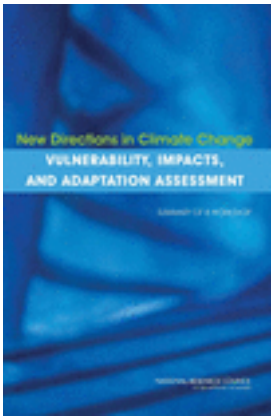

New Directions in Climate Change Vulnerability, Impacts, and Adaptation Assessment: Summary of a Workshop

Jennifer F. Brewer, Rapporteur, National Research Council

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New Directions in Climate Change
VULNERABILITY, IMPACTS, AND ADAPTATION ASSESSMENT

SUMMARY OF A WORKSHOP

Jennifer F. Brewer, *Rapporteur*

Subcommittee for a Workshop on New Directions in Vulnerability, Impacts, and Adaptation Assessment

Committee on the Human Dimensions of Global Change

Division of Behavioral and Social Sciences and Education

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The project originated under the auspices of the Committee on the Human Dimensions of Global Change. I thank my fellow members of the steering committee responsible for concept development, organization, and planning for their enthusiastic efforts. Cynthia Rosenzweig deserves special thanks for providing the original idea, motivation, and organizational efforts. Our work also benefited significantly from the thoughtful contributions of Gary Yohe and Linda Mearns.

In addition to the members of the subcommittee, the other workshop presenters, Neil Leary, Richard Moss, Martin Parry, and Roger Pulwarty, helped greatly in orienting and stimulating workshop discussion. I also thank all of the workshop participants from academic institutions, public agencies, the private sector, and nongovernmental organizations for contributing such constructive comment and dialogue (see the Appendix for a list of participants).

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the Report Review Committee of the National Research Council (NRC). The purpose of this independent review is to provide candid and critical comments that will assist the institution in

making its published report as sound as possible and to ensure that the report meets institutional standards for quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We thank the following individuals for their review of this report: Kristie L. Ebi, Consultant, ESS, LLC, Alexandria, VA, and Alexander Pfaff, Terry Sanford Institute of Public Policy, Duke University. Although these reviewers have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release.

The review of this report was ably overseen by Diana Liverman of the Environmental Change Institute at Oxford University. Appointed by the NRC, she was responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the author and the institution.

Finally, I would like to recognize the contributions of the National Research Council staff: Paul Stern, who provided oversight for workshop organization; Jennifer Brewer, who wrote this report; Linda DePugh, who organized the workshop logistical arrangements; Kirsten Sampson Snyder, who facilitated the peer review process; and Eugenia Grohman, whose careful editing was invaluable.

Thomas J. Wilbanks, *Chair*
Committee on the Human Dimensions of Global Change

Contents

Introduction

Policy makers are increasingly seeking scientific advice on climate change adaptation strategies, despite a historic lack of funding and program development in this area. The existing research community focused on issues of climate change vulnerability, impacts, and adaptation is not necessarily prepared, organizationally or conceptually, to meet these growing public needs. This report summarizes a National Research Council (NRC) workshop at which presentations and discussion identified specific needs associated with this gap between the demand and supply of scientific information about climate change adaptation.

Climate change has become a dominant issue in U.S. policy arenas, with debates on the causes of climate change giving way to debates on the responses to climate change. The need for informed response strategies is voiced with increasing frequency by governments at all levels, as well as by groups in the private and nongovernmental sectors.

With effective climate change mitigation policies still under development, and with even the most aggressive proposals unable to halt climate change immediately, many decision makers are focusing unprecedented attention on the need for strategies to adapt to climate changes that are now unavoidable. The effects of climate change will touch every corner of the world's economies and societies; adaptation is inevitable. The remaining question is to what extent humans will anticipate and reduce undesired consequences of climate change, or postpone response until after climate change impacts have altered ecological and socioeconomic systems so significantly that opportunities for adaptation become limited.

The second volume of the *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC), which addresses impacts, adaptation, and vulnerability, was produced by IPCC Working Group II in 2007. It summarizes the likely impacts of climate change already under way and the potential for adaptation to reduce vulnerability to, and the risks of, climate change. The IPCC assessment reports are produced through a uniquely rigorous, international, and consensus-based process that includes both government representatives and scientific experts. As such, it provides a powerful impetus for the identification of clear social needs and associated research priorities.

In March 2008 a panel under the auspices of the NRC's Committee on the Human Dimensions of Global Change convened lead U.S. authors of the IPCC Working Group II report, federal agency representatives, and other interested individuals to discuss next steps in the development of a needs-driven research agenda on climate change vulnerability, impacts, and adaptation. Formal workshop presentations were augmented by extended discussions, all of which are summarized in this report. Although this report identifies themes that were expressed by several of the workshop participants, it cannot be construed as a consensus statement.

The next section of this report summarizes the introductory remarks and six presentations that began the workshop. The following three sections present the discussions, organized by topic. The last section covers the final workshop session. The Appendix lists the workshop participants.

Presentations

Tom Wilbanks opened the workshop with the assertion that in recent months several things have changed in the U.S. climate policy context:

1. Decision makers have increasingly expressed interest in the consequences of climate change.
2. Climate change predictions are giving greater credence to more severe climate changes, including larger average temperature increases, increased frequency and severity of extreme events, and related impacts.
3. Policy interest in adaptation is increasing, including interest in practical action as well as theoretical analysis. The existing research community does not necessarily have ready-made answers about practical actions.
4. Climate scientists and integrated assessment modelers are now considering vulnerability, impacts, and adaptation and requesting assistance in the identification of information needs and knowledge bases. Their large, centralized modeling approaches are unfamiliar to some researchers already conducting research on vulnerability, impacts, and adaptation with strengths in field-based case studies.

Wilbanks suggested that these changes should impel scientists working on vulnerability, impacts, and assessment, and decision makers who rely on this research, to establish research priorities.

Cynthia Rosenzweig observed that Working Group II (on impacts, adaptation, and vulnerability) of the International Panel on Climate

Change (IPCC) includes the widest array of disciplines of all the IPCC working groups. It has taken some time for this group to synthesize the wide range of research in the field and to develop clear messages that are easily communicated to the larger IPCC process. However, in the fourth IPCC assessment, integration of Group II's findings in the final synthesis report for policy makers represented significant progress.

The field of climate vulnerability, impacts and adaptation is gaining greater recognition, but researchers need to continue the hard work of advancing our methodologies. This work will require funding and self-organization. The intensity of IPCC meeting and report schedules has not provided opportunities for the research community to evaluate the IPCC process, identify institutional needs, or explore follow-up options. The present meeting is unique in offering this venue, and is timely in following closely after the release of the IPCC's fourth assessment report.

MARTIN PARRY

Martin Parry, cochair of IPCC Working Group II, talked about trends in climate change and responses, research priorities, and the IPCC process.

Trends in Climate Change and Responses

Parry pointed out that global greenhouse gas emissions are accelerating, including CO_2 (carbon dioxide) as the largest contributor. Without mitigation, these emissions will continue to grow. Since the third IPCC assessment in 2001, the upper range of projected temperature increases has been revised upward, and a greater range of uncertainty has been established. Of 29,000 data sets on environmental trends, 90 percent of observed trends are in the direction expected from anthropogenic warming. These trends can be seen on every continent.

Some climate effects may be occurring faster than expected. Such effects present policy challenges, but they also provide opportunities to gain information useful to future adaptation planning. For example:

- Early identification of the most vulnerable regions and sensitive sectors has begun, although reporting and results are limited thus far.
- Some ecosystem changes, including species extinctions, have now been quantitatively assessed.
- Reduced water availability is a primary driver of secondary impacts, especially in the dry tropics.
- Crop yield responses will vary regionally, but many projections trend downward, with greater temperature increases, especially in low latitudes.

- Already stressed and marginal environments, such as tundra, boreal forest, mountains, mangroves, and coral reefs, will see more immediate impacts.
- Major impacts are likely from altered frequencies and intensities of extreme weather.
- Densely populated megadeltas are most at risk, especially in Asia and Africa, as well as small islands and the Arctic.
- In all regions, poor, elderly, young, and marginalized people are most vulnerable, regardless of national economic prosperity.
- Poverty will aggravate health impacts. Some large-scale events such as ice sheet melting and thermohaline circulation shifts, which would cause very large impacts, are possible, and will become more likely after 2100.

Although timing is uncertain, aggregate economic impacts of climate change are negative. Outcomes will vary, contingent on development and investment decisions. Sustainable development approaches can reduce vulnerability in many instances, but climate change will impede sustainable development, as multiple stresses converge to amplify total impacts. Climate change becomes a multiplier of other threats. Many adaptation options are available, but very few cost and efficacy analyses exist. Some limited adaptation is occurring now, and some sectors exhibit more elasticity than others. Coping range, or the ability to live with a range of climate futures, varies among regions, making planning difficult and complex. Both mitigation and adaptation efforts are urgently required. Aggressive mitigation can avoid, reduce, or delay many impacts, and is imperative in order to avoid major catastrophe at the global scale. Some impacts cannot be averted, however, especially at the regional scale, due to the chemophysical inertia of the earth system. Partly due to the delay in considering adaptation as necessary public policy, major uncertainties remain about:

- impacts under different development pathways,
- impacts under varying mitigation strategies,
- adaptive capacities, including technological, social, and economic, and
- optimal ratios of adaptation and mitigation.

Research Priorities

With this information as background, Parry identified several research topics for the vulnerability, impacts, and adaptation community:

1. the observed effects of climate change: adaptation rates, sensitivities, and learning;
2. the scaling and mapping of climate change impacts against a range of mitigation pathways, including unavoided climate change, and fill gaps for missing regions, sectors, and higher-end climate change projections;
3. the scaling and mapping of impacts against a range of development pathways;
4. the impacts of extreme and non-extreme weather events;
5. clarification of near-term inflection points for benefits versus damages;
6. evaluation of interaction between climate impacts and sustainable development;
7. evaluation of impacts of multiple stresses from climate and non-climate variables (or "threat multipliers");
8. assessment of adaptation costs; and
9. assessment of capacities, limits, and barriers to adaptation.

The IPCC Process

The process of developing a structure for what will be the fifth IPCC assessment is beginning. Some governments express a desire for a faster process and propose more rapid special reports. Parry noted, however, that such processes would have less capacity to establish broad consensus.

The IPCC does not provide a venue in which to consider relationships or gaps across working groups. Working Group II is larger than the others, and the amount of information it must integrate is increasing dramatically. Some people have proposed splitting it into two groups, impacts and adaptation. Others have proposed producing regional and sectoral reports or report sections. The additional research needed to fill gaps on important vulnerability, impacts, and adaptation issues requires new funding, organizational structures, and capacity building.

RICHARD MOSS

Richard Moss suggested that integrated scenario development is one way to facilitate interactions across IPCC working groups and broader research communities. Presently, new scenarios for analysis of emissions, impacts, and responses are being developed not by IPCC but by related research groups, although IPCC could produce special reports or technical papers. Climate modelers are developing new integrated scenarios through the World Climate Research Program (WCRP), International Geosphere-Biosphere Program (IGBP), and a Working Group on Coupled Models (WGCM). Such self-organization facilitates model compari-

sons and the selection of scenarios for further work. Similarly, integrated assessment modelers have established the Integrated Assessment Modeling Consortium (IAMC) to meet the need for research coordination. Some researchers in the vulnerability, impact and assessment community are involved in new scenario development, but more formal self-organization could stimulate broader and more systematic involvement.

Scenarios are now being developed for short-term time periods, to about 2035, and for long-term time periods to 2100 (and in a more stylized way to 2300). The two time scales have different implications for policy, decision making, climate system responses, and model projection capabilities, with near-term scenarios being more useful for adaptation purposes.

Moss also described a recent innovation in the timing and logic of integrated climate change scenario building, moving from sequential to parallel modeling efforts. The standard linear approach starts with socioeconomic variables and the production of emissions scenarios, then models greenhouse gas concentrations, then models climate outcomes (including surface temperatures), and lastly analyzes impacts and adaptation. The new parallel process starts from four representative levels or pathways of greenhouse gas concentrations, simultaneously develops corresponding climate outcomes and emissions/socioeconomic scenarios, and then links both the climate projections and the emissions/socioeconomic scenarios in analyses of impacts, adaptation, vulnerability, and mitigation. This parallel modeling innovation permits a number of socioeconomic futures to be associated with each representative greenhouse gas concentration pathway. It may also speed up the production of integrated scenarios.

The four representative concentration pathways are not intended to be policy prescriptive, but provide minimal climatic information to support the broader exploration of socioeconomic dimensions. As the risks posed by higher pathways become more widely understood, public interest in lower pathways may increase. Other outstanding research issues include standardization of land use/land cover data, uncertainties around the re-scaling of climatic variables across scenarios, and the breakdown of socioeconomic information when modeling out to 2300.

A key component of the new scenario process is the construction of narrative storylines. These are intended to be detailed descriptions of assumptions associated with representative concentration pathways, and are to be developed at the global scale, then used as guidelines for regional and smaller scale storylines relevant to people working on adaptation and impacts. The IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) is considering how to provide guidelines and material to people working at small scales, to encourage the development of scenarios that will fulfill local assessment needs, and

also embed into the development of larger storylines or pathways. This will require funding and further thinking, but ultimately the completed integrated assessment modeling and vulnerability, impacts, and adaptation work can be synthesized into a set of integrated scenarios, which can then undergo IPCC peer review and publication.

Fully integrated scenario development may require increased self-organization of vulnerability, impacts, and adaptation researchers to coordinate a common set of assumptions and inputs, and to effectively represent their research perspectives. Agreement on some specified time slices for the analyses would produce a body of literature with common assumptions. This can increase research relevance and efficiency, permitting easier communication, transfer, and comparisons across research communities.

LINDA MEARNS

Speaking as a lead author for the IPCC reports of both Working Groups I (physical science) and II (impacts, adaptation, and vulnerability), Linda Mearns said that the gap between the two is too big. Both top-down and bottom-up approaches to policy-relevant adaptation research are needed. Top-down approaches start with global development, then model through emissions, climate change, regionalized impacts, and physical vulnerabilities. Bottom-up approaches start with multiple indicators, including economic resources, information, technology, infrastructure, institutions, and equity, then model through adaptive capacity and social vulnerabilities.

Relationships between earth system models and adaptation models continue to evolve. There is a growing need for adaptation studies at U.S. government agencies. Higher resolution scenarios enable mediation between top-down and bottom-up approaches, and the incorporation of impacts from multiple stressors. Goals for incorporating human dimensions into earth system models are unclear. A completely coupled model, including all human feedbacks as both climate drivers and responders, would represent a determinate system and seems unrealistic. Coupled models may help to explore vulnerability, adaptation, and mitigation policy options, but they also raise questions about what spatial and temporal scales must be represented for what purposes. Scenarios must, by definition, be internally consistent. They are limited in their ability to reflect changes in human behavior, such as mitigation.

GARY YOHE

Gary Yohe noted that the fourth IPCC assessment report anticipates broad physical impacts on water, ecosystems, food, coastlines, and human

health, at specified ranges of global mean temperature increase. Relationships between greenhouse gas concentrations and temperatures are uncertain, however, and it is virtually certain that precise associations will never be known. Similarly, social dimensions of vulnerability complicate adaptation planning. Aggregate cost-benefit analyses, such as those offering estimates of the social cost of carbon, are dangerous because they conceal the range of vulnerabilities across space and time; they do not incorporate many of the diverse ways in which climate impacts are revealed; and they cannot account for variations born of social and natural scientific uncertainties. These uncertainties are increased by missing information on both physical predictions and valuation (including market and nonmarket valuations, but especially large-scale social transformations that may occur). That missing information will be easier to develop if criteria are established for the key vulnerabilities of interest.

The fourth assessment report of the IPCC, in language that was unanimously approved by governments, adopts a risk management approach, in which risk is a product of the probability that an event will occur and the magnitude of consequences or impacts. This approach helps to elevate the importance of considering not only high probability climate-related events, but also those that have lower probability, but serious consequences. Risk profiles can organize multiple metrics across multiple scales. The IPCC assessment report also highlights the need for an iterative and evolving portfolio of mitigation and adaptation actions in which decisions are less about how to write perfect climate policy for decades to come and more about how to minimize adjustment costs as future challenges become clearer. Development path dependence also becomes a central factor. Cost-benefit frameworks cannot be dismissed entirely, but they must be complemented by risk frameworks and social frameworks that account for multiple impacts and inequalities.

ROGER PULWARTY

Roger Pulwarty commented that IPCC Working Group II found adaptation to climate change to be taking place already, but on a limited basis, and seldom in response to climate change alone. Many adaptations can be implemented at low cost, but there are no comprehensive estimates of adaptation costs and benefits. Furthermore, adaptive capacity is uneven across and within societies, and different rates of climate change may yield different response curves and vulnerabilities.

The climate services approach suggests that research is necessary to support adaptation. There is now some evidence of feedback effects at climate extremes, and the models incorporate population, affluence, resources, and technology; however, information about culture, communication, context, and capacity variables is missing. Researchers in the

field of vulnerability, impacts, and adaptation need to work *with* decision making groups to identify the important research questions, not just communicate scientific information and assume it will reach the proper audiences. Pulwarty reminded workshop participants that the track record of adaptive management experiments is poor. Most models fail, some implementations fail, and there have been only a few successes.

Priorities for human dimensions research have recently been identified:[1]

1. understanding climate change vulnerabilities: human development scenarios for potentially affected regions, populations, and sectors;
2. understanding mitigation potential: driving forces, capacity for change, and possible limits of change;
3. understanding adaptation contexts, capacities for change, and possible limits of change;
4. understanding how mitigation and adaptation combine in determining human system risks, vulnerabilities, and response challenges associated with climate change;
5. understanding decision support needs for climate change responses and how to meet them; and
6. constraints on applying our understanding.

Several characteristics about behavior and change are important to keep in mind. Humans do not necessarily change their behavior when they reach thresholds. It can be important to understand buffers, nonlinearities, and multiple stresses at multiple scales. Resilience requires some balance between coordination and decentralization, including cross-scalar and cross-jurisdictional issues, stakeholder involvement to reach multiple objectives, and integration of mitigation and adaptation. There are barriers and paradoxes to adaptation—temporal, physical, technological, financial, informational, cognitive, social, and cultural. For some mitigation scenarios, adaptation may be inadequate. Even with planning, actions occur after focusing events. The cumulative reduction of smaller-scale risks may increase vulnerability to large events. Communities may or may not understand their risk or see themselves as able to reduce risk. Even climate baselines may change, including decadal scale variabil-

[1]Paul C. Stern and Thomas J. Wilbanks. (2009). Fundamental research priorities to improve the understanding of human dimensions of climate change. Appendix D in *Restructuring Federal Climate Research to Meet the Challenges of Climate Change*, Committee on Strategic Advice to the U.S. Climate Change Science Program, Division of Earth and Life Sciences, National Research Council. Washington, DC: The National Academies Press.

ity. Short-term adjustments in development pathways may constrain or enable long-term adaptation.

Although there are numerous programs and activities to reduce climate-related risks and increase resilience at regional, national, and local scales, few climate change adaptation initiatives have been evaluated, and evaluation criteria have not been established, so the effectiveness in reducing vulnerability to the range of climate projections is unknown. Better understanding could facilitate learning across countries, such as comparisons of costs and benefits, and ways to overcome constraints. Results could be integrated into national and regional plans for development, land use, water use, and diffusion efforts. Climate adaptation may synergize with, or require tradeoffs with, other development priorities. Climate services might help to provide anticipatory coordination as well as anticipatory technology as a way of improving self-organization. Research is scant on economic and social costs and benefits of adaptation measures involving ecosystem protection, health interventions, and land use. Particular adaptations might have broader implications for economic growth and employment.

There are significant outstanding research challenges in understanding the processes by which adaptation is occurring and will occur in the future and in identifying areas for leverage and action. Risk assessment, planning, and management need to be integrated, including national, regional, and community profiles. A given approach is often implemented piecemeal, but then abandoned with a conclusion that the entire paradigm does not work. Early warning systems are needed for extreme climate changes. Evaluation needs to follow analytic-deliberative processes to indicate decision quality. Researchers are generally urged to include stakeholders often and early, but this may or may not be the best use of resources, especially if participatory processes are not well designed.

NEIL LEARY

Neil Leary reported that the mission of the Global Change System for Analysis, Research, and Training (START) is to promote research in developing countries on global environmental change and to link science to decision making for sustainable development. START has ten regional research centers, nodes, and secretariats, including four in Africa, four in Asia, one in the South Pacific, and one in North America. It is funded by several national governments, international organizations, and private foundations. START-supported assessments of impacts and adaptation to climate change (AIACC) have produced 24 regional or national assessments, more than 100 peer-reviewed publications, more than 100 citations

in the fourth IPCC assessment report, and numerous networking and training opportunities.

Emerging international priorities for regional climate-related research include needs in two broad areas:

1. Target decision making needs and decision support, particularly adaptation and risk management decisions. Focus on vulnerability and risk assessment approaches. This work will require information that is temporally, spatially, and sectorally specific.

a. Engage stakeholders, through participatory approaches.

b. Work across multiple temporal scales. Current and near-term hazards have greater salience than longer-term ones, but the latter are also important because of inertia and irreversibilities.

2. Address growing demands for information (not just on climate) at fine and nested spatial scales that challenge the state of science; and address cross-scale interactions.

a. Link to development, sustainability, poverty, equity, and livelihoods.

b. Address uncertainty.

In developing countries, there are numerous barriers to regional global environmental change research, including the following:

- inadequate government funding for science;
- project-based funding by assistance agencies with constantly shifting priorities and no sustained program support;
- too few scientists, heavy teaching demands for those in academia, and "brain drain" to other countries;
- few "global change" scientists, due to

— few interdisciplinary programs to educate new global change scientists, and

— no career path for global change scientists (though this may be changing);

- dissonance in frameworks and methods;
- poor information technology infrastructure, library resources, and physical infrastructure;
- social, economic, and institutional instabilities; and

- limited data availability, access, and capacity to use climate information.

There are at least three specific concerns in relation to the future of the IPCC:

1. inadequacy of research on regional aspects of climate change, particularly in developing country regions, though an initiative similar to AIACC could help fill gaps;
2. identifying appropriate roles and actions of IPCC and the U.S. research community; and
3. demands of climate response research may exceed the capacities of existing global programs (the International Geosphere-Biosphere Programme [IGBP], the International Human Dimensions Programme on Global Environmental Change [IHDP], and the World Climate Research Programme [WCRP], Diversitas).

Discussion: Emerging Needs in Decision Support

Workshop participants commented that some adaptation policy decisions are politically difficult and suggested that open and informed discussion between scientists and policy makers could help. Agencies and researchers are receiving increasing numbers of questions from various sectors and government offices. With scientific expertise stretched so thin, it can be hard to meet all the expressed needs. In the simultaneous rush for action on so many climate-related fronts, some necessary science policy priority-setting discussions may be bypassed. For instance, some policy initiatives may set certain mitigation or adaptation targets so high that compliance would require shortcuts that might be inadvisable. Similarly, some international development funders are so intent on funding immediate adaptation actions that basic research, needs assessment, capacity building, and strategic planning may be overlooked. Researchers are being asked to provide policy advice and decision support while the research base for this advice is underdeveloped and underfunded.

U.S. federal agencies are generally not tracking or budgeting climate-related research as such, so that some of this research is not counted in climate research budgets. At the same time, projects that only have a small climate component are sometimes identified as climate research. Existing work sponsored by the agencies is not necessarily coordinated or directed by needs and priorities. Efforts to share information about models, datasets, programs, and personnel would be helpful.

New and unanticipated uses of scientific information are emerging rapidly. For example, because of the Supreme Court decision that the U.S. Environmental Protection Agency (EPA) must decide whether to regulate

motor vehicle greenhouse gas emissions on the basis of the risks to public health and welfare, the agency is facing huge analytic tasks, including the challenge of cost–benefit analyses of phenomena that are difficult to quantify. The U.S. Department of Energy (DOE) may be required to include climate impact statements in energy efficiency rulemakings, creating pressures to establish regulatory precedents using numbers generated by the Intergovernmental Panel on Climate Change (IPCC) for unanticipated purposes, perhaps without the appropriate methodological deliberations. Municipalities are asking consultants to tell them what the climate impacts will be on their infrastructure, utilities, and other services, but without sufficient funds and research to produce the necessary information. Authors of the IPCC Working Group II chapter on North America identified major gaps in the literature, including climate impacts on energy use, transportation, and biomass productivity. Time constraints prevented inclusion of that discussion in the working group's report, however. Congress and others are not aware that the money going to climate research may not be directed toward meeting the needs of local constituents.

Even the IPCC is limited in the guidance and leadership it provides. Some of the questions asked of IPCC report contributors are dated and make it difficult to include important scientific findings. The demands on Working Group II will increase in the next assessment report; meeting those demands will require additional organizational efforts. Chapter outlines and templates might help when writing the next report, even though some authors object to top-down formatting of content, but the bigger challenge is to structure the research community at large. International research organizations, including the U.N. Environmental Program, the World Climate Research Programme (WCRP), the International Human Dimensions Programme on Global Environmental Change (IHDP), and START (the Global Change System for Analysis, Research, and Training), have not produced sufficient administrative or funding resources in the past. Funding has emphasized projects, not networking or capacity development.

In writing the fourth IPCC assessment report, it became clear that there are policy tradeoffs between mitigation and adaptation. Feedbacks are becoming more visible, and many report authors now want to link the two in concept and organization. For example, the rapid development of biofuels has immediate effects on food security. The siting of nuclear power plants in coastal areas becomes problematic when sea levels rise. As air temperatures rise, people use more electricity for air conditioning. Population growth and migrations can overwhelm water supplies already burdened by more direct impacts of climate change on hydrologic cycles, as well as by agricultural and hydropower needs. Policy and research

paradigms need to reflect such shifting realities. Analysis requires modeling and scenario building.

Several workshop participants posited that the next IPCC report must include robust damage narratives for different mitigation timelines. It will also likely discuss the costs of failing to mitigate and adapt. Since three of the four new IPCC scenarios for trajectories of radiative forcing project mean global warming higher than 3°C by the end of this century, public concern about impacts and adaptation will increase.

Discussion: Organizational Needs and Issues

ORGANIZATION OF THE RESEARCH COMMUNITY

Several workshop participants commented that researchers working on vulnerability, impacts, and adaptation—as well as those working more broadly on the human dimensions of global change—have no centrally organizing focus and seem to be fragmented. Research on vulnerability, impacts, and adaptation is funded by multiple and dispersed entities, which are often not dedicated to climate-related work and therefore do not establish formal networks and relationships to identify and set priorities for research (or decision support) needs.

Much of the existing work is focused at fine scales, which is often necessary for rigorous methodologies, but it does not facilitate comparative or integrative collaborations. By contrast, climate work in the physical sciences is organized around specific models and identified needs, often with public funding, such as through the World Climate Research Programme (WCRP). Achieving similar gains in research and deliverables in the field of vulnerability, impacts, and adaptation will require financial investments, coordination, and cross-scalar linkages that are needed but do not presently exist.

Participants offered several ideas for actions to help lay the groundwork for such an effort:

- Create a world climate impacts and responses program, to complement the work of the WCRP.
- Identify the human and funding resources needed to strengthen

the vulnerability, impacts, and adaptation research base, fill gaps, and build research capacity, while meeting increasingly urgent and unfulfilled public needs for expertise and decision support.

- Strengthen coordination of research efforts with the vulnerability, impacts, and adaptation research community, and across working group research areas and communities, including organized involvement in scenario development exercises already under way in anticipation of the next assessment report process of the Intergovernmental Panel on Climate Change (IPCC).
- Identify gaps in existing knowledge about climate impacts on individual sectors and policy areas.
- Emphasize the broader context of adaptation to draw on prior research on sustainability, development, and multiple stressors.

IPCC STRUCTURE AND ACTIVITIES

The IPCC has accomplished a great deal, including building linked scientific and political consensus, communicating scientific findings to decision makers and the public, stimulating the development of an international climate change research community, facilitating science-based policy development, and protecting science from political distortion. Other assessment processes have followed its format as precedent.

Despite these important successes, some IPCC contributors wish to offer constructive criticisms. Some of the criticisms concern the IPCC process, which is seen as increasingly ponderous, expensive, and bureaucratic. Other criticisms are that the IPCC moves by virtue of inertia, without sufficient strategic planning or capacity for change, so that time and energy invested in the process may begin to show diminishing returns. Process evaluation mechanisms are sorely needed to channel such criticisms and foster organizational learning, so that the process can be strengthened from within and in full communication with its leadership. Workshop participants identified quite a few options for improving the IPCC process, including the following:

- Formalize a regular self-evaluation process, perhaps including stakeholders.
- Increase attention to what is not known as well as what is known.
- Address structural obstacles to an integrated assessment of mitigation and adaptation, including:

— Incorporate a synthesis effort in the beginning process stages of future assessments.

— Increase interactions across working groups.

— Create a structural level above working group chairs to link across them, such as an IPCC vice chair.

- Strengthen relationships among climate modelers, impacts modelers, and analysts working on vulnerability, impacts, and adaptation.
- Provide socioeconomic scenarios as context for impact and response assessments.
- Develop special reports on integrated scenarios and adaptation.
- Synthesize mitigation and adaptation in regional IPCC chapters, building on the existing volumes.
- Pick a few high-priority gaps in the research base and accelerate targeted gap-filling efforts, such as potential impact costs, adaptation prospects and approaches, multicausal driving forces for impacts and responses, possible impact thresholds, and tipping points.
- Catalyze research through special reports, expert meetings, and workshops, through which smaller groups can answer urgent and cross-cutting questions (perhaps permitting longer times between full assessments).
- Develop more effective approaches to plenary session approvals, to reduce exhaustion and adversarial interactions.
- Increase outreach and access, especially through the Internet, since closed deliberations are vulnerable to leaks; forethought and caution are warranted, however, if stakeholders are to be directly involved.
- Seek a balance between the identification of synthesis questions early in the process and the need for fluidity in later stages of writing and plenary negotiation.
- Recognize that the purpose of the IPCC may be shifting.
- Identify uncertainties and research needs.
- Provide robust damage narratives for different mitigation timelines.
- Develop indicators and updates for annual or periodic release, sidestepping the repeated scrutiny of confidence levels.
- Include conclusions that may have lower confidence levels but high public risks.

U.S. FEDERAL AGENCIES

Workshop participants clearly articulated the reality that major climate impacts are global; they will cross sectors, agency responsibilities, and international borders. In addition to the growing needs for mitigation and adaptation research, geosecurity issues will arise with new geoengineering proposals and experiments. These realities challenge the existing

research and funding networks and require new modes of organization, bridge-building, and facilitation.

There are extensive and relevant datasets in agencies and reports that are presently invisible and inaccessible to the public and to science and need to be made available. Physical datasets, such as those collected by National Aeronautics and Space Administration (NASA) satellites and by the U.S. Environmental Protection Agency (EPA) on emissions, are difficult to integrate with datasets on human phenomena (such as census data on income, demographics, and migration). Interoperability will require innovation, planning, resources, management, and administration. Though sufficient funding is not yet available for implementation, planning could begin now. A separate public entity could be created to manage climate-related data, or the role could fall within the climate services function proposed by the National Oceanic and Atmospheric Administration. Data-handling precedents in risk and vulnerability research might help. However, congressional definitions of federal agencies' missions sometimes restrict their research programs from playing needed data management roles. Participants briefly discussed a few agencies with relevant mandates and datasets.

U.S. Environmental Protection Agency

Workshop participants pointed out that major changes have taken place at EPA over the last year or more, due to the IPCC's impact on the agency's ability to discuss climate-related issues and to the Supreme Court's decision requiring EPA to reconsider risks to public health and welfare when considering regulation of motor vehicle greenhouse gas emissions under the Clean Air Act. New incentives have arisen to connect science and policy, costs of impacts and adaptation policies, and EPA's mandates to protect public health and the environment. Almost every EPA office is rethinking the work it does. This rethinking includes using risk management frameworks in addition to more conventional cost-benefit tools. It may include organizing around sectors, though this strategy may run counter to the usual self-organization of constituencies. It may also include planning and regulation that encompass both mitigation and adaptation, especially since climate change will affect EPA's ability to meet its legal mandates.

U.S. Department of Energy

Participants noted that U.S. Department of Energy (DOE) has an integrated assessment program that funds basic research. Questions about impacts and adaptation have recently come to the fore and will take on

greater importance in the years ahead, with concomitant funding. Planning now can help maximize effective use of future resources.

Especially from the DOE perspective, integrated assessment models may be the most promising modeling frameworks for exploring the full range of human-natural systems dynamics in climate change. Current models are considerably more capable in their treatment of mitigation (climate drivers) than in their treatment of impacts and adaptation (climate consequences). The integrated assessment modeling community is beginning to address this imbalance, including collaborations with researchers and analysts working on vulnerability, impacts, and adaptation, but exploration of different tools, techniques, and collaborations is required if integrated assessment models are to be truly useful for the analysis of climate change consequences. Initial priorities reflect a need for better modeling of the connected land-water-energy impacts of climate change, as well as general methodological approaches.

Fundamentally, the research questions are becoming more dynamic: What does climate change mean for researchers and analysts? What are the tradeoffs? Do researchers and analysts need to develop different scenarios that inform a broader range of possible issues? Are single-point estimates and scenarios a substitute or complement to probabilistic frameworks? How should the nonlinearities, such as tipping points, be handled? These and many more questions will require intense research focus if balanced models reflecting vulnerability to, impacts of, and adaptation to climate change are to be developed.

U.S. National Aeronautic and Space Administration

The National Aeronautic and Space Administration (NASA) studies the earth system from space, traditionally from a global perspective. The agency has played a key role in understanding physical climate change and is now looking at new questions, such as regional modeling and scaling. NASA wishes to expand the utility of its satellite observations and other assets for decision support, as well as basic science. Easier access to observations archived in longer time series is needed, to inform impacts and vulnerability assessments and for other purposes.

U.S. Geological Survey

The U.S. Geological Survey (USGS), the research arm of the U.S. Department of Interior (DOI), has long-term time-series datasets. DOI manages one of every five acres of U.S. land and uses both staff and volunteers to collect data on wildlife, ecosystems, and climate change. This includes basic research, decision support, and information transfer.

U.S. National Science Foundation

The National Science Foundation supports climate-related research, not through any central priority setting, but through its usual researcher-driven peer review process. Numerous research funding opportunities exist in disparate programs.

SCIENCE AND POLICY TIMELINES

The public and decision makers have become aware that responses to climate change are of utmost urgency. They want to know what they can do now. Even without this new pressure, policy makers operate on shorter decision horizons than researchers do. Few think farther ahead than 8 years at most. Nonetheless, the research community is now laying out longer-term agendas and needs.

Pragmatically, researchers can accommodate this discrepancy by offering short-term messages. That doesn't mean abandoning longer-term analysis and planning; rather, it means interacting with the public on practical and effective terms. Yet climate is an unprecedented policy challenge and will require public institutions to change the way they do business.

Discussion: Research Priorities

A number of research priorities were identified by workshop participants. They covered a broad range of issues: linking vulnerability, impacts, and adaptation research with mitigation and climate models; developing risk approaches; linking across scales; scenarios; stakeholder involvement; support for pending decisions; and research syntheses.

LINKING VULNERABILITY, IMPACTS, AND ADAPTATION RESEARCH WITH MITIGATION AND CLIMATE MODELING

Increasing agreement is emerging that mitigation and adaptation policies and research cannot be treated separately from one another. The two are tightly linked in the context of broad tradeoffs in both macro-level climate response strategies and more localized decision contexts, such as infrastructure, transportation, and land use planning. Even with strong mitigation initiatives, some adaptation will be needed. Conversely, insufficient mitigation efforts will preclude or nullify some or all adaptive strategies due to the magnitude of earth system change. Despite recent calls for integration across adaptation and mitigation, including within the Intergovernmental Panel on Climate Change (IPCC) process, progress in this direction has thus far been limited. Adaptation work generally receives less attention and funding. Scales, tools, and methods of analysis often differ between the two areas of research and policy.

Path-breaking initiatives can be developed in the area of integrated planning for adaptation and mitigation, especially at the regional scale.

Without such efforts, it is likely that feedback loops will generate unintended consequences. For example, biofuel production is affecting food security, which in turn has impacts on migration, health, land use, and sustainable development. Increased efficiency in energy production can increase rates of energy use. Demographic trends or shifts can overwhelm otherwise effective strategies for mitigation, adaptation, or both. The effects of water projects can vary with different levels of flow and usage. As multiple stressors accelerate, these kinds of feedback relationships across mitigation- and adaptation-related variables are likely to increase in policy importance. Researchers need to ask questions such as: Are there critical thresholds in the ability to adapt? If so, what kinds of response can avoid these thresholds? How might future climate-related changes, especially abrupt ones, affect remaining capacities for climate change response? For instance, might some livelihood systems become more or less feasible? Are certain populations more vulnerable?

Climate modelers are also becoming more interested in issues of vulnerability, impacts, and adaptation, especially as they give more serious attention to more severe climate futures than previously examined. In the emerging effort to develop linked mitigation-adaptation scenarios and models, the community of vulnerability, impacts, and adaptation researchers needs to be a full partner, not just to provide input data as an add-on or afterthought. Nonetheless, the necessary integrated approaches have not yet been developed. Both communities will be challenged and will need to work together to address this research front. Development of improved capabilities for vulnerability, impacts, and adaptation modeling in integrated assessment will depend on underlying research by the vulnerability, impacts, and adaptation research community and more focused vulnerability, impacts, and adaptation models and tools that are interoperable with climate models. Approaches to modeling and data acquisition for climate impacts will, in many cases, be scaled differently than for climate drivers: the impacts work will be more local and regional and will need to scale up. In all likelihood, modeling of climate drivers will require downscaling as well. Innovative approaches will be required to overcome data limitations.

DEVELOPING RISK APPROACHES

Participants observed that decision makers are coming to accept that climate change is a risk management problem, which implies a need to attend more to events that have low probabilities of occurrence, but can produce dramatic impacts if they do occur. Analytic structures are needed to think about costs and benefits in risk terms, to estimate the sensitivity of cost to mitigation, and to address the variety of climate-driven

hazards. Climate change projections are now giving greater credence to more severe changes in average temperature and other parameters. Some decision makers are becoming more interested in these low-probability, high-impact risks. In addition, indications that prior earth system models grossly underestimated the uncertainty bounds of rapid and large-scale phenomena, such as ice sheet melting, suggest that more attention is merited by other extreme events to which low estimated probabilities have been previously assigned. For example, projected rises in sea levels vary widely even within a narrow range of mean global temperature increases.

Physical scientists often prefer to discuss phenomena for which they can cite higher confidence levels, which tend to be associated with higher probability and lower-consequence events. At the same time, public officials often avoid discussing low-probability, high-impact phenomena to avoid alarming constituencies. Improved climate models may reduce uncertainties around the locations, timing, and extent of future impacts, but less research attention has focused on the considerable uncertainties about how associated vulnerabilities and adaptation measures will change over time.

The concept of risk as a product of statistical probability and social consequence resonates with decision makers. The following research directions can help the vulnerability, impacts, and adaptation community to engage with risk approaches more directly:

- Analyze impacts and adaptation approaches in terms of risk, on both short- and long-term time scales, and for both social groups and locales.
- Ask in what instances communities understand their risks or perceive themselves as able to reduce risk.
- Ask in what instances the cumulative reduction of small-scale risks increases or decreases vulnerability to more significant events.
- Provide clear information about risks as input to cost-benefit discussions.

LINKS ACROSS SCALES

Researchers in the field of vulnerability, impacts, and adaptation often conduct finely scaled analyses, which are essential, but to be useful for broader climate-related research, policy, and assessment their work must link upward to larger geographical scales. The rigor of the research itself can be sharpened, not necessarily with quantitative models, but with careful selection of datasets and methods.

Regionally integrated studies are one option, such as analyzing the

growth, use, and outputs of specific biomass sources and how they interface with local ecosystems and resources in specific places. These results can be structured as scenarios or narratives. If this research community is to respond to emerging needs for decision support, a series of corresponding methodological needs arise. Stakeholder involvement is a related issue that may merit separate attention.

SCENARIOS

Illustrative scenarios, storylines, and regional narratives are compelling ways to use qualitative methods to accomplish integration and identify potential disasters. They can be constructed from the bottom up, incorporating participation by stakeholders and vulnerable groups. They can begin with the scenarios of projected greenhouse gas concentration pathways and physical impacts. For example, as a metropolis such as Mexico City faces increasing water scarcity and decreasing water quality, what are two or three possible adaptation routes and associated complications?

Such scenarios, however, need to incorporate feedback mechanisms. For example, gains in economic development or energy supply have effects on fertility and other demographic variables. Even small demographic changes can foil expectations for existing and pending policies. Public perceptions are often of central importance. Perceptions of risk and of capacity to effect change can influence the success or failure of policy, since policy implementation relies on a series of actions by individual and collective decision makers. Outcomes may be highly contingent on a broad range of human-environment variables.

STAKEHOLDER INVOLVEMENT

Some workshop participants expressed concern that it may be necessary to balance tradeoffs between research coordination and stakeholder participation. Stakeholders and implementation communities are sometimes included early and intensively in research project development without sufficient forethought or caution. These groups are diverse in their needs, goals, roles, values, and definitions of success. Many are vulnerable to political pressures, which can discourage healthy scientific critique or unduly raise client expectations. Risk management frameworks, as noted above, can assist. Corresponding models may be available from adaptation work by public health organizations.

SUPPORT FOR PENDING DECISIONS

There is a growing need for short-term decision support, including rapid assessments and indicators. Workshop participants identified ways in which researchers in vulnerability, impacts, and adaptation might contribute:

- Provide clear and precise quantitative estimates of climate change impacts and costs of mitigation and adaptation failures, as needed by decision makers, even if these must be accompanied by caveats and uncertainties.
- Develop metrics that are useful in decision making, including integrated monetary and nonmonetary social indicators.
- Identify the economic and social costs and benefits of specific adaptation measures, such as ecosystem protection, health interventions, and land use measures.
- Rely on scientific foundations vetted by the IPCC to help protect against political censorship or backlash.

RESEARCH SYNTHESES

Increasing opportunities are arising to link diverse human–environment research methods, data and research areas, including qualitative and quantitative methods, space-based observational datasets, and security perspectives. To make these connections, researchers in the field of vulnerability, impacts and adaptation need to be clear and articulate in communicating the broad range of variables that must be included for effective, integrated, quantitative models, recognizing that appropriate inputs may vary for particular decision support goals and users. Participants noted several specific research areas in need of attention and synthesis:

- Identify specific outputs needed from biogeochemical models of climate change as inputs to analyses of vulnerability, impacts, and adaptation.
- Elevate understanding of empirical complexities in human-environment systems, such as institutional and demographic dynamics, that are often neglected in existing impacts projections. Economic analyses tend to focus only on aggregate impacts, without looking at unquantified household- and local-level phenomena that ultimately scale up to larger scale impacts. They also tend to rely on means, excluding impacts of more extreme and nonlinear physical phenomena.
- Use the strengths of systems theory to facilitate interactions across working group communities and within the vulnerability, impacts, and adaptation community.

Wrap-Up Comments

Martin Parry, Cynthia Rosenzweig, and Thomas Wilbanks offered wrap-up comments on the workshop. Their comments addressed changes in the context of vulnerabilities, impacts, and adaptation research; research challenges; organizational needs; and anticipation of the fifth IPCC assessment report.

THE CHANGING CONTEXT

As noted by Wilbanks, the *Fourth Assessment Report* of the IPCC sharpened the focus of global climate change science and policy making on impacts, vulnerabilities, and mitigation and adaptation. After a period in which support for most research on climate change impacts and adaptation was scarce, policy makers began seeking answers to urgent questions on those topics.

Wilbanks also pointed out three other changes in the context. First, there is a wide sense of greater urgency in response to the very real possibility that the magnitudes of climate change will be greater than previously estimated. Second, there is increasing interest in collaboration among different parts of the climate change research community. Third, the prospect for increases in research support seem to be improving.

RESEARCH CHALLENGES

Rosenzweig pointed out that there is a strong contrast between the urgency expressed by agency program managers seeking help in the short term and longer-term needs. In the short term, managers want help for decision making regarding climate change impacts and adaptation (such as rapid, stakeholder-driven assessments). At the same time, there is a longer-term need to develop in-depth, rigorously tested research on vulnerability, impacts, and adaptation, including model comparisons and large-scale comparative studies. Especially for that longer-term need, the rigor of vulnerability, impacts, and adaptation research needs sharpening, not necessarily through the use of quantitative models, but through enhanced data collection, availability, and analysis, and a spectrum of research methods that can continue to address uncertainties.

One needed focus is on costs and metrics, involving both monetary and nonmonetary social variables. Emerging risk management paradigms frame analyses in terms of vulnerabilities and risk management, in contrast to older paradigms that emphasize impact projection and cost estimation. New methods are emerging for creating risk profiles for groups and locales on both short-term and long-term time scales. The synergies and conflicts between mitigation and adaptation need to be characterized. Finally, the role of vulnerability, impacts, and adaptation research in the future development of new emissions and climate scenarios is unclear. Though some researchers have worked hard to participate in this arena, the outcomes do not yet benefit from full collaboration. It is helpful to invest in those partnerships, but this community of researchers needs to self-organize on broader terms in order to strengthen those research outcomes.

Wilbanks summarized additional challenges to the vulnerability, impacts, and adaptation research community. First, it is difficult to cope with urgent needs for timely assessments while simultaneously strengthening a seriously incomplete research base. The field may need to move on two parallel tracks—with different organizational frameworks but a common base of knowledge and expertise. Second, the possibility that the magnitudes of climate change impacts and adaptation challenges will be greater than previously assumed adds to the importance and urgency of considering possible thresholds and assuring anticipatory monitoring. Third, there is a need to consider climate change impacts and responses in the broader context of sustainability. This consideration needs to include specific development pathways, evolving socioeconomic conditions, multiple stresses, gaps between anticipated and actual human behavior, and associated complexities inherent to the relationships among strategy, policy, and action. Fourth, the existing scholarship on vulnerabilities and risks does not sufficiently fulfill decision makers' requests for specific

estimates of climate impacts, including the costs of failing to mitigate. These estimates are needed to inform economic tradeoffs.

ORGANIZATIONAL NEEDS

Parry, Rosenzweig, and Wilbanks said that an effective self-organization process is needed. Such a process will require mobilization to improve communications both in the vulnerability, impacts, and adaptation community and between that community and other parts of the climate science effort, including earth system and integrated assessment modeling. Researchers focusing on vulnerability, impacts, and adaptation can contribute geographic and sectoral diversity to the larger effort, as other researchers mainly work through larger, more aggregated models. Such a process of self-organization needs to be sensitive to the diversity and bottom-up culture of the vulnerability, impacts, and adaptation research community to establish full collaboration with the earth system and integrated assessment modeling communities.

THE IPCC FIFTH ASSESSMENT REPORT

Parry noted that IPCC organization will be influenced not only by scientific opinion, but also by intergovernmental negotiations. The organization issues discussed included relationships between Working Group II and other working groups, such as possibilities for early identification of questions and key messages in the development of synthesis report outlines. The participants identified several key issues for the next IPCC assessment, including the need to strengthen the knowledge base in peer-reviewed research, especially for such understudied sectors as cities and settlements; maintaining the risk management paradigm, including non-climate changes in projections of longer-term impacts and costs; and developing reference scenarios for vulnerability, impacts, and adaptation assessments.

Appendix: Workshop Participants

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