Foreword

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Climate change is real. The climate has changed, is changing, and will continue to change, regardless of any human influence. But since the Industrial Revolution, human activities have begun to significantly affect the Earth's atmosphere and climate, and the changes are expected to continue for the foreseeable future. Although the timing and magnitude of future climate change is uncertain, it will have consequences for human health, ecosystems, economic activity and social well-being. Some of the effects will be harmful, and some beneficial.

The significance of the climate change issue was captured in the Joint G8 Statement, issued on 8 July 2005:

Climate change is a serious and long-term challenge that has the potential to affect every part of the globe. We know that increased need and use of energy from fossil fuels, and other human activities, contribute in large part to increases in greenhouse gases associated with the warming of our Earth's surface. While uncertainties remain in our understanding of climate science, we know enough to act now to put ourselves on a path to slow and, as the science justifies, stop and then reverse the growth of greenhouse gases.

There are two approaches for dealing with climate change. One strategy is to mitigate the emission of gases that contribute to warming – the so-called 'greenhouse gases' (GHGs). Since the Industrial Revolution, human activities, particularly the burning of fossil fuels, have contributed to increases in the atmospheric concentrations of CO₂, one of the more significant and long-lived greenhouse gases, from about 280 ppm to 377 ppm in 2004 (Keeling and Whorf 2005; IPCC 2001). The mitigation of GHG emissions provides a mechanism for slowing the buildup of GHGs in the atmosphere and the rate of climate change. It is important to mitigate because the rate of climate change may be of greater concern than the magnitude of change for many systems, particularly ecological systems.

A second strategy is to adapt in anticipation of future climate change. Adaptive actions are those responses or actions taken to enhance the resilience

of systems sensitive to changes in climate, thereby reducing the risks and taking advantage of the opportunities presented by climate change (National Academy of Sciences 1992). It is essential to adapt because the climate will continue to change regardless of actions taken to mitigate GHG emissions. There is a lag in the time it takes the climate system to respond to changes in atmospheric concentrations of GHGs, so past GHG emissions have already committed us to some amount of future climate change. Anticipatory adaptation may also have the side benefit of increasing the resilience of various systems to natural variations in the Earth's climate system. A sensible policy package will consist of both mitigation and adaptation strategies.

An understanding of the potential consequences of climate variability and change is essential for the development of both mitigation and adaptation strategies. Decisions about the appropriate magnitude and timing of actions to mitigate GHG emissions will depend, in part, on the magnitude of expected impacts (the so-called 'consequences of inaction'). Sensible adaptation strategies cannot be developed until one first understands the sensitivity of systems to changes in climatic conditions and the anticipated impacts that may warrant an adaptive response. But assessment of system sensitivity and anticipated impacts is a complex undertaking. Since changes in climate vary by location, there will be a regional 'texture' to the impacts of climate change. Adaptation strategies must therefore be site-specific. Further, there will be distributional effects across demographic groups as well as across geographic regions. Affected populations will vary, depending upon the effect of climate change being considered. One person's risk may be another person's opportunity. For example, decreases in wintertime snowfall in the Great Lakes region may hurt the skiing industry, but would also reduce the costs of snow removal to different communities. Hence, at any particular location, the distributional effects of climate change must also be assessed, to inform decision makers about the tradeoffs they may have to make as they choose among different adaptation strategies. Decisions about the investment of scarce resources in adaptive responses will inherently be value laden, and decision makers will have to represent the values of their communities in the tradeoffs they make (Scheraga and Grambsch 1998).

This book reports on work that provides new insights about the potential consequences of climate change, and possible adaptation strategies in particular places. The work was sponsored by the US Environmental Protection Agency's (EPA's) Global Change Research Program within the Office of Research and Development (ORD).

The EPA's Global Change Research Program has its primary emphasis on evaluating the potential consequences of climate variability and change on air quality, water quality, ecosystems and human health in the United States. This includes improving the scientific basis for evaluating effects of global change in the context of other stressors, and evaluating the risks and

opportunities presented by global change. The EPA uses the results of these studies to investigate adaptation options to improve society's ability to effectively respond to the risks and opportunities presented by global change. The program is multidisciplinary and emphasizes the integration of the concepts, methods and results of the physical, biological, and social sciences into decision support frameworks. As called for by the National Research Council (2001), the EPA supports and fosters projects that link knowledge producers and users in a dialogue that builds a mutual understanding of what is needed, what can credibly be said, and how it can be said in a way that maintains scientific credibility.

The work done by the EPA's program is coordinated and consistent with the 2003 Strategic Plan of the US Climate Change Science Program (CCSP 2003). The CCSP coordinates and integrates scientific research on global change and climate change sponsored by 13 participating departments and agencies of the US Government. The CCSP incorporates the US Global Change Research Program, established by the Global Change Research Act of 1990, and the Climate Change Research Initiative, established by President Bush in 2001. The EPA coordinates with other CCSP agencies to develop and provide useful and scientifically sound information in a timely fashion to decision makers.

The CCSP Strategic Plan calls for the development of information resources to support adaptive management and planning for responding to climate variability and change. The Plan calls for research that integrates natural and social systems within an application context of managed resources or infrastructure, utilizing climate and environmental observations, model outputs, socioeconomic data and decision models. The research should also incorporate elements of regional/sub-regional climate science and associated environmental processes, socioeconomic impacts, technological capabilities, management institutions and policies, and decision processes including evaluation.

Consistent with this CCSP objective, the EPA sponsored the six research projects presented in this book to further our understanding of the potential impacts of, and responses to, climate variability and change. The work was funded through the ORD Science to Achieve Results (STAR) program that funds research grants in numerous environmental science and engineering disciplines through a competitive solicitation process and independent peer review. The EPA Global Program dedicates a significant portion of its resources to extramural research grants to capitalize on expertise in the academic community that complements the EPA's laboratory research, as well as research conducted by other federal agencies.

The six projects focus on a range of potential impacts, including the effects of climate change on air quality, water quality, fisheries, urban infrastructure, public health and wildfires. They also focus on a variety of

geographic scales, ranging from the regional level (for example the Southwest US and the Northern Plains) to the basin and watershed level (such as San Joaquin Basin in California's Central Valley and Mackinaw River watershed in Illinois), to the urban level (for example the New York and Boston metropolitan areas). The projects provide valuable insights about potential strategies for reducing the site-specific impacts of climate variability and change. Some of the strategies that would reduce risks posed by climate change or exploit opportunities may be viewed as 'no regrets,' because they make sense whether or not the effects of climate change are realized. For example, enhanced responses to urban heatwaves can save lives now, whether or not the frequency and intensity of heatwaves change as the climate changes. Similarly, new crop varieties that are heat- and drought-resistant may reduce crop losses during hot, dry summers today, whether or not the frequency and intensity of droughts change as the climate changes.

The insights provided by the six projects are valuable because adaptation has a cost. The scarce natural and financial resources used to adapt to climate change could be used for other productive activities. In the vernacular of economics, there are opportunity costs to using scarce resources for adaptation. These costs must be carefully weighed when considering the tradeoffs between alternative adaptation strategies, and between adapting to the change, reducing the cause of the change, and living with the residual impacts.

The research projects and assessments like those reported in this book support informed discussion of climate variability and change issues by decision makers, stakeholders and the general public. The assessments provide timely and useful information to decision makers so they can utilize the science to strengthen their environmental decisions, and implement programs and adaptation strategies that will increase the resilience of systems to climate variability and change. This type of decision support is an important mechanism for attaining the ultimate goal of meaningful improvements in human health and environmental quality.

REFERENCES

- Intergovernmental Panel on Climate Change (IPCC) (2001), *Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (eds), Cambridge: Cambridge University Press, p. 38.
- Keeling, C.D. and T.P. Whorf (2005), 'Atmospheric CO₂ Records from Sites in the SIO Air Sampling Network', in *Trends: A Compendium of Data on*

- Global Change*, Oak Ridge: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy.
- National Academy of Sciences (1992), *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base*, Washington, DC: National Academy Press.
- National Research Council (2001), *The Science of Regional and Global Change: Putting Knowledge to Work*, Committee on Global Change Research, Washington, DC: National Academy Press.
- Scheraga, J.D. and A.E. Grambsch (1998), 'Risks, Opportunities, and Adaptation to Climate Change', *Climate Research*, **10**: 85–95.
- US Climate Change Science Program (CCSP) (2003), *Strategic Plan for the US Climate Change Science Program*, Washington, DC, July 2003.