

WORLD METEOROLOGICAL ORGANIZATION

PROCEEDINGS  
OF THE  
**WORLD CLIMATE  
CONFERENCE**

A CONFERENCE OF EXPERTS ON CLIMATE AND MANKIND



GENEVA, 12-23 FEBRUARY 1979

WMO — No. 537



Secretariat of the World Meteorological Organization — Geneva — Switzerland



56.45  
W957

WORLD METEOROLOGICAL ORGANIZATION

PROCEEDINGS  
OF THE  
**WORLD CLIMATE  
CONFERENCE**

A CONFERENCE OF EXPERTS ON CLIMATE AND MANKIND

GENEVA, 12-23 FEBRUARY 1979

WMO — No. 537

Secretariat of the World Meteorological Organization — Geneva — Switzerland

© 1979, World Meteorological Organization

ISBN 92 - 63 - 10537 - 5

NOTE

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

## FOREWORD

The Executive Committee of the World Meteorological Organization at its twenty-ninth session (May-June, 1977) decided that the Organization should convene a scientific and technical World Climate Conference to be held in February, 1979, in Geneva. The main purposes of this Conference were to be:

- (a) To review knowledge of climatic change and variability, due both to natural and anthropogenic causes; and
- (b) To assess possible future climatic changes and variability and their implications for human activities.

An Organizing Committee was formed comprising representatives from a number of international bodies and scientists in their individual capacities. Dr. Robert M. White was elected chairman. The Committee agreed that, in order to meet its objectives, the Conference should consist of two phases each lasting one week and the arrangements proceeded on this basis.

During the first week (12-16 February 1979) a number of invited speakers presented comprehensive and authoritative Overview Papers covering current knowledge of climate and the interactions between climate variability and change and human society. These were discussed at length by an assembly of some 350 participants from all parts of the world.

In the second week (18-23 February 1979) more than 120 invited experts representing many disciplines and regions of the globe drew upon the information presented in the first week and their own knowledge to assess the present understanding of climate and its interactions with mankind, and to formulate general recommendations for international action.

The deliberations of the second week of the Conference were largely organized to follow the structure of the emerging World Climate Programme which was to be submitted to the Eighth WMO Congress (May-June, 1979). The World Climate Programme as then planned and subsequently approved by Congress, consists of four closely related components:

- Climate Data;
- Applications of Knowledge of Climate;
- Study of the Impacts of Climate on Human Activities;
- Research on Climate Change and Variability.

The Conference noted that there was an additional issue of special importance that pervades all the above-mentioned components: The problem of possible human influences on climate. The invited experts who took part in the second week were therefore organized into working groups dealing with the four components of the World Climate Programme and the problem of human influences on climate.

A very important outcome of the Conference was the adoption of "The Declaration of the World Climate Conference" which has already been given wide distribution by WMO. The results of the work of the above-mentioned groups were drawn up in the form of Supporting Documents to the Declaration of the Conference and may be considered a summary of the views of the Conference as a whole.

This present volume is entitled "Proceedings of the Conference". It contains:

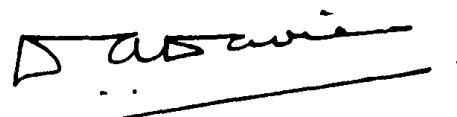
- (a) The complete texts of the overview papers presented;
- (b) The summary of discussions which took place during the first week;
- (c) The text of "The Declaration of the World Climate Conference";
- (d) The Supporting Documents to the Declaration of the World Climate Conference.

I wish to take this opportunity of expressing the gratitude of WMO to the many persons and organizations who made this publication possible. The Organizing Committee under the brilliant chairmanship of Dr. White played an outstanding role in all phases of the project while the authors of the overview papers are also to be thanked and congratulated on their outstanding contributions. Indeed all participants at the Conference, in their respective ways, contributed to its undoubted success.

As already mentioned above the Conference was a joint effort by WMO and other United Nations Agencies such as the United Nations Environment Programme (UNEP), the Food and Agriculture Organization (FAO), the United Nations Educational, Scientific and Cultural Organization (Unesco), and the World Health Organization (WHO). Special mention should be made of the assistance provided by the International Institute for Applied Systems Analysis in hosting the preliminary review session of the Overview Speakers at its Headquarters in Laxenburg in April 1978. The co-operation of these organizations contributed a great deal to the success of the Conference.

This publication may safely be considered as the most profound and comprehensive review of climate and of climate in relation to mankind yet published. As a major input into the deliberations of the Eighth WMO Congress, the Conference has already contributed greatly to the World Climate Programme now approved for implementation. In a wider context it is believed that the Conference has contributed greatly to a better understanding of the overall problems of climate and to finding solutions to these problems.

The publication of the Proceedings of the Conference in this present form will ensure a very wide dissemination of the knowledge, views and judgments it contains and will thereby facilitate a full discussion of many issues of great importance to the future of our world society.

A handwritten signature in dark ink, appearing to read 'D.A. Davies', written over a horizontal line.

D.A. Davies  
Secretary-General

## PREFACE

The World Climate Conference was convened during the period 12-23 February 1979 at the request of the Executive Committee of the World Meteorological Organization. Scientists and other specialists from fifty different countries representing many scientific and other disciplines attended the Conference to assess the present state of knowledge about climate and to examine the nature of the impact of climate upon society. A list of the participants in the Conference is presented in Appendix B to this report. Those whose names have asterisks represent the invited experts who also participated during the second week of the Conference.

The Declaration of the Conference appearing in these Proceedings was prepared and unanimously adopted during the second week of the Conference. This Declaration was based upon the Supporting Documents prepared by working groups of invited experts, and these are also reproduced in this volume.

The assessment of our present state of knowledge about climate is represented by the Overview Papers which comprise the main body of these Proceedings. They describe the present status of our scientific knowledge of climate and its variability, as well as of the impacts of climate upon society. The presentation of the Overview Papers was accompanied by extended discussions among the participants and the Overview Speakers. A summary of the highlights of these discussions is presented at the end of the overview section.

The programme of the Conference is presented in Appendix A and identifies the Overview Speakers, the titles of their papers, and the Chairmen and Co-chairmen of the various sessions and working groups. I wish to extend special appreciation to Dr. Robert W. Kates who, at the request of the Bureau of the Organizing Committee, prepared a paper at very short notice which provides a framework for some interdisciplinary approaches to many different problems of climate.

The Overview Papers, the Declaration, the Supporting Documents, and the Session Summaries were prepared and edited through the efforts of many people in addition to the authors. Dr. F. Kenneth Hare, Director of the Institute for Environmental Studies of the University of Toronto, Canada, acted as the principal editor of the Overview Papers in collaboration with Mr. Patrick J. Meade, British Meteorological Office (retired), and Dr. William W. Kellogg, consultant to the Secretary-General of the World Meteorological Organization. Assisting in the preparation of the documentation for the Conference were Dr. T.E. Munn of the Institute for Environmental Studies of the University of Toronto, Canada; Dr. Ilya Polyak, Main Geophysical Observatory, Leningrad, USSR; Dr. John S. Perry and Mr. Jesse Ausubel, U.S. National Academy of Sciences; and Dr. Victor Boldirev, State Committee for Hydrometeorology and Control of Natural Environment, USSR.

The preparation of these Proceedings of the World Climate Conference could not have been possible without the outstanding support of the Secretary-General and members of the staff of WMO. Special note must be taken of the assistance rendered by Dr. H.A. Taba, Director of the Office of Programme Planning and U.N. Affairs, and Mrs. J. Stickings, Administrative Assistant.

Robert M. White  
Chairman  
World Climate Conference.



## CONTENTS

	<u>Page</u>
Foreword .....	VII
Preface .....	XI

### Keynote Address

Climate at the Millennium .....	1
Robert M. White, Conference Chairman, U.S. National Academy of Sciences, Washington, D.C., U.S.A.	

### Overview Papers

#### Climate and Public Policy

Climatic Change and Human Strategy .....	15
E.K. Fedorov, U.S.S.R. State Committee for Hydrometeorology and Control of Natural Environment, Moscow, U.S.S.R.	

#### The Global System that Determines Climate

Global Ecology and Man .....	27
Bert Bolin, Department of Meteorology, University of Stockholm, Sweden	

Climatic Variation and Variability: Empirical Evidence from Meteorological and Other Sources .....	51
F. Kenneth Hare, Institute for Environmental Studies, University of Toronto, Canada	

Climates of Past Geological Epochs .....	88
I.P. Gerasimov, U.S.S.R. State Committee for Hydrometeorology and Control of Natural Environment, Moscow, U.S.S.R.	

The Physical Basis of Climate .....	112
W. Lawrence Gates, Oregon State University, Corvallis, Oregon, U.S.A.	

Modelling of Climatic Changes and the Problem of Long-Range Weather Forecasting .....	132
G.I. Marchuk, Central Computing Centre, Siberian Academy of Sciences, Novosibirsk, U.S.S.R.	

	<u>Page</u>
Climate Monitoring and Climatic Data Collection Services for Determining Climatic Changes and Variations: Monitoring Data Relevant to Climate .....	154
Ju. A. Izrael, U.S.S.R. State Committee for Hydrometeorology and Control of Natural Environment, Moscow, U.S.S.R.	
<u>Influences of Mankind on the Climate System</u>	
Human Activities that Affect Climate .....	170
R.E. Munn, Institute for Environmental Studies, University of Toronto, Canada	
L. Machta, Air Resources Laboratories, National Oceanic and Atmospheric Administration, Washington, D.C., U.S.A.	
Some Results of Climate Experiments with Numerical Models .....	210
B. J. Mason, Meteorological Office, Bracknell, U.K.	
A Scenario of Possible Future Climates - Natural and Man-Made .....	243
H. Flohn, Meteorological Institute, University of Bonn, Federal Republic of Germany	
Energy and Climate: A Review with Emphasis on Global Interactions .....	2
J. Williams, International Institute for Applied Systems Analysis, Laxenburg, Austria	
W. Häfele, International Institute for Applied Systems Analysis, Laxenburg, Austria	
W. Sassin, International Institute for Applied Systems Analysis, Laxenburg, Austria	
<u>Impacts of Climate on Mankind</u>	
<u>Water Resources</u>	
Climate Variability and the Design and Operation of Water Resource Systems ...	290
John C. Schaake, Jr., Hydrologic Services Division, National Weather Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, U.S.A.	
Zdzislaw Kaczmarek, Institute of Meteorology and Water Management, Warsaw, Poland	
<u>Human Health</u>	
Climate, Health and Disease .....	313
Wolf H. Weihe, Biological Central Laboratory, University Hospital, Zurich, Switzerland	
<u>Agriculture</u>	
Global Aspects of Food Production .....	369
M.S. Swaminathan, Indian Council of Agricultural Research, New Delhi, India	

	<u>Page</u>
Climatic Variability and Agriculture in the Temperate Regions .....	406
James D. McQuigg, Consulting Climatologist, Columbia, Missouri, U.S.A.	
Climatic Variability and Agriculture in Tropical Moist Regions .....	426
Hayao Fukui, Centre for Southeast Asian Studies, Kyoto University, Japan	
Climatic Variability and Agriculture in the Semi-Arid Tropics .....	475
Francesco Mattei, National Research Council and Central Office of Agricultural Ecology, Rome, Italy	
Study on the Climatic Change and Exploitation of Climatic Resources in China .....	510
Chang Chia-cheng, Academy of Meteorological Science, Central Meteorological Service, Peking, China	
Wang Shao-wu, Peking University, China	
Cheng Szu-chung, Geographical Institute, Academia Sinica, Peking, China	
Renewable Resources and Agriculture in Latin America in Relation to the Stability of Climate .....	525
Juan J. Burgos, University of Buenos Aires and National Council of Scientific and Technical Research, Argentina	
 <u>Land Use</u>	
Climatic Variability and Land Use: An African Perspective .....	552
Julius A. Oguntinyinbo, Department of Geography, University of Ibadan, Nigeria	
Richard S. Odingo, Department of Geography, University of Nairobi, Kenya	
 <u>Forestry</u>	
Climatic Variability and Forestry .....	581
A. Baumgartner, Department of Bioclimatology and Applied Meteorology, University of Munich, Federal Republic of Germany	
 <u>Fisheries and Offshore Development</u>	
Climate Variation and Marine Fisheries .....	608
D. H. Cushing, Fisheries Laboratory, Ministry of Agriculture, Fisheries and Food, Lowestoft, Suffolk, U.K.	
The Effects of Climatic Change on Inland Fisheries (Appendix to previous paper) .....	628
R.L. Welcomme, United Nations Food and Agriculture Organization, Rome, Italy	
Climatic Variability, Marine Resources and Offshore Development .....	633
T. F. Gaskell, Oil Industry International Exploration and Production Forum, London, U.K.	

	<u>Page</u>
<u>World Economy</u>	
Climate and Economic Activity ..... Ralph C. d'Arge, University of Wyoming, Laramie, Wyoming, U.S.A.	652
Climate and Society: Lessons from Recent Events ..... Robert W. Kates, Graduate School of Geography, Clark University, Worcester, Massachusetts, U.S.A.	682
Report on discussions held during the first week of the Conference .....	693
<u>Declaration and Supporting Documents</u>	
The Declaration of the World Climate Conference .....	709
Climate Data .....	719
Applications of the Knowledge of Climate .....	727
The Influence of Society on Climate Change and Variability .....	739
Impacts of Climate Change and Variability on Society .....	744
Research on Climatic Change and Variability .....	751
<u>Appendices</u>	
A. Programme of the World Climate Conference (WCC) .....	759
B. List of Participants .....	765

---

CLIMATE AT THE MILLENNIUM

by  
Robert M. White\*

Chairman  
World Climate Conference

Keynote Address

---

\* U.S. National Academy of Sciences, Washington, D.C., U.S.A.





Mr. President, Mr. Secretary-General, distinguished participants: The World Climate Conference has been convened to assess the state of man's knowledge of climate and to consider the effects of climate variability and change on human society. The issues we will address during the next two weeks are as old as mankind and as new as our interdependent social and economic systems. During this Conference we will hear how climate has shaped our past, moulds our society today, and may affect our future. We can learn from the past, endure the present, but the future is in our hands. We can contribute to a bright future for mankind by national and international actions to provide for the wise use of climatic resources to improve the economic and environmental welfare of people everywhere and to mitigate destructive impacts of climate. This conference can be the beginning of that process.

One may ask, "Why a World Climate Conference now?" The timing of our meeting is a response to several concerns. The first is the worldwide reaction to the climatic events that have so disrupted human society over the past decade. The second arises from a growing appreciation that not only is humanity vulnerable to variations in climate, but climate is also vulnerable to the acts of humanity. The third is a perception of a broader climatic vulnerability stemming from world population growth, increased world demand for food, energy, and other resources, increased interdependence of nations, and the pace of economic development. It is a vulnerability that can only increase because the underlying causes will intensify, not diminish.

The disastrous consequences of climatic events of the past decade are well known. No part of the world has been immune. During the late sixties and early seventies the southern border regions of the Sahara desert, the Sahel, succumbed to a five-year drought with famine and death on a continental scale. The year 1972 saw a worldwide epidemic of costly climatic episodes, including drought in the Soviet Union and the occurrence of El Niño off Peru. In 1974, poor monsoons reduced food production in India. In 1975, cold waves in Brazil badly damaged coffee crops. In 1976, drought in Europe caused widespread economic dislocation. In the United States, the recent cold winters forced many industries and schools to close.

These events have demonstrated the sensitivity of human welfare and international relations to climatic events. They have demonstrated the fragility of world food production and trade systems and the extent to which income and employment continue to depend on the workings of the natural world. The remarkable aspect of these climatic fluctuations is that they are not unusual. Similar events have occurred frequently in the historical record. What is new, is the realization that vulnerability of human society to climatic events has not disappeared with technological development.

Moreover, we cannot allow shorter period fluctuations of climate to lull us into complacency. We have been blessed by a benign climate in most of the world during the past several years, save for parts of the Sahel in the past year. As a result there has been a lessening of attention in the public press and among governmental officials in their concerns about climate.

To connect human suffering exclusively to natural events is utterly mistaken because the vulnerability or resilience of a society to climate obviously depends on many factors. To illustrate, it is interesting to observe that during the decade of the seventies the world grain trade went through one full cycle of surplus to shortage and back to surplus. In the early 1970's, there were large world grain reserves. During the period 1972 - 1974 world food production on a per-capita basis suffered its sharpest decline in twenty years. Crop failures due to climatic stress occurred in many parts of the world. We then reached a stage in which the stocks of grain, on a worldwide basis, had been reduced from a normal 20 per cent of world consumption to about 10 per cent. But, by 1977 and 1978, global grain harvests were setting records. With such fluctuations in the world food grain picture, it is easy for decision-makers to forget the disaster of yesterday and remember only the good times of today. As climate specialists, we know better.

If natural climate disasters had not been enough to motivate governments and the scientific community to action, the ominous possibilities for man-induced climatic changes would have triggered our presence here. Until the beginning of the industrial age some 100 years ago, variations in climate and their associated impacts could be considered as natural events beyond the control of man. In recent years, we have come to appreciate that the activities of humanity can and do affect climate. We now change the radiative processes of the atmosphere and perhaps its circulation by emission of the products of our industrial and agricultural society. We now change the boundary processes between earth and atmosphere by our use of the land.

We are only dimly beginning to understand some of the potential consequences of human impacts on the climatic resources of the world. However, it is difficult to remain complacent. The potential consequences of increasing atmospheric carbon dioxide resulting from fossil fuel combustion are already a major world concern. But evidence continues to accumulate that the growth of human habitations and the consequent destruction of forests reduces the terrestrial reservoir of carbon and further increases airborne carbon dioxide. Recent findings that other gases reinforce and amplify the effects of carbon dioxide further intensify this concern. It is hard to be complacent when we know that the population of the world will need increasingly to turn to nitrogen fertilizers to maintain agricultural production with the potential for releasing nitrogen compounds which can alter the photochemical balance of the stratospheric ozone. The potential effect on stratospheric ozone of the oxides of nitrogen released in supersonic flight, and of chlorofluoromethanes (CFMs) used as refrigerants or propellants also raise the issue of human impact upon climate.

Moreover, it is the future course of these trends that must be a central concern of this Conference. In little more than twenty years, we will celebrate the year 2000. This millennium may very well represent the ending of one era in the relation of humanity to the planet and the beginning of another. The millennium may mark a fundamental change in the ability of the planet to sustain its people or at least in the ways in which this will be done. There are many who will disagree with the timing of this fundamental change but few who will disagree with its likelihood. By any criteria, whether relating to population, food, energy, or the state of the global environment, we are likely to pass to a new world condition around the year 2000. This transition will also signal a new level of importance of climate to society.

Let us look at what the millennium holds. Conservative projections indicate that the population of the world, which in 1970 was approximately 3.5 billion, will increase to approximately 6.5 billion by the year 2000. Projections made by the United Nation's Food and Agriculture Organization indicate that, as a result, world aggregate food demand will rise by about 44 per cent by 1985 and 112 per cent by the year 2000 - a doubling by the millennium. The challenge facing the world to increase its food production by this amount is staggering. Some surveys of additional land and water potential for agricultural expansion indicate that the developing areas of the world (except in Asia) possess abundant underused land and water resources with great agricultural potential. This view is not universally accepted, however. While it will be costly to bring these virgin land and water resources into production, it can be done if the best in technology and science is brought to bear.

Beyond the year 2000, the world will face a different food situation. We will need to move beyond bringing virgin lands into agricultural production. Agricultural scientists will have to look to new strains of crops, crops that can be grown in brackish or salt water, multiple cropping, and other new approaches to meet the situation. However, projections of world food demand and supply indicate a continuing and growing imbalance. In the next twenty years, climatic information and services derived from strengthened climate data bases in the developing world will be particularly critical to assure the necessary agricultural productivity. Eventually, perhaps by the year 2000, it will become necessary to advise on how agricultural lands of the entire globe and their characteristic climates can be used in an optimum fashion to maximize the world production of food and fibre. We must therefore begin to think of climate itself as a resource to be allocated wisely.

By the millennium, the world energy situation will be no less ominous. Estimates are that by the year 2000 the desire of the world for oil will have far surpassed world oil production, even with a 50 per cent increase in oil prices. In seeking to meet our energy needs we may pose a threat to global climate with formidable consequences for world society. In the next twenty years, we will see both the introduction of new sources of energy and a growing dependence on coal and nuclear power.

The growing dependence of the world on coal may create the most serious threat to the world's climate. By the addition of carbon dioxide to the atmosphere, we change its fundamental temperature controls. It is estimated that the burning of fossil fuels and destruction of forests - also, incidentally, a source of fuel - have already, in the short span of one half century, increased atmospheric carbon dioxide content over 10 per cent. The implications of further projected increases are uncertain, but the weight of scientific evidence predicts a significant global surface temperature increase. Other energy sources also have important climatic implications. The increasing use of renewable forms of energy derived from the sun, the wind, and the ocean will call for a new level of climatic services and present a new set of challenges to climate science.

As with food, we will need credible projections of consequences by the millennium, if energy policies are to be modified in time to avoid adverse climatic impacts. The implications of the world food and energy outlooks for our science are