29. Research Needs for Climate and Global Change Assessments

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Overview

This chapter identifies key areas of research to provide foundational understanding and advance climate assessments. Many of these research topics overlap with those needed for advancing scientific understanding of climate and its impacts and for informing a broader range of relevant decisions.

The research areas and activities discussed in this chapter were identified during the development of the regional and sectoral technical input reports, from the contributions of over 250 National Climate Assessment (NCA) chapter authors and experts, and from input from reviewers. The five high-level research goals, five cross-cutting research capabilities, and more specific research elements described in this chapter also draw from a variety of previous reports and assessments.

Box: 5 Research Goals

- Improve understanding of the climate system and its drivers
- Improve understanding of climate impacts and vulnerability
- Increase understanding of adaptation pathways
- Identify the mitigation options that reduce the risk of longer-term climate change
- Improve decision support and integrated assessment

5 Priorities for Foundational Cross-Cutting Capabilities

- Integrate natural and social science, engineering, and other disciplinary approaches
- Ensure availability of observations, monitoring, and infrastructure for critical data collection and analysis
- Build capacity for climate assessment through training, education, and workforce development
- Enhance the development and use of scenarios
- Promote international research and collaboration

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The last national climate assessment report, released by the U.S. Global Change Research Program (USGCRP) in 2009, recommended research on: 1) climate change impacts on

ecosystems, the economy, health and the built environment; 2) projections of climate change and extreme events at local scales; 3) decision-relevant information on climate change and its impacts; 4) thresholds that could lead to abrupt changes in climate or ecosystems; 5) understanding the ways to reduce the rate and magnitude of climate change through mitigation; and 6) understanding how society can adapt to climate change.[1] Some of these topics have received continued or increased attention in the last five years – such as ecosystem impacts, downscaled climate projections, and mitigation options – but USGCRP plans and funding[2] have not yet focused on other topics.

This current assessment finds that significant knowledge gaps remain for all of the research priorities identified in 2009. This conclusion is reinforced by the findings of many subsequent reviews by the National Research Council (NRC) and others who have continued to identify these as priorities. For example, the NRC's America's Climate Choices Panel on Advancing the Science of Climate Change and the Panel on Informing Effective Decisions and Actions[3,4] highlighted several priorities that are relevant to climate assessments. These included the need for a more comprehensive, interdisciplinary, use-inspired, and integrated research enterprise that combines fundamental understanding of climate change and response choices; that improves understanding of human-environment systems; that supports effective adaptation and mitigation responses; and that provides better observing systems and projections (Cross-cutting Themes box).

Box: Cross-cutting Themes for the New Era of Climate Change Research Identified by America's Climate Choices

Research to Improve Understanding of Human-Environment Systems

1. Climate forcings, feedbacks, responses, and thresholds in the Earth system
2. Climate-related human behaviors and institutions

Research to Support Effective Responses to Climate Change

3. Vulnerability and adaptation analyses of coupled human-environment systems
4. Research to support strategies for limiting climate change
5. Effective information and decision support systems

Research Tools and Approaches to Improve Both Understanding and Responses

6. Integrated climate observing systems
7. Improved projections, analyses, and assessments

Source: America's Climate Choices, Advancing the Science of Climate Change, National Academy of Sciences 2010, p. 92.[5]

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The U.S. Global Change Research Program's 2012-2021 Strategic Plan[2] lists a number of strategic goals and objectives for advancing science, informing decisions, conducting sustained assessments, and communicating and educating about global change. The plan includes research priorities to understand Earth system components, their interactions, vulnerability and resilience, advance observations, modeling, and information management, and evaluate assessment processes and products.

This chapter focuses specifically on the research identified through the National Climate Assessment process as needed to improve climate assessments. It is not intended to cover the full range of goals and related research priorities of the USGCRP and other groups, but instead to focus on research that will improve ongoing assessments. Therefore, many USGCRP priorities for climate change and global change science more broadly are not reflected here. The chapter does, however, directly support the USGCRP Strategic Plan's sustained assessment activities (USGCRP Strategic Plan box).

Box: USGCRP Strategic Plan

Conduct Sustained Assessments: Build sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities.

The USGCRP will conduct and participate in national and international assessments to evaluate past, current, and likely future scenarios of global change and their impacts, as well as how effectively science is being used to support and inform the United States' response to change. The USGCRP will integrate emerging scientific understanding of the Earth system into assessments and identify critical gaps and limitations in scientific understanding. It will also build a standing capacity to conduct national assessments and support those at regional levels. The USGCRP will evaluate progress in responding to change and identify science and stakeholder needs for further progress. The program will use this regular assessment to inform its priorities.

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We identify five priority research goals and five additional priorities for foundational cross-cutting capabilities necessary to advance future climate and global change assessments. This chapter is not intended to prescribe a specific research agenda but summarizes the research needs and gaps that emerged during development of this Third National Climate Assessment report that are relevant to the development of future USGCRP research plans.

During the development of this report, the authors were concerned that several important topics could not be comprehensively covered in the present report. In addition, several commenters noted the absence of these topics and felt that they were critical to consider in future reports. These include analyses of the economic costs of climate change impacts (and the associated benefits of mitigation and adaptation strategies); the implications of climate change for U.S. national security as a topic integrated with other regional and sectoral discussions; and the interactions of adaptation and mitigation options, including consideration of the co-benefits and potential unintended consequences of particular decisions.

Priority Research Goals

Research Goal 1: Improve understanding of the climate system and its drivers

Research investments across a broad range of disciplines are critically important to building understanding of, and in some cases reducing uncertainties related to, the physical and human-induced processes that govern the evolution of the climate system. This assessment demonstrates

the continued need for high quality data and observations, analysis of Earth system processes and changes, and modeling that increases understanding and projections of climate change across scales. Social science research is also essential to improved understanding and modeling of the drivers of climate change, such as energy use and land-use change, as well as understanding impacts (see Research Goal 2). Assessing a changing climate requires understanding the role of feedbacks, thresholds, extreme events, and abrupt changes and exploring a range of scenarios (see Priorities for Cross-cutting Research Capabilities section) that drive changes in the climate system.

This assessment reveals several research needs including:

- **Continue efforts to improve the understanding, modeling, and projections of climate changes,** especially at the regional scale, including driving forces of emissions and land use change. In particular, changes in temperature, precipitation, soil moisture, runoff, groundwater, evapotranspiration, permafrost, ice and snow cover, sea level change and ocean processes and chemistry need more work;
- **Improve characterization of important sources of uncertainty, including feedbacks and possible thresholds in the climate system** associated with changes in clouds, land and sea ice, aerosols (tiny particles in the atmosphere), greenhouse gases, land use and land cover, emissions scenarios, and ocean dynamics;
- **Develop indicators that allow for timely reporting and enhanced public understanding** of climate changes and that allow anticipation and attribution of changes, including abrupt changes and extreme events in the context of a changing climate; and
- **Advance understanding of the interactions of climate change and natural variability** at multiple time scales, including seasonal to decadal changes (and consideration of climate oscillations including the El Niño Southern Oscillation, Pacific Decadal Oscillation, and the North Atlantic Oscillation), and extreme events (such as hurricanes, droughts, and floods).

Research Goal 2: Improve understanding of climate impacts and vulnerability

Assessing the implications of climate change for the U.S. relies not just on studies of the threats associated with changing weather patterns due to climate change and emerging chronic stresses such as sea level rise, but also on studies of who or what is exposed and sensitive to those threats, their underlying vulnerability, the associated costs, and adaptive capacity. The detailed sectoral and regional chapters of this assessment show that considerable progress has been made in understanding the extent to which natural and human systems in the U.S. are vulnerable to climate change and how these vulnerabilities combine with climatic trends and exposures to create impacts, but there is still a need to build capacity for assessing vulnerability.

This assessment suggests related research goals and activities including:

- **Maintain and expand research and development of data collection and analyses to monitor and attribute ongoing and emerging climate impacts across the U.S.,** including changes in ecosystems, pests and pathogens, disaster losses, water resources, oceans, and social, urban, and economic systems. Priorities include ensuring enhanced geographic coverage of impacts research; the assessment of economic costs and benefits, as well as comparative studies of alternative response options; social science research focused on impacts; and the use of geospatial data systems;
- **Assess the impacts of climatic extremes, high-end temperature scenarios, and abrupt climate change** on ecosystems, health, food, water, energy, infrastructure, and other critical sectors, and improve modeling capabilities to better project and understand the vulnerability and resilience of human systems and ecosystems to climate change and other stresses such as land-use change and pollution;
- **Increase the understanding of how climate uncertainties combine with socioeconomic and ecological uncertainties** to exacerbate climate impacts and identify improved ways to communicate the joint outcomes;
- **Develop measurement tools and valuation methods** for documenting the economic consequences of climate changes;
- **Expand climate impact analyses to focus on understudied but significant economic sectors** such as natural resources and energy development (for example, mining, oil, gas, and timber); manufacturing; infrastructure, land development, and urban areas; finance and other services; retail; and human health and well-being; and
- **Investigate how climate impacts are affected by, or increase inequity in, patterns of vulnerability of particular population groups** within the U.S. and abroad (for example, children, the elderly, the poor, and natural resource dependent communities).

Research Goal 3: Increase understanding of adaptation pathways

This assessment and others, including the America's Climate Choices *Adapting to the Impacts of Climate Change* report[3] and Chapter 4 (on adaptation and mitigation options and responses) of the Intergovernmental Panel on Climate Change's (IPCC) AR4 Synthesis Report,[6] identifies a broad set of research needs for understanding and implementing adaptation. These include research on adaptation processes, adaptive capacity, adaptation option identification, implementation and evaluation, and adaptive management of risks and opportunities. Important needs include research on the limits to, timing of, and trade-offs in adaptation, and understanding of how adaptation interacts with mitigation activities, other stresses, and broader sustainability issues.

This assessment suggests research activities to:

- **Identify the best practices for adaptation planning, implementation, and evaluation** across federal, state, and local agencies, tribal entities, private firms, non-governmental organizations, and local communities. This requires the rigorous and comparative analysis of the effectiveness of iterative risk management, adaptation strategies and

decision-support tools (for example, in terms of stakeholder views, institutional structures (including regional centers and multi-agency programs), cost/benefit, assessment against stated goals or social and ecological indicators, model validation, and use of relevant information, including traditional knowledge; and

- **Understand the institutional and behavioral barriers to adaptation and how to overcome them,** including revisions to legal codes, building and infrastructure standards, urban planning, and policy practices.

Research Goal 4: Identify the mitigation options that reduce the risk of longer-term climate change

The severity of climate change impacts in the U.S. and the needs for adapting to them over the longer term will depend on the success of efforts to reduce or sequester heat-trapping greenhouse gas (GHG) emissions, particularly those associated with the burning of fossil fuels but also those associated with changes in land use. Managing the consequences of climate change over this century depends on reducing concentrations of greenhouse gases, including short-lived climate pollutants such as black carbon (soot). While such efforts are necessarily worldwide, the U.S. produces a significant share of global greenhouse gases and can assist and influence other countries to reduce their emissions. Assessments can play a significant role in providing a better information base from which to analyze mitigation options.

Therefore, the mitigation section of this assessment (Ch. 27: Mitigation) noted the importance of research to understand and develop emission reductions through: 1) identifying climate and global change scenarios and their impacts; 2) providing a range of options for reducing the risks to climate and global change; and 3) developing options that allow joint mitigation-adaptation strategies, such as buildings that are more energy efficient and resilient to climate change impacts.. More generally, the America's Climate Choices report on *Limiting the Magnitude of Climate Change*[4] recommended that the U.S. promptly develop and implement appropriate strategies to reduce GHG emissions and identified important research needs, including the need to study the feasibility, costs, and consequences of different mitigation options. In addition, the report recommended research to support new technologies and the effective deployment of existing options, research into how best to monitor emissions and adherence to international policies, and research into how human behavior and institutions enable mitigation.[4]

This Third National Climate Assessment also suggests research activities to:

- **Develop information that supports analysis of new technologies** for energy production and use, carbon capture and storage, agricultural and land-use practices, and other technologies that could reduce or offset greenhouse gas emissions; research into the policy mechanisms that could be used to foster their development and implementation; analyses of the costs, benefits, trade-offs, and synergies associated with different actions and combinations of actions; and improved understanding of the potential and risks of geoengineering;

- **Investigate the co-benefits, interactions, feedbacks, and trade-offs between adaptation and mitigation** at the local and regional level, for example, in sectors such as agriculture, forestry, energy, health, and the built environment. This involves, as a priority, the assessment of the economics of impacts, mitigation, and adaptation;

- **Improve understanding of the effectiveness and timescales of mitigation measures** through deepened understanding of the relationship between the fate of human-induced and natural carbon emissions, uptake by the terrestrial biosphere and oceans, and atmospheric concentrations; and

- **Identify the critical social, cultural, institutional, economic, and behavioral processes that present barriers and opportunities for mitigation** at the federal and international level and by individuals, state and local governments and corporations**.**

Research Goal 5: Improve decision support and integrated assessment

For assessments to be useful to policy makers, they need to provide integrated results that can be used in decision-making. Research can develop tools that facilitate decision-making and the integration of knowledge.

Critical gaps in knowledge for decision support include the issues that affect the capacity of agencies, individuals, and communities to access and use the best available scientific information in support of decision-making, including the need to assess the ability of existing institutions, legal, and regulatory structures to respond to highly interdependent climate impacts. There are instances where policy barriers, institutional capacity or structure, or conflicting laws and regulations can create barriers to effective decisions. For instance, Chapter 12 (Indigenous Peoples) notes that there is no institutional framework for addressing responses to village relocation in response to climate change in Alaska,[7] and Chapter 3 (Water) points out that existing water management institutions may be inadequate in the context of rapidly changing conditions. These instances point to research to evaluate whether the existing legal and regulatory structures, largely developed to address specific issues in isolation, can adequately respond to the highly interconnected issues associated with climate change. Decision support and integrated assessment also require research into the behavioral and other factors that influence individual decisions.

Assessments can benefit from research activities that:

- **Identify decision-maker needs** within regions and sectors, and support the development of research methods, tools, and information systems and models for managing carbon, establishing early warning systems, providing climate and drought information services, and analyzing the legal, regulatory, and policy approaches that support adaptation and mitigation efforts in the context of a changing climate;

- **Develop tools to support risk-based decision processes**, including tools to identify risk management information needs, transfer vulnerability assessment techniques, and evaluate alternative adaptation options. In addition, tools are needed to improve understanding of consumption patterns and environmental consequences; effective resource management institutions; iterative risk management strategies; and social learning, cognition, and adaptive processes;

- **Improve, fill gaps, and expand research efforts to evaluate the effectiveness, costs, and benefits of mitigation and adaptation actions,** including economic and non-economic metrics that evaluate the costs of action, inaction, and residual impacts. Focus is also needed on the development of methods and baseline information supporting evaluation of completed and ongoing adaptation, mitigation, and assessment efforts that will foster adaptive learning;

- **Develop, test and, expand integrated assessment models** that link decisions about emissions with impacts under different development pathways and ways to categorize uncertainties in the supporting data.

Priorities for Cross-cutting Research Capabilities to Support Future Climate Assessments

This assessment identifies a set of five cross-cutting foundational capabilities that are essential for advancing our ability to continue to conduct climate and global change assessments and for addressing the five research goals.

1. Integrate natural and social sciences, engineering, and other disciplinary approaches

Continued advances in comprehensive and useful climate assessments will rely on additional interdisciplinary research. Understanding of the coupled human-environment system is enriched by combining research from natural and social sciences with research and experience from the engineering, law, and business professions. Since human activities and decisions are driving many Earth system processes, models and observations of natural and social changes at planetary, regional, and local scales are needed to understand how climate is changing, its impacts on people and environments, and how human responses feedback on the Earth system. Building experienced interdisciplinary research teams that are able to understand each other's theories, methods, and language as well as the needs of stakeholders will allow for more rapid and effective assessments.

Interdisciplinary research is needed, for example, to:

- Understand how hydrological drivers of water supply interact with changing patterns of water demand and evolving water management practices to increase risks of drought, or influence the effectiveness of adaptation and mitigation options;

- Understand climate change in the context of multiple stresses on Earth, ecological, and human systems;

- Bring together economic and quantitative assessment of climate impacts and policies with other more qualitative assessments that include non-market and cultural values; and

- Integrate the understanding of human behavior, engineering, and genomics to expand the range of choice in responding to climate change by providing and thoroughly evaluating new options for adaption and mitigation that improve economic development, energy, health, or food security.

2. Ensure availability of observations, monitoring, and infrastructure for critical data collection and analysis

Our understanding and ability to assess changes in climate and other global processes is based on a comprehensive and sustained system of observations that document the history of climate and related changes at spatial and time scales relevant to global, regional, and sectoral needs. The most recent USGCRP Strategic Plan[2] states that to advance scientific knowledge of an integrated natural and human Earth system, an interoperable and integrated observational, monitoring, and data access capability is also essential. This observational capability is needed to gain the fundamental scientific understanding of essential status, trends, variability, and changes in the Earth system. It should include the physical, chemical, biological, and human components of the Earth system over multiple space and time scales.

To attain their full value, observational systems must provide data that are responsive to the needs of decision-makers in government, industry, and society. These needs include observations and data that can inform the nation's strategies to respond to climate and global change, including, for example, efforts to limit emissions, monitor public health, capture and store carbon, monitor changes in ocean processes, and implement adaptation strategies. This will require establishing explicit baseline conditions, specifying spatial detail and temporal frequency of observations, including social data, and setting standards for metadata (information about collected data), interoperability, and regulatory and voluntary reporting, such as those outlined in the Informing an Effective Response to Climate Change Panel Report of the National Research Council's Americas Climate Choices series.[8] These data need to be openly and widely available in order to support the best and most comprehensive science and for use in decision-making by a range of stakeholders.

This assessment shows that additional research and development will be necessary to ensure that the scope and integration of relevant scientific data improves overall utility for decision-makers, including better ways to communicate metadata, data quality, and uncertainties. The observations must include critical geophysical variables such as temperature, precipitation, sea level changes, ocean circulation, atmospheric composition, and hydrology; the essential parameters that describe the biosphere; and social science information on drivers, impacts, and responses to climate and other global changes. More comprehensive and integrated data capabilities are needed to document the processes and patterns that drive natural and social feedbacks and better describe the mechanisms of abrupt change. Progress is needed in particular for data-poor regions, focusing on poorly documented socioeconomic, ecological, and health-related factors, and under-observed regional and sectoral data. There are opportunities to take advantage of citizen science observations where appropriate; monitor system resilience and robustness; and attend to physical and social systems that are not currently observed with sufficient temporal or spatial resolution to enable vulnerability analysis and decision support at regional and sectoral scales. More explicitly, strategic redesign of our nation's observations, monitoring, and data capabilities should be considered in order to:

- **Sustain and strengthen the nation's capacity to observe** long-term changes in the Earth system and improve fundamental understanding of the complex causes and

consequences of global change, including integration of essential socioeconomic, health, and ecological observations;

- **Maintain and expand advanced modeling capability**, including high-performance computing infrastructure, new investments in analysis of large and complex data sets, comprehensive Earth system and integrated assessment models, reanalysis, verification, and model comparisons;

- **Better integrate observations and modeling** to advance scientific understanding about past, present, and future climate within government, industry, and civil society; and

- **Develop more fully the components and structure of a national climate and global change indicator system** to support assessment that includes indicators of climate change, impacts, vulnerabilities, opportunities, and preparedness as well as trends and changes in land use, air and water pollution, water supply and demand, extreme events, diseases, public health, and agronomic data, coastal and ocean conditions (such as marine ecosystem health, ocean acidity, sea level, and salinity), cryosphere data (such as snow, sea ice conditions, ice sheets and glacier melt rates), and changes in public attitudes and understanding of climate change. All of these are important to assessing climate change, and should eventually be developed at local, as well as national and regional levels in collaboration with local agencies.

3. Build capacity for climate assessment through training, education, and workforce development

Building human capacity for improved assessments requires expansion of skills within the existing public and private sectors and developing a much larger workforce that excels at critical and interdisciplinary thinking. Useful capacities include the ability to facilitate and communicate research and practice, manage collaborative processes to allow for imaginative analysis and solutions, develop sustainable technologies to reduce climate risks, and build tools for decision-making in an internationally interdependent world. A deeper understanding of the processes and impacts of climate change, disaster risk reduction, energy policy impacts, ecosystem services and biodiversity, poverty reduction, food security, and sustainable consumption requires new approaches to training and curriculum, as well as research to evaluate the effectiveness of different approaches to research and teaching.

Assessments will benefit from activities that:

- **Strengthen approaches to education about climate, impacts, and responses** including developing and evaluating the best ways to educate in the fields of science (natural and social), technology, engineering, and mathematics and related fields of study (such as business, law, medicine, and other relevant professional disciplines). Ideally, such training would include a deeper understanding of the climate system, natural resources, adaptation and energy policy options, and economic sustainability, and would build capacity at colleges and institutions, including minority institutions such as tribal colleges; and

- **Identify increasingly effective approaches to developing a more climate-informed society** that understands and can participate in assessments, including alternative media and methods for communication; this could also include a program to certify climate interpreters to actively assist decision-makers and policymakers to understand and use climate scenarios.[8]

4. Enhance the development and use of scenarios

Scenarios are "coherent, internally consistent and plausible descriptions of possible future states of the world"[9] that provide reasoned projections of energy and land use, future population levels, economic activity, the structure of governance, social values, and patterns of technological change. They survey, integrate, and synthesize science, within and among scientific disciplines and across sectors and regions. Such scenarios are essential tools that enable projections of emissions, climate, vulnerabilities, and global change. They are indispensable for linking science and decision-making and for assessing choices about America's climate future. Stakeholders and scientists within this assessment identified a need for more fully developed scenario-building capabilities that better enable assessments at regional and sectoral scales in timeframes of relevance to policy and decision-making and that more effectively reflect climate and global change at these scales.

Achieving capacity in scenario development will:

- **Enhance understanding of how and why climate may change and its implications,** especially at the regional scale. For example, a set of scenarios can be used to better understand the way energy, land use, and policy choices create alternative emissions pathways; how changes at global scales can be downscaled to estimate local climate possibilities; how various socioeconomic development pathways increase or decrease climate vulnerability; and to assess alternative strategies for reducing emissions and implementing adaptation; and
- **Develop new methods, tools, and skills for applying scenarios to policy development** at local levels in order to broaden society's understanding of a changing climate and to analyze the full range of policy choices. In addition, improve capabilities in integrated assessment modeling to inform policy analysis and allow stakeholders to co-produce information and explore options for local and national decisions.

5. Promote international research and collaboration

Research efforts in support of climate assessment are very dependent on the international research community. International teams conduct Earth system monitoring and analysis using observing systems that cannot be funded and maintained by any one country alone. Many of the impacts of climate change in the U.S. are closely linked to how climate affects other parts of the world. There is general understanding that impacts of climate change on U.S. socioeconomic systems are mediated or amplified through globally connected commodity chains and prices; more detailed research on climate change and its impacts elsewhere is needed to provide accurate assessments of what will happen to U.S. regional and local economies. The U.S. has the capacity to leverage investments in collaborative international climate and global change scientific research efforts, examples of which include IGBP (International Geosphere-Biosphere

Programme), WCRP (World Climate Research Programme), DIVERSITAS, IHDP (International Human Dimensions Programme) (as they evolve into or in affiliation with the new Future Earth program), and IGFA (International Group of Funding Agencies for Global Change Research).

Supporting international collaborative research will:

- **Contribute to international systems of data collection, monitoring, indicators, and modeling** that closely track and project changes in Earth system dynamics, climate, human drivers, and climate impacts that are needed for national and international assessments;
- **Assess the implications of climate change for globally shared common resources** such as the oceans, polar regions, and migratory species; and
- **Fill important gaps in understanding of how climate change in other countries** affects U.S. food, energy, health, manufacturing, and national security.

Conclusions

This chapter summarizes research recommendations across a broad range of topics – research that the assessment authors deem essential to support future assessments. The authors recognize that federal agencies and others are making progress on many of these research areas and that sustained assessment is included in the goals of the USGCRP.

While the research goals discussed in this chapter are not ranked, criteria for setting the research priorities to improve assessments are proposed. The nation's federal research investments in support of the sustained assessment strategy should be designed to enhance and extend substantively the nation's ability to limit climate-related risk and increase the utility of scientific understanding in supporting decisions.

The following criteria should be considered in establishing research priorities that support assessments:

- **Promote understanding of the fundamental behavior of the Earth's climate and environmental systems:** The consequences of climate variability and change will require enhanced investment in use-inspired research using both fundamental and applied analysis, providing a foundation for the nation's sustained assessment process;
- **Promote understanding of the socioeconomic impacts of a changing climate:** Provide comprehensive understanding, including the development of indicators of the impacts and consequences of climate variability and change for all regions and sectors within the U.S.;
- **Build capacity to assess risks and consequences:** Support improved, timely, and accessible estimations and predictions of climate and other global change risks, their consequences and relevance for stakeholders, associated costs and benefits, and interactions with other stresses;
- **Support research that enables infrastructure for analysis:** Sustain and expand critical infrastructure, including observations and data essential to monitoring trends, projecting

climate risks, and evaluating the effectiveness of responses in decision-making and policy implementation;

- **Build decision-support capacity:** Build the knowledge base essential for decision support including developing and evaluating climate mitigation and adaptation solutions, technology innovation, institutions, and behavioral change; and
- **Support engagement of the private sector and investment communities:** Develop strategies to leverage federal research investments by engaging the private sector more fully in research and technology development, including partnerships with the nation's universities and scientific research institutions, to address critical gaps in knowledge and to build the nation's future scientific, technical, and sustained assessment capacities.
- **Leverage private sector, university and international resources and partnerships:** Take advantage of topics and expertise where the U.S. can leverage and complement private sector and university capabilities, obtain return on research investments, and lead internationally on research investment efforts; build capacity through education and training; support humanitarian response; and fill critical gaps in global knowledge of relevance to the U.S.

Traceable Accounts

Chapter 29: A research agenda to support US climate assessments

Chapter Process:

The author team asked each of the other chapter author teams to identify important gaps in knowledge and key research needs in the course of writing their chapters, particularly in the context of the needs for research to support future assessments. In addition to the lists provided by each chapter author team, the team also drew on analyses from over 100 technical and public review suggestions and a wide variety of technical and scholarly literature, especially the U.S. Global Change Research Program's Strategic Plan[2] and the National Research Council's America's Climate Choices reports,[3,4,5,8,10] to compile a potential research agenda. Using expert deliberation, including a number of teleconference meetings and email conversations among author team members, the author team agreed on high-priority research needs, organized under five research goals.

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