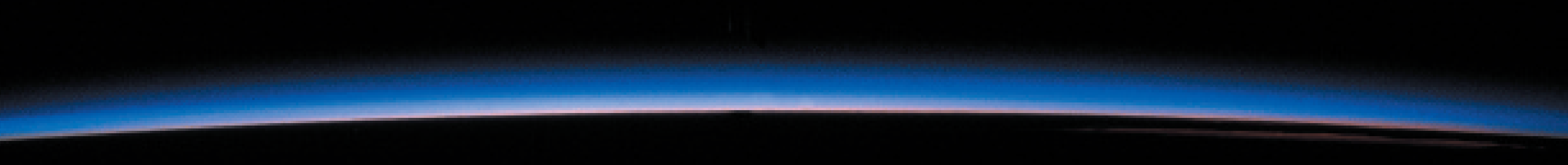
ANNEXES



A ANNEX
Authors, Reviewers, and Workshop Participants

Mark R. Abbott	Oregon State University
Waleed Abdalati	National Aeronautics and Space Administration
Thomas P. Ackerman	Pacific Northwest National Laboratory
Larry Adams	U.S. Department of Agriculture
Thomas C. Adang	The Aerospace Corporation
Jeremy A. Adler	Canadian Embassy
Robert F. Adler	NASA Goddard Space Flight Center
Syun Akasofu	University of Alaska Fairbanks
Saromi Adedeji Akeem	Compotech Nigeria Limited
Marryl Alber	University of Georgia
Steven R Albersheim	Federal Aviation Administration
Bruce Alberts	National Academy of Sciences
Mariann Albjerg	NASA Goddard Space Flight Center
Daniel L. Albritton	NOAA Aeronomy Laboratory
Stephen C. Aldrich	Bio Economic Research Associates
Latonya Alexander	National Aeronautics and Space Administration
Arthur G. Alexiou	UNESCO/Intergovernmental Oceanographic Commission
David M. Allen	Climate Change Science Program Office
Douglas R. Allen	Naval Research Laboratory
Anthony D. Amato	University of Maryland
Stephen D. Ambrose	National Aeronautics and Space Administration
P. Foerd Ames	Ocean Wave Energy Company
Jeff Amthor	U.S. Department of Energy
Paul Anastas	Office of Science and Technology Policy
Cort Anastasio	University of California, Davis
Karen Andersen	National Aeronautics and Space Administration
Stephen Andersen	U.S. Environmental Protection Agency
Donald E. Anderson	National Aeronautics and Space Administration
James Anderson	Harvard University
Lee Anderson	University of Delaware
Ken Andrasko	U.S. Environmental Protection Agency
Jean-Claude Andre	NASA Earth System Modeling Framework Advisory Board
James K. Andreasen	U.S. Environmental Protection Agency
Jeffrey A. Andresen	Great Lakes Regional Climate Change Assessment/Michigan State University
James E. Andrews	Office of Naval Research
James R. Angel	Illinois State Water Survey
Richard A. Anthes	University Corporation for Atmospheric Research
Behrooz Arastoo	Natural Resources Higher Education of Semnan
Hugo Arevalo	Insituto del Mar del Perú
Richard Arimoto	New Mexico State University
Phillip A. Arkin	University of Maryland
Joan L. Aron	Science Communication Studies
Vicki Arroyo	Pew Center on Global Climate Change
Christo Artusio	U.S. Department of State
Dan E. Arvizu	CH2M HILL
Richard Aspinall	National Science Foundation
Ghassem R. Asrar	National Aeronautics and Space Administration
Cynthia Atherton	Lawrence Livermore National Laboratory
Carol L. Auer	National Oceanic and Atmospheric Administration
Stephen J. Auer	National Oceanic and Atmospheric Administration/OAR
Susan K. Avery	University of Colorado
Roni Avissar	Duke University
Peter W. Backlund	National Center for Atmospheric Research
David Bader	U.S. Department of Energy
Stephen Baenziger	Crop Science Society of America
Mitchell T. Baer	U.S. Department of Energy
William L. Baer	Space Imaging
Thomas J. Baerwald	National Science Foundation
Rick Bailey	Commonwealth Scientific and Industrial Research Organisation
Ronald Bailey	Reason Magazine
Ronald C. Baird	National Oceanic and Atmospheric Administration/OAR
Marcia Baker	University of Washington
Wayman Baker	NOAA/Nat'l Centers for Environmental Prediction
Dennis Baldocchi	University of California, Berkeley
Mark P. Baldwin	Northwest Research Associates, Inc.
Todd W. Baldwin	Island Press
Virgil C. Baldwin, Jr.	USDA Forest Service
Roger C. Bales	University of Arizona
Peter J. Balint	George Mason University
Roberta Balstad Miller	Center for Int'l Earth Science Information Network
Seema Balwani	Office of Senator Daniel K. Akaka
Gil Bamford	
Anjuli S. Bamzai	National Oceanic and Atmospheric Administration
Raymond J. Ban	The Weather Channel
Mary Barber	Ecological Society of America
Fairley J. Barnes	Los Alamos National Laboratory
Christopher D. Barnet	NASA/Goddard Space Flight Center
Tim P. Barnett	Scripps Institution of Oceanography
Thomas O. Barnwell, Jr.	U.S. Environmental Protection Agency
Jill Baron	U.S. Geological Survey
Enriqueta Barrera	National Science Foundation
Jennifer H. Barrett	Office of Representative Mark Udall
Ko Barrett	U.S. Agency for International Development
Eric J. Barron	Pennsylvania State University
Ana P. Barros	Harvard University
Roger Barry	University of Colorado, Boulder (CIRES)
Patrick J. Bartlein	University of Oregon
Gerald S. Barton	NOAA (retired)
Joseph L. Bast	The Heartland Institute
John J. Bates	NOAA/National Environmental Satellite, Data, and Information Service
Robert Bauer	NASA Goddard Space Flight Center
Eric J. Bayler	National Oceanic and Atmospheric Administration
Reginald A. Beach	Consortium for Oceanographic, Research and Education (CORE)
William H. Beasley	University of Oklahoma
Joe M. Becerra	U.S. Navy
Glynda A. Becker	U.S. Department of Commerce
Markus E. Becker	RWE
David Beecy	U.S. Department of Energy
Carolyn C. Bell	U.S. Geological Survey
Nancy Beller-Simms	University Corporation for Atmospheric Research/NOAA
Deborah R. Belvedere	NASA Goddard Space Flight Center
Michael Bender	Princeton University
Richard E. Benedick	Battelle Pacific Northwest National Laboratory
Timothy C. Benner	U.S. Environmental Protection Agency
Richard A. Benson	Los Alamos National Laboratory
Kathleen A. Beres	Orbital Sciences Corporation
Jonas Berg	Humboldt State University
Brian Berger	Space News
Wolfgang Berger	Scripps Institution of Oceanography, UCSD
Belle Bergner	University of Pennsylvania
Chris Bernabo	National Council for Science and the Environment
James Berner	Alaska Native Tribal Health Consortium
Leonard S. Bernstein	L. S. Bernstein & Associates, L.L.C.
Joe Berry	Carnegie Institution of Washington
Uma Bhatt	University of Alaska Fairbanks
Kathryn A. Bickel	U.S. Department of Agriculture
Eugene W. Bierly	American Geophysical Union
Robert Bindschadler	National Aeronautics and Space Administration
Richard A. Birdsey	USDA Forest Service
Jennifer L. Biringer	World Wildlife Fund
Ronald J. Birk	National Aeronautics and Space Administration
Charon M. Birkett	University of Maryland College Park
Jeanne M. Bisanz	Great Lakes Regional Climate Change Assessment
Suzanne S. Bishop	Arctic Research Consortium of the United States
Maurice L. Blackmon	National Center for Atmospheric Research
Rainer Bleck	Los Alamos National Laboratory
Paul Bledsoe	National Commission on Energy Policy
Jack Blevins	City of Fairfax, Virginia
Janine Bloomfield	Environmental Defense
Richard A. Blum	Integrity in Science Project
Richard Blumenthal	State of Connecticut
Tom A. Boden	Oak Ridge National Laboratory
Samuel W. Bodman	U.S. Department of Commerce
Bo Bodvarssi	Lawrence Berkley National Laboratory
Kerry D. Bolognese	National Association of State Universities and Land Grant Colleges
George D. Bolton	AgCert International, LLC
Suzanne H. Bolton	National Oceanic and Atmospheric Administration/NMFS
John Bonitz	Independent Reviewer
Brian Bonlender	Congressman Jay Inslee
James V. Bonta	USDA/Agricultural Research Service
Paula Bontempi	National Aeronautics and Space Administration
Davis B. Bookhart	Consumer Energy Council of America
James E. Bossert	Los Alamos National Laboratory
Lisa D. Botluk	National Oceanic and Atmospheric Administration
Sara R. Bowden	U.S. Global Change Research Program/International Program
Michael Bowers	National Science Foundation
Dan Braden	National Council for Science and the Environment
Raymond S. Bradley	University of Massachusetts, Amherst
Russell Bradley	PRBO Conservation Science
Raymond J. Braitsch	U.S. Department of Energy
Sarah K. Brandel	U.S. Department of State
Stephen B. Brandt	NOAA/Great Lakes Environmental Research Laboratory
Lee E. Branscome	Climatological Consulting Corporation
Marcia Branstetter	Oak Ridge National Laboratory
Garrett W. Brass	U.S. Arctic Research Commission
Richard C. Bratcher	Electric Power Research Institute

Hans G. Brauch	Free University of Berlin/AFES-PRESS
Troy Bredenkamp	American Farm Bureau Federation
Sean T. Brennan	U.S. Geological Survey
William J. Brennan	U.S. Department of Commerce
David D. Breshears	Los Alamos National Laboratory
Francis P. Bretherton	University of Wisconsin-Madison
Michael J. Brewer	National Weather Service
Lawson W. Brigham	U.S. Arctic Research Commission
Julie Brigham-Grette	IGBP-PAGES
Anthony J. Broccoli	NOAA/Geophysical Fluid Dynamics Laboratory
Eduardo Brondizio	Indiana University
Priscilla Brooks	Conservation Law Foundation
Dail W. Brown	National Marine Fisheries Service
Joel Brown	New Mexico State University
Judy P. Brown	Rio Tinto North American Group Companies
Louis B. Brown	National Science Foundation
Sandra Brown	Winrock International
W. Steven Brown	National Institute of Standards and Technology
William H. Brune	Pennsylvania State University
David Bttisti	University of Washington
Claire L. Buchanan	Interstate Commission on the Potomac River Basin
Katherine F. Buckley	U.S. Environmental Protection Agency
Shannon H. Buckley	Hart Downstream Energy Services
Janice L. Buckner	NASA Goddard Space Flight Center
Marilyn A. Buford	USDA Forest Service Research and Development
James L. Buizer	NOAA Office of Global Programs
Stas Burgiel	Defenders of Wildlife
Virginia R. Burkett	U.S. Geological Survey
Mark A. Burnham	Lewis-Burke Associates
George H. Burrows	Autonomous Undersea Systems Institute
Robert C. Burruss	U.S. Geological Survey
Antonio J. Busalacchi	Earth System Science Interdisciplinary Center (ESSIC)
James H. Butler	NOAA Climate Monitoring and Diagnostics Laboratory
Carsten Butsch	German National Committee on Global Change Research
Lee Hayes Byron	U.S. Climate Action Network
Daewon W. Byun	University of Houston
Terry Cacek	NASA Earth System Modeling Framework Advisory Board/National Park Service
Ming Cai	University of Maryland
Ken Caldeira	Lawrence Livermore National Laboratory
John A. Calder	National Oceanic and Atmospheric Administration
Francisco J. Calderon	USDA/Agricultural Research Service
William Russell Callender	DOC/NOAA/OAR/Office of Scientific Support
Stephen E. Calopedis	Energy Information Administration
David B. Campbell	National Science Foundation
Julie K. Campbell	The Campbell Marketing Group, Inc.
Penelope Canan	University of Denver
Mark A. Cane	Lamont Doherty Earth Observatory
Ralph D. Cantral	NOAA Ocean Service
Linda A. Capuano	Honeywell Inc.
Robert Card	U.S. Department of Energy
Ann B. Carlson	Executive Office of the President
Peter S. Carlson	MHPC Corporation
R. Jared Carpenter	CREA
David J. Carson	World Meteorological Organization
Lynne M. Carter	Environmental Consultant
Thomas B. Carter	Portland Cement Association
Eileen M. Casabianca	DOC/NOAA/OAR
Ben Cash	Center for Ocean-Land-Atmosphere Studies
Michael Caughey	Illinois State Water Survey
Billy D. Causey	NOAA/Florida Keys National Marine Sanctuary
Nancy Cavallaro	USDA/Cooperative State Research, Education, and Extension Service
Daniel R. Cayan	Scripps Institution of Oceanography, UCSD
Richard P. Cebula	Science Systems and Applications, Inc.
Christine Celata	Lawrence Berkeley National Laboratory
Kelly Chance	Smithsonian Astrophysical Observatory
Stanley A. Changnon	Illinois State Water Survey
Elaine G. Chapman	Pacific Northwest National Laboratory
Thomas W. Chapman	National Science Foundation
Chris Charles	Scripps Institution of Oceanography
Robert J. Charlson	University of Washington
Michael L. Charney	Massachusetts Climate Action Network
Eric Chassignet	NASA Earth System Modeling Framework Advisory Board
Keya Chatterjee	National Aeronautics and Space Administration
Chen-Tung A. Chen	National Sun Yat-sen University
R. Douglas Chiappetta, M.A.	National Alternative Fuels Association
Gary Chilefone	
Anne F. Choate	ICF Consulting
Elizabeth Chornesky	University of California, Santa Cruz
Bob Christian	East Carolina University
John R. Christy	University of Alabama in Huntsville
Margaret M. L. Chu	U.S. Environmental Protection Agency
Pamela M. Chu	National Institute of Standards and Technology
William P. Chu	NASA Langley Research Center
Thomas Church	University of Delaware
Alice T. Cialella	Brookhaven National Laboratory
Noreen Clancy	RAND Corporation
Candyce E. Clark	National Oceanic and Atmospheric Administration
Cathy Clark	University Corporation for Atmospheric Research
Martyn Clark	University of Colorado
Rebecca Clark	National Institutes of Health
William C. Clark	Harvard University
Eileen Claussen	Pew Center on Global Climate Change
Mary L. Cleave	National Aeronautics and Space Administration
Pablo Clemente-Colón	NOAA/National Environmental Satellite, Data, and Information Service
Nicholas L. Clesceri	National Science Foundation and RPI
James A. Coakley	Oregon State University
Stella Melugin Coakley	Oregon State University
Roz E. Cohen	National Oceanic and Atmospheric Administration
Kenneth A. Colburn	Northeast States for Coordinated Air Use Mgmt
Alessandro Coletti	TITAN Systems Corp.
Kimberly N. Collell	American Soybean Association
Nancy S. Colleton	Institute for Global Environmental Strategies
Jackson D. Collier	National Aeronautics and Space Administration
Stan Coloff	U.S. Geological Survey
Rita Colwell	National Science Foundation
Josefino Comiso	NASA Goddard Space Flight Center
Susan G. Conard	USDA Forest Service
Margarita Conkright Gregg	NOAA/National Oceanographic Data Center
Joseph M. Conny	National Institute of Standards and Technology
Dawn M. Conway	Canadian Foundation for Climate and Atmospheric Sciences
Gary A. Cook	Greenpeace
Todd Phillip Cook	Lakeview Terrace Sanitarium
Charli Coon	The Heritage Foundation
Philip A. Cooney	White House Council on Environmental Quality
James N. Cooper	Earth Satellite Corporation
Ellen J. Cooter	U.S. Environmental Protection Agency
Rob Coppoch	
Robert W. Corell	American Meteorological Society and Harvard University
John G. Cormier	National Institute of Standards and Technology
Peter Cornillon	University of Rhode Island
Roman Michail Corobov	Institute of Geography, Moldavian Academy of Sciences
Christine Corwin	Bluewater Network
Ellis Cowling	North Carolina State University
Paul Craig	Sierra Club Global Warming and Energy Committee
Rachael G. Craig	National Science Foundation
Jonah B. Crawford	Stirling Energy Systems
Ted S. Cress	DOE/Pacific Northwest Laboratory
David Crisp	Jet Propulsion Laboratory/California Institute of Technology
Thomas M. Cronin	U.S. Geological Survey
Thomas J. Crowley	Duke University
Richard M. Cruse	Iowa State University
Ivan A. Csiszar	University of Maryland
Bill J. Cunningham	Unions for Jobs and the Environment (UJAE)
Thomas A. Curran	Sippican, Inc.
William B. Curry	Woods Hole Oceanographic Institution
Michael R. Curtis	U.S. Department of Energy
Robert M. Cushman	Oak Ridge National Laboratory
Ned Cyr	NOAA Fisheries
Harvey D. Dahljelm	ITT Industries
Roger C. Dahlman	U.S. Department of Energy
H. Daily	Independent Researcher
Virginia H. Dale	Oak Ridge National Laboratory
Marie Chantale Damas	National Science Foundation
William P. Dannevik	Lawrence Livermore National Laboratory
H. Lee Dantzler	DOC/NOAA/NESDIS
Margaret A Davidson	NOAA Ocean Service
Kert Davies	Greenpeace
Anthony B. Davis	Los Alamos National Laboratory
Joseph A. Davis	Society of Environmental Journalists
Danny M. Day	Eprda
Barbara M. De Rosa-Joynt	U.S. Department of State
Gitane De Silva	Canadian Embassy
Russell De Young	NASA Langley
Helvecio De-Polli	Embrapa Labex/ARS
Lois Dean	U.S. Department of Housing and Urban Development
Robert T. Deck	University of Toledo
Cynthia J. Decker	Office of the Oceanographer of the Navy
Philip L. DeCola	National Aeronautics and Space Administration
Ruth DeFries	University of Maryland
Victor E. Delnore	NASA Langley Research Center
John J. DeLuisi	National Oceanic and Atmospheric Administration
Thomas L. Delworth	NOAA/Geophysical Fluid Dynamics Laboratory
Scott Denning	Colorado State University
John G. Dennis	NASA Earth System Modeling Framework Advisory Board/National Park Service

Lawrence M Denton	The Weather Channel
Matthew S. DeRosier	Northrop Grumman
Paul V. Desanker	University of Virginia
Floyd DesChamps	U.S. Senate Committee on Commerce, Science, and Transportation
Mike Dettinger	U.S. Geological Survey
Russell DeYoung	NASA Langley
Atulya Dhungana	Independent
Howard J. Diamond	NOAA/National Environmental Satellite, Data, and Information Service
Hilda Diaz-Soltero	U.S. Department of Agriculture Forest Service
Robert Dickinson	Georgia Institute of Technology, American Geophysical Union
Nancy M. Dickson	Harvard University
Thomas Dietz	George Mason University
Lisa Dilling	National Center for Atmospheric Research
John Dilustro	University of Georgia
Joseph P. DiPietro	Energetics, Incorporated
Paul Dirmeyer	Center for Ocean, Land and Atmosphere
Gerald J. Dittberner	NOAA/National Environmental Satellite, Data, and Information Service
Keith W. Dixon	U.S. Department of Commerce / NOAA / GFDL
Larisa E. Dobriansky	U.S. Department of Energy
Richard D. Doctor	Argonne National Laboratory
David J. Dokken	U.S. Global Change Research Program/CCSP
Randall M. Dole	NOAA Climate Diagnostics Center
Dennis C. Doll	U.S. Environmental Protection Agency
J.R. M. Donald	AETC Inc.
Scott Doney	Woods Hole Oceanographic Institution
Martin J. Donohoe	Independent
John W. Doran	USDA-ARS/Soil Science Society of America
Craig Dorman	University of Alaska Fairbanks
Paul Doskey	Argonne National Laboratory
Bruce C. Douglas	Florida International University
David H. Douglass	University of Rochester
Harry J. Dowsett	U.S. Geological Survey
JR Drabick	Environmental and Energy Study Institute
Hank Drahos	NOAA/National Environmental Satellite, Data, and Information Service
John B. Drake	Oak Ridge National Laboratory
Robert S. Drosdzal	Computer Sciences Corporation
Charles J. Drummond	U.S. Department of Energy
Qingyun Duan	NOAA/National Weather Service
Manvendra K. Dubey	Los Alamos National Laboratory
Melissa L. Dubinsky	Stone and Webster Management Consultants, Inc.
Robert Duce	Texas A&M University
Claude E. Duchon	University of Oklahoma
James L. Duda	IPO/NPOESS
Chris Duffy	Pennsylvania State University
Philip B. Duffy	Lawrence Livermore National Laboratory
J.C. Duh	National Aeronautics and Space Administration
Robert J. Dumont	National Oceanic and Atmospheric Administration
Stephen V. Dunn	U.S. Environmental Protection Agency
Lisa F. Duriancik	USDA/CSREES
Margaret E. Dushin	University of Minnesota
Ellsworth Dutton	NOAA Climate Monitoring and Diagnostics Laboratory
Jon D. Dykstra	Earth Satellite Corporation
C. Mark Eakin	NOAA/National Climate Data Center
Richard C. Easter	Pacific Northwest National Laboratory
David R. Easterling	NOAA/National Environmental Satellite, Data, and Information Service
William E. Easterling III	The Pennsylvania State University
Cheryl Eavey	National Science Foundation
Myron Ebell	Competitive Enterprise Institute
Kristie L. Ebi	Electric Power Research Institute
Frank Eden	Eden Consulting
Susanna Eden	Climate Change Science Program Office
N. Terence Edgar	U.S. Geological Survey
Kodjovi Sidéra Edjame	University of Lomé
James A. Edmonds	Pacific Northwest National Laboratory
Marta Edwards	Compliance Solutions Corporation
Steven Edwards	National Oceanic and Atmospheric Administration
Kenneth Eggert	Los Alamos National Laboratory
Franco Einaudi	NASA Goddard Space Flight Center
Bernard P. Elero	Harris Corporation
Chris Elfring	The National Academies
Scott M. Elliott	Los Alamos National Laboratory
Ann L. Elsen	Montgomery County Department of Environmental Protection
Chris Elvidge	NOAA-NESDIS National Geophysical Data Center
Jerry W. Elwood	U.S. Department of Energy
William R. Emanuel	University of Virginia
David B. Enfield	NOAA AOML
Jürgen Engelhard	RWE
Jared K. Entin	National Aeronautics and Space Administration
A. Christine Eppstein	Environmental Council of the States
Paul R. Epstein	Center for Health and the Global Environment
David J. Erickson	Oak Ridge National Laboratory
Mary C. Erickson	National Oceanic and Atmospheric Administration
Jaime Esper	National Aeronautics and Space Administration
Robert Etkins	National Oceanic and Atmospheric Administration
Diane L. Evans	NASA/Jet Propulsion Laboratory
John T. Everett	UN Atlas of the Oceans
David Fahey	NOAA Aeronomy Laboratory
William L. Fang	Edison Electric Institute
Mike Farrell	Oak Ridge National Laboratory
Sherry O. Farwell	South Dakota School of Mines and Technology
Stephen P. Faulkner	U.S. Geological Survey
Kevin Fay	International Climate Change Partnership
Richard A. Feely	National Oceanic and Atmospheric Administration
Robert W. Fegley	EPA/Research and Development
Jay S. Fein	National Science Foundation
Howard J. Feldman	American Petroleum Institute
John C. Felmy	American Petroleum Institute
Murray Felsher	Washington Remote Sensing Letter
Benjamin Felzer	Marine Biological Laboratory
Ed J. Fendley	U.S. Department of State
George R. Fenske	Argonne National Laboratory
Ron Ferek	Office of Naval Research
Frank M. Ferrell	U.S. Department of Energy
Wanda R. Ferrell	U.S. Department of Energy
Anton C. Ferrer	Earth Scout International
Florence M. Fetterer	National Snow and Ice Data Center
Christopher B. Field	Carnegie Institute
Ann Fisher	Pennsylvania State University
Genene M. Fisher	Climate Change Science Program
Matt Fladeland	National Aeronautics and Space Administration
Brian P. Flannery	Exxon Mobil Corporation
Paul G. Flikkema	Northern Arizona University
Ruxandra M. Floroiu	The National Academies
Lawrence E. Flynn	U.S. Department of Commerce/NOAA
Gary Foley	U.S. Environmental Protection Agency
Jonathan A. Foley	Institute for Environmental Studies, University of Wisconsin
Peter F. Folger	American Geophysical Union
Jennifer E. Folta	International City/County Management Association
Kathleen S. Fontaine	NASA Goddard Space Flight Center
Keith J. Forbes	Fundação da Faculdade de Ciências da Universidade da Lisboa
Ned Ford	Sierra Club
Michael A. Fortune	Climate Science Forum
Ariele Foster	SustainUS
Ian Foster	NASA Earth System Modeling Framework Advisory Board
Joshua G. Foster	University Corporation for Atmospheric Research/NOAA
Guido F. Franco	California Energy Commission
Gerald T. Fraser	National Institute of Standards and Technology
Edward N. Frazier	TRW
Melissa P. Free	National Oceanic and Atmospheric Administration
J. Randall Freed	ICF Consulting
Andrew C. Freedman	Congressional Quarterly
Kenneth P. Freeman	Caelum Research Corporation
Amy J. Freise	International START Secretariat
Lars Friberg	Johns Hopkins University, SAIS
Elbert (Joe) W. Friday	National Academies, National Research Council
Julie Friddell	U.S. Army Corps of Engineers
Lawrence Friedl	National Aeronautics and Space Administration
Robert M. Friedman	The Heinz Center
Deborah Frisch	NSG
Jeffrey B. Frithsen	U.S. Environmental Protection Agency
J. Fruci	United States House of Representatives
Peter C. Frumhoff	Union of Concerned Scientists
Roland J. Fuchs	International START Secretariat
William Fulkerson	LERDWG
Inez Fung	University of California, Berkeley
John Furlow	U.S. Environmental Protection Agency
Clifford J. Gabriel	Office of Science and Technology Policy
Najwa Abbas Gadaheldam	UNIDO/ Energy Efficiency Branch
Mary Gade	Sonnenschein, Nath, and Rosenthal
Michael Gaffen	Datum International
Jeffrey S. Gaffney	Argonne National Laboratory
Peter T. Gage	World Resources Institute
William B. Gail	Ball Aerospace and Technologies Corporation
Gerardo V. Galamay	Volunteers Movement For Green Concerns
James Galloway	University of Virginia
L. Peter Galusky	Marathon Ashland Petroleum LLC
Janet L. Gamble	U.S. Environmental Protection Agency
Susan M. Gander	U.S. Environmental Protection Agency
Mary M. Gant	NIH/National Institute of Environmental Health Sciences
Yuan Gao	Princeton University
Jurgen D. Garbrecht	U.S. Department of Agriculture
Hernan E. Garcia	National Oceanic and Atmospheric Administration
Martha N. Garcia	U.S. Geological Survey
Edward P. Gardiner	American Museum of Natural History
David K. Garman	U.S. Department of Energy
Charles T. Garten, Jr.	Oak Ridge National Laboratory

Silvia L. Garzoli	National Oceanic and Atmospheric Administration
Lawrence W. Gates	Lawrence Livermore National Laboratory
Lydia Dumenil Gates	Lawrence Berkeley National Laboratory
Stephen D. Gawtry	University of Virginia
Gerald L. Geernaert	Los Alamos National Laboratory
Charlette A. Geffen	Pacific Northwest National Laboratory
Robert P. Gehri	Southern Company
Melvyn E. Gelman	National Oceanic and Atmospheric Administration
Bruce M. Gentry	National Aeronautics and Space Administration
Dylan George	National Science Foundation
Paul J. Georgia	Competitive Enterprise Institute
Janette C. Gervin	NASA Goddard Space Flight Center
Steven Ghan	Pacific Northwest National Laboratory
Anver Ghazi	European Commission
Michael Ghil	University of California, Los Angeles
Henry Gholz	National Science Foundation/Division of Environmental Biology
Anne Giblin	Marine Biological Laboratory
Lewis E. Gilbert	Columbia University
Ron S. Gird	NOAA National Weather Service
Anatoly A. Gitelson	University of Nebraska Lincoln
Mary M. Glackin	NOAA/National Environmental Satellite, Data, and Information Service
Karl M. Glasener	Soil Science Society of America
James F. Gleason	National Aeronautics and Space Administration
Peter Gleick	Pacific Institute for Studies in Development, Environment, and Security
Patricia Glick	National Wildlife Federation
Anand Gnanadesikan	NOAA/Geophysical Fluid Dynamics Lab
David S. Godwin	U.S. Environmental Protection Agency
Jeff Goebel	U.S. Department of Agriculture
Scott J. Goetz	University of Maryland
Roberto Goidanich	Brazilian Embassy in Washington
Alan M. Goldberg	The MITRE Corp.
Donald M. Goldberg	Center for International Environmental Law
Mitchell D. Goldberg	NOAA/National Environmental Satellite, Data, and Information Service
Stephen M. Goldberg	Argonne National Laboratory
Edward S. Goldstein	National Aeronautics and Space Administration
Rachel Goldstein	George Washington University Graduate Program
David J. Goldston	United States House of Representatives
Janet R. Gomon	Smithsonian Institution
Patrick Gonzalez	U.S. Geological Survey
Margaret G. Goodbody	District of Columbia Public Library
David C. Goodrich	USDA/Agricultural Research Service
David M. Goodrich	NOAA Climate Office
Steven M. Goralczyk	TRW
William D. Goran	U.S. Army Corps of Engineers
Thomas E. Graedel	Yale University
Thomas J. Grahame	U.S. Department of Energy
Anne E. Grambsch	U.S. Environmental Protection Agency
Mads Greauer	Resources for the Future
Kenneth Green	Fraser Institute
Richard S. Greenfield	American Meteorological Society
Suzie E. Greenhalgh	World Resources Institute
Greg Greenwood	California Resources Agency
Gregory B. Greenwood	Resources Agency of California
Robert A. Griffin	University of Alabama
Vanessa L. Griffin	NASA Goddard Space Flight Center
Roger B. Griffis	National Oceanic and Atmospheric Administration
David J. Griggs	Hadley Centre for Climate Prediction and Research
Stanley H Grigsby	Virginia Tech
William F. Griswold	University of Georgia
Charles Groat	U.S. Geological Survey
Robert Grossman	NorthWest Research Associates (NWRA)
Wolf D. Grossmann	Center for Environmental Research
Arnold Gruber	NOAA/National Environmental Satellite, Data, and Information Service
Hermann Gucinski	USDA Forest Service
Scott B. Gudes	National Oceanic and Atmospheric Administration
Franklin R. Guenther	National Institute of Standards and Technology
Manoj K. Guha	American Electric Power
Anthony R. Guillory	National Aeronautics and Space Administration
Mohan Gupta	NASA/Goddard Space Flight Center
Guy G. Guthridge	National Science Foundation
Garik Gutman	National Aeronautics and Space Administration
Shahid Habib	NASA/Goddard Space Flight Center
James Hack	National Center for Atmospheric Research
Peter Hacker	University of Hawaii
Charles S. Hakkarinen	Consultant
Ida M. Hakkarinen	NOAA/National Environmental Satellite, Data, and Information Service
Sirpa M.A. Hakkinen	NASA Goddard Space Flight Center
Robert C. Hale	University of Oklahoma
Michael B. Hales	NOAA/National Environmental Satellite, Data, and Information Service
Dorothy K. Hall	NASA Goddard Space Flight Center
Forrest G. Hall	University of Maryland, Baltimore County
Colin K. Haller	International City/County Management Association (ICMA)
Richard E. Hallgren	American Meteorological Society
David Halpern	Office of Science and Technology Policy
Kevin Hamilton	University of Hawaii
Annette P. Hanada	George Mason University
Steve Hankin	NOAA/PMEL
Lisa J. Hanle	U.S. Department of Energy
Lee Hannah	Center for Applied Biodiversity Science
Bryan J. Hannegan	United States Senate
James M. Hannon	Sippican Inc.
Lara J. Hansen	World Wildlife Fund
James E. Hansen	NASA Goddard Institute for Space Studies
Penelope Hansen	Environment and Energy Study Institute (EESI)
Robert C. Hansen	National Oceanic and Atmospheric Administration
Howard P. Hanson	Los Alamos National Laboratory
Paul J. Hanson	Oak Ridge National Laboratory
Penny Hanson	Environmental and Energy Study Institute
Singy Hanyona	Green Living Movement
Pat Harcourt	Waquoit Bay National Estuarine Research Reserve
Douglas R. Hardy	University of Massachusetts
Lowry A. Harper	USDA-Agricultural Research Service
Stephanie Harrington	National Oceanic and Atmospheric Administration
Susan W Harris	National Oceanic and Atmospheric Administration
Ed Harrison	NOAA/PMEL
Edwin F. Harrison	NASA Langley Research Center
Jake Haselswerdt	Lewis-Burke Associates
John C. Haskins	Moss Landing Marine Laboratories
Jerry L. Hatfield	USDA/Agricultural Research Service
John R. Haugh	Bureau of Land Management
Karl Hausker	PA Consulting Group
Katharine Hayhoe	ATMOS Research and Consulting
Anthony D. Haymet	CSIRO
John A Haynes	National Aeronautics & Space Administration
Badra Sriyani Hearath	University of Sri Jayawardhanapura
Sarah V. Heath	GF Energy, LLC
Michael A. Heeb	National Oceanic and Atmospheric Administration
Steve Heibein	
BertJan Heij	Netherlands Climate Change Research Programme
Douglas W. Heim	NEDO
Isaac M. Held	NOAA/Geophysical Fluid Dynamics Laboratory
Edward Helminski	National Carbon Sequestration Conference
George R. Hendrey	Brookhaven National Laboratory
Blair C. Henry	University of North Dakota
Robert T. Henson	University Corporation for Atmospheric Research
Einar-Arne Herland	European Space Agency - ESTEC
Charles N. Herrick	Stratus Consulting Inc.
Antonia Herzog	Natural Resources Defense Council
Shannon D. Heyck-Williams	Senate Environment & Public Works Committee
Joseph S. Hezir	EOP Group, Inc.
Thomas J. Hickey	Raytheon
Clifford A. Hickman	USDA Forest Service
Winston H. Hickox	California Environmental Protection Agency
Bruce B. Hicks	National Oceanic and Atmospheric Administration
Jennifer Hicks	Chesapeake Climate Action Network
Wayne Higgins	Climate Prediction Center/NOAA/NWS/NCEP
Steven D. Hilberg	Illinois State Water Survey
Peter H. Hildebrand	NASA Goddard Space Flight Center
Steve G. Hildebrand	Oak Ridge National Laboratory
Harvey S. Hill	National Aeronautics and Space Administration
Dexter Hinckley	Retired
Brian R. Hinman	U.S. Climate Action Network
Larry Hinzman	University of Alaska Fairbanks
Leonard P. Hirsch	Smithsonian Institute
Porter Hoagland	WHOI
Stacey Hockett Sherlock	University of Maryland
Robert Hoeft	American Society of Agronomy
Martin I. Hoffert	New York University
David J. Hofmann	NOAA Climate Monitoring and Diagnostics Laboratory
William G. Hohenstein	U.S. Department of Agriculture
Patrick W. Holden	Waterborne Environmental, Inc.
Eric K. Holdsworth	Edison Electric Institute
Elisabeth A. Holland	National Center for Atmospheric Research
David Y. Hollinger	USDA Forest Service
Steven E. Hollinger	Illinois State Water Survey
Tony Hollingsworth	European Centre for Medium-Range Weather Forecasts
Connie D. Holmes	National Mining Association
Susan H. Holte	U.S. Department of Energy
John L. Hom	USDA Forest Service
Maria Hood	Intergovernmental Oceanographic Commission - UNESCO
William H. Hooke	American Meteorological Society
Robert P. Hopkins	National Oceanic and Atmospheric Administration
Eli W. Hopson	House Science Committee
Christopher C. Horner	Competitive Enterprise Institute
Fiona M. C. Horsfall	National Weather Service
Linda L. Horton	Oak Ridge National Laboratory

Andrew H. Horvitz	NOAA/National Weather Service
Wayne Hosking	Horne Engineering
John C. Houghton	U.S. Department of Energy
Richard A. Houghton	Woods Hole Research Center
Thomas F. Hourigan	NOAA Fisheries
Paul R. Houser	NASA Goddard Space Flight Center
Bob Howarth	Cornell University
Douglas Hoyt	Retired
James M. Hrubovcak	U.S. Department of Agriculture
Jin Huang	National Oceanic and Atmospheric Administration
Ho Chun Huang	Illinois State Water Survey
Robert E. Huie	National Institute of Standards and Technology
Allen G. Hunt	National Science Foundation
Thomas G. Huntington	U.S. Geological Survey
James Hurrell	University Corporation Atmospheric Research
George C. Hurtt	University of New Hampshire
Robert C. Hyman	Cambridge Systematics
Helen Ingram	University of California, Irvine
Ron Isaacs	Atmospheric and Environmental Research, Inc. (AER)
Eric C. Itsweire	National Science Foundation
R. Cesar Izaurralde	Joint Global Change Research Institute
Clifford A. Jacobs	National Science Foundation
Daniel J. Jacob	Harvard University
Katharine L. Jacobs	Arizona State Department of Water Resources
Henry D. Jacoby	Massachusetts Institute of Technology
L. Douglas James	National Science Foundation
Anthony C. Janetos	H. John Heinz, III Center for Science, Economics, and the Environment
Jack E. Janisch	Washington Department of Ecology
Steven Japar	Ford Motor Company
Emily A. Jarvis	Senator Snowe's Office
Julie D. Jastrow	Argonne National Laboratory
Pincas Jawetz	New York University
Michael D. Jawson	USDA/Agricultural Research Service
David A. Jay	Oregon Health & Science University
Tara Jay	University Corporation for Atmospheric Research (UCAR)
Steven Jayne	Woods Hole Oceanographic Institution
Ming Ji	National Oceanic and Atmospheric Administration
Gensuo J. Jia	University of Virginia
J. Scott Jiusto	George Perkins March Institute
Anne K. Johnson	U.S. General Accounting Office
B. Carol Johnson	National Institute of Standards and Technology
Mark Johnson	University of Alaska Fairbanks
Michael R. Johnson	NOAA Office of Global Programs
Gary H. Johnston	National Park Service
Amber L. Jones	National Science Foundation
Carol A. Jones	U.S. Department of Agriculture
James Jones	University of Florida
Philip W. Jones	Los Alamos National Laboratory
Russell O. Jones	American Petroleum Institute
Sonja B. Jones	Oak Ridge National Laboratory
Linda A. Joyce	Rocky Mountain Research Station
Glenn Patrick Juday	University of Alaska Fairbanks
Lesley Julian	Retired National Weather Service
Susan Julius	USEPA/Office of Research and Development
Chris O. Justice	University of Maryland
John R. Justus	Library of Congress - Congressional Research Service
Tina M. Kaarsberg	United States Congress Science Committee
Menas Kafatos	George Mason University
Ramesh K. Kakar	National Aeronautics and Space Administration
Eugenia Kalnay	University of Maryland
Sally M. Kane	National Science Foundation
Ben J. Kangasniemi	British Columbia Ministry of Water, Land and Air Protection
Zoe H. Kant	The Nature Conservancy
Marlene Kaplan	National Oceanic and Atmospheric Administration
Jeffrey S. Kargel	U.S. Geological Survey
Dave Karl	University of Hawaii
Thomas R. Karl	NOAA/National Climatic Data Center
Miriam Kastner	Scripps Institution of Oceanography, UCSD
Seiji Kato	Hampton University
Kelli L. Kay	American Legislative Exchange Council
Leslie Kay	National Aeronautics and Space Administration
Jack A. Kaye	National Aeronautics and Space Administration
Terry J. Keating	U.S. Environmental Protection Agency Office of Air and Radiation
Alvin E. Keaton	Senior Scientists and Engineers
Michael J. Keeler	Ecologic Solution
Ralph Keeling	Scripps Institution of Oceanography
Timothy R.E. Keeney	National Oceanic and Atmospheric Administration
Stephen E. Kelleher	World Wildlife Fund-WWF
Bill Keller	Ontario Ministry of the Environment
John J. Kelly, Jr.	NOAA/National Weather Service
Walter B. Kelly	U.S. Department of State
Willett Kempton	University of Delaware
Charles F. Kennel	Scripps Institution of Oceanography, UCSD

John L. Kermond	University Corporation for Atmospheric Research/NOAA
William Kessler	NOAA Pacific Marine Environmental Laboratory
Ehsan U. Khan	U.S. Department of Energy
Reza M. Khanbilvardi	City University of New York
Haroon S. Kheshgi	Exxon Mobil Research and Engineering Company
Margaret Kieffer	National Aeronautics and Space Administration
Jeffrey Kiehl	National Center for Atmospheric Research
Timothy Killeen	National Center for Atmospheric Research
Edward J. Kim	National Aeronautics and Space Administration
John Kimble	U.S. Department of Agriculture
Anthony W. King	Oak Ridge National Laboratory
Michael D. King	NASA Goddard Space Flight Center
Roger King	National Aeronautics and Space Administration
James L. Kinter	Institute of Global Environment and Society
William Kirby	U.S. Geological Survey
S.M. Kirschner	Union of Concerned Scientists
David Kirtland	U.S. Geological Survey
David E. Kissel	University of Georgia
Michael J. Klassen	Science Applications Int'l Corporation
Steven L. Kleespie	Rio Tinto
Axel Kleidon	University of Maryland
George A. Klouda	National Institute of Standards and Technology
Robert G. Knox	NASA Goddard Space Flight Center
Malcolm K. Ko	NASA Langley Research Center
Chester J. Koblinsky	NASA and CCSPO
Kristen Koch	DOC/NOAA/OAR/Office of Scientific Support
Louisa Koch	National Oceanic and Atmospheric Research (NOAA)
Drew K. Kodjak	National Commission on Energy Policy
Russell Koffler	NOAA (Retired); Consultant
Felix Kogan	National Oceanic and Atmospheric Administration/NESDIS
Christine R Kojac	House Appropriations Committee
Charles Kolstad	Massachusetts Institute of Technology
Karen H. Koltes	U.S. Department of the Interior
George J. Komar	NASA/Goddard Space Flight Center
Burton H. Koske	Idaho National Engineering and Environmental Laboratory (INEEL)
Thomas Krafft	German National Committee on Global Change Research
Richard J. Kramer	DynCorp
Kristen L. Krapf	National Research Council
Jamie M. Krauk	National Oceanic and Atmospheric Administration
David A.R. Kristovich	Illinois State Water Survey
Herbert W. Kroehl	National Oceanic and Atmospheric Administration
Dina Kruger	U.S. Environmental Protection Agency
Edward W. Kruse	National Oceanic and Atmospheric Administration
Jeff Kueter	George Marshall Institute
Jeff R. Kuhn	University of Hawaii
Keelin S. Kuipers	National Oceanic and Atmospheric Administration
George Kukla	Lamont Doherty Earth Observatory of Columbia University
Betsy A. Kulle	Maryland Department of Natural Resources
Arun Kumar	National Oceanic and Atmospheric Administration
Sunil Kumar	Metropolitan Washington Council of Governments
Michael J. Kurylo	National Aeronautics and Space Administration; NIST
Won-Tae Kwon	Meteorological Research Institute
Kent P. Laborde	National Oceanic and Atmospheric Administration
Klaus S. Lackner	Columbia University
Murari Lal	Indian Institute of Technology Delhi
Rattan Lal	The Ohio State University
Peter J. Lamb	The University of Oklahoma
H. Richard Lane	National Science Foundation
Nadine T. Laporte	University of Maryland
Daniel A. Lashof	Natural Resources Defense Council
John A. Lasley	SAIC
Istvan Laszlo	National Oceanic and Atmospheric Administration
Jim Latimer	U.S. Environmental Protection Agency
Thomas Laughlin	NOAA/International Affairs
Conrad C. Lautenbacher	Under Secretary of Commerce for Oceans and Atmosphere
Peggy A. Lautenschlager	State of Wisconsin Department of Justice
James D. Laver	NOAA/NWS/NCEP
Richard G. Lawford	National Oceanic and Atmospheric Administration
Edward A. Laws	University of Hawaii
Linda L. Lawson	U.S. Department of Transportation
David Layzell	Queens University, Canada
Judith L. Lean	Naval Research Laboratory
Neil A. Leary	START
Stephen Leatherman	Florida International University
Sharon K. LeDuc	NOAA/National Environmental Satellite, Data, and Information Service
Albert Lee	National Institute of Standards and Technology
Arthur Lee	ChevronTexaco Corporation
Cindy Lee	State University of New York at Stony Brook
Tsengdar J. Lee	NASA Earth Science Enterprise
Virginia Lee	RI Sea Grant/ URI CRC
Ants Leetmaa	NOAA/Geophysical Fluid Dynamics Laboratory
Robert J. Leffler	NOAA National Weather Service
David M. Legler	U.S. CLIVAR Office

Margaret Leinen	National Science Foundation
Richard Lempert	National Science Foundation
Barry M. Lesht	Argonne National Laboratory
Dennis Lettenmaier	University of Washington
Daniel W. Leubecker	Maritime Administration, U.S. Department of Transportation
L. Ruby Leung	Pacific Northwest National Laboratory
Sydney Levitus	NODC/NOAA
Joel M. Levy	National Oceanic and Atmospheric Administration
Gad Levy	NorthWest Research Associates (NWRA)
Orest Lewinter	New York State Department of Environmental Conservation (retired)
Craig A. Lewis	ChevronTexaco
Marlo Lewis, Jr.	Competitive Enterprise Institute
Clement D. Lewsey	NOAA/NOS
Frances C. Li	National Science Foundation
Tim Li	University of Hawaii
Zin-Zhong Liang	Illinois State Water Survey
Sanjay S. Limaye	Office of Space Science Education, Space Science and Engineering Center
Allison F. Linden	Department of Health and Human Services
John J. Lipsey	Tetra Tech, Inc.
Michael M. Little	NASA Langley Research Center
Chung-Ming Liu	National Taiwan University
Diana M. Liverman	University of Arizona
Robert E. Livezey	National Weather Service
Steven A. Lloyd	The Johns Hopkins University
Maryalice Locke	U.S. Federal Aviation Administration
Eric R. Locklear	National Oceanic and Atmospheric Administration
Brent M. Lofgren	NOAA Great Lakes Environmental Research Laboratory
William Logan	National Research Council
Susan Long	Columbia University
Geoff B. Love	Intergovernmental Panel on Climate Change
Thomas R. Loveland	U.S. Geological Survey
Alan A. Lucier	National Council for Air and Stream Improvement, Inc.
Roger Lukas	University of Hawaii
Peter Lunn	U.S. Department of Energy
Le N. Ly	NPS/NOAA
Sheila Lynch	Northeast Advanced Vehicle Consortium
Lingfang Ma	University of Virginia
Michael MacCracken	International Commission on Climate
Sandy MacCracken	U.S. Global Change Research Program/CCSPO
Alexander MacDonald	NOAA/Oceanic and Atmospheric Research
Anthony MacDonald	Coastal States Organization
Tahamoana Macpherson	Embassy of New Zealand
Caren W. Madsen	NOAA Research
Lorenz Magaard	University of Hawaii
Judith Maguire	Environmental Protection Agency
Obed A. Mahena	VIijana Vision of Tanzania
Jerry D. Mahlman	National Center for Atmospheric Research
Bernard J. Mahoney	Independent
James R. Mahoney	NOAA/U.S. Climate Change Science Program
Martha E. Maiden	National Aeronautics and Space Administration
Gyorgy Major	Hungarian Meteorological Society
Gene Makar	Forte Associates, Inc.
Jonathan T. Malay	Ball Aerospace and Technologies Corp.
Kate Maliga	NASA Office of External Relations
Elizabeth L. Malone	Joint Global Change Research Institute
Robert C. Malone	Los Alamos National Laboratory
Deborah R. Mangis	U.S. Environmental Protection Agency
Martin R. Manning	Intergovernmental Panel on Climate Change/WG I
Antonio Mannino	NASA Goddard Space Flight Center
Nathan Mantua	University of Washington
John H. Marburger III	Office of Science and Technology Policy
Kristin Marcell	NYS DEC Hudson River Estuary Program
Suzanne K. M. Marcy	U.S. Environmental Protection Agency
Jan W. Mares	EOP Group
Hank Margolis	Universite Laval, Canada
Hal Maring	National Aeronautics and Space Administration
Helaine W. Markewich	Department of the Interior/U.S. Geological Survey
Gregg Marland	Oak Ridge National Laboratory
Robert Marlay	U.S. Department of Energy
Todd Marse	University of New Orleans
Robert R.R. Marston	National Oceanic and Atmospheric Administration
R. Gene Martin	University Corporation for Atmospheric Research
Judy Martz	Western Governors' Association
Paul L. Marx	Federal Transit Administration
Byron Mason	National Academies
Cheryl L. Mason	National Science Foundation
Katie Mastriani	Columbia University
Edward J. Masuoka	NASA Goddard Space Flight Center
Roser Matamala	Argonne National Laboratory
David Mathis	USACE
Gary C. Matlock	NOAA/National Ocean Science
Patty Matrai	Bigelow Laboratory
David A. Matthews	DOI/U.S. Bureau of Reclamation
Mike A. Matthews	National Oceanic and Atmospheric Administration
Lourdes Q. Maurice	Federal Aviation Administration
Nancy G. Maynard	NASA Goddard Space Flight Center
Wilfred E. Mazur	NOAA/National Environmental Satellite, Data, and Information Service
Michael Mazzella	Science Applications International Corp.
Margaret R. McCalla	NOAA/Office of the Federal Coordinator
Eileen McCauley	California Air Resources Board
Bonnie McCay	Rutgers University
Douglas A. McChesney	Washington Department of Ecology
Charles R. McClain	NASA Goddard Space Flight Center
Lindsay R. McClelland	National Park Service
John L. McCormick	Citizens Coal Council
John McCoy	
Julian McCreary	University of Hawaii
Kenneth R. McDonald	NASA Goddard Space Flight Center
Robert H. McFadden	GHG Associates
Mack McFarland	DuPont Fluoroproducts
Jim McGrath	Retired
James Mcguire	National Aeronautics and Space Administration
Edward L. McIntosh	Citizen
Douglas G. McKinney	National Risk Management Research Laboratory
Diane McKnight	University of Colorado
Andrea McMakin	Pacific Northwest National Laboratory
Larry M. McMillin	NOAA/National Environmental Satellite, Data, and Information Service
John A. McMorris	AgCert International, LLC
Catherine P. McMullen	Allophilia
James M. McNeal	U.S. Geological Survey
Richard T. McNider	National Space Science and Technology Center
Diane McNight	University of Colorado
Ronald D. McPherson	American Meteorological Society
Steve Meacham	National Science Foundation
Linda O. Mearns	National Center for Atmospheric Research
Esther Mecking	Burke Mountain Academy
Tom Medaglia	RWE
Michelle Medeiros	Greenpeace
Jerry Meehl	University Corporation Atmospheric Research
J. Patrick Megonigal	Smithsonian Environmental Research Center
Vikram M. Mehta	The Center for Research on the Changing Earth System
Eric A. Meindl	National Data Buoy Center
Jill R. Meldon	National Oceanic and Atmospheric Administration
Jie Meng	NOAA/National Environmental Satellite, Data, and Information Service
Phil Merilees	National Center for Atmospheric Research (NCAR)
Karen L. Metchis	U.S. Environmental Protection Agency
Alden M. Meyer	Union of Concerned Scientists
Jim Meyer	Shannon Lab
Frederick Meyerson	AAAS/NSF Science and Technology Policy Fellow
Horst Meyrahn	RWE Rheinbraun AG
Patrick J. Michaels	University of Virginia
Aurelia J. Micko	UCAR/NOAA
Elizabeth M. Middleton	NASA/Goddard Space Flight Center
Paulette B. Middleton	Panorama Pathways
Edward Miles	University of Washington
Constance I. Millar	U.S. Forest Service, PSW Research Station
Alan Miller	The World Bank
Charles E. Miller	Haverford College
Christopher D. Miller	National Oceanic and Atmospheric Administration
David L. Miller	Idaho National Engineering and Environmental Laboratory
Douglas A. Miller	Pennsylvania State University
Mark Miller	Brookhaven National Laboratory
Norman L. Miller	Lawrence Berkeley National Laboratory
Ralph Milli	NorthWest Research Associates (NWRA)
John L. Mimikakis	United States House of Representatives Committee on Science
Laura Miner-Nordstrom	U.S. Environmental Protection Agency
Jean-Bernard Minster	University of California, San Diego
Irving Mintzer	Pacific Institute
Sara E. Mirabilio	National Oceanic and Atmospheric Administration
Ron Mitchell	University of Oregon
Humio Mitsudera	University of Hawaii
Alan C. Mix	Oregon State University
John R. Moisan	National Aeronautics and Space Administration
Bruce F. Molnia	U.S. Geological Survey
Craig F. Montesano	National Oceanic and Atmospheric Administration
Linda V. Moodie	National Oceanic and Atmospheric Administration
Harold A. Mooney	Stanford University
Kenneth A. Mooney	National Oceanic and Atmospheric Administration
Berrien Moore III	University of New Hampshire
Dennis W. Moore	Pacific Marine Environmental Laboratory, NOAA
Melinda Moore	U.S. Department of Health and Human Services
Thomas G. Moore	Hoover Institution, Stanford University
Joseph M. Moran	American Meteorological Society
Stephen G. Moran	Raytheon Company
Barbara J. Morehouse	University of Arizona
Jack A. Morgan	USDA Agricultural Research Service

Jennifer Morgan	World Wildlife Fund
Richard E. Moritz	University of Washington
John H. Morrill	Arlington County
John M. Morrison	North Carolina State University
Wayne A. Morrissey	Library of Congress
Susanne Moser	Union of Concerned Scientists
John F. Moses	National Aeronautics and Space Administration
Richard Moss	U.S. Climate Change Science Program
Philip W. Mote	University of Washington
Jarvis L. Moyers	National Science Foundation
Glenn D. Mroz	Michigan Tech University
Hussin Muhamed	Department of Geography, Damascus
Patrick J. Mulholland	Oak Ridge National Laboratory
Duane M. Muller	U.S. Agency for International Development
Charles H. Murphy	Unidata/UCAR
William L. Murray	NOAA/Office of Global Programs
John N. Musinsky	Conservation International
John C. Mutter	Columbia University
Carolyn Z. Mutter	International Research Institute for Climate Prediction, Columbia University
Charles E. Myers	National Science Foundation
Gerald Myers	Ophir Corporation
Knute J. Nadelhoffer	National Science Foundation
Hironori Nakanishi	NEDO
Don Nangira	World Meteorological Organization
Arthur F. Napolitano	Raytheon - Space and Airborne Systems
Syed Mahmood Nasir	Ministry of Environment, Local Government & Rural Development
Patrick J. Neale	Smithsonian Environmental Research Center
Thomas R. Neff	Mitretek Systems
William D. Neff	National Oceanic and Atmospheric Administration/OAR
Juniper M. Neill	National Oceanic and Atmospheric Administration
Ronald P. Neilson	U.S. Department of Agriculture Forest Service
Loren Nelson	Ophir Corporation
Paul Nelson	Southwest Research Institute
Patrick J. Neuman	National Oceanic and Atmospheric Administration
Sandra G. Neuzil	U.S. Geological Survey
Richard E. Newell	U.S. Department of Commerce (retired)
George B. Newton	U.S. Arctic Research Commission
Mary D. Nichols	California Resources Agency
Elizabeth E. Nicholson	National Oceanic and Atmospheric Administration
Ala Vladimir Nicolenco	Moldavian Academy of Sciences
Claudia Nierenberg	National Oceanic and Atmospheric Administration
Ian R Noble	The World Bank
Juan C. Nogales	JRM Inc.
Vivian Pardo Nolan	U.S. Geological Survey
Richard J. Norby	Oak Ridge National Laboratory
John J. Novak	Electric Power Research Institute
Albert Nunez	City of Takoma Park, Cities for Climate Protection Campaign
Frank Nutter	Reinsurance Association
James J. O'Brien	Florida State University
Maureen R O'Brien	Office of Science and Technology Policy
Robert E. O'Connor	National Science Foundation
Sean O'Keefe	National Aeronautics and Space Administration
William F. O'Keefe	George C. Marshall Institute
James M. O'Sullivan	National Oceanic and Atmospheric Administration
Godwin O.P. Obasi	World Meteorological Organization
Walter C. Oechel	San Diego State University
Robert J. Oglesby	National Aeronautics and Space Administration/MSFC
John Ogren	NOAA Climate Monitoring and Diagnostics Laboratory
Eiji Ohira	Ministry of Economy, Trade and Industry
Richard L Ohlemacher	National Oceanic and Atmospheric Administration
Peter E. Ohonsi	York University
George Ohring	National Oceanic and Atmospheric Administration
Dennis S. Ojima	Colorado State University
Charles Chinedu Okeke	NUSA International ltd.
Kirsten U. Oldenburg	U.S. Department of Transportation
Lembulung O. Kosyando	Naadutaro (Pastoralists' Survival Options)
Curtis R. Olsen	University of Massachusetts Boston
John O. Olsen	Heatlog Industries Inc.
Kathie L. Olsen	Office of Science and Technology Policy
Lola M. Olsen	NASA/Goddard Space Flight Center
Joan Oltman-Shay	NorthWest Research Associates (NWRA)
James Opaluch	University of Rhode Island
Michael Oppenheimer	Princeton University
William C. Orr	National Alternative Fuels Foundation
Jessica P. Orrego	Climate Change Science Program Office
Charles B. Osmond	Columbia University
Doug Osugi	State of California, Department of Water Resources
Ralph P. Overend	National Renewable Energy Laboratory
James E. Overland	PMEL/NOAA
Jonathan T. Overpeck	University of Arizona
Stphen W Pacala	Princeton University
Rajendraa K. Pachauri	TATA Energy Research Institute. TERI, The Habitat Place
Pamela E. Padgett	USDA Forest Service

Julie M. Palais	OPP/NSF
Michael A. Palecki	Illinois State Water Survey
Anna C. Palmisano	U.S. Department of Energy
Theresa Paluszkiewicz	National Science Foundation
Robert J. Pankiewicz	Product Application Services
Kathryn L. Parker	U.S. Environmental Protection Agency
Claire L. Parkinson	NASA Goddard Space Flight Center
Martin I. Parry	School of Environmental Scientists
Edward A. Parson	Harvard University
Mark Parsons	University of Colorado, Boulder (CIRES)
David F. Paskausky	Wind, Water and Waves
Toral Patel-Weynand	U.S. Department of State
Ari A. Patrinos	U.S. Department of Energy
James W. Patten	Battelle Pacific Northwest National Laboratory
Jonathan A. Patz	Johns Hopkins Bloomberg School of Public Health
Eldor A. Paul	Colorado State University
James H. Paul	House Science Committee
Milan J. Pavich	U.S. Geological Survey
Steven Pawson	UMBC/GEST & NASA/DAO
D. S. Peacock	National Science Foundation
Donald H. Pearlman	The Climate Council
Sam Pearsall	The Nature Conservancy - North Carolina Chapter
William T. Pennell	Pacific Northwest National Laboratory
Diana L. Perfect	NOAA National Weather Service
Alan D. Perrin	U.S. Environmental Protection Agency
Veronika Pesinova	U.S. Environmental Protection Agency
Christa Peters-Lidard	NASA Goddard Space Flight Center
William Peterson	NOAA Fisheries
Annie Petsonk	Environmental Defense Fund
Lawrence Pettinger	U.S. Geological Survey
Rickey C. Petty	U.S. Department of Energy
Jonathan T. Phinney	National Oceanic and Atmospheric Administration
Roger A. Pielke, Sr.	American Association of State Climatologists
Crispin H. Pierce	University of Washington
Henry J. Pierce	SAIC
Raymond Pierrehumbert	The University of Chicago
Leonard J. Pietrafesa	North Carolina State University
Paul R. Pike	Ameren
Rick S. Piltz	Climate Change Science Program Office/USGCRP
Nicholas Pinter	Southern Illinois University
Rodrigo G. Pinto	Brazilian Embassy
Stephen R. Piotrowicz	NOPP/Ocean.US
Hugh M. Pitcher	Pacific Northwest National Laboratory
Warren Piver	National Institutes of Health
William A. Pizer	Resources for the Future
Robert J. Plante	Raytheon Information Systems
Gayther L. Plummer	GEORGIA Climatology Association
Mitchell A. Plummer	Idaho National Engineering and Environmental Laboratory
Ethan J. Podell	Consultant
John Drew Polisar	U.S. Department of State
Igor Polyakov	University of Alaska Fairbanks
David M. Pomerantz	House Committee on Appropriations
William M. Porch	Los Alamos National Laboratory
Dianne L. Poster	National Institute of Standards and Technology
Krishna Rao Potarazu	TRW
Joanne R. Potter	Cambridge Systematics
Murray Poulter	National Institute of Water and Atmospheric Research, New Zealand
Kendall S. Powell	Nature
Daniel Power	Climate Institute
Michael J. Prather	University of California, Irvine
Cary Presser	National Institute of Standards and Technology
Benjamin L. Preston	Pew Center on Global Climate Change
Stuart V. Price	RSVP Communications
Joseph Prospero	University of Miami
Alex Pszenny	University of New Hampshire
Roger Pulwarty	NOAA/CIRES
Mary Quillian	Nuclear Energy Institute
John Quinn	Constellation Energy Group
Nancy Rabalais	Louisiana Universities Marine Consortium
Frank R. Rack	Joint Oceanographic Institutions
Alexander Radichevich	National Oceanic and Atmospheric Administration
Patricia A. Rainey	The Boeing Company
Michael T. Rains	USDA Forest Service
Don R. Raish	California Casualty Insurance
Sudhir Chella Rajan	Tellus Institute
V. Ramanathan	Scripps Institution of Oceanography
Bruce H. Ramsay	NOAA/National Environmental Satellite, Data, and Information Service
Robert L. Randall	The RainForest ReGeneration Institute
Randy Randol	Exxon Mobil
R. Keith Raney	Johns Hopkins University Applied Physics Laboratory
Robert H. Rank	NOAA/National Environmental Satellite, Data, and Information Service
Kenneth J. Ranson	NASA Goddard Space Flight Center
S. Trivikrama Rao	National Oceanic and Atmospheric Administration

Aaron G. Rappaport	Union of Concerned Scientists
Beth G. Raps	Independent Scholar
A. R. Ravishankara	National Oceanic and Atmospheric Administration
Walter J. Rawls	USDA/Agricultural Research Service
K.B. N. Rayana	IAMMA
Scott C. Rayder	Department of Commerce/NOAA
Donald G. Rea	Senior Scientists and Engineers, AAAS
Anthony L. Reale	NOAA/National Environmental Satellite, Data, and Information Service
Ruth A. Reck	University of California
Kambham Raja Reddy	Mississippi State University
Michelle Redlin	Hart Downstream Energy Services
Kelly T. Redmond	Western Regional Climate Center
Denise Reed	University of New Orleans
Michelle A. Reed	National Oceanic and Atmospheric Administration
Eileen Regan	Strategic Environmental Research and Development
David E. Reichle	Environmental Consultant
Stephen J. Reid	National Science Foundation
Daniel A. Reifsnyder	U.S. Department of State
Chris Reilly	Argonne National Laboratory
John M. Reilly	Massachusetts Institute of Technology
Thomas Reilly	Commonwealth of Massachusetts
David S. Renné	National Renewable Energy Laboratory
Nilton O. Renno	The University of Michigan
Andrew C. Revkin	The New York Times
Jose A. Rial	University of North Carolina at Chapel Hill
Charles W. Rice	Kansas State University
Don Rice	National Science Foundation
Joseph P. Rice	National Institute of Standards and Technology
Richard C. Rich	Virginia Tech
Kelvin Richards	University of Hawaii
Richard Richels	Electrical Power Research Institute
Michele M. Rienecker	NASA/Goddard Space Flight Center
Ray A. Rigert	U.S. Army
David Rind	National Aeronautics and Space Administration
Kathleen E. Ritzman	Scripps Institution of Oceanography
Alberto L.R.-Rentas	Metropolitan University
John O. Roads	Scripps Institution of Oceanography, UCSD
Franklin R. Robertson	NASA/ MSFC
David A. Robinson	Rutgers University
Richard Robinson	Coastal and Watershed Resources Advisory Committee
Margaret Robnett	Chesapeake Climate Action Network
Alan Robock	Rutgers University
Barrett N. Rock	University of New Hampshire
Arturo E. Rodriguez	Miami-Dade Community College
Phillip J. Roehrs	American Coastal Coalition
Dean Roemmich	Scripps Institution of Oceanography, UCSD
Catriona E. Rogers	U.S. Environmental Protection Agency
Richard B. Rood	NASA Goddard Space Flight Center
Peter W. Rooney	House Science Committee
Maurice D. Roos	California Department of Water Resources
Eugene Rosa	Washington State University
Richard D. Rosen	Atmospheric and Environmental Research, Inc.
Norman J. Rosenberg	Pacific Northwest National Laboratory
Jeffrey O. Rosenfeld	American Meteorological Society
Joshua P. Rosenthal	National Institutes of Health - Fogarty International Center
Joyce E. Rosenthal	Columbia University
Cynthia Rosenzweig	NASA Goddard Institute for Space Studies
Richard Rosenzwieg	Natsource LLC
Kevin T. Rosseel	U.S. Environmental Protection Agency
William B. Rossow	NASA Goddard Institute for Space Studies
Doug Rotman	NASA Earth System Modeling Framework Advisory Board
Steven Rowe	Office of the Attorney General of Maine
Amy E. Royden	STAPPA/ALAPCO
Howard Runge	Orbital Sciences Corporation
George B. Runion	USDA/Agricultural Research Service
Steven W. Running	University of Montana
Leslie F. Ruppert	U.S. Geological Survey
David P. Russ	U.S. Geological Survey
Thomas A. Russell	ITT Industries
William (Bill) E. Russo	U.S. Environmental Protection Agency
Gene Russo	THE SCIENTIST News Journal
Glenn K. Rutledge	NOAA National Climatic Data Center
Robert Ryan	NBC4
Jeffrey D. Sachs	The Earth Institute at Columbia University
Rafe D. Sagarin	Office of Congresswoman Hilda Solis
Raphael Sagarin	University of California, Santa Barbara
William A. Salas	Applied GeoSolutions, LLC
Ross J. Salawitch	Jet Propulsion Laboratory, Caltech
Michael J. Sale	Oak Ridge National Laboratory
Vincent V. Salomonson	NASA Goddard Space Flight Center
Jason P. Samenow	U.S. Environmental Protection Agency
Alan H. Sanstad	Lawrence Berkeley National Laboratory
Jessica A. Santacruz	
Benjamin D. Santer	Lawrence Livermore National Laboratory
Edward S. Sarachik	NASA Earth System Modeling Framework Advisory Board/University of Washington
Myriam Sarachik	American Physical Society
Jorge Sarmiento	Princeton University
Jayant A. Sathaye	Lawrence Berkeley National Laboratory
Tetsuya Sato	Japan Maritime, Science and Technology Center
Janet L. Sawin	Worldwatch Institute
Karyn Sawyer	University Corporation for Atmospheric Research
Earl C. Saxon	The Nature Conservancy
Donald Scavia	NOAA National Ocean Service
John C. Schaake	NOAA/National Weather Service
Jacqueline Schafer	U.S. Agency for International Development
Joel D. Scheraga	U.S. Environmental Protection Agency
Kenneth Schere	U.S. Environmental Protection Agency
Craig Schiffries	National Council for Science and the Environment
David Schimel	National Center for Atmospheric Research
Michael E. Schlesinger	University of Illinois at Urbana-Champaign
William H. Schlesinger	Duke University
Adam Schlosser	GEST/UMBC/NASA
David Schmalzer	Argonne National Laboratory
Cynthia E. Schmidt	University Corporation for Atmospheric Research
Gavin Schmidt	NASA Earth System Modeling Framework Advisory Board
John A. Schmidt	NASA Earth System Modeling Framework Advisory Board
Raymond W. Schmitt	Woods Hole Oceanographic Institution
Anne-Marie Schmoltner	National Science Foundation
Marcus Schneider	U.S. Clean Energy Program
Niklas Schneider	University of Hawaii
Stephen Schneider	Stanford University
Russ Schnell	NOAA Climate Monitoring and Diagnostics Laboratory
Mark Schoeberl	NASA Goddard Space Flight Center
Paul S. Schopf	NASA Earth System Modeling Framework Advisory Board
Siegfried D. Schubert	NASA Goddard Space Flight Center
Laurel J. Schultz	U.S. Environmental Protection Agency
Heidi Z. Schuttenberg	NOAA Coral Team
Richard A. Schwabacher	The Cousteau Society
Stephen E. Schwartz	Brookhaven National Laboratory
Franklin B. Schwing	NOAA Pacific Fisheries Environmental Laboratory
Karen M. Scott	U.S. Environmental Protection Agency
Roger A. Sedjo	Resources for the Future
Dian J. Seidel	NOAA Air Resources Laboratory
Piers Sellers	NASA/JSC
Cynthia E. Sellinger	NOAA/GLERL
Hratch G. Semerjian	National Institute of Standards and Technology
Jeff Severinghaus	Scripps Institution of Oceanography, UCSD
Craig Shafer	National Park Service
Steven R. Shafer	U.S. Department of Agriculture
Awdhseh K. Sharma	NOAA/National Environmental Satellite, Data, and Information Service
Gary D. Sharp	Center for Climate/Ocean Resources Study
Walter Shaub	U.S. Chamber of Commerce
Eileen L. Shea	East-West Center
Edwin J. Sheffner	National Aeronautics and Space Administration
J. Marshall Shepherd	NASA Goddard Space Flight Center
Noriko L. Shoji	Office of Senator Daniel K. Inouye
Steve E. Short	Short & Associates, Inc.
Randy Showstack	American Geophysical Union
Jagadish Shukla	George Mason University
Martha Shulski	University of Alaska Fairbanks
David Shultz	U.S. Geological Survey
C. K. Shum	Ohio State University
Smita Siddhanti	Endyna Inc.
Hilary H. Sills	Sills Associates
Katherine Silverthorne	World Wildlife Fund
Lynn Simarski	National Science Foundation
Emmy B. Simmons	U.S. Agency for International Development
Michael E. Simmons	North Carolina A&T State University
Robert J. Simon	Chlorine Chemistry Council
Fiorella V. Simoni	George Mason University
Caitlin F. Simpson	National Oceanic and Atmospheric Administration
Michael M. Simpson	U.S. Congressional Research Service
N. Michael Simpson	NOAA/National Environmental Satellite, Data, and Information Service
Naaman M. Simpson	Department of Commerce/NOAA/NESDIS
Michael J. Singer	Soil Science Society of America
Michael W. Singer	Harris Corp
S. Fred Singer	Science and Environmental Policy Project
Ashbindu Singh	United Nations Environment Programme
Vijai Pratap Singh	Institute of Environment Management & Plant Sciences, Vikram University
Douglas L. Sisterson	Argonne National Laboratory
Sreeshankar S. Nair	SES, NOAA (contractor)
Howard Skinner	USDA-Agricultural Research Service
William Skirving	NOAA/National Environmental Satellite, Data, and Information Service
David Skole	Michigan State University
Francis P. Slakey	Public Affairs

Michael W. Slimak	U.S. Environmental Protection Agency
Julia M. Slingo	NERC Centre for Global Atmospheric Modelling
Richard L. Slonaker	Raytheon
James R. Slusser	Colorado State University
John A. Small	National Institute of Standards and Technology
D. Brent Smith	NOAA/National Environmental Satellite, Data, and Information Service
Ellen S. Smith	Columbia University
Lowell F. Smith	Retired
Neville R Smith	Australian Bureau of Meteorology
Robert E. Smith	Compass International Development
Steven J. Smith	Joint Global Change Research Institute
Wade B. Smith	Mitretek Systems
Anthony D. Socci	U.S. Environmental Protection Agency
Robert H. Socolow	Princeton University
Brian Soden	NOAA Geophysical Fluid Dynamics Laboratory
Youngsinn Sohn	University of Maryland Baltimore County
Allen M. Solomon	U.S. Environmental Protection Agency
Susan Solomon	NOAA Aeronomy Laboratory
Andrew Solow	Woods Hole Oceanographic Institution
Shiv Someshwar	International Research Institute for Climate Prediction, Columbia University
W. Somplatsky-Jarman	Presbyterian Church (USA)
J. Richard Soulen	Retired
Thomas W. Spence	National Science Foundation
Peter L. Spencer	U.S. House of Representatives
Elliott C. Spiker	Retired
Eliot Spitzer	State of New York Office of the Attorney General
Martin A. Spitzer	House Science Committee
Michael S. Spranger	University of Florida
Bill Sprigg	University of Arizona
Margaret F. Spring	U.S. Senate Commerce Committee
Everett P. Springer	Los Alamos National Laboratory
Jordan P. St. John	National Oceanic and Atmospheric Administration
Judson E. Stailey	NASA Goddard Space Flight Center
Detlef Stammer	Scripps Institution of Oceanography, UCSD
John M. Stamos	U.S. Department of Energy
Carroll L. Stang	National Weather Service Office of Science and Technology
Diane Stanitski-Martin	Shippensburg University, PA
Carl P. Staton	National Oceanic and Atmospheric Administration/CIO
Amanda C. Staudt	The National Academies
Eugene Steadman, Jr.	CELANESE
Konstantinos Stefanidis	NASA/Goddard Space Flight Center
Will Steffen	IGBP: International Geosphere-Biosphere Programme
David E. Steitz	National Aeronautics and Space Administration
Sue P. Stendebach	National Science Foundation
Pamela L. Stephens	National Science Foundation
Louis T. Steyaert	U.S. Geological Survey
Raphaela Stimmelmayr	Tanana Chiefs Conference, Inc.
Alexander R. Stine	Massachusetts Institute of Technology
Bryce J. Stokes	USDA Forest Service
Carrie Stokes	U.S. Agency for International Development
Gerald M. Stokes	Joint Global Change Research Institute
Douglas H. Stone	American Meteorological Society
John M.R. Stone	Environment Canada
William E. Stoney	Mitretek Systems
Ronald J. Stouffer	NOAA/Geophysical Fluid Dynamics Laboratory
Greg Stover	NASA Langley Research Center
Tana L. Stratton	Department of Foreign Affairs and International Trade
Alan E. Strong	NOAA/National Environmental Satellite, Data, and Information Service
Chris Struble	Software Engineer
Jeffrey A. Stuart	National Weather Service
Max J. Suarez	NASA/Goddard Space Flight Center
Susan E. Subak	University of East Anglia
Carla C. Sullivan	National Oceanic and Atmospheric Administration
Charles Sun	National Oceanic and Atmospheric Administration
Shan Sun	NASA Goddard Institute for Space Studies
S.S. Sundarvel	Pondicherry University
Eric T. Sundquist	U.S. Geological Survey
Nicholas A. Sundt	Climate Change Science Program Office
Terry Surles	California Energy Commission
Jon Sutinen	University of Rhode Island
Jan A. Suurland	Royal Netherlands Embassy
Freyr Sverrisson	Independent Energy Consultant
Lea E. Swanson	Global Environment & Technology Foundation
William Sydeman	PRBO Conservation Science
Gregory H. Symmes	National Academies
Keiko Takahashi	Earth Simulator Center
Taro Takahashi	Lamont-Doherty Earth Observatory, Columbia University
Eugene S. Takle	Iowa State University
Pieter Tans	NOAA Climate Monitoring and Diagnostics Laboratory
Jay J. Tanski	State University of New York
Leland Tarnay	NASA Earth System Modeling Framework Advisory Board/National Park Service
Dan Tarpley	NOAA/National Environmental Satellite, Data, and Information Service
John Taylor	Argonne National Laboratory
Phillip R. Taylor	National Science Foundation
Kathy A. Tedesco	NOAA Office of Global Programs
Miguel J. C. A. Tenreiro	U.L.H.T.
Angel R. Terán	National Weather Service
Maxime J. Thibon	Consulate General of France
Mark Thiemens	University of California, San Diego
Alan R. Thomas	World Meteorological Organization (WMO)
Julie E. Thomas	DOI/National Park Service
Elvia H. Thompson	National Aeronautics and Space Administration
Louisa R. Thompson	Maryland Native Plant Society
Peter Thompson	NOAA/SEFSC
Elizabeth Thorndike	Center for Environmental Information
Carolyn Thoroughgood	University of Delaware
Alan J. Thorpe	University of Reading
Sidney Thurston	National Oceanic and Atmospheric Administration
James G. Titus	U.S. Environmental Protection Agency
Andreas Tjernshaugen	CICERO
James F. Todd	National Oceanic and Atmospheric Administration
Sean P. Todd	Fox Potomac Resources LLC
Christine Todd-Whitman	Administrator, US Environmental Protection Agency
Pamela L. Tomski	EES Group, Ltd.
John C. Topping	Climate Institute
Margaret S. Torn	Lawrence Berkeley Lab/UCB
Michael P. Totten	Conservation International
John R. Townshend	University of Maryland
Charles C. Trees	National Aeronautics and Space Administration
Kevin E. Trenberth	National Center for Atmospheric Research
Thomas Triller	German Embassy
Dennis A. Trout	Retired
Juli M. Trtanj	University Corporation for Atmospheric Research
Paul D. Try	International GEWEX Project Office
Lucia S. Tsaoussi	National Aeronautics and Space Administration
Nancy C. Tuchman	National Science Foundation
Diane M. Turchetta	U.S. Department of Transportation
Karl K. Turekian	Yale University
Vaughan C. Turekian	U.S. State Department
Kenneth W. Turgeon	U.S. Commission on Ocean Policy
William T. Turnbull	NOAA/CIO
Kelly M. Turner	National Oceanic and Atmospheric Administration
William W. Turner	National Aeronautics and Space Administration
Alexander Tuyahov	National Aeronautics and Space Administration
Paul F. Twitchell	International GEWEX Project Office
Henry Tyrrell	U.S. Department of Agriculture
Michael Uhart	National Oceanic and Atmospheric Administration
Deborah P. Underwood	North Carolina A&T State University
Sushel Unninayar	National Aeronautics and Space Administration
Ana L. Unruh	Office of Rep. Edward Markey
Lall Upmanu	Columbia University
Deanne R. Upson	Teletrips
David P. Urbanski	Air Force Combat Climatology Center
Susan Ustin	Department of Land, Air, and Water Resource
Arthur C. Vailas	University of Houston
Francisco P.J. Valero	Scripps Institution of Oceanography University of California, San Diego
Azita Valinia	NASA/Goddard Space Flight Center
Deborah G. Vane	Jet Propulsion Laboratory
Lelia B. Vann	NASA Langley Research Center
Dalia E. Varanka	U.S. Geological Survey
Lisa Farrow Vaughan	National Oceanic and Atmospheric Administration
Robert Venezia	National Aeronautics and Space Administration
David J. Verardo	National Science Foundation
Michael Verkouteren	National Institute of Standards and Technology
Hans J.H. Verolme	British Embassy
Konstantin Vinnikov	University of Maryland
Hassan Virji	START Secretariat
Martin Visbeck	Lamont-Doherty Earth Observatory
Stephen M. Volz	National Aeronautics and Space Administration
Thomas H. Vonder Haar	Cooperative Institute for Research in the Atmosphere
Richard Wagener	Brookhaven National Laboratory
David L. Wagger	Independent Researcher
Frederic H. Wagner	Utah State University
Thomas W. Wagner	University of Michigan
Cameron Wake	University of New Hampshire
Shelby E. Walker	National Science Foundation
Margaret K. Walsh	ICF Consulting
John Walsh	University of Alaska Fairbanks
Chris Walvoord	National Environmental Trust
Bin Wang	University of Hawaii
Julian X.L. Wang	Air Resources Laboratory
Rik Wanninkhof	NOAA/AOML
James T. Waples	University of Wisconsin-Milwaukee/Great Lakes WATER Institute
M. Neil Ward	International Research Institute for Climate Prediction (IRI)
Morris (Bud) A. Ward	Moris A. Ward, Inc.

David A. Warrilow	UK Department for Environment, Food and Rural Affairs
Warren M. Washington	National Center for Atmospheric Research
Lewis T. Waters	Consultant
Harlan L. Watson	U.S. Department of State
Kathy L. Watson	NOAA, Office of Global Programs
Thomas B. Watson	National Oceanic and Atmospheric Administration
Mark P. Weadon	U.S. Air Force
John W. Weatherly	Cold Regions Research Lab, ERDC, US Army Corps of Engineers
Ronald L. S. Weaver	National Snow and Ice Data Center
Robert S. Webb	NOAA/OAR/Climate Diagnostics Center
Elke U. Weber	Columbia University
Larry H. Weber	National Science Foundation
Ted Weber	Chesapeake and Coastal Watershed Service, Maryland Department of Natural Resources
Eric Webster	United States House of Representatives
Michael F. Wehner	Lawrence Berkeley National Laboratory
Rodney Weiher	National Oceanic and Atmospheric Administration
Allan M. Weiner	Harris Corporation
Joseph M. Welch	NOAA/National Ocean Service
Gunter Weller	University of Alaska Fairbanks
Robert A. Weller	Woods Hole Oceanographic Institution
Mark Weltz	USDA/Agricultural Research Service
Gerd Wendler	University of Alaska Fairbanks
Frank J. Wentz	Remote Sensing Systems
Carol A. Werner	Environmental and Energy Study Institute
Jon Werner	U.S. Department of Agriculture
Jason West	AAAS Environmental Fellow
Jordan M. West	U.S. Environmental Protection Agency
June M. Whelan	National Petrochemical and Refiners Association
Elizabeth A. White	National Oceanic and Atmospheric Administration
James C. White	Center for Environmental Information
Robert M. White	Washington Advisory Group
Jeff Whitlow	U.S. Environmental Protection Agency
Carol E. Whitman	National Rural Electric Cooperative Association
Gene Whitney	Office of Science and Technology Policy
Diane E. Wickland	National Aeronautics and Space Administration
Bruce A. Wielicki	NASA Langley Research Center
John Wiener	Independent Reviewer
Tom M.L. Wigley	UCAR, WORI, Acacia Project
Mark Wigmosta	Pacific Northwest National Laboratory
Thomas J. Wilbanks	Oak Ridge National Laboratory
George T. Wilcox	American Meteorological Society
Harold Wilhite	University of Oslo
Richard R. Wilk	Indiana University
Diana Wilkins	UK Department for Environment, Food and Rural Affairs
Debra A. Willard	U.S. Geological Survey
Sean R. Willard	NOAA Climate Office
Ted Z. Willard	NASA Programs/CSC
Allen Williams	Illinois State Water Survey
Darrel L. Williams	NASA Goddard Space Flight Center
Elizabeth O. Williams	National Aeronautics and Space Administration
Gregory J. Williams	National Aeronautics and Space Administration
Larry J. Williams	Electric Power Research Institute

Richard S. Williams, Jr.	U.S. Geological Survey
Samuel P. Williamson	NOAA/Office of the Federal Coordinator for Meteorology
Stanley Wilson	Department of Commerce
Doug Wilson	National Oceanic and Atmospheric Administration
Gary P. Wilson	Ball Aerospace and Technologies Corp.
Jim Wilson	University of Dublin
Tyrone P. Wilson	U.S. Geological Survey
David M. Winker	NASA Langley Research Center
Julie A. Winkler	Michigan State University
Darrell A. Winner	U.S. Environmental Protection Agency
Robert S. Winokur	Earth Satellite Corporation (EarthSat)
Derek Winstanley	Illinois State Water Survey
Creighton D. Wirick	Brookhaven National Laboratory
Warren Wiscombe	NASA Goddard Space Flight Center
Gregory W. Withee	DOC/NOAA/NESDIS
James M. Witting	Unaffiliated
Steve Wittrig	BP Amoco Chemicals Company
Steven C. Wofsy	Harvard University
David E. Wojick	Climatechangedebate.org
Henry Wolf	George Mason University School of Computational Science
David W. Wolfe	Cornell University
George Wolff	General Motors Corporation
Kevin R. Wood	National Oceanic and Atmospheric Administration
George Wooddell	University of Louisiana at Lafayette
Ginny L. Worrest	United States Senate
Robert C. Worrest	U.S. Global Change Research Information Office (GCRIO)
Darlene Wright	Tanana Chiefs Conference, Inc.
Xiangqian Wu	DOC/NESDIS/Office of Research and Application
Stan D. Wullschleger	Oak Ridge National Laboratory
Annie Wyndham	Independent Reviewer
David Yap	Ontario Ministry of the Environment
Brent Yarnal	Pennsylvania State University
Jim Yoder	National Science Foundation
Shira Yoffe	U.S. Department of State
Abby M. Young	International Council for Local Environmental Initiatives
Michael T. Young	Short and Associates
Barbara G. Yuhas	International City/County Management Association
Cheryl L. Yuhas	National Aeronautics and Space Administration
Scott A. Yuknis	Meteorlogix
Bernard Zak	Sandia National Laboratory
Rahul A. Zaveri	Pacific Northwest National Laboratory
Stephen E. Zebiak	NASA Earth System Modeling Framework Advisory Board/Int'l Research Institute for Climate Prediction
Steve Zebiak	NASA Earth System Modeling Framework Advisory Board
Richard Zepp	U.S. Environmental Protection Agency
Chris Zganjar	The Nature Conservancy
Renyi Zhang	Texas A&M University
Jiayu Zhou	NOAA/National Weather Service
Herman B. Zimmerman	National Science Foundation
Patrick R. Zimmerman	South Dakota School of Mines and Technology
Rae Zimmerman	New York University
Mark A. Zito	U.S. Department of Agriculture
Francis Zwiers	Canadian Centre for Climate Modelling and Analysis

B ANNEX

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ANNEX C

Graphics and Photography Source Information

Only Strategic Plan graphics with more detailed captions and/or source information have been included in this annex—hence the gaps in figure numbering.

Figure 3-2: Schematic illustrating a comparison among several factors that influence Earth's climate. These factors can be broadly compared using the concept of radiative forcing. The principal forcings arise from changes in atmospheric composition of gases, aerosols, clouds, land use, and solar output. The rectangular bars represent best estimates of the contributions of these forcings, some of which yield warming and some cooling. The forcing contributions are shown for different aerosol types and for those produced or emitted by aviation. The indirect effect shown for aerosols is their effect on the size and number of cloud droplets. A second indirect effect, namely the effect on cloud lifetime, which would lead to a negative forcing, is not shown. The vertical line about the rectangular bars indicates the range of estimates. A vertical line without a rectangular bar denotes a forcing for which no best estimate can be given owing to large uncertainties. Aerosol forcings are generally not uniform over the globe, unlike those of well-mixed greenhouse gases (e.g., CO_2). A more detailed description of this schematic and its interpretation is provided by the IPCC (IPCC, 2001a,d).

Figure 3-3: Schematic of the processes that cause the formation and transformation of aerosol particles in the atmosphere. Aerosols can be emitted directly into the atmosphere or be formed there from the emissions of gaseous precursors. Particles grow by condensation of gases and by coagulation with other particles. Sizes of important atmospheric particles vary over several orders of magnitude. Reactions can occur on the surfaces of particles that can alter the composition of the particle or the surrounding atmosphere. Particles can also grow to become cloud droplets or ice crystals. Particle number and composition can influence the formation and radiative characteristics of clouds. Particles scavenge a variety of gases from the atmosphere and are eventually removed from the atmosphere by wet or dry deposition to Earth's surface. Graphic adapted from: Heintzenberg, J., F. Raes, and S.E. Schwartz, 2003: Tropospheric aerosols. In: *Atmospheric Chemistry in a Changing World: An Integration and Synthesis of a Decade of Tropospheric Chemistry Research* [Brasseur, G.P., R.G. Prinn, and A.A.P. Pszenny (eds)]. Springer-Verlag, New York, NY, USA, pp. 125-156.

Figure 3-4: Schematic illustrating the estimated recovery of stratospheric ozone in the coming decades. Observations show the decline of global total ozone (top panel) and minimum values of total ozone over Antarctica (lower panel) beginning in 1980. In the future, the amounts of chlorine- and bromine-containing gases are expected to further diminish in the stratosphere as a result of international compliance with the Montreal Protocol and, in response, ozone amounts are expected to recover significantly toward values observed in 1980 and before. The range of recovery times shown is based on predictions of atmospheric models. The model results differ because they have different assumptions about the composition and meteorology of the future stratosphere. The research needs as outlined in Section 3.4 address reducing the range of uncertainty in ozone recovery estimates. More detail on the recovery of stratospheric ozone is provided in the *Scientific Assessment of Ozone Depletion: 2002* (WMO, 2003).

Figure 4-1: The Earth's surface temperature has increased by about 0.6°C over the record of direct temperature measurements (1860-2000, top panel)—a rise that is unprecedented, at least based on proxy temperature data for the Northern Hemisphere, over the last millennium (bottom panel). In the top panel the departures from global mean surface temperature are shown year-by-year (red bars with *very likely* ranges as thin black line) and approximately decade-by-decade (continuous red line). Analyses take into account data gaps, random instrumental errors and uncertainties, uncertainties in bias corrections in the ocean surface temperature data, and also uncertainties in adjustments for urbanization over the land. The lower panel merges proxy data (year-by-year blue line with *very likely* ranges as gray band, 50-year-average purple line) and the direct temperature measurements (red line) for the Northern Hemisphere. The proxy data consist of tree rings, corals, ice cores, and historical records that have been calibrated against thermometer data. Insufficient data are available to assess such changes in the Southern Hemisphere. Source: IPCC (2001d).

Figure 4-2: Simulating the Earth's temperature variations and comparing the results to the measured changes can provide insight into the underlying causes of the major changes. A climate model can be used to simulate the temperature changes that occur from both natural and anthropogenic causes. The simulations represented by the band in (a) were done with only natural forcings: solar variation and volcanic activity. Those encompassed by the band in (b) were done with anthropogenic forcings: greenhouse gases and an estimate of sulfate aerosols. Those encompassed by the band in (c) were done with both natural and anthropogenic forcings included. From (b), it can be seen that the inclusion of anthropogenic forcings provides a plausible explanation for a substantial part of the observed temperature changes over the past century, but the best match with observations is obtained in (c) when both natural and anthropogenic factors are included. These results show that the forcings included are sufficient to explain the observed changes, but do not exclude the possibility that other forcings may also have contributed. Similar results to those in (b) are obtained with other models with anthropogenic forcing. Source: IPCC (2001d).

Figure 5-1: Conceptualization of the global water cycle and its interactions with all other components of the Earth-climate system. The figure illustrates the transport and transformation of water within the Earth system, and the distribution of freshwater over the Earth's surface. The cycling of water in the Earth system involves water in all three of its phases: solid (snow, ice), liquid (precipitation, the oceans, land water bodies, groundwater, rivers/lakes, etc.), and gaseous (atmospheric water vapor, fluxes between the atmosphere and the land surface in the form of evaporation, evapotranspiration from vegetation, and evaporation from the oceans). The water cycle operates on a continuum of time and space scales and exchanges large amounts of energy as water undergoes phase changes and is moved dynamically from one part of the Earth system to another. The energy exchanges involving water in all its phases include interactions with radiation and dynamics of the atmospheric circulation; together, they intertwine the water and energy cycles of the Earth system. Source: Paul Houser and Adam Schlosser, NASA GSFC.

Figure 5-3: Observational evidence showing the effect of aerosols on cloud formation and precipitation processes. TRMM Visible and Infrared Scanner (VIRS) paints yellow pollution tracks in the clouds over South Australia due to reduced droplet size (Area 2). The TRMM Precipitation Radar shows precipitation as white patches only outside the pollution tracks (Areas 1 and 3). TRMM Microwave Imager (TMI) data (not shown) indicated ample water in the polluted clouds. The effective droplet radius retrieved by TRMM VIRS does not exceed 14 μm in polluted clouds within Area 2, lending credence to the hypothesis that pollution causes effective cloud water droplet size to drop below this precipitation threshold. Source: NASA GSFC (research results from Daniel Rosenfield, The Hebrew University of Jerusalem).

Figure 5-5: Factors affecting the predictability of precipitation in summer (June, July, and August). The influence on the predictability of precipitation is shown for (a) sea surface temperature (SST) alone and (b) both SST and land surface moisture state. The values of the predictability index were determined through an analysis of an ensemble of multi-decade atmospheric general circulation model simulations. The plotted precipitation predictability index varies from 0 to 1. Areas with values close to 1 indicate that precipitation is strongly determined by SST (and/or soil moisture), and is thus "predictable" on seasonal time scales if the SSTs (and soil moisture) themselves are predictable; whereas values close to 0 indicate that a foreknowledge of these fields may not lead to useful seasonal precipitation predictions. In the latter areas (values close to 0), nonlinear turbulent atmospheric processes would appear to dominate over SST (or soil moisture) control. Source: R.D. Koster, M. Suarez, and M. Heiser, NASA.

Figure 6-2: Forest cover increase and abandonment of marginal agricultural lands in Grand Traverse County, Michigan. Analyses of the upper midwestern United States show an increase in forest cover since 1970. This increase results in greater carbon sequestration because forest cover is primarily replacing pastures and croplands. The left image illustrates land-use change by parcel interpreted from aerial photographs. Green colors are forest, beige/yellow agriculture, and pink color residential development. The right image is forest cover from Landsat MSS satellite images. Green is forest and light yellow not forest. The images illustrate the forest regrowth that is occurring across the Upper Midwest concurrently with parcel fragmentation, agricultural abandonment, and rural residential development. Source: School of Natural Resources and Environment, University of Michigan.

Figure 6-3: Land-cover change in eastern U.S. ecosystems, 1973-2000. An analysis of land-use and land-cover change in eastern U.S. ecological regions provides evidence of distinctive regional variation in the rates and characteristics of changes. USGS, in cooperation with EPA and NASA, used Landsat images from 5 years (1973, 1980, 1986, 1992, and 2000) to map the rates of ecoregion change in each time interval (portrayed in ecoregion color), and the primary land-cover transformations (portrayed in the pie charts). Land cover of approximately 20 percent of the land in the Mid-Atlantic Coastal Plain and Southeastern Plain changed during the nearly 30-year period due to the rapid, cyclic harvesting and replanting of forests. The adjacent Piedmont region also showed substantial change in forest cover. Urbanization was the dominant conversion in the Northern Piedmont and Atlantic Coast Pine Barrens. The two Appalachian regions studied (Blue Ridge and North Central Appalachia) had comparatively low overall change, with the primary transformations being urban development and forest conversion, respectively. Source: USGS EROS Data Center.

Figure 6-4: The map on the left is a true reflection of land use types as of 1994 in the seven-county area of central Maryland and the map on the right is the predicted distribution of land use types based on a 'polycentric' city model. Comparing the two maps, one sees remarkable similarity in commercial, high, and medium densities, but disagreement in the low density residential category. This finding is important because it is this fragmented, low density residential development that is consuming a disproportionate amount of open space and is causing high public service costs and possibly large environmental costs. Models with better projections of this type of development will better support development-related decisionmaking. Work is being done with grants from NASA to develop models that can predict this type of development. Source: Nancy Bockstael, University of Maryland.

Figure 6-5: Increasing atmospheric carbon dioxide (CO_2), climatic variation, and fire disturbance play substantial roles in the historical carbon dynamics of Alaska. Analyses of stand-age distribution in Alaska indicate that fire has likely become less frequent compared to the first half of the 20th century. The contemporary stand-age distribution of forest in interior Alaska is reproduced by assuming that fire return interval (FRI) prior to 1950 was 55% of FRI since 1950. Logging associated with the gold rush appears to be responsible for the discrepancy between observed and simulated for stands that are approximately 100 years old. Application of the Terrestrial Ecosystem Model indicates that regrowth under a less frequent fire regime leads to substantial carbon storage in the state between 1980 and 1989. Source: David McGuire and Dave Verbyla, University of Alaska, Fairbanks.

Figure 7-1: The global carbon cycle. Storages [in petagrams carbon (PgC)] and fluxes (in PgC yr^{-1}) of carbon for the major components of the Earth's carbon cycle are estimated for the 1990s. The carbon storage and flux figures are from the IPCC's Third Assessment

Report (IPCC, 2001a). Carbon is exchanged among the atmosphere, oceans, and land, and, more slowly, with sediments and sedimentary rocks. The natural cycling of carbon within the Earth system is fundamental to the capture and storage of the energy that fuels life and human societies and to regulating the climate of the planet. In this figure, the components are simplified and average values are presented. There is strong evidence of significant year-to-year fluctuations in many of the key fluxes (see, e.g., Figure 7-3), which this static view cannot portray. Source: Graphic courtesy of David Schimel and Lisa Dilling, NCAR; it is updated from UCAR, 2000: *The Carbon Cycle* [Wigley T. and D. Schimel (eds.)]. Cambridge University Press, New York, NY, 292 pp. Figure update courtesy of D. Schimel and L. Dilling, NCAR.

Figure 7-3: Rate of increase of atmospheric CO_2 and fossil-fuel emissions. The upper curve shows the annual global amount of carbon added to the atmosphere (in PgC yr^{-1}) in the form of CO_2 by burning coal, oil, and natural gas. The strongly varying curve shows the annual rate of increase of carbon in the atmosphere based on measurements, originally at Mauna Loa Observatory, and later at a global network of monitoring sites. The difference between the two curves represents the total net amount of CO_2 absorbed each year by the oceans and terrestrial ecosystems. Source: CMDL, 2002: *Climate Monitoring and Diagnostics Laboratory Summary Report 26, 2000-2001* [King, D.B., et al. (eds.)]. Climate Monitoring and Diagnostics Laboratory, Boulder, Colorado.

Figure 7-4: Map showing the climatological mean annual distribution of net sea-air CO_2 flux (moles CO_2 m^{-2} yr^{-1}) over the global oceans in a reference year 1995. The blue-magenta areas indicate that the ocean is a sink for atmospheric CO_2, and the yellow-red areas, a source. The annual CO_2 uptake by the oceans has been estimated to be in the range of 1.5 to 2.1 PgC. This map has been constructed on the basis of about 1.4 million measurements of partial pressure of CO_2 (pCO_2) in surface waters made during the past 40 years. The sea-air pCO_2 difference is computed using atmospheric CO_2 concentrations from the GLOBALVIEW-CO_2 data set compiled by CMDL/NOAA. The monthly net sea-air CO_2 flux in each 4° x 5° pixel area has been estimated using the NCEP 41-mean wind speed at 10 meters. Source: After Takahashi et al. (2002). Reference: Takahashi, T., Sutherland, S.C., Sweeney, C., Poison, A., Metzl, N., Tilbrook, B., Bates, N., Wanninkhof, R., Feely, R.A., Sabine, C., Olafsson, J., and Nojiri, Y., 2002: Global sea-air CO_2 flux based on climatological surface ocean pCO_2, and seasonal biological and temperature effects. *Deep Sea Research II*, **49**, 1601-1622.

Figure 7-5: Soil processes influence carbon sequestration and transport. The dynamics of carbon transformations and transport in soil are complex and can result in sequestration in the soil as organic matter or in groundwater as dissolved carbonates, increased emissions of CO_2 to the atmosphere, or export of carbon in various forms into aquatic systems. Source: DOE, 1999: *Carbon Sequestration Research and Development* [Reichle, D., J. Houghton, B. Kane, J. Ekmann (eds.), S. Benson, J. Clarke, R. Dahlman, G. Hendrey, H. Herzog, J. Hunter-Cevera, G. Jacobs, R. Judkins, J. Ogden, A. Palmisano, R. Socolow, J. Stringer, T. Surles, A. Wolsky, N. Woodward, and M. York]. Department of Energy, Oak Ridge, TN.

Figure 9-2: Possible pathways of public health impacts from climate change. Source: Adapted from Patz and Balbus, 1996: Methods for assessing public health vulnerability to climate change. *Climate Research*, **6**, 113-125.

Figure 12-1a: Three-dimensional representation of the latitudinal distribution of atmospheric carbon dioxide (CO_2) in the marine boundary layer. The data are from the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) cooperative air sampling network. The surface represents data smoothed in time and latitude. Source: Pieter Tans and Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado.

Figure 12-1b: The NOAA CMDL Carbon Cycle Greenhouse Gases group operates four measurement programs. *In situ* measurements are made at the CMDL baseline observatories: Barrow, Alaska; Mauna Loa, Hawaii; Tutuila, American Samoa; and South Pole, Antarctica. The cooperative air sampling network includes samples from fixed sites and commercial ships. Measurements from tall towers and aircraft began in 1992. Presently, atmospheric CO_2, methane, carbon monoxide, hydrogen, nitrous oxide, sulfur hexafluoride, and the stable isotopes of CO_2 and methane are measured. Source: Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado.

Figure 12-2: The U.S. Geological Survey (USGS) Hydro-Climatic Data Network (HCDN) was compiled in 1988 and included 854 gauges that were active and had at least 36 years of record. Stations that are still active are shown in green. Stations discontinued since 1988 are shown in red. These stations would have at least 50 years of record as of 2002 if they had been kept in operation. HCDN is a subset of the USGS stream gauge network that includes continuous long-record stations that have relatively accurate records and are relatively free of overt regulation or diversions. Source: William Kirby, Global Hydroclimatology Program, USGS.

Appendix 12.1: Adapted from Unninayar, S. and R.A. Schiffer, 2002: Earth Observing Systems. In: *Encyclopedia of Global Environmental Change, Volume 1: The Earth System: Physical and Chemical Dimensions of Global Environmental Change* [MacCracken, M.C. and J. S. Perry (eds.)]. John Wiley & Sons, Ltd, Chichester, United Kingdom, pp. 61-81.

D ANNEX

Glossary of Terms

Acclimatization
The physiological adaptation to climatic variations. Biologically, acclimation is a physiological (phenotypic) adjustment by an organism to an environmental change (distinguished from *adaptation*, which is genotypic).

Adaptation
Adjustment in natural or *human systems* to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Adaptive capacity
The ability of a *system* to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Adaptive management
Operational decisions principally for managing entities that are influenced by *climate variability* and *change*.

Adaptive management decisions
Operational decisions, principally for managing entities that are influenced by *climate variability* and *change*. These decisions can apply to the management of infrastructure (e.g., a waste water treatment plant), the integrated management of a natural resource (e.g., a watershed), or the operation of societal response mechanisms (e.g., health alerts, water restrictions). *Adaptive management* operates within existing policy frameworks or uses existing infrastructure, and the decisions usually occur on time scales of a year or less. See *policy decisions*.

Aerosols
Airborne solid or liquid particles, with a typical size between 0.01 and 10 μm that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence *climate* in two ways: directly through scattering and absorbing radiation, and indirectly through acting as condensation nuclei for cloud formation or modifying the optical properties and lifetime of clouds.

Albedo
The fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow-covered surfaces have a high albedo; the albedo of soil ranges from high to low; vegetation-covered surfaces and oceans have a low albedo. The Earth's albedo varies mainly through varying cloudiness, snow, ice, leaf area, and *land-cover* changes.

Assessments
Processes that involve analyzing and evaluating the state of scientific knowledge (and the associated degree of scientific certainty) and, in interaction with users, developing information applicable to a particular set of issues or decisions.

Atmosphere
The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases such as argon (0.93% volume mixing ratio), helium, and radiatively active *greenhouse gases* such as carbon dioxide (0.035% volume mixing ratio) and *ozone*. In addition, the atmosphere contains water vapor, whose amount is highly variable but typically 1% volume mixing ratio. The atmosphere also contains clouds and *aerosols*.

Attribution
See *detection and attribution*.

Biosphere
The part of the Earth system comprising all *ecosystems* and living organisms in the atmosphere, on land (terrestrial biosphere), or in the oceans (marine biosphere), including derived dead organic matter such as litter, soil organic matter, and oceanic detritus.

Carbon cycle
The term used to describe the flow of carbon [in various forms such as carbon dioxide (CO_2), organic matter, and carbonates] through the atmosphere, ocean, terrestrial biosphere, and lithosphere.

Climate
Climate can be defined as the statistical description in terms of the mean and variability of relevant measures of the atmosphere-ocean system over periods of time ranging from weeks to thousands or millions of years.

Climate change
A statistically significant variation in either the mean state of the *climate* or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or to external forcing, including changes in solar radiation and volcanic eruptions, or to persistent human-induced changes in atmospheric composition or in *land use*. See also *climate variability*.

Climate feedback
An interaction among processes in the *climate system* in which a change in one process triggers a secondary process that influences the first one. A positive feedback intensifies the change in the original process, and a negative feedback reduces it.

Climate model
A numerical representation of the *climate system* based on

*Italicized words or phrases within definitions cross-reference to other glossary terms.

the physical, chemical, and biological properties of its components, their interactions and *feedback* processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity—that is, for any one component or combination of components a "hierarchy" of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical *parametrizations* are involved. Coupled atmosphere/ocean/sea-ice general circulation models provide a comprehensive representation of the climate system. There is an evolution towards more complex models with active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate *predictions*.

Climate scenario
A plausible and often simplified representation of the future *climate*, based on an internally consistent set of climatological relationships, that has been constructed for explicit use in investigating the potential consequences of anthropogenic *climate change*, often serving as input to impact models. Climate *projections* often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. A "climate change scenario" is the difference between a climate scenario and the current climate.

Climate sensitivity
In IPCC assessments, "equilibrium climate sensitivity" refers to the equilibrium change in global mean surface temperature following a doubling of the atmospheric (equivalent) CO_2 concentration. More generally, equilibrium climate sensitivity refers to the equilibrium change in surface air temperature following a unit change in radiative forcing (°C/Wm^{-2}). In practice, the evaluation of the equilibrium climate sensitivity requires very long simulations with coupled general circulation models. The "effective climate sensitivity" is a related measure that circumvents this requirement. It is evaluated from model output for evolving non-equilibrium conditions. It is a measure of the strengths of the *feedbacks* at a particular time and may vary with forcing history and climate state. See also *climate model*.

Climate system
The highly complex system consisting of five major components: the *atmosphere*, the *hydrosphere*, the *cryosphere*, the land surface, and the *biosphere*, and the interactions among them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations, and human-induced forcings such as the changing composition of the atmosphere and *land-use change*.

Climate variability
Variations in the mean state and other statistics of climatic features on temporal and spatial scales beyond those of individual *weather* events. These often are due to internal processes within the *climate system*. Examples of cyclical forms of climate variability include *El Niño-Southern Oscillation*, the *North Atlantic Oscillation* (NAO), and Pacific Decadal Variability (PDV). See also *climate change*.

Critical dependencies
Topics within the Strategic Plan for which progress in one research element is only possible if related research is first completed in other areas.

Cryosphere
The component of the *climate system* consisting of all snow, ice, and permafrost on and beneath the surface of the Earth and ocean.

Decision support
The provision of timely and useful information that addresses specific questions. See also *decision support resources*.

Decision support resources
The set of *observations*, analyses, interdisciplinary research products, communication mechanisms, and operational services that provide timely and useful information to address questions confronting policymakers, resource managers, and other users. See also *decision support*.

Detection and attribution
Climate varies continually on all *time scales*. Detection of *climate change* is the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change. Attribution of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence.

Ecosystem
A community (i.e., an assemblage of populations of plants, animals, fungi, and microorganisms that live in an environment and interact with one another, forming together a distinctive living system with its own composition, structure, environmental relations, development, and function) and its environment treated together as a functional system of complementary relationships and transfer and circulation of energy and matter.

Ecosystem goods and services
Through numerous biological, chemical, and physical processes, ecosystems provide both goods and services to humanity. Goods include food, feed, fiber, fuel, pharmaceutical products, and wildlife. Services include maintenance of hydrologic cycles, cleansing of water and air, regulation of climate and weather, storage and cycling of nutrients, and provision of beauty and inspiration. Many goods pass through markets, but services rarely do.

El Niño-Southern Oscillation (ENSO)
El Niño, in its original sense, is a warmwater current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. This oceanic event is associated with a fluctuation of the intertropical surface pressure pattern and circulation in the Indian and Pacific Oceans, called the Southern Oscillation. This coupled atmosphere-ocean phenomenon is collectively known as El Niño-Southern Oscillation. During an El Niño event, the prevailing trade winds weaken and the equatorial countercurrent strengthens, causing warm surface waters in the Indonesian area to flow eastward to overlie the cold waters of the Peru current. This event has great impact on the wind, sea surface temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the

Pacific region and in many other parts of the world. The opposite of an El Niño event is called La Niña.

Emissions
In the *climate change* context, emissions refer to the release of *greenhouse gases* and/or their precursors and *aerosols* into the atmosphere over a specified area and period of time.

Emissions scenario
A plausible representation of the future development of *emissions* of substances that are potentially radiatively active (e.g., *greenhouse gases*, *aerosols*), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change) and their key relationships. Concentration scenarios, derived from emissions scenarios, are used as input into a *climate model* to compute *climate projections*.

Evapotranspiration
The combined process of evaporation from the Earth's surface and transpiration from vegetation.

External forcing
See *climate system*.

Extreme weather event
An extreme weather event is an event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called extreme weather may vary from place to place. An extreme *climate* event is an average of a number of weather events over a certain period of time, an average which is itself extreme (e.g., rainfall over a season).

Feedback
See *climate feedback*.

Full carbon accounting
Complete accounting of all carbon stocks and changes in them for all carbon pools related to a given spatial area in a given time period.

Global change
Changes in the global environment (including alterations in *climate*, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life (from the Global Change Research Act of 1990, PL 101-606).

Global change research
Study, monitoring, *assessment*, prediction, and information management activities to describe and understand the interactive physical, chemical, and biological processes that regulate the total Earth system; the unique environment that the Earth provides for life; changes that are occurring in the Earth system; and the manner in which such system, environment, and changes are influenced by human actions.

Greenhouse gas
Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol.

Human system
Any system in which human organizations play a major role. Often, but not always, the term is synonymous with "society" or "social system" (e.g., agricultural system, political system, technological system, economic system).

Hydrosphere
The component of the *climate system* composed of liquid surface and subterranean water, such as oceans, seas, rivers, freshwater lakes, underground water, etc.

(Climate) Impact assessment
The practice of identifying and evaluating the detrimental and beneficial consequences of *climate change* on natural and *human systems*.

(Climate) Impacts
Consequences of *climate change* on natural and *human systems*. Depending on the consideration of *adaptation*, one can distinguish between potential impacts and residual impacts.

- Potential impacts: All impacts that may occur given a projected change in *climate*, without considering adaptation.
- Residual impacts: The impacts of climate change that would occur after adaptation.

Information
Knowledge derived from study, experience, or instruction.

Integrated assessment
A method of analysis that combines results and models from the physical, biological, economic, and social sciences, and the interactions between these components, in a consistent framework, to evaluate the status and the consequences of environmental change and the policy responses to it.

Land cover
The vegetation and artificial built-up materials covering the land surface. This includes areas of vegetation (forests, shrublands, crops, deserts, lawns), bare soil, developed surfaces (paved land, buildings), and wet areas and bodies of water (watercourses, wetlands).

Land use
The total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). The social and economic purposes for which land is managed (e.g., grazing, timber extraction, and conservation).

Land-use change
A change in the use or management of land by humans, which may

lead to a change in land cover. Land cover and land-use change may have an impact on the albedo, evapotranspiration, *sources*, and *sinks* of *greenhouse gases*, or other properties of the *climate system*, and may thus have an impact on *climate*, locally or globally.

Lifetime
Lifetime is a general term used for various *time scales* characterizing the rate of processes affecting the concentration of trace gases. In general, lifetime denotes the average length of time that an atom or molecule spends in a given reservoir, such as the atmosphere or oceans. The following lifetimes may be distinguished:

- "Turnover time" (T) or "atmospheric lifetime" is the ratio of the mass M of a reservoir (e.g., a gaseous compound in the atmosphere) and the total rate of removal S from the reservoir: $T = M/S$. For each removal process separate turnover times can be defined.
- "Adjustment time," "response time," or "perturbation lifetime" (T_a) is the time scale characterizing the decay of an instantaneous pulse input into the reservoir. The term adjustment time is also used to characterize the adjustment of the mass of a reservoir following a step change in the source strength. Half-life or decay constant is used to quantify a first-order exponential decay process. See *response time* for a different definition pertinent to *climate* variations. The term "lifetime" is sometimes used, for simplicity, as a surrogate for "adjustment time."

In simple cases, where the global removal of the compound is directly proportional to the total mass of the reservoir, the adjustment time equals the turnover time: $T = T_a$. An example is CFC-11 which is removed from the atmosphere only by photochemical processes in the *stratosphere*. In more complicated cases, where several reservoirs are involved or where the removal is not proportional to the total mass, the equality $T = T_a$ no longer holds. CO_2 is an extreme example. Its turnover time is only about 4 years because of the rapid exchange between atmosphere and the ocean and terrestrial biota. However, a large part of that CO_2 is returned to the atmosphere within a few years. Thus, the adjustment time of CO_2 in the atmosphere is actually determined by the rate of removal of carbon from the surface layer of the oceans into its deeper layers. Although an approximate value of 100 years may be given for the adjustment time of CO_2 in the atmosphere, the actual adjustment is faster initially and slower later on. In the case of CH_4, the adjustment time is different from the turnover time, because the removal is mainly through a chemical reaction with the hydroxyl radical OH, the concentration of which itself depends on the CH_4 concentration. Therefore the CH_4 removal S is not proportional to its total mass M.

Mitigation (climate change)
An intervention to reduce the causes of change in climate. This could include approaches devised to reduce emissions of greenhouse gases to the atmosphere; to enhance their removal from the atmosphere through storage in geological formations, soils, biomass, or the ocean; or to alter incoming solar radiation through several "geo-engineering" options.

Mitigative capacity
The social, political, and economic structures and conditions that are required for effective *mitigation*.

Monitoring
A scientifically designed system of continuing standardized measurements and observations and the evaluation thereof.

North Atlantic Oscillation (NAO)
The North Atlantic Oscillation consists of opposing variations of barometric pressure near Iceland and near the Azores. On average, a westerly current, between the Icelandic low pressure area and the Azores high pressure area, carries cyclones with their associated frontal systems towards Europe. However, the pressure difference between Iceland and the Azores fluctuates on *time scales* of days to decades, and can be reversed at times. It is the dominant mode of winter climate variability in the North Atlantic region, ranging from central North America to Europe.

Observations
Standardized measurements (either continuing or episodic) of variables in *climate* and related systems.

Parameterization
In *climate models*, this term refers to the technique of representing processes that cannot be explicitly resolved at the spatial or temporal resolution of the model (sub-grid-scale processes), by relationships between the area- or time-averaged effect of such sub-grid-scale processes and the larger scale flow.

Place-based
Related to the locus (regional, sectoral, cultural) of a particular object or action (e.g., place-based decisions).

Planning
A process inherently important for both *policy decisions* and *adaptive management*. It usually occurs in the framework of established or projected policy options.

Policy decisions
Decisions that result in laws, regulations, or other public actions. These decisions are typically made in government settings (federal, state, local) by elected or appointed officials. These decisions, which usually involve balancing competing value issues, can be assisted by—but not specified by—scientific analyses. See *adaptive management decisions*.

Prediction (climate)
A probabilistic description or forecast of a future *climate* outcome based on *observations* of past and current climatological conditions and quantitative models of climate processes (e.g., a prediction of an El Niño event).

Projection (climate)
A description of the response of the *climate system* to an assumed level of future radiative forcing. Changes in radiative forcing may be due to either natural sources (e.g., volcanic emissions) or human-induced causes (e.g., emissions of *greenhouse gases* and *aerosols*, or changes in *land use* and *land cover*). Climate "projections" are distinguished from climate "predictions" in order to emphasize that climate projections depend on *scenarios* of future socioeconomic, technological, and policy developments that may or may not be realized.

Radiative forcing
A process that directly changes the average energy balance of the Earth-atmosphere *system* by affecting the balance between incoming solar radiation and outgoing or "back" radiation. A positive forcing tends to warm the surface of the Earth and a negative forcing tends to cool the surface.

Rapid climate change
The non-linearity of the *climate system* may lead to rapid *climate change*, sometimes called abrupt events or even surprises. Some such abrupt events may be imaginable, such as a dramatic reorganization of the thermohaline circulation, rapid deglaciation, or massive melting of permafrost leading to fast changes in the *carbon cycle*. Others may be truly unexpected, as a consequence of a strong, rapidly changing, forcing of a non-linear system.

Regional reanalysis
The process of "freezing" or holding constant a recent version of a regional climate or weather model with the latest process representations and assimilation capabilities, and rerunning that model with historical satellite and *in situ* data sets to generate products for the period covered by the historic records. This process allows climatological analyses to be carried out using the best consistent data products possible.

Resilience
The ability of an organism or other entity to recover from or to adjust easily to change or other stress.

Response time
The response time or adjustment time is the time needed for the *climate system* or its components to re-equilibrate to a new state, following a forcing resulting from external and internal processes or *feedbacks*. It is very different for various components of the climate system. The response time of the *troposphere* is relatively short, from days to weeks, whereas the *stratosphere* comes into equilibrium on a *time scale* of typically a few months. Due to their large heat capacity, the oceans have a much longer response time, typically decades, but up to centuries or millennia. The response time of the strongly coupled surface-troposphere system is, therefore, slow compared to that of the stratosphere, and mainly determined by the oceans. The biosphere may respond fast (e.g., to droughts), but also very slowly to imposed changes. See *lifetime* for a different definition of response time pertinent to the rate of processes affecting the concentration of trace gases.

Scenario
A coherent description of a potential future situation that serves as input to more detailed analyses or modeling. Scenarios are tools to explore, "if …, then…" statements, and are not *predictions* of or prescriptions for the future. See *climate scenario* and *emissions scenario*.

Sensitivity
Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise). See also *climate sensitivity*.

Sequential decisionmaking
Stepwise decisionmaking aiming to identify short-term strategies in the face of long-term uncertainties, by incorporating additional information over time and making mid-course corrections.

Sequestration
The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of CO_2 from the atmosphere through *land-use change*, afforestation, reforestation, and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of CO_2 from flue gases or from processing fossil fuels to produce hydrogen- and CO_2-rich fractions and long-term storage in underground depleted oil and gas reservoirs, coal seams, and saline aquifers.

Sink
Any process, activity, or mechanism that removes a *greenhouse gas*, an *aerosol*, or a precursor of a greenhouse gas or aerosol from the atmosphere.

Socio-economic potential
The socio-economic potential represents the level of greenhouse gas *mitigation* that would be approached by overcoming social and cultural obstacles to the use of technologies that are cost-effective.

Source
Any process, activity, or mechanism that releases a *greenhouse gas*, an *aerosol*, or a precursor of a greenhouse gas or aerosol into the atmosphere.

Spatial and temporal scales
Climate may vary on a large range of spatial and temporal scales. Spatial scales may range from local (less than 100,000 km^2), through regional (100,000 to 10 million km^2) to continental (10 to 100 million km^2). Temporal scales may range from seasonal to geological (up to hundreds of millions of years).

Stabilization
The achievement of stabilization of atmospheric concentrations of one or more *greenhouse gases*.

Stakeholders
Individuals or groups whose interests (financial, cultural, value-based, or other) are affected by *climate variability*, *climate change*, or options for adapting to or mitigating these phenomena. Stakeholders are important partners with the research community for development of *decision support resources*.

Stratosphere
The highly stratified region of the atmosphere above the *troposphere* extending from about 10 km (ranging from 9 km in high latitudes to 16 km in the tropics on average) to about 50 km.

System
Integration of interrelated, interacting, or interdependent components into a complex whole.

Technology
A piece of equipment or a technique for performing a particular activity.

Technology transfer
The broad set of processes that cover the exchange of knowledge, money, and goods among different *stakeholders* that lead to the spreading of *technology* for adapting to or mitigating *climate change*. As a generic concept, the term is used to encompass both diffusion of technologies and technological cooperation across and within countries.

Time scale
Characteristic time for a process to be expressed. Since many processes exhibit most of their effects early, and then have a long period during which they gradually approach full expression, for the purpose of this report the time scale is numerically defined as the time required for a perturbation in a process to show at least half of its final effect.

Troposphere
The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from 9 km in high latitudes to 16 km in the tropics on average) where clouds and "weather" phenomena occur. In the troposphere, temperatures generally decrease with height.

Uncertainty
An expression of the degree to which a value (e.g., the future state of the *climate system*) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Vulnerability
The degree to which a system is susceptible to, or unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its *sensitivity*, and its *adaptive capacity*.

Weather
The specific condition of the atmosphere at a particular place and time. It is measured in terms of parameters such as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation.

ANNEX E Acronyms, Abbreviations, and Units

ACIA	Arctic Climate Impact Assessment
ACRIM	Active Cavity Radiometer Irradiance Monitor
ACSYS	Arctic Climate System Study
AMIP	Atmospheric Model Intercomparison Project
AMSR	Advanced Microwave Scanning Radiometer
AOSB	Arctic Ocean Sciences Board
APN	Asia-Pacific Network for Global Change Research
AQRS	Air Quality Research Subcommittee
ARM	Atmospheric Radiation Measurement
ASOF	Arctic and Subarctic Ocean Fluxes Study
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP core project)
BER	Biological and Environmental Research
CAP	Climate Action Partnership
CART	Cloud Atmospheric Radiation Testbed
CCCSTI	Committee on Climate Change Science Science and Technology Integration
CCGG	Carbon Cycle Greenhouse Gases
CCRI	Climate Change Research Initiative
CCSM	Community Climate System Model
CCSP	Climate Change Science Program
CCSPO	Climate Change Science Program Office
CCTP	Climate Change Technology Program
CDC	Centers for Disease Control and Prevention
CDR	Climate Data Record
CDST	Climate Data Science Team
CEOP	Coordinated Enhanced Observing Period
CEOS	Committee on Earth Observation Satellites
CEQ	Council on Environmental Quality
CERES	Clouds and the Earth's Radiant Energy System
CFC	chlorofluorocarbon
CGIAR	Consultative Group on International Agricultural Research
CH_3SCH_3	dimethyl sulfide
CH_4	methane
CliC	Climate and Cryosphere
CLIVAR	Climate Variability and Predictability
CMDL	Climate Monitoring and Diagnostics Laboratory
CMI	Common Modeling Infrastructure
CMIP	Coupled Model Intercomparison Project
CO	carbon monoxide
CO_2	carbon dioxide
COLA	Center for Ocean-Land-Atmosphere Studies
CONCAUSA	Central American-United States of America Joint Accord
CPT	Climate Process and Modeling Team
DIF	Directory Interchange Format
DIS	Data and Information System
DL	Digital Library
DMWG	Data Management Working Group
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
DPC	Domestic Policy Council
EMF	Energy Modeling Forum
ENSO	El Niño-Southern Oscillation
EOS	Earth Observing System
EPA	Environmental Protection Agency
ESA	European Space Agency
ESG	Earth System Grid
ESMF	Earth System Modeling Framework
ESS-P	Earth System Science Partnership
EU	European Union
FAO	Food and Agriculture Organization
FAQ	Frequently Asked Question
FCS	Fire-Climate-Society
FEWS NET	Famine Early Warning System Network
FGDC	Federal Geographic Data Clearinghouse
FRI	Fire Return Interval
GACC	Geographic Area Coordination Center
GAW	Global Atmosphere Watch Programme
GCM	general circulation model
GCMD	Global Change Master Directory
GCP	Global Carbon Project
GCOS	Global Climate Observing System
GCTE	Global Climate and Terrestrial Ecosystems
GECAFS	Global Environmental Change and Food Systems
GEF	Global Environment Facility
GEOHAB	Global Ecology and Oceanography of Harmful Algal Bloom
GEWEX	Global Energy and Water Cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GHG	greenhouse gas
GIS	geographic information system
GLOBEC	Global Ocean Ecosystem Dynamics
GOFC-GOLD	Global Observation of Forest Cover and Global Observations of Land Cover Dynamics
GOIN	Global Observation Information Network
GOOS	Global Ocean Observing System
GOS	Global Observing System
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center
GSN	GCOS Surface Network
GTOS	Global Terrestrial Observing System
GUAN	GCOS Upper-Air Network

GWS Global Water System
HAB harmful algal bloom
HCDN Hydro-Climatic Data Network
HCFC hydrochlorofluorocarbon
HECRTF High-End Computing Revitalization Task Force
HELP Hydrology for Environment, Life, and Policy
HFC hydrofluorocarbon
HHS Department of Health and Human Services
HLC High-Level Consultations on Climate Change
HPS hantavirus pulmonary syndrome
HRDLS High-Resolution Dynamics Limb Sounder
HSB Humidity Sounder for Brazil
IAI Inter-American Institute for Global Change Research
IASC International Arctic Sciences Committee
ICSU International Council of Scientific Unions
IDN International Directory Network
IGAC International Global Atmospheric Chemistry
IGBP International Geosphere-Biosphere Programme
IGFA International Group of Funding Agencies for Global Change Research
IGOS International Global Observing Strategy
IGOS-P International Global Observing Strategy Partnership
IHDP International Human Dimensions Programme
ILTER International Long-Term Ecological Research
IOC Intergovernmental Oceanographic Commission
IODP Integrated Ocean Drilling Program
IPCC Intergovernmental Panel on Climate Change
IRC International Research and Cooperation
IRI International Research Institute for Climate Prediction
ITCZ Intertropical Convergence Zone
IWG Interagency Working Group
IWGCCST Interagency Working Group on Climate Change Science and Technology Integration
JGOFS Joint Global Ocean Flux Study
LBA Large-Scale Biosphere-Atmosphere Experiment in Amazonia
LOICZ Land-Ocean Interactions in the Coastal Zone project
LUCC Land-Use and Land-Cover Change
MA Millennium Ecosystem Assessment
MEXT Ministry of Education, Culture, Sport, Science and Technology
MMV Measurement, Monitoring, and Verification
MODIS Moderate-Resolution Imaging Spectroradiometer
MOPITT Measurement of Pollution in the Troposphere
MSS Multispectral Scanner
MSU Microwave Sounding Unit
N nitrogen
N_2O nitrous oxide
NACIP National Aerosol–Climate Interactions Program
NACP North American Carbon Program
NAM northern hemisphere annular mode
NAO North Atlantic Oscillation
NAS National Academy of Sciences
NASA National Aeronautics and Space Administration
NASDA Japan's National Space Development Agency
NCAR National Center for Atmospheric Research
NCEP National Centers for Environmental Prediction
NEC National Economic Council
NEESPI Northern Eurasia Earth Science Partnership Initiative
NERSC National Energy Research Scientific Computing
NGO Non-governmental organization
NH_3 ammonia
NIEHS National Institute of Environmental Health Sciences
NIH National Institutes of Health
NIST National Institute of Standards and Technology
NOAA National Oceanic and Atmospheric Administration
NOPP National Oceanographic Partnership Program
NO_x nitrogen oxides
NPEO North Pole Environmental Observatory
NPOESS National Polar-Orbiting Operational Environmental Satellite System
NRC National Research Council
NSC National Security Council
NSF National Science Foundation
O_2 oxygen
O_3 ozone
ODP Ocean Drilling Program
OH hydroxyl radical
OMB Office of Management and Budget
ONR Office of Naval Research
OSMEC Observing System Management Executive Council
OSOEC Observing System Operations Executive Council
OSSE Observation System Simulation Experiment
OSSEC Observing System Science Executive Council
OSTP Office of Science and Technology Policy
PAGES Past Global Changes
PDSI Palmer Drought Severity Index
PDV Pacific Decadal Variability
PFC perfluorocarbon
PMIP Paleoclimate Model Intercomparison Project
PNNL Pacific Northwest National Laboratory
RCM regional climate model
RESACs Regional Earth Science Applications Centers
RISA Regional Integrated Sciences and Assessments
SAGE Stratospheric Aerosol and Gas Experiment
SAM southern hemisphere annular mode
SBSTA Subsidiary Body for Scientific and Technical Advice
SCAR Scientific Committee on Antarctic Research
SCOR Scientific Committee on Oceanic Research
SeaWiFS Sea-Viewing Wide Field-of-View Sensor
SF_6 sulfur hexafluoride
SGCR Subcommittee on Global Change Research
SGP Southern Great Plains
SO_2 sulfur dioxide
SOLAS Surface Ocean–Lower Atmosphere Study
SPARC Stratospheric Processes and their Role in Climate
SSS sea surface salinity
SST sea surface temperature
START Global Change SysTem for Analysis, Research, and Training
SWAQ Sub-committee on Water Availability and Quality
TAV Tropical Atlantic Variability

TISO Tropical Intra-Seasonal Oscillation
TM Thematic Mapper
TMI TRMM Microwave Imager
TOGA Tropical Ocean and Global Atmosphere project
TOMS Total Ozone Mapping Spectrometer
TRMM Tropical Rainfall Measuring Mission
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
UNESCO United Nations Educational, Scientific, and Cultural Organization
UNFCCC United Nations Framework Convention on Climate Change
USAID U.S. Agency for International Development
USDA U.S. Department of Agriculture
USGCRP U.S. Global Change Research Program
USGS U.S. Geological Survey
UV-B ultraviolet-B
VIRS Visible and Infrared Scanner
VOC volatile organic carbon
VAMOS Variability of the American Monsoon Systems
WCRP World Climate Research Programme
WDCS World Data Center System
WGCM Working Group on Coupled Modeling
WHO World Health Organization
WMO World Meteorological Organization
WOCE World Ocean Circulation Experiment
WRAP Water Resources Applications Project
WWW World Weather Watch

UNITS

SI (Systéme Internationale) Units

Physical Quantity	Name of Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
thermodynamic temperature	kelvin	K
amount of substance	mole	mol

Special Names and Symbols for Certain SI-Derived Units

Physical Quantity	Name of SI Unit	Symbol for SI Unit	Definition of Unit
force	newton	N	$kg\ m\ s^{-2}$
pressure	pascal	Pa	$kg\ m^{-1}\ s^{-2}$ (= Nm^{-2})
energy	joule	J	$kg\ m^{2}\ s^{-2}$
power	watt	W	$kg\ m^{2}\ s^{-3}$ (= Js^{-1})
frequency	hertz	Hz	s^{-1} (cycle per second)

Decimal Fractions and Multiples of SI Units Having Special Names

Physical Quantity	Name of Unit	Symbol for Unit	Definition of Unit
length	ångstrom	Å	10^{-10} m = 10^{-8}cm
length	micrometer	µm	10^{-6}m = µm
area	hectare	ha	$10^{4}\ m^{2}$
force	dyne	dyn	10^{-5} N
pressure	bar	bar	$10^{5}\ N\ m^{-2}$
pressure	millibar	mb	1hPa
weight	ton	t	10^{3} kg