

CLIMATE CHANGE 2001: IMPACTS, ADAPTATION, AND VULNERABILITY

Climate Change 2001: Impacts, Adaptation, and Vulnerability is the most comprehensive and up-to-date scientific assessment of the consequences of, and adaptation responses to, climate change. The report:

- Evaluates evidence that recent observed changes in climate have already affected a variety of physical and biological systems.
- Makes a detailed study of the vulnerabilities of human populations to future climate change, including associated sea-level rise and changes in the frequency and intensity of climate extremes such as floods, droughts, heat waves and windstorms, and taking into account potential impacts on water resources, agriculture and food security, human health, coastal and other types of settlements, and economic activities.
- Assesses the potential responses of natural environments and the wildlife that inhabit them to future climate change and identifies environments at particular risk.
- Considers how adaptation to climate change might lessen adverse impacts or enhance beneficial impacts.
- Provides an overview of the vulnerabilities and adaptation possibilities by major region of the world (Africa, Asia, Australia/New Zealand, Europe, Latin America, North America, Polar Regions, and Small Island States).
- Contrasts the different vulnerabilities of the developed and developing parts of the world and explores the implications for sustainable development and equity concerns.

This latest assessment of the IPCC will again form the standard scientific reference for all those concerned with the environmental and social consequences of climate change, including students and researchers in ecology, biology, hydrology, environmental science, economics, social science, natural resource management, public health, food security, and natural hazards, and policymakers and managers in governmental, industry, and other organizations responsible for resources likely to be affected by climate change.

James J. McCarthy is Co-Chair of IPCC Working Group II, and the Alexander Agassiz Professor of Biological Oceanography and Director of the Museum of Comparative Zoology at Harvard University.

Osvaldo F. Canziani is Co-Chair of IPCC Working Group II, and Professor of Applied Meteorology of the National Universities of La Plata and Comahue, Argentina.

Neil A. Leary is the Head of the IPCC Working Group II Technical Support Unit, Washington DC, USA.

David J. Dokken is a Senior Technical Editor for the IPCC Working Group II Technical Support Unit, Washington DC, USA.

Kasey S. White is a Program Specialist for the IPCC Working Group II Technical Support Unit, Washington DC, USA.

Climate Change 2001: Impacts, Adaptation, and Vulnerability

Edited by

James J. McCarthy

*Museum of Comparative Zoology
Harvard University*

Oswaldo F. Canziani

*National Universities
of La Plata and Comahue*

Neil A. Leary

*IPCC Working Group II
Technical Support Unit*

David J. Dokken

*University Corporation
for Atmospheric Research*

Kasey S. White

*IPCC Working Group II
Technical Support Unit*

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Earth's city lights—shown for a projection spanning Europe, Asia, and Africa—is one indicator of the scale of human influence on the world. The brightest areas of the Earth are the most urbanized, but not necessarily the most populated. Image by Robert Simmon and Craig Mayhew, Science Systems and Applications, Inc.; data courtesy of the United States Air Force Defense Meteorological Satellite Program (DMSP) and the National Oceanic and Atmospheric Administration's National Geophysical Data Center, based on research performed by Dr. Marc Imhoff of the National Aeronautics and Space Administration's Goddard Space Flight Center.

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Foreword

The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988. Its terms of reference includes: (i) to assess available scientific and socioeconomic information on climate change and its impacts and on the options for mitigating climate change and adapting to it, and (ii) to provide, on request, scientific/technical/socioeconomic advice to the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). From 1990, the IPCC has produced a series of Assessment Reports, Special Reports, Technical Papers, methodologies, and other products that have become standard works of reference, widely used by policymakers, scientists, and other experts.

This volume, which forms part of the Third Assessment Report (TAR), has been produced by Working Group II (WGII) of the IPCC and focuses on the environmental, social, and economic consequences of climate change and potential adaptation responses. It consists of 19 chapters covering the sensitivity, adaptive capacity, and vulnerability of natural and human systems to climate change, and the potential impacts and adaptation options at regional and global scales.

As is usual in the IPCC, success in producing this report has depended first and foremost on the knowledge, enthusiasm, and cooperation of many hundreds of experts worldwide, in many related but different disciplines. We would like to express

our gratitude to all the Coordinating Lead Authors, Lead Authors, Contributing Authors, Review Editors, and Expert Reviewers. These individuals have devoted enormous time and effort to produce this report and we are extremely grateful for their commitment to the IPCC process. We would like to thank the staff of the WGII Technical Support Unit and the IPCC Secretariat for their dedication in coordinating the production of another successful IPCC report.

We are also grateful to the governments that have supported their scientists' participation in the IPCC process and that have contributed to the IPCC Trust Fund to provide for the essential participation of experts from developing countries and countries with economies in transition. We would like to express our appreciation to the governments of Australia, Japan, Malta, Morocco, Peru, Portugal, South Africa, Switzerland, and the United States that hosted drafting sessions in their countries, to the government of Switzerland that hosted the Sixth Session of Working Group II in Geneva, and to the government of the United States that funded the WGII Technical Support Unit.

We would particularly like to thank Dr. Robert Watson, Chairman of the IPCC, for his sound direction and tireless and able guidance of the IPCC, and Prof. James McCarthy and Dr. Osvaldo Canziani, the Co-Chairmen of Working Group II, for their skillful leadership of Working Group II through the production of this report.

G.O.P. Obasi

Secretary-General
World Meteorological Organization

K. Töpfer

Executive Director
United Nations Environment Programme
and
Director-General
United Nations Office in Nairobi

Preface

This volume, *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, is the Working Group II (WGII) contribution to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC). The companion volumes of the TAR are *Climate Change 2001: the Scientific Basis* (WGI) and *Climate Change 2001: Mitigation* (WGIII). A fourth volume of the TAR is being prepared to provide a synthesis of the findings of the three Working Groups and will focus on questions addressing particular policy issues raised in the context of the Framework Convention on Climate Change.

Since the inception of the IPCC, its Working Group II has focused on the impacts of projected climate change. The current WGII report differs somewhat in scope from earlier WGII assessments. This report examines climate change impacts, adaptation, and vulnerability across a range of systems and sectors, as was done in the Second Assessment Report (SAR, published in 1996), and includes a regional assessment, updated from the *Special Report on Regional Impacts of Climate Change* (1998). Environmental, social, and economic dimensions of these issues are assessed in this report, whereas the previous WGII report focused primarily on environmental dimensions. Efforts are made in the new assessment to address a number of issues that cut across the various sectors and systems covered by the WGII report, as well as across the three Working Groups of IPCC, such as sustainable development, equity, scientific uncertainties, costing methodologies, and decisionmaking frameworks. Mitigation of climate change, treated in previous WGII reports, is now the subject of WGIII's contribution to the TAR.

Research on climate impacts has grown considerably since the SAR, and much has been learned in the past 5 years regarding the potential risk of damage associated with projected climate change. The research has added to what we know about the vulnerabilities to climate change of a wide range of ecological systems (forests, grasslands, wetlands, rivers, lakes, and marine environments) and human systems (agriculture, water resources, coastal resources, human health, financial institutions, and human settlements).

Observational evidence of changes has accumulated in many physical and biological systems (e.g., glacial melting, shifts in geographic ranges of plant and animal species, and changes in plant and animal biology) that are highly consistent with warming observed in recent decades. These observations are adding to our knowledge of the sensitivity of affected systems to changes in climate and can help us to understand the vulnerability of systems to the greater and more rapid climate changes projected for the 21st century. A number of unique systems are increasingly recognized as especially vulnerable to

climate change (e.g., glaciers, coral reefs and atolls, mangroves, boreal and tropical forests, polar and alpine ecosystems, prairie wetlands, and remnant native grasslands). In addition, climate change is expected to threaten some species with greater probability of extinction. Potential changes in the frequency, intensity, and persistence of climate extremes (e.g. heat waves, heavy precipitation, and drought) and in climate variability [e.g., El Niño Southern Oscillation (ENSO)] are emerging as key determinants of future impacts and vulnerability. The many interactions of climate change with other stresses on the environment and human populations, as well as linkages between climate change and sustainable development, are increasingly emphasized in recent research and preliminary insights from these important efforts are reflected in the report.

The value of adaptation measures to diminish the risk of damage from future climate change, and from present climate variability, was recognized in previous assessments and is confirmed and expanded upon in the new assessment. Understanding of the determinants of adaptive capacity has advanced and confirms the conclusion that developing countries, particularly the least developed countries, have lesser capacity to adapt than do developed countries. This condition contributes to relatively high vulnerability to damaging effects of climate change in these countries.

The WGII report was compiled by 183 Lead Authors between July 1998 and February 2001. In addition, 243 Contributing Authors submitted draft text and information to the Lead Author teams. Drafts of the report were circulated twice for review, first to experts and a second time to both experts and governments. Comments received from 440 reviewers were carefully analyzed and assimilated to revise the document with guidance provided by 33 Review Editors. The revised report was presented for consideration at a session of the Working Group II panel held in Geneva from 13 to 16 February 2001, in which delegates from 100 countries participated. There, the Summary for Policymakers was approved in detail and the full report accepted.

This report contains a Summary for Policymakers (SPM) and a Technical Summary (TS) in addition to the 19 chapters comprising the full report. Each paragraph of the SPM has been referenced to the supporting sections of the TS. In turn, each paragraph of the TS has been referenced to the appropriate section of the relevant chapter. The first three chapters set the stage for the report by discussing the context of climate change, methods for research and assessment, and development of scenarios. Chapters 4 through 9 assess the state of knowledge regarding climate change impacts, adaptation, and vulnerability for different natural and human systems or sectors. Chapters 10

through 17 assess vulnerabilities and key concerns of eight regions of the world: Africa, Asia, Australia/New Zealand, Europe, Latin America, North America, polar regions, and small island states. Chapter 18 presents a synthesis of adaptation challenges, options, and capacity. Chapter 19 concludes the report with a synthesis of climate change risks for unique and threatened systems, extreme climate events, uneven distribution of impacts, global aggregate impacts, and large-scale high-impact events. An electronic version of the report that can be searched for key words will be available on the web (<http://www.ipcc.ch>) and CD-ROM.

We wish to express our sincere appreciation to all the Coordinating Lead Authors, Lead Authors, Contributing Authors, Review Editors, and expert and government reviewers, without whose expertise, diligence, and patience and considerable investments of uncompensated time a report of this quality could never have been completed. We would also like to thank members of the Working Group II Bureau for their assistance throughout the preparation of the report.

We would particularly like to thank Neil Leary, who headed the WGII Technical Support Unit, and his staff, Dave Dokken, Kasey Shewey White, Sandy MacCracken, and Florence Ormond. Their tireless and very capable efforts to coordinate the WGII assessment ensured a final product of high scientific quality. In addition we thank Richard Moss for his invaluable contributions to the early planning phase of this work.

We would also like to thank Narasimhan Sundararaman, the Secretary of IPCC; Renate Christ, Deputy Secretary; and the staff of the IPCC Secretariat, Rudie Bourgeois, Chantal Etori and Annie Courtin who provided logistical support for government liaison and travel of experts from the developing and transitional economy countries.

Robert T. Watson
IPCC Chairman

James J. McCarthy and Osvaldo F. Canziani
IPCC WGII Co-Chairs