Integrating Climate and Global Change Research

CCSP integrates the USGCRP, which was mandated by Congress in the Global Change Research Act of 1990 (P.L. 101-606, 104 Stat. 3096-3104), and the CCRI, which was established by President Bush in 2001, to improve understanding of uncertainties in climate science, expand global observing systems, develop science-based resources to support policymaking and resource management, and communicate findings broadly among scientific and stakeholder communities. Thirteen departments and agencies of the U.S. Government participate in CCSP, including:

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

DEFINITION OF KEY TERMS

Adaptation
Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Climate
The statistical description of the mean and variability of relevant measures of the atmosphere-ocean system over periods of time ranging from weeks to thousands or millions of years.

Climate Change
A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or to external forcing, including changes in solar radiation and volcanic eruptions, or persistent human-induced changes in atmospheric composition or in land use.

Climate Feedback
An interaction among processes in the climate system in which a change in one process triggers a secondary process that influences the first one. A positive feedback intensifies the change in the original process, and a negative feedback reduces it.

Climate System
The highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface, the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations, and human-induced forcings such as the changing composition of the atmosphere and land-use change.

Climate Variability
Variations in the mean state and other statistics of climatic features on temporal and spatial scales beyond those of individual weather events. These often are due to internal processes within the climate system. Examples of cyclical forms of climate variability include the El Niño Southern Oscillation, the North Atlantic Oscillation, and the Pacific Decadal Oscillation.

Decision-Support Resources
The set of observations, analyses, interdisciplinary research products, communication mechanisms, and operational services that provide timely and useful information to address questions confronting policymakers, resource managers, and other users.

Global Change
Changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life (from the Global Change Research Act of 1990, PL 101-606).

Mitigation
An intervention to reduce the human-induced factors that contribute to climate change. This could include approaches devised to reduce emissions of greenhouse gases to the atmosphere; to enhance their removal from the atmosphere through storage in geological formations, soils, biomass, or the ocean; or to alter incoming solar radiation through several "geo-engineering" options.

Observations
Standardized measurements (either continuing or episodic) of variables in climate and related systems.

Prediction
A probabilistic description or forecast of a future climate outcome based on observations of past and current climatological conditions and quantitative models of climate processes (e.g., a prediction of an El Niño event).

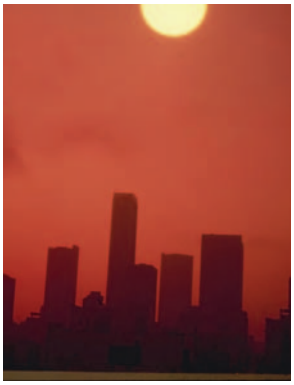
Projection
A description of the response of the climate system to an assumed level of future radiative forcing. Changes in radiative forcing may be due to either natural sources (e.g., volcanic emissions) or human-induced factors (e.g., emissions of greenhouse gases and aerosols, or changes in land use and land cover). Climate "projections" are distinguished from climate "predictions" in order to emphasize that climate projections depend on scenarios of future socioeconomic, technological, and policy developments that may or may not be realized.

Weather
The specific condition of the atmosphere at a particular place and time, measured in terms of variables such as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation.

In addition, the Executive Office of the President and other related programs have designated liaisons who participate on the CCSP Interagency Committee, including:

- Office of Science and Technology Policy (OSTP)
- Council on Environmental Quality (CEQ)
- Office of Management and Budget (OMB)
- Climate Change Technology Program (CCTP)
- Office of the Federal Coordinator for Meteorology (OFCM)
- National Institute of Standards and Technology (NIST).

Appendix A, "The Climate Change Science Program Participating Agencies," contains information about the specific missions and roles of each agency participating in CCSP. Appendix B, "Climate Change Science Program FY 2006 Budget Tables," in the insert pocket, contains budgetary analyses of the program grouped by agency as well as a program-wide interagency cross-cut grouped by the strategic goals and research elements of CCSP as described in the *Strategic Plan for the U.S. Climate Change Research Program* published in July 2003.

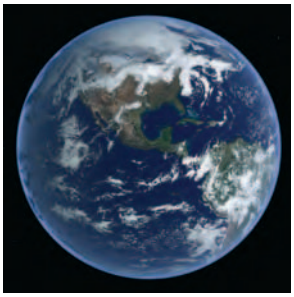


As a multi-agency program, CCSP harnesses the unique approaches and missions of its participating agencies to encourage research that leads to expanded and new results. A significant challenge that arises from working across many agencies is integrating climate and global change research to develop a comprehensive view of climate change and its potential significance. CCSP adds value to the individual Earth and climate science missions of its 13 participating agencies and their national and international partners by coordinating research and facilitating integration of information to achieve results that no single agency, or small group of agencies, could attain.

CCSP relies not only on the agency programs stated in its budget cross-cut, but also on agency activities that are not formally included in the CCSP budget. Examples of these directly related activities are NOAA's long-term surface, balloon, and satellite-based meteorological observations; surface hydrological and satellite land-cover observations from USGS; and future satellite measurement programs including the tri-agency (NOAA, DOD, NASA) National Polar-Orbiting Operational Environmental Satellite System (NPOESS) and the planned multi-program implementation of continuity of Landsat observations. Without input from activities such as these, CCSP would be unable to fulfill its mission.

CCSP also relies on and provides input to other major interagency programs that observe and study particular aspects of the environment and associated human activities.

Foremost among these is the Climate Change Technology Program, which develops and studies technological options for responding to climate change. A key observational linkage is with the U.S. Integrated Earth Observation System, which is part of the international Global Earth Observation System of Systems. CCSP is also linked to another set of activities articulated in the Ocean Action Plan recently released by the Cabinet-level Committee on Ocean Policy. Connections to programs such as these allow CCSP and its partners to leverage their resources to derive mutual benefits from advances in any one program.



Coordinating Research Elements

Efforts to foster integration occur on many levels. One is improving coordination of scientific research and the flow of information through interdisciplinary and interagency working groups focused on each of seven main "research elements" of the program plus a number of cross-cutting activities or themes. CCSP's research elements include atmospheric composition, climate variability and change, the global water cycle, land-use and land-cover change, the global carbon cycle, ecosystems, and human contributions and responses to environmental change. For each of the research elements, recent highlights and program plans for FY 2006 are described in subsequent chapters of this report. The budget tables appendix contains information on the CCSP budget by research element. This budget cross-cut illustrates integrative management of the program that starts from research-driven requirements and extends to coordinated planning to distribute and integrate work efficiently across CCSP's participating agencies.

Integration through Products Addressing CCSP Goals

CCSP seeks to integrate basic research in a variety of products related to the five goals of the program. These goals span the full range of climate-related issues, including natural climate conditions and variability; forces that influence climate, including cycles and processes that affect atmospheric concentrations of greenhouse gases and aerosols; climate responses; consequences for ecosystems, society, and the economy; and application of knowledge to decisionmaking. This comprehensive characterization provides a useful organizing scheme for examining key climate change issues. The accompanying box identifies the program's goals and examples of key research focus areas.

For the first time, the FY 2006 edition of *Our Changing Planet* provides a budget cross-cut of the program organized by CCSP goal. This new analysis of the program is introduced in the next section of this chapter and is contained in the budget tables appendix.

CCSP GOALS AND EXAMPLES OF KEY RESEARCH FOCUS AREAS

Goal 1: Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.

- Better understand the natural long-term cycles in climate (e.g., Pacific Decadal Oscillation, North Atlantic Oscillation).
- Improve and harness the capability to forecast El Niño and La Niña events and other seasonal-to-interannual cycles of variability.
- Sharpen understanding of climate extremes through improved observations, analyses, and modeling, and determine whether any changes in their frequency or intensity lie outside the range of natural variability.
- Increase confidence in the understanding of how and why climate has changed.
- Expand observations and data/information system capabilities.

Goal 2: Improve quantification of the forces bringing about changes in the Earth's climate and related systems.

- Reduce uncertainty about the sources and sinks of greenhouse gases, emissions of aerosols and their precursors, and their climate effects.
- Monitor recovery of the ozone layer and improve understanding of the interactions among climate change, ozone depletion, and other atmospheric processes.
- Increase knowledge of the interactions among pollutant emissions, long-range atmospheric transport, climate change, and air quality management.
- Develop information on the carbon cycle, land cover and use, and biological/ecological processes by helping to quantify net emissions of carbon dioxide, methane, and other greenhouse gases, thereby improving the evaluation of carbon sequestration strategies and alternative response options.
- Improve capabilities to develop and apply emissions and related scenarios for conducting "If…, then…" analyses in cooperation with CCTP.

Goal 3: Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.

- Improve characterization of the circulation of the atmosphere and oceans and their interactions through fluxes of energy and materials.
- Improve understanding of key "feedbacks" including changes in the amount and distribution of water vapor, extent of ice and the Earth's reflectivity, cloud properties, and biological and ecological systems.
- Increase understanding of the conditions that could give rise to events such as rapid changes in ocean circulation owing to changes in temperature and salinity gradients.
- Accelerate incorporation of improved knowledge of climate processes and feedbacks into climate models to reduce uncertainty about climate sensitivity (i.e., response to radiative forcing), projected climate changes, and other related conditions.
- Improve national capacity to develop and apply climate models.

Goal 4: Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.

- Improve knowledge of the sensitivity of ecosystems and economic sectors to global climate variability and change.
- Identify and provide scientific inputs for evaluating adaptation options, in cooperation with mission-oriented agencies and other resource managers.
- Improve understanding of how changes in ecosystems (including managed ecosystems such as croplands) and human infrastructure interact over long periods of time.

Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

- Support informed public discussion of issues of particular importance to U.S. decisions by conducting research and providing scientific synthesis and assessment products.
- Support adaptive management and planning for resources and physical infrastructure affected by climate variability and change; build new partnerships with public and private sector entities that can benefit both research and decisions.
- Support policymaking by conducting comparative analyses and evaluations of the socioeconomic and environmental consequences of response options.

CCSP products include synthesis and assessment reports (see chapter on "Decision-Support Resources Development and Related Research on Human Contributions and Responses"), as well as numerous scientific deliverables that are described in the *Strategic Plan for the U.S. Climate Change Research Program*, issued in July 2003. The research element chapters of this report include updates on the preparation of CCSP research products, milestones, and activities, with reference to the research focus areas for each goal. These products and activities integrate research from many disciplines conducted or supported across the participating agencies.

Integrating research and observational approaches across disciplinary boundaries is essential for understanding how the Earth system functions and how it will change in response to future forcing. This is due to the interconnectedness among components of the Earth system, which often relate to each other through feedback loops. Interdisciplinary interactions in CCSP are scaled to the nature of the problem. In some cases, the necessary science may be conducted within a small set of disciplines, such as those required to improve understanding of cloud microphysics. In other cases, highly interdisciplinary approaches are required, such as in the case of making projections about the future state of the Earth system and analyzing their implications. In the latter example, expertise ranging from the social sciences to atmospheric dynamics and chemistry to oceanography to the biological sciences is required.

Interdisciplinary research is only one aspect of the integration facilitated by CCSP. Integration in CCSP also refers to the steps being taken to create more seamless approaches between the theory, modeling, observations, and applications that are required to address the multiple scientific challenges being confronted by CCSP. Finally, integration in CCSP also refers to the enhancement of cooperation across agencies toward meeting the objectives articulated in the *CCSP Strategic Plan*.

The accompanying box provides one example of how different research elements may help address a key uncertainty. This example illustrates some of the key scientific issues within each of the CCSP research elements that need to be coordinated within the Global Carbon Cycle research element to improve future projections of atmospheric carbon dioxide (CO_2) levels.

Program Management

As described in the *CCSP Strategic Plan*, CCSP employs a management approach that integrates the planning and implementation of individual climate and global change research programs of the participating Federal agencies and departments to reduce overlaps, identify and fill programmatic gaps, and synthesize products and deliverables

INTEGRATING ACROSS RESEARCH ELEMENTS TO IMPROVE PROJECTIONS OF CARBON DIOXIDE CONCENTRATIONS

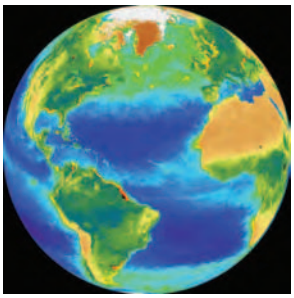
CCSP research on carbon dioxide (CO_2) is coordinated through its Global Carbon Cycle research element. The success of that research element's ability to improve projections of future CO_2 concentrations depends significantly on inputs from and coordination with all of the program's other research elements. This includes consolidating and improving understanding of past and current CO_2 concentrations; past, current, and future sources and magnitudes of emissions and sinks; processes that transport CO_2; processes that remove it from the atmosphere; and integrative modeling of these processes. A few examples are provided below of the types of scientific research from each CCSP research element that must be advanced and coordinated with the Global Carbon Cycle research element to improve projections of CO_2 concentrations.

- *Atmospheric Composition* – Although the measurement of the distribution of CO_2 and methane in the atmosphere is a major component of the CCSP Global Carbon Cycle research element, identifying and understanding sources and sinks of these gases is augmented by information on other atmospheric constituents such as carbon monoxide and other gases that can be used as tracers of anthropogenic or natural processes.
- *Climate Variability and Change* – The climate system circulates CO_2 from its source regions and distributes it around the globe. Climate also plays an important role in determining the uptake and release of CO_2 by the oceans and ecosystems through its effects on marine chemistry, photosynthesis, respiration, and decay. Improved estimates of current and projected climate conditions are essential to projecting future changes in CO_2 concentration.
- *Global Water Cycle* – Precipitation, humidity, and soil moisture play crucial roles in determining terrestrial uptake and release of CO_2 through their influence on vegetation. Runoff transports carbon from the land surface to the oceans. Understanding the interplay between the water and carbon cycles is vital to projecting future changes in both.
- *Land-Cover/Land-Use Change* – Some changes in land use (e.g., conversion from timber production to livestock grazing) are associated with net CO_2 emissions. Other changes in land use and management are associated with net CO_2 sequestration (e.g., changing from intensive tillage to no-till agriculture). Improved understanding of how land is used in different locations, as well as how land uses might change over time, is crucial to estimating current and projecting future emissions as well as future sequestration opportunities.
- *Ecosystems* – Widespread but subtle changes in ecosystem distribution and composition may lead to significant changes in the concentration of atmospheric CO_2 because such large amounts of carbon are exchanged in ecosystems through photosynthesis, respiration, decay, and disturbance. Advances in carbon cycle research depend upon improvements in understanding the effect of climate on ecosystems, including their projected rates of carbon uptake and release.
- *Human Contributions and Responses* – The main human processes responsible for changing the concentration of atmospheric CO_2 are fossil-fuel burning, deforestation, land-use change, and cement production. These processes have changed and will continue to change over time, hence must be considered in estimating current and projecting future emissions, as well as mitigating future climate change.

generated under the auspices of CCSP. Five mechanisms are used to achieve this management approach:

- *Executive Direction* – The Interagency Working Group on Climate Change Science and Technology and the CCSP Principals Committee are responsible for overall priority setting, program direction, management review, and accountability to deliver program goals.
- *Agency Implementation* – CCSP participating departments and agencies are responsible for conducting research, developing and operating observing systems, and producing CCSP-required products, often in collaboration with interagency working groups.

- *Interagency Planning and Implementation* – Several interagency working groups, including one for each CCSP research element, are responsible for coordinating planning and implementation to align agency programs with CCSP priorities.
- *External Guidance and Interaction* – External advisory groups and organizations, including the National Academies (see section below), provide external guidance, oversight, and interactions to ensure scientific excellence, credibility, and utility.
- *Program Support* – The CCSP Office provides staffing and day-to-day coordination of CCSP-wide program integration, strategic planning, product development, and communications.



Integrated Program Analysis

In a highly distributed program such as CCSP, it is often a challenge to develop and maintain a cohesive perspective, ensuring that key components or interactions of the integrated Earth system are not overlooked. To help address this challenge, the program has often turned to the National Academies for guidance. Two of the dozens of reports that have helped guide the program's activities are *Global Environmental Change: Research Pathways for the Next Decade* (NRC, 1999) and *Climate Change Science: An Analysis of Some Key Questions* (NRC, 2001). CCSP has recently requested that the National Research Council (NRC) establish a new committee to provide high-level integrated advice on the evolution of the program. This committee will provide independent annual reports on different aspects of the program, including:

- Strategic advice on program priorities and implementation strategy in the context of scientific and societal objectives, including the recommendation of high-priority program areas not previously supported.
- An evaluation of progress toward meeting the program's goals. This evaluation will build on the recommendations of the NRC Committee on Metrics for Global Change Research, and will offer advice to the program and the Nation on performance measurement systems (including non-quantitative measures) that can be used for multi-agency programs like CCSP.
- A strategic review of the program's decision-support activities in the context of the program's goals. The initial review will focus on the program's synthesis and assessment products, but also will examine other significant CCSP decision-support activities, including:
  - The adequacy of the overall portfolio of decision-support activities to meet the program's goals
  - The scientific and technical quality of the program's decision-support tools and products
  - The potential evolution of the program's decision-support activities over time to meet the program's goals.

When requested, the new committee will participate in the review of draft prospectuses for CCSP synthesis and assessment products, and will provide analysis associated with the interpretation of scientific findings in the products.

CCSP will continue to also rely on other mechanisms for scientific guidance and advice, including other NRC committees that focus on particular components of the climate system, scientific advisory groups that support individual agencies, scientific steering groups organized to coordinate different CCSP research elements, and open dialog with the domestic and international scientific and user communities interested in global change issues.