

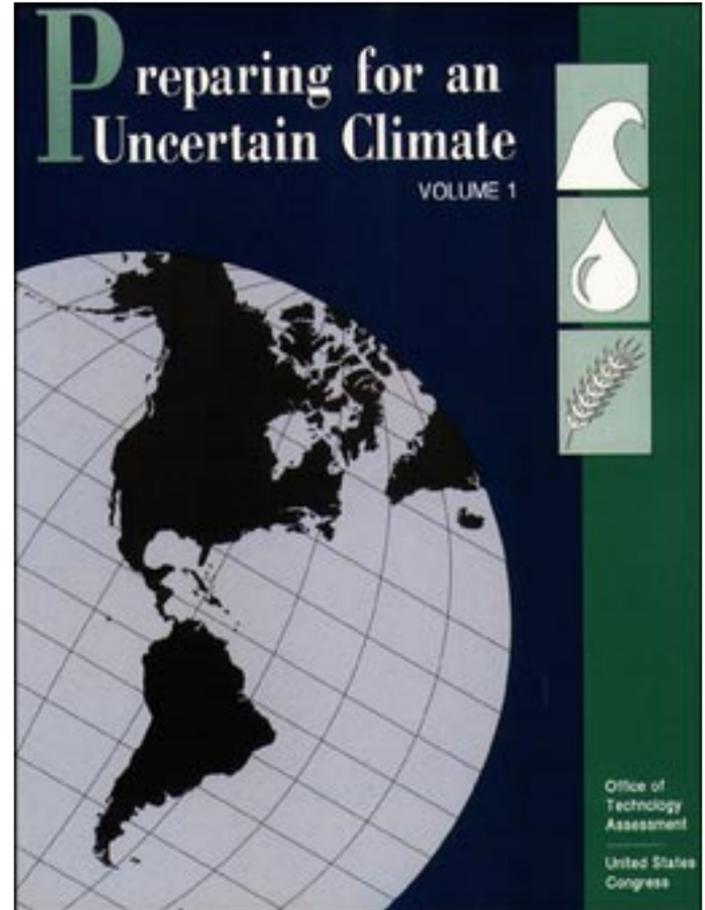
*Preparing for an Uncertain Climate—Vol. I*

October 1993

OTA-O-567

NTIS order #PB94-134640

GPO stock #052-003-01356-8



**Recommended Citation:**

**U.S. Congress, Office of Technology Assessment, *Preparing for an Uncertain Climate--Volume I, OTA-O-567* (Washington, DC: U.S. Government Printing Office, October 1.993).**

ii

---

For Sale by the U.S. Government Printing Office  
Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328  
ISBN 0-16 -042986-2

# Foreword

**P**reparing for an Uncertain Climate is OTA'S second report on climate change. In 1991, we published *Changing by Degrees: Steps to Reduce Greenhouse Gases*, which focused on ways to reduce the buildup of greenhouse gases in the atmosphere. Slowing the rate of growth in these emissions continues to be very important, but most analyses conclude that despite international efforts, the Earth is likely to warm several degrees over the next century.

Climate change poses many potential problems for human and natural systems, and the long-term effects of climate change on these systems are becoming increasingly important in public policy. For example, international agreements were recently signed on both climate change and biodiversity. Recognizing the potential problems, Congress asked OTA to examine how the Nation can best prepare for an uncertain future climate. This assessment tackles the difficult tasks of assessing how natural and human systems maybe affected by climate change and of evaluating the tools at our disposal to ease adaptation to a warmer climate. Volume 1 addresses coastal areas, water resources, and agriculture; volume 2 includes wetlands, preserved lands, and forests.

OTA identifies more than 100 options in the full report that could help ease the transition to an uncertain climate. We categorized a subset of these options as 'first steps. Options that fall into this group are near-term concerns because they will take a long time to complete, address 'front-line" or urgent issues that need attention first in order to make better decisions later, can be approached through efforts already under way, are beneficial for reasons other than helping to prepare for climate change, or represent near-term 'targets of opportunity."

The United States has put in place an ambitious Global Change Research Program to "observe, understand, and ultimately predict global and regional climate change." This effort, which has so far been based overwhelmingly in the physical sciences, is not geared to help make natural resource planning and management decisions, to identify ecosystem-level responses to climate change, or to readily provide policy guidance on mitigation or adaptation. While scientists continue to reduce uncertainty, policy makers will continue to reauthorize environmental legislation, manage natural resources, and develop energy policy. Having mechanisms for integrating research and evaluating reasonable policy routes while we are completing the science would be a valuable addition to the Federal effort. This assessment could help guide these needed improvements.

*Preparing for an Uncertain Climate* was requested by three congressional committees: the Senate Committees on Environment and Public Works and on Commerce, Science, and Transportation, and the House Committee on Science, Space, and Technology. OTA appreciates the support this effort received from hundreds of contributors. Workshop participants, reviewers, contractors, and informal advisors gave us invaluable support as we attempted to sift through the voluminous material on this subject. OTA, however, remains solely responsible for the contents of this report.



Roger C. Herdman, Director

# Advisory Panel

**Helen M. Ingram**, *Chairman*  
Director  
Udall Studies in Public Policy  
University of Arizona

**Richard M. Adams**  
Professor of Resource Economics  
Department of Agricultural and  
Resource Economics  
Oregon State University

**Vera Alexander**  
Dean, School of Fisheries  
and Ocean Sciences  
University of Alaska

**Michael J. Bean**  
Senior Attorney  
Environmental Defense Fund

**Margaret Adela Davidson**  
Executive Director  
south Carolina sea Grant  
Consortium

**J. Clarence Davies**  
Director  
Center for Risk Management  
Resources for the Future

**Baruch Fischhoff**  
Professor of Engineering  
and Public Policy  
Carnegie Mellon University

**Michael H. Glantz**  
program Director  
Environmental Impacts Group  
National Center for Atmospheric  
Research

**George Hoberg**  
Assistant Professor  
Political Science Department  
University of British Columbia

**Henry D. Jacoby**  
Director, Joint Program on the  
Science and Policy  
of Global Change  
Sloan School of Management  
Massachusetts Institute of  
Technology

**Waiter Jarck**  
Corporate Director  
Forest Resources  
Georgia-Pacific Corporation

**David N. Kennedy**  
Director, California State  
Department of Water Resources

**Jon Kusier**  
Executive Director  
Association of State Wetlands  
Managers

**Douglas MacLean**  
Associate professor  
Philosophy Department  
University of Maryland

**Jerry Mahlman**  
Director, Geophysical Fluid  
Dynamics Laboratory/NOAA  
Princeton University

**Barbara Miller**  
Senior Civil Engineer  
Tennessee Valley Authority

**Steve Peck**  
Director, Environmental Sciences  
Department  
Electric Power Research Institute

**Herman Shugart**  
**Chairman**  
Department of Environmental  
Sciences  
University of Virginia

**Phil Sisson**  
Director, Commodities and  
Economic Analysis Division  
Quaker oats

**Don Wilhite**  
Director  
International Drought  
Information Center  
University of Nebraska

**Gary Yohe**  
Professor  
Department of Economics  
Wesleyan University

*NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.*

# Project Staff

**Clyde Behney**  
Assistant Director, OTA  
Health and Environmental  
Sciences Division

**John Andelin**  
Assistant Director,  
to Aug. 31, 1993

**Robert Niblock**  
Program Manager  
Oceans and Environment

## ADMINISTRATIVE STAFF

**Kathleen Bell**  
Office Administrator

**Kimberly Holmlund**  
Administrative Secretary

**Sharon Knarvik**  
Secretary

## CONTRIBUTORS

**Bob Friedman**

**Beth Robinson**

**Mark Zinniker**

## EDITOR

**Cynthia Allen**  
Editorial services

**ROSINA BIERBAUM**  
Project Director

**Michael Bowes**  
Senior Analyst

**William Westermeyer**  
Senior Analyst

**Jacqueline Courteau**  
Analyst

## CONTRACTORS

**Timothy Beatley**  
University of Virginia

**Stanley Changnon**  
Illinois State Water Survey

**William Cline**  
Institute of International Economics

**Charles Cooper**  
San Diego University

**William Easterling**  
University of Nebraska-Lincoln

**Jae Edmonds**  
Pacific Northwest Laboratory  
Environmental Defense Fund

**David Gillilan**  
University of Arizona

**Patrick Halpin**  
University of Virginia

**Robert Lilleholm**  
Utah State University

**Janice Longstreth**  
Pacific Northwest Laboratory

**Geraldine McCormick-Ray**  
University of Virginia

**Mary McKenney**  
consultant

**Walt Oechel**  
San Diego State University

**Sherry Showell**  
Analyst

**Nadine Cutler**  
Research Analyst

**Elise Holland**  
Research Analyst

**Julie Phillips**  
Indexer

**Frank Potter**  
consultant

**Carleton Ray**  
University of Virginia

**Theodore Schad**  
consultant

**Daniel Sheer**  
Water Resources Management, Inc.

**Joel Smith**  
RCG/Hagler, Bailley, Inc.

**William Smith**  
Yale University

**Nick Sundt**  
consultant

**Richard Wahl**  
University of Colorado

**Scott Warren**  
Connecticut College

**Daniel Willard**  
Indiana University

# Workshop Participants

## WORKSHOP ON WETLANDS

**Tom Bancroft**  
National Audubon Society

**Ann Bartuska**  
U.S. Forest Service

**Michael Bean**  
Environmental Defense Fund

**Elizabeth Bokman**  
U.S. Department of the Interior

**Dieter Busch**  
U.S. Fish and Wildlife Service

**Douglas Canning**  
Washington Department of Ecology

**James Chambers**  
National Oceanic and Atmospheric Administration

**Kevin Erwin**  
Kevin L. Erwin Consulting Ecologist, Inc.

**Lee Foote**  
U.S. Fish and Wildlife Service

**Taber Hand**  
Association of State Wetlands Managers

**Suzette Kimball**  
University of Virginia

**James Kundell**  
The University of Georgia

**Jon Kusler**  
Association of State Wetlands Managers

**Bruce Moulton**  
Texas Water Commission

**Walter Oechel**  
San Diego State University

**Richard Park**  
Indiana University

**Karen Poiani**  
Cornell University

**Michael Sauer**  
North Dakota Department of Health

**Charles Segelquist**  
U.S. Fish and Wildlife Service

**John Simpson**  
Massachusetts Department of Environmental Protection

**James Titus**  
U.S. Environmental Protection Agency

**John Toliver**  
U.S. Forest Service

**Richard Tomczyk**  
Massachusetts Department of Environmental Protection

**Virginia Van Sickle-Burkett**  
U.S. Fish and Wildlife Service

**Don Voros**  
U.S. Fish and Wildlife Service

**Scott Warren**  
Connecticut College

**Dennis Whigham**  
Smithsonian Environmental Research Center

**Daniel Willard**  
Indiana University

**Tom Winter**  
U.S. Geological Survey

**Irene Wisheu**  
University of Ottawa

**Donald Witherill**  
Maine Department of Environmental Protection

## WORKSHOP ON FORESTS

**Robert Bailey**  
University of Georgia

**Richard Birdsey**  
Northeastern Forest Experiment Station

**Bruce Bongarten**  
University of Georgia

**J.E. de Steigeur**  
U.S. Forest Service

**Phil Dougherty**  
Southeastern Forest Experiment Station

**Lauren Fins**  
University of Idaho

**Michael Fosberg**  
U.S. Forest Service

**Kathleen Geyer**  
U.S. Forest Service

**Robin Graham**  
Oak Ridge National Laboratory

**Robert Haack**  
Michigan State University

**Edward Hansen**  
U.S. Forest Service

**Roy Hedden**  
Clemson University

**Arnold Holden**  
U.S. Forest Service

**David Le Blanc**  
Ball State University

**F. Thomas Ledig**  
U.S. Forest Service

**Robert Lilleholm**  
Utah State University

**Rex McCullough**  
Weyerhaeuser Company

**Stephen Nodvin**  
University of Tennessee

**David Parsons**  
National Park Service

**Phillip Riggan**  
U.S. Forest Service

**Clark Row**  
consultant

**Con Schallau**  
American Forest Council

**Hank Shugart, *Chair***  
University of Virginia

**William Smith**  
Yale University

**Alan Solomon**  
U.S. Environmental Protection Agency

**Jack Winjum**  
U.S. Environmental Protection Agency

**John Zerbe**  
Forest Products Laboratory

**Robert Ziemer**  
U.S. Forest Service

#### **WORKSHOP ON WESTERN LANDS**

**Cecil Armstrong**  
U.S. Forest Service

**Will Blackburn**  
U.S. Department of Agriculture

**Terence Boyle**  
Colorado State University

**Michael Cassity**  
University of Wyoming

**Stan Coloff**  
Bureau of Land Management

**Charles Cooper**  
San Diego State University

**Doug FOX**  
U.S. Forest Service

**Helen Ingram, *Chair***  
University of Arizona

**Linda Joyce**  
U.S. Forest Service

**John Kelmelis**  
U.S. Geological Survey

**Gil Lusk**  
Glacier National Park

**Mitch McClaran**  
University of Arizona

**Gary McVicker**  
Bureau of Land Management

**Ron Moody**  
U.S. Department of Agriculture

**David Mouat**  
Desert Research Institute

**Walter Oechel**  
San Diego State University

**Pat Reece**  
Panhandle Research and Extension  
Center

**Patrick Reed**  
University of Georgia

**Tim Seastedt**  
University of Colorado

**Richard Stroup**  
Political Economy Research Center

**Eleonora Trotter**  
University of New Mexico

**Sara Vickerman**  
Defenders of Wildlife

**Mary Wallace**  
University of Arizona

**Don Wilhite**  
University of Nebraska

#### **WORKSHOP ON CLIMATE TREATIES AND MODELS**

**Dan Bodansky**  
University of Washington

**Tony Brenton**  
Harvard University

**Herman Cesar**  
Tilburg University

**Joel Darmstadter**  
Resources for the Future

**Hadl Dowlatabadi**  
Carnegie Mellon University

**Jae Edmonds**  
Pacific Northwest Laboratory

**Howard Gruenspecht**  
U.S. Department of Energy

**James Hammitt**  
Rand Corp.

**William Hogan**  
Harvard University

**Ted Parson**  
Harvard University

**Steve Rayner**  
Pacific Northwest Laboratory

**John Reilly**  
Massachusetts Institute  
of Technology

**Joel Scheraga**  
U.S. Environmental Protection Agency

**Dennis Tirpak**  
U.S. Environmental Protection Agency

**David Victor**  
Harvard University

**John Weyant**  
Stanford University

**WORKSHOP ON  
AGRICULTURE**

**Richard Adams**  
Oregon State University

**Robert Chen**  
Consortium for the International **E a r t h**  
Science Information Network

**Ralph Chite**  
The Library of Congress

**John Clark**  
Battelle Institute

**Roy Darwin**  
Us. Department of Agriculture

**William Easterling**  
University of Nebraska

**Dean Ethridge**  
U.S. Department of Agriculture

**Gary Evans**  
U.S. Department of Agriculture

**Steven Hollinger**  
University of Illinois

**Marvin Jensen**  
Colorado state university

**C. Allan Jones**  
Texas **A&M** University

**Jan Lewandrowski**  
Us. Department of Agriculture

**Robert Loomis**  
University of California

**Robert Mendelsohn**  
Yale university

**Calvin Quaiset**  
university of California

**Wayne Rasmussen**  
U.S. Department of Agriculture

**Steve Rawlins**  
U.S. Department of Agriculture

**John Reilly**  
Massachusetts Institute of Technology

**Norman Rosenberg, Chair**  
Battelle Institute

**Cynthia Rosenzweig**  
Columbia University

**Vernon Ruttan**  
University of Minnesota

**Paul Unger**  
U.S. Department of Agriculture

**John van Es**  
University of Illinois

**WORKSHOP ON ECOLOGY  
AND REMOTE SENSING**

**Jim Bunce**  
U.S. Department of Agriculture  
**Leonard David**  
Space Data Resources and Information

**Ruth Defries**  
University of Maryland

**Irv Forseth**  
university of Maryland

**Robert Hudson**  
University of Maryland

**David Inouye**  
university of Maryland

**Tony Janetos**  
National Aeronautics and  
Space Administration

**Michael Kearney**  
University of Maryland

**Penelope Koines**  
university of Maryland

**Bill Lawrence**  
University of Maryland

**Eileen McClellan**  
University of Maryland

**Aian Miller**  
University of Maryland

**Raymond Miller**  
University of Maryland

**Rob Nicholls**  
university of Maryland

**Karen Prestegaard**  
University of Maryland

**Steve Prince**  
University of Maryland

**Alan Robock**  
University of Maryland

**John Townshend**  
university of Maryland

**Richard Weismiller**  
University of Maryland

**Robert Worrest**  
Consortium for the International **E a r t h**  
Science Information Network

**WORKSHOP ON EOS AND  
USGCRP: ARE WE ASKING  
AND ANSWERING THE  
RIGHT QUESTIONS?**

**Dan Albritton**  
National Oceanic Atmospheric  
Administration

**James Anderson**  
Harvard University

**Francis Bretherton**  
University of Wisconsin

**Ronald Brunner**  
University of Colorado

**William Clark**  
Harvard University

**Robert Corell**  
National Science Foundation

**Jeff Dozier**  
University of California

**John Eddy**  
Consortium for the International Earth  
science Information Network

**Diane Evans**  
Jet Propulsion Laboratory

**James Hansen**  
National Aeronautics and Space  
Administration

**Tony Janetos**  
National Aeronautics and Space  
Administration

**Jerry Mahlman**  
Princeton University

**M Patrinos**  
U.S. Department of Energy

**Robert Watson**  
National Aeronautics and Space  
Administration

**WORKSHOP ON  
WATER RESOURCES**

**Tony Bagwell**  
Texas Water Development Board

**Stanley Changnon**  
Illinois State Water Survey

**Hanna Cortner**  
University of Arizona

**Stephen Estes-Smargiassi**  
Massachusetts Water Resources  
Authority

**Myron Fiering**  
Harvard University

**Kenneth Frederick**  
Resources for the Future

**Jerome Gilbert**  
Water Transfer Associates

**Michael Glantz, *Chair***  
National Center for Atmospheric  
Research

**Helen Ingram**  
University of Arizona

**William Kellogg**  
National Center for Atmospheric  
Research

**Dennis Lettenmaier**  
University of Washington

**Steve Macaulay**  
California Department of water  
Resources

**Barbara Miller**  
Tennessee Valley Authority

**Peter Rhoads**  
South Florida Water Management  
District

**John Schefter**  
U.S. Geological Survey

**Nell Schild**  
U.S. Department of the Interior

**Rusty Schuster**  
Bureau of Reclamation

**Joel Smith**  
Us. Environmental Protection Agency

**Eugene Stakhiv**  
Us. Army Corps of Engineers

**Dan Tarlock**  
Chicago-Kent College of Law

**Richard Wahl**  
University of Colorado

**Don Wilhite**  
University of Nebraska