs are changing too, so that periodic reviews of monitoring networks and data archives need to be encouraged (see section 2).

1.4.2  **DATA NEEDS FOR THE STUDY OF THE IMPACTS OF CLIMATE ON HUMAN ACTIVITIES**

Almost every type of climatic impact study is complex and interdisciplinary. Therefore, impact studies will make extensive use of data relating to other disciplines. Along with hydrological, meteorological and geophysical information the following kinds of data should be included in the data base:

(a) Agricultural data;
(b) Land-use inventories;
(c) Industrial data;
(d) Ecological data.

The essential part of the data related to these other disciplines should be collected and archived at national archives, and they will probably be used at the national level. Authoritative knowledge of related data sources and archives rests in the United Nations and its specialized agencies, as well as specialized institutions established under the aegis of ICSU. The co-operation of several organizations and national governments may be essential to fulfil the data needs of a major impact study.

What is most important is to develop a data infrastructure such that impact studies can capitalize on much that already exists, and so that entirely new data-gathering exercises can be avoided.

1.4.3  **DATA NEEDS FOR RESEARCH ON CLIMATIC CHANGE AND VARIABILITY**

Data for research on climatic change and variability are required:

(a) To elaborate the comprehensive climate theory;
(b) To provide data sets for validating and calibrating climate models;

(c) To provide long time-series of measurements of climate-related parameters of global significance needed for assessment of climate changes and variabilities.

The data requirements in the three cases are quite different (see section 5). The collection of a complete set of atmospheric, ocean and land-surface data for the period of at least the last 30 years is the major task.

The FGGE (Global Weather Experiment) data set will provide the most detailed picture to date of one annual cycle, which is of great importance. The assembly of “long-term instrumental record” data sets is also essential. It will be necessary to locate and assemble instrumental observations made during the last 100 years or more, examine the data for quality and consistency, and arrange for the data to be readily accessible and suitable for both manual and computer processing.

In general, it is recognized that a variety of additional information will be required for climate research, including particularly:

(a) Special data sets based on intensive measurements of specific climatic processes for the purpose of parameterization;

(b) Documentation of past climates and paleoclimatological records.

1.4.4 CLIMATIC COMPONENTS OF “ENVIRONMENTAL IMPACT ASSESSMENTS”

Large-scale engineering projects, deforestation (especially in tropical regions), over-grazing and diversion of rivers could also have a potentially important impact on climate. The impact of such activities is to be specially monitored.

1.5 Data management

Data-management planning must be an important element of the World Climate Programme.

Large amounts of physical data relevant to the problem of climate have been obtained and are being accumulated in a variety of data banks and archives. However, a large portion of these data are either not readily usable, since they are not always physically compatible and adequately quality-controlled, or not easily accessible. It is therefore essential that the resources of modern data-processing and data-retrieval techniques be applied to the management of climatological data and that an urgent effort be applied to developing internationally compatible formats and data-processing and exchange procedures.

The primary responsibility for acquiring, storing and retrieving climatological data should rest with national archives. It is urgent to organize a timely and direct flow of information between these archives. Consideration may also be given to regional archiving activities. With this in view it is recommended:

(a) To prepare and maintain an inventory of climatological stations;

(b) To prepare and maintain a catalogue of available reliable climatic data;

(c) To collect, collate and make available a core of climatic data of a standard quality level and standard format from a representative global network;

(d) To develop appropriate statistical processing schemes for condensing the mass of raw climatological data down to manageable data sets.
Once the presently available data have been identified, the next step is to pinpoint where the data gaps are on a national, regional, and global scale. To augment the data systems of many countries major support will be necessary to achieve the expansion of networks, data collection, quality control, processing and storage. It will be essential to provide an exchange of technology and to organize education and training to achieve viable systems.

1.6 Conclusions

1.6.1 Priorities

To improve the availability of reliable data in support of the other components of the WCP, it is proposed that participating nations, WMO, and other international bodies include the following tasks in their priority programmes, as appropriate:

(a) To locate and assemble instrumental observations made during the last 100 years or more, examine the data for quality and consistency, and ensure that these data are readily available for both manual and computer processing (see section 1.4.3);

(b) To establish, maintain and improve the network of climatological stations (see section 1.3.2.1);

(c) To establish, maintain and improve the network of observations over the oceans (see section 1.3.2.2);

(d) To establish, maintain and improve networks of hydrological stations;

(e) To establish a commonly agreed data-management plan and promote data exchanges (see section 1.5);

(f) To collate, organize and process climatological data into readily usable formats (see section 1.5);

(g) To undertake a survey of sources of meteorological, hydrological, oceanographic, paleo-climatic, geophysical, ecological and socio-economic data and establish a referral system on data sources (see section 1.5);

(h) To promote the development of new observing technology and, in particular, space technology applicable to climate monitoring on a global scale (see section 1.3.2 and 1.4.3).

Particular consideration must be given to developing countries by providing assistance for implementing the above priority tasks.

1.6.2 Goals of the Climate Data System

The success of applications, climate impact studies, and climate research depends upon the development of a vast and diverse data base, including:

(a) Meteorological, oceanographic, hydrological and geophysical data;

(b) Biological and ecological data;

(c) Sociological and economic data.

The primary goal of international co-operation on climate is the acquisition of the type (a) data referred to above that are necessary for documenting the present world climates and climatic evolutions.
A second goal is to stimulate the acquisition of the remaining elements of the data base (types \((b)\) and \((c)\) above), some of which are beyond the resources and competence of WMO, through the co-ordination of national and regional efforts with the appropriate specialized international bodies.

Highest priority should be given to the extension and improvement of existing climatological networks on the one hand and the development of an internationally agreed, compatible data system on the other. With respect to the first point, particular attention must be given to increasing satellite data and to extending ground-level observations, including those concerning the radiation and hydrological balance, and making world-wide oceanographic observations. With regard to the second point, greatest attention should be given to developing compatible procedures and formats for timely collection, quality control, archiving, and exchange of climatological data in order to document the worldwide climate, to allow early assessments of significant deviations from the current global climate, and to ensure the availability of climate data to other users.
2. APPLICATIONS OF THE KNOWLEDGE OF CLIMATE

2.1 Introduction

During recent years, there has been a striking and rapidly growing realization by governments, as well as by the general public, of the dependence of national economies and human welfare on climate and its variability. This was particularly highlighted by recent important, although perhaps not abnormal, climate fluctuations in a world where nations have become increasingly economically and ecologically interdependent, but where until recently there existed a widespread belief that the main practical purpose of meteorology was weather forecasting.

To lessen this vulnerability to the vagaries of climate, climate knowledge has long been applied for the benefit of human welfare to both economic and environmental activities. In general, knowledge of climate and its characteristics is essential to support decision-making in two major aspects of human activities with different time frames: (a) planning and design and (b) operation and management.

Furthermore, the growing recognition of the important role to be played by the application of climatic knowledge in planning national socio-economic development has led to the realization of the need for more effective international action in this field. This need has been expressed by a number of major intergovernmental meetings organized by the United Nations, such as the Conference on the Environment (Stockholm, 1972), the World Food Conference (Rome, 1974), the Conference on Human Settlements (Vancouver, 1976), the Water Conference (Mar del Plata, 1977), and the Conference on Desertification (Nairobi, 1977).

2.2 The use of climatic knowledge

Climatological information can be applied to a wide variety of planning and operational activities in all nations. The most sensitive are those sectors dealing with food production, water resources, energy and human settlements and health. Socio-economic activities in those sectors have evolved over a long period of time and reflect adaptation to regional and local climates. In many developed countries, a reasonably adequate archive of climate data has been employed by climatologists to provide significant applied services to the relevant sectors. Unfortunately, however, planners and managers often underestimate climate as an economic variable and consequently make poor or little use of this socio-economic resource. Further, many developing countries need assistance to establish the necessary service organization and to train staff so that services in applied climatology may be provided to other government services and to the public.

2.2.1 Planning activities

When the general statistical characteristics of climate and its variability are known for a locality or a region, this information may be used to assist in the choice of a design or policy which is intended to remain in being for a long period of time, for example, a water-management system which will remain in operation for a century or more. Employing information on the mean precipitation and its variability, we could contribute to ensuring that flood damage, availability of irrigation water, and costs were kept within bounds during that period with some degree of certainty. Other climatic knowledge could be applied to the planning of agricultural developments and to the introduction of new sources of energy (e.g. solar
radiation, wind, tides, etc.). Such planning decisions are of great importance for economic development, particularly in the developing countries where major decisions involving climatic knowledge must be made within the next few decades.

Efforts to apply this climatic knowledge must be based on the statistics of climate and its variability.

2.2.2 Operational activities

Current climatic information can be of great value to managers of climate-sensitive operations on a day-to-day basis. For example, precipitation and snowmelt data are used in the operation of flood-control systems and temperature and wind data are needed in managing fuel supplies in cold regions.

2.3 Objectives and principles

2.3.1 Objectives of applications

The basic objective of a climate applications programme is to assist societies to improve their capabilities to carry out various activities and to obtain maximum economic and social benefit under different climatic conditions while maintaining environmental integrity.

Specifically, international efforts relating to climate applications should seek:

(a) To respond to the demands of users and determine the climate information needed for the most effective operation of climate-sensitive activities, or to reduce their vulnerability to climatic hazards;

(b) To increase the awareness of planners and decision-makers of the uses of climatic information and to improve their capability to employ this information;

(c) To devise, implement and improve operational programmes to provide this information and to assist developing countries in this task;

(d) To assist both national Services (meteorological and hydrological), particularly in developing countries, and managers of climate-sensitive activities in providing and using these services;

(e) To disseminate information on climate applications, transfer relevant technology and facilitate training in climate applications;

(f) To refine or state requirements for new climate and climate-related data and for research results needed for improved applications services.

At the international level, efforts should concentrate on the provision of climate information and methodologies to assist in dealing with regional or global problems. Such problems would include desertification control or preparedness for international disaster relief. Other efforts might involve the promotion of more effective management of agriculture and water resources than presently exists or the planning and development of new energy-producing facilities. WMO and other international bodies are already involved, to varying degrees, in many of these actions; future planning should make full use of climatic applications, building on current programmes.
2.3.2 **Principles for development of an effective applications programme**

Based on the experience of meteorologists, hydrologists and other experts in relevant fields, several general principles for the effective application of climatological information can be formulated. These have been clearly set forth by J. D. McQuigg in WMO Technical Note No. 132, and may be summarized as follows:

(a) In order to make effective use of climatological information, active efforts must be made to identify climate-sensitive processes for which the required information can be specifically defined; to develop documented, quantified relationships between climate information and activity; to produce the information in a usable form; and to communicate it to users who understand how to employ it in their decision processes;

(b) Climatological information is likely to have the largest economic impact if it is produced and used before major resource use patterns are firmly established or before changes are made. If long-term strategic decisions are made without consideration of climatological information, it may be impossible to make optimum use of short-term weather information in the future management/operation of the system involved;

(c) Specialized climatological information and guidance can usually be developed for a particular planning/design/policy decision for a small fraction of the total cost of the enterprise concerned;

(d) Individuals who understand both the application and the nature of available climatological information play a crucial role in linking users and the information they need.

2.4 **Problems and deficiencies in the application of climatic information**

2.4.1 **Availability and timeliness of the information**

Climate information must be available and used before the decision is taken, and before new patterns or procedures are determined and established. Since climate information is based on multi-year records of past weather, unless the necessary networks have been in operation for years and the data collected and analysed, it will be impossible for climate factors to be taken into account in the decision process.

2.4.2 **Trained personnel and tailoring information to the users' needs**

A common requirement of all climate information users is for trained and motivated people. Skilled people are needed to translate user needs into clear requirements for climatological information and services, to develop specialized climatological products from generalized data archives, and to work with users in applying this knowledge to their problems, thereby increasing their awareness of the influence of climate on their activities, and hopefully improving the priority given to climatological services within the nations. Special needs for trained personnel in climatology can be perceived for such activities as: data processing, computer techniques, building and urban development, energy problems, air pollution, agriculture, water resources and offshore operations. These specially trained people will not all be employed by the Meteorological Services. However, the training must be at an advanced level because, amongst other activities, climatologists are frequently asked to evaluate environmental impact assessments and the experts called upon by the developers to prepare these assessments often resort to elaborate analyses that require a critical appraisal.
2.4.3 Translating Basic Data Into Useful Information

In some locations, adequate data exist upon which applications can be effectively based. However, in other locations data may not have been collected and organized into readily usable form (see section 1). Even if basic data are conveniently available, these may need to be transformed into derived data products shaped to the needs of the various customer groups. For example, basic meteorological data may be converted in terms of parameters significant to the specific agricultural problems of a given location, e.g. length of growing season, probability of favourable or adverse conditions for planting, cultivation and harvest. This information must then be made available to planners and decision-makers in a form convenient for their use.

One pervasive problem that arises here is the fact that climatic knowledge is often needed on the local scale, while basic data are usually available only on the macroscale. For example, the location and design of a power plant depends on the local climate of the valley in which it is located, while the only climatological data may be available from an airport many kilometres away. Agroclimatic parameters may be needed for a small region, while the only data available may come from a conventional meteorological station with a different local climate or from a specialized agrometeorological station with different environmental conditions. Thus, the provision of useful information from available data, however high in quality or quantity, is neither straightforward nor simple.

2.4.4 Resources for Climatic Applications

The growth and strengthening of Meteorological Services in developing countries and the allocation of resources for this purpose have tended to give priority to the establishment of synoptic networks, the provision of operational services to aviation and other real-time weather observing and forecasting activities. In contrast, the less visible, less glamorous, but also less expensive, development of networks of climatological stations and climatological services appropriate to the development of the resources of the country has received lower priority and few resources and in fact has often been carried out by other organisms than the Meteorological Service. This has presumably resulted from the unawareness of development planners and managers of the potential value of climate knowledge available to them, and also because the more immediate effects of the weather, that may endanger life and property, are more likely to attract the attention of the responsible authorities in government. Another major obstacle to the applications of climate knowledge is the frequent inadequacy or absence of systems for data archiving and retrieval — an obstacle which occurs in some developed as well as developing countries. Satellite observing systems present special problems in this regard.

In some instances, resources for climatological services to users may be provided from outside the country through bi- or multilateral aid programmes. But the primary source of support for any nation's basic services must, in the long run, be its own resources. In all cases, climatological applications programmes should be given support that is proportional to their potential contribution to socio-economic development and human welfare.

2.4.5 Dissemination of Information

Climate information potentially relevant to the solution of national problems increases rapidly, while the finite national resources of manpower, expertise and funds to acquire this information grow but slowly. Furthermore, in a developing country there may be only a handful of experienced climatologists and insufficient funds to acquire the world’s technical literature. Yet the country may face in a single generation the full range of problems already experienced by a major industrialized nation over several centuries. Special efforts are therefore needed to ease and accelerate the flow of information.
In addition to basic and specialized climatic data the requisite information includes derived data products, atlases, annotated bibliographies pertaining to climate applications, specialized technical reports, computer software, and guidelines for the development of such information dissemination vehicles as publications, seminars, demonstrations, etc.

2.5 Areas for international action

Climate applications services should be commensurate with the needs and consistent with feasibility in different nations and geographical areas. Although considerable services already exist, international actions are recommended to satisfy further major needs. These include:

(a) The promotion of the use of applications (e.g. by more effective interaction with users, education, the use of interdisciplinary studies of economic benefits, etc.);

(b) The development of an appropriate data information system (e.g. by the integration of data from different sources, the creation of archives that are more complete and of improved quality);

(c) The more effective and efficient development of new methodology (e.g. by developing more efficient means of extracting desired information from basic data);

(d) More effective technology transfer, particularly to developing countries (e.g. by expanding and systematizing present activities, increasing assistance, improving computing facilities, providing more manuals in the users' languages, etc.);

(e) Development and implementation of related educational and training programmes (e.g. by expanding and systematizing training conferences, seminars, pilot programmes, and increasing and improving training and material assistance).

These areas for potential action, which are not presented in an order of priority, are described in the following sections.

2.5.1 Promotion of the use of climate applications

Although recent climatic events have increased the awareness of users and potential users of the value of climatological information, obstacles remain to optimizing its use. Users may not grasp the full potential value of applying climatology to their problems; climatologists often lack an understanding of the decision processes of and alternatives available to potential users; in other cases, organizational circumstances act to reduce the effectiveness of a climatological applications service. Although these problems are common throughout the world, the necessary remedial measures may vary with levels of development and the socio-political system. While strategies for promotion may differ from one country or region to another, within all countries the interface between climatologist and users must be further developed so as to remove perceptual barriers. Consumer involvement can be greatly enhanced by the use of committees, where the user is free to express his views, and by improved understanding of his activities by applications climatologists. Because of the existing resource limitations the scope of the applications programme ought to be directed toward high-priority activity sectors where early benefits will be considerable, e.g. agriculture, water resources, and energy.

In many developing countries, there is a need for internal recognition of the importance of climatological services. Observational and applications programmes may be undertaken by a variety of agencies and consideration should be given to their consolidation within, or co-ordination through, a central climatological service, thereby providing a more appropriate data base and decreasing considerably the cost of the total system necessary for an effective applications programme.
While many of the problems are national, international efforts could help stimulate the intelligent applications of climatology by such actions as: (a) documenting and publicizing selected pilot projects in climatological applications; (b) conducting selected case studies demonstrating the efficacy of specific climatic services, since few countries have identified in a convincing manner the major benefits that accrue through the applications of climatology; (c) organizing visible activities such as seminars, symposia and conferences dealing with the methods and benefits of climatic applications and involving users, climatologists and political leaders.

Very effective interaction techniques have been identified by WMO and recorded in the report of the WMO Solar Energy Meeting, October 1978. These involve meetings at all levels of programme development including technical conferences, seminars and workshops at the regional level where the participants are few, but well selected. The use of roving seminars should be encouraged because they reinforce local interest and training relevance.

2.5.2 DEVELOPMENT OF A DATA INFORMATION SYSTEM

A climatologist cannot effectively serve a client if he does not have access to a reasonably adequate climatic data base. Such a data base must usually cover a period of at least ten years, and the longer the period of record, the better will be the climatological statistics that can be derived from it. While it is recognized that provision of services related to data is largely a national matter, certain efforts might be undertaken internationally, for example:

(a) Development and dissemination of regional climatic atlases and other data products relevant to such applications areas as land-use planning, pollution control, etc.;

(b) Preparation and distribution of bibliographies and specialized technical reports;

(c) Operation of an international bibliographic research service which could readily assemble the most relevant world literature bearing upon a problem presented by a national application specialist.

(For further information see section 1.)

2.5.3 DEVELOPMENT OF NEW METHODOLOGY

At present, new applications methodology is largely being developed on an ad hoc limited national needs basis. This leads to redundance and the development of products that do not necessarily make use of the best methodology. Continued development of applications methodology on an efficient, best-use-of-science basis is essential in the interests of both developing and developed countries. Coordination and integration of this effort are essential.

Multi-disciplinary studies of the interaction between climate and human activities should be stimulated because these are a potentially useful tool for developing programme priorities and strategies.

Operational climatological services that combine knowledge of current hazard or opportunity levels determined from recent climatic and other information together with the information content of current weather forecasts can provide major benefits to a community or sector of industry. Such services are invaluable in periods of impending drought, or when combined with user information for operations such as fertilizer application and soil conservation. The development of this type of service should be encouraged and supported as a matter of priority.

Also, the possibilities for an international "climate alert" system deserve exploration.
2.5.4 TECHNOLOGY TRANSFER

Much experience and technology relevant to the application of climate knowledge to human problems already exists. However, many potential applications have not yet been adequately developed, while applications developed in one country may not be immediately transferable to another. The technology transfer process requires: knowledge of what is required, what is available and what is transferable to the areas of need; the development or modification of applications to suit requirements; the development of the support systems and of the education, training, and other actions needed for implementation. Technology transfer may be relatively simple, as in the case of satellite photo interpretation, or complex where the development of major new physical plants and expertise is involved.

A significant effort in climate-related technology development should focus upon the needs of the developing countries. Considerable effort, for example, has been devoted to research on climatic effects on wheat, but little work has been done on tef or cassava, for example, although these crops play a major role in the economies of numerous countries. Efforts are needed to increase research and development in climate-related problems, especially those of developing countries.

The following priorities are identified in the technology transfer area:

(a) Inventories of internal needs and both internal and external capabilities;
(b) Information regarding the availability of technical assistance;
(c) Local experts to work with and advise external technical experts;
(d) Computing facilities at centralized locations;
(e) Information and computer software packages to transform climatic data into user-relevant parameters;
(f) Adaptable numerical models for such applications as pollution assessment, crop-weather evaluation, agricultural zoning, water-resource assessment, etc.;
(g) Continued and strengthened technical publishing programmes;
(h) The provision of relevant guides, manuals and technical journals and other such reference material from other countries;
(i) Co-ordination and interaction of relevant national and international agencies.

The transfer process requires the use of regional training seminars and demonstration projects which are the subject of the next section.

2.5.5 EDUCATION AND TRAINING

People are usually the critical elements in the application of climatological information. There are needs for:

(a) Broadly qualified climatologists knowledgeable in applications areas who can interpret user needs in climatological terms and assist users in employing climatic information in their planning and decision processes;
(b) Specialists from other disciplines, such as agriculture, hydrology or marine activities, with an appreciable knowledge of climatology;
(c) Data specialists who can transform existing archives of general-purpose data into special-purpose information for specific applications;
(d) Technicians to apply computer and other modern technologies to these tasks.
While experts from outside may from time to time assist in providing these needs, in the long term these people must come from a nation's own resources. Indeed, training within a country is most likely to develop expertise in that country's unique problems and relate more closely to national priorities.

International efforts can assist by:

(a) Providing guidelines for educational requirements, syllabuses, and qualification standards for climatological experts;

(b) Developing reference and instructional material for use in climatological training;

(c) Co-ordinating fellowships, exchange and similar programmes to provide educational/training opportunities for developing-country personnel in countries with climatological expertise;

(d) Co-ordinating assistance programmes for in-country educational programmes, including arranging for instruction, course materials, etc.;

(e) Helping develop suitable climate applications training centres, especially in developing countries, e.g. at universities, institutes and technical schools.

In some developing areas regional centres may be useful, especially for the training of specialists who will become instructors. Regional training programmes are often a very efficient way of stimulating the implementation of applications programmes within developing countries. Regional training seminars of a roving nature have been particularly effective, for example, in the area of hydrological applications. Such types of activity should be expanded on a needs basis.

The Voluntary Assistance Programme (VAP)* of WMO was adopted as a means for providing technical assistance, equipment and training for developing countries. Hitherto the VAP has been restricted to support of the WWW Programme. It is urged that the VCP be extended to provide appropriate assistance in applications of knowledge of climate and the use of climatic data. Other United Nations bodies have similar programmes and these too should be used in support of the applications programme.

2.6 Priorities

2.6.1 PRIORITIES OF SOCIO-ECONOMIC SECTORS

The climatic problems related to the activities listed below are becoming increasingly significant and they should therefore be considered as a matter of urgency in combination with the five areas indicated in section 2.6.2 of this report.

The applications of climatology to the following specific areas should receive high priority generally, but relative priorities will depend on local situations:

(a) Food production — agriculture, fisheries, alleviation of crop and animal disease, soil conservation, land use, desertification control;

(b) Water resources;

(c) Energy — exploration, production, transportation, conservation, demand;

(d) Human health and settlements — building and construction, tourism and recreation, environmental pollution control, natural hazards;

* Now renamed Voluntary Co-operation Programme (VCP).
(e) Transportation and communications, manufacturing and other industry;
(f) Marine and coastal zone development.

2.6.2 Priorities of areas for international action

The major areas (see section 2.5) have been presented in a manner that does not reflect their priority. Priorities differ from one geographical region or nation to another, and among other things they are dependent on feasibility. Nevertheless, it is possible to assign overall priorities, as follows, recognizing that they may not have universal application:

(a) Development of an appropriate data-information system;
(b) Development and implementation of education and training programmes in applications;
(c) More effective technology transfer;
(d) The promotion of the use of applications;
(e) The more effective and efficient development of new technology.

2.7 Organizational questions

The application of climatic knowledge relies on the interaction of experts with knowledge of climate and users in a wide variety of application areas. Within individual countries, we have seen that close co-operation between climatologists and users is essential for success. Similarly, co-operation between WMO and other specialized international organizations is desirable in the planning and implementation of an international applications programme.

In this light, the following ideas should be considered:

(a) At the national level: National committees to co-ordinate and stimulate the application of climatic knowledge would be useful. Such a committee might include representatives both of the government services having climatic expertise and of operational and planning sectors of the national economy, such as agriculture, water resources, energy, marine resources, etc.;

(b) Within WMO: There are many current programmes and projects within WMO that relate directly or indirectly to applications. Technical commissions and regional associations are involved in many appropriate aspects of applications of climatology to various fields of human activity. Co-ordination steps should be taken as needed to improve existing capabilities and encourage useful new efforts.

(c) Among international bodies: It is necessary to improve the co-ordination of efforts by climatologists and users at the international level and, at the same time, to facilitate the co-ordination between specific international bodies and corresponding national authorities. Among the terms of reference of international groups or committees would be: definition, planning and evaluation of co-operative international projects as appropriate; assistance to national and international programme planners in drawing upon the resources of co-operating international agencies; and co-ordination by commitment of national resources to international programmes.
2.8 Goals of the Climate Applications Programme

In many parts of the world, there is sufficient information to provide applied climate services. These are invaluable for planning social and economic development and for day-to-day management decisions. Through the application of climate information, planners and operators can reduce the vulnerability of society to climatic extremes. However, only a start has been made; data and expertise are generally lacking in developing countries while, everywhere, effective methodologies for use in climate-related problems need yet to be developed.

Although a wide variety of planning and operational activities are sensitive to climate, the most sensitive are food production, water resources, energy and the very important sector of human settlements and health. In serving each of these applications, climatologists must work with agriculturalists, engineers, etc., as well as with others within national weather services: data specialists, researchers, etc. Only cooperative efforts can make the goals of the WCP attainable.

Specific goals of the Climate Applications Programme must be to enlighten the general public and policy-makers regarding the value of applying climate knowledge to socio-economic problems and to ensure that this knowledge is available. Action plans therefore must include programmes to assist national Meteorological and Hydrological Services to (a) increase the awareness of users of the potential benefits to be gained through the use of climate information; (b) improve capabilities to provide and disseminate this information; and (c) facilitate training in nationally significant climate applications. Other action plans, on a global scale, must include programmes to develop new methodologies for the application of climate data in the food, water, energy and health sectors. Finally, programmes must be set up to assist developing countries to participate fully in the WCP through training and the transfer of appropriate methodologies.
3. THE INFLUENCE OF SOCIETY ON CLIMATE CHANGE AND VARIABILITY

3.1 Introduction

Since the birth of civilization, mankind has experienced changes of climate, but no large-scale man-induced change has ever been documented. However, with a large and growing world population and with human activities on an increasing scale, man now appears capable of inadvertently altering the climate of this planet within the next few generations to an extent comparable with major natural climatic changes. There may now be the opportunity for man to use knowledge and wise action to avert the adverse effects of such changes.

The present state of our scientific understanding of climate does not permit confident predictions regarding the nature of the changes likely to result from human activities, nor the rate at which such changes would occur. However, that understanding is sufficient for it to be suggested that certain human activities, if maintained at their current levels or pursued on an increasing scale, could lead in the decades ahead to changes in climate which would have profound effects upon mankind. There is therefore a special urgency for the establishment of an international research programme to examine the various aspects of human impacts upon climate, giving special attention to the accumulation of carbon dioxide in the atmosphere, a subject which merits immediate attention.

3.2 Human influences on climate

Human influences on climate cannot be considered in isolation, but need to be examined in the context of the natural variation and evolution of climate in the future, with all its subtle ramifications with regard to our overall human environment and to social and economic development. A great deal of research is required in order to be able to discriminate between climatic variability and changes that occur naturally and that are the result of human activities. Present estimates suggest that our climatic destiny will probably continue to be dictated mainly by natural geophysical processes at least until the end of the present century. Thereafter, however, man himself may well hold the key to developments in the global climate and to that extent may largely influence our longer-range fate with regard to climate.

The World Climate Conference has focused part of its attention on those activities of man which may influence the climate of the Earth. These influences are seen to include the emission of carbon dioxide and other infra-red absorbing gases to the atmosphere, changes in the nature of the land surface, military activities, increased concentration of aerosols, effects on the ozone layer, discharge of waste heat, and weather and climate modification.

Since no nation alone could deal with such issues, planning for climate change or action to avert the adverse effects of such events must clearly take place internationally. As an example, if the use of fossil fuel is to be curtailed, world-wide action must be taken in order to be effective. Such decisions will have to be implemented bearing in mind that some nations and regions will benefit while there may be considerable cost to others.
3.3 Categories of major human impact on climate

Man’s activities of various kinds may contribute to changes of climate. The principal climatic effects of these activities, however, are likely to differ in both the geographical scale of the effects and the period of time over which the effects may accumulate. Clarification of the temporal and spatial scales of these climate-modifying processes is urgently required.

The more important categories of human impact on climate may be identified and are briefly described in the following sections.

3.3.1 Carbon dioxide release from fossil fuel combustion and deforestation

The release of carbon dioxide (CO$_2$) to the atmosphere by man, involving carbon withdrawn from the atmosphere through photosynthesis or otherwise a relatively long time ago, is capable of resulting in an accumulation of CO$_2$ in the atmosphere. Such an accumulation has been reliably observed to occur in measurements of background CO$_2$ levels since the International Geophysical Year in 1958 (amounting to about five per cent in that interval). The climatic effects of CO$_2$ occur through its absorption of infra-red (heat) radiation, which results in a global warming of the lower atmosphere; this is commonly referred to as the “greenhouse effect”. The rise of atmospheric CO$_2$ concentration in this century has not yet been sufficient to produce measurable warming of the lower atmosphere. However, current projected trends in CO$_2$ concentration may lead to significant warming early in the next century. Indirect climatic effects on atmospheric circulation and precipitation and evaporation (hydrological cycle) are also likely.

There are many interacting mechanisms which determine climate and account for the complexity of the problem of predicting the influence of carbon dioxide and other infra-red-absorbing gases. The stability of polar ice sheets is a matter of concern. Model experiments suggest that the polar regions will probably experience greater warming than the equatorial regions, an effect that would lead to changes in the large-scale circulation of the atmosphere and ocean, with concomitant changes in precipitation and temperature patterns over most regions of the globe. A marked warming of the polar regions would clearly influence the distribution of ice and snow, giving a possibility of the Arctic ice-pack disappearing, at least in the summer months. Such a warming would also give rise to concern about the polar ice sheets, especially the West Antarctic ice sheet, which, being grounded below sea-level, may be more liable to wastage and thus contribute to a world-wide raising of the sea-level.

3.3.2 Other infra-red absorbing gases

Several other gases, also released to the atmosphere as a consequence of human activities, are similar to CO$_2$ in their radiative effects and therefore in their potential impacts on climate. Among these gases are chlorofluoromethanes (used for refrigeration agents, spray-can propellants, and other purposes), carbon tetrachloride and methylchloroform (used as industrial solvents) and other chlorine compounds that evidently possess very long residence times in the atmosphere and are observed to be accumulating. Nitrous oxide is also to be identified in the same category of long-range concern in view of the possibility of massive additions to the atmosphere over the next century through the decomposition of nitrogen compounds stemming from industrial, domestic and agricultural activities. Not enough is known about the behaviour of these and other gases, and it is possible that some processes involving them could lead to a cooling of the atmosphere.

3.3.3 Changes of land surface

In the course of time the surfaces of the continents are increasingly being altered through various activities of man. In many areas forests are being cleared for agriculture, massive water impoundments and
irrigation systems are being constructed, roads are being built, and urban areas are being expanded. Every such alteration of the land surface has the potential to influence climate on a local or regional scale. This influence arises through one or more of four main effects:

(a) Changes of surface roughness, which governs the exchange of momentum and energy of air motion between the atmosphere and the ground;
(b) Changes of surface albedo, which governs the fraction of solar radiation converted to surface heating;
(c) Changes in thermal characteristics of the ground and in heat transfer to the atmosphere; and
(d) Changes of moisture-holding capacity of the surface, causing the flow of water between the surface and the atmosphere to be redistributed in space and time.

Such influences on climate can be significant on a local level. Their importance on larger scales, however, is less clear, and this remains to be clarified through appropriate studies of climate on the regional or global scale.

3.3.4 STRATOSPHERIC CHANGES

Changes of ozone and other chemical constituents of the upper atmosphere may arise through the introduction of certain pollutants from man's activities. These changes depend on complex chains of chemical reactions capable of being altered by chlorine compounds (e.g. chlorofluoromethanes) and other materials introduced into the stratosphere by human activities. It has been estimated that the continued world-wide production of chlorofluoromethanes in the quantities produced in the decade of the 1970s might cause a gradual depletion of total atmospheric ozone, accumulating to about 15 per cent by the middle of the next century. An ozone loss, in turn, would weaken the ultra-violet screen, which could significantly affect the biosphere and human health. The effects on climate of a depletion of stratospheric ozone may be significant, but this again requires verification through climate-modelling experiments in which stratospheric chemical processes and effects are adequately represented.

3.3.5 ATMOSPHERIC PARTICLES (AEROSOLS)

Many human activities produce particulate materials (dust, smoke, etc.), or gases, such as sulphur dioxide, that are later converted to particles by hydrolization in the atmosphere. As a result of air-pollution control measures by many nations, releases to the atmosphere of large particles have decreased in recent decades. Particles smaller than one micrometre, however, are still produced (or later develop from sulphur dioxide releases), and it is these small particles that may have important effects on the passage of radiation through the atmosphere. The net effects of future changes in the populations of such particles on climate are now estimated to be quite small, except locally or regionally in areas of very high particle concentrations (i.e. urban or industrial areas, or certain agricultural regions of the world). The net influence of atmospheric particles on temperature or precipitation is difficult to assess without detailed information concerning the particles and the chemical and photochemical processes involved, and may be in the direction of either cooling or warming, and either greater or less cloudiness or precipitation. Such climatic effects are difficult to assess but, based on present information, appear to be small.

3.3.6 HEAT EMISSIONS

As the end-product of virtually all energy used by man, heat is released in substantial quantities either directly or indirectly to the atmosphere. Much of this heat is released from electric power stations and from heavy industry. The total of all heat releases to the atmosphere by man is now, and will continue
to be for a considerable time to come, very small compared with the flow of solar radiation to the Earth. However, heat releases are not now, and will not be, distributed evenly over the surface of the Earth. It is the concentration of heat emissions that have local effects and could have impacts on the regional scale. Large-scale impacts on climate are not expected to arise from this source in the foreseeable future.

3.3.7 Weather modification

In certain areas of the world efforts are made to modify the local weather for particular purposes, e.g. to induce rainfall or to suppress hail formation. If these activities were to develop more widely, it might become necessary to examine the possible effects on climate on a regional and perhaps larger scale.

3.3.8 The military aspect

Among the human activities which have an impact on the world’s climate it is necessary to include the possibility of military conflict. Global thermonuclear war, besides its catastrophic consequences for mankind, would degrade the natural environment and might cause climatic changes on a large scale.

3.4 Conclusions

Of the several forms of potential human impact on climate already identified, the impacts that may arise specifically from the accumulation of carbon dioxide in the atmosphere deserve most urgent attention of the world community of nations. This is warranted because:

(a) The long-continued reliance of society on fossil fuels as a principal energy source in the future, along with continued deforestation, is considered likely to result in massive atmospheric CO₂ increases in future decades and centuries;

(b) Our present understanding of climate processes leads us to recognize the clear possibility that these increases in CO₂ could result in significant and possibly major long-term changes of global-scale climate;

(c) Carbon dioxide added to the atmosphere by man’s activities is removed only slowly by natural processes, and the climatic consequences of increased CO₂ concentrations would therefore last for a long time.

Similar preoccupations to those expressed above also arise with regard to potential increases in other trace gases which have a greenhouse effect and which have very long residence times in the atmosphere, but which in many cases would have less profound economic consequences even if it should prove desirable to reduce their emissions to the atmosphere in the near future.

Research should be accelerated at the national and international levels on various aspects of the CO₂ problems in order to determine the effects of increasing CO₂ on global and regional climates and on the carbon cycle within the atmosphere-ocean-biosphere system, as well as the socio-economic consequences of these effects.
4. IMPACTS OF CLIMATE CHANGE AND VARIABILITY ON SOCIETY

4.1 Introduction

Many examples of the interaction between climate and human activities were described in the overview papers and in the discussions during the first week of the World Climate Conference. The impacts of climate on society were presented according to sector (energy, water resources, health, forestry, fisheries, marine resources and offshore development) and for agriculture in various regions (temperate zone, humid tropics, semi-arid tropics; China, Latin America, Africa). In addition, an attempt at an integrated analysis of the macro-economic consequences of climate changes was presented. The presentations and discussions suggested that climate may be considered both as an asset to be wisely used and as a problem to be overcome.

In a rational allocation of resources between work relating to climate and other efforts towards improving the well-being of society, reliable estimates of the socio-economic impacts of climate changes and variability are of primary importance. A proper analysis must establish both the magnitude and distribution of the benefits and the costs of climatic impact. Such an analysis is not an easy task. While some impacts are direct and obvious, others are less so; secondary or indirect impacts may sometimes produce larger effects than primary ones. A full assessment of climatic impact must trace its consequences well into the economic and social fabric of society and examine the whole complexity of linkages and feedbacks in climatic impacts on the biosphere and on human activities. In this connexion, analyses of sensitivity of climate-society interactions are among the most important tasks to be undertaken.

4.2 Climate change and variability

Fluctuations and variability have always been characteristics of climate and weather. The perception of the impact of these characteristics has intensified over the last decade. This has given rise to increased anxiety in relation to potentially adverse consequences should significant climatic changes occur (such as a steady drop in temperature or a possible marked warming, more frequent droughts and desertification, or even changes in sea-level).

Unfortunately, there is little agreement among scientists on the magnitude or timing of possible future climatic change. Much scientific work remains to be done on the collection of climatic data, the determination of future climatic changes and the forecasting of their consequences. The importance of possible trends, possible cyclical behaviour and other variations of climatic elements with time needs further investigation and research. Scientists and governments of all countries should be responsible, where necessary with international help, for an increased effort in scientific research, in informing their populations and in training specialists. Furthermore, governments will need to consider capital outlays so that the above objectives may be met and measures taken to prevent or lessen possible unfavourable consequences arising from fluctuations or changes in climate.

4.3 The interaction of climate and society

The character of the impact of climate in a given region will depend in part on the nature of the climatic fluctuation and in part on the nature of the society. Thus, for example, the occurrence of extremes
may have a sudden effect (as in floods or frosts) or a gradual effect (as in droughts or permafrost). Impacts of climatic fluctuations may be manifested in different ways depending on the environmental and socio-economic conditions in the countries or regions concerned. Interactions between climatic fluctuations, environmental conditions, socio-economic status and other infrastructural factors can cause significant differences in the vulnerability of different regions to given climatic variations.

Climatic impacts affect many aspects of human activity. These include (a) human health and capacity to work; (b) housing and settlements; (c) agriculture of all types; (d) development and management of water resources; (e) forestry resources; (f) fisheries and marine resources; (g) energy production and consumption; (h) industry and commercial activities; (i) transportation and communication; (j) public services of many kinds. All of these provide possible areas for an investigation of the interaction between human society and climatic variations.

Certain regions and States — for example, the economically less-developed regions, regions affected by armed conflicts, States with a large number of illiterate and poor members of the population, States with limited resources, States technically underdeveloped without their own specialists and unprepared for combating the distress caused by the elements — can be specially susceptible to climatic variability, resulting in conditions of economic disaster and severe suffering, especially amongst the impoverished sector of the population. However, this increased vulnerability is a complex combination of climatic and other factors.

While societies will experience climatic impacts in a range of ways, two essential categories of impact may be identified:

(a) The impacts of variable climate on basically stable or resilient sets of socio-economic factors with other elements of the environment held constant; and

(b) The impacts of specific climatic perturbations on social and economic subsystems, which may be changed irreversibly while attempts are being made to adjust to the impact.

While it is possible to determine objectively the nature of climatic variations on the basis of climatic statistics, the vulnerability of a society will depend on its own ability to respond under stress. This ability varies from country to country, and from one time to another, and it is possible to express many points of view about it.

4.4 Objectives for the Impact Study Programme

The ultimate objective of the Impact Study Programme within the World Climate Programme should be to bring to light the importance of climatic considerations in the formulation of rational policy alternatives. In areas of the world characterized by different natural environmental conditions, social structures or economic systems, and differing levels of development, there can be different interactions and responses to climatic variability. The basic studies should aim at an integration of climatic, ecological and socio-economic factors entering into complex problems of vital importance for society, such as availability of water, food, health conditions, energy resources, etc. The following objectives should be given special attention:

(a) Improvement of our knowledge of the impact of climatic variability and change in terms of the specific primary responses of natural and human systems (such as agriculture, water resources, energy, ocean resources and fisheries, transportation, human health, land use, ecology and environment, etc.);

(b) Development of our knowledge and awareness of the interactive relations between climatic variability and change and human socio-economic activities;
(c) Improvement of the *methodology employed* (e.g. case studies and models) so as to deepen the understanding and improve the simulation of the interactions among climatic, environmental and socio-economic factors;

(d) Determining the characteristics of human societies at different levels of development and in different natural environments which make them either *especially vulnerable* or *especially resilient* to climatic variability and change and which also permit them to take advantage of the opportunities posed by such changes.

### 4.5 Methods in the Impact Study Programme

The approaches and methods to be used in climatic impact analyses must be selected with a view to effectiveness, time and resource constraints, consistency, compatibility, comparability and credibility of results. They must also allow for periodic review and evaluation and take full account of the many disciplines that must be involved if the programme objectives are to be met.

Historical case studies have a special place in climatic impact studies in their own right. Lessons from the past can be used directly by decision-makers where a close analogy exists between a past situation and the present. Furthermore, just as empirical relationships are often incorporated in physical models of the atmosphere and oceans, so do case studies of the interactions of society provide parameterizations that can be used in socio-economic models by testing them against past situations, provided the information is sufficiently detailed.

When relationships are more obscure, involving many factors in complex feedback or non-linear interactions, relatively complex models integrating socio-economic factors with directly impacted activities will be needed. Such models will be useful both in research, to develop improved understanding, and in practice, to evaluate with more confidence the relative merits of different technologies, infrastructures, land use, energy policies, etc.

The interdisciplinary character of the problems underlines the usefulness of mathematical models. In particular, existing models (such as models for food production and sectoral or national economic models) should be adapted to allow the inclusion of climate variables among the inputs.

In summary, a wide range of approaches (historical case studies and examples, simpler analogue and extrapolation models, relatively complex integrated models with feedback) will be needed in the Impact Study Programme. The historical analyses will provide highly credible appreciations of potential risks and consequences. The simpler, specialized models can be used for testing alternatives. The complex models, which will still have to be developed in greater detail, will provide a multidisciplinary approach and should be the result of work by interdisciplinary teams of scientists and experts with a full knowledge of practical problems in order to identify areas of sensitivity for changes of climate of different types and magnitudes.

### 4.6 Types of study

A large number of potential study areas were proposed in the overview papers presented to the World Climate Conference and in the discussions during the conference. In considering the types of study to be undertaken, it should be noted that the proposals in the draft Plan of Action recognized studies on a global scale as well as in specific geographical areas, and studies by socio-economic sectors (agriculture,
The impacts of climate change on society (including water resources, energy, ocean resources, etc.). The validity of such a division was fully recognized. Nevertheless, another typology of studies has also been identified. Thus the types of possible study could be grouped as follows.

4.6.1 **Review and synthesis of existing knowledge**

One example of such a study would be a summary of existing knowledge of interactions between climate and society based on historical information and case studies. Another might be a survey of existing quantitative models (sectoral or national econometric models, or global system models) which take into account climatic variables.

4.6.2 **Geographic, sectoral and societal studies**

There is an urgent need for preliminary impact assessment in terms of risks and benefits of alternative courses of action, particularly in areas where climate may have major effects on human welfare. Under this heading would be included case studies and models which incorporate climatic inputs relating to agricultural activities in a number of critical regions (e.g. semi-arid areas or the humid tropics). The complex interactions between climate and water resources and between climate and energy would also come under this heading.

4.6.3 **Studies urgently needed for developing countries**

An example here is the effect of climate and climate change on human health and disease. A second example would be studies on disasters (such as floods, droughts and desertification) which have a particularly severe impact on developing countries. Of great importance for developing countries would be research on the vulnerability and resilience of various types of society to climatic variation and change. The Sahel region in Africa could serve as a case study in this type of research.

4.6.4 **Methodological studies**

One example under this heading would be the use of the results of climate model experiments to study the possible ranges of impact of the regional changes in temperature and precipitation that may occur with increasing carbon dioxide. A second area of study might be research on the inclusion of climatic inputs in sectoral, national and global econometric models. A third example is the study of the anticipated response of governments and peoples to new information regarding climatic variability and change.

It will be noted that the above identification of types of study and the illustrative examples quoted are in agreement with the view of the WMO Executive Committee as expressed in Part B of the annex to Resolution 19(EC-XXX).

4.7 **Criteria for priorities in the Impact Study Programme**

An important part of any plan of action is a set of criteria to be used in the identification and selection of problem areas which should be investigated. An initial programme should concentrate on problem areas which have more than one of the following characteristics:

(a) Capable of serving the urgent interests of developing countries or a common need of all countries;

(b) Concerned with problems of sectoral or regional importance;
(c) Related to theoretically significant and scientifically important problems (e.g., analysis of global systems or the CO₂ problem);

(d) Multidisciplinary and interdisciplinary (including the social and economic sciences).

The criteria suggested above relate to the intrinsic characteristics of each potential project. They may be used to arrive at a preliminary selection. In order to arrive at a final selection of projects with a certain order of priorities, it would be necessary to take into account additional considerations:

(a) High priority should be considered for studies which may be developed in association with other existing programmes so as to maximize the utilization of resources. There are a number of examples of climate-related programmes carried out by other international organizations: FAO agricultural programmes; programmes of the Consultative Group for International Agricultural Research; Unesco programmes such as the MAB and the IHP; the UNRISD programme on food systems; the UNEP programme on desertification; ICSU programmes (e.g., SCOPE projects on biogeochemical cycles, etc.);

(b) Some studies may be carried out by individual countries or groups of countries, either independently or with varying degrees of support from international sources. The international Impact Studies Programme should complement, not duplicate, these programmes;

(c) Selection of case studies should be made with a knowledge of the content of other internationally or nationally sponsored studies, so as to achieve a wide spectrum of cases of interest from the point of view of the objectives of the overall programme;

(d) Efforts should be made to ensure that the environment in the institutions in which the projects will be carried out is favourable to interdisciplinary research, which is a necessary condition for progress in such a complex field of investigation;

(e) Before a final selection of projects is made, there should be a feasibility study of the availability of data, research workers, resources, etc., in order to ensure that each project will give the maximum possible return for the investment in it.

4.8 Drafting and implementing the Impact Study Programme

The thirtieth session of the WMO Executive Committee invited the Secretary-General, in consultation with the chairman of the WCC Organizing Committee and other experts, to establish a small working group to "formulate a draft plan on climate impact studies for consideration and adoption by the WCC". It was considered by the working group that Part 4 (Programme of action to study impacts of climate) of the document entitled "Action plan for programme of studies on the impact of climate on mankind" submitted to the World Climate Conference by the conference chairman included useful guidance for the elaboration of an action plan on the impacts of climate on mankind. It was also noted by the working group that the above document served as a basis for the proposals on the Impact Study Programme included in the document "Proposed plan for the World Climate Programme 1980–1983" by the Secretary-General (Part III of Appendix C to Cg–VIII/Doc. 44). It is recommended that a more detailed plan of action and a scientific programme should be prepared by a group of experts of a multidisciplinary character, in cooperation with interested international governmental and non-governmental organizations, guided by the above-mentioned documents as well as by the considerations set forth in this report.

While the criteria for the selection of projects outlined above are valid for at least one decade and thus the general plan of action would be valid for at least a similar period, it is more realistic that for the period 1980–1983 only a small number of projects (less than a dozen) should be undertaken. The final selection of projects can be made by the responsible planning groups only after approval of the general
Plan of Action. The identification of potential projects and the planning and selection of these should be done by interdisciplinary groups, which should take into account the criteria mentioned. On the basis of the detailed plan of action, funding of urgent selected projects should be sought from all appropriate national and international sources.

The working group noted with appreciation that, in organizing the World Climate Conference, WMO had moved effectively to involve researchers from the many disciplines required for the assessment of the interaction between climate and society. The accomplishment of the latter task will not be easy. The working group therefore hoped that all interested international governmental and non-governmental organizations would co-operate in the follow-up to the conference and in the implementation of the Plan of Action.
5. RESEARCH ON CLIMATIC CHANGE AND VARIABILITY

5.1 Nature of the problem

5.1.1 Objectives

Our social and economic life is vulnerable to periods of climate stress. Human activity may itself influence local, regional and global climate. These are problems which the international community should address through the World Climate Research Programme (WCRP), which will attempt to determine why, how and where climate changes and variations occur, and thereby attempt prediction of their future occurrence.

The major objectives of the WCRP should be to determine:

— To what extent climate can be predicted;
— The extent of man’s influence on climate.

To achieve these objectives it is necessary:

(a) To improve our knowledge of global and regional climates, their temporal variations, and our understanding of the responsible mechanisms;
(b) To assess the evidence for significant trends in global and regional climates;
(c) To develop and improve physical-mathematical models capable of simulating, and assessing the predictability of, the climate system over a range of space and time scales;
(d) To investigate the sensitivity of climate to possible natural and man-made stimuli and to estimate the changes in climate likely to result from specific disturbing influences.

5.1.2 Climate defined

There have been a great variety of definitions distinguishing climate from weather. For the purposes of this document we adopt the following:

— Weather is associated with the complete state of the atmosphere at a particular instant in time and with the evolution of this state through the generation, growth and decay of individual disturbances.

— Climate is the synthesis of weather over the whole of a period essentially long enough to establish its statistical ensemble properties (mean values, variances, probabilities of extreme events, etc.) and is largely independent of any instantaneous state.

— Climate change defines the difference between long-term mean values of a climatic parameter or statistic, where the mean is taken over a specified interval of time, usually a number of decades.

— Climatic variability includes the extremes and differences of monthly, seasonal and annual values from the climatically expected value (temporal mean). The differences are usually termed anomalies.
5.1.3 COMPONENTS OF THE CLIMATE SYSTEM

The climate system consists of the following components:

— *The atmosphere* is the most variable part of the system. The troposphere has a characteristic response or thermal adjustment time of the order of one week while the stratosphere and higher layers of the atmosphere have quite different processes and time scales.

— *The oceans* in the upper layers interact with the overlying atmosphere or ice on time scales of months to years, while the deeper ocean has a thermal adjustment time of the order of centuries.

— *The cryosphere*, which comprises the world’s ice masses and snow deposits, includes the continental ice sheets, mountain glaciers, sea ice and surface snow cover. The changes of snow cover and the extent of sea ice show large seasonal variations while the glaciers and ice sheets respond much more slowly.

— *The land surface* is here taken to comprise the land masses of the continents, including the mountains and plains, surface rock, soil and vegetation as well as the lakes, rivers and groundwater, which are important components of the hydrological cycle. They are variable parts of the climate system at all time scales. The Earth’s surface is an important source of airborne particulates which may be of climatic significance. The soil, in turn, evolves in response to climate and vegetation.

Life on Earth is found on land (terrestrial biota), in the sea (marine biota) and in the atmosphere. The *biosphere* is the collective term for this part of our environment within which living and dead organic matter is present.

5.1.4 TIME AND SPACE SCALES

The WCRP should be primarily concerned with time scales varying from *several weeks to several decades*. However, the ensemble properties of individual weather events with characteristic time scales of less than several weeks, such as synoptic disturbances, are included. The general limitation to several decades is consistent with the availability of comprehensive data sets, the practicalities of numerical modelling and the major concern of planners and decision-makers. Some requirements such as palaeoclimatic reconstructions will undoubtedly involve larger time scales.

The WCRP should be primarily concerned with space scales varying from *regional* (of about 1000 km) to *global*. The emphasis on these larger scales is consistent with the technical limitations on climate modelling and the correlation scale of climatic anomalies. It is recognized that small-scale processes can play a significant role in climate. An understanding of these processes and the parameterization or representation of their effects in models is an important research problem.

Conversely, in the final analysis, many applications of climate information, both empirically and theoretically derived, can be used for local decision-making. It is therefore desirable to develop methods making it possible to interpret large-scale climatic information on the appropriate smaller scale.

It is recommended that climate studies, both of real data and of model simulations, should focus not only upon averages but upon the characteristics of variations about these averages, including the probabilities of the occurrence of rare or extreme events.
5.2 **Research elements**

In the following subsections we identify and discuss briefly six categories of research or effort which are necessary for the development of an effective climate research programme.

5.2.1 **Climate diagnostics**

A comprehensive quantitative description of the Earth's climate is an essential foundation for research. The simpler statistics, namely, means, variances and to some extent covariances, are fairly well known for the basic variables. However, there is a need for a more complete statistical description of the climate than is presently available. This should include the determination of the higher statistical moments which would aid the study of the responses to perturbations of the climate system.

Furthermore, the statistical description of the atmospheric climate needs to be supplemented by a corresponding one for the oceans, although here the difficulty of obtaining sufficient data will be severe.

Studies of physical processes interrelating atmospheric variables and parameters external to the atmosphere (e.g. solar input, snow/ice cover, ocean temperatures, etc.) would be essential to elucidate what part of the observed variability arises from quasi-random internal fluctuations and what part is due to variations in the external forcing.

Apart from statistical diagnostics, some synoptic/empirical studies should be pursued especially to study the tendency of the atmosphere to undergo sudden shifts in its behaviour, e.g. sudden changes in the track of cyclones, the sudden onset of blocking, etc.

5.2.2 **Climate model development**

Climate models are developed for the purpose of describing in a quantitative manner the various physical, chemical and biological processes in the climate system which collectively determine the climate.

Numerical models for the study of many aspects of the behaviour of the global atmosphere provide a well-established research tool, and undoubtedly they will play a major part in the study of climate and its sensitivity to human influences. For climate research, however, the demands on the models will in certain respects be much greater than has been the case in the past. In particular, the parameterization problems will be more wide-ranging and of greater difficulty.

The development of models is not simply a means to an end; it is a central organizing and co-ordinating process within climate research as a whole.

The modelling research community will need to employ a hierarchy of modelling approaches ranging from those of the full general-circulation models or coupled ocean/atmosphere models to simpler models which do not attempt time integration of the full three-dimensional system. The simpler models call for a higher level of parameterization, but where this can be achieved successfully they provide a means of gaining useful insight for the expenditure of smaller computing resources. Laboratory models may also have a part to play and should not be neglected.

All of the models will need the data base discussed earlier to aid their design and for validation purposes (see section 1).
5.2.3 **CLIMATOLOGICALLY SIGNIFICANT PROCESSES**

Many processes in and among the components of the climate system may influence the climate. Among these the following require special attention:

5.2.3.1 **Ocean processes**

The oceans play a key role in the global heat balance through storage and transport of heat and should be taken into account in any programme which attempts to describe or predict climate or climate variability. Consequently, the development of a climate programme should be integrated with an ocean programme which seeks to observe, understand, model and predict those processes in the ocean that play major roles in the climatic interaction of ocean and atmosphere.

Within the time scales of months to years ocean-atmosphere interactions are, for the most part, limited to the upper few hundred metres of the oceans. The most active interactions occur in the low-latitude areas where the planetary jets (e.g. Gulf Stream and Kurashio currents) originate, in the zones of unstable stratification, at the ice-edge, in regions of upwelling, and in zones of monsoon formation. For the purpose of climate prediction, it will be necessary to design a system of monitoring of the upper layers and to develop further viable techniques of observation. The observational system should be designed to make use of and provide data for combined thermohydrodynamic models of the ocean and atmosphere.

Attention should also be given to the poleward heat flux and its incorporation into global climate models, and to the transport of heat from one region of the ocean to the other, which fluctuates considerably due to open ocean eddies. Furthermore, it should be noted that the change in ocean albedo which might arise from a change in biological productivity could have a significant effect on global climate.

At the longer time-scales of tens of years to centuries, account must be taken of the abyssal circulation of the ocean and the processes leading to the sinking of water to greater depths in the polar regions. The problems involved will have to remain in the realm of research for the present due to the difficulty of observation.

A relatively complete understanding of the climate system cannot be achieved without an understanding of the influence of sea ice which will involve, for example, investigations of the extent of sea ice in the Arctic and Antarctic, of the existence of polynias, and of other phenomena which affect heat exchange. The ice problem is complex, involving ocean currents, and will be solved only by successful modelling based upon observation.

5.2.3.2 **Biogeochemical cycles**

Certain trace gases can influence the climate through their effect on radiative transfers and must therefore be considered. They include carbon dioxide, ozone, oxides of hydrogen, nitrogen and chlorine type compounds. To provide a capability of forecasting the future level of such constituents in the atmosphere as a consequence of human activities there is need for intensified research on the dynamics of biogeochemical cycles and their interaction. One requirement must clearly be to monitor the concentration of such gases present in the atmosphere, and the adequacy of existing monitoring therefore needs to be reviewed.

5.2.3.3 **Clouds and their radiation processes**

Clouds play a central role in determining the balance between the incoming short-wave and the outgoing long-wave radiation. Calculation of the complex radiative effects is in principle possible but this is...
hampered by an inadequate knowledge of the distribution of clouds and of their optical/radiative properties. For use in future climate models there will be a requirement for better empirical relations between cloudiness and the explicit model variables.

5.2.3.4 Aerosols and their various impacts

These can influence the climate through their direct effect on radiative transfers or indirectly through their effect on the formation and properties of clouds. They can be natural or man-made, e.g. industrial. We need to identify the important aerosol types and determine their climatological distribution. We need then to investigate by model experiments the relative importance of aerosol effects as compared with other physical effects.

5.2.3.5 Hydrological cycle

The hydrological cycle provides a dominant energy source for driving the motions of the atmosphere. Therefore it is necessary to study the components of this cycle, such as precipitation, evaporation, soil moisture, runoff, etc., on a global scale.

5.2.3.6 Land surface and cryosphere processes

Numerical experiments show that regional albedo and soil-moisture changes may significantly affect climate. However, although the model experiments have been revealing, the models require better treatments of albedo, evaporation, evapotranspiration, surface friction and snow/ice cover. The design of improved formulations for these land-surface effects is rendered difficult by the marked inhomogeneities on sub-grid scales.

It is understood that interaction processes between the atmosphere and the cryosphere should be taken into account when modelling the climate system. It is therefore recommended that the energy exchange between snow and ice and the atmosphere be investigated.

5.2.3.7 Sun-earth investigation

It is recommended that a quantitative evaluation be made of the influence of solar activity on climate. The role of the interaction processes in the upper and lower atmosphere in climatic variations needs to be assessed.

5.2.4 Climate predictability

Although a large part of climate variability on time scales of up to a few months is the composite effect of weather systems which are individually predictable only for a week or so, there is a reasonable expectation that some features of the variability may be predictable for much longer, e.g. the tracks of cyclones, the incidence of blocking, some aspects of the monsoon, etc. The requirement is therefore to test the capability of models to predict significant features of atmospheric variability over periods of time ranging from several weeks to decades. This should include the influence of slowly varying components of the climate system.

5.2.5 Climate sensitivity

Here we are concerned with experiments to assess the sensitivity of the climate to changes in the following conditions:
(a) Boundary conditions (solar radiation, albedo, phenomena of the ocean-atmosphere interface, vegetation, etc.):

(b) An atmospheric constituent (carbon dioxide, ozone, aerosols, chlorofluoromethanes, etc.).

Such studies will include most of those bearing on the effect of human influences on climate.

5.2.6 Long-term climatic trends

It is recommended that the long-term trends in variability of the modern climatic régime be assessed and analysed using the best available sets of data on climate of the previous century and the last millennia.

It should be stressed that paleoclimatic studies should be expanded, since they provide a basis for such assessment and for other climate-prediction research including possible scenarios. Modern geomorphological, paleogeographic biological methods should be further developed.

5.3 Data requirements for climate research

Apart from the data needed to establish the statistical diagnostics discussed in section 5.2.1, data are required for a variety of other purposes in climate research (see also section 1).

(a) Parameterization. Climate models will in general require that certain physical processes can be taken into account only in a statistical sense; the design of some of these parameterization schemes may require special observation programmes on appropriate space and time scales.

(b) Verification. The data base generated by the Global Observing System, which exists for general purposes including weather prediction, will probably suffice for the verification of the results from climate models. However, its adequacy for this purpose requires study. Furthermore, paleoclimatic reconstructions provide an important and unique validation of the ability of climate models to reproduce the very large swings of terrestrial climatic régime known to have occurred.

5.4 Scientific priorities

The following specific topics should receive high priority in the WCRP. They have been identified as scientifically tractable and of fundamental importance in climate research:

(a) Observational synthesis of the global and regional climate system (see section 5.2.1);

(b) Development of a hierarchy of models to study the dynamics and statistics of global and regional climate (see section 5.2.2);

(c) The role of the oceans in the climate system (see section 5.2.3.1);

(d) Biogeochemical cycles of radiatively important trace gases (see section 5.2.3.2);

(e) Cloud formation, distribution and radiative properties (see section 5.2.3.3);

(f) Aerosol types, optical properties and influence on clouds (see section 5.2.3.4);

(g) The hydrological cycle, evaporation and precipitation, etc. (see section 5.2.3.5);
(h) Land surface and cryosphere properties and processes and their impacts on climate (see section 5.2.3.6);

(i) Paleoclimatic reconstructions relevant to global and regional climate changes (see section 5.2.3.7).
AGREEMENT BETWEEN
THE WORLD METEOROLOGICAL ORGANIZATION
AND THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS
ON THE WORLD CLIMATE RESEARCH PROGRAMME

THE WORLD METEOROLOGICAL ORGANIZATION and THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS,

BEING MINDFUL of the Working Arrangements agreed upon by the two organizations which specify that “the two organizations, with a view to facilitating the attainment, in the most effective and economical manner, of the objectives set forth in the respective constitutions, will act in close co-operation . . .”,

RECOGNIZING the intrinsic scientific importance of understanding the physical basis for climate, the increasing vulnerability of our social and economic life to fluctuations in the annual cycle of climate and the possibility that human activity is now reaching a scale which could influence local, regional and global climate,

NOTING that, in order to take full advantage of the opportunities thus presented, the two organizations are jointly undertaking a Global Atmospheric Research Programme (GARP) under the terms and conditions specified in a formal Agreement between them signed on 10 October 1967,

CONSIDERING:

(1) That the activities undertaken under GARP have proved successful in that they have resulted in a major advance in man’s knowledge of the atmospheric processes and have provided the basis for substantial future research which will advance such knowledge still further,

(2) That GARP has shown in a striking manner that, despite the differing constitutions and procedures, the two organizations are able to work together in an effective and harmonious manner for the common good,

RECOGNIZING that the principal components of the World Climate Programme (WCP) will be:

— The Climate Data Programme (CDP)
— The Climate Applications Programme (CAP)
— The Climate Impact Study Programme (CIP)
— The Climate Change and Variability Research Programme (CRP)*

BEING MINDFUL OF:

(1) The need for the completion of activities with regard to the First GARP Objective,

* This component will be referred to below by a short title “The World Climate Research Programme” (WCRP).
AGREEMENT BETWEEN WMO AND ICSU

(2) The fact that the research activities related to the Second GARP Objective will be included in the Climate Change and Variability Research Programme of the WCP,

AGREE:

(1) That there should be only one World Climate Research Programme, and that it should be sponsored jointly by the two organizations;

(2) To invite and call upon all other appropriate national and international organizations and the world community of scientists to collaborate in this globally important task;

(3) That the WCRP should have as its long-range objectives a better understanding of climate change and variability and their causes, whether from natural or human influences;

(4) To establish a joint WMO/ICSU Scientific Committee (JSC):

(a) To provide scientific guidance in those aspects of the Climate Change and Variability Research Programme that need international co-operation for their successful conduct within the framework of the joint WMO/ICSU interests;

(b) To be regarded by both organizations as the main scientific organ for the formulation of overall scientific concepts and the co-ordination of efforts at the international level within the framework of the World Climate Research Programme, conforming to the WMO and ICSU practices and procedures;

(c) To determine the main research objectives of the Climate Change and Variability Research Programme to be jointly implemented by WMO and ICSU;

(d) To review and assess the development of all elements of this research programme, and to report to the executive bodies of both organizations on progress;

(e) To facilitate the exchange of information among scientists responsible for carrying out the research at the national and international levels;

(f) To complete the planning and studies within the framework of the First GARP Objective;

(5) To ensure that the administrative and financial arrangements provide for a large measure of flexibility to the JSC and to its supporting staff;

APPROVE:

(1) The programmatic transition from GARP to the WCRP, to take place gradually from the date of this Agreement, and the transition in membership of the JOC to the JSC, to reflect the evolving programmatic emphasis;

(2) The details and procedures to be followed in the practical application of this Agreement which are specified in the following annexes to this Agreement:

Annex A: Procedures to be followed in implementing this Agreement
Annex B: Definition of the World Climate Research Programme
Annex C: Financial arrangements
Annex D: Functions and rules of procedure for the Joint Scientific Committee (JSC) and the Joint Planning Staff (JPS)
Annex E: Initial membership of the JSC
Annex F: Initial budget for the WCRP
AGREE:

(1) That this Agreement shall be reviewed every four years by both organizations;

(2) That this Agreement may be terminated by either organization with two years' notice;

AGREE that this Agreement shall come into force on the first day of the month of January 1980, on which date the GARP Agreement shall terminate.

Signed at

on the day of

President
International Council of
Scientific Unions

President
World Meteorological Organization

*   *   *

*   *   *
ANNEX A

Procedures to be followed in implementing the Agreement

Decisions

All major decisions affecting the implementation of the World Climate Research Programme shall be taken jointly by the two organizations. Such decisions may relate to pilot projects, preliminary experiments, the main programme and other major forms of activity which might foster the common aim.

Implementation of decisions

The methods of implementing such decisions shall be agreed jointly. In some cases, implementation may be on a joint basis (e.g. joint conference); in others, one or other of the two organizations may, by mutual consent, accept sole responsibility. In the case of joint projects the procedures and methods adopted shall conform to the basic constitutions of both organizations. If the implementation requires action by another body or organization, the request will be submitted to that body by one or other of the organizations but in the name of both. All proposals from the Joint Scientific Committee should clearly indicate the method of implementation recommended.
ANNEX B

Definition of the World Climate Research Programme

Objectives

Our social and economic life is vulnerable to periods of climate stress. Human activity may itself influence local, regional and global climate. These are problems which the international community should address through the World Climate Research Programme (WCRP), which will attempt to determine why, how and where climate changes and variations occur, and thereby attempt prediction of their future occurrence.

The major objectives of the WCRP should be to determine:
- To what extent climate can be predicted;
- The extent of man's influence on climate.

To achieve these objectives it is necessary:

(a) To improve our knowledge of global and regional climates, their temporal variations, and our understanding of the responsible mechanisms;

(b) To assess the evidence for significant trends in global and regional climates;

(c) To develop and improve physical-mathematical models capable of simulating, and assessing the predictability of, the climate system over a range of space and time scales;

(d) To investigate the sensitivity of climate to possible natural and man-made stimuli and to estimate the changes in climate likely to result from specific disturbing influences.

Time and space scales

The WCRP should be primarily concerned with time scales varying from several weeks to several decades. However, the ensemble properties of individual weather events with characteristic time scales of less than several weeks, such as synoptic disturbances, are included. The general limitation to several decades is consistent with the availability of comprehensive data sets, the practicalities of numerical modelling and the major concern of planners and decision-makers. Some requirements such as paleoclimatic reconstructions will undoubtedly involve larger time scales.

The WCRP should be primarily concerned with space scales varying from regional (of about 1000 km) to global. The emphasis on these large scales is consistent with the technical limitations on climate modelling and the correlation scale of climatic anomalies. It is recognized that small-scale processes can play a significant role in climate. An understanding of these processes and the parameterization or representation of their effects is an important research problem.

Research elements

Within the WCRP the following elements are identified:
- Climate model development;
- Climate predictability.
Miscellaneous income

10. Additional contributions or grants to the JCRF from sources other than WMO or ICSU may be accepted by the Secretary-General of WMO provided that the purposes for which such contributions or grants are made are consistent with the policies, aims and activities of both WMO and ICSU. Such contributions cannot be accepted if they directly or indirectly involve expenditures additional to those specified in the approved budget as defined in paragraph 5 above.

11. Any accrued interest will be credited to the JCRF and used in accordance with the decision to be commonly agreed to by the executive bodies of WMO and ICSU.

Liquidation of the assets of the Joint Scientific Committee

12. Should either the activities of the Joint Scientific Committee or those of one of the two parties concerned, i.e. WMO or ICSU, be brought to an end, then the remaining balance of the JCRF, after the settlement of all financial commitments by the Secretary-General of WMO, will be shared between WMO and ICSU or their liquidating authorities in proportion to their respective contributions to the Fund.

Administration of the JCRF

13. The Secretary-General of WMO shall be responsible for the provision of services for the Joint Scientific Committee and its supporting staff within the cash resources available in the JCRF, and in accordance with the procedures approved by the executive bodies of both WMO and ICSU. The Secretary-General of WMO will consult the Secretary-General of ICSU on any important questions that may arise.

Travel arrangements

14. Travel and subsistence expenses authorized for payment from the Fund shall be in conformity with WMO rules and regulations. Travel shall be by tourist/economy air services. All travel costs charged to the Fund shall be in conformity with the programmes established by the JSC. Travel authorizations shall be issued by the Secretary-General of WMO.

Logistic support

15. Supplementary logistic support to the JSC and the JPS will be provided by the Secretary-General of WMO, within the resources approved for this purpose in the regular WMO budget.

Other provisions

16. These Financial Arrangements may be modified at any time by common agreement between WMO and ICSU, provided that no modification would result in conflict with the applicable WMO Financial Regulations.

17. In case of doubt as to the interpretation or application of any of the present provisions, the Secretary-General of WMO is authorized to rule thereon, subject to prior consultation with the Secretary-General of ICSU in important cases.
ANNEX D

Functions and rules of procedure for the JSC and the JPS

1. Membership and functions of the Joint Scientific Committee (JSC)

1.1 The JSC shall consist of twelve scientists selected by mutual agreement between WMO and ICSU and be appointed jointly by the executive bodies of the two organizations. The members of the JSC will be selected for their scientific knowledge, capability and breadth of vision.

1.2 It shall evolve from the present Joint WMO/ICSU Organizing Committee (JOC) in a smooth fashion during the transitional period. Every four years the executive bodies should review the membership rotation plan.

1.3 It shall guide the activities of a small full-time Joint Planning Staff (JPS).

2. Officers of the JSC

2.1 The Officers of the JSC shall consist of:
   (a) The Chairman and Vice-chairman, elected for a term of four years by the JSC;
   (b) Two members of the JSC, elected annually by the JSC.

2.2 Between the meetings of the JSC responsibility for transacting urgent business of the JSC is vested in the Officers.

2.3 The Chairman may call for a meeting of the Officers when there are urgent questions which, in his opinion, could not be handled by correspondence.

2.4 A quorum for a meeting of the Officers shall consist of three of the Officers.

2.5 The Secretaries-General of WMO and ICSU shall be informed of the decision to convene a meeting of the Officers. Both organizations may send observers to the meeting without expense to the Joint WMO/ICSU Fund.

2.6 The Director of the JPS (as defined in paragraph 7) shall at all times keep members of the JSC, as well as the Secretaries-General of ICSU and WMO, informed of any action taken as a matter of urgency by the Officers.

3. Chairman of the JSC

The duties of the Chairman of the JSC shall be:
   (a) To preside over the sessions of the JSC;
   (b) To act on behalf of the JSC between meetings of the Officers and the full committee;
(c) To co-ordinate the scientific activities of the JSC, and of other groups contributing to the WCRP;

(d) To carry out such specific duties as are prescribed by decisions taken in agreement by the executive bodies of ICSU and WMO;

(e) To issue directives to the JPS with respect to the fulfilment of its duties;

(f) To ensure that the activities, recommendations and resolutions of the JSC are in accordance with this Agreement;

(g) To arrange for the views of the JSC to be presented to the executive bodies of both organizations;

(h) To conduct, either directly or through the JPS, correspondence on matters related to the JSC;

(i) To maintain files of his official correspondence as Chairman of the JSC and to send copies of this correspondence to the JPS;

(j) To submit to the JSC, at the end of each session, a report on the session;

(k) To submit to each session of the JSC a report of the activities between sessions, including those of the Officers, working groups, special study groups, and consultants.

4. Sessions of the JSC

4.1 The JSC shall meet at least annually.

4.2 The date and place of sessions of the JSC shall be decided by the Chairman of the JSC in consultation with the Secretary-General of WMO (who is responsible for the provision of services for the sessions and the financial arrangements). Whenever an invitation is extended for holding a session, such an invitation shall be considered. However, the cost of a session held outside Geneva should not, on the average, exceed that of holding one in the WMO Secretariat. The Secretary-General of ICSU should be notified sufficiently in advance of the date, place and arrangements.

4.3 The Director of the JPS, on the authority of the Chairman of the JSC, after consultation with the Secretary-General of WMO on administrative matters, shall notify all members of the JSC of the arrangements for each session.

4.4 Notification of ordinary sessions shall be made at least 90 days before the opening meeting of the session. Notification of an extraordinary session shall be made at least 60 days before the opening of the session.

4.5 A quorum shall consist of two-thirds of the members of the JSC.

4.6 The report of each session shall be approved by the JSC before the end of the session.

4.7 The reports of the JSC sessions shall be furnished to the Secretaries-General of ICSU and WMO with copies of the documents considered by the session.

4.8 The Secretary-General of WMO shall provide such interpretation and translation facilities as may be required, within the budgetary provision. The documents will normally be distributed in the language in which they were submitted.
4.9 Public statements upon the proceedings and resolutions shall be issued only by the Chairman, or by a person authorized by him.

4.10 The rules of procedure will be established by the JSC with the approval of the executive bodies of WMO and ICSU, due regard being given to the basic procedures of both organizations.

4.11 As sponsoring bodies of the JSC, WMO and ICSU automatically have the right to send observers to all meetings but will exercise restraint as regards the number of observers in order to avoid increasing attendance unduly. One or two observers from each might be considered.

4.12 Observers from international scientific and intergovernmental organizations or individuals may be invited to attend sessions upon decision of the JSC, and in accordance with the procedures of both organizations.

4.13 The attendance of an observer will not be a charge on the Fund.

5. Working groups and special study groups

5.1 The JSC shall be authorized to select and convene working groups, special study groups, consultants, etc., within its field of responsibility, within the plans and budgets approved annually by the appropriate organ of each organization and taking into account existing technical and scientific groups in both organizations, and to use these bodies whenever appropriate. The convening of a group may be delegated by the Chairman of the JSC.

The JSC shall take full and appropriate consideration of the expressed interests of such WMO and ICSU bodies, including technical commissions and advisory bodies.

5.2 It will be assumed that the agreement by an individual to participate in a meeting implies that he has received the approval of his employing organization.

5.3 The date and place of a session of a group shall be approved by the Chairman of the JSC. The Chairman will review these decisions with the Secretary-General of WMO to avoid scheduling conflicts.

5.4 In cases of urgency and subject to the approval of the Officers, the Chairman may, between sessions, establish any working group or special study group that may be deemed useful by him and nominate its chairman.

5.5 The Chairman, after consultation with the Secretary-General of WMO in any case in which financial expenses may be involved, may invite technical experts to assist him or the JPS or, at the request of a group, to participate in the work of the group.

5.6 In the case of a recommendation made by a working group or a special study group between sessions of the JSC, either in a session or by correspondence, the Chairman of the JSC may approve the recommendation, after consultation with the Officers, when the matter is, in his opinion, urgent.

6. Consultants

6.1 The JSC may invite technical experts to serve as consultants to the Chairman, to any of the working groups or to the JPS, within approved plans and budgets.
6.2 It will be assumed that agreement by an individual to act as a consultant implies that he has received the approval of his employing organization.

6.3 When the place of duty is Geneva, WMO will provide office accommodation. If the work to be performed by the consultant requires that the place of duty be at some other location, the prior agreement of the host country, organization or institute, as appropriate, shall be obtained.

6.4 A consultant may be designated to carry out a specific research project in his own laboratory or institution, or to join another existing research group which has agreed to provide the required facilities.

6.5 When more than one consultant is required for a specific task, a special study group will be established. In such cases the provisions for working groups and study groups shall apply.

7. **The Joint Planning Staff (JPS)**

7.1 The general functions of the JPS shall be to carry out the duties allocated to the JPS in this Agreement and such other work as the JSC may decide. In particular, the JPS shall be responsible for the following work:

(a) Formulating, for approval by the JSC, in accordance with the scientific objectives established by it, and in the light of the guidance provided by the working groups, special study groups, etc., detailed plans for the World Climate Research Programme;

(b) Providing secretarial assistance for the Joint Scientific Committee;

(c) Assisting in the preparation of reports and supplying information concerning the WCRP, directed by the Joint Scientific Committee;

(d) Following up the implementation of the World Climate Research Programme and the GARP sub-programmes, submitting to the Joint Scientific Committee adequate information concerning the degree of fulfilment of the objectives, within the approved plans;

(e) Serving as the documentary and information centre of the JSC;

(f) Making technical studies as directed by the JSC;

(g) Maintaining records of the extent to which the decisions based on recommendations from the JSC are implemented;

(h) Preparing or editing, and arranging for the publication and distribution of, the approved publications of the JSC;

(i) Organizing and performing secretarial duties for the working groups or special study groups that may be established;

(j) Preparing and communicating the agenda for each session in accordance with the appropriate provisions of these regulations;

(k) Maintaining files of the correspondence of the JPS.

7.2 The JPS shall be composed of a Director and the scientific, technical and clerical staff, as may be required for the work of the JSC. They shall be staff members of the WMO. The cost of the JPS shall be met from the Joint Climate Research Fund.

7.3 For the appointment of the JPS, the JSC, having made an assessment of the scientific capability of the candidates, and having obtained the prior endorsement of ICSU, will make recommendations to the Secretary-General of WMO. The Secretary-General of WMO will then make the appointments in the normal way.
7.4 The Director of the JPS should be responsible to the Chairman of the JSC for the scientific and supporting work of the JPS, except for those aspects of the work involving financial commitments for which approval of the Secretary-General of WMO is required.

7.5 The duties of the Director shall be:

(a) To direct the work of the JPS;
(b) To conduct correspondence and maintain liaison with the Chairman and Members of the JSC;
(c) To act as the channel for communication (notification, invitations, etc.) between the JSC and both organizations;
(d) To facilitate liaison and to collaborate as necessary with the Secretaries-General of both organizations.

7.6 The office of the JPS shall be located in the WMO Secretariat. Members of the JPS may, however, have to discharge their duties, either for periods or permanently, in research institutes or organizations which provide office accommodation and are actively participating in the World Climate Research Programme.
ANNEX E

Initial membership of the JSC

This annex will become available when the membership of the JSC has been approved by WMO and ICSU.
## Initial budget for the World Climate Research Programme

**Budget of the Joint WMO/ICSU Climate Research Fund for the year 1980**

*(in thousands of US dollars)*

<table>
<thead>
<tr>
<th></th>
<th>Personnel and temporary staff</th>
<th>Meetings</th>
<th>Consultants, seconded experts</th>
<th>Travel</th>
<th>General Services</th>
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<td>Global Weather Experiment (FGGE)</td>
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<td>Regional experiments</td>
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<td>Mountain experiment (ALPEX)</td>
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<td>World Climate Research Programme</td>
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**Total** 1073

US $1 = 1.68 Sfrs.

- Contribution by WMO 873
- Contribution by ICSU 200
- **Total** 1073
THE DECLARATION OF THE WORLD CLIMATE CONFERENCE

PREAMBLE

The World Climate Conference, a conference of experts on climate and mankind, held in Geneva from 12 to 23 February 1979, was sponsored by the World Meteorological Organization in collaboration with other international bodies.

The specialists from many disciplines assembled for the Conference expressed their views concerning climatic variability and change and the implications for the world community. On the basis of their deliberations they adopted “The Declaration of the World Climate Conference”, the text of which follows.

An appeal to nations

Having regard to the all-pervading influence of climate on human society and on many fields of human activity and endeavour, the Conference finds that it is now urgently necessary for the nations of the world:

(a) To take full advantage of man’s present knowledge of climate;

(b) To take steps to improve significantly that knowledge;

(c) To foresee and to prevent potential man-made changes in climate that might be adverse to the well-being of humanity.

The problem

The global climate has varied slowly over past millennia, centuries and decades and will vary in the future. Mankind takes advantage of favourable climate, but is also vulnerable to changes and variations of climate and to the occurrence of extreme events such as droughts and floods. Food, water, energy, shelter, and health are all aspects of human life that depend critically on climate. Recent grain-harvest failures and the serious decline in some fisheries emphasize this vulnerability. Even normal variations and modest changes relative to the normal climate have a significant influence upon man’s activities.

All countries are vulnerable to climatic variations, and developing countries, especially those in arid, semi-arid, or high-rainfall regions, are particularly so. On the other hand, unfavourable impacts may be mitigated and positive benefits may be gained from use of available climate knowledge.

The climates of the countries of the world are interdependent. For this reason, and in view of the increasing demand for resources by the growing world population that strives for improved living conditions, there is an urgent need for the development of a common global strategy for a greater understanding and a rational use of climate.
Man today inadvertently modifies climate on a local scale and to a limited extent on a regional scale. There is serious concern that the continued expansion of man's activities on Earth may cause significant extended regional and even global changes of climate. This possibility adds further urgency to the need for global co-operation to explore the possible future course of global climate and to take this new understanding into account in planning for the future development of human society.

Climate and the future

Climate will continue to vary and to change on account of natural causes. The slow cooling trend in parts of the northern hemisphere during the last few decades is similar to others of natural origin in the past, and whether it will continue or not is unknown.

Research is revealing many basic features of climatic changes of the past and is providing the basis for projections of future climate. The causes of climate variations are becoming better understood, but uncertainty exists about many of them and their relative importance.

Nevertheless, we can say with some confidence that the burning of fossil fuels, deforestation and changes of land use have increased the amount of carbon dioxide in the atmosphere by about 15 per cent during the last century and it is at present increasing by about 0.4 per cent per year. It is likely that an increase will continue in the future. Carbon dioxide plays a fundamental role in determining the temperature of the Earth's atmosphere, and it appears plausible that an increased amount of carbon dioxide in the atmosphere can contribute to a gradual warming of the lower atmosphere, especially at high latitudes. Patterns of change would be likely to affect the distribution of temperature, rainfall and other meteorological parameters, but the details of the changes are still poorly understood.

It is possible that some effects on a regional and global scale may be detectable before the end of this century and become significant before the middle of the next century. This time scale is similar to that required to redirect, if necessary, the operation of many aspects of the world economy, including agriculture and the production of energy. Since changes in climate may prove to be beneficial in some parts of the world and adverse in others, significant social and technological readjustments may be required.

Increasing energy use and thus release of heat have already caused local climatic changes. In the future such heat sources from densely populated and heavily industrialized regions could possibly have some effects on climate on a larger scale. Other human activities, such as agriculture, pastoral practices, deforestation, increased use of nitrogen fertilizers and release of chlorofluoromethanes, might have climatic consequences and therefore require careful study. Also, a systematic search for still other possible effects on climate of major human efforts is needed.

Some forms of warfare have local climatic effects. World thermonuclear conflict, besides its catastrophic consequences for mankind, would degrade the natural environment and might cause climatic changes on a large scale.

It is conceivable that, in the future, man may be able to produce limited changes in climate on a large scale by deliberate intervention. It would be irresponsible to consider such actions until we have acquired the essential understanding of the mechanisms governing climate that is needed to predict the consequences. Moreover, international agreement must be reached before such projects are implemented.
Conclusions and recommendations

The World Climate Programme proposed by the World Meteorological Organization deserves the strongest support of all nations.

Its main thrusts are:

— Research into the mechanisms of climate in order to clarify the relative roles of natural and anthropogenic influences. This will require the further development of mathematical models which are the tools for simulating and assessing the predictability of the climate system. They will also be used to investigate the sensitivity of climate to possible natural and man-made stimuli such as the release of carbon dioxide and to estimate the climatic response.

— Improving the acquisition and availability of climatic data. The success of the climate programme depends on the development of a vast amount of meteorological, hydrological, oceanographic and other pertinent geophysical data. Furthermore, climatic impact studies and practical application of knowledge of climate by nations require in addition detailed information about their natural resources and socio-economic structures.

— Application of knowledge of climate in planning, development and management. This effort should include programmes to assist national Meteorological and Hydrological Services to increase the awareness of users of the potential benefits to be gained through the use of climate information, to improve capabilities to provide and disseminate this information, and to facilitate training in nationally significant climate applications. It should include programmes to develop new methodologies for the application of climate data in the food, water, energy and health sectors.

— Study of the impacts of climatic variability and change on human activities and the translation of the findings of such studies in terms of greatest use to governments and the people. This will require improvement in our understanding of the relationships between climate and human society including:

   (a) The possible range of societal adjustments to climate variations and change;
   (b) The characteristics of human societies at different stages of development and in different environments that make them especially vulnerable or resilient in the face of climate variability and change;
   (c) The means by which human societies can protect against adverse consequences of, and take advantage of the opportunities presented by, climate variations and changes.

The overall purposes of the programme are thus to provide the means to foresee possible future changes of climate and to aid nations in the application of climatic data and knowledge to the planning and management of all aspects of man’s activities. This will require an interdisciplinary effort of unprecedented scope at the national and international levels.

The conduct of the World Climate Programme involves a broad range of activities and requires leadership and co-ordination among international bodies and close collaboration among nations. It is fully recognized that the international co-operation which is the prerequisite for the World Climate Programme can be successfully pursued only under conditions of peace.

There is an immediate need for nations to utilize existing knowledge of climate and climatic variations in the planning for social and economic development. In some parts of the world, there is already sufficient information to provide many applied climate services. However, only a start has been
made; data and expertise are generally lacking in developing countries. Programmes must be set up to assist them to participate fully in the World Climate Programme through training and the transfer of appropriate methodologies.

The long-term survival of mankind depends on achieving a harmony between society and nature. The climate is but one characteristic of our natural environment that needs to be wisely utilized. All elements of the environment interact, both locally and remotely. Degradation of the environment in any national or geographical area must be a major concern of society because it may influence climate elsewhere. The nations of the world must work together to preserve the fertility of the soils; to avoid misuse of the world’s water resources, forests and rangelands; to arrest desertification; and to lessen pollution of the atmosphere and the oceans. These actions by nations will require great determination and adequate material resources, and they will be meaningful only in a world at peace.