

National Assessment of the Consequences of Climate Variability and Change for the United States

By Michael C. MacCracken

Climate is an important influence on both the environment and society. Year-to-year variations are reflected in such things as the number and intensity of storms, the amount of water flowing in rivers, the extent and duration of snow cover, ocean-current induced changes in the height of sea level, and the intensity of waves that strike coastal regions and erode the shoreline. These factors in turn determine agricultural productivity, the occurrence of floods and droughts, the safety of communities, and the general productivity of society. Science now suggests that human activities are causing the natural climate to change, mainly by inducing global warming and an associated intensification of the global hydrologic cycle. Although the details are still emerging about the magnitude, regional pattern, and timing of the changes projected for the next century, that climate will be changing is widely recognized. Indeed, temperatures have increased in many areas, Arctic sea ice is much thinner, continental snow cover is not lasting as long in the spring, and total precipitation is increasing, with more rainfall occurring in intense downpours. These changes also appear to be affecting the distribution of plants and wildlife. There is evidence of a longer growing season in northern areas and changing ranges for butterflies and other species.

The Global Change Research Act of 1990 [Public Law 101-606] gave voice to early scientific findings that human activities were starting to change the global climate: “(1)

Industrial, agricultural, and other human activities, coupled with an expanding world population, are contributing to processes of global change that may significantly alter the Earth habitat within a few generations; (2) Such human-induced changes, in conjunction with natural fluctuations, may lead to significant global warming and thus alter world climate patterns and increase global sea levels. Over the next century, these consequences could adversely affect world agricultural and marine production, coastal habitability, biological diversity, human health, and global economic and social well-being.”

To address these issues, Congress established the U.S. Global Change Research Program (USGCRP) and instructed the Federal research agencies to cooperate in developing and coordinating “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural process of global change.” Further, the Congress mandated that the USGCRP *shall prepare and submit to the President and the Congress an assessment which*

- *integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;*
- *analyzes the effects of global change on the natural environment, agriculture, energy*

production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and

- *analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.*

The cycle of climate change assessments began in 1990 with USGCRP support for international assessments by the Intergovernmental Panel on Climate Change (IPCC). The IPCC assessments from 1990, 1996, and 2001 document existing global-scale changes and project that these changes will increase in magnitude over the next 100 years. As a consequence of the changes in climate, the IPCC also projects significant environmental change, generally at the continental scale. To provide a more focused picture of what climate change might mean for the U.S., the USGCRP initiated the *National Assessment of the Potential Consequences of Climate Variability and Change* in 1997. This Assessment focused on answering why people in the U.S. should care about climate change and how actions might be taken to effectively prepare for an average national warming of 5 to 9°F and significantly altered patterns of precipitation and soil moisture. It is just such changes that are simulated by global climate models assuming that global emissions of carbon dioxide and other greenhouse gases continue to climb as projected.

The overall goal of the Assessment has been to analyze and evaluate what is known about the potential consequences of such changes in the context of other pressures on the public, the environment, and the Nation's resources. By building broader understanding of the prospects for climate change and of the importance of these changes for the Nation, the USGCRP is aiming to promote an intensifying exploration of options that can help to reduce the vulnerability of individuals, public and private sector organizations, and the resource base on which society depends. With good information, these responses should be able to help build resilience

to climate variations and, to at least some extent, avoid or reduce the deleterious consequences of climate change while taking advantage of conditions that may be more favorable.

The Assessment process has been broadly inclusive in its approach, drawing on inputs from many sources. Support has been provided in a shared manner by the set of USGCRP agencies, including the departments of Agriculture, Commerce (National Oceanic and Atmospheric Administration), Energy, Health and Human Services, and Interior plus the Environmental Protection Agency, National Aeronautics and Space Administration, and the National Science Foundation. Although support for various activities has come mostly from the federal agencies, the conduct of the Assessment has been carried out in a highly distributed manner. Each of a diverse set of activities has been led by a team comprised of experts drawn from universities and government, from the public and private sectors, and from the spectrum of stakeholder communities. Through workshops and assessments, a dialogue has been started about the significance of the scientific findings concerning climate change and the degree to which existing and future changes in climate will affect issues that people care about, both at present and in the future. The reports that have been prepared have all gone through an extensive review process involving scientific experts and other interested stakeholders, ensuring both their technical accuracy and balance.

Three types of activities have underpinned the Assessment effort:

1. **Regional analyses and assessments:** An initial series of workshops provided the basis for characterizing the potential consequences of climate variability and change in regions spanning the U.S. A total of 20 workshops were held around the country in 1997 and 1998; sixteen of these groups then went on to prepare assessment reports focusing on the most critical issues identified. These activities focused on the implications of the patterns and texture of changes where people live. Although issues

considered often seemed to have a common thread, the implications often played out in different ways in different places. For example, various manifestations of the issue of water arose in virtually all regions. In some regions, it was changes in winter snowpack that project the need to adjust water allocations and the operational procedures for managing reservoir systems to ensure safety and supplies for electric generation, irrigation, industry, and communities; in other regions issues related to the potential influences of changes in precipitation amount on water quality, summertime drought, or river and lake levels. Table 1 highlights examples of issues as they arose across the country in nine consolidated regions.

2. **Sectoral analyses:** To explore the potential consequences for sectors of national interest that cut across environmental, economic, and societal interests, the Assessment examined implications for agriculture, forests, human health, water, and coastal areas and marine resources. These sectoral studies analyzed how the consequences in each region would affect the nation, and how national level changes would affect particular areas. Key findings from each of the sectoral studies contributed to the findings at both the regional level and the national level (see Tables 1 and 2, respectively).
3. **National overview:** A fourteen-member National Assessment Synthesis Team (NAST) drawn from academia, industry, government, and non-governmental organizations had responsibility for summarizing and integrating the findings of the regional and sectoral studies and then drawing conclusions about the importance of climate change and variability for the

United States. To document their findings, an extensive Foundation report was prepared that ties the findings to the scientific literature. To convey their message to the broader public and leading decision makers, an Overview report was prepared that describes the key issues facing nine regions across the U.S. and five sectors. The key findings from their report that apply to the nation as a whole are summarized in Table 2. An important advance was consistent use of a set of well-defined terms to indicate the relative likelihood of various outcomes based on the considered judgment of the experts that NAST represented. While some types of changes were found to be highly likely or unlikely, many were judged to be only possible based on current understanding. To gain better information, the NAST summarized key directions for research, urging particularly the strengthening of efforts to take an integrated look at the changing set of stresses facing regions and resource managers.

With the increasing level of understanding of global-scale environmental challenges, the conduct of assessments provides an important means for linking the emerging findings of the scientific community with the information needs of stakeholders. While also creating an urgency for new and elaborated scientific findings, these couplings in turn provide insights about potential vulnerabilities and response options for those responsible for economic development and societal welfare. The progress made in the initiation of the National Assessment and related activities in other nations is stimulating the beginning of a greater number of such activities around the world, building a society that is better informed and better prepared for not just climate change, but other long term issues of sustainability.

Table 1. Examples of important consequences of climate change affecting particular areas of the United States.

Regions and Subregions	Examples of Key Consequences Affecting:		
	The Environment	The Economy	People's Lives
Northeast New England and upstate NY Metropolitan NY Mid-Atlantic	Northward shifts in the ranges of plant and animal species (e.g., of colorful maples) Coastal wetlands inundated by sea-level rise	Reduced opportunities for winter recreation such as skiing; increased opportunities for warm-season recreation such as hiking and camping Coastal infrastructure will need to be buttressed	Rising summertime heat index will make cities less comfortable and require more use of air-conditioning Reduced snow cover
Southeast Central and Southern Appalachians Gulf Coast Southeast	Increased loss of barrier islands and wetlands, affecting coastal ecosystems Changing forest character, with possibly greater fire and pest threat	Increased productivity of hardwood forests, with northward shift of timber harvesting Increased intensity of coastal storms threaten coastal communities	Increased flooding along coastlines, with increased threat from storms Longer period of high heat index, forcing more indoor living
Midwest Eastern Midwest Great Lakes	Higher lake and river temperatures cause trend in fish populations away from trout toward bass and catfish	Increasing agricultural productivity in many regions, ensuring overall food supplies but possibly lowering commodity prices	Lowered lake and river levels, impacting recreation opportunities Higher summertime heat index reduces urban quality of life
Great Plains Northern Central Southern Southwest/Rio Grande Basin	Rising wintertime temperatures allow increasing presence of invasive plant species, affecting wetlands and other natural areas Disruption of migration routes and resources	Increasing agricultural productivity in north, more stressed in the south Summertime water shortages become more frequent	Altered and intensified patterns of climatic extremes, especially in summer Intensified springtime flood and summertime drought cycles
West California Rocky Mountains/Great Basin Southwest/Colorado River Basin	Changes in natural ecosystems as a result of higher temperatures and possibly intensified winter rains	Rising wintertime snowline leads to earlier runoff, stressing some reservoir systems Increased crop yields, but with need for greater controls of weeds and pests	Shifts toward more warm season recreation activities (e.g., hiking instead of skiing) Greater fire potential created by more winter rains and dry summers Enhanced coastal erosion
Pacific Northwest	Added stress to salmon populations due to warmer waters and changing runoff patterns	Earlier winter runoff will limit water availability during warm season Rising forest productivity	Reduced wintertime snow pack will reduce opportunities for skiing, increase opportunities for hiking Enhanced coastal erosion
Alaska	Forest disruption due to warming and increased pest outbreaks Reduced sea ice and general warming disrupts polar bears, marine mammals, and other wildlife	Damage to infrastructure due to permafrost melting Disruption of plant and animal resources supporting subsistence livelihoods	Retreating sea ice and earlier snowmelt alter traditional life patterns Opportunities for warm season activities increase

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Regions and Subregions	Examples of Key Consequences Affecting:		
	The Environment	The Economy	People's Lives
Coastal and Islands Pacific Islands South Atlantic Coast and Caribbean	Increased stress on natural biodiversity as pressures from invasive species increase Deterioration of corals reefs	Increased pressure on water resources needed for industry, tourism and communities due to climatic fluctuations, storms, and saltwater intrusion into aquifers	Intensification of flood and landslide-inducing precipitation during tropical storms More extreme year-to-year fluctuations in the climate
Native People and Homelands	Shifts in ecosystems will disrupt access to medicinal plants and cultural resources	The shifting climate will affect tourism, water rights, and income from use of natural resources	Disruption of the religious and cultural interconnections of Native people and the environment

Table 2. Key consequences of climate change of importance to the United States.

1. Increased warming and more intense precipitation will characterize the 21st century.
2. Differing regional impacts will occur, with greater warming in the western U.S., but a greater rise in heat index in the east and south.
3. Vulnerable ecosystems, particularly alpine areas, barrier islands, forests in the Southeast, and other vulnerable ecosystems will be significantly impacted.
4. Water will be a concern across the country, with increased competition for available resources, and the potential for more droughts and floods and reduced winter snowpack in some areas.
5. Food availability will increase because of increased crop productivity, although lowered commodity prices will stress farmers in marginal areas.
6. Forest growth will increase in the near-term, but some forests will be threatened over the long-term by increased susceptibility to fire, pests, and other disturbances.
7. Increased damage is very likely in coastal regions due to sea-level rise and more intense storms, while damage in other areas will result from increased melting of permafrost.
8. Adaptation will determine the importance of health outcomes, so that strengthening of the nation's community and health infrastructure will become increasingly important.
9. The impacts of other stresses will be magnified by climate change, with multiple factors causing adverse impacts on coral reefs, wildlife habitats, and air and water quality.
10. Uncertainties remain in current understanding and there is a significant potential for unanticipated changes.

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Michael MacCracken retired from the University of California's Lawrence Livermore National Laboratory in the fall of 2002. His research there for the past 34 years had focused on numerical modeling of various causes of climate change (including study of the potential climatic effects of greenhouse gases, volcanic aerosols, land cover change, and nuclear war) and of factors affecting air quality (including photochemical pollution in the San Francisco Bay Area and sulfate air pollution in the northeastern United States). Most recently, he had been on assignment as senior global change scientist to the interagency Office of the U.S. Global Change Research Program (USGCRP) in Washington DC. From 1993 to 1997, he served as executive director of the Office, which is charged with helping to coordinate the combined research efforts of eleven federal agencies to understand and improve predictions of climate variability and change, depletion of stratospheric ozone, and the long-term, global-scale impacts of humans on the environment and society. From 1997-2001, Mike served as executive director of the National Assessment Coordination Office, a USGCRP-sponsored activity to facilitate regional, sectoral, and national assessments of the potential consequences of climate variability and change for the United States.