Enhancing Participation in the U.S. Global Change Research Program

DETAILS

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Acknowledgments

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 National Academies of Sciences, Engineering, and Medicine's Report Review Committee. 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 objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in their review of this report:

Roger Beachy, University of California, Davis
Adam Rose, University of Southern California, Los Angeles
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William Clark, Harvard University, Cambridge, MA

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions nor did they see the final draft of the report before its release. The review of this report was overseen by **Kenneth H. Brink**, Woods Hole Oceanographic Institution, appointed by the Division on Earth and Life Studies, and **David M. Karl**, University of Hawaii at Manoa, appointed by the Report Review Committee, who were responsible for making certain that an independent examination of this 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 authoring committee and the institution.

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Executive Summary

The US Global Change Research Program (USGCRP) is a collection of 13 Federal departments and agencies[1] charged by law (the Global Change Research Act [GCRA] of 1990) to assist the Nation and the world to "understand, assess, predict, and respond to human-induced and natural processes of global environmental change." As the understanding of global change has evolved over the past decades, and as demand for scientific information on global change has increased from both the public and private spheres, the Program has increasingly focused on use-inspired research that can inform decisions to cope with current global environmental change—in particular to understand climate variability and change, to reduce the magnitude of future changes, and to prepare for changes projected over coming decades.

In light of the challenges faced by USGCRP to produce actionable scientific knowledge and better serve the needs of the nation, the National Academies of Sciences, Engineering, and Medicine's Committee to Advise the U.S. Global Change Research Program has written this report. The goals of the report are to explain why it is necessary to identify potential new partners to participate (or current partners to more fully participate) in USGCRP activities, to explore the current set of USGCRP capabilities in light of this rationale, and to identify examples of gaps and areas of potential adjustments (a more detailed Statement of Task for this report can be found in Appendix A).

The federal government funds and conducts research aimed at building global change science that supports a broad range of decisions to manage the risks and opportunities that global change presents to the nation. The USGCRP has set forth an ambitious path toward meeting the nation's needs for global change information in its 2012 Strategic Plan. However, it has become clear that the current group of member agencies is not adequate for addressing the breadth of the challenges that the United States faces, as described in the plan. Working with additional partners is a useful way for USGCRP to achieve its mandate. In some cases, other federal agencies and non-federal entities are conducting important research that could be brought to bear on global change science. In other cases, USGCRP research could be better connected with efforts to inform decisions that are affected by global change.

Additional partnerships are needed to address all of the goals and objectives described in the Program's evolving Strategic Plan. The advantages of such partnerships will have to be balanced against the costs to the partners, both in forming and continuing a partnership and in the potential for diversion of agency resources to national goals tangential to the current understanding of agency responsibilities. The process of determining potential partners will need to evolve with time, but the Committee has

[1] For simplicity, the term "agencies" is used from here on.

identified a number of current examples that highlight opportunities where enhanced participation could benefit the nation.

Drawing upon past and ongoing examination of the USGCRP, the Committee reached four broad conclusions, which are illustrated with the case studies highlighted throughout the report:

- ***Conclusion 1**: USGCRP needs broader partnerships and participation from within existing member agencies and from new entities to achieve its goals.*
- ***Conclusion 2**: USGCRP could most effectively achieve its goals by embracing a variety of approaches to partnership.*
- ***Conclusion 3**: The Interagency Working Groups are one particularly useful approach that could be more fully exploited as a means to promote ongoing collaboration around specific areas of interest and to create networks of partners.*
- ***Conclusion 4**: USGCRP would more fully meet its mandate by taking the lead in arguing for increased participation by other agencies—including formal membership—when the benefits to the nation outweigh the costs of collaboration to the agencies.*

The Committee has found that there are opportunities for enhanced participation in support of all four goals of USGCRP's 2012 Strategic Plan—(1) Advance Science, (2) Inform Decisions, (3) Conduct Sustained Assessments, and (4) Communicate and Educate. This report provides several concrete examples of mechanisms and levels of participation that can serve as useful models for enhancing collaboration across the family of U.S. agencies and with non-Federal partners. In order to achieve the ambitious goals of the Strategic Plan, the USGCRP will need to employ new and existing mechanisms that will enhance participation in the Program and ultimately provide greater societal benefit from the conduct of global change science.

Introduction

The U.S. Global Change Research Program (USGCRP)[2] is a collection of 13 Federal departments and agencies (Box 1) charged by law (the Global Change Research Act [GCRA] of 1990[3]) to assist the Nation and the world to "understand, assess, predict, and respond to human-induced and natural processes of global change." From its initiation, the USGCRP has understood this charge to include two primary functions. The first of these is to coordinate the research activities and research sponsorship of its member agencies, and the second is to assess the state of the science at four-year intervals.

USGCRP has guided its overall strategy for coordinating research by a series of strategic plans (USGCRP, 1990, 2003, 2008, 2012) and in the annual report *Our Changing Planet* (e.g., USGCRP, 2015). Through the 1990s, the main emphasis of the USGCRP was clearly on enhancing the underlying scientific foundation for understanding processes of global environmental change, a broad and varied suite of challenges which includes future climate change (see Box 2 for a description of global change research). The large investment in observing programs, a substantial investment in process-based research on the physical aspects of the climate system, and the emphasis on Earth system science as a framework for modeling all reflected the high priority given to increasing the fundamental understanding of Earth as a biophysical system.

BOX 1: Federal Entities that are Currently Members of USGCRP

Department of Agriculture (USDA)
Department of Commerce (DOC)
Department of Defense (DoD)
Department of Energy (DOE)
Department of Health and Human Services (HHS)
Department of the Interior (DOI)
Department of State (DOS)
Department of Transportation (DOT)
Environmental Protection Agency (EPA)
National Aeronautics and Space Administration (NASA)
National Science Foundation (NSF)
Smithsonian Institution (SI)
U.S. Agency for International Development (USAID)

[2] Also referred to as "the Program."
[3] http://www.globalchange.gov/about/legal-mandate

BOX 2: Global Change Research

"Global change research" encompasses a broad suite of global environmental challenges. Human-induced climate change is a particularly large challenge within the broader list of global change issues, but it is not the only one. Quoting from a previous report (NRC, 2012): "The U.S. Global Change Research Act (GCRA) of 1990, which established the Program, mandates a broad definition: 'Global change' means changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life. 'Global change research' means study, monitoring, assessment, prediction, and information management activities to describe and understand

- the interactive physical, chemical, and biological processes that regulate the total Earth system;
- the unique environment that the Earth provides for life;
- changes that are occurring in the Earth system; and
- the manner in which such system, environment, and changes are influenced by human actions."

This Committee has also stated (NRC, 2012): "Although the concept of global change is not precisely defined at the edges, and remains a matter of active debate, the GCRA clearly calls for a program that encompasses more than climate change alone."

As the program has matured, there has been an important shift in the relative balance of its goals and objectives. The science of global change has demonstrated the importance of human choices in shaping the future of the planet and its constituent ecosystems, as well as in the options available to manage the consequences of global environmental change for human and natural systems. Moreover, rising awareness of a changing climate has led decision makers in both the private and public spheres to look to science for guidance in making choices about policies, actions, and funding. For both reasons, the Program has increasingly focused on use-inspired research that can inform decisions to cope with current climate variability and change, to reduce the magnitude of future changes, and to prepare for changes projected over coming decades. The most recent strategic plan (Box 3) demonstrates a continuing evolution that includes research meant to aid problem solving, as well as research intended to increase fundamental understanding of the processes of global environmental change.

The National Academies of Sciences, Engineering, and Medicine's Advisory Committee to the U.S. Global Change Research Program (the authoring committee of this report) has commented previously on the evolving role of the USGCRP:

> From *A Review of the U.S. Global Change Research Program's Strategic Plan* (NRC, 2012): "The proposed broadening of the Program—to better integrate the social and ecological sciences, to inform decisions about mitigation and adaptation, and to emphasize decision support more generally—is welcome and in fact essential for meeting the legislative mandate for a program aimed at understanding and responding to global change."

BOX 3: USGCRP Strategic Plan

USGCRP is mandated by Congress to develop a new strategic plan every 10 years, with triennial revisions and updates. The most recent Strategic Plan, entitled *National Global Change Research Plan 2012–2021: A Strategic Plan for the U.S. Global Change Research Program* (USGCRP, 2012), lays out a vision for the Program that "maintains a clear emphasis on advancing global change science, but it also calls for a strengthened focus on ensuring USGCRP science informs real-world decisions and actions."[a] As described in the Strategic Plan, there are four strategic goals for the Program:

- **Advance Science**—Advance scientific knowledge of the integrated natural and human components of the Earth system to understand climate and global change.
- **Inform Decisions**—Provide the scientific basis to inform and enable timely decisions on adaptation and mitigation.
- **Conduct Sustained Assessments**—Build sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities.
- **Communicate and Educate**—Advance communication and education to broaden public understanding of global change and develop the scientific workforce of the future.

The Strategic Plan was developed through an intensive interagency process involving a team of more than 100 Federal scientists in collaboration with USGCRP leadership and drawing on input from numerous stakeholder groups. The final document was revised in response to reviews by USGCRP and the Committee on Environment, Natural Resources, and Sustainability (CENRS[b]) member agencies, comments from the public, and a review by the Advisory Committee that is also writing this document (NRC, 2012).

[a] http://www.globalchange.gov/about/mission-vision-strategic-plan
[b] https://www.whitehouse.gov/administration/eop/ostp/nstc/committees/cenrs

"The Committee concurs that this broader scope is appropriate, but realizes that such an expansion may be constrained by budget realities and by the practical challenge of maintaining clear boundaries for an expanded program. We encourage sustained efforts to expand the scope of the Program over time, along with efforts to better define and prioritize what specific topics are included within the bounds of global change research."

"… we suggest that the Program identify some initial steps it will take in the proposed broadening of scope—including steps to develop critical science capacity that is currently lacking and to improve linkages between the production of knowledge and its use…."

From *A Review of the Draft 2013 National Climate Assessment* (NRC, 2013a): "An assessment of this broader range of questions would, of course, require a broader foundation of research findings to draw upon, and thus it would be necessary to explore how this broader range of issues could be addressed, either within the scope of the USGCRP's research program or elsewhere. It might, for instance,

> require expanded involvement of programmatic agencies not typically involved with the USGCRP (e.g., the Department of Housing and Urban Development, the General Services Administration, Navy Facilities Engineering Command, Federal Highway Administration) to conduct pilot projects for mitigation and adaptation…."

In summary, the Committee sees the expanding role of USGCRP to support decisions as a necessary evolution, but one that comes with challenges from constrained budgets and maintaining clearly defined boundaries.

Along with these strategic and funding challenges, there is a significant institutional challenge in how the "membership" of the USGCRP might best reflect the evolution of its research strategy within the mandate of the law. Thirteen federal departments and agencies (Box 1) are formal members of USGCRP. Other agencies may participate in the USGCRP with appropriate formal arrangements, such as memoranda of understanding or an invitation to a particular staff person or component to participate in a meeting. There is no legal limitation on the participation of agencies in the USGCRP, so the rationale for determining membership is derived from what is in the best interest of the nation as articulated in the original mandate in the GCRA and the subsequent Strategic Plans. USGCRP has had successes in helping coordinate research across agencies, but it is the Committee's assessment that the member agencies form an incomplete patchwork of what is needed to help the Nation prepare for, respond to, cope with, and recover from global change. Overall, the current breadth and depth of research in these agencies is insufficient to meet the Nation's needs, particularly to support decision makers. Addressing these challenges to produce actionable scientific knowledge and better serve the Nation raises important questions about how that might best be done and which agencies should be represented.

In light of these issues, and under the guidance of The National Academies of Sciences, Engineering, and Medicine, the Committee undertook writing this brief report to explore mechanisms and opportunities for enhancing participation in USGCRP's evolving scope of activities. The Committee's statement of task (see Appendix A) did not stipulate a comprehensive survey of the capabilities in federal agencies and other partners that should either use or contribute global change research in the pursuit of their missions. Rather, the Committee's task was to explore the current set of USGCRP capabilities in comparison to goals and objectives in the Program's Strategic Plan and to identify example gaps and areas of potential adjustments that can provide guidelines for the Program as it moves forward.

Although the Committee's task initially focused on participation of federal agencies in the Program, the objectives specified in the Strategic Plan imply a need for participation beyond the federal government. To build a science base that integrates the natural and human components of the Earth system—which is useful for informing decisions, building a sustained assessment capacity, and broadening public understanding of global change—the Program requires integration of the perspectives of entities outside the federal government, particularly those responsible for making decisions about global change.

Global change will increase risks to society in a number of sectors—energy, agriculture, health, etc.—and efforts to respond effectively to those risks would benefit from collaboration among those who have extensive expertise in global change, those who have deep scientific expertise in the nature of the risk, and those who have "on the ground" experience developing programs to respond to risk.

It is of course the case that federal agencies participating in the USGCRP already engage with non-federal users of federally sponsored research, in some cases extensively. For example, in the National Climate Assessment (NCA) completed in 2014, non-federal partners helped shape the process from the beginning. In many other domains as well, the Program can meet its goals far better by engaging with a variety of non-federal entities, including state and local governments, international programs and foreign governments, business and community groups, professional societies, mass media entities, educational institutions, and other entities engaged in making or informing global change decisions. Although these entities will not be involved in budgetary decisions, their input needs to be included in setting program priorities. The sustained assessment process provides a particularly important venue for such partnership because a major goal of the assessment process is to inform non-federal decision makers.

Specific recommendations on which partners are most appropriate in which contexts and on how best to engage them with the Program are beyond the scope of this report. However, the issue has been addressed in part in previous reports from the National Academies of Sciences, Engineering, and Medicine (e.g., NRC, 2008, 2009a). As recommended in those previous reports, the appropriate non-federal partners to be approached depend on the task or activity and should therefore be chosen to suit the activity. The Committee emphasizes that one of the tasks of Program leadership and of the various Program elements, as a broadened Program scope is being defined and implemented, will be to identify and engage the appropriate non-federal partners suited for each specific activity.

Current Participation in the Program

From the beginning of the Program, there have been important cultural differences among the USGCRP agencies in terms of how they address their scientific missions related to global change. NSF, for example, exclusively supports the scientific community (primarily in academia) to perform fundamental research according to the community's priorities, which are identified and vetted through peer-reviewed proposals, with some attention paid to avoiding overlap with other agencies' main foci. The U.S. Geological Survey (USGS), on the other hand, primarily supports science related to its mission through an in-house scientific staff. The National Oceanic and Atmospheric Administration (NOAA), NASA, DOE, EPA, and USDA support a mix of in-house and extramural mission-oriented research, with the balance between the two set by agency needs. The magnitudes of extramural and intramural research support, as well as the mechanisms by which proposals are sought and evaluated, vary among USGCRP members. The agencies also vary in the degree to which they invest in efforts to inform decisions as a part of the research process.

USGCRP members have a variety of reasons for their participation and thus have varying levels of participation from within their agencies. First, there are agencies whose missions prominently include research on the science of global change, e.g., NOAA, NSF, DOE, and NASA. In addition, many of the agencies with membership in the USGCRP also have regulatory or policy functions related to global change (e.g., EPA, DOE, NOAA, and DOI). The scientific and policy functions may be in different offices within USGCRP agencies, as is the case with EPA and DOE, or they may largely be in separate agencies, as in DOI. Several agencies, e.g., NOAA, have parts that have both regulatory and research functions, such as the National Marine Fisheries Service and the Office for Coastal Management. Many of the agencies that are members of USGCRP have multiple parts (e.g., sub-agencies or offices) that participate in or contribute to the USGCRP to varying degrees. For example, parts of the USDA that contribute include the Agricultural Research Service (ARS), Forest Service (USFS), National Institute of Food and Agriculture (NIFA), Natural Resources Conservation Service (NRCS), National Agricultural Statistics Service (NASS), and Economic Research Service (ERS).

Participation in the USGCRP takes several forms. The principal and most visible role is supporting research responsive to the priorities outlined in the strategic plan. But there are other modes of participation for engaging in the stimulation, facilitation, shaping, and coordination of global change research, as well as for envisioning the research needed to proactively prepare for projected environmental changes. Those other modes include:

- staff support for the USGCRP Office;
- participation in budget cross-cuts as requested by Office of Management and Budget (OMB);

- interaction with the Office of Science and Technology Policy (OSTP) and OMB in setting national research priorities, as set out in an annual memo from OSTP to the agencies;
- intellectual and staff contributions to strategic planning and preparation of program documents;
- participation in the National Climate Assessment (USGCRP, 2014);
- participation in the governance of the USGCRP through membership on the committee of Principals (i.e., representatives from each of the 13 formal member agencies) that oversees the entire program; and
- participation in various Interagency Working Groups (IWGs) that coordinate a wide variety of activities among the agencies (see Appendix D).

Some of these other modes have been quite effective. In particular, some of the IWGs have had real success in coordinating efforts across multiple agencies, including the Adaptation Working Group and the Climate Change and Human Health Working Group, that were very active in the most recent National Climate Assessment (USGCRP, 2014).

The degree to which the various agencies take on such activities varies widely. At a minimum, all member agencies are represented by a Principal. Further, among agencies that are formally part of the USGCRP, some parts of the agencies may be highly engaged, while other parts of those agencies may not engage at all, even though there may be increasing reason for them to do so as the activities for which they have responsibility are affected by global change. In addition, there are other agencies that are not formal members of USGCRP that participate in one or more of the modes identified in the previous paragraph, in particular through the IWGs.

Benefits to the agencies from participation in these activities include gaining support for their research programs, using the results of USGCRP science to support their missions, and increasing the audience for their research. Because both the science and the problems of global change cross disciplinary lines and agency missions, the USGCRP's coordination responsibilities include instances in which a participating agency can readily perceive its own interest in participating, as well as cases in which the research capabilities of an agency are needed by others but are not initially a high priority to the agency. The latter is a challenge in many different agency settings that needs to be addressed as the Nation prepares for the risks of global and regional change.

The Committee recognizes, moreover, that participation in the USGCRP is not free: At minimum, staff time is required, and the interactions with the Program may trigger reallocation of the resources of an agency or department. The latter may be both beneficial and, in the short run, inconvenient. The Committee's conclusions below take these costs of participation into account. The case studies discussed throughout the rest of this report explore examples of how enhanced participation in USGCRP could be of value to USGCRP, the nation, and a number of agencies and federal entities that are not currently engaged heavily in USGCRP activities.

Opportunities for Broader Participation

The examples that follow illustrate how greater participation in USGCRP could benefit agencies and other entities not currently engaged in USGCRP activities. They are organized around the four major goals of the USGCRP Strategic Plan (USGCRP, 2012; Box 3) and include both past efforts and potential future ones.

Goal 1 – Advance Science

In its previous review of the USGCRP Strategic Plan (NRC, 2012), the Committee concluded that, in order to meet its legislative mandate, the Program needs to address "all of global change, whether or not related to climate." The Committee encouraged the Program to continue moving toward a risk-based framework that aims to understand how interactions among current and future global change, vulnerabilities, and capacities could alter challenges and opportunities for individuals, communities, and states in coming decades. This means integrating knowledge from the physical, biological, and social sciences and understanding sectoral risks and options for response *broadly*. Providing the science to support informed decision making to effectively and efficiently manage changing sectoral risks is a priority for the Nation. As global changes continue, a broader range of agencies will need to address the associated risks to achieve their mission mandates.

The Committee's 2012 review further recommended that to achieve the goal of addressing all risks associated with global change, the Program needs "to better integrate the social and ecological sciences" and to move toward "an integrated observational system that connects observations of the physical environment with a wide variety of social and ecological observations" (NRC, 2012). The Committee reiterates the 2012 report's conclusion that achieving this expansion presents a grand challenge, especially considering budget constraints and the fragmented structure of federal research (NRC, 2010, 2013b). For challenges like better integration of social and ecological sciences, one set of promising opportunities for advancing science under the constraints mentioned lies in more fully engaging agencies that already collect data relevant to the USGCRP mission. Box 4 presents an example of data that could be used to provide baseline information on vulnerability and resilience to global changes and to measure the effectiveness of adaptation efforts. It also discusses the broader challenge of linking data collected for purposes unrelated to global change with the needs of global change science and ways to meet it. Many of these agencies also serve constituencies likely to be affected by global change and can thus help the USGCRP identify and prioritize directions for advancing science that would support those constituencies.

BOX 4: Case Study on Integrating Data for Advancing Global Change Science

There are opportunities for federal agencies to work together in specific areas related to advancing global change science that are not currently being addressed by interagency activities; this includes integrating data from various sources across the federal government. As noted in previous NRC analyses (NRC, 1992, 2004, 2005, 2008, 2009a, b), federal agencies, along with public and private sector organizations in the United States and elsewhere, collect high-quality, long-term, readily accessible data on a variety of phenomena relevant to the impacts, vulnerability, and potential for adaptation to global changes. These data include human population characteristics, economic productivity and consumption, health and disease patterns, insurance coverage, crop yields, hazards exposure, air quality, distributions of threatened and endangered species, ecosystem status, forest inventory, livestock, fisheries, soil and vegetation distributions, fresh water quality and quantity, and nutrient distributions.[a] Although developed for purposes unrelated to global change, many of these databases could provide valuable baseline information about human and biological systems that may be affected by global changes and could be used in vulnerability assessment and evaluating possible adaptation efforts.

Federal agencies with such resources that are not currently central participants in USGCRP activities include parts of USDA, DOC, DOI, HHS, DOT, the Department of Homeland Security (DHS), the Department of Housing and Urban Development (HUD), and the Department of Labor. They could be usefully engaged with core USGCRP agencies, sometimes including agencies within their own Departments. One goal of such engagement is to facilitate analyses of multi-sectoral effects of global change, such as linked effects on water, agriculture, energy, and health, by taking advantage of existing data with longer time series.

Linking federal data collected for purposes unrelated to global change science with the needs of global change science and decision making presents a significant challenge because, although the data are available, their usefulness may not be evident. A previous NRC analysis (NRC, 2009b) concluded that understanding interactions among global environmental and human systems, and thus supporting societal responses, required that observation systems include physical, biological, and social observations, and that this would necessitate a restructuring of the federal research effort. Short of such a major restructuring, the main challenge of linking data lies in identifying for scientific analysis the data most useful for addressing specific questions. To do this, the federal agencies or units that collect data of potential value for global change science and decision making need to engage with data users in discussions around particular topics that call for data linkages. This could occur in many ways. For example, engagement of such agencies or units in national, regional, or sectoral assessment processes, along with global change scientists and decision makers, can help identify data linkages in ways that inform the various data suppliers on key objectives for data linkage.

[a] See specific examples of databases from the U.S. West Coast: http://oceanspaces.org/ and http://www.piscoweb.org/

Goal 2 – Inform Decisions

As understanding of global change has evolved, the relative emphases among the multiple roles of USGCRP have also evolved to attempt to meet the challenges faced by the nation. This shift is reflected in the four goals of the 2012 Strategic Plan (Box 2), which

included an increased emphasis on Goal 2—to inform decisions—compared to earlier plans (e.g., USGCRP, 1990). As such, the Committee discusses this Goal in more depth than the other Goals.

Informing decisions goes beyond the traditional division between basic and applied research (Stokes, 1997), because of the way that the needs of users stimulate changes in the priorities of research (see NRC, 2009a and McNie et al., 2015). Basic research has traditionally been guided by the researchers themselves, while applied research generally aims to solve problems defined primarily by users in the field and in mission agencies. The scientific knowledge needed to inform many important decisions concerning global changes is best developed in response to decision makers' needs as well as to developments in science. Thus, the priorities of scientific research investment will evolve as changes occur in both these domains. The priorities of both users and researchers evolve with changes among key stakeholders, shifts in the institutional arenas in which decisions are made, emerging risks from global change, the eruption of crises, and—not least—from the production of new and surprising research results.

The task of the USGCRP is to facilitate coordination among and within its member agencies so as to capture the benefits of the learning that accompanies scientifically informed decision making in response to global change. As the climate changes, for example, there is an increasing need for actionable information for adaptation and resilience planning at the regional and local level. Effective mobilization of the federal government's important but not unlimited capabilities is of instrumental benefit to the Nation—as demonstrated by how experience with previous large cyclones enabled better preparations in 2012 as the track of Superstorm Sandy was being analyzed.

The evolution of the Program to include more emphasis on supporting decisions has encountered serious challenges to its progress, not all of which have been fully surmounted. A key challenge is the sparse and uneven availability of social science expertise and data among the constituent agencies, which impedes progress toward both Program Goals 1 and 2. In a constrained budget environment that has only tightened over the past five years, it can be difficult to find the modest resources needed to improve social science research for global change, particularly when the data and expertise are located within one agency but the decisions to be supported are in parts of other agencies. As a result, use-inspired research (which is central to the Strategic Plan's Informing Decisions goal) remains new and somewhat fragmented—and therefore fragile—within many USGCRP member agencies.

One example where scientific information is crucial for informing decisions around managing risk is at the intersection of global health and national security. This is embodied in the work of the Global Health Security Agenda,[4] which seeks—in collaboration with other nations, international organizations, and public and private stakeholders—to accelerate progress toward a world safe and secure from infectious disease threats and to promote global health security as an international security priority.

[4] http://www.globalhealth.gov/global-health-topics/global-health-security/ghsagenda.html

This agenda includes preventing and reducing the likelihood of disease outbreaks and detecting threats early to save lives. Achieving these aims will become more effective and efficient by considering how climate change, globalization of trade and travel, and other global environmental changes could affect the geographic range, incidence, and seasonality of infectious diseases, as well as by using environmental data in developing and deploying early warning systems. Agencies involved in this agenda include HHS, DOS, DoD, USDA, and USAID. Determining the extent to which global change contributes to events such as the recent Ebola crisis or the ongoing refugee crisis in Europe is extremely difficult because of multiple interacting drivers, but such crises exemplify the kinds of events anticipated with accelerating global change. Greater participation of the National Institutes of Health (NIH; within HHS), DoD, USAID, and other agencies in the Program will be mutually beneficial, providing scientific information to agencies to aid them in prioritizing efforts to address global health security and obtaining information and data from agencies to better characterize vulnerabilities and capacities. There is an opportunity for USGCRP to help engage these agencies further in the work of this agenda, as well as in related work on global health and national security.

Another key area where scientific information is essential is the research and analysis needed to support emissions reduction decisions (i.e., mitigation). Federal, state, and city/local authorities face choices in the selection and design of regulatory actions, subsidy programs, and public investments to address mitigation and adaptation aspects of global change at their jurisdictional level. Understanding the economic cost, environmental effectiveness, and distributional consequences of these measures depends on sound engineering data, insights from the social sciences into public response, and appropriate risk analysis and decision science. Research and analysis that can bring this information to bear is spread across many federal agencies. It is available in DOE Offices of Fossil and Nuclear Energy, Energy Efficiency and Renewable Energy, and Energy Policy and Systems Analysis, and in many projects in the national laboratories. It is also found in agencies that deal with greenhouse-gas (GHG)-emitting sectors, such as parts of HUD, DOT, HHS, and USDA, and in some states and local agencies. The USGCRP has an opportunity to serve mitigation decision support needs by improving the connection of information from relevant parts of these agencies to decision makers and identifying the most important gaps in data, research, and analysis (Box 5).

In addition to informing decisions related to mitigation, another key area where scientific information is essential is in community resilience and the adaptation to global change, especially climate change. There are opportunities for agencies or parts of agencies that do not currently participate heavily in USGCRP activities to help inform stakeholder groups outside the government as well, e.g., supporting local level planning and engagement. This will be especially important as non-federal stakeholders increasingly confront the challenges of connecting scientific projections of global change with actions designed to increase local or regional resilience, for example, by working more closely with the engineering community that designs, builds, and manages infrastructure to co-produce knowledge on climate resilient solutions. Specifically, there are opportunities for work on these issues through DHS, in particular through the Federal

BOX 5: Case Study on Mitigation Decisions

One example of an opportunity where federal agencies could work together more effectively on using global change science to support decisions is in the area of emissions reductions (mitigation). The Federal government is involved in a number of efforts to reduce GHG emissions, which are an important part of the U.S. response to the global change threat. In one example, President Obama issued an Executive Order (EO) on March 19, 2015 mandating that all federal agencies reduce their global environmental impacts (White House, 2015). Specifically, under the EO, federal agencies are given deadlines for achieving specific GHG emissions reduction targets, thus creating a federal constituency for research and analysis to support implementation of this task. These agencies will need credible, objective, and science-based means to assess options, measure progress, and inform choices. For example, to design programs to reduce GHG emissions from product and service supply chains, they need life-cycle assessment data, as well as research to understand opportunities and barriers to meeting particular emissions reductions goals. USGCRP could help coordinate the flow of scientific information to help inform these decisions.

In addition, many mitigation decisions are made outside the federal government. The Clean Air Act imposes mitigation requirements on the states, as recently done via the Administration's Clean Power Plan. Many power generation options rely on water and other natural resources, so effects of global change on these resources, as well as its influence on energy demand (e.g., hotter days that drive increased air conditioning), are important factors in the implementation of this federal initiative. Moreover, the long-lived nature of power infrastructure implies that mitigation decisions need to account for multi-decadal changes. In addition, the technologies supported by DOE's research and development that aid all mitigation efforts would benefit from information from global change science about ways to improve their resiliency.

USGCRP could also help coordinate the work of agencies such as HUD, USDA, and DOT in their support of efforts by a wide range of stakeholders to reduce GHG emissions—for example, by providing data on the effectiveness of various possible mitigation programs in the sectors where they have responsibilities and by giving technical support to the particular actions undertaken. This coordination work would involve communication in both directions—relevant scientific information flowing from the agencies to decision makers and pressing gaps in data, research, and analysis—being fed back to agencies responsible for funding and performing research.

Emergency Management Agency (FEMA) and through HUD. Internationally, there are opportunities for work on these issues through DOS and USAID.

In this discussion of resilience and adaptation, the impact of global change on transportation infrastructure and operating systems is another example in which global change science could link productively to decision makers' concerns. There is an increasing need for resilience planning for roads and railways to ensure that this critical infrastructure is able to adapt to climate change. This is an opportunity for USGCRP to engage with this community, potentially including working with DOT (already a formal member of USGCRP) to provide information and tools to state departments of transportation, metropolitan planning organizations, and transit agencies to incorporate climate change in their planning processes. These processes could also serve as models of

how to move new knowledge and decision support tools from agencies and organizations that are primarily research focused to those at the federal, state and local level who make decisions that could be better informed by the research.

Other examples of opportunities related to resilience and adaptation for enhanced participation by parts of an agency that is already within the USGCRP membership are the fisheries and coastal sections of NOAA (Box 6). There are examples of existing programs that demonstrate how federal agencies and various non-federal entities can work together around specific tasks, including interagency efforts on the permitting process for oil exploration on North Shore of Alaska (see Box 7) and the task force to examine the multiple causes for dead zones in the Gulf of Mexico.[5] Finally, an example of federal and regional collaboration is that formed around community health risks in the Great Lakes region (Box 8).

Goal 3 – Conduct Sustained Assessments

One of the most important tasks of the USGCRP is the National Climate Assessment (NCA). The GCRA requires that USGCRP produce a National Assessment every four years that:[6]

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

The 2012 Strategic Plan states that Goal 3 is to "Build sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities" (USGCRP, 2012).

In general, collaboration that is motivated by a need to solve concrete problems, such as meeting a statutory mandate to report to the American people as is the case for conducting the NCA, can foster informal ties and habits of cooperation that can create a more agile and responsive government. Although not all previous efforts have succeeded, having a deadline and a specific task can often help promote working together. The previously mentioned Alaska Interagency Working Group on Oil and Gas Development described in Box 7 is an example of the capacity of the government to form mission-oriented, multi-agency collaborations that link science to decision making, when faced with well-defined and time-constrained objectives that require a multidisciplinary approach.

[5] http://water.epa.gov/type/watersheds/named/msbasin/zone.cfm
[6] http://www.globalchange.gov/about/legal-mandate

BOX 6: Case Study on Opportunities for Participation by Multiple Parts of One Agency

The National Oceanic and Atmospheric Administration (NOAA) contributes to global change research and decision making in multiple ways, and that multiplicity tests the capabilities of the USGCRP as coordinator of the federal research effort. This challenge can be seen in other members of the USGCRP, including DOI, for example; NOAA is by no means unique in this challenge.

NOAA, a charter member of the USGCRP, is an agency of DOC and a leading federal agency in the study of global change, especially with regard to long-term data collection, stewardship, and analysis. NOAA's Office of Oceanic and Atmospheric Research (OAR[a]) collects and processes primary data on the atmosphere and oceans (e.g., from its weather and climate satellites and NASA's satellites), conducts research, and has helped build foundational knowledge of the biophysical climate system. NOAA also provides scientific knowledge to inform decisions that can build resilience in coastal environments and across the country. Its program of Regional Integrated Sciences and Assessments centers (RISAs[b]) has pioneered collaboration between universities and users in subnational governments, business, and civil society.

Within the USGCRP, the climate science and observational expertise of NOAA have been well represented and influential over the life of the Program. NOAA's budget authority is included in the budget cross-cut of the Global Change Research Program. NOAA has been a visible presence in the Subcommittee on Global Change Research (SGCR), including the current chair of the SGCR, who is an internationally renowned NOAA climate scientist.

Yet the breadth of NOAA's expertise in global change research means that the link between that knowledge and the USGCRP is uneven. For some time, the National Ocean Service (NOS) has been a leader in coastal adaptation science, building the knowledge needed by coastal planners to prepare for and respond to sea-level rise and changes in the hazards of severe storms. Another part of the agency, the National Marine Fisheries Service (NMFS[c]), is the government's scientific authority in the management of commercial fisheries in federal waters that extend 200 nautical miles from shore. NMFS announced that it is developing a Climate Science Strategy[d] (Sobeck, 2015), drawing together information needed to inform fisheries management in a changing climate—such as observed and projected changes in the spatial range of commercially important fish species as ocean conditions change. The climate, coastal, and fisheries parts of the agency are of necessity largely separate in their operations. While the climate part has been strongly engaged in USGCRP, the NOS and NMFS have not been as active.

Improving the coordination by different parts of agencies (or different agencies within departments) is often stymied by the need for federal entities to have unique identities and to avoid duplication of effort. USGCRP can promote the robust inclusion of NOAA expertise in accord with the strategic plan, not only when that expertise can strengthen the work of other agencies, but sometimes when better coordination of different parts of the same agency can help meet strategic plan goals. In this example, there is an opportunity for NOAA's NOS and NMFS to have access to better information on the challenges of global change, for NOS and NMFS to have stronger input into the determination of USGCRP research priorities, and for NOS and NMFS to contribute their scientific capabilities to advance understanding of global change. USGCRP activities could be potential mechanisms for achieving these outcomes.

[a] http://research.noaa.gov/
[b] http://cpo.noaa.gov/climateprograms/climateandsocietalinteractions/risaprogram.aspx
[c] http://www.nmfs.noaa.gov/
[d] http://www.st.nmfs.noaa.gov/ecosystems/climate/national-climate-strategy

BOX 7: Case Study on the Alaska Interagency Working Group on Oil and Gas Development

Successful working groups established in non-USGCRP contexts can provide good insights to the Program on methods for coordinating the efforts of federal agencies with entities outside the federal government. For example, in July of 2011, President Obama issued Executive Order 13580, establishing the *Interagency Working Group on Coordination of Domestic Energy Development & Permitting in Alaska.* The Order was issued in response to growing pressure from within and outside government to establish an improved decision-making process with respect to offshore oil and gas exploration and production in Alaska (Clement et al., 2013) and also reflected growing concerns about resource development in a rapidly changing Arctic (Bush, 2009; National Security Council, 2014; NSTC, 2013; Obama, 2015).

The Working Group (WG) is led by DOI, in collaboration with the National Ocean Council and US Arctic Research Commission, and approximately 90 other federal, state, tribal, municipal, private-sector, and non-governmental organization (NGO) affiliates contributed substantially. The immediate motivator leading to creation of this partnership was the incipient rise in drilling permit requests, which continues to this day.[a] Such requests are likely to continue, given that the outer continental shelf of the Chukchi and Beaufort Seas are anticipated to be rich in oil and natural gas (Holland-Bartels and Pierce, 2011), so the WG will likely be needed moving forward.

The WG was convened to integrate all relevant government and (where possible) private sector data sources relevant to the offshore energy permitting process in the outer shelf—essentially creating a ready-made audience and demand for scientific information. Many of the variables, indicators, and metrics essential to the offshore permitting process are in fact those that are also generated by the research community, including baseline inventories depicting the region's oceanography, climate, geology, and biology as well as environmental sensitivity studies.

While the USGCRP has long used interagency working groups to focus interagency coordination around specific topics, this new WG offers a model for how the Program can expand its representation across different levels of government, the private sector, and extra-governmental stakeholders. A series of challenges and opportunities can be identified through this WG example: (i) effective coordination across agencies has been essential in order to appropriately transfer scientific knowledge to the applied (permitting) arena; (ii) having the information needs of decision makers be well-matched to ongoing scientific research has been important, and new research has needed to be responsive to specific calls for applied knowledge (something the WG has generally accomplished well); (iii) synthesis and integration of complex scientific knowledge has needed to make science useful for applications; (iv) assessments have been needed to complement basic research, stimulate dialogue with stakeholders, and create new avenues of inquiry (which then spur further research); and (v) monitoring and metrics have been essential to tracking success or failure in the permitting process and need to be operationalized. These lessons bear clear links to the issues that USGCRP will likely encounter if it expands beyond its traditional federal agency base.

[a] See http://dog.dnr.alaska.gov/permitting/permitting.htm, http://www.boem.gov/About-BOEM/BOEM-Regions/Alaska-Region/Leasing-and-Plans/Plans/Shell---Chukchi-Sea-Exploration-Plan-and-Supporting-Documents.aspx, and http://www.boem.gov/ak-gg-permits/.

BOX 8: Case Study on Collaborating to Cope with Health Risks

USGCRP could learn from successful regional efforts to collaborate with partners in state and local communities. One such issue relates to health risks, which are expected to increase due to climate change in many regions of the United States (Luber et al., 2014). These include respiratory diseases as a result of increased air pollution and allergens, heat illness, water-borne diseases, vector-borne diseases, wildfire, flooding, and injuries from use of alternative home heating sources during power outages and extreme weather events. These and other effects of climate change can also be a source of mental stress for vulnerable individuals. As with many problems where climate change exacerbates an existing risk, effective response requires collaboration among agencies that have extensive expertise in climate change, those who have deep scientific expertise in the nature of the risk, and local, state and federal agencies that have "on the ground" experience developing programs to respond to risk.

The Great Lakes Integrated Sciences and Assessments Center (GLISA),[a] a NOAA RISA center, is helping the State of Michigan develop approaches to deal with climate related health risks in the state, working directly with both the Michigan Department of Community Health (MI DCH) and with the Centers for Disease Control (CDC). Initially GLISA funded a project that allowed the MI DCH to develop heuristic models to facilitate discussions of heat stress events with municipal public health departments (Schmitt-Olabisi et al., 2012).[b] This led to further collaborations and, with CDC funding, a Climate Profile Report that synthesizes historical and future climate information for the state, with emphasis on specific geographic areas of concern (Cameron et al., 2015). With GLISA and CDC support, MI DCH previously identified several health risks and associated climate stressors, and GLISA is continuing to tailor climate information to address specific MI DCH concerns with respect to projected climate change.

The approach used in this effort has several features that the USGCRP may want to explore as they seek to collaborate with partners in local and regional communities. First, it began with a relatively modest exploratory effort that served both to develop a better understanding of the issues salient to the region and to allow the partners to develop mutual understanding and modes of collaboration. Second, while the participants from MI DCH, GLISA, and CDC were engaged primarily in developing a research-based assessment, the project focused early on those who would have to implement steps to reduce vulnerability. Third, the specific projects each yielded useful products (e.g., workshops, reports) but also have the added benefit of building effective links between these organizations that will facilitate future work (Bidwell et al., 2013).

[a] glisa.msu.edu, glisa.umich.edu
[b] http://glisa.msu.edu/projects/modeling-framework-informing-decision-maker-response-extreme-heat-events-michigan-0

The most recent NCA has demonstrated that having a tangible task provides an opportunity to promote collaboration across multiple agencies and entities at the Federal, state, and local levels and with the users of the assessments. This last NCA was successful in promoting connections with a wide array of federal and non-federal entities. More than 70 workshops were held, engaging a wide range of stakeholders and involving a team of more than 300 experts from diverse backgrounds to write the report (USGCRP, 2014).

Looking forward, ongoing assessments will be an important way to catalyze coordination. For example, in addition to the engagement described above, the third NCA catalyzed the development of a system of climate change indicators, impacts, and response strategies that was then adopted by the USGCRP for review and ultimately for implementation. The development process involved nine agencies among the current core membership of the USGCRP, several other federal agencies, and additional critical contributions from outside the federal government. The USGCRP can use this kind of process to launch collaborations that can then be built on over time. One area likely to benefit from ongoing assessment efforts is informing decisions in urban environments (Box 9).

Goal 4 – Communicate and Educate

The 2012 Strategic Plan commits USGCRP to strengthen communication and education research, to cultivate a scientific workforce that understands global change, and to integrate "global change communication, education, and engagement into core Program activities" (p. 82). Research has advanced significantly over the past decade in social network phenomena, behavioral economics, and the social psychology of opinion formation. All of these bear on a central issue in global environmental change: the link between public understanding of science, fostered by Goal 1, and an array of decisions, addressed in Goal 2. Indeed, a task of the sustained assessment process (Goal 3) is to improve public understanding by providing access to the available scientific knowledge. Research under Goal 4 thus plays an important supporting role across the Program by improving understanding of the communications challenges facing federal agencies and their partners and by providing better methods when they are available and appropriate.

The Strategic Plan also promises that the Program will "contribute to the development of multi-agency products and programs." These commitments imply a broadening of the Program's activities and increased integration across agencies to advance understanding of global change communication and education and to apply that understanding within agencies' programs and to interagency needs.

These are laudable long-term objectives, but to achieve them, agencies need to coordinate, and scientists and educators within agencies need to work more effectively with science educators and stakeholders within and outside the Federal government. Considering this, the objectives will probably best be approached in stages. A promising way to start is with efforts focused on specific global change issues that intrinsically require the coordination of activities and expertise across agencies and between federal and non-federal entities.

There are many such opportunities. For example, in education and communication about seasonal climate forecasts, NOAA could work with USDA and its constituencies on communication and education about using these forecasts for informing agriculturists, with DOI and its constituencies about the implications for informing water managers and

BOX 9: Case Study on Urban Environments

Specific topics—such as the impacts of global change on urban environments—showcase opportunities where resources of the federal agencies could be brought to bear on the decisions being made at local levels on an ongoing basis. Impacts from extreme events, such as Superstorm Sandy (2012), Hurricanes Katrina and Rita (2005), and the Chicago heat wave of 1995, are often the most immediate ways that the physical climate system affects well-being on both immediate and longer time scales. Urban areas are particularly vulnerable to extreme events, given their locations (often on coasts or rivers), high concentration of people, and complex, interdependent, and aging infrastructure. Aftermaths of such disasters demonstrate not just infrastructure failures, but also the inadequacy of institutions, resources, and information systems to prepare for and respond to rare high-consequence events.

The diversity of challenges in cities provides a perfect example of how USGCRP activities to inform decisions and conduct sustained assessments could benefit from greater involvement with federal agencies, as well as with external participants. Interest is high at local, regional, national, and international levels in urban vulnerability to climate change, especially the increasing frequency and magnitude of extreme events and adaptation strategies for cities. This interest—indeed, urgency—is reflected in activities from the international 100 Resilient Cities program (Rockefeller Foundation[a]) to the formation of national organizations like the Urban Sustainability Directors' Network to reports such as the *State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience Recommendations to the President* to local urban adaptation plans like New York's *PlaNYC*.

The coordination between federal agencies addressing urban issues and USGCRP has been limited to date. Both the 2009 and 2014 NCAs included assessments of the risks of climate change to urban areas, including their populations and infrastructure, but there is opportunity for more engagement on this topic. DHS and HUD can make important contributions to the challenge of understanding and preparing for global change risks to urban areas. FEMA (part of DHS) responds to and provides relief from disasters. HUD has partnered with EPA and DOT to create the *Sustainable Communities* program, which encourages planning for resilience; however, the USGCRP has not played a major role in this effort so far.

One potential role for the USGCRP is to stimulate public-private collaborations that can connect appropriate federal expertise to decision makers at the city level. One such collaboration is the Rockefeller 100 Resilient Cities program, which funds the development of a staff position in urban government, together with "access to solutions, service providers, and partners." The federal government includes a prominent set of such partners, and USGCRP could play a central role in marshaling the diverse resources of the government to leverage more of these public-private collaborations and connect with more decision makers at the city level. Cities are vulnerable to a range of global changes, including human migration, food insecurity, and political disruption. These challenges intersect with the global change mission of the USGCRP. Because of the diverse nature of these challenges, the Program would be a logical point of integration across the federal government for collaboration with other institutions and governments.

[a] http://www.100resilientcities.org/#/-_/

entities responsible for wildfire preparedness and response, with HHS and FEMA on informing preparation and response for floods and wildfires, and with NSF and the Department of Education on the pedagogical aspects of understanding and using this relatively unfamiliar type of forecast. Some of this work is already underway in regional centers—NOAA RISAs, USDA Climate Hubs,[7] the DOI Climate Science Centers,[8] and the DOI Landscape Conservation Cooperatives (LCC[9]). Enhanced collaboration in these areas of interest—potentially fostered under USGCRP—could help agencies like USDA, DOI, HHS, and FEMA to better fulfill their missions by leveraging information from other USGCRP agencies, in this case NOAA.

Another opportunity is for USGCRP to engage networks of actors beyond the federal agencies in education and communication activities. A major class of stakeholders in Goal 4 is institutions of education at every level. These include teaching, outreach to communities of various kinds, and research, which are all activities of educational institutions in which the research done in pursuit of Goals 1-3 is taught, used, and argued over. As with the other goals of the Strategic Plan, much is already being done by the agencies participating in the USGCRP, and the Program's role is largely to coordinate across agencies when needed in order to advance citizen understanding, education, and workforce training when agency missions lead to important gaps or omissions.

The education and communication missions of the USGCRP agencies can be productively implemented through regional networks to make effective use of the USGCRP's research, technical data, and agency support. In addition to near and mid-term decisions related to mitigation options, communities throughout the United States are tackling the short- and mid-term challenges posed by such climate-related disruptions as extreme storm, flooding, and wind events. Additionally, in many areas, jurisdictions partner to conduct multi-jurisdictional planning and risk reduction actions (see Box 10). Local governments will make decisions on implementation actions to address climate risks in the Local Hazard Mitigation Plans as an initial step. Regional and federal agencies working on collaborative planning anticipate, at this point, that communities will adjust land use development policies and decisions to account for sea level rise and coastal flooding impacts. There is also the expectation that communities will enact updated wild land fire measures and drought mitigation practices stemming from the regional planning and coordination activities currently in process (including numerous resources utilized by the NCA[10]). One example of collaborative resilience planning is being conducted in the San Francisco Bay Area by the regional council of governments, sponsored by FEMA, NOAA, USGS, and EPA (see Box 10). Communicating with local communities around issues of resilience and climate adaptation planning is an area where USGCRP could engage larger networks of possible partners, not just other agencies.

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[7] http://climatehubs.oce.usda.gov/
[8] https://nccwsc.usgs.gov/
[9] http://lccnetwork.org/
[10] http://ncanet.usgcrp.gov/partners/resources#TOC-Resources-related-to-topics-that-may-be-considered-in-the-ongoing-National-Climate-Assessment-process

BOX 10: Case Study on Climate Adaptation and Resilience Planning in the San Francisco Bay Area

USGCRP could broaden their reach for communicating and educating stakeholders by engaging with entities which have existing interests in working with local and regional stakeholders. An inventive approach to community planning and action was proposed by the Association of Bay Area Governments (ABAG) and FEMA Region IX senior officials to assist local jurisdictions obliged to develop Local Hazard Mitigation Plans, as required by the Disaster Mitigation Act 2000.

The regional partners, ABAG and the Bay Conservation and Development Commission, serve as the technical support hub for Bay Area cities to tap regarding climate and natural hazards' risk information. The foundational planning data, research findings, and risk modeling on global change used to provide technical assistance are primarily culled from USGCRP agencies.

ABAG is managing an innovative process to assist the Bay Area partner communities (101 cities and 7.4 million residents) in developing improved regional resilience planning that will result in coordinated, independent local resilience plans. This initiative supports cities to integrate solutions to anticipated climate-generated and natural disaster impacts to fulfill federal disaster risk reduction and state GHG reduction and climate adaptation requirements.

This is an example where a potential collaboration with the USGCRP agencies could enhance the combined planning for adaptation and resilience, as well as mitigation of GHG emissions. The collaboration could take advantage of the existing interest on the part of the ABAG and more fully integrate the research interests of the USGCRP agencies, not simply their observational data sets.

Conclusions

In accordance with its charge to advise the USGCRP (See Appendix B for the Committee's overall charge), the Committee has consulted regularly with the Program and its principals. Reflecting on those discussions, the Committee undertook this report, under the guidance of The National Academies of Sciences, Engineering, and Medicine, to consider current Program membership and capabilities in light of the Strategic Plan. The USGCRP is an interagency entity created as a partnership between the Executive Office of the President and the mission agencies that are the Program's members. The Program seeks to coordinate the partners' activities so as to advance the Nation's interest in global change research. The goal of this report is to evaluate the current set of USGCRP capabilities, given emerging opportunities and demands, and from this analysis develop a rationale for determining potential partners; to identify gaps and areas of potential leverage; and to recommend adjustments if necessary. The Committee did not set out to undertake a comprehensive survey of the capabilities in federal agencies and other partners that should either use or contribute global change research in the pursuit of their missions. Rather, the Committee explores the current set of USGCRP capabilities in comparison to goals and objectives in the Strategic Plan and identifies examples of how adjustments in participation could enable the program to better meet its stated goals (see Appendix A for the Committee's Statement of Task).

There are three parts to the Committee's explanation for why enhanced participation in USGCRP activities is needed and suggestions for encouraging that participation. First, there is a mismatch between the current levels of participation compared to the GCRA and the Program's Strategic Plan, as these documents describe the Program's original mandate and current plans for fulfilling that mandate. In view of the challenges that USGRP agencies face—in particular from constrained budgets—the most effective way of addressing the Strategic Plan is to encourage multiple modes of participation with various partners, including federal agencies and parts of agencies that currently do not participate in USGCRP activities, as well as entities outside the federal government. IWGs present a particularly effective approach for coordinating activities at the federal level. Lastly, the Committee suggests that USGCRP has the responsibility to argue which new partnerships should be pursued. This is discussed in detail below.

Determining potential partners for achieving the objectives of the Strategic Plan will be an evolving process. The Committee's goal in this report is to bring to light the role that is or could be played by agencies that do not now participate in the budget cross-cut, by parts of agencies not well represented even when their cabinet department takes part in the cross-cut, and by entities beyond the federal government. The case studies presented in this report are not meant to be comprehensive, but neither are they random. Rather, the Committee intends the cases selected to be representative of the spectrum of issues that need to be discussed. Inevitably, the cases selected reflect the perspectives of the

committee members and the history of the USGCRP. If the task were a comprehensive review of agency capabilities, as compared to the goals in the Strategic Plan, the case study approach would not be sufficient. Instead of such a comprehensive analysis, the conclusions presented below contribute advice to the Program in an ongoing discussion of ways to achieve the ambitious goals of the USGCRP Strategic Plan.

Mismatch between USGCRP Goals and Participation

As has been described above, there is significant and growing pressure from decision makers in numerous sectors for better information to support decisions about adaptation and mitigation, to inform ongoing assessments, and for further efforts to communicate global change information and educate interested and affected parties. This has expanded the Program's focus from Goal 1 to include Goals 2, 3, and 4, but at the same time introduced a tension between the role of Goal 1—to "advance science" including discovery, system approaches, and innovation—with a role that provides "use oriented" science that is needed in support of "services" for Goals 2, 3, and 4. It is critical that a balanced portfolio of science be established that satisfies both of these aspects, but the current USGCRP membership is insufficient for tackling these challenges.

As emphasized throughout this report, integration of more agencies, parts of agencies, or other entities that are outside the USGCRP "membership" or that do not currently participate actively in USGCRP is critical to advancing each of the strategic plan's four goals and for serving the needs of the Nation. USGCRP has a mandate to envision what risks are likely to arise with global change over coming decades, what science is needed to inform decisions on how to prepare for, mitigate, and manage these risks, and what methods and tools decision makers will need. Addressing the mismatches between the current capabilities of the USGCRP member agencies and this mandate will require partnerships with various agencies, parts of agencies, and non-federal entities.

The discussion in the previous chapters highlights (1) important differences across agencies and other relevant entities in their missions, operations, and policy and regulatory functions, (2) how broadening participation can help address the four key goals of the USGCRP Strategic Plan, and (3) a variety of modes that participation in the USGCRP might take. In considering an expansion of participation, the USGCRP leadership would benefit by recognizing links among these three factors and use those links to help identify participation opportunities with different scopes and goals.

For example, for Goal 1 (Advancing Science), participation by agencies and entities with strong research or data generation missions and capacity is likely to be most important. Where a key goal of the participation is advancing knowledge, potential partners increasingly include entities collecting social data, such as demographic and economic data sets (see Box 4).

Meeting Goal 2 (Informing Decisions) requires participation by agencies and entities whose primary mission involves policy or regulatory decision-making and program evaluation and design. For these Goal 2 opportunities, the primary objective of

expanded participation would be guiding scientific efforts coordinated by USGCRP toward providing knowledge useful for informing decisions and translating knowledge into action. In particular, there are critical issues that require improved use of global change science information, such as the provision of health information (Box 8), the challenge of urban environments (Box 9), and the need for mitigation of GHG emissions (Box 5) where broader partnerships are needed.

To achieve Goal 3 (Conduct Sustained Assessment), USGCRP will need to continue and expand engagement with agencies and entities that have been key contributors to the National Climate Assessment, for example, because they represent key sectors or regions included in the NCA or represent key stakeholders or user groups that should be involved in future NCAs. An important goal of this participation would be to ensure that the NCA accurately reflects the current state of knowledge and also presents that knowledge in a way that is most useful to potential users (based on input from those users).

Finally, Goal 4 (Communicate and Educate) could be advanced by increased participation by agencies and entities whose missions include a strong science education or workforce development component and that have additional capacity to disseminate information and products generated by the USGCRP. Some of this work is already underway in regional centers (NOAA RISAs, USDA Climate Hubs, DOI Climate Science Centers, and DOI LCCs), but it could also be expanded to include partnerships with other regional entities who are already engaged with local communities, such as the Association of Bay Area Governments (Box 10).

Conclusion 1: USGCRP needs broader partnerships and participation from within existing member agencies and from new entities to implement the goals and objectives developed in the Strategic Plan.

Employing Several Modes of Participation

As USGCRP looks to expand the number and types of partners with which it engages, it will also need to broaden the sorts of partnerships it employs. The mode of collaboration will need to be tailored to address the specific tasks or objectives at hand. Furthermore, the types of partnerships will continue to evolve as the challenges of global change, particularly climate change, increase. The USGCRP will need to continue to explore new partnerships to help address these evolving challenges.

An important consequence of engaging other agencies or parts of agencies is that the networks of actors with which those agencies already work can become engaged as well. For example, activities related to informing decisions will involve scientific products developed by the agencies, but, depending on the decisions in question, they may also involve regional-, state-, and local-level governmental agencies, tribal and territorial governments, sector-based owners and managers (e.g., banking and finance, energy and infrastructure), and boundary organizations. An earlier NRC report, *Informing Decisions in a Changing Climate* (NRC, 2009a), noted that providing decision support will require the USGCRP to "facilitate distributed responses to climate change" at multiple scales and

among diverse actors. Similarly, communication and education activities will require the participation of entities both within and outside the USGCRP agency structure.

Achieving the broader societal impacts envisioned in these program goals can be thought of as requiring the engagement of *networks* of partners (Bidwell et al., 2013), as opposed to *agencies*. Some networks will be enduring, while others will be *ad hoc* or relatively short-lived. Evolving in ways that support diverse network activities will present a challenge to the USGCRP, but such evolution is consistent with the program's strategic plan.

The way in which the USGCRP engages will differ across various potential partners and across the four goals of the Strategic Plan. For example, in pursuit of Goal 1 (Advancing Science), collaboration might take the form of coordinated or even joint intra- and extra-mural research programs, and perhaps partnering agencies might eventually become full USGCRP members. Improved data collection and curation serves all 4 goals, and here engagement might involve regular communication. Goal 2 (Informing Decisions) requires processes that link analysis to deliberation to ensure that there is mutual understanding between scientists and decision makers of what is known and what needs to be known.

As has been mentioned in several examples throughout this report, focusing on specific tasks could help focus collaborations; see discussions in Goal 3 and Boxes 7, 8, and 9 as examples. This could be done through the identification of specific tasks and challenges within the program, around which multi-agency participation is clearly needed. These collaborations can be thought of as bridges to connect networks of communities; these bridges need to be built consciously in places where they will help the flow of information become self-sustaining. These collaborations might take the form of interagency working groups—such as for data sharing (Box 4)—or other working groups—for example on permitting for oil and gas (Box 7). It is important to note that the federal government is already having some success in these types of collaborations through the various regional centers, e.g., RISAs, Climate Hubs, Climate Science Centers, and LCCs (e.g., Box 8).

Goal 3 (Sustained Assessments) has already been demonstrated to require linkages both across government agencies and with outside stakeholders in order to make assessments relevant to a wide variety of decision processes. Linkages in service of Goal 4 (Communications and Education) are likely to be as diverse as the many kinds of formal and informal educational efforts undertaken across the breadth of the federal, state, and local governments and could also involve business communities and non-profits. Opportunities to work with a broader network of partners on these issues could take the form of programs spearheaded by regional centers on specific topics in which USGCRP helps facilitate agency participation—such as climate adaptation and resilience planning in specific regions (Box 10)—or collaborations with public-private partnerships—for example for work on urban environments (Box 9).

Conclusion 2: USGCRP could most effectively achieve its goals by embracing a variety of approaches to partnership.

Utilizing Interagency Working Groups to Address Specific Tasks and Engage Networks of Actors

Beyond core participation in USGCRP, there is a need for mechanisms to promote enhanced participation at the federal level. The Interagency Working Groups (IWGs) present one such option; see Appendix D for a list of the IWGs. In particular, some of these IWGs have had real success in coordinating efforts across multiple agencies, including the Adaptation Working Group and the Climate Change and Human Health Working Group, which were very active in the most recent National Climate Assessment. Non-member agencies have made some important contributions to these assessment and IWG activities already, and these examples point to the potential value of these types of activities.

Agencies that are not formally members of USGCRP already participate in the IWGs. The USGCRP can create and disband IWGs as they are needed or as they fulfill their appointed tasks, and they thus provide a potentially very useful mechanism for different agencies to interact at a working level with a minimum of administrative oversight. Areas like the linking of data sets (Box 4) or the support of mitigation decisions (Box 5) could be explored as opportunities for new IWGs. Determination of which tasks will be addressed by new (or existing) IWGs would be best served by incorporating input from decision makers and agencies facing challenges with specific problems. As discussed in Conclusion 4 below, USGCRP could serve an important function in connecting these tasks with the goals and objectives in the Strategic Plan and taking the lead in arguing for the development of new IWGs.

The establishment of IWGs with clear goals and roles in overseeing such specific tasks can be a very effective mechanism for broadening participation in the USGCRP, especially for ensuring there is a sustained relationship between knowledge generation and activities and their potential use. The degree to which such specific challenges and tasks can be identified will be an important determinant of whether an IWG that oversees them has clear goals and objectives, and therefore whether success can be evaluated.

Conclusion 3: The Interagency Working Groups are one particularly useful approach that could be more fully exploited as a means to promote ongoing collaboration around specific areas of interest and to create networks of partners.

Considering the Full Costs and Benefits of Participation

Participation in the activities of USGCRP takes many forms, but whatever the form, that participation does have real costs associated with it. Core participants devote staff time to supporting USGCRP central activities, including coordination meetings among the participants, and they participate in extensive budget crosscuts and analyses of how their programs are addressing administration priorities for global change research. At the federal level, these costs are almost exclusively borne by the agencies themselves.

But there is no reason that all agencies with an interest in global change research must participate at such an intensive level. For example, employing a range of approaches for interaction of science user constituencies with science producer constituencies could broaden the Program's focus and better engage new partners, but these approaches need not require the addition of new formal participants. For transitory research challenges, for example, only a temporary collaboration makes sense. For longer-term strategic challenges, a more permanent institutional form of collaboration would need to be employed.

Agencies that have standing commitments of resources to long-term research in global change are likely candidates to consider for core participation in the USGCRP. Many of the agencies that fall in that category are already included in USGCRP's budget cross-cut, but in some cases broader participation within an agency could help it better meet its own mission. For instance, for some agencies (e.g., NOAA), it is important for multiple bureaus (Climate Program Office, National Marine Fisheries Service, Coastal Services; see Box 6) to be involved in the Program (also see section on Goal 2 for discussion of DOE as an example). Formal membership affords regular access to budget deliberations and priority setting within the interagency strategic planning process. Broader participation in these processes by more bureaus within an agency would allow more parts of the agency to influence the use of scientific knowledge.

However, any form of collaboration will incur some administrative costs—through staff time and effort at a minimum—and agencies will need to examine the trade-offs of benefits and costs. The Committee is not recommending participation for its own sake, or simply for the sake of an interdisciplinary approach. Indeed, the problem-driven perspective of informing decisions implies a frank appraisal of the costs of collaboration, including the burdens of ongoing management of the knowledge gained. These costs will have to be weighed against the benefits of enhanced collaboration to the agencies, such as the ability to influence directly an administration's priorities for global change research, and more diffuse benefits to the nation as a whole.

As has been mentioned in the examples throughout the report, there are benefits to the agencies from enhanced participation in USGCRP activities, and those benefits must be perceived to be important if there is to be buy-in from the agencies. It is unlikely that agencies will contribute voluntarily to things that might bring large benefits to the federal community at large but not necessarily to their agency. This speaks to the need for careful consideration and articulation of costs and benefits to agencies' missions from increased participation in USGCRP processes. Articulating the benefits to the nation of enhanced collaboration on cross-cutting topics like urban environments (Box 9) or data sharing (Box 4) is more naturally an activity for an interagency group; thus USGCRP would be best positioned to have the responsibility for arguing when and where increased participation—including formal membership—is warranted and clarifying the costs and benefits of that participation.

There is a simple guideline to consider about which entities should be formal members of the USGCRP and which should participate in other ways: Entities that support

significant amounts of global change research should be formal members and entities that serve primarily as users of research should be engaged in other ways, such as through IWGs, but need not be formal members. The Committee recognizes that these are not always clear distinctions. Large, sprawling Departments and agencies may have both roles encompassed within their mandates, and it will be important to ensure that those agencies that reap substantial benefits from USGCRP research also bear some of the administrative burdens and costs of operating the program. Decisions about formal membership are likely to be guided by multiple considerations in addition to roles in funding research. And while the Committee believes that the USGCRP itself should have the responsibility for making the case for including new agencies or parts of agencies, the final decision will more appropriately be made above the Program's level, presumably within the OSTP.

One possible step that USGCRP could undertake would be a comprehensive review of potential partners to identify key partners and their roles, provide an overview of research they are undertaking, and define opportunities for further needed research. Such a review may provide a basis to engage partners beyond the existing USGCRP membership. Doing so could provide tangible benefits to USGCRP and the nation—including users of global change science and everyone who is or will be affected by global change. It may be appropriate for some new partners to become full participants in the USGCRP while others engage with the Program through other coordination modes.

Just as the Strategic Plan was collaboratively produced by the agencies (Box 3), it will also need to be collaboratively implemented by the agencies, as well as coordinating with entities outside the federal government. The USGCRP already has substantial input into the annual research priorities memo that goes from OSTP and OMB to the science agencies. Implementing the Strategic Plan collaboratively will best be accomplished if the agencies use their input to argue for resource allocations that make implementation easier. Success in this process will be important to ensure a continued collaborative approach to both planning and implementation of successive Strategic Plans within the USGCRP family of agencies.

Conclusion 4: USGCRP would more fully meet its mandate by taking the lead in arguing for increased participation by other agencies—including formal membership—when the benefits to the nation outweigh the costs of collaboration to the agencies.

Closing Thoughts

The USGCRP is responsible for coordinating the global change science that is the foundation for a broad range of decisions about managing the risks and opportunities that global change presents to the nation. As the program has matured, it has found that its original group of collaborating agencies is not adequate for addressing the breadth of the challenges that the United States faces, and hence additional partnerships are needed to address all of the goals and objectives described in the Program's Strategic Plan. The USGCRP already has a variety of mechanisms and levels of participation that can serve as useful models for enhancing collaboration across the family of U.S. agencies, and with non-Federal partners. In order to achieve its potential, those mechanisms should be more fully employed so as to provide greater societal benefit from the conduct of global change science. The Committee suggests that the responsibility to argue for particular new partnerships where the benefits to the nation outweigh the costs to the individual agencies lies with USGCRP.

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Appendix A: Statement of Task for This Report

The Committee to Advise the US Global Change Research Program (USGCRP) will author a short report discussing the scope of agency participation in and engagement with the USGCRP and possible augmentation needed to address stated goals of the program. In addressing its charge, the Committee will:

1. Provide a rationale, derived from the USGCRP Strategic Plan, for evaluating current Program membership and capabilities and identifying potential new agencies and departments (or bureaus and agencies within USGCRP members) and how the Program and the nation could benefit from that new participation;
2. Evaluate the current set of USGCRP capabilities against this rationale to identify any gaps and areas of potential leverage, recommending adjustments if necessary; and
3. If the current pattern of agency engagement is found to need adjustment, include examples of how the adjustments could enable the program to better meet its stated goals (e.g., where relevant data are not being used, efforts are not well-coordinated or being duplicated, research goals are not well informed by decision needs).

Appendix B: Overall Charge for the Advisory Committee to the U.S. Global Change Research Program

An expert committee will provide ongoing and focused advice to the US Global Change Research Program (USGCRP). The committee will be broadly constituted to bring expertise in all the areas addressed by the multi-agency, multi-dimensional USGCRP and will be supported by expertise housed in many units across the National Research Council. The committee will, over time, organize ongoing discussions, take on specific tasks, and issue reports.

In its role as a single entry source of contact to the National Research Council and source of strategic discussion with appropriate experts, the Committee to Advise the US Global Change Research Program will:

1. Provide ongoing, integrated advice to the USGCRP on broad, program-wide issues when requested. This began with a review of the 2011 USGCRP Strategic Plan, will include other tasks such as a review of the National Climate Assessment (NCA) and evaluation of USGCRP progress toward its Strategic Plan objectives.
2. Provide a forum for informal interaction between the USGCRP and the relevant scientific communities.
3. Provide a forum for exchange of experience and insights for integrating across science communities and improving linkages between officials of the Program and the science communities.
4. Improve the internal coordination across existing and future NRC entities related to global change (including coordination across NAS, NAE, and IOM).
5. Help identify issues of importance for the global change research community. This implies a proactive role that goes beyond simply responding to requests from the USGCRP.
6. Interact with and help USGCRP with its international activities, such as shaping the future of relevant international global environmental change programs.
7. In addition to producing NRC reports as tasked, the committee may help develop other work requests and ensure that they are conducted by the appropriate NRC units in a collaborative fashion.

Appendix C: Committee Member Biographies

Warren M. Washington (NAE, *Chair*) is a Senior Scientist at the National Center for Atmospheric Research (NCAR). He has published more than 150 papers in professional journals and co-authored a book entitled, An Introduction to Three-Dimensional Climate Modeling. He has served on the National Science Board (chair, 2002-2006), the NOAA Science Advisory Board, President's National Advisory Committee on Oceans and Atmosphere, several panels of the National Research Council, the Secretary of Energy's Advisory Board, among others. Washington areas of research are in the development and use of climate models for climate change studies. He has also served as President of American Meteorological Society and a member of the AAAS Board of Directors. He is a member of the National Academy of Engineering, American Philosophical Society, and the American Academy of Arts and Sciences. He has received many awards, including the Le Verrier Medal of the Societe Meteorologique de France, the National Weather Service Modernization Award, and the AMS Dr. Charles Anderson Award. He has honorary degrees from the Oregon State University and Bates College. In 2010 he was awarded the National Medal of Science by President Obama.

Kai N. Lee (*Vice Chair*) leads the Science subprogram in Conservation & Science at The David and Lucile Packard Foundation. The science subprogram provides support for science that informs decision making in the near term, advancing the strategies guiding the conservation activities of the Foundation. He also provides program support and liaison for the Monterey Bay Aquarium Research Institute, the Center for Ocean Solutions, and the Aldo Leopold Leadership Program. He taught at Williams College from 1991 to 2007 and is the Rosenburg Professor of Environmental Studies, emeritus. He directed the Center for Environmental Studies at Williams from 1991 to 1998 and 2001 to 2002, and taught from 1973 to 1991 at the University of Washington in Seattle. He is the author of Compass and Gyroscope (1993) and coauthor of Our Common Journey (NRC, 1999). He is a National Associate of the National Research Council. He was a member of the National Academies Roundtable on Science and Technology and served as vice-chair of the National Academies panel that wrote *Informing Decisions in a Changing Climate* (2009). Earlier, he had been a White House Fellow and represented the state of Washington as a member of the Northwest Power Planning Council. He was appointed in 2009 to the Science Advisory Board of the EPA. He holds a Ph.D. in Physics from Princeton University and an A.B., Magna Cum Laude in Physics, from Columbia University.

Doug Arent is Executive Director of the Joint Institute for Strategic Energy Analysis at the National Renewable Energy Laboratory (NREL). He specializes in strategic planning and financial analysis competencies; clean energy technologies and energy and water issues;

and international and governmental policies. In addition to his NREL responsibilities, Arent is Sr. Visiting Fellow at the Center for Strategic and International Studies. Arent was recently appointed as a Coordinating Lead Author for the 5th Assessment Report of IPCC. He is a member of Policy Subcommittee of the National Petroleum Council Study on Prudent Development of North America Natural Gas and Oil Resources, and the American Academy of Arts and Sciences Steering Committee on Social Science and the Alternative Energy Future. Arent served from 2008 to 2010 on the National Academy of Sciences Panel on Limiting the Magnitude of Future Climate Change. Arent is, a Member of the Keystone Energy Board and is on the Advisory Board of E+Co, a public purpose investment company that supports sustainable development across the globe. He served on the Executive Council of the U.S. Association of Energy Economists from 2008 to 2010. Prior to coming to his current position, Arent was Director of the Strategic Energy Analysis Center at NREL from 2006 to 1010. Prior to joining NREL, he was a management consultant to clean energy companies, providing strategy, development and market counsel. Dr. Arent has a Ph.D. from Princeton University, and an MBA from Regis University.

Susan K. Avery took office as President and Director of the Woods Hole Oceanographic Institute in 2008. She holds a Master's in Physics and a Doctorate in Atmospheric Science from the University of Illinois. Avery was on the faculty of the University of Colorado at Boulder from 1982 to 2008, most recently holding the academic rank of Professor of Electrical and Computer Engineering. Her research interests include studies of atmospheric circulation and precipitation, climate variability and water resources, and the development of new radar techniques and instruments for remote sensing. She also has a keen interest in scientific literacy and the role of science in public policy. She is the author or co-author of more than 80 peer-reviewed articles. A Fellow of CIRES since 1982, Avery became its Director in 1994. In that role, she facilitated new interdisciplinary research efforts spanning the geosciences and including the social and biological sciences. She spearheaded a reorganization of the institute and helped establish a thriving K-12 outreach program and a Center for Science and Technology Policy Research. She also worked with NOAA and the Climate Change Science Program to help formulate a national strategic science plan for climate research. Recently she served on two NRC panels: One produced a decadal plan for earth science and applications from space, and the other provided strategic guidance for the atmospheric sciences at the National Science Foundation. Avery is a Fellow of the Institute of Electrical and Electronics Engineers, the American Association for the Advancement of Science, and of the American Meteorological Society, for which she also served as President. She is a past chair of the board of trustees of the University Corporation for Atmospheric Research.

Arrietta Chakos is a public policy advisor on urban resilience. She works on community resilience strategies and multi-sectoral engagement. Her work with San Francisco, Palo Alto, and regional institutions, such as the Association of Bay Area Governments, focuses on disaster readiness and community resilience. She is a member of the Resilience Roundtable at the National Academy of Sciences and chairs the Housner Fellow committee at the Earthquake Engineering Research Institute. Ms. Chakos served as

research director of the Harvard Kennedy School's Acting in Time Advance Recovery Project. She was assistant city manager in Berkeley, California, directing innovative risk mitigation initiatives, intergovernmental coordination, and multi-institutional negotiations. Specialties: Urban resilience strategies, public policy development, climate change adaptation, disaster risk assessment and loss estimates, mitigation and risk financing, strategic fiscal planning, multi-party negotiations, and municipal government operations.

Peter Daszak, President of EcoHealth Alliance, is a leader in the field of conservation medicine and a respected disease ecologist. EcoHealth Alliance is a global organization dedicated to innovative conservation science linking ecology and the health of humans and wildlife. EcoHealth Alliance's mission is to provide scientists and educators with support for grassroots conservation efforts in 20 high-biodiversity countries in North America, Asia, Africa, and Latin America. Nine years ago Dr. Daszak became the Executive Director of EcoHealth Alliance's Consortium for Conservation Medicine (CCM) - a collaborative think-tank of institutions including Johns Hopkins Bloomberg School of Public Health, The University of Pittsburgh Graduate School of Public Health, The University of Wisconsin-Madison Nelson Institute for Environmental Studies, Tufts Cummings School of Veterinary Medicine Center for Conservation Medicine, and the USGS National Wildlife Health Center. The CCM is the first formal inter-institutional partnership to link conservation and disease ecology. Dr. Daszak's research has been instrumental in revealing and predicting the impacts of emerging diseases on wildlife, livestock, and human populations. He is originally from Britain, where he earned a B.Sc. in zoology and a Ph.D. in parasitology.

Thomas Dietz is Assistant Vice President for Environmental Research, Professor of Sociology, Environmental Science and Policy, and Animal Studies at Michigan State University. His current research examines the human driving forces of environmental change, environmental values and the interplay between science and democracy in environmental issues. Dietz is also an active participant in the Ecological and Cultural Change Studies Group at MSU. He is a Fellow of the American Association for the Advancement of Science, and has been awarded the Sustainability Science Award of the Ecological Society of America, the Distinguished Contribution Award of the American Sociological Association Section on Environment, Technology and Society, and the Outstanding Publication Award, also from the American Sociological Association Section on Environment, Technology and Society. He has served on numerous National Academies' panels and committees and chaired the Committee on the Human Dimensions of Global Change and the Panel on Public Participation in Environmental Assessment and Decision Making. He holds a Bachelor of General Studies degree from Kent State and a PhD in Ecology from the University of California at Davis.

Kristie L. Ebi is a Professor in the Department of Global Health and in the Department of Environmental and Occupational Health Sciences, University of Washington; a Guest Professor at Umea University, Sweden; and Consulting Professor at Stanford University and George Washington University. She conducts research on the impacts of and adaptation to climate change, including on extreme events, thermal stress, foodborne safety and security, waterborne diseases, and vectorborne diseases. Her work focuses on

understanding sources of vulnerability and designing adaptation policies and measures to reduce the risks of climate change in a multi-stressor environment. She has worked on assessing vulnerability and implementing adaptation measures in Central America, Europe, Africa, Asia, the Pacific, and the US. She is co-chair with Tom Kram (PBL, The Netherlands) of the International Committee On New Integrated Climate change assessment Scenarios (ICONICS), facilitating development of new climate change scenarios. She was Executive Director of the IPCC Working Group II Technical Support Unit from 2009 -2012. She was a coordinating lead author or lead author for the human health assessment for two US national assessments, the IPCC Fourth Assessment Report, the Millennium Ecosystem Assessment, and the International Assessment of Agricultural Science and Technology for Development. Dr. Ebi's scientific training includes an M.S. in toxicology and a Ph.D. and a Masters of Public Health in epidemiology, and postgraduate research at the London School of Hygiene and Tropical Medicine. She edited fours books on aspects of climate change and published more than 150 papers.

Baruch Fischhoff (IOM) is Howard Heinz University Professor, in the Departments of Social and Decision Sciences and of Engineering and Public Policy at Carnegie Mellon University, where he heads the Decision Sciences major. A graduate of the Detroit Public Schools, he holds a BS in mathematics and psychology from Wayne State University and an MA and PhD in psychology from the Hebrew University of Jerusalem. He is a member of the Institute of Medicine of the National Academies and is a past President of the Society for Judgment and Decision Making and of the Society for Risk Analysis. He chaired the Food and Drug Administration Risk Communication Advisory Committee and the National Research Council Committee on Behavioral and Social Science Research to Improve Intelligence Analysis for National Security. He has been a member of the Eugene, Oregon Commission on the Rights of Women, the Department of Homeland Security Science and Technology Advisory Committee, and the Environmental Protection Agency Scientific Advisory Board, where he chaired the Homeland Security Advisory Committee. He has written or edited several books: Acceptable Risk (1981), A Two-State Solution in the Middle East: Prospects and Possibilities (1993), Preference Elicitation (1999), Risk Communication: The Mental Models Approach (2001), Intelligence Analysis: Behavioral and Social Science Foundations (2011), Risk: A Very Short Introduction (2011), Communicating Risks and Benefits: An Evidence-Based User's Guide (2011), Judgment and Decision Making (2011), Risk Analysis and Human Behavior (2011), and Counting Civilian Casualties (in press).

Nancy B. Grimm studies the interaction of climate variation and change, human activities, and ecosystems. Her long-term research focuses on how disturbances (such as flooding or drying) affect the structure and processes of desert streams, how chemical elements move through and cycle within both desert streams and cities, and how storm water infrastructure affects water and material movement across an urban landscape. Grimm is the director of the Central Arizona–Phoenix LTER program—an interdisciplinary study by ecologists, engineers, physical and social scientists. She was President and is a fellow of the Ecological Society of America (ESA), is a fellow of the American Association for the Advancement of Science, and lead author for the National Climate Assessment.

Henry D. Jacoby is Professor of Management in the M.I.T. Sloan School of Management and former Co-Director of the M.I.T. Joint Program on the Science and Policy of Global Change, which is focused on the integration of the natural and social sciences and policy analysis in application to the threat of global climate change. He oversees the design and application of the social science component of the Joint Program's Integrated Global System Model—a comprehensive research tool for analyzing potential anthropogenic climate change and its social and environmental consequences—and he is a leader of M.I.T. research and analysis of national climate policies and the structure of the international climate regime. An undergraduate mechanical engineer at the University of Texas at Austin, Professor Jacoby holds a Ph.D. in Economics from Harvard University where he also served on the faculties of the Department of Economics and the Kennedy School of Government. He has been Director of the Harvard Environmental Systems Program, Director of the MIT Center for Energy and Environmental Policy Research, Associate Director of the MIT Energy Laboratory, and Chair of the MIT Faculty. He has made extensive contributions to the study of economics, policy and management in the areas of energy, natural resources and environment, writing widely on these topics including seven books. He currently serves on the Scientific Committee of the International Geosphere-Biosphere Program.

Anthony Janetos is the director of the Joint Global Change Research Institute, a joint venture between the Pacific Northwest National Laboratory and the University of Maryland. Prior to this position, he served as vice president of the H. John Heinz III Center for Science, Economics, and the Environment. Dr. Janetos also directed the center's Global Change program. Before coming to The Heinz Center, he served as vice president for science and research at the World Resources Institute and senior scientist for the Land-Cover and Land-Use Change Program in NASA's Office of Earth Science. He was also program scientist for NASA's Landsat 7 mission. He has had many years of experience in managing scientific research programs on a variety of ecological and environmental topics, including air pollution effects on forests, climate change impacts, land-use change, ecosystem modeling, and the global carbon cycle. He was a co-chair of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, and an author of the IPCC Special Report on Land-Use Change and Forestry, the Fourth Assessment Report of IPCC, the Millennium Ecosystem Assessment, and the Global Biodiversity Assessment. Dr. Janetos recently served on the NRC Committee for the Decadal Survey for Earth Sciences and Applications from Space, and has been a member of several other NRC Committees, including the NRC Committee for Review of the U.S. Climate Change Science Program Strategic Plan, the Committee on Review of Scientific Research Programs at the Smithsonian Institution (2002), and the Committee on Ecological Indicators for the Nation.

Haroon S. Kheshgi is the Global Climate Change Science Program Leader at ExxonMobil's corporate Strategic Research. He studied chemical engineering at the University of Illinois (Urbana, B.S. 1978) and the University of Minnesota (Minneapolis, Ph.D. 1983). He pursued research at Lawrence Livermore National Laboratory (1983-1986) before joining ExxonMobil Research and Engineering Company in 1986. At ExxonMobil Corporate

Strategic Research his research addresses many aspects of global climate change including carbon cycle, detection and attribution of climate change, paleoclimate implications, and the mitigation of greenhouse gas emissions. He has contributed to the Intergovernmental Panel on Climate Change (IPCC) as lead author, contributing author, and review editor in the IPCC's last three assessment reports and its Special Reports on Carbon Dioxide Capture and Storage, and on Land Use Change. Recent activities include participation in the International Petroleum Industry Environmental Conservation Association's Climate Change Working Group, the Engineering Founder Societies' project on carbon management, the Society on Petroleum Engineering's committee on carbon capture and storage, and the American Institute of Chemical Engineers Energy Advisory Board. He is currently Associate Editor of the journal Adaptation and Mitigation Strategies for Global Change, and a member of the US Carbon Cycles Science Steering Group.

Richard H. Moss is senior research scientist with the Joint Global Change Research Institute at the University of Maryland, visiting senior research scientist at the Earth Systems Science Interdisciplinary Center, and senior fellow with the World Wildlife Fund (WWF). He has served as director of the Office of the US Global Change Research Program/Climate Change Science Program (2000-06), vice president and managing director for Climate Change at WWF (2007-09), and senior director of the U.N. Foundation Energy and Climate Program (2006-2007). He also directed the Technical Support Unit of the Intergovernmental Panel on Climate Change (IPCC) impacts, adaptation, and mitigation working group (1993-1999) and served on the faculty of Princeton University (1989-91). He was a coordinating lead author of Confronting Climate Change and Realizing the Potential of Energy Efficiency, led preparation of the U.S. government's 10-year climate change research plan, and has been a lead author and editor of a number of IPCC Assessments, Special Reports, and Technical Papers. Moss remains active in the IPCC and currently co-chairs the IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis. He serves on the U.S. National Academy of Science's standing committee on the "human dimensions" of global environmental change and the editorial board of Climatic Change. He was named a fellow of the American Association for the Advancement of Science (AAAS) in 2006, a Distinguished Associate of the U.S. Department of Energy in 2004, and a fellow of the Aldo Leopold Leadership Program in 2001. He received an M.P.A. and Ph.D. from Princeton University (Public and International Affairs) and his B.A. from Carleton College in Northfield, Minnesota. Moss' research interests include development and use of scenarios, characterization and communication of uncertainty, and quantitative indicators of adaptive capacity and vulnerability to climate change.

Ian Roy Noble has spent 10 years with lead responsibility for the World Bank's activities in adaptation to climate change. He has also worked with the Carbon Finance Unit on emissions reductions through reduced deforestation and forest degradation. Before coming to the Bank in 2002 he was Professor of Global Change Research at the Australian National University. He has had senior roles in the IPCC process and in international cooperative research on climate change as part of the IGBP (International Geosphere Biosphere Program) including chairing the Global Change and Terrestrial Ecosystems for

some years. An ecologist by training, he holds a PhD from the University of Adelaide, and his research interests cover animal behavior, vegetation and biodiversity management, ecosystem modeling, expert systems and the science-policy interface. In 1999 he was elected as Fellow of the Australian Academy of Technological Sciences and Engineering.

Margo Oge served the United States Environmental Protection Agency for more than 30 years from 1980 to September 2012. She is widely recognized as having been a key architect of the EPA's efforts to reduce air pollution and greenhouse gas emissions. During her recent 18-year tenure as Director of the Office of Transportation and Air Quality, Ms. Oge led the EPA's first ever national greenhouse gas emission standards for cars and heavy-duty trucks to double fuel efficiency by 2025, reduce GHG emissions by 50% and save consumers $1.7 trillion at the pump. In parallel, she also helped to establish the renewable fuels standard, which will significantly increase the volume of biofuels in our nation's fuel supply. These new rules are viewed as some of the most significant steps forward in improving the sustainability of the U.S. transportation sector. Ms. Oge earned her Master's Degree in Engineering from the University of Massachusetts, Lowell. She also attended George Washington University and the John F. Kennedy School of Government at Harvard University.

Kathleen Segerson is a Professor of Economics at the University of Connecticut. She was the Head of the Department of Economics from 2001 to 2005. Dr. Segerson specializes in natural resource economics, and in particular, the economics of environmental regulation. She is currently a member of both the Chartered Executive Board of the Environmental Protection Agency's Science Advisory Board, and the Vice Chair of the Advisory Board's Committee on Valuing the Protection of Ecological Services and Systems. She was a member of the U.S. General Accounting Office's Expert Panel on Climate Change Economics from 2007 to 2008 and frequently serves on external review committees for the U.S. Department of Agriculture. She has also served on three National Research Council study committees: the Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems (2002-2004), the Committee on the Causes and Management of Coastal Eutrophication (1998-2000), and the Committee on Improving Principles and Guidelines for Waste Resources Planning by the U.S. Army Corps of Engineers (2008- present). In 2008, she was named a Fellow by both the American Agricultural Economics Association and the Association of Environmental and Resource Economists. Dr. Segerson earned a PhD from Cornell University in 1984.

Kathleen J. Tierney is the Director of the Natural Hazards Research and Applications Information Center at the University of Colorado. Dr. Tierney is a Professor of Sociology and Director of the Natural Hazards Research and Applications Information Center at the University of Colorado. The Hazards Center is housed in the Institute of Behavioral Science, where Prof. Tierney holds a joint appointment. Dr. Tierney's research focuses on the social dimensions of hazards and disasters, including natural, technological, and human-induced extreme events. With collaborators Michael Lindell and Ronald Perry, she recently published *Facing the Unexpected: Disaster Preparedness and Response in the United States* (Joseph Henry Press, 2001). This influential compilation presents a wealth of information derived from theory and research on disasters over the past 25 years. Among

Dr. Tierney's current and recent research projects are studies on the organizational response to the September 11, 2001 World Trade Center disaster, risk perception and risk communication, the use of new technologies in disaster management, and the impacts of disasters on businesses.

Charles J. Vorosmarty is a Professor of Civil Engineering, a Distinguished Scientist with NOAA-Cooperative Remote Sensing Science and Technology Center and Director of The City University of New York's Environmental Crossroads Initiative at The City College of New York. His research focuses on the development of computer models and geospatial data sets used in synthesis studies of the interactions among the water cycle, climate, biogeochemistry and anthropogenic activities. His studies are built around local, regional and continental to global-scale modeling of water balance, discharge, constituent fluxes in river systems and the analysis of the impacts of large-scale water engineering on the terrestrial water cycle. He is a founding member of the Global Water System Project that represents the input of more than 200 international scientists under the International Council for Science's Global Environmental Change Programs. He is spearheading efforts to develop global-scale indicators of water stress, to develop and apply databases of reservoir construction worldwide and to analyze coastal zone risks associated with water diversion. He recently won one of two national awards through the National Science Foundation to execute studies on hydrologic synthesis. Dr. Vorosmarty also is on several national and international panels, including the U.S. Arctic Research Commission, the NASA Earth Science Subcommittee, the National Research Council Committee on Hydrologic Science, the National Science Foundation's Arctic System Science Program Committee and the Arctic HYDRA International Polar Year Planning Team. He also was on a National Research Council panel that reviewed NASA's polar geophysical data sets, the decadal study on earth observations, and is Co-Chair of the National Science Foundation's Arctic CHAMP hydrology initiative. He has assembled regional and continental-scale hydro-meteorological data compendia, including the largest single collection, Arctic-RIMS (covering northern Eurasia and North America).

Appendix D: List of Interagency Working Groups and Participating Agencies

As described by USGCRP[11]: "Interagency Working Groups (IWGs) are the primary USGCRP vehicles for implementing and coordinating global change research activities within and across agencies. These groups are critical to integration and assessment of progress throughout the Program. The working groups span a wide range of interconnected climate and global change issues and address major components of the Earth's environmental and human systems, as well as cross-disciplinary approaches for addressing these issues.

IWGs are designed to bring agencies together to plan, develop, and implement coordinated activities, and to identify and fill gaps in the Program's plans. They allow public officials to communicate with each other on emerging directions within their agencies, their stakeholder needs, and best practices learned from agency activities. Together, these functions allow the agencies to work in a more coordinated and effective manner."

There are currently 13 IWGs:

- Integrated Observations Interagency Working Group
- Process Research Coordinating Committee
- Interagency Group on Integrative Modeling
- Carbon Cycle Interagency Working Group
- Adaptation Science Interagency Working Group
- Interagency Crosscutting Group on Climate Change and Human Health
- Social Sciences Coordinating Committee
- Interagency National Climate Assessment Working Group
- Coordinating Group on Scenarios and Interpretive Science
- International Research and Cooperation Interagency Working Group
- Global Change Information System Interagency Coordination
- Education Interagency Working Group
- Indicators Interagency Working Group (IndIWG)

[11] http://www.globalchange.gov/about/iwgs

Appendix E: Acronyms and Initialisms

ABAG	Association of Bay Area Governments
ARS	Agricultural Research Service
CDC	Centers for Disease Control
CENRS	Committee on Environment, Natural Resources, and Sustainability
DHS	Department of Homeland Security
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
EO	Executive Order
EPA	Environmental Protection Agency
ERS	Economic Research Service
FEMA	Federal Emergency Management Agency
GCRA	Global Change Research Act
GHG	Greenhouse Gas
GLISA	Great Lakes Integrated Sciences and Assessments Center
HHS	Department of Health and Human Services
HUD	Department of Housing and Urban Development
IWG	Interagency Working Group
LCC	Landscape Conservation Cooperatives
MI DCH	Michigan Department of Community Health
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NCA	National Climate Assessment
NGO	non-governmental organization
NIFA	National Institute of Food and Agriculture

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
OAR	Oceanic and Atmospheric Research
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
RISA	Regional Integrated Sciences and Assessment
SGCR	Subcommittee on Global Change Research
SI	Smithsonian Institution
USAID	U.S. Agency for International Development
USDA	Department of Agriculture
USFS	Forest Service
USGCRP	US Global Change Research Program
USGS	US Geological Survey
WG	Working Group