The Climate Impacts Group, a CCSP-supported Regional Integrated Sciences and Assessments (RISA) team, and King County, Washington's Climate Team created a guidebook on preparing for and adapting to climate change. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* recommends a detailed, easy-to-understand process for climate change preparedness based on familiar resources and tools.[41] Local Governments for Sustainability contributed to the production and dissemination of the guidebook to make it accessible to local governments across the United States. The results of this guidebook will be used in future planning for sectoral work on urban issues.

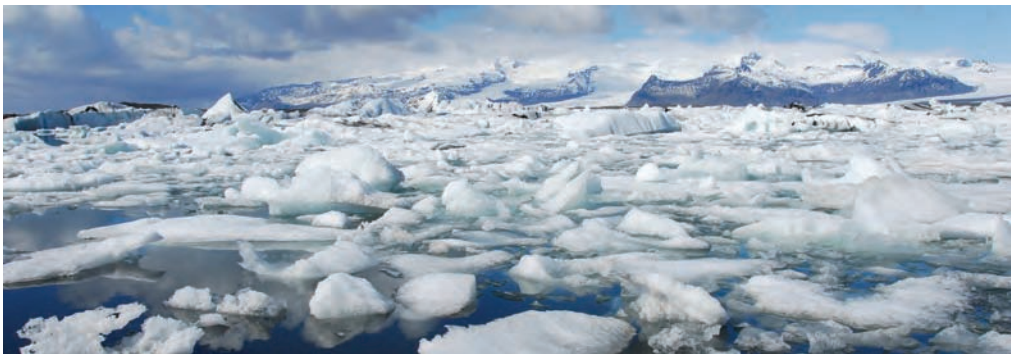
## CCSP FY 2009 Key Interagency Implementation Activities

The program's long-term vision, mission, goals, and objectives are described in the CCSP Strategic Plan. Implementation of this long-term plan occurs through agency activities that often benefit significantly from ongoing CCSP-facilitated coordination. CCSP has identified several key areas for FY 2009 that require particularly strong interagency coordination to achieve success; they cannot be adequately addressed by one agency alone. Although these priorities are only a small part of the overall program, they are vital mechanisms through which CCSP will continue to integrate agency activities to create knowledge and products that are greater than the sum of the individual agency inputs. The development of CCSP interagency priorities is the result of a variety of planning processes, including planning processes within the 13 CCSP agencies (see Appendix A) and interagency planning conducted by the CCSP Interagency Committee (i.e., the Subcommittee on Global Change Research) and its subsidiary Interagency Working Groups. CCSP's interagency planning is informed by external advice from several NRC committees. CCSP's annual implementation priorities are logical evolutions of the program's interagency approaches to the priorities established in the CCSP Strategic Plan. The selection criteria for these activities require that they are founded upon a solid intellectual basis and are of high scientific quality; require coordination and/or integration across multiple CCSP agencies to create value-added products and services that cannot be created by any one agency alone; improve the characterization of key areas of scientific uncertainty and/or improve decision-support tools; provide a timely response to a particular need or leveraging opportunity; and are cost-effective.

The interagency implementation priorities generally represent only a fraction of CCSP's portfolio. The focus areas are listed here in an order similar to the research elements described in the CCSP Strategic Plan. However, due to their integrative nature they do not follow a one-to-one mapping to the research elements.

*Quantification of Climate Forcing and Feedbacks by Aerosols, Non-$CO_2$ Greenhouse Gases, Water Vapor, and Clouds.* This research will continue to use an array of observational approaches (satellite, intensive field campaigns using aircraft, ships, and balloons, and ground-based *in situ* and remote sensing networks) to quantify the abundances of atmospheric climate forcing agents and their precursors. The observations are being coupled with modeling analyses and laboratory studies to quantify the interrelated chemical and physical processes that control the magnitude and distribution of aerosols, clouds, tropospheric ozone, non-$CO_2$ trace gases, and water vapor. Developing an integrated understanding of the chemical and physical processes that determine the distribution and properties of these atmospheric constituents is a primary research emphasis, in order to improve the spatial and temporal representation of these atmospheric constituents in models and to improve the ability of those models to simulate current and future climate.

*Assessing Abrupt Change in a Warming Climate: Examining the Feasibility of Developing an Abrupt Change Early Warming System.* Paleoclimate research provides abundant evidence that major shifts in regional and global climate have occurred in the past over periods as short as a few years to decades. Previous work has focused on two primary areas: paleoclimate reconstructions to provide insight into past abrupt climate events, and mechanistic studies of potential causes for rapid changes. Paleoclimate studies have highlighted the importance of changes in the Atlantic meridional overturning circulation (sometimes called the thermohaline circulation) in producing past abrupt climate changes. Climate modeling studies have suggested specific mechanisms for producing such changes, especially varying freshwater inputs into the North Atlantic. Rapid changes are now being observed in high-latitude regions, especially in summer Arctic sea ice, but the future implications of these changes are uncertain. Observational evidence indicates that the mass of large ice sheets in Greenland and Antarctica has decreased in recent years, contrary to projections described in the IPCC Third Assessment Report. The reasons for these decreases are not well understood, but if they continue to increase they will have important implications for future rates of sea-level rise.



While considerable progress has been made in these and other areas, significant gaps remain that limit ability to provide early warning assessments of the likelihood of future abrupt climate change, either globally or over the United States, within this century. Addressing these gaps will require a focused national effort that includes collaboration across multiple agencies. Key elements include (1) an integrated Earth system observational analysis capability that will serve as a primary means for detecting and monitoring rapid changes in the Earth system, and that will provide the observational foundation for developing an abrupt change early warning system; (2) an improved decadal forecasting capability that blends predictions of natural variability together with scenarios of future radiative forcing to improve estimates of the likelihood of near-term rapid changes; (3) a vigorous paleoclimate research program to reconstruct and analyze causes of past abrupt climate changes; and (4) accelerated efforts to determine implications for society and ecosystems of abrupt change.

*Development of an Integrated Earth System Analysis Capability: A Focus On Creating a High-Quality Record of the State of the Atmosphere and Ocean since 1979.* A national capacity for Integrated Earth System Analysis (IESA) is being developed that extends beyond current attempts to map individual components of the Earth system separately. Such a capacity is a fundamental prerequisite to understanding the coupling of, and feedbacks within, the Earth system (i.e., the atmosphere, ocean, land surface, and cryosphere, including their physical, chemical, and biological components). It is also fundamental to advancing climate prediction capabilities, whether on seasonal or multi-year to decadal time scales, because these predictions intrinsically involve coupling of Earth system components. Moreover, an IESA capability is required to realize the full value of measurements made by GEOSS.

*Development of an End-to-End Hydrologic Projection and Application Capability.* The development of an end-to-end water cycle/hydrologic projection and application capability will require improvements in (1) the characterization and parametric representation of water cycle processes in Earth system models; (2) the ability to downscale output from global Earth system models to improve the quality of the input used in hydrologic modeling at watershed and river basin scales; and (3) guidance on how to effectively use hydrologic model output to inform specific, long-term hydrology-related planning and policy decisions. This set of activities will examine the reliability and uncertainties in U.S. outcomes from different climate forcing scenarios, and will explore different approaches for making projections of surface and subsurface hydrologic conditions for the coming decades. Outputs will include improved parameterizations and projections of soil moisture, surface runoff and river flows, groundwater recharge, and base flow that characterize not only changes in the mean state, but also possible changes in patterns of variability. This activity will use a broad range of specific

decisionmaking contexts as prototypes to explore approaches for improving the use of research outputs to inform decisionmaking related to long-term hydrologic changes. These decisionmaking contexts include not only water resource planning, but also other sectors that are affected by changes in hydrologic conditions. One specific example is the set of effects on public health, including the effects of changing hydrologic conditions on the abundance and distribution of disease vectors and on water quality.

*Enhanced Carbon Cycle Research on High-Latitude Systems.* There is evidence that warming is occurring in some high-latitude areas, and published research suggests that it may be affecting ecosystem function and structure. The IPCC Fourth Assessment Report stated that average Arctic temperatures increased by nearly twice the global average rate over the past 100 years, and that sea ice extent decreased on average by 2.7% per decade since 1978. Temperatures at the top of the permafrost layer have generally increased by up to 3°C since the 1980s. High-latitude temperature increases, predicted by most general circulation models, may influence carbon storage and release in both Arctic and sub-Arctic soils and ecosystems. Since these ecosystems contain nearly 40% of the global soil carbon that could potentially influence climate change, thawing associated with the predicted temperature increases could produce a substantial release of $CO_2$ and methane to the atmosphere and oceans, further perturbing climate. Although it is highly uncertain at what rate these gases might be released, it has been suggested that the release could occur relatively rapidly. High-latitude warming also affects the ability of the polar oceans to absorb $CO_2$ and other greenhouse gases.

*Ecological Forecasting.* The CCSP ecosystems component addresses three high-level research goals: (1) improve understanding of the feedbacks between ecosystems and global change, especially climate change; (2) determine potential consequences of global change for ecosystems; and (3) provide options for sustaining and improving ecosystems and their provision of goods and services. This requires the development of ecological forecasting capabilities to test understanding of these feedbacks, making projections of the potential consequences, and assessing the ability of various policy options and decisions to sustain and improve ecosystems of concern. Ecological forecasting will require advances in experimental ecological research, advances in ecological observing networks, and scientific synthesis across the

physical, biological, and social sciences. Successful ecological forecasting will be related to interdisciplinary work across the CCSP working groups in order to understand and project the potential effects of human interactions with natural systems and the feedbacks from these interactions. There will no doubt be limits to what can be forecast, but discovering these limits and their causes will only enhance overall understanding of the ecosystems to manage and preserve. Likewise, explicit statements regarding uncertainties and estimates of error associated with the forecasts are essential. An FY 2009 priority for enhancing the ability to generate reliable ecological forecasts should take advantage of the full suite of research supported by the Ecosystems Interagency Working Group membership. Ecological forecasts will allow the incorporation of observations, experimental results, process studies, and modeling activities at a wide variety of scales ranging from molecular through regional and even global, addressing the needs of basic science researchers, and the agencies that support them. Development of these ecological forecasts also fulfills the requirements of natural resource managers and policymakers who seek to understand the effects of particular policies or management approaches on ecosystem function. Improved ecological forecasting capabilities will play an important role in informing decisionmakers about the potential effects of climate change and in supporting the development of policy instruments and management actions to address anticipated ecosystem changes.

## Decision Support: Information to Support Policy Development and Adaptive Management

CCSP sponsors and conducts research that is ultimately related to policy and adaptive management decisionmaking. CCSP's decision-support approach is guided by several general principles, including:

- Early and continuing involvement of stakeholders
- Explicit treatment of uncertainties
- Transparent public review of analysis questions, methods, and draft results
- Evaluation of lessons learned from ongoing and prior decision-support and assessment activities.

### Synthesis and Assessment Products

As noted previously, CCSP is generating a suite of synthesis and assessment products that integrate research results focused on key issues and related questions frequently raised by decisionmakers. Current evaluations of the science can be used for informing public debate, policy development, and adaptive management decisions and for defining