

PREFACE

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Climate change is a global problem, and its solutions will require global cooperation. International climate negotiations will have to involve all nations, spurred by the recognition that the impacts of climate change cannot be isolated. Our economies are connected by global flows of capital and goods, disease vectors fail to recognize or respect national boundaries, and environmental refugees carry the tragedy of natural resource disasters to distant places.

Nonetheless, even vigorous action on mitigation will not prevent the world from experiencing some impacts of climate change in the coming century. We are committed to warming from the greenhouse gases already emitted; indeed, we may have already begun to see these impacts in record temperatures, the melting of glaciers and permafrost, sea-level rise, and the lengthening of growing seasons. Nations will have to adapt. A nation's response to, and planning for, adaptation will depend on its potentially unique social, technological, and economic circumstances, and on the expectations of the likely regional or local manifestations of climate change. Given the degree to which regional impacts will determine adaptation activity, scientists and policy makers alike agree that local to regional assessments are crucial to an improved understanding of, and response to, global climate change.

Thus, determining the regional implications of climate change has taken on a new urgency. The Intergovernmental Panel on Climate Change (IPCC) recently produced a global assessment of the regional vulnerabilities to climate change. In addition, the IPCC has also developed a special report on technology transfer with a decidedly more regional emphasis than previous reports. The United States National Assessment of Climate Change is also currently under way. This effort involves 20 teams that are assessing the impacts of climate variation and change on the various regions of the nation and on its natural-resource-based

economic sectors. In addition, research centers, such as The Pennsylvania State University's Center for Integrated Regional Assessment, are springing up to bring the local to regional viewpoint to the traditionally global perspective of the climate-change problem.

Assessments of regional changes in climate will require bridging scales—from the larger-scale analyses generally carried out in global climate models to the smaller-scale experiments designed to test the response and resilience of our ecological and natural-resource systems. For regional analysis to be effective, climate modelers will have to devise new techniques for 'scaling down' to forecast local or regional variations in climate impacts from the traditional larger-scale constraints and dynamics produced in today's global climate models. Similarly, empiricists will have to make strides in extrapolating the results of experiments occurring on very small plots to landscape-level phenomena and dynamics. Until that bridging occurs, we are left without an understanding of the critical spatial and temporal scales at which change will occur. Further, we are saddled with only a very limited ability to compare the results of experiments and models at similar scales, and we therefore limit our ability to use the combined conceptual power of theoretical and empirical work in understanding regional climate dynamics and the appropriate mitigation or adaptation responses.

The current capacity of general circulation models (GCMs) to project future climate on a regional basis is limited. A variety of methods and models, however, are improving our abilities to make geographically explicit projections, and one of the largest growth areas in climate science involves elucidation of the local to regional implications of climate change. This growing focus has led to a 'downscaling' of previous global change impacts studies.

In spite of these increased efforts, projections of regional climate change are and will remain more highly uncertain than projections of global climate change. These uncertainties mandate that regional

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assessments examine impacts from several different perspectives. Imposing GCM-generated scenarios on a region and examining the consequences for ecosystems, hydrology, agriculture, and human health is but one approach. Another is to examine the critical thresholds or interactions that determine a region's vulnerabilities to changes in temperature, precipitation, or climate variability, and to assess those potential 'breaking points' relative to the range of local to regional climate-change scenarios generated for the region. This type of analysis allows not only identification of possible impacts, but an assignment of probability of exceeding thresholds given the potentially different climate projections for the region. Moreover, knowing those characteristics of a region that contribute to the greatest vulnerabilities under a changing climate also allows identification of those sectors for which climate mitigation or adaptation policies may be most effective.

Similarly, ecologists and other experimentalists devoted to assessing natural resource dynamics under global change must advance our capabilities to forecast dynamics at regional or even local scales over long time periods. In 1993, the National Research Council reported that 50% of United States ecological research was conducted on areas of less than a square meter and that only 7% was carried on for more than 5 yr. Improved observations on all scales are critical for improvement of the modeling activities that hold promise for explaining the effects of multiple stresses and creating a predictive capability to support natural resource management. Until recently, the scales at which the 'on the ground' ecological community and the global climate change community have been operating have been largely separate—to each community's detriment, and to the detriment of society's capacity to predict and respond to global climate change at the appropriate spatial and temporal scales.

Regional assessments of impacts and vulnerabilities can generate significant benefits now. The impacts of climate variability and extreme events already create significant economic and social costs, and those costs are rising as capital investments and population densities increase. Assessing mitigation and adaptation strategies under future climates allows improved policies for addressing vulnerabilities and responses under today's climate.

Given these compelling needs, the editors of *Climate Research* have organized this CR Special on regional assessments of climate change and their policy implications. Instead of a political region-by-region approach to the subject, the editors have chosen to examine some of the more important resource areas known to be affected by climate variation and climate change. In the lead paper, Robert Nicholls and Nobuo Mimura

explore the impacts of sea-level rise on coastal zones around the world, and the resulting policy implications. They conclude that some potential impacts of sea-level rise have strong regional dimensions and regional cooperation is needed to combat both the causes and effects of climate change.

The second paper, by Richard Adams, Brian Hurd, Stephanie Lenhart, Neil Leary, and Walter Baethgen, focuses on climate change impacts on agriculture, with a concentration on North and South America. They discuss regional 'winners' and 'losers' resulting from climate change, and present a unique 'lessons learned' section that highlights the similarities and differences in both the biogeophysical and socioeconomic responses of the 2 regions.

In the following paper, Alistair Woodward, Simon Hales, and Philip Weinstein examine the impacts of climate change on human health. Their paper addresses the Asia Pacific region, and describes 5 causes of vulnerability to health problems there, comprising destructive growth, poverty, political rigidity, dependency, and isolation. They suggest measures to reduce vulnerability to climate change, and, although these proposed measures are specifically designed for the Asia Pacific region, there are some obvious extensions to health policies in other regions of the world.

Steven Winnett reviews the potential impacts of climate change on U.S. forests, and evaluates results from various models that describe a range of species and ecosystems. In addition, Winnett looks at plant responses to elevated CO₂ environments, and how these plant physiological responses can in turn create changes in insects' distributions and behavior, fire frequency, and response to elevated tropospheric ozone. Finally, he evaluates the economic effects of climate change on forests by examining results from 3 studies.

Geoff Pickup tackles the Australian perspective on desertification and climate change in the next article. His research shows that much of the climate sensitivity of this region stems from unsustainable land use and the impact of European settlement, rather than the varying and changing climate itself. Nonetheless, climate variation and changes can and have exacerbated these problems. Given the multiple causes underlying desertification in the region, Pickup concludes that policy responses should address the broader issue of sustainable land use and not climate issues alone.

Brent Yarnal uses the study of climate change impacts on river basins as an illustration of the more general topic of integrated regional assessment. He concludes that integrated assessments are crucial for understanding the dynamics of scientific, social, and political interactions at local and regional levels.

Richard Bord, Ann Fisher, and Robert O'Connor then investigate public perceptions of climate change, and

compare results across several countries. They find significant national and regional differences in the public perceptions of the causes and threats of climate change. Although most people do not consider global warming to be a high-priority issue, they are willing to support modest efforts to combat it as long as these efforts do not engender undue hardships or significant lifestyle changes.

In the final paper, Joel Scheraga and Anne Grambsch turn from the impacts of climate change to the risk and opportunities that adaptation to climate change present to individuals and societies. They present a number of fundamental principles to be considered when designing adaptation policy, with particular emphasis on how regional variations in circumstances will affect adaptation.

These papers demonstrate that understanding the regional texture of climate-change impacts, political and social responses, and biogeophysical and economic vulnerabilities will be an integral component of solving the climate-change problem. Climate-change policy must be flexible, allowing localities and regions sufficient freedom to deal with place-bound peculiarities. At the same time, we are connected by one atmosphere, and increasingly connected by global markets and flows of capital. Therefore, local and regional impacts and response options will depend on geographically distant events

and activities. Bottom-up and regional assessments need to be complemented by top-down and global assessments, and vice versa.

Assessment means taking stock of the state of science at a point in time, evaluating what is known, what is not known, what is knowable over what time scales, and what is most important to know. Assessment defines both a near-term and long-term R&D agenda *and* helps managers make wise natural resource decisions today even as more information is being developed. As Peter Drucker said, 'long-range planning does not deal with future decisions, but with the future of present decisions'. Assessment must be iterative. The papers in this CR Special highlight some of the important progress that has been made in regional assessments of climate change, and, just as importantly, identify some of the existing gaps in regional analysis and in the integration of analyses from local to regional to global scales. For example, the focus on sectors, by region, presented here does not yet permit critical analysis of the interlinkages in both impacts and adaptation that manifest themselves across sectors—though this special issue offers a foundation for that more integrated assessment. These papers therefore serve as a step in the iterative dance, and cast some light on the problems of regional assessment so we can better see both where we have come from and where we need to go.