Preparing the Nation for Change:
Building a Sustained National Climate Assessment Process

National Climate Assessment Development and Advisory Committee
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Executive Summary

Recent extreme weather events (including drought, wildfire, storms and flooding) have elevated society's concern about how to manage climate risks. As climate change makes many extremes more likely and severe, decision-makers across the nation are increasingly focused on anticipating, mitigating, and adapting to climate change. The strategic goal of conducting a sustained climate assessment, as proposed in *The National Global Change Research Plan 2012-2021: A Strategic Plan for the U.S. Global Change Research Program* (NSTC 2012), is aimed at increasing the federal government's ability to effectively and efficiently support the expanding need for information, foster collaboration between various levels of government and non-governmental entities, and produce and communicate timely, scientifically-sound climate information products, technologies, and processes for the nation.

Effectively managing the risks of climate change will require society to prepare for a wide variety of changing conditions on an ongoing basis and to make decisions in the context of uncertainty. The present report describes the knowledge base and capacity needed to enable the effective integration of new scientific understanding into management decisions. This can be achieved by enhancing the production of decision-support tools, initiating continuous improvements in collecting and synthesizing information, and providing feedback to ongoing research efforts. By strategically selecting topics for assessment as user needs emerge via ongoing public engagement, both input to and use of assessment products can be improved. This vision and the report's recommendations provide a basis for achieving the USGCRP's goal to conduct a sustained assessment.

Because a sustained process offers the opportunity for planning and investment decisions to be more deliberate and phased in over time, the U.S. government can more efficiently provide support for science focused on solutions and investment opportunities; support the science and adaptation needs of federal agencies; and provide transparent access to data at a variety of scales for private businesses, local/state/regional/tribal governments, and other organizations that are planning for the future. The success of this proposed new framework depends on the support of government and non-governmental participants, including academia and the private sector, and on connecting federal, tribal, regional, and state-focused efforts. While the sustained assessment process will be responsive to a variety of practitioner-focused needs, a strong federal commitment to documenting and anticipating both the positive and the negative aspects of climate and global change demonstrates leadership that can further encourage broad non-governmental engagement.

Additionally, a truly sustained assessment activity provides a mechanism for connecting research with decision-making, facilitating evaluation of the state of knowledge, and establishing rigorous ways of documenting changes over time, while improving communication with stakeholders to ensure that new tools and capabilities will meet their needs. A sustained approach will allow greater efficiency in development of assessment products (including quadrennial reports) to contribute to continued progress in research and responsive delivery of credible information for decision-making (NSTC 2012).

This report responds to the requirement of the charter of the National Climate Assessment and Development Advisory Committee (NCADAC) to provide advice and recommendations toward the development of an ongoing, sustained national

assessment of global change impacts and adaptation and mitigation strategies for the nation. The recommendations presented here build on the plans set forth in the USGCRP Strategic Plan (NSTC 2012).[1]

Vision for a Sustained Assessment in a Dynamic Landscape

Past and current national assessment reports have successfully served as periodic milestones in assessing climate change and its impacts on the United States and communicating that understanding to a wide variety of stakeholders, including policy-makers. Going forward, we recommend a more sustained process of assessment to build on these successes, address rapidly evolving national needs on an ongoing basis, and promote effective adaptation to climate change impacts. The sustained nature of the process recommended here will also enable federal agencies to more effectively meet mission objectives, improve outcomes, and implement the integrated USGCRP Strategic Plan in which assessments play a central role. Sustained assessment processes can achieve this while engaging a broader array of participants, serving broader needs of the nation. If properly managed, they can provide greater efficiency in meeting statutory obligations while also bringing potential additional resources to bear.

A key conclusion of this report is that a sustained assessment process is better able than periodic assessment reports to support the legal mandate to integrate, evaluate, and assess the findings of the USGCRP for a variety of reasons, including:

- a sustained process can more effectively support adaptation and mitigation decisions. An ongoing effort that maintains central coordination capacity and strategically deploys and enhances activities within regions and sectors will be more efficient than recreating capacity every few years. This will make it much more likely for USGCRP to be able to both fulfill the legal requirements of the Global Change Research Act (GCRA) and meet the risk management needs of decision-makers throughout the country;
- it can employ insights from USGCRP research, external research, *and* applications of that research on a regular basis, enhancing their currency and relevance to immediate stakeholder concerns; and
- it can support ongoing stakeholder engagement, which is a crucial component of effective assessments and in enhancing their impact.

We strongly endorse USGCRP's goal of establishing a sustained assessment process (NSTC 2012), building on lessons learned from past efforts (Parson et al. 2003) and

[1] "The strategic vision for the NCA differs in multiple ways from previous U.S. climate assessment efforts. Building on the recommendations of the National Research Council, it will implement a long-term, consistent, and ongoing process for evaluation of climate risks and opportunities, and informing decision making processes within regions and sectors. An essential component of this process is to establish sustained assessment activity both inside and outside of the Federal government that draws upon, and sustains, the work of stakeholders and scientists across the country. A sustained assessment process is most appropriate to effectively respond to the four-year reporting requirement of the Global Change Research Act, and will reduce the need for the lengthy reports of past assessments. It will also be more focused on evaluating the current state of scientific knowledge relative to climate impacts and trends, and on supporting the Nation's activities in adaptation and mitigation." (NSTC 2012)

from preparation of the Third National Climate Assessment (NCA) Report. With slight amendments (shown in italics), we recommend that the goal and vision for the NCA that was first adopted in the NCA Strategic Plan in May 2011 should continue to guide sustained assessment efforts:

> **Goal:** Enhance the ability of *decision-makers at multiple scales throughout* the United States to **anticipate, mitigate, and adapt** to changes in the global environment.
>
> **Vision:** Advance an **inclusive, broad-based, and sustained process** for assessing and communicating scientific knowledge of the vulnerabilities, impacts, risks, *and opportunities* associated with a changing global climate in support of decision-making across the United States.

A sustained national assessment process will require ongoing leadership and commitment of resources by the federal government, even as a decentralized assessment capacity is being developed and external partnerships are pursued. As in previous national assessments, the research community will provide essential scientific expertise leveraged from the federal investment in global change research, and this continued rigor and credibility will be essential. But because the sustained assessment process is an unusually complex and challenging effort, involving multiple scientific disciplines, multiple federal agencies, and partners and stakeholders across the United States, an ongoing coordination office is essential to its success. Funding such an office is therefore a prerequisite to all recommendations that follow in this report.

Our more specific recommendations have been grouped into the following four critical elements (not in any implied order of priority):

- **Establish mechanisms to support enduring collaborative partnerships that sustain assessment activities;**
- **Enhance and organize the scientific foundations for managing the risks and opportunities of climate change;**
- **Provide infrastructure to support a sustained assessment process; and**
- **Diversify the resource base and set priorities.**

These elements are summarized further below and are examined in greater detail in the main body of the report. Together, these elements represent a vision for the USGCRP goal of conducting sustained assessments:

1. Establish mechanisms to support enduring collaborative partnerships that sustain assessment activities

One of the most critical advantages of a sustained process will be the opportunity to engage on an ongoing basis with a diverse array of participants and ensure that the development of products and services benefits from their expertise. The objectives of informing adaptation and mitigation decision-making and facilitating risk management inherently involve both the research community and decision-makers in society who are being affected by and managing the risks. These groups may not find it easy to communicate directly, leading to the important role of intermediaries who can link

producers and users of information. USGCRP can facilitate these relationships and enhance roles that agencies and others already play in this regard. Intermediaries play a number of important roles, including translating science for decision-making at scales at which actions are being taken (e.g. local, or watershed scales) and identifying information needs that require new research.

This report describes necessary components of engagement, communication, and partnerships and discusses recommended approaches for developing and sustaining relationships that provide joint or "co-production of knowledge"[2] opportunities (including at the regional and local scales) that are well placed to link science and action. While we see establishing and strengthening these partnerships as critical, we also recognize that these must be set up in a way that federal agencies and partners alike can actively support and benefit from.

2. Enhance and organize the scientific foundations for managing the risks and opportunities of climate change

Enhancing a scientific foundation for managing climate-related risk and opportunity requires a robust discovery-driven research program that is also responsive to emerging national gaps in knowledge. This foundation of scientific knowledge must also be organized and integrated in new ways so that products and tools for assessment and translation emerge. Building on the science endeavors within the USGCRP and staying within its strategic framework, there are nonetheless three additional contributions a sustained assessment approach will make to influence these scientific foundations.

- It will facilitate the flow of local-to-national knowledge needs (from assessment partners and diverse participants), thus informing the scientific investments that are needed.
- It will provide incentive and capacity for incorporating scientific advances into critical tools for translating science to practical applications, such as defining indicators of change and developing scenarios for planning.
- It will continue to facilitate new research—for example, on the practice of vulnerability assessment, in integrating multiple sources of knowledge, or in developing rigorous and usable valuation methods—to fill critical needs for information.

Taking these three roles of a sustained assessment into account along with the stated needs of current assessment partners and practitioners, research and organizational advances are needed in the following areas: (1) methods for vulnerability assessment and risk management; (2) indicators of climate changes, impacts, vulnerabilities, and preparedness; (3) scenario methods and products for framing risk and developing robust responses, technologies, and processes; (4) valuation methods for measuring the consequences of change and the benefits of adaptation/mitigation responses; (5) methods to incorporate climate-related international influences on the United States; (6) methods for assessing confidence and uncertainty in scientific information for decision-

[2] In this report "co-production" refers to the process of engaging both producers and users of climate information in the design and production of science-based decision support tools. This process is aimed at bridging the gap between science and resource management and public policy in order to arrive at knowledge products that are more likely to be applied to address climate-related management challenges.

making; (7) adaptive learning within assessment processes; and (8) identification of risk-management information needs. Specific recommendations regarding priorities in each of these areas are included in the report.

3. Provide infrastructure to support a sustained assessment process

Further progress is needed in establishing the "infrastructure" for sustained assessment, including the following critical elements: (1) leadership and coordination; (2) processes for supporting preparation of quadrennial and special reports and an array of ongoing products and online resources; (3) data management and information needs (both as inputs to assessment and as a means of disseminating findings); and (4) regional institutions and networks that provide a means of sustaining interactions among researchers and decision-makers at regional to local scales.

The USGCRP, through a sustained assessment process, should continue to work with existing federal, state, tribal, NGO, university, extension, private sector, and regional science partners on an ongoing basis to expand and coordinate regional science application and data development networks in ways that are mutually beneficial. Among the benefits of regional engagement are support for coordinated and distributed assessment capacities and the development of trusted relationships between scientists and decision-makers across local and broader scales.

4. Diversify the resource base and set priorities

The vast majority of costs associated with producing past assessments has been borne, directly or indirectly, by the federal government, even though the Third NCA Report involved more substantial voluntary contributions from outside the federal government than some past assessments. Many of the activities associated with the production of a sustained assessment process represent quintessential federal government functions that support the fundamental requirements of the GCRA (see, for example, Appendix D), and rely on and benefit from a credible, central source such as the federal government. However, a successful future sustained assessment will also draw upon and benefit from a more diversified resourcing model. A range of public-private partnerships to support particular components of NCA activities should be considered.

Even with a broader resource base, there will inevitably be constraints on the activities associated with the sustained assessment process, requiring the setting of priorities. Prioritization criteria should be applied transparently and systematically on an annual basis to select special topics and interim investments between the quadrennial reports through the preparation of the President's budget and by setting longer-term objectives on a periodic basis. One obvious opportunity for long-term stock-taking and priority-setting is following the major quadrennial synthesis reports, each of which invites evaluation of identified needs and capacities. Ideally, needs for advancing a sustained assessment process will be reflected in the research priorities of the USGCRP and in the budget for the assessment. We recommend that priority be given to activities that establish and maintain partnerships, document impacts and vulnerabilities, incorporate scientific information into adaptation and mitigation decisions, contribute to ongoing evaluation and adaptive learning about the process/needs for assessment, and/or meet priority information needs of society, the government, and private entities, as well as build capacity in these areas. These activities will complement and enhance the

investment in discovery-driven science already undertaken throughout the USGCRP Agencies.

The recommendations in this report are aimed at those components of a sustained climate assessment that are deemed foundational to such an effort. How, when, and to what degree they are implemented would depend entirely on the priorities and funding capacities of the implementing agencies.

Key Conclusions

Our key conclusions are:

- A sustained assessment process is the most effective and efficient way to: respond effectively to the four-year report requirement of the GCRA; increase the utility of assessment information by providing more focused special reports and web-based products for decision-makers; and more equitably distribute the workload burden on the expert and management communities. It will also allow more timely and focused evaluation of the current state of scientific knowledge relative to climate impacts and trends, support the nation's activities in adaptation and mitigation, and improve responsiveness to rapidly emerging needs of decision-makers.

- The USGCRP should maintain a sustained assessment coordination office headed by a strong leader. We consider the coordination office, under the direction of a strong leader, to be a prerequisite for the success of the sustained assessment process.

- The USGCRP should support and nurture the development of a consistent and constantly updated suite of national indicators of climate change to improve understanding of change and strengthen the ability of U.S. communities and the economy to prepare and respond, as specified in the USGCRP Strategic Plan and using recommendations from the NCADAC Indicators Working Group (Janetos et al. 2012b).

- The USGCRP should also continue to support and benefit from the development of an interagency information management system, such as the proposed global change information system (GCIS) that will provide timely, authoritative, and relevant information, and produce reports and web-based products that are useful for decision-making at multiple levels. Electronic access to data and tools is critical for decision support and for transparency of assessment conclusions.

- Careful attention should be paid to the *process* of assessment: i.e., the engagement, communication, and evaluation components as well as the methodologies for data collection and analysis. To ensure broad support (and additional sources of relevant information), more defined relationships should be explored with external partners from the private sector, NGOs, foundations, and a broad set of regional, tribal, and sectoral stakeholders. Alternative governance structures for the NCA should also be considered to ensure a responsive and efficient management process that also enhances the breadth and magnitude of resources to support the ongoing assessment activities.

- As has been pointed out by the National Research Council in past evaluations, it is critical to properly resource assessments, particularly given their increasing importance as the climate continues to change. Although substantial components of the Third NCA Report were produced through volunteer efforts, it is unreasonable to assume that an ongoing, rigorous, and consistent approach to assessment can take place without some additional investment in the *process* of assessment. Implementation of the sustained assessment process described herein will provide a strong foundation for the USGCRP Strategic Plan, for implementing the GCRA, and for contributions to international assessments and programs (e.g., the Intergovernmental Panel on Climate Change [IPCC], the U.N. Global Framework for Climate Services, and national efforts (such as the Hurricane Sandy Task Force). As such it can very significantly enhance the quality of information used for decision-support in the United States.

We endorse a flexible approach to building and sustaining assessment capacity that can expand and contract in response to resource availability and needs while also focusing on constant improvements in the process. While we acknowledge that providing resources to support a sustained assessment process could be challenging, a prudent path forward will be to carefully protect the core capacity of the USGCRP to support the coordination of assessment partners and produce rigorous and updated information, while strategically implementing investments in foundational elements such as scenarios, information systems, and indicators. The relative investment in these critical components should be outlined in a five-year, annually updated operating plan that also supports the quadrennial report process and promotes continual support for the USGCRP as a whole. Activities, plans, and investments can be phased over time as USGCRP develops a strategy for sustained assessment.

In this report we recommend sustained assessment activities that are fully supportive of the USGCRP strategic goal to conduct a sustained climate assessment, to enhance the ability of the USGCRP to meet obligations under the GCRA and to do it with greater efficiency across the whole program. An assessment of cost is not explicitly provided, since the USGCRP agencies are uniquely and solely equipped to produce cost estimates associated with components of its strategic plan. We also believe that the sustained assessment will help the USGCRP meet its obligations under the GCRA with greater efficiency across the whole program. This efficiency comes from: (1) a wider distribution of participants and partners (who can also help resource a sustained assessment); (2) greater feedback to and more targeted enhancement of scientific foundations (which address national needs, improve assessment products, and yield greater benefits from federal investment); and (3) the increased reach of assessment-driven information, which allows initial investments to go further and yield better overall results for decision-support. The opportunities to leverage existing programs and new partnerships can ultimately improve the efficiency and effectiveness of the nation's overall assessment capacity, and increase outcomes in relation to inputs if a sustained assessment is properly and strategically implemented.

Introduction and Background

Effectively managing the risks associated with climate change[3] will require society to transition to a new approach, wherein preparing for potentially costly changes and uncertainty in the climate system is incorporated into decision-making an ongoing basis. The present report, *Preparing the Nation for Change: Building a Sustained National Climate Assessment Process,* envisions such a new model for assessments, where continuous research, assessment, and engagement are carried out to build society's capacity to manage the risks of climate variability and change. It also encourages a more flexible, multidisciplinary, and integrated approach that utilizes various types of data analyses that may not have been previously attempted. The success of this new model depends on government[4] and non-governmental participants and on connecting existing and emerging efforts. While there is already considerable collaboration on climate issues among these sectors, existing relationships are informal and the interactions intermittent. As such, in most sectors and regions the critical climate risks cannot be adequately managed at this time.

A strong federal commitment to documenting and anticipating both the positive and the negative aspects of climate and global change will demonstrate leadership, nationally and internationally. Further, strong governmental commitment can encourage broad non-governmental engagement. Within the new approach proposed here, the National Climate Assessment (NCA) can more efficiently and effectively: (1) support science that is focused on solutions; (2) help to fulfill the science and adaptation needs of federal agencies; and (3) provide transparent access to data at multiple scales for the many private businesses and local/state/regional/tribal governments that are planning for the future. The NCA can continue to evolve to help provide an information foundation for decisions through engagement in a variety of public-private partnership opportunities.

The purpose of this report is to fulfill (on an initial basis) the requirement of the charter of the National Climate Assessment and Development Advisory Committee (NCADAC) to provide advice and recommendations toward the development of an ongoing, sustainable national assessment of global change impacts and adaptation and mitigation strategies for the nation. This report is being issued as a special report of the NCADAC to the U.S. Global Change Research Program (USGCRP) and the White House Office of Science and Technology Policy (OSTP).[5] This is not a government document, but a report from the NCADAC comprising advice to the government.

[3] When we use the term 'climate change' in this document, we are referring to climate change and related global environmental and socioeconomic changes, not only physical climate changes.

[4] Throughout this document, unless a type is specified, 'government' includes all levels and types: tribal, federal, state, and local, and their agencies.

[5] Materials previously produced by the NCADAC's Sustained Assessment Working Group and by the authors of the Sustained Assessment chapter of the draft Third NCA Report have been used extensively in this report; however, most material in this report is original.

A Vision for a Sustained Assessment in a Dynamic Landscape

Climate change is already happening; it has been observed in every region and has caused significant impacts on a wide range of sectors throughout the United States. Environmental and economic damages from climate change are already motivating planning and investment in activities that promote resilience and limit emissions. As climate change accelerates and intensifies (Karl et al. 2009), an increasing number of institutions and individuals will be confronted with evaluating how climate change is affecting their interests and determining how best to respond. The needs of these institutions and individuals for information to support decision-making to prepare and adapt is growing rapidly, touching more and more sectors of the economy.

Anticipating these needs, the USGCRP was created by the 1990 Global Change Research Act (GCRA) to provide scientific information on global environmental change and its impacts so as to inform sound policy and decision-making. Since its establishment, USGCRP's essential mission has been to conduct research on the Earth system, its natural cycles, the impacts of human activities, and the consequences of natural and human-driven change. USGCRP investments have included research into climate and environmental processes; observation and monitoring systems on land, sea, and air; models of environmental and human systems; and data-management systems.

The GCRA also requires the USGCRP to conduct assessments and evaluate the impacts of global change on key sectors at least every four years. These assessments evaluate the state of knowledge and apply the scientific information available at a point in time to a variety of sectors. The law also requires projections of impacts into the future. From its inception, the USGCRP's thirteen agencies[6] have responded to the original statutory mandate: "*To provide for development and coordination of a comprehensive and integrated U.S. research program which will assist the Nation and the world to* ***understand, assess, predict, and respond*** *to human-induced and natural processes of global change."*

Also as required by the GCRA, the USGCRP in 2012 completed an updated strategic plan for the coming decade (NSTC 2012), calling for:

> "*A Nation, globally engaged and guided by science, meeting the challenges of climate and global change,"* brought about by its efforts to "*build a knowledge base that informs human responses to climate and global change…"*

The 2012 Strategic Plan envisions a substantial transition for the program, with increased emphasis on informing decisions, conducting sustained assessments, and communicating/educating. Specifically, the Plan calls for the establishment of a *sustained assessment process* as the most effective way to meet the nation's evolving information needs.

[6] The agencies and departments are: Department of Agriculture, Department of Commerce, Department of Defense, Department of Energy, Department of Health and Human Services, Department of the Interior, Department of State, Department of Transportation, Environmental Protection Agency, National Aeronautics and Space Administration, National Science Foundation, The Smithsonian Institution, and U.S. Agency for International Development.

Why a <u>sustained</u> assessment?

A sustained process will improve the efficiency and efficacy of assessments (NSTC 2012). This is true for many reasons, including the potential to broaden the resource base (and leverage investments) through partnerships with organizations that are outside the federal system. Such partners can provide timely and relevant information that can be incorporated into the assessment if it meets rigorous quality criteria, providing "on-the-ground" data and knowledge that would otherwise be inaccessible to the government. A sustained assessment can be designed as an ongoing learning process, focused on improvements in processes and products over time (see box at right). This can allow existing and new investments to be more strategically planned, and could help to reduce expensive and sudden escalations in expenditures to meet the legal requirements of the GCRA (see, for example, Appendix D). Ideally, costs and effort can be distributed over time and among a wider array of participants, including scientists and stakeholders new to the assessment community. The results of this ongoing activity can then be integrated when the USGCRP addresses its Congressional mandate for a quadrennial synthesis report rather than starting each report activity anew each time.

A **sustained assessment** is *an evolving framework* for connecting institutions and activities in regions and sectors through a network of scientists and practitioners from academia, government, civil society, the private sector, tribal communities, and practitioners *to strengthen the nation's capacity to understand, assess, predict, and respond to human-induced and natural processes of global change*. The assessment network will define climate-related risks and opportunities over time, at national, regional, and local scales, providing the basis for periodic assessment reports and an array of ongoing products and online resources, while building sustained capacity for decision-makers to use this information.

A sustained assessment process incorporates ongoing evaluation of effectiveness, which facilitates adaptive management; supports adaptation actions across various time scales; stimulates civic engagement; and enhances the nation's capacity to effectively respond to the many challenges of accelerating global change.

Although the GCRA of 1990 mandated the preparation of assessment reports at least every four years, only two such reports have been completed over the lifetime of the program—in 2000 and 2009—and a third is in preparation. Starting each without the benefit of continuity from the previous effort has not only impacted the timing of the quadrennial synthesis reports, but has exacted high costs both on the time of participants (including the research community) and from a budgetary perspective. With intermittent assessments there has been little opportunity for institutional learning and much loss of efficiency, as for example the need to redevelop expertise for each successive report because of turnover in staff, leadership, and contributors (albeit with some return of participants for each), as well as loss of trust from the stakeholder community as the assessment effort peaks, then recedes.

Because climate change is intensifying and accelerating (Karl et al. 2009), questions and decision needs are arising in unexpected ways and at multiple time and spatial scales. A sustained process will be better able to meet these rapidly evolving demands with timely and relevant information (see box, next page). Decision-making about adaptation and

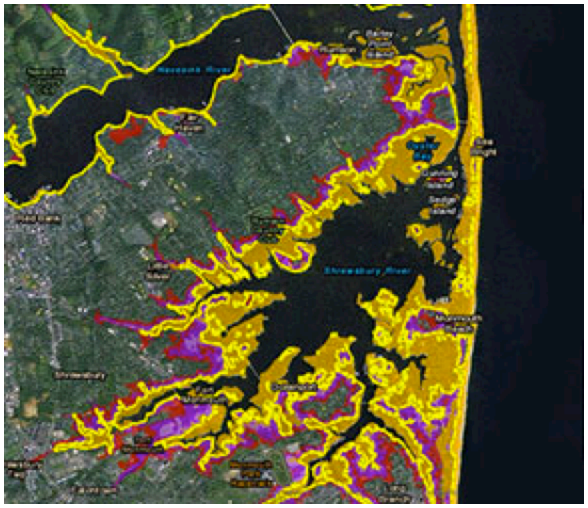
mitigation is not occurring according to a fixed schedule or a four-year recurring timetable. It is ongoing on a wide variety of time scales, given the context of the decisions and the institutions involved. A sustained process provides the framework for continuous improvement and updating of information and observations from USGCRP agencies and beyond in a wide variety of time scales. A sustained assessment will: (1) more efficiently support adaptation and mitigation decisions and policy, including at national and international scales; (2) allow for ongoing improvements in the ability to manage risk; (3) employ insights both from USGCRP research, external research, *and* applications of that research on a regular basis; and (4) support ongoing stakeholder engagement.

A sustained process can accommodate continuous updates of varied topical and regional information and knowledge, punctuated with intermittent comprehensive scientific updates, while an intermittent process can only provide the latter. Ongoing engagement and dialogue have multiple documented benefits, enhancing the usefulness of the nation's investment in scientific research through communication and education (NRC 2009b, 2010a, 2010b, 2010c, 2010d).

A sustained assessment will also enable learning by both scientists and practitioners (and from each other), improving society's ability to anticipate climate impacts and opportunities. Developing and maintaining ongoing dialogue clarifies information needs, provides opportunities to discuss interim results and adjust focus, and communicates findings more effectively. Sustained participatory assessment processes that bridge local and regional needs and resources to national efforts can provide information that is more relevant, of higher quality, and of greater legitimacy than individual reports or intermittent processes.

How a Sustained Assessment Benefits the Nation: One Success Story

A sustained climate assessment will promote the readiness of the nation to respond to extreme weather events. Case in point: Recovery activities following Hurricane Sandy were aided by the ongoing National Climate Assessment. A sea-level-rise scenarios document was just being completed as interagency input to the NCA when Hurricane Sandy struck in 2012. Because the National Oceanic and Atmospheric Administration, USGCRP, and the U.S. Army Corps of Engineers were already working together on the sea-level rise scenarios, when FEMA identified a need for a mapping tool as part of the rebuilding effort to show which areas of New York and New Jersey would be inundated under a variety of future sea-level rise scenarios, the capacity existed in real time to develop it. The tool was deployed by FEMA within months after the storm hit. President Obama included the tool as an example in his Climate Action Plan in June 2013.



Sea-level rise mapping tool for Hurricane Sandy Recovery (www.globalchange.gov)

Finally, a continuing process allows for deliberate improvements in the process over time (i.e., through ongoing evaluation of progress and adaptive learning, and development of scenarios, indicators, and data systems).

The USGCRP agencies have varied perspectives that are needed to inform the process of developing this new approach. A sustained assessment process has the potential to improve information available to federal agencies and Congress. The agencies are managers of substantial land and other resources across the Nation; they will be making adaptation and mitigation decisions in response to evolving conditions and mandates. Federal policies and guidelines also shape the way many local management decisions are made. Sustained assessment can improve management and inform legislation, policies, and programs at the national scale on an ongoing basis.

Some government agencies are primarily research-focused, while others are "mission" agencies (i.e., have specific mission responsibilities such as regulatory roles, land and resource management, or national and homeland security) that need information from a sustained assessment process to assist them in decision-making. Some mission agencies (such as the Environmental Protection Agency) have a regulatory role that gives them a unique perspective on and requirements from the assessment process so that they may use information in regulatory justifications, for example. Although a sustained assessment will have different implications for different agencies within USGCRP, it should be designed to directly support the other three goals of its ten-year Strategic Plan: to advance science, inform decisions, and communicate and educate.

For these reasons, we strongly endorse USGCRP's goal of establishing a sustained assessment process, building on lessons learned from past efforts (Parson et al. 2003) and from preparation of the Third NCA quadrennial synthesis report. And, with a slight amendment (shown in italics), we recommend that the goal and vision for the NCA first adopted in the NCA Strategic Plan in May 2011 should continue to guide sustained assessment efforts:

> **Goal:** Enhance the ability of *decision-makers at multiple scales throughout* the United States to **anticipate, mitigate, and adapt** to changes in the global environment
>
> **Vision:** Advance an **inclusive, broad-based, and sustained process** for assessing and communicating scientific knowledge of the impacts, risks, *opportunities,* and vulnerabilities associated with a changing global climate in support of decision-making across the United States.

Overarching critical elements for a sustained assessment

We recommend that the national assessment be an ongoing process that provides access to the observations, data, scientific syntheses, sectoral, cross-sectoral and regional analyses used in assessments, and other products needed to enable decision-makers to manage risks and seize opportunities presented by climate change. If it is conducted in a rigorous and consistent way, a sustained assessment should be a seen as a legitimate source of credible and salient information for a very broad range of adaptation and mitigation decisions. Those benefitting from access to sustained assessment activities and products will include decision-makers in communities,

businesses, trade associations, and non-governmental organizations, as well as officials in federal agencies, state and local governments, and tribes.

Many of the activities recommended within this report will provide science-based input to decisions made in managing risk in sectors affected by climate variability and change. However, as envisioned here, the Sustained Assessment differs from a "climate service" (Miles et al. 2006) in several important ways. It does not serve clients or develop products for specific classes of decision-makers. Rather, it is an information base from which climate services can be deployed, but does not have the operational characteristics of a climate service.

Throughout this report a distinction is made between specific assessment ***products***, whether required by Congress or initiated by the USGCRP and/or participating agencies, and a sustained, distributed assessment ***process***—the ongoing set of activities/processes described here that develop and provide science-based products and other online resources, facilitate communication, build societal capacity for self-initiated assessments, and encourage adaptive management and learning.

The underpinnings of the assessment process—foundational information such as scenarios, indicators, methodologies, and new data—can be supported and used by a wide array of participants. Products that emerge from foundational efforts inform the quadrennial assessments *and* serve as stand-alone rigorous and relevant resources. In summary, a sustained assessment can a) improve the quality of the products, b) share the costs of producing them across a broader set of participants, c) increase the likelihood that the science-based decision-support products will be adopted and applied, and d) provide the information needs of the private sector community, thus helping to improve national economic strength and societal well-being (see Figure 1, next page).

Establishing such a sustained assessment will require a number of actions by the agencies that participate in USGCRP. Specific recommendations have been grouped under four critical elements that are addressed in the sections of this report that follow:

- **Establish mechanisms to support enduring collaborative partnerships that sustain assessment activities**
- **Enhance and organize the scientific foundations for managing the risks and opportunities of climate change.**
- **Provide infrastructure to support a sustained assessment process.**
- **Diversify the resource base and set priorities.**

Within each of these broad elements, we recommend specific measures that we believe are essential to establishing a sustained assessment process. Some of these measures can be undertaken by individual agencies on behalf of the USGCRP, but others will require a high degree of interagency coordination and external partnerships. Implementation of these recommendations will take time and must occur in the context of the program's attainment of its ten-year Strategic Plan objectives. Moreover, evolving public interest, information needs, budget initiatives and constraints, and other factors will present a dynamic landscape of opportunities and limitations that are impossible to foresee. Accordingly, we focus on identifying necessary conditions, tools, methods, information, and other aspects of a sustained assessment, rather than specifying detailed recommendations on implementation. Further, we recommend criteria that

should be used in prioritization of implementation activities within this unfolding situation, rather than specifying detailed, potentially dated recommendations on implementation. Appendix E outlines the overall process used in developing the recommendations presented in this report.

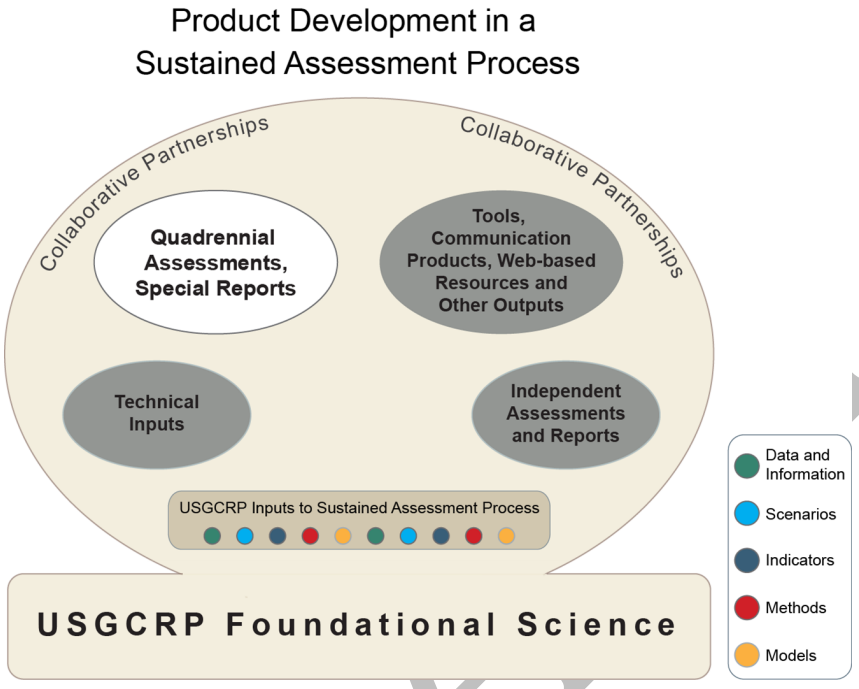


Figure 1. While the development of products is not the only output intended from the sustained process described in this report, this figure illustrates the product-focused output. All sustained assessment products are supported by robust and extensive collaborative partnerships, as illustrated by the background circle, and flow from a strong foundation of science and information contributed by USGCRP and partner organizations. Technical inputs (requested as part of the input to the quadrennial report process) and independent assessments alike may be developed by government agencies, interagency collaborators, or non-governmental organizations independently of the formal legal reports. These types of reports add value and information to the products that directly meet the legal obligations of the GCRA (i.e., the quadrennial assessments and special reports, which are reviewable by the government [white oval in diagram]). All inputs and reports can also contribute to an array of other assessment products that communicate to a wider audience. In turn, the quadrennial reports and other output help to identify continued needs for and within technical inputs, independent assessments, and foundational science.

A sustained assessment that can be supported over time must be flexible and adaptive under changing conditions and the effort may expand and contract in response to budgetary limitations and changing information needs. With that clear recognition/ understanding, an effort that maintains central coordination capacity and strategically deploys ongoing efforts within regions and sectors will be more efficient and effective than re-creating capacity every few years and will make it much more likely for USGCRP

to be able to both fulfill the legal requirements of the GCRA and meet the risk management needs of decision-makers around the country (see also Appendix D).

The importance of enduring partnerships, leadership, and coordination

Before we delve into specific recommendations within each theme area, the importance of establishing enduring collaborative partnerships among government and non-governmental entities must be acknowledged. Active pursuit of this objective will encourage non-governmental institutions to assume an increasing share of the contributions to a sustained assessment and help build a rigorous information base that also serves their needs. Building on a fledgling but important national trend, a number of decision-makers across the country are already engaged in self-initiated and self-motivated evaluations of the ways in which climate change needs to be factored into their decisions. A number of private and public organizations are also beginning to work collaboratively with such decision-makers to facilitate data gathering and communication. As discussed more thoroughly in Recommendation 1.1, these organizations are building relationships with stakeholders by facilitating access to NCA information and products, sharing results and expertise, encouraging evaluation and dissemination of "lessons learned", and other activities, thus building on-the-ground knowledge of climate impacts and opportunities.

Partnerships with governments and institutions beyond the United States also will help to both inform our national assessment efforts and provide critical information to connect changes happening elsewhere to impacts that might be felt in the United States. Similarly, a sustained process will help to inform international assessments even if the U.S. quadrennial reports do not always align in timing with international information needs.

A sustained national assessment process will require ongoing leadership by the federal government, even as more decentralized assessment capacity is being developed. As in previous national assessments, the research community will provide essential scientific expertise leveraged from the federal investment in global change research. But the USGCRP agencies should maintain an efficient core infrastructure required for a sustained assessment, including an ongoing coordination office that helps manage the process and ensures that information meets the needs of users.

Any effort that involves a broad and diverse group of stakeholders and participants requires dedicated, focused, and skillful leadership. The importance of effective leadership is highlighted in the NRC's *Analysis of Global Change Assessments: Lessons Learned* (2007). Good leadership is especially critical in a sustained assessment process because it is an unusually complex and challenging effort, involving multiple scientific disciplines, multiple federal agencies, and partners and stakeholders across the United States.

Therefore, funding a coordination office is seen as an essential prerequisite to all recommendations that follow in this report. Although leadership is needed at multiple levels, it is most critically needed in an assessment coordination office staffed by professionals and focused on supporting the priority aspects of the assessment process that require such centralized coordination. Such an office is needed to support members of the scientific community who serve as authors and reviewers, coordinate interactions with "internal" stakeholders (i.e., agencies and members of the scientific community who

participate in the process), plan and implement outreach activities related to sustaining and fostering partnerships with external stakeholders (e.g., users of assessment products, intermediary/boundary organizations), provide a focal point for coordination with international and other national assessments, and support preparation of specific products, resources, and reports. The coordination office must have convening capacity both inside and outside the federal government. The activities of the coordination office must be implemented so as to build upon and promote synergies with activities and programs of USGCRP agencies and partners. To be effective, the office requires support from and regular access to the federal agency representatives to the USGCRP, and would ideally be located within the USGCRP offices in Washington, D.C., as a fundamental part of the Program.

Different models for coordination were considered; some involved placing this responsibility within an agency and others maintained it within USGCRP's coordination office. While each broad approach has merit, on balance we concluded that establishing a central coordination activity embedded within the USGCRP office was preferable for a variety of reasons. Chief among these is that such an office is neutral with respect to the interests or mission of any single agency and thus creates a level playing field for the coordination process, encouraging active participation and contributions from all USGCRP agencies. Breadth of agency participation has been a strength of past assessments that needs to be encouraged. Having drawn these conclusions, we also recommend that the specific functions of the coordination office be examined closely and include consideration of where coordination capacity can also be leveraged from outside the USGCRP and federal government generally. We feel strongly that coordination capacity internal to the federal government is a core function and essential to success, but it is possible that some coordination activities might be contributed from organizations with external funding and interests.

It is especially important for the office to have the ability to initiate and coordinate appropriate partnerships among the groups wishing to collaborate on a sustained assessment because these relationships are central to achieving the NCA vision and will provide major benefits through leveraging efforts of partners. Staff members who have primary responsibility for partnerships and engagement would: communicate about the assessment, including its products; illustrate the assessment's value to participants and users (which requires evaluation, see Recommendation 2.7); recruit participants into a sustained assessment effort; create sufficiently frequent opportunities for meaningful engagement; ensure good internal communications across the agencies, multiple partners, and workgroups; and offer transparent opportunities for input, direction, review, and feedback on the assessment. Many similar activities have already been conducted by staff during development of the Third NCA.

The budget for the USGCRP coordination office should have a distinct component specifically targeted to support NCA activities and from which the office has authority to make spending decisions such as on staffing, travel, events, and products. Longer-term core staff should be supplemented with individuals detailed from federal agencies, universities, state agencies, and nonprofits. Decisions about the staffing and activities of the coordination office should preserve flexibility and be consistent with the objectives of the USGCRP Strategic Plan, thus helping the program achieve its long-term vision. Existing USGCRP activities and commitments can be leveraged, and effectiveness—not just cost minimization—should be an important criterion in setting staffing levels. It will

be important to create incentives that reward service in the coordination office by providing positive career development opportunities for staff and detailees.

Within the office, an Executive Director is needed who focuses all or most of his/her time on the sustained assessment and takes responsibility for establishing and maintaining the assessment's core functions. The Executive Director should have the ability and opportunity to contribute to the intellectual directions and accomplishments of the assessment, to represent it in a variety of scientific and programmatic forums, and to take a leadership role inside and outside the federal government.

Critical Element 1: Establish mechanisms to support enduring collaborative partnerships that sustain assessment activities

The objectives of informing adaptation and mitigation decision-making and facilitating risk management inherently involve both the research community and the decision-makers in society who are confronting and managing the risks. Several National Research Council reports (e.g., NRC 2009a, NRC 2010c) highlight the importance of developing an "end-to-end" research and assessment activity that links science with decision-making and coordinates the USGCRP with relevant governmental and non-governmental organizations.[7] This theme was carried forward into the 2012 Strategic Plan for USGCRP. A sustained assessment process is already seen as an essential element in linking knowledge to action by those who are implementing adaptation and mitigation activities, and thus is considered an important component of USGCRP progress toward its objectives. As part of the process for producing the Third NCA quadrennial synthesis report, a number of relationships and partnerships that provide a foundation for further progress were established.

This section of the report provides recommendations on establishing ongoing partnerships across federal, state, local, and tribal government jurisdictions and with diverse organizations external to the government (including the private sector) that are well placed to link science and action. Among the essential mechanisms are: (1) partnerships with academic, public, and private institutions that can become part of open and flexible knowledge systems; (2) a strategy for engagement and communication; (3) a network of partners at federal, regional, state, tribal, and local levels who provide outreach, engagement and communication capacity; (4) coordination with other national and international assessments; and (5) an advisory committee, which includes non-federal experts from sustained assessment partner organizations and the broader community, that can change in size and composition over time, focused specifically on a sustained assessment.

[7] Non-governmental organizations Include civil society (advocacy nonprofits, community-based organizations, professional associations, religious groups, private foundations, and private citizens that give voice to various sectors of society and enrich public participation) and the private sector (companies run for profit and thus are not state-owned, and trade groups that seek to influence the operation of the economy).

Recommendation 1.1: Expand partnerships to build assessment capacity.

Meeting society's needs for science that is useful for informing actions requires partnerships among the research and mission agencies of the federal government, other governmental jurisdictions, universities, the broader research community, and other organizations outside the government (including the private sector). Expanding these partnerships will have multiple benefits, including encouraging non-governmental institutions to assume an increasing share of assessment activity. (See Figure 2 below and Recommendation 4.1 for more detailed illustration of expanded assessment activities through partnerships.)

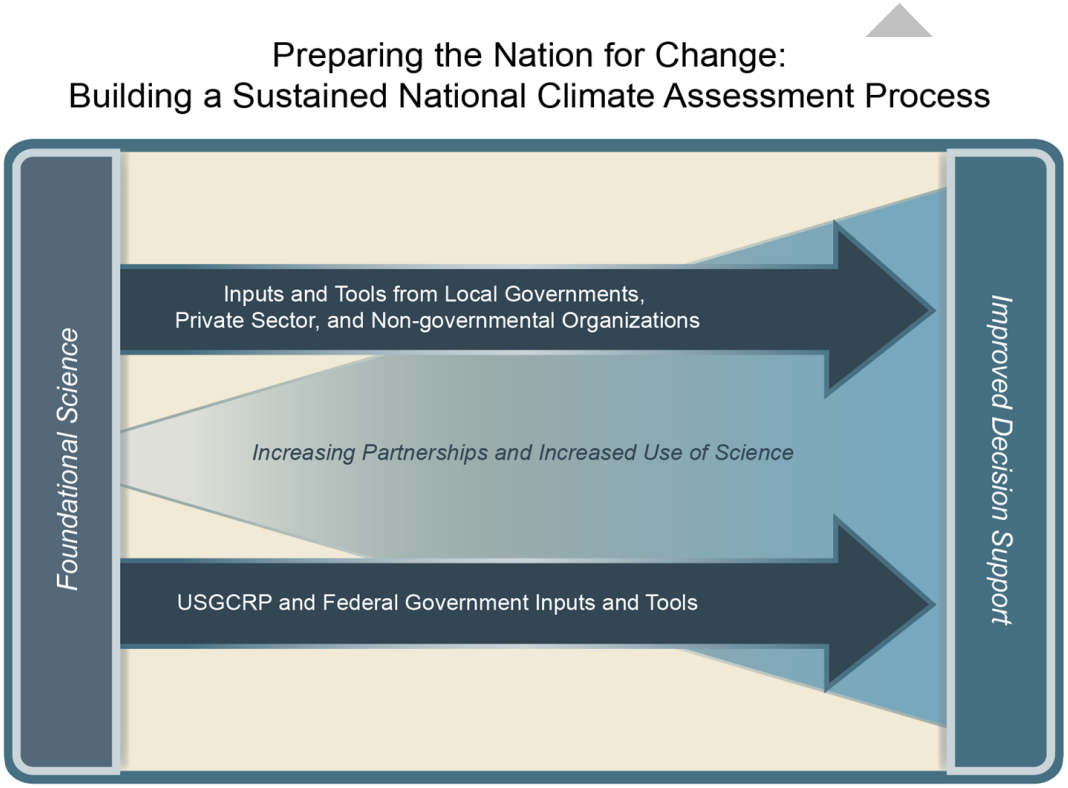


Figure 2. By increasing partnerships and the co-production of knowledge among governmental and non-governmental institutions and the private sector, the sustained national climate assessment process will expand the nation's capacity to understand, assess, predict, and respond to global change.

Because of the well-documented challenges of communication between science and stakeholder communities, it is particularly important for the USGCRP to facilitate development of relationships with organizations that can serve as intermediaries between producers and users of information. Investments of this kind are already in place within some agencies, private companies, NGOs and other organizations, and exist independently of the NCA. These intermediaries can serve three important roles: translating science for decision-making at scales at which actions are being taken, identifying information needs that require new research, and working collaboratively in a "co-production" mode. Related to the NCA, these organizations are building relationships with stakeholders by facilitating access to assessment information and products, sharing

results or expertise, encouraging evaluation and dissemination of "lessons learned," and other activities, thus building on-the-ground knowledge of climate impacts and opportunities. It will be important for the USGCRP to continue pursuing ways to initiate and maintain the diverse types of partnerships that encourage these trends and assist the USGCRP in catalyzing the sustained, participatory assessment process it seeks to create.

Many groups could certainly partner as contributors of technical information in a sustained assessment, provide case studies of how climate data is obtained, used, or included in decision support and adaptation planning, and contribute to special reports, online resources, and chapters in subsequent quadrennial synthesis reports. Identifying and establishing ongoing collaborations with the desired stakeholders of sustained assessment products will help ensure that the most usable products and services are developed, and should help accelerate the rate of adoption and implementation of assessment-based decision-making by individuals and organizations within the targeted sectors and regions. This requires an understanding of complex organizations and the functional roles played by different individuals in such organizations, especially with respect to diffusion of information (Dearing et al. 2006).

There are multiple additional benefits for partners who engage with a sustained assessment activity. These include but are not limited to: the opportunity to help shape national plans and strategies for providing actionable science relevant to non-federal needs; credibility with peers who see that the partners have clearer understanding of assessment products and the mechanisms used to produce them; potentially more widespread use of partners' data (that meet assessment criteria and are used as input to the assessment process);[8] and improved connectedness to other partners, allowing further collaboration and mutual benefit. Expectations and activities of partners and participants should be clearly defined and moderated by assessment leaders and staff so that there is no actual or apparent conflict of interest.

Private sector collaborations have significant potential to increase the quality of information available, both by providing additional, high quality inputs to the assessment and by increasing the relevance of assessment outputs to private sector needs. As the private sector's information needs are met by participation in a sustained assessment, it will be better equipped to help play its pivotal role in strengthening the nation's economy and improving overall societal well-being in the face of climate variability and change.

Historically, most of the experts participating in assessments such as those of the IPCC and the USGCRP have come from academia or governments. Technical experts from the private sector represent an underutilized source of information regarding both adaptation and mitigation measures. There are concerns to be addressed in involving these experts, however. From the private sector perspective, there is usually commercial value in proprietary information relevant to the assessment, and thus principles of engagement need to carefully establish protocols for managing data and legal rights to this information. It is equally important that potential conflicts of interest that could arise from interaction of regulated and regulatory bodies be avoided (though this concern is

[8] This does not suggest that the assessment process would somehow endorse data from partners, but if data or information are submitted for consideration, meet the stringent assessment criteria for quality, and are used in assessment products, they could then be included in the online information system, thereby both increasing their use and ensuring transparency of data sources.

not only limited to private sector participants). An additional challenge is that private sector participants, who may not be able to charge for the time they contribute to the assessment process, are discouraged from participating since this diminishes their income. For other public, academic and non-governmental participants, contributions of time and effort are often at least partially supported as part of their salaried roles.

One successful model for involving the private sector in the assessment process has been the Technology and Economic Assessment Panels (TEAPs) established under the Montreal Protocol. These panels provided technical information related to alternative technologies that have virtually eliminated use of substances that harm the ozone layer. With increased private sector participation, improved information on adaptation and mitigation options could be available to practitioners at multiple scales.

In addition to the collaborations with non-governmental institutions, collaborations should be established or enhanced with other government entities of varying scale, for example:

Native Peoples are an important source of potential partnerships. As noted in the draft Third NCA Report, climate change impacts on the 566 federally recognized tribes and other indigenous groups in the United States, including state-recognized and non-federally recognized tribes, are already severe. Native populations are particularly vulnerable because of their close relationship with and dependence on the environment for their physical, mental, intellectual, social, and cultural well-being. Many Native leaders are very interested in collaborations that will facilitate improved access to scientific information and assistance in managing risks. Tribal contributions to the knowledge base are also essential; Native populations manage significant land and resources and input of indigenous environmental knowledge, science, and adaptation expertise to central sources of information is critical. Because of these particularly urgent needs and opportunities, developing and enhancing existing partnerships with tribal groups is especially important.

States are expanding their engagement in both adaptation and mitigation activities. As indicated in the adaptation and mitigation chapters of the draft Third NCA Report, some states are significantly more engaged than others, with the state of California leading in many categories. Although past NCA efforts have not explicitly worked with state governments, many state agencies have contributed to regional assessments. States are an untapped resource that could significantly increase capacity and provide significant data sources. In addition, there are opportunities for significant improvements in communication and coordination at multiple scales if state, regional, local, and tribal organizations are more effectively included in NCA conversations.

Local Governments (including cities) are often characterized as being on the front lines of climate change, given that they are responsible for providing or overseeing the provision of essential services that can be affected by climate change. Over the past several years many cities have become increasingly sophisticated in obtaining and using climate information to assess how climate change may affect their city or individual sectors within it, and to inform decision-making and adaptation planning. Their first-order familiarity with the potential direct effects of climate change on the delivery of essential services, combined with the tacit, applied knowledge that city employees often have of the systems they manage, makes city government a potentially valuable collaborator in a sustained assessment.

Subrecommendations:

- ***1.1.A.*** *The NCA should ensure adequate support for tribal engagement in future assessments, and include tribal engagement as a metric of success for ongoing efforts.*

  Tribal communities across the United States are particularly vulnerable to impacts of climate change. Tribal organizations, such as the Institute for Tribal Environmental Professionals (ITEP) have indicated a strong willingness to participate in a sustained climate assessment. Their participation is critical to the success of a sustained assessment, by providing science support and data collection, including indigenous knowledge, on tribal lands.

  However, the ability of tribes to participate in ongoing and emerging assessment related activities is seriously hampered by a lack of resources. The USGCRP agencies, as appropriate, should make funding available to tribal environmental organizations for production of technical inputs and coordination of these inputs as part of a sustained assessment. Further, specific metrics related to engagement by tribes in future assessment activities should be developed and employed.

  1.1.B. *Maintain and regularly update a guiding strategy and responsive operating plan for engagement.*

  *T*o successfully meet the needs of scientists and decision-makers, the NCA should continue to maintain an engagement strategy and operating plan that is updated periodically (see NCA 2011b for the current plan). Engagement and communication should be responsive to emerging opportunities—which may well be sudden or unexpected—and occur or be shared through a variety of information products and ongoing updates. These communication media include preparation and delivery of assessment products via the Internet and social media, creation of active engagement opportunities, continual updating of the "infrastructure" for ongoing engagement, and periodic evaluation of engagement activities. Engagement should widen a pathway to the types of partnerships identified above. For full implementation of the strategy and delivering on this promise and the "Communicate and Educate" component of the USGCRP Strategic Plan, more dedicated resources are likely to be needed along with continued assistance from NCAnet partners (see Recommendation 1.2 below).

  The ultimate goal is to establish an efficient, transparent, and open assessment process that leads to the creation of credible, useful, legitimate, and timely products that will promote sound decision-making in the face of climate change.

Recommendation 1.2: Encourage and support communication and engagement networks.

A sustained assessment process can build on the important accomplishments in communication and engagement that underpin the Third NCA effort, including the Engagement and Communication (E&C) Working Group within the NCADAC, the NCA central coordination office staff, and the NCA Network (NCAnet). The continued building of networks should accommodate voluntary processes as well as structured, intentional efforts to promote broad, actively inclusive engagement.

NCAnet (http://ncanet.usgcrp.gov/), which now has more than 80 partner organizations, has been highly successful from a number of vantage points. This network of partner organizations from the private sector, local government, academia, and non-government organizations—many of which have thousands of members—has been important in leveraging the communication, partnering, and engagement capacities of the NCADAC and NCA coordination staff. NCAnet provides access to and updates about the NCA to partner organizations, allows them to create and sustain relationships with others, shares scientific information and best practices, and provides capacity to give feedback to NCA coordination staff. NCAnet provided significant communications and engagement capacity in announcing the review process for the Third NCA Report.

NCAnet serves as a foundation for many kinds of future partnerships, including partnerships with science teams across the country such as the National Ecological Observing Network (NEON), the Long-Term Ecological Research (LTER) network, professional organizations such as the American Society of Civil Engineers, and NGOs focused on climate issues, who are important intermediaries in climate research and communication. NCAnet may even be able to foster targeted research within the partner organizations as gaps are identified as part of the assessment process. NCAnet is still in an experimental phase, but we recommend supporting and expanding this approach to engagement, with careful evaluation of effectiveness of relationships, satisfaction, and expectations among the participants. NCAnet could also be useful in fostering other types of partnerships among organizations and USGCRP agencies, such as those organized around the development of derivative products. The use of "affinity groups" within NCAnet to self-organize around particular activities of interest is a positive development, since it has the potential to address more specific needs and reduces the impacts on the central coordination staff.

Recommendation 1.3: Build international engagement.

While some initial connections have been made in the Third NCA Report with several non-U.S. assessment efforts, there is a need to more deliberately and strategically engage with and contribute to international assessments, such as the IPCC and other international and non-U.S. assessments. Doing so will serve multiple purposes, including increasing the accuracy and credibility of U.S. assessments, increasing the utility of international assessments that have a U.S. component, supporting international development and resilience goals, and learning from assessment efforts in other nations or internationally. By giving particular attention to assessment efforts in Canada and Mexico, and in partnership with our neighboring nations, the United States would be better positioned to address critically important climate challenges that are unique to our border regions, such as impacts on trade or shared river and lake systems.

Building mechanisms that facilitate learning from other assessment processes and that support international engagement in all aspects of the NCA (regional, sectoral, methodological, etc.) will yield multiple benefits. Strong international engagement has the potential to be a win-win for the NCA. One advantage comes from the opportunity to see and understand risks related to social teleconnections as they emerge. The NCA can be informed, strengthened, and improved through interactions with other assessment organizations and groups, including the IPCC and national climate assessments in many other countries. A second advantage afforded by active international engagement is its contribution to capacity building.

Subrecommendation:

- ***1.3.A.*** *International engagement in assessment processes should have clear goals, an emphasis on collaborating at the appropriate scale, and a commitment to adaptive learning.*

  Many countries are now involved in managing or establishing national assessment programs. These programs, along with the assessment architectures maintained by the IPCC and by NGOs, can provide fertile ground for international engagement and learning about best practices. Initiating and expanding sustained interactions with key non-U.S. assessment efforts can increase the value of future U.S. national assessments.

  The sustained assessment process should also consider ongoing international reporting requirements, such as those under the United Nations Framework Convention on Climate Change (UNFCCC). The Department of State, the lead negotiator for the United States, relies on USGCRP to provide comprehensive assessments of climate change impacts on the United States. Reporting under the UNFCCC typically follows a three-year cycle. The next report, the 6th Climate Action Report under the Convention, will be substantially informed by the draft Third NCA Report and is due to be published in January 2014. While a full, comprehensive assessment is not needed every three years, showing that national assessment activities are regular and ongoing is important in demonstrating that the United States is meeting its commitments under the Convention.

Recommendation 1.4: Launch and support a sustained assessment advisory committee.

We recommend that an advisory committee that is appropriately sized and established with legal status under federal law be created and maintained to provide ongoing advice on forming and sustaining the NCA process. This committee would replace the existing NCADAC as its term expires in 2014. This recommendation is based on the premise that an advisory committee, more than just meeting a legal requirement, could in itself be a fundamental component of engagement and partnership by providing a substantial and recognized role for partners to participate in the guidance of the sustained assessment, promoting transparency throughout, and encouraging diverse outreach and engagement. We note a parallel recommendation in the *America's Climate Choices* Science Panel report for establishment of an advisory committee for the USGCRP (NRC 2010a):

> "An external advisory board would help to ensure that priorities for research are informed by and responsive to the needs of decision makers and other information users, and it could assess and improve the program's decision-support capabilities. If established, such a board should be composed of decision makers and stakeholders from a broad range of communities (e.g., leaders in state, local, and tribal governments; relevant businesses and industries; citizen groups; and other non-governmental organizations), including communities that are currently not strongly linked with the program, as well as members from across the scientific research community."

One purpose of the recommended advisory committee for a sustained assessment is to facilitate interactions with assessment users, but it could also contribute significantly to

the user-engagement function for the USGCRP envisioned in the Science Panel's report, since the assessment is one of USGCRP's primary engagement tools.

Two obvious roles for a sustained assessment advisory committee are to provide: (1) recommendations on enhancing interactions/communication with the user community; and (2) a sounding board for proposals for research and other activities that support a sustained assessment process. These aspects of the committee's work will inform ongoing investments in building the indicator and information management systems, making improvements in scenarios and how they are used, and in building partnerships and engaging stakeholders, for example. A third possible role is to have working groups of the advisory committee take responsibility for identifying and/or preparing specific products, online resources, special reports, or technical inputs to future quadrennial assessments, so long as that activity is clearly allowed within the charter of the full committee. A standing advisory committee that holds public meetings will simplify requirements for transparency and due process. A smaller advisory committee will be more manageable and less expensive than a large one. The advisory committee should be designed with the flexibility to grow and contract as needed, for example, to support interim products or quadrennial reports, to ensure the success of a sustained assessment.

We recommend that this new sustained assessment advisory committee include a combination of existing NCADAC members and new candidates, including scientists and other participants who have not traditionally engaged in the assessment community but who have a strong interest in its success. Continuity with the current process is important, although new ideas and approaches should of course be encouraged. In order to ensure that institutional capacity is not lost over time, it would be advisable to have staggered appointments for the advisory committee, e.g., three-year terms with one-third of the members up for renewal each year. There is probably not a need for as many regional and sectoral experts as within the current NCADAC; expertise can be added as needed to working groups or author teams for assessment and special reports and products. Leadership is critical and the leaders must have sufficient time for the task, be strong communicators, have good convening skills, and be consistently available.

It is crucial that representatives of the USGCRP agencies be included in the advisory process as ex officio members. The current model of including ex officio members on the NCADAC is an improvement over the more limited role they had in the first and second NCA; applying a similar approach within the new advisory committee will be important to the success of efforts to establish a sustained assessment.

As a new advisory committee is named and the sustained assessment process continues to evolve and mature, it will be important to maintain an appropriate degree of continuity with the current NCADAC structure. Although the current NCADAC is planned to sunset in June 2014, many ongoing sustained assessment activities started by the NCADAC should continue after that date. It is beyond the scope of this current report to delve into the details of specific working groups and the degree to which each of them may have an ongoing role to play within a sustained assessment. However, we do recommend that the new advisory process described in this report be used in order to prioritize any working groups and their individual activities.

Critical Element 2:
Enhance and organize the scientific foundations for managing the risks and opportunities of climate change

Improving risk management and developing a sustained assessment will require continued progress in understanding the evolution of the relationships of human and natural systems. This progress in turn depends on ongoing investments in USGCRP research on the physical, chemical, and biological components of the Earth system, including atmosphere, ocean, and land-surface components. But as noted in the USGCRP Strategic Plan (NSTC 2012) and in the *America's Climate Choices* (ACC) reports from the National Research Council (NRC 2010a, 2010b, 2010c, 2010d), effective decision support will also depend on continued progress in areas that traditionally have been less central to the USGCRP: research focused on human systems. The ACC reports reviewed the state of science and detailed research challenges in sectors and systems, considering challenges in fundamental understanding, adapting to, and limiting climate change, and needed information for the public and decision-makers. Continued progress in fundamental physical, social, and decision science is essential.

Decision-makers face a multitude of challenges every day, and changes in the climate represent only some of them. There are evolving perspectives in decision-making in the context of uncertainty, moving from a historic focus on crisis management to a "predict, then act" approach, and more recently to forms of "robust"[9] decision-making and the use of multiple scenarios to frame a range of possible futures (Weaver et al. 2013). A sustained assessment will complement and support an iterative approach to addressing and reducing risk across the Nation, increasing the capacity for translating continued advances in scientific understanding of the climate system to decision support and adaptive management.

With the growing emphasis on risk-management approaches to address climate and global change comes the need to improve the foundation for these efforts. Improved data collection and coordination will bring together new and existing information across sectors and scales—including social, economic, ecological, household, and community characteristics—that will facilitate this more robust analysis of risk and vulnerability. For example, substantial limitations in the process of reporting impacts of drought currently make it difficult to accurately characterize drought risk and the potential magnitude of associated losses, as well as patterns of vulnerability (Meadow et al. 2013; Hayes et al. 2011). A sound scientific foundation requires new tools and approaches to evaluate vulnerabilities of natural resources and other communities dependent on climate-sensitive enterprises, ecosystem services, etc. Economic relationships play a major role in connecting communities around the globe, creating the potential for cascading impacts across great distances; the economics of impacts and adaptation is now one of the most critical research gaps.

New research approaches can identify pathways of risks and associated vulnerabilities created by these connections as well as capture and incorporate the cross-scale nature of vulnerability. For example, risk and vulnerability assessments that are strictly sector-

[9] In this context, *robustness* refers to a scientific finding or method that can stand up to a wide range of critique. In the context of climate adaptation planning, a robust strategy will be successful across a wide range of possible future conditions.

based cannot capture significant interactions across sectors, such as the energy/water nexus or food/fuel linkages. An increased emphasis on cross-sectoral and multi-scale analyses can more adequately inform risk and vulnerability assessments.

The evolution of effective decision-making pathways and processes can also be furthered through sustained assessment by addressing issues such as the tradeoffs between mitigation and adaptation options and evaluating alternative risk-management and adaptation strategies. Deliberations over risk management often engage a wide range of decision criteria, from the probability and magnitude of impacts, to an array of social, economic, cultural, health, and ecological impacts, to questions of procedural and distributional equity. Guidance in the design of such decision-making processes as well as tools and methods capable of incorporating a diverse range of evaluation criteria are important elements of a knowledge base that informs our response to climate change.

This report does not repeat the priorities identified in the USGCRP Strategic Plan or the ACC documents in spite of their importance to the establishment of a sustained assessment. Here the focus is instead on foundational topics that an assessment effort will need to incorporate in order to better meet the GCRA and emerging national needs. In addition, we identify needed research advances in the science and practice of assessment. Many of the needed foundational topics and research advances are underway at some level among USGCRP agencies and elsewhere, but will greatly benefit from further coordinated development. They include: (1) methods for vulnerability/risk assessment; (2) indicators of climate changes, impacts, vulnerabilities, opportunities, resilience, and preparedness; (3) scenario methods and products for framing uncertainties and developing robust responses; (4) valuation methods for measuring the consequences of change and the benefits of adaptation/mitigation responses; (5) methods to incorporate international influences on the United States; (6) methods for assessing confidence and uncertainty in scientific information for decision-making; (7) adaptive learning within assessment processes; and (8) identification of risk-management information needs.

Recommendation 2.1: Build capacity for vulnerability assessment.

Vulnerability—the propensity to be harmed by changes in climate—is not evenly distributed across space and time. Understanding who is vulnerable, where vulnerable populations and systems are located, and what measures could reduce vulnerability is a pivotal research issue and essential input for risk management approaches to climate adaptation. It is also essential information for decision-makers confronted with the need to protect populations, sectors, resources, assets, or livelihoods that are particularly vulnerable to climate change given limited resources. Vulnerability assessments are a fundamental step in many adaptation decisions.

The conceptual elements needed to assess vulnerability—exposure, sensitivity, and adaptive capacity—are well established. Methods and data remain relatively uneven across sectors, populations, and geographical regions (USGCRP 2011). Basic data related to exposure (coastal elevation, for example) are generally the best developed, but remain incomplete and fragmented for many systems. Understanding the sensitivity and adaptive capacity of systems requires significant attention to both individual cases and to more generalizable indicators. While all populations are to some degree vulnerable to impacts of climate change, many of the most urgent issues of vulnerability

are related to small and isolated populations that are often poorly represented in data and indicators, and efforts are needed to improve capacity and methods for these settings. Studies of the potential impacts of different scenarios or levels of climate change have progressed, but the sensitivity of some economic activities or infrastructure systems to different types of climate extremes—from sustained heat waves to intense precipitation—is also poorly understood.

Beyond basic work on indicators development and monitoring activities that gauge sensitivity and adaptive capacity of individual systems, a particular research need is the interactions of impacts across systems or populations—the potential connections among land management, water resources, energy systems, urban development, or economic decisions that can lead to unexpected and potentially tragic consequences, as illustrated by events such as Hurricanes Katrina or Sandy. How well prepared are different communities or population groups within communities to respond to extreme events or resulting dislocation and which adaptation measures are likely to increase resilience? Existing vulnerability assessment methods and measures must be evaluated for their effectiveness in capturing impacts of concern and to determine the sensitivity of their indices to the spatial and temporal scale of analysis. Methodological and data gaps identified in the ongoing Third NCA quadrennial synthesis report should be mined for research needs and priorities. Updated methods should be included in templates that are made available through a sustained assessment process for those initiating and conducting vulnerability assessments, thus facilitating synthesis in future quadrennial and special reports (see Figure 3 below).

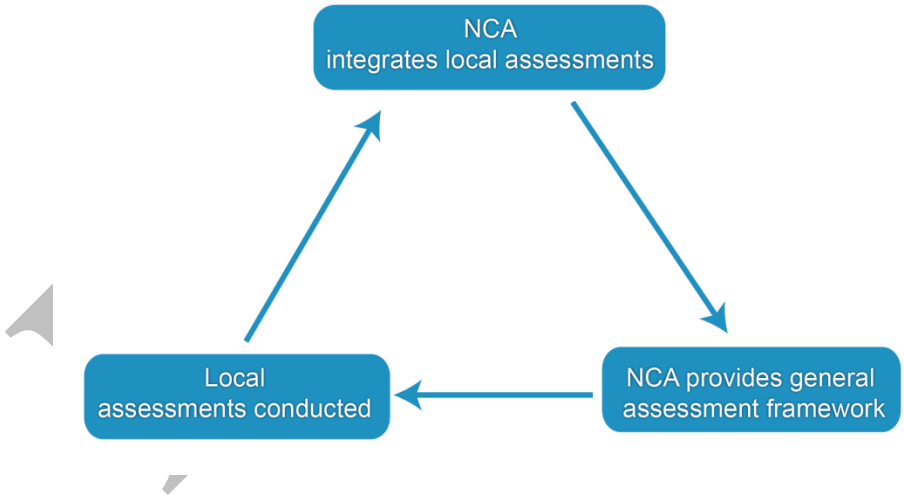


Figure 3. Assessments must be tailored to the specific needs and management challenges that are being addressed and to the availability of resources to conduct them. Independent assessments conducted at local, state, regional, tribal, or national scales using vulnerability assessment methods made available through a sustained assessment will provide a foundation for NCA quadrennial and special reports, ongoing products, and online resources (from USGCRP 2011).

Recommendation 2.2: Develop indicators of climate changes, impacts, vulnerabilities, resilience, opportunities, and preparedness.

This recommendation builds on the USGCRP Strategic Plan and a long history of efforts to more rigorously document changes in social, physical, and ecological systems over time (see, e.g., NRC 2009b; Michalak et al. 2011; Janetos et al. 2012). Such documentation is particularly needed for monitoring impacts, since climate is only one of many stressors, and for evaluating progress in mitigation and adaptation. Development of an initial national indicator system is beginning to prototype the existing conceptual framework (http://www.globalchange.gov/what-we-do/assessment/indicators-system), identify candidate indicators for inclusion in the initial system, and describe physical, natural, and social science research priorities to improve the science basis for the indicator system. Through the NCADAC Indicators Working Group, this work includes the voluntary participation of over 150 scientists and practitioners and builds on (and incorporates) much distributed and rigorous effort across the federal agencies, regional science efforts and management authorities.

An indicators program that supports a sustained assessment process will have numerous benefits for all of USGCRP, and can integrate existing government and external data, observations, and indicator products to more coherently assess climate changes, impacts, vulnerabilities, opportunities, and preparedness. Bringing together such diverse resources through an indicator system will allow better evaluation of changes from established baselines over time, intercomparison of changes between different regions and environments, improved scientific understanding of thresholds and tipping points, and expanded access to easily-interpretable, decision-relevant information.

The indicators effort can provide a range of products that support sustained assessments and all four of the USGCRP strategic goals. Specifically, the USGCRP has the potential to establish a system that includes socioeconomic, biological, and physical indicators that are nationally important[10] and that:

- include climate drivers, impacts, and responses focusing on: (1) changes in the climate system; (2) related impacts in a multi-stress context; and (3) mitigation and adaptation responses and preparedness;
- leverage and build on the decades of investments in data, observing systems, and indicator products developed by the federal agencies, while also identifying near-term and long-term research priorities to better meet the national needs from such an indicator system;
- facilitate access to up-to-date information (keeping information current between quadrennial reports, for example, and supporting decision-making on an ongoing basis), while ensuring methods for extending trends and updating the indicators meet the high standards implicit in assessment endeavors; and
- permit multiple modes of electronic access, including through the integrated information systems (e.g. the Global Change Information System [GCIS]). This is essential in order to clearly document indicator development processes and

[10] We recommend that in order to keep a national indicator system manageable and useful, that it not try to be comprehensive at all scales, but focus on indicators of national value and importance. These may be regional in scale (such as the extent of sea ice), yet have national implications. This is consistent with recommendations in a technical input report to the NCA from an indicators technical team (Janetos et al. 2012b).

provide data, and to encourage adoption and use of the indicators, products, and reports by user communities (government, private sector, and others) that comprise both general and technical audiences (see also Recommendation 3.4 for more about data access and the GCIS).

The utility of the indicator system should be evaluated on an ongoing basis for scientific, policy, decision support, and educational/communication purposes, including helping USGCRP to update research priorities.

There are different models that can be considered to provide support for the indicator system over time. They include housing this effort within the USGCRP coordination office, having a single agency host the effort (but continue to recognize the interagency nature and coordination required of it), or hosting it in an outside organization (similar to the Heinz Center effort to gauge the state of the nation's ecosystems through a suite of indicators [e.g., Heinz Center 2008]). USGCRP should consider these options and establish a path forward for the indicator effort (preferably at least a five-year plan) that ensures an effective outcome. Given the early stage of this effort and the advantages and disadvantages of each of these options (or a hybrid approach), no specific recommendation is included here on where to host this effort. More analysis through the USGCRP is required.

Recommendation 2.3: Establish scenario methods and products for framing uncertainties and developing robust responses.

Scenarios—quantitative and narrative depictions of plausible futures, including trends in socioeconomic, technological, emissions, climate, land and ocean use, and other conditions—play an important role in global change research and assessment. Scenarios support research and modeling, for example by providing coordinated inputs and outputs for a full range of global change models. They inform long-term planning and operations of government, the private sector, and non-government organizations by providing consistent bounding conditions under different assumptions. And they are used in assessments—including those of the IPCC and the NCA—to coordinate reports and chapters by providing a common set of assumptions for analysis within specific chapters as well as cross-chapter synthesis.

The scenario strategy adopted for the Third NCA Report by NCADAC resulted in several innovations, including a set of regional climate outlooks for the United States under a low- and a high-emissions scenario (NCADAC 2013), a set of global sea-level-rise scenarios and guidelines for regionalization, and an online distributed archive of scenario products adopted for preparation of the 2013 report (NOAA 2012, 2013). These scenarios are being widely and directly used across a broad community, but anecdotal evidence (via interviews with participants in the Third NCA Report development process) indicates the scenarios would have been more useful to assessment participants if they had been available earlier in the process. Therefore, planning and development of scenarios for the next NCA quadrennial synthesis report should begin as soon as the previous report is completed. Other evidence suggests that governmental and non-governmental decision-makers have not yet been able to make optimal use of participatory scenarios (Bizikova et al. 2009) to inform their long-term planning and investment decisions, due in part to the relative novelty and complexity of the methods (Salter et al. 2010).

Several specific steps could improve preparation and use of scenarios in a sustained assessment process, including:

- Evaluation of the Third NCA Report scenario strategy and products so as to improve them before the next quadrennial synthesis report is developed. The evaluation will be conducted by working groups of the new advisory committee and, to the extent reasonable, interested partners.
- Engage the scientific community and stakeholders in identifying research needs and opportunities related to the scenario process and the inputs it provides to the next round of modeling efforts, in particular the Coupled Model Intercomparison Project (CMIP-6), integrated assessment modeling, and modeling and research on vulnerability, impacts, and adaptation.
- Even before the Third NCA Report is complete, establish a scenario working group (within the USGCRP or coordinated with related USGCRP activities) that can recommend a scenario strategy for the next NCA cycle and help to evaluate the existing Third NCA scenario strategy.
- Determine the need for internal consistency across scenarios for different regions or for those that are nested in larger-scale (e.g., global) scenarios, in terms of bounding uncertainty and framing risk. Improvements are needed in the areas of developing technical guidelines, disseminating scenarios and guidelines more widely and in a more timely manner, and encouraging further development and use of scenario planning techniques.
- Develop socioeconomic scenarios and scenarios for land, river, lake, estuary, and coastal ocean use. These can serve as the basis for regional and sectoral assessments for the Fourth NCA quadrennial synthesis report.

Having a mechanism to ensure coordination across federal agencies that support scenario research and development or that use scenarios in planning and management will improve the effectiveness of scenario use in a sustained assessment process.

Recommendation 2.4: Develop valuation methods for measuring the consequences of change and the benefits of adaptation/mitigation responses.

"Valuation" is the process of assigning worth. It is often expressed in monetary terms but also through other measures such as mortality, loss of natural habitats or biodiversity, dislocation, and even intangibles such as intrinsic enjoyment. Just as "value" is defined and measured differently by different groups or individuals, there is no single method for the process of valuation.

None of the first three national climate assessments was able to include consistent economic or other approaches to valuation of potential impacts for sectors, regions, or the nation as a whole, even though for the Third NCA Report, a preparatory workshop on valuation methods noted "an urgent need to include economic valuation in the NCA" (NCA 2011a). Such information could inform public and private sector decision-making, for example in valuing potential damages of climate impacts or benefits of both adaptation and mitigation. Understanding the costs of both inaction and action is likely to inform adaptation, at least within specific regions and sectors that are particularly vulnerable. It would also help drive broader and deeper engagement of the American public in a sustained assessment process. Underscoring the importance of this is the

recent Government Accountability Office conclusion that climate change is a source of financial risk to government operations (USGAO 2013).

How can valuation of impacts be brought into the NCA when there is no agreement on preferred methodologies and when such estimates would be sure to spark controversy? While the discipline of economics includes a substantial focus on valuation and a number of federal agencies have conducted valuation exercises using economic and other methods to support policy formulation on other environmental and societal issues, challenges exist in the process of valuation as it relates to climate change. These arise from several factors, such as the incorporating impacts of climate change over longer time periods; the intangibility of some impacts; alternative characterizations of anticipated effects by different groups affected by them; the potential for chain reactions of impacts across sectors and regions; the existence of low-probability, high-consequence catastrophic effects; the state of science, which contains many uncertainties; and the lack of systematically collected data about impacts and the costs associated with both adaptation and mitigation options.

Because of the difficulty of collapsing valuation into one metric (such as dollars), a range of economic and non-economic valuation techniques must ultimately be applied within the NCA process to different sectors or topics. The NCA will also need to encourage a focus on the *processes* of valuation, which must be transparent and reproducible.

***Subrecommendations*:** Several near-term actions by the USGCRP can set the stage for making valuation a component of the ongoing sustained assessment process:

- ***2.4.A.*** *Conduct an analysis of methods commonly used in valuation studies, including understanding the relative merits, quality, and biases of each in the context of assessments.*
  This is an essential precursor for initiating the valuation activities below, and could be carried out by a technical expert team, a subgroup of the sustained assessment advisory committee, an agency, a USGCRP working group, or a combination thereof.
- ***2.4.B.*** *Establish methodologies for collecting and aggregating economic information.*
  The current lack of comprehensive methods for collection of economic information makes it very difficult to document the costs associated with climate impacts, as well as the benefits associated with adaptation. Methodologies are needed for collecting relevant economic information in a central way or using rigorous processes. Methods must permit collection of consistent information across regions and sectors and for individual extreme events so that teams within regional and sectoral networks can start building a database for valuation studies.
- ***2.4.C.*** *Conduct several "case study" or prototype valuation exercises focused on topics that have arisen in preparation of the regional and sectoral chapters of the 2013 report.*
  These initial case studies would be prepared after completion of the 2013 report and can use the data and information from the approved report as inputs. These case studies could be undertaken by the agencies directly (including the White House Office of Management and Budget [OMB] that is also integrating approaches to valuation across the government) and coordinated through the

NCA office, commissioned from a private group, or conducted by an independent organization such as the National Research Council.

- ***2.4.D.*** *Evaluate these case studies, assessing the applicability of different methods in the context of sectors, regions, and the nation as a whole.*
  The case studies should also be evaluated to identify data or information that was missing from the 2013 report that would have been helpful in the valuation processes.
- ***2.4.E.*** *Using the results of the case studies and their evaluation, valuation should be incorporated into the next quadrennial synthesis report.*
  When inputs to the next quadrennial report are solicited, an explicit request for independent valuation studies of impacts, damages avoided from mitigation, and costs/benefits of adaptation should be encouraged and data collected to support such studies. Such independent valuation studies and associated research needs will provide inputs to the valuation process undertaken in the report.

Engaging the intended users of valuation studies is crucial throughout this process.

Recommendation 2.5: Build capacity to document and incorporate international influences.

U.S. assessments must consider the context of non-U.S. climate change drivers and adaptation and mitigation activities. There is an opportunity for more effective coordination with IPCC products and processes, more engagement with the integrated assessment modeling community, and more investment in understanding how to document and incorporate international influences on the United States into national, regional, and sectoral assessments and decision processes. An NCA special report on this topic has been scoped; this should be a high priority effort because of its potential to improve future assessments.

U.S. assessments can also be improved by building and expanding partnerships and sharing data with other nations, especially Canada and Mexico. Canada has sophisticated nationwide assessment activities as well as province-led efforts, and has indicated a strong interest in developing more explicit relationships with the U.S. assessment. Similarly, binational efforts involving stakeholders and governments in northeastern Mexico and the U.S. Southwest are beginning to address regional vulnerabilities and formulate strategies for both mitigating and adapting to the impacts of climate change in such areas as wildfire suppression, transboundary aquifer and estuary management, and greenhouse gas inventorying (Wilder et al. 2013). Given the economic and social linkages between these countries, more collaborative efforts to manage cross-border risk are critically needed.

Many of the greatest challenges in understanding and preparing for impacts of climate change involve drivers and responses in a domain that can be called “societal teleconnections” (Adger et al. 2008). Teleconnections in the physical climate system occur when a physical change at some location drives a change in a process at some distant location. The parallel in social systems is when an impact of climate change in one location transmits an effect through economic, social, security, or cultural signals to other locations. For example, abundant rain in south central Brazil might lead to a bumper crop of soybeans, driving down the price on the international market and

harming U.S. farmers. Perhaps less obvious are climate impacts in other countries, such as extensive flooding that affects supply chains for U.S. manufacturing or private U.S. investments overseas.

The interconnected nature of the global economy suggests the potential importance of societal teleconnections, as does the concentration of climate-change vulnerability in the poorest communities. Many of the possible societal teleconnections have yet to be identified; fewer still are understood in detail.

Meaningful assessments of societal teleconnections and their outcomes will significantly enhance the U.S. National Climate Assessment process. Without strong sections on such topics, future assessment products risk overlooking a wide range of potential impacts related to climate change and many of the mechanisms through which impacts are spread.

***Subrecommendations*:** We recommend two actions to ensure that future U.S. assessments are appropriately sensitive to societal teleconnections:

- ***2.5.A.*** *Feature assessments of the scientific understanding of societal teleconnections prominently in future U.S. national assessments.* These assessments can play a critical role in informing partnerships and stimulating observations, as well as improving the quality of regional and sectoral projections of impacts and vulnerabilities.
- ***2.5.B.*** *Consider including appropriate global observations and data systems, particularly noting the need for more economic data and social science analysis, in U.S. national climate assessments,* since societal teleconnections are likely to generate impacts over great distances. Strategies for deploying sensors or data collection systems, acquiring and accessing priority data, and working with relevant analytical facilities, research teams, and partners outside the United States are needed. Effectively establishing and maintaining these partnerships are key priorities for both acquiring relevant data and developing understanding. See also recommendation 1.3.

Recommendation 2.6: Improve methods for assessing confidence and uncertainty in scientific information for decision-making.

In synthesizing and evaluating scientific information to inform decisions or policy, assessments must evaluate the state of science available at a given point in time. Thus it is essential that in an assessment, readers or users be provided an evaluation of how confident authors are of available scientific information. Evaluation of uncertainties is required as part of the NCA under the GCRA.

Approaches to assessing confidence and describing uncertainty and its implications have been developed for prior NCA quadrennial synthesis reports and for other bodies such as the IPCC (e.g., Moss and Schneider 2000; Schimel and Manning 2003; Mastrandrea et al. 2010). Morgan et al. (2007) provided recommendations for assessing confidence and reporting uncertainty for the Climate Change Science Program (CCSP SAP 5.3). To support preparation of the Third NCA Report, Moss and Yohe (2011) recommended graphics for communicating confidence and provided guidelines for risk-based framing, standardized confidence terms, ranges for likelihoods, and a checklist of steps for authors, including preparation of traceable accounts to summarize and

evaluate the principal lines of evidence used. Of these recommendations, risk-based framing was applied less formally, and the traceable accounts are included in an appendix to each chapter of the Third NCA Report.

***Subrecommendations*:** The USGCRP could take a number of steps to improve the evaluation of uncertainty and confidence in a sustained assessment process and in future special and quadrennial synthesis reports and other products, including:

- ***2.6.A.*** *Invest in research in decision analysis to improve the technical guidelines on confidence and uncertainty assessment for authors.*
  Research is needed on two topics: (1) determining which processes are effective in helping multidisciplinary author teams to evaluate confidence and scientific uncertainty; and (2) discerning how users interpret and understand different approaches to communicating confidence and uncertainty. This research is needed as an input to drafting more effective guidelines. The findings could become a new topical report of the NCA.
- ***2.6.B.*** *Prepare and adopt technical guidelines for confidence and uncertainty assessment well before the next assessment cycle begins.*
  A good starting point would be to evaluate prior recommendations developed for the IPCC, NCA, and CCSP. Revised guidelines should be made available to those preparing technical inputs to the report, and training should be provided for authors of the next quadrennial synthesis report at the beginning of the assessment process. These guidelines should be used in each special report or work product of the NCA.
- ***2.6.C.*** *Routinely include decision analysis experts in the NCA process.*
  This will help the assessment process to move beyond "state of science" to provision of information useful in decision- and policy-making.

Recommendation 2.7: Foster adaptive learning through the establishment of an assessment evaluation strategy.

Climate adaptation is increasingly being considered from a risk management perspective (see, e.g., World Bank 2009). While this is a reasonable approach, it must be recognized that many of the tools and assumptions inherent in traditional risk management principles for climate sensitive sectors are no longer useful. For example, the assumption of "stationarity" in natural systems (that fluctuations in weather and other natural systems stay with a known range of variability) no longer holds true (Milly et al. 2008). As natural systems move beyond known ranges, society must expect and prepare for events outside historical experience (Karl et al. 2009). Furthermore, scientists' ability to project changes to many weather extremes in the medium term (5 to 25 years) remains limited, especially those related to precipitation. As a result, with the inevitability of continued uncertainty and change, decision-making and research priorities must be approached as part of an overall adaptive learning process.

Adaptive learning is a social, scientific, and institutional process that includes iterative assessment, monitoring, research, and response. The only way that adaptive learning works well is if there are effective feedbacks in both the biophysical and social systems. This is where indicators, valuation, and rigorous ongoing assessments have a great deal to contribute. If baseline conditions as well as changing conditions over time are

documented, it will be much easier to understand the relationship between actions and outcomes.

As noted in the ACC Science panel report (NRC 2010a), climate change responses will require a "learning by doing" approach, partly because past climate conditions and management practices cannot guide future decisions, and partly because as actions are taken to limit greenhouse gas emissions or adapt to impacts of climate change, the effectiveness of these actions will only be revealed through experience and over time. "Learning by doing" is *not* the same as "trial and error"; rather, it is a deliberate approach to incorporating knowledge over time. Science and assessment must support this approach by monitoring and evaluating the evolving climate system and the costs/benefits of responses. This will require flexibility in pursuing emerging research and assessment challenges, a hallmark of a sustained assessment process. Just as ongoing evaluation will benefit society, it will also benefit development of an assessment process that provides information needed in flexible, iterative risk management.

A clear strategy is needed to track and evaluate progress toward a sustained assessment. It is a challenge to develop and apply metrics to an activity as complex as the NCA. Progress toward objectives must in some sense be measurable, and because of complexity and the level of effort, priorities need to be carefully established. Metrics that focus on process, inputs, outputs, and outcomes could all play a role. An NRC report on potential metrics for the Climate Change Science Program (NRC 2005) investigated potential approaches for monitoring and providing feedback on the program's attainment of objectives. The recommendations of the report should be heeded in developing an evaluation strategy for the NCA.

The principal purpose of evaluation is to assist a sustained assessment process in functioning as a learning-oriented, adaptive, flexible, and responsive mechanism to meet the needs of the nation (Kusek and Rist 2004). Periodic evaluation based on ongoing tracking of efforts and their impacts will allow the NCA to reveal its successes, prompt improvements, and demonstrate the impact the NCA is having in sectors and regions throughout the country.

Subrecommendations:

- ***2.7.A.*** *Establish an evaluation subcommittee of the sustained assessment advisory committee and a process to ensure a sustained assessment meets national needs.*

  An ongoing body with responsibility for evaluation of progress toward creating a sustained assessment and a mechanism for implementation—for example, a subcommittee of the sustained assessment advisory committee—can provide this focus.

  To adequately value the contributions of the sustained assessment process will require a range of approaches and a transparent process for evaluation. The timing and content of periodic evaluations should be developed by the USGCRP in concert with public and private funders. Evaluation of a sustained assessment process and products should be conducted often enough to identify when something particularly helpful has been introduced or when a change of direction or adjustment is necessary.

Input from a wide variety of partners, participants, and stakeholders should be sought. Evaluation as a tool in establishing a learning-oriented, adaptive, flexible, and responsive institution should be established as a routine task rather than approached in a stop-and-go fashion, dependent on changing leadership or political support.

Routine evaluation will help ensure that a sustained assessment will be relevant and will garner ongoing support, also demonstrating it can meet current and emerging national needs. These are necessary attributes (NRC 2009a). A sustained assessment must develop and nurture multiple constituencies, not merely to show responsiveness to constituent demands or produce a periodic report. It must be more effective and efficient than the previous stop-and-go approach to assessments, provide additional tangible benefits, and ultimately help build the nation's capacity to meet diverse information needs and incorporate that information into decisions. Most importantly, it must demonstrate an ability to maintain scientific rigor and quality control while coordinating a diverse and more widely distributed array of supporting activities, including the use of diverse sources of information.

- ***2.7.B***. *Establish metrics for success***.**
  A key challenge is to identify and organize the many objectives of the NCA into a manageable number of metrics and evaluative processes. Particular consideration should be given to establishing specific metrics within the following topic or theme areas, which complement the critical elements of the present report, recognizing that it is unlikely that all will be able to be incorporated during evaluation of the next phase of the assessment process:
  - Advances in building the scientific foundations of the assessment (e.g., increased use of scenarios or scenario planning; establishment of indicators, which themselves will require an evaluation process)
  - Process improvements (e.g., more widespread and effective use of methods for assessing confidence)
  - Increase in effectiveness and scope of partnerships with non-government entities
  - Increased support for co-producing assessment products and information resources with priority constituencies (such as tribal or other groups identified as highly vulnerable to the risks of climate change)
  - Improvements in quality and effectiveness of internal and external communications
  - Establishment of governance mechanisms
  - Adequacy and diversification of resourcing given objectives
  - Relevance, credibility, legitimacy, and usability of key assessment products

- ***2.7.C.*** *Produce a report that provides a thorough evaluation of the preparation process of the Third Assessment Report and the other initialized components of a sustained assessment process.*
  The evaluation will guide improvements in near-term NCA outcomes in anticipation of the Fourth NCA Report.

Recommendation 2.8: Establish mechanisms to identify risk-management information needs for consideration in USGCRP research priorities.

A sustained NCA process provides a unique opportunity to ensure that research needs of decision-makers in regions and sectors as well as across federal government agencies can influence the USGCRP research priorities in a timely way. The research needs that are identified through assessment processes must be integrated into the annual and longer-term research priority-setting activities of the USGCRP. One mechanism for this is formal consideration of the NCA research agenda chapter and the specific research needs identified in individual chapters of the quadrennial synthesis reports. However, it would also be important to "harvest" research needs (perhaps annually) from research teams and partners who are engaged in ongoing regional or sectoral assessment activities and who are already providing this information to the assessment process through reports, meetings, and other forums.

Critical Element 3: Provide infrastructure to support a sustained assessment process

In addition to furthering broad-based partnerships essential to sustaining interactions with users and the ongoing development of the scientific foundations for assessment, critical steps in establishing the "infrastructure" for assessment must also be taken.

A number of NRC reports and the USGCRP ten-year Strategic Plan make recommendations on infrastructure needed for the overall USGCRP effort, including integrated observing systems, modeling programs, and mechanisms for coordinating across the individual agencies that comprise the USGCRP. We recognize that these investments are all critical for a sustained assessment in that they support the research that leads to needed scientific insights and data.

This section of the report focuses on additional critical elements of infrastructure specifically needed for sustained assessment: (1) leadership and coordination; (2) processes for supporting preparation of quadrennial and special reports; (3) data management and information needs (both as inputs to assessment and as a means of disseminating findings); and (4) regional institutions and networks that provide a means of sustaining interactions with decision-makers at regional to local scales.

Recommendation 3.1: Provide strong mechanisms to support interagency coordination.

The USGCRP Principals[11] and key agency program managers need to play essential leadership roles in a sustained assessment, both within their own agencies and in the broader interagency context. We recommend that existing mechanisms for interagency coordination be strengthened. Specific suggestions include scheduling progress reports during the Principals' regular meetings on implementation of the recommendations contained in this report and collecting input from other participants involved in the process.

[11] 'Principals' refers to the federal agency representatives to the USGCRP.

The benefits of coordination to support the NCA can extend beyond the NCA itself and support other interagency efforts within USGCRP. The agencies have been important contributors to the assessment process, not only through their provision of resources, but also through preparation of technical input products to the quadrennial synthesis report and as stand-alone products useful in their own right. Hopefully this role continues into the future for sustained assessment foundational activities, topical reports, and quadrennial synthesis reports. Even when the development of these products is primarily led by individual agencies, coordination will ensure the products meet their objectives. Most of the information needs identified through previous assessments and the ongoing report process fall outside the boundaries of individual agency missions; coordination will ensure that products and processes are relevant and usable at the right spatial and temporal scales. In addition, coordination will improve the connection between USGCRP science and the needs of mission agencies. While the GCRA includes both types of agencies as charter members of the USGCRP, the mission agencies have played a less active role in program support and decision-making. Coordination around a sustained assessment can help to refine the understanding of their information needs and the design of USGCRP research programs to provide usable information.

Recommendation 3.2: Establish an ongoing process to produce quadrennial synthesis reports.

The GCRA of 1990 mandated the preparation of assessment reports not less than every four years. Yet only two such quadrennial assessment reports have been completed over the lifetime of the USGCRP program—in 2000 and 2009—and a third is currently in preparation. During the period from 2001 to 2008 when the program was known as the Climate Change Science Program (CCSP), a series of twenty-one "Synthesis and Assessment Products" were also prepared and released.

Among the reasons that the legal mandate for a quadrennial synthesis report has not been met consistently is the failure to establish an ongoing process that is properly staffed and resourced. We distinguish between specific assessment ***products*****,** whether required by Congress or initiated by the USGCRP and/or participating agencies, and a sustained, distributed assessment ***process*** (the ongoing set of activities/processes described here that develop and provide science-based products, facilitate communication, build societal capacity for self-initiated assessments, and encourage adaptive management and learning).

Quadrennial synthesis reports should be seen as "snapshots" of the state of national understanding about climate change and its impacts. In addition, they should articulate available options to reduce the magnitude of future climate changes by limiting emissions, increasing resilience to the changes being experienced, and preparing for anticipated future changes in response to the GCRA "understand, assess, predict, respond" language. These reports should synthesize recent scientific literature, technical input reports, and transparently produced and vetted independent suite of inputs from governments, civil society, and the private sector. In fact, a metric of the success of a sustained assessment should be the extent to which such independent technical products provide a foundation for answering priority questions about potential impacts, adaptation, and mitigation measures being evaluated and considered in different regions and sectors of the United States. The quadrennial synthesis reports produced by the USGCRP should consider this independently produced information via the assessment

process and incorporate it to the extent that it meets information-quality guidelines and is deemed useful.

A balance is required between a sustained assessment process and ensuring sufficient attention in the preparation of specific products, such as the mandatory quadrennial synthesis reports and associated online tools and databases. The quadrennial NCA synthesis reports, required under the GCRA of 1990, should be viewed as progress reports within an ongoing process of generating new knowledge, rather than as ends in themselves. Nevertheless, the reports are critical to the credibility and utility of research findings and are important products of the NCA and the USGCRP.

Recommendation 3.3: Establish a process and provide resources for foundational elements and topical reports.

Special efforts should focus on improving the foundational components of assessment and on topics of particular interest. These special efforts are intended to complement and augment the quadrennial NCA synthesis reports, and are of two types:

- ***Foundational Elements*:** Activities to update and advance the scientific methodologies and processes that are central to a sustained assessment. Examples of these foundational elements are described under Critical Element 2.
- ***Topical Reports*:** Reports focused on topics of keen interest to agencies or stakeholders, for example, climate change and food security, the relationship between drought and climate change, or the state of scientific knowledge related to ice melt in the Arctic.

While these foundational elements and topical reports will support the quadrennial NCA synthesis reports, they will be of interest and utility to agencies and a range of stakeholders. Many of these efforts may be undertaken separately from the NCA, and can be linked to the broader assessment efforts. USGCRP agencies should support the elements and reports that are conducted as part of the NCA, drawing upon agency research initiatives. The agencies should establish priorities for these efforts based on national/governmental information needs, advances in science and risk management, synergies with building capacity for assessment, and the availability of resources. In addition, less formal technical input reports from federal government and external sources can be produced to support the process and the quadrennial synthesis reports. Foundational tools, products, and methods such as scenarios and valuation methodologies that are made more broadly available to assessment teams well in advance of report development will support preparation of useful independent technical input reports and products that will in turn strengthen the quadrennial synthesis report *and* build capacity for ongoing assessment.

Potential foundational elements and topical reports, criteria for prioritization, and suggested priorities based on these criteria are provided in Appendix B.

An additional important component of a sustained assessment process is that it can provide foundational elements and topical analysis according to a timeline that better supports the development of the quadrennial report. For example, ensuring that internally consistent and updated climate (and other) scenarios are available for quadrennial synthesis authors to draw on as they compare different future pathways is more feasible within a sustained process.

Recommendation 3.4: Manage data to maximize utility and transparency.

Improved access to data and information are essential for those conducting research and assessments and in order to make assessment products more widely available for decision-makers. Many prior NRC and government reports have focused on the importance of observing and data/information systems as inputs to research.

The USGCRP's investment in the development of the Global Change Information System (GCIS) is a well-conceived approach to developing a comprehensive web-based system to deploy and manage global change information and present it in a way that can be used by and benefit scientists, the public, and decision-makers. Efforts should initially strengthen sustained assessment products, sources, data, and related information but broaden to other information produced in a sustained assessment process. A phased, long-term strategic plan that considers the breadth of resources required to build and maintain an operable, efficient, and user-friendly data management and access system is fundamental to the success of both USGCRP as a whole and a sustained assessment.

Subrecommendations in this section reflect this need and build on the ACC Science Panel report, which points out that observations across a range of systems and time/geographic scales are needed to provide a foundation for both research and assessment/decision support purposes (NRC 2010a, 159-162). We endorse and build on the recommendations of this report, specifically:

Subrecommendations:

- ***3.4.A.*** *Drawing on the chapters and technical reports prepared as part of the Third NCA, the USGCRP should review observational assets and needs to identify both sources and gaps in data required for understanding global change and its consequences and for monitoring/improving adaptation and mitigation responses.*
- ***3.4.B.*** *The USGCRP should improve access to heretofore under-represented socioeconomic and ecological information, including by developing partnerships with federal, state/local, and other agencies not traditionally part of the research program* (for example, social and economic agencies such as the U.S. Department of Housing and Urban Development, Census Bureau, Bureau of Labor Statistics, and Bureau of Economic Analysis).
  Here we give greatest attention to the infrastructure needed to provide easy access to NCA products and underlying data. Timely, transparent, and traceable access to evidence used to reach NCA findings is one means of enhancing credibility of the assessment and making it of greater value to a broader range of decision-makers. Coupled with a focus on usability (i.e., interpretability, ease of use in decision models, and linkage to additional information), access to products and data/information is of paramount importance in a sustained assessment process.
- ***3.4.C****. The NCA should provide data and information through a system that supports stable, long-term archiving and access to periodic reports and products of a sustained assessment process.*
  The system should (1) incorporate guidance to participants and adherence to best practices, including full metadata and source information; (2) develop policies and agreements for distributed archiving that ensure safe storage and stewardship; and (3) include an appropriate and user-friendly interface for

retrieving the assessment products themselves as well the data and information behind them.

Recommendation 3.5: Build and maintain engagement with regional science, assessment, and service institutions.

The USGCRP, through a sustained assessment process, should continue to work with existing federal, state, tribal, NGO, university, extension, private sector, and regional science, assessment, and service partners on an ongoing basis to expand and coordinate regional science application and data development networks in ways that are mutually beneficial. These regional partners provided significant assistance to the Third NCA in drawing together diverse teams of experts to develop regional technical input documents for the Third NCA Report. Many of these partners are also contributing to the NCA as part of regional chapter author teams and producing other technical inputs for the Third NCA Report.

Among the benefits of regional engagement are support for coordinated and distributed assessment capacities and the development of trusted relationships across local and broader scales. These relationships can support significant knowledge exchange, providing access for federal agencies to the information, perspectives, and needs of local and regional decision-makers and vice versa. Engagement with regional networks allows for a diversity of approaches to science, decision support, and associated learning that best fits regional needs and support exchange of learning. These regional partners are expected to be valuable collaborators in advancing the foundations of assessment science and practice, as discussed in Critical Element 2.

Building sustained regional capacity is challenging for a variety of reasons. First of these is the limited and uneven distribution of human and financial resources, which are generally inadequate to support adaptation and mitigation decisions or a sustained assessment process. A second challenge is the vast and diverse array of existing regional service boundaries and goals. There are dozens of federal climate science and climate-related service offices (although many are not fully engaged in providing regional climate information). Figure 4 (next page) illustrates the national distribution of 93 regional partner offices supported by three federal agencies—the National Oceanic and Atmospheric Administration (NOAA), the Department of the Interior (DOI), and the U.S. Department of Agriculture (USDA)—as of 2011. Nevertheless, the benefits of a coordinated approach are multiple, including the potential for reduced friction between stakeholders and the federal government.

In virtually every public forum related to climate there has been a clamor for greater coordination of regional scientific activities and services so that state, tribal, NGO, and other partners can more easily find resources and invest their resources strategically with consideration of other regional efforts. Currently, much regional climate science and assessment is funded by separate grant calls from separate agencies. The Third NCA process has benefitted already from greater coordination from some agencies in helping to fund a coordinated suite of input. This more coordinated approach to funding regional knowledge and service development could yield increased benefits over time and we recommend continued cross-agency efforts to increase the reach and impact of combined federal funds.

In order to ensure the viability of critical regional networks, a deliberate strategy should be developed to evaluate the adequacy of combined resources in each region and encourage a leadership and engagement approach. The regional partners and expertise are not distributed evenly and in the larger regions it can be difficult to achieve balanced coverage and engagement with decision-makers. Attention must be paid to the size and homogeneity of the region and the adequacy of existing and future plans for resourcing greater coordination among networks. In addition, the personnel-related impacts of conducting assessments on these regional science communities and partners can be managed by fostering capacity-building, coordinating timelines for activities, and providing resources and incentives for participation.

Figure 4. Regional climate information providers supported by the USDA, NOAA, and DOI. Developed by the Interagency Climate Change Adaptation Task Force, 2011.

Critical Element 4:
Diversify the resource base and set priorities

The final set of recommendations in this report concerns the resource base and priorities for the next phase of development of a sustained assessment. This set of recommendations is based on the assumption that with careful management, increased diversity of funding sources can increase the stability of the whole enterprise without compromising the credibility of reports and data sources.

Although already mentioned in this report, it bears repeating that in providing these recommendations, an explicit assessment of cost is not provided, since the USGCRP agencies are uniquely and solely equipped to produce cost estimates associated with components of its strategic plan. We also believe that the sustained assessment will help the USGCRP meet its obligations under the Global Change Research Act with greater efficiency across the whole program. This efficiency comes from (1) a wider

distribution of participants and partners (who can also help resource a sustained assessment); (2) greater feedback to and more targeted enhancement of scientific foundations (which address national needs, improve assessment products, and yield greater benefits from federal investment); and (3) the increased reach of assessment-driven information, allowing initial investments to go further and yield better overall results for decision-support. The opportunities to leverage existing programs and new partnerships can ultimately improve the efficiency and effectiveness of the nation's overall assessment capacity, and enhance outcomes in relation to inputs if a sustained assessment is properly and strategically implemented.

Recommendation 4.1: Diversify the resource base for assessment.

The vast majority of costs associated with producing past assessments has been borne —directly or indirectly—by the federal government, even though the Third NCA Report involved substantial voluntary contributions from outside the federal government. The mechanisms by which government funding has been obtained include contributions to a central coordination effort (as part of the costs associated with the centralized functions of the USGCRP), agency-led activities such as workshops that are related to the production of the assessment, and funding (in the form of grants, for example) provided to academic and other non-federal organizations to perform research and write reports that underpin the assessment. All of these investments have been in addition to the investments in underlying science and research that are the foundation of the USGCRP activities.

This government support has been essential to the generation of past assessments and remains so. Indeed, many of the activities associated with the production of a sustained assessment represent quintessential federal government functions: those that no other entity would or could typically undertake. For example, the creation of scenarios, indicators, and guidance surrounding vulnerability assessments (as discussed in Critical Element 2) are essential components of an assessment that will likely be most effective if promulgated from a credible, central source such as the federal government. Establishment of a director and significant coordination to facilitate the process are additional examples of functions best fulfilled at the federal level.

In the future, a successful sustained assessment will benefit from and may require a more diversified resourcing model. The USGCRP should consider how federal investment sustains or increases its rate of return. Investing government funding in activities that seed expanded contributions from the community (in expertise or in willingness to jointly support an activity) may enhance the value to federal programs, national preparedness, and the assessment itself. Small federal investments may leverage supplemental funding at regional or local scales and increase willingness to engage nationally among the local participants.

Fortunately, if properly managed in the context of federal investments, significant financial and in-kind capacities are available to support a sustained assessment process (see box, next page). Many partners are interested in contributing to and will benefit from a sustained assessment effort, although it should be noted that many are less interested in the production of periodic reports than they are in the ongoing assessment process, which produces updated scientific information that supports management decisions. Potential partners include non-government-based groups, universities, and professional

organizations, the private sector, and state, tribal and local governments. While the NCA engagement strategy currently in place has been highly successful in leveraging the activities of such organizations, and in turn they appear to be benefiting from engagement, more diversification is in order.

Diversifying the Resource Base

This list of potential contributions from partners could include technical, communication, and coordination contributions. Resources (expertise and funds) could contribute to activities such as those listed below, as coordination and co-production continue to expand through the sustained assessment process.

Technical inputs: Literature reviews, discussion papers, case studies, data, modeling results, analyses of impacts in particular topics or regions (similar to the more than 500 technical inputs submitted for the draft Third NCA);

Supporting Indicator systems: Identifying or maintaining key observation sets, case studies that apply indicators or derive combinatory or higher resolution indicators for a particular sector or area;

Products: Decision-support tools that use assessment information or indicators available through the global change information system, white papers to support decisions for a particular stakeholder group (such as that produced by Labor4Sustainability);

Communication: Development of derivative educational materials (such as fact sheets from Climate Reality), communicating with stakeholders and the public, evaluating the effectiveness of engagement efforts;

Coordination: Staff time to coordinate multi-partner contributions on regional, sectoral, or topical issues, convening meetings and facilitating discussion among producers and users of assessments;

Research: Guidance for using assessment products and foundational science in partner-specific situations, funding, or support for scientific studies or case studies.

Integrated Modeling: Numerous groups are investing in various forms of modeling tools that could support the development of enhanced assessment capacity (e.g., MIT, Stanford, the International Food Policy Research Institute [IFPRI], the ILSI Research Foundation Center for Integrated Modeling of Sustainable Agriculture and Nutrition Security [CIMSANS], etc.).

A range of public-private partnerships to support particular components of NCA activities should be considered. For example, efforts to assess specific sector needs, perform vulnerability assessments, or support meeting and communication services in a location or sector could all be undertaken by non-governmental entities. Community-based organizations, NGOs, professional societies, universities, and private industry are already engaged in these activities, in some cases very significantly. However, limited communication and coordination means many of these efforts remain isolated and unable to benefit from the synergies that could emerge if they were informing a larger knowledge base. For example, a considerable amount of capacity-building, assessment, and outreach efforts that are currently being supported through private foundations could more effectively build the capacity to manage the risks of climate variability and change if they were better linked with a national effort.

Many non-governmental organizations are interested in a collaborative ("co-production") approach to assessments, particularly at state and local scales, and these opportunities should be further explored as well. Public-private partnerships in this area could help to diversify funding and expertise in particular activities such as the production of special reports, online resources, or vulnerability assessments at multiple scales and specific sectors over time. With careful management, increased diversity of funding sources can increase the stability of the whole enterprise without compromising the credibility of reports and data sources.

The engagement of external organizations as core partners in supporting and leading elements of a sustained assessment—as outlined above—presents both challenges and opportunities. For example, linking resources provided by non-governmental organizations to assessment efforts could create an expectation of influence over the assessment process or even the ultimate content of future reports. Since even the *perception* of such outside influence over the assessment would damage its credibility, it is imperative that USGCRP and NCA managers and staff avoid conflicts of interest to prevent the content of the assessment from being inappropriately influenced by a contributor to the process. Attention to establishing clear expectations and transparent processes, as well as independent review of products is particularly important for the quadrennial reports and any others that are a product of the USGCRP or the NCA. Work done in preparation for the Third NCA Report, in which standards and guidelines for the inclusion of material were established by the NCADAC for use by chapter authors, is a good step in this direction. These standards and guidelines should be revisited and, if necessary, adjusted or augmented.

Cooperative agreements between firms/foundations and a host agency could be established in which the agency, the NCA advisory committee, or USGCRP itself establishes funding mechanisms and documents expenditures. Another approach would be to establish a trust fund or similar vehicle that would provide a buffer between the donors and the assessment process, so that the identity and role of donors is transparent and no donor can have undue influence on the products. This approach has been used to help provide funding to past international assessments.

More broadly, if the recommendations of this report are implemented as suggested, there may be a shift over time in the role of the federal government in relation to external partners. Shared management approaches for a sustained assessment will be needed. There is likely to be increased potential for leveraging additional funds if there is a greater sense of shared ownership. The evolution of the NCA process could go through

a number of planned stages with migration of some specific components—for example, some regional or sectoral assessments—to outside the government over time. As this happens, it is likely that the composition of the advisory committee and the role of the USGCRP in governance will need to change in order to reflect changing priorities and partners.

There are additional perspectives to consider. One is complexity versus simplicity: a more distributed process is almost by necessity more complicated. A centrally managed and resourced NCA may be less complex, but may have limited applicability beyond its statutory obligations, especially if it is based on limited stakeholder involvement in content development. An otherwise similar approach to documenting impacts, vulnerabilities, and options with broad-based involvement in content development would likely expand the relevance of the document, while admittedly increasing the complexity of the process. Ultimately these tradeoffs must be considered in light of many factors, including the nature and purpose of each product that is being developed. For example, development of the NCA quadrennial report may require a different approach than the course selected for developing topical reports. Given the significant ongoing budget pressures experienced by federal agencies, innovative approaches to funding specific components of a sustained assessment—even for development of the quadrennial reports—may need to be considered.

Recommendation 4.2: Adopt criteria for prioritization and clear priorities for the next phase of development of the NCA process.

Even with the broadened resource base envisioned here, there will inevitably be constraints imposed on the activities associated with implementation of a sustained assessment process, requiring the setting of priorities. Past presidential administrations have organized prioritization processes associated with the USGCRP differently, but all of these processes have involved some combination of responsible officials of the USGCRP agencies working through the USGCRP coordination process, representatives of the Executive Office of the President (e.g., the Office of Management and Budget and the Office of Science and Technology Policy), the director and other staff of the coordination office, and input from external stakeholders through advisory committees, the National Research Council, and other input. Participants drawn from these groups should be involved in setting priorities for the activities related to a sustained assessment, which will in turn help guide USGCRP priorities.

The prioritization process should apply criteria transparently and systematically on an annual basis, through the preparation of the President's budget and by setting longer-term objectives on a periodic basis. One obvious opportunity for long-term stock-taking and priority-setting is following the major quadrennial synthesis reports, each of which invites evaluation of identified needs and capacities. Ideally, needs for advancing a sustained assessment process will be reflected in the research priorities of the USGCRP and in the budget for the assessment.

The USGCRP Principals requested that this report consider a process to establish priorities. This section describes the criteria used, which we urge be adopted by USGCRP, as well as the resulting priorities.

The recommendations in this report address the most essential functions of a sustained assessment. In the context of this report, prioritization is a matter of sequencing activities in a logical fashion, reflecting the fact that some capabilities or activities must be built on others and thus should follow in a logical order within the assessment development process. Priorities should be set as implementation of the assessment proceeds, always considering opportunities to stage and scale efforts, expanding or contracting in an adaptive manner rather than completely eliminating important components of the assessment.

Criteria for prioritization

The criteria identified presume that standard budget considerations such as scientific/ technical quality, relevance to identified societal or governmental needs, and cost effectiveness are already incorporated into the decision process.

For the purposes of setting priorities for a sustained assessment process, we have emphasized additional criteria for evaluating whether proposed activities contribute to development of characteristics associated with effective assessments, as discussed in the Vision section of this report. In what we consider to be the next phase of the sustained assessment development process, we recommend that priority be given to activities that:

- Establish and maintain partnerships
    - Support engagement with stakeholders, enabling two-way learning between scientists and practitioners
- Advance the science of assessment and decision support
    - Improve methods, tools, data, and other resources highlighted by participants in the current report process
- Contribute to ongoing evaluation and adaptive learning about the process/needs for assessment
    - Ensure that over time, a sustained assessment process improves to meet the evolving priorities of its stakeholders
- Meet priority information needs of society, the federal government, governments and private entities
    - Build bridges from national resources to local and regional needs
    - Capitalize on existing strengths and resources, leading to rapid application of USGCRP science
- Build capacity
    - Contribute to scientific capacity essential for risk and opportunity management
    - Through ongoing outreach and engagement activities, build understanding and risk-management capacity among assessment users

We believe that if these criteria are systematically employed, the sustained assessment will meet its objectives and contribute to achieving the goals of the USGCRP Strategic Plan by improving risk management throughout the Nation.

Priorities for the recommendations in this report

Using these criteria, we have developed the following recommended priorities, grouped into two broad categories: (1) those that are currently essential if the USGCRP is to credibly claim that it is moving towards establishing a sustained assessment, and (2) those that can be phased in over time to build capacity that fundamentally adds to the capacity of the USGCRP, the NCA, and of groups of participants to engage in the process.

Recognizing that agency budgets, which vary from year to year, will ultimately determine the level of activity undertaken, we recommend that the following **functions and products** (not listed in order of importance) deemed essential in a sustained assessment be supported at some level from the outset, ramping up to optimal levels as funds become available:

- Build capacity to develop and conduct vulnerability assessments.
- Develop and interpret indicators of climate changes, impacts, resilience, opportunities, and preparedness.
- Establish scenario methods and products for framing uncertainties and developing robust responses.
- Develop valuation methods for measuring the consequences of change and the benefits of adaptation/mitigation responses.
- Advance methods for assessing and communicating confidence and uncertainty in scientific information for decision support.
- Ensure adequate resources to produce quadrennial synthesis reports that are timely and reflect advancements in science and decision support.
- Build and maintain engagement with regional science institutions and programs.

Further, success in a sustained assessment requires acknowledgment of the need for and support for a number of design and operational **principles**, which we also believe are vital to the effort and should be adopted from the outset:

- Adaptive management; support for an ongoing coordination office that is responsive and scaled according to changing needs
- Empowered leadership responsible for sustaining the assessment
- A well-supported standing sustained assessment advisory committee scaled according to the needs of a sustained assessment and adjusted to support the production of the quadrennial synthesis reports
- Partnerships with tribal, state, and local governments, civil society, and the private sector to build assessment capacity
- Well-supported engagement and communication networks across the nation
- Well-supported engagement with International assessments and programs
- A diversified financial base of support for a sustained assessment beyond the federal government
- Governance structures that support the goals and vision of a sustained assessment process
- Adaptive learning and ongoing improvements in the process, fostered through the establishment of an assessment evaluation strategy

Other suggested principles are focused on developing and improving assessment related processes. These components should be phased into the program as funds

become available:

- Build capacity to document and incorporate international influences on the United States in U.S. and international assessments.
- Establish mechanisms to identify risk management information needs for consideration in USGCRP research priorities.
- Manage data to maximize utility and transparency.
- Produce periodic foundational and topical reports, ongoing products, and online resources as issues emerge and as budgets are identified.

Concluding Remarks

Among the key conclusions of this report are:

- A sustained assessment process is the most effective and efficient way to: respond effectively to the four-year report requirement of the Global Change Research Act; increase the utility of assessment information by facilitating broader input and providing more focused special reports and web-based products for decision-makers; and more equitably distribute workload burden on the scientific and management communities now required to produce quadrennial reports. It will also allow more timely and focused evaluation of the current state of scientific knowledge relative to climate impacts and trends, support the nation's activities in adaptation and mitigation, and improve responsiveness to rapidly emerging needs of decision-makers.

- The USGCRP should maintain a sustained assessment coordination office headed by a strong leader. We consider the coordination office, under the direction of a strong leader, to be a prerequisite for the success of the sustained assessment process.

- The USGCRP should support and nurture the development of a consistent and constantly updated suite of national indicators of climate change to improve understanding of change and strengthen the ability of U.S. communities and the economy to prepare and respond, as specified in the USGCRP Strategic Plan and using recommendations from the NCADAC Indicators Working Group (Janetos et al. 2012b).

- The USGCRP should also continue to support and benefit from the development of an interagency information management system, such as the proposed global change information system (GCIS) that will provide timely, authoritative, and relevant information, and produce reports and web-based products that are useful for decision making at multiple levels. Electronic access to data and tools is critical for decision support and for transparency of assessment conclusions.

- Careful attention should be paid to the process of assessment: i.e., the engagement, communication, and evaluation components as well as the methodologies for data collection and analysis. To ensure broad support (and additional sources of relevant information), more defined relationships should be explored with external partners from the private sector, NGOs, foundations, and a broad set of regional, tribal, and sectoral stakeholders. Alternative governance

structures for the NCA should also be considered, to ensure a responsive and efficient management process that also enhances the breadth and magnitude of the resources to support the ongoing and sustained assessment.

- As has been pointed out by the National Research Council in past evaluations, it is critical to properly resource an assessment to ensure improvements in quality, impact, and importance as the climate continues to change. Although substantial components of the Third NCA Report were produced through volunteer efforts, it is unreasonable to assume that an ongoing, rigorous, and consistent approach to assessment can take place without some additional investment in the *process* of assessment. Implementation of a sustained assessment process described herein will provide a strong foundation for the USGCRP Strategic Plan and for contributions to international assessments and programs (e.g., the IPCC, the World Meteorological Organization's Global Framework for Climate Services), and national efforts (such as the Hurricane Sandy Task Force). As such it can enhance significantly the quality of information used for decision support in the United States.

We endorse a flexible approach to building and sustaining assessment capacity that can expand and contract in response to resource availability while also focusing on constant improvements in the process. While providing resources to support a sustained assessment process could be challenging, a prudent path forward will be to carefully protect the core capacity of the USGCRP to support the coordination of assessment partners and produce updated and usable information, while strategically implementing investments in foundational elements such as scenarios, information systems, and indicators. The relative investment in these critical components should be outlined in a five-year, annually updated operating plan that also supports the quadrennial report process and promotes continual support for the USGCRP as a whole. Activities, plans, and investments can be phased over time as USGCRP develops a strategy for sustained assessment.

The vision and recommendations presented in this report—utilizing an assessment process that is ongoing, rigorous, inclusive, and transparent—can ultimately improve the nation's ability to respond effectively to the challenges and opportunities that climate change is bringing.

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Appendix A

National Climate Assessment and Development Advisory Committee
Sustained Assessment Special Report Working Group
Terms of Reference

Purpose: The Sustained Assessment Special Report Working Group (SASRWG) is established by the National Climate Assessment and Development Advisory Committee (NCADAC) to write a report for consideration by the full NCADAC. The purpose of the report is to fulfill the requirement of the charter of the NCADAC to provide advice and recommendations toward the development of an ongoing, sustainable national assessment of global change impacts and adaptation and mitigation strategies for the Nation.

A suggested outline for the report, developed by the NCADAC, will be provided to the SASRWG. In addition, materials previously produced by the Sustained Assessment Working Group and National Climate Assessment Sustained Assessment Chapter Author Team will be provided to the SASRWG. However, the SASRWG may make changes to the outline and to use other materials as it sees fit. The SASRWG members are encouraged to stay in close communication with the Chairs of the NCADAC as they deliberate regarding the contents of the report and may be asked to report periodically on their progress to the NCADAC.

Product: The SASRWG will produce a draft Special Report for the NCADAC that provides advice and recommendations through NOAA to USGCRP, towards the development of an ongoing, sustainable national assessment of global change impacts and adaptation and mitigation strategies for the Nation. It will not be a government document but a report from the NCADAC to the government.

Membership: The membership of the SASRWG will be comprised of nine individuals with expertise in the area of climate change. The members of the SASRWG were selected and confirmed by the NCADAC using standard procedure after nominations were evaluated by the Executive Committee. The members are - Jim Buizer, Kirsten Dow, Chris Field, Paul Fleming, David Gustafson, John Hall, Sharon Hays, Amy Luers, and Richard Moss. If a member resigns, he/she may be replaced by a member with comparable expertise.

Report's Authors: The report's authorship team will be as follows: Three Convening Lead Authors: Jim Buizer, Paul Fleming and Sharon Hays, and five Lead Authors: Kirsten Dow, Chris Field, David Gustafson, Amy Luers, and Richard Moss.

All of the members of this author team are non-federal; five are members of the NCADAC and three are not. The CLAs can appoint a small number of

contributing authors to add essential expertise. The contributing authors should not be federal employees

Liaison: John Hall is designated as the liaison between the SASRWG and the Interagency National Climate Assessment (INCA) working group of USGCRP. He is an ex officio member of the NCADAC representing the Department of Defense and so is a non-voting member of the NCADAC for purposes of establishing a consensus on accepting the final document within the NCADAC.

Timeline: The SASRWG was established in December 2012 and will provide a final draft version of its report to the NCADAC by the middle of September 2013. They will operate as a working group of the NCADAC until their report has been finalized. A draft timeline with suggested milestones has been drafted and will be provided to the SASRWG.

Staffing and other support: The NCA Coordination office will provide staff support. The NOAA National Climatic Data Center (NCDC) Technical Support Unit (TSU) will provide editing and layout for the document as required. Travel for at least one meeting in Washington DC will be provided by NOAA through the TSU. It is hoped that other business of the group can be conducted remotely or in the context of other NCADAC and ES meetings.

Relevant language from the NCADAC Charter: The committee's mission is to synthesize and summarize the science and information pertaining to current and future impacts of climate change upon the United States; and to provide advice and recommendations toward the development of an ongoing, sustainable national assessment of global change impacts and adaptation and mitigation strategies for the Nation. Within the scope of its mission, the committee's specific objective is to produce a National Climate Assessment that:

A. Integrates, evaluates, and interprets the findings of the U.S. Global Change Research Program ("USGCRP") and discusses the scientific uncertainties with such findings;
B. Analyzes the effects of current and projected climate change upon ecosystems, biological diversity, agriculture, energy production and use, land and water resources, transportation, human health and welfare, social systems, including a regional context;
C. Analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years;
D. Is a continuing, inclusive National process that synthesizes relevant science and information about changes in the Earth system as they affect the Nation's climate, and about how such changes relate to and interact with changes in social, economic, ecological, and technological systems; and
E. Supports climate-related decisions by providing an information base in multiple formats, including Web-based and hard copy formats.

Appendix B

Potential Foundational Elements and Topical Reports, Criteria for Prioritization, and Suggested Priorities Based on These Criteria

This section suggests a path forward for selecting and prioritizing foundational elements and topical reports that should be undertaken in the intervening years between the larger NCA quadrennial synthesis reports required under the GCRA. It is important to note that these activities, while supportive of assessments, will be selected in large part for their utility for other governmental and stakeholder needs. Therefore, many related efforts may be conducted independently of NCA, and USGCRP can facilitate their input into quadrennial synthesis reports. For those efforts that are part of the USGCRP, an annual prioritization process should be developed that results in an annually updated five-year outlook of assessment activities that can be linked to broader USGCRP planning and implementation efforts. Conducting these activities on an ongoing basis not only has multiple benefits from a budgeting and staffing perspective, but also has the additional benefit of resulting in more timely and responsive delivery of USGCRP information and products that are useful to agencies, scientists, and public and private stakeholders.

The selection of both foundational elements and topical reports should be facilitated by the USGCRP, which should compile input on priorities from a variety of sources, including the NCADAC Sustained Assessment Advisory Committee, NCAnet partners and stakeholders, the public, federal agencies, and the National Research Council. Important considerations in the subsequent decision process of the USGCRP Principals include interagency priorities and capacity and availability of resources, and research and product needs identified within the NCA process, among others. An initial annual priorities proposal (starting with inputs from stakeholders, agencies, and the sustained assessment advisory committee) could be followed by an iterative conversation with the advisory committee and the Principals, preferably resulting in an annually updated five-year priorities document for the NCA that can be approved by the Principals in time to influence the annual budget discussions.

The following criteria should be used for prioritizing NCA foundational elements, topical reports, and sustained assessment processes:

- Governmental needs: Respond to established priorities of USGCRP, other related interagency efforts, and individual agencies.
- Societal needs: Engage with external stakeholders to determine topics of greatest interest to civil society.
- Science needs: Deepen scientific understanding of climate change risks, impacts, vulnerabilities, and opportunities, including both those identified as gaps and any emerging science areas that could support sustained assessment goals.
- Decision-support needs: Advance decision-support for risk-management, vulnerability assessment, and evaluation of new opportunities associated with climate change.
- Resources: Identify the availability of resources, staffing, and capacity to successfully support and complete each proposed report, while balancing long-term process support and short-term high priority product-focused efforts.

- Assessment capacity: Build critical enhanced assessment capacity, including the ability to support the governmental, societal, and scientific goals of the NCA sustained assessment environment.

Potential foundational and topical reports priorities based on these criteria are provided below. The level for review for the special reports should be decided on a case-by-case basis, but the review should be rigorous and credible. The review of technical input documents is not as critical as the review of actual NCA products, such as foundational elements and special reports.

Potential Foundational Elements:

1. Development and deployment of the NCA indicator system, accompanied by special reports on the topic.
2. Development of climate scenarios for the Fourth NCA synthesis report, to provide information for enhanced decision support for regional and sectoral stakeholders.
3. Incorporation of new scientific information, ranging from socioeconomic conditions to physical systems and ecosystems (including CMIP5 results, new emissions information, and regional sea-level rise information) into regional scenarios and projections of impacts on sectors for 25 years and 100 years in the future, accompanied by an interagency technical input document in 2014.
4. Development of standardized land-use and socioeconomic scenarios for the NCA regions, including a reviewed interagency report produced in 2015.
5. Development of guidance on scenario development methodologies, downscaling techniques, regional modeling, and model selection. Guidance will lead to improved approaches to scenario development and decision support. Special attention should be focused on formulating a stronger framework for evaluating model capabilities, including evaluation of downscaling and regional modeling analyses and their ability to optimally support impact studies.
6. Development of methods for the NCA for establishing the cost of climate-related impacts in the United States as related to benefits of adaptation, as proposed by the new Board on Environmental Change and Society of the National Research Council by the end of 2015.[12]
7. Evaluation of the effectiveness of communication around uncertainty.

Potential Topical Reports:

1. *Preparing the Nation for Change: Building a Sustained National Climate Assessment Process* (present report)
2. International context assessment, with interagency product in 2014
3. State of knowledge in drought science, prediction, and attribution.
4. US food security assessment, with USDA-led interagency report due in 2015.
5. Methods for evaluating costs of the impacts of recent extreme weather events (drought, Hurricane Sandy, etc.) in a consistent way.
6. A thorough evaluation and review of the activities conducted for the Third NCA synthesis report and other sustained assessment processes already underway.
7. An assessment of American attitudes, effective communication and education regarding climate change.

[12] The proposal is preliminary and has not been funded. There may be a need to consider costs of adaptation to variability in a different context from costs associated with climate change, which requires an attribution component of the analysis.

Appendix C

Glossary and Abbreviations

ACC – *America's Climate Choices,* a series of reports released in 2010 by the National Research Council, which included Advancing the Science of Climate Change; Limiting the Magnitude of Future Climate Change; Adapting to the Impacts of Climate Change; and Informing an Effective Response to Climate Change (NRC 2010a, 2010b, 2010c, 2010d).

adaptation – Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. (NCADAC 2013, p.985)

capacity-building – Developing the technical skills and institutional capabilities to enable participation in all aspects of adaptation to, mitigation of, and research on climate change. (from IPCC 4th Assessment, http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-app.pdf)

CCSP – *Climate Change Science Program*, the name of the USGCRP during the George W. Bush Administration.

civil society – The sector of society that is distinct from government and for-profit business, which includes community-based organizations, professional associations, religious groups, private foundations, and private citizens.

communication – Methods of providing individuals and organizations with opportunities to access information about the NCA process and products (including to elicit stakeholders' input to the Assessment); to learn about and increase their interest in and understanding of the NCA, climate change, and the implications of a changing climate for the US; and to evaluate and improve the effectiveness of NCA communications. (NCA 2011b)

co-production – Collaborative work by organizations in the private sector, academia, government, and civil society with users on projects or activities that further the goals of the NCA.

engagement – An organized process that provides individuals and organizations with access to the design, assembly, content, and products of the NCA through participation and communication.

FAC – *Federal Advisory Committee*, a group of experts sponsored by a federal agency to advise the President and the Executive Branch on various issues in adherence with the Federal Advisory Committee Act.

FACA – *Federal Advisory Committee Act,* "Public Law 92-463 enacted in 1972 to ensure that advice by citizen advisory committees is objective and accessible to the public. The Act formalized a process for establishing, operating, overseeing, and terminating these advisory bodies and monitoring their compliance with the Act."

foundational elements – Activities to update and advance the scientific tools, products, and methods that are central to a sustained assessment.

GCIS – *Global Change Information System*, a USGCRP-sponsored web-based source of authoritative, accessible, usable, and timely information about climate and global change for use by scientists, decision-makers, and the public.

GCRA – *U.S. Global Change Research Act of 1990*, "A U.S. law requiring the establishment of a U.S. Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes." from http://www.gcrio.org/gcact1990.html

human systems – Any system in which human organizations play a major role. Often, but not always, the term is synonymous with "society" or "social system" (e.g., agricultural system, political system, technological system, economic system) (Gamble et al. 2008, p. 187)

Hurricane Katrina – One of the strongest storms to impact the coast of the U.S. in the last 100 years, Katrina reached hurricane force strength off the coast of Florida on Aug. 23, 2005 and caused widespread damage along the Gulf Coast, especially in New Orleans, LA; Mobile, AL; and Gulfport, MS.

Hurricane Sandy – A hurricane that developed in the Gulf of Mexico on Oct. 22, 2012 and caused significant damage in the Caribbean and the eastern seaboard of the United States, particularly New Jersey and New York; also referred to as "Superstorm Sandy."

indicators – Summary measurements or calculations that represent important features of the status, trend, or performance of a system of interest (e.g. the economy, agriculture, air quality).

IPCC – *Intergovernmental Panel on Climate Change*, a scientific body under the auspices of the United Nations (UN). It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters.

mitigation – Technological changes or substitutions that reduce resource inputs and emissions per unit of output in order to reduce greenhouse gas emissions and enhance sinks. (adapted from NCADAC 2013, p. 985)

NCA – *National Climate Assessment*

NCADAC – *National Climate Assessment Development and Advisory Committee*, a 60-member Federal Advisory Committee

NCADAC Indicator Working Group – An interagency group working to build an integrated set of national indicators of change that includes ecological, social, and physical components.

NCAnet – A network of organizations working with NCA to engage producers and users of assessment information across the United States.

NGO – *Non-government organization*

NOAA – *U.S. National Oceanic and Atmospheric Administration*

non-government participants – Participants from civil society, academia and the private sector.

NRC – *National Research Council*

OSTP – *Office of Science and Technology Policy*

practitioners – Professionals actively engaged in utilizing, deploying or creating climate change information outside of academia.

preparedness – The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions. (from U.N. Office for Disaster Risk Reduction: http://www.unisdr.org/we/inform/terminology)

private sector - Organizations that are privately owned and not part of the government including corporations, partnerships and non-profit organizations.

public-private partnerships – Partnerships established among public institutions, such as government agencies and universities, and the private sector in order to support particular components of NCA.

quadrennial synthesis reports - Congressionally mandated reports to be compiled at least every four years by the NCA that survey, integrate, and synthesize science on climate change. The third synthesis report is expected to be released in Spring 2014.

resilience – The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. (from IPCC 4th Assessment, www.ipcc.ch/publications_and_data/publications_and_data_glossary.shtml#.Uebn2o3OlvA)

risk - A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur. (NCADAC 2013, p. 985)

risk-based framing – Planning based on the pros and cons of a given set of possibilities; includes assessment of a risk in terms of the likelihood of its occurrence and the magnitude of the impact associated with the risk

SASRWG – *Sustained Assessment Special Report Working Group*, A working group of the NCADAC.

scenarios – Quantitative and narrative descriptions of plausible future conditions that provide assumptions for analyses of potential impacts and responses to climate change.

special efforts – Sustained assessment activities and outputs that include foundational components and topical reports

stationarity - In natural systems, this refers to the expectation that fluctuations in weather and other natural systems stay with a known range of variability

sustained assessment – An evolving framework for connecting institutions and activities in regions and sectors through a network of scientists and other learned professionals from academia, government, civil society, the private sector, tribal communities, and decision-makers to strengthen the nation's capacity to understand, assess, predict, and respond to human-induced and natural processes of global change.

synthesis reports –See *quadrennial synthesis reports*.

technical input reports – Reports submitted by federal agencies and other interested parties in response to a request for information by the NCADAC.

teleconnections – Linkages between weather, climate change, or social systems that occur in widely separated regions of the globe.

topical reports – Report output products resulting from special efforts focused on topics of keen interest to agencies or stakeholders.

USGCRP – *U.S. Global Change Research Program*, initiated in 1990 by the Global Change Research Act.

v**ulnerability** – With respect to climate change, the degree to which social, biological, and geophysical systems are susceptible to, and unable to cope with, the adverse impacts. (Parry et al. 2007).

vulnerability assessment – Identification of the degree to which a system or facilities are susceptible to, or unable to cope with adverse effects of climate change. (NCADAC 2013, p.985)

Appendix D

Matrix of Selected Sustained Assessment Recommendations and Their Relationship to Core Components of the GCRA

	GCRA			
Sustained Assessment Research and Focus Areas	Understand	Assess	Predict	Respond
Methods for vulnerability/risk assessment		**X**		**X**
Indicators of change, impact, and response	x	**X**	x	
Scenarios, methods, and products for framing risk and robust responses		**X**	x	**X**
Valuation methods for measuring consequences of change and evaluating benefits of responses	**X**	**X**		**X**
Methods to incorporate international influences on the U.S.	**X**	**X**	x	x
Methods for assessing confidence and uncertainty in scientific information for decision-making	x	**X**		**X**
Adaptive learning within assessment processes		**X**		x
Identification of risk-management information needs		**X**		**X**
Partnerships for developing knowledge systems	**X**	**X**		**X**
Partnerships for providing data, engagement, and communication		**X**		**X**
Data management and information system development		**X**		**X**

Large X – Provides important contributions to the GCRA element
Small x – Provides some contribution to the GCRA element

Appendix E

Explanation of Process Used for Developing Recommendations and Discussion of Options

In developing this report, and in keeping with its charge, the NCADAC has provided specific recommendations for the components of a sustained assessment. The process of developing these recommendations involved the following stages:

1. NCADAC appointed a panel of nine members who represented a variety of perspectives including government, private industry, international, national and regional assessments, non-governmental organizations, and academia.

2. Authors interviewed several key stakeholder groups, which included the Interagency National Climate Assessment Working Group, the Subcommittee on Global Change Research, NCA leadership and staff, the Regional Integrated Sciences and Assessment (RISA) program community, and other individuals from the USGCRP and federal government. Conversations soliciting input and feedback were also held with networks of partners in the NCA process, such as NCAnet.

3. Authors drafted a report, considering the need for, advantages, and disadvantages of a sustained assessment approach, and the essential elements needed for success. A wide variety of options and components were considered and distilled to recommendations based on the criteria shown below.

4. NCADAC reviewed the draft report along with invited external reviewers. Five external reviewers were chosen based on their experience with assessments, work within or with stakeholder communities or the government, relevant expertise and interest, understanding of needs, or a combination thereof.

5. Authors hosted a series of webinars with NCADAC to allow members to discuss the rationale behind the recommendations and make suggestions for changes. All were also encouraged to provide written comments.

6. Authors responded to comments, revised the draft and presented the responses and potential remaining issues at a formal NCADAC meeting; remaining changes were addressed the following month.

7. A final draft was presented for approval and solicitation of remaining concerns or comments at a phone meeting of the NCADAC, and was approved and adopted by the NCADAC in September 2013.

In developing the special report's recommendations, the following criteria were used by the authors to evaluate options. Not all criteria were applicable to all recommendation topics, but all recommendations considered a combination of them:

Will adoption of the recommendation…

- enhance the ability to meet the requirements of the Global Change Research Act? ("GCRA")
- support the strategic planning process and implementation for the USGCRP? ("PLANNING")
- increase the utility of the assessment outputs for a variety of stakeholders, but especially practitioners? ("UTILITY")
- advance the scientific foundations for climate risk management? ("RISK MGMT")
- increase the opportunity for including new, rigorous and relevant science and information into an assessment process? ("NEW SCI" in table below)
- broaden participation from scientists and stakeholders? ("PARTICIPATION")
- take advantage of existing infrastructure where it is already successful and efficient? ("INFRA")
- ensure continued credibility and authority in the process and output? ("CREDIBILTY")
- increase accessibility and transparency of the assessment process and output? ("ACCESS")
- increase the likelihood of stable and appropriate funding? ("FUNDING")
- utilize current investments efficiently? ("EFFICIENCIES")

The options considered in one of the report's recommendations are shown below to illustrate the decision process and criteria used.

Example: Fund a Central Coordination Office.
Effective coordination was considered a requirement in the execution of any assessment, including one within a more sustained approach. The author panel considered several options in achieving this coordination:

Option A: a coordinating office located *within a single agency* (several possible agencies were discussed)
Option B: a coordinating office located *in an interagency program or function*
Option C: a coordinating office located *outside the federal government* and managed by stakeholders of the process

In the table below, we demonstrate how each of the options was found to relate to the criteria listed above in comparison to each other. While all options could contribute in small ways to meeting the criteria, the check marks indicate that the option has a *high* degree of contribution to achieving each criterion.

CRITERION	Option A (single agency)	Option B (interagency)	Option C (outside fed govt)
GCRA	✓	✓	
PLANNING		✓	
UTILITY		✓	✓
RISK MGMT	✓	✓	✓
NEW SCI	✓	✓	✓
PARTICIPATION		✓	✓
INFRA	✓	✓	✓
CREDIBILITY	✓	✓	
ACCESS		✓	✓
FUNDING		✓	✓
EFFICIENCIES		✓	

The final recommendation concluded that an interagency coordinating unit within the present USGCRP would be the preferred option. However, authors acknowledged the value and desire of some external organizations to assist as well as the benefit of diversifying the resources needed for coordination and the opportunity for new science and partnerships. So, in this report, the USGCRP was advised to examine which elements of coordination might be undertaken by stakeholders. In sum, Option B was preferred, with additional consideration needed of how coordination outside the federal government could contribute.