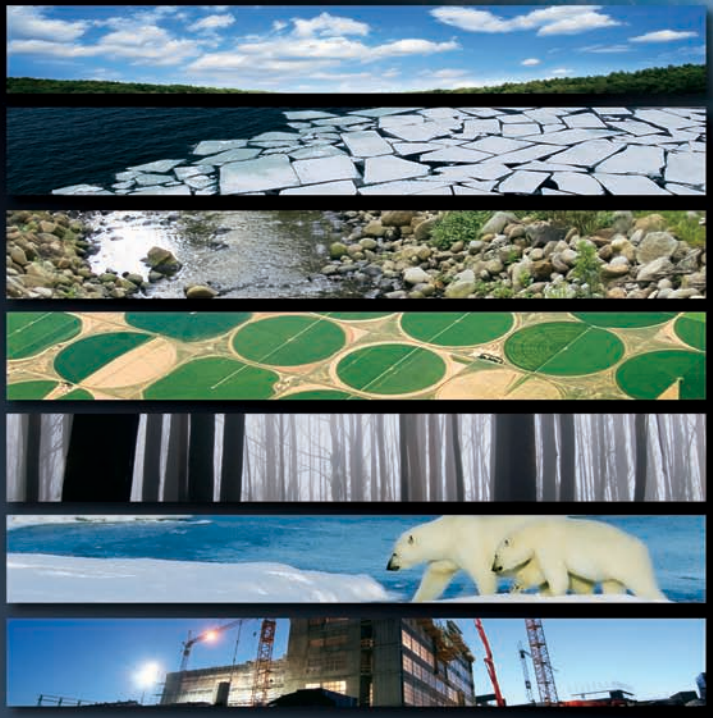
PREVIEW OF

OUR CHANGING PLANET

The U.S. Climate Change Science Program for Fiscal Year 2008



A Report by the
Climate Change Science Program and
the Subcommittee on Global Change Research

A Supplement to the President's Budget for Fiscal Year 2008

Climate Change Science Program and Subcommittee on Global Change Research

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April 2007

Members of Congress:

I am pleased to transmit a copy of *Preview of Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2008*. The Preview provides a timely and brief description of the plans for FY 2008 as well as a summary of recent accomplishments, and is intended to support CCSP-related elements of the FY 2008 budget. A more comprehensive reporting of accomplishments, plans, and budgets will be published later in the year as the FY 2008 edition of the Climate Change Science Program (CCSP) annual report, *Our Changing Planet*. CCSP incorporates the U.S. Global Change Research Program, which was established under the Global Change Research Act of 1990, and the Climate Change Research Initiative, established by the President in 2001. CCSP coordinates and integrates scientific research on climate and global change supported by 13 participating departments and agencies of the U.S. Government.

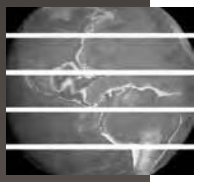
This FY 2008 Preview highlights recent advances supported by CCSP-participating agencies in each of the program's research and observational elements, as called for in the *Strategic Plan for the U.S. Climate Change Science Program*. The Preview includes an analysis of the significant recent progress that CCSP has made toward its overarching goals. The document describes the coordination of research and overall program management, and the eight key interagency implementation priorities for FY 2008. The document also outlines how CCSP plans to continue implementation of the *Strategic Plan* during FY 2008, emphasizing work on 21 scientific synthesis and assessment reports integrating research results focused on key issues and related questions of interest to decisionmakers.

CCSP is committed to its mission to facilitate the creation and application of knowledge of the Earth's global environment through research, observations, decision support, and communication. I thank the CCSP-participating agencies for their close cooperation, and look forward to working with Congress in the continued development of this important program.

Respectfully,

William J. Brennan
Acting Director, Climate Change Science Program
Chair, Subcommittee on Global Change Research
Department of Commerce / National Oceanic and Atmospheric Administration

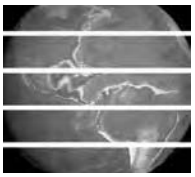
TABLE OF CONTENTS



PREVIEW OF OUR CHANGING PLANET: THE U.S. CLIMATE CHANGE SCIENCE PROGRAM FOR FISCAL YEAR 2008

APPENDICES

Numbered superscripts in the text indicate endnotes.



PREVIEW OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM FOR FY 2008

The purpose of this document is to provide a timely and brief preview of plans for FY 2008 as well as a summary of recent accomplishments. A more comprehensive reporting of accomplishments, plans, and budgets will be published later in 2007 as the full *Our Changing Planet – Annual Report*.

Climate plays an important role in shaping the environment, natural resources, infrastructure, economy, and other aspects of life in all countries of the world. Therefore, variations and changes in climate can have substantial environmental and socioeconomic implications. The Climate Change Science Program (CCSP) was established in 2002 to empower the Nation and the global community with the science-based knowledge to manage risks and opportunities of change in the climate and related environmental systems. CCSP incorporates and integrates the U.S. Global Change Research Program (USGCRP) with the Administration's U.S. Climate Change Research Initiative (CCRI). The USGCRP was mandated by Congress in the Global Change Research Act of 1990 (P.L. 101-606, 104 Stat. 3096-3104) 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. These departments and agencies are listed in Appendix A of this report.

Climate research conducted over the past several years indicates that most of the global warming experienced in the past few decades is very likely due to the observed increase in greenhouse gas concentrations from human activities. Research also indicates that the human influence on the climate system is expected to increase.[1] It is therefore essential for society to be equipped with the best possible knowledge of climate variability and change so that we may exercise responsible stewardship for the environment, lessen the potential for negative climate impacts, and take advantage of positive opportunities where

CCSP GUIDING VISION

A nation and the global community empowered with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems.

they exist. The importance of these issues and the unique role that science can play in informing society's responses give rise to CCSP's guiding vision.

CCSP carries out its mission through four core approaches: scientific research, observations, decision support, and communication. These approaches build upon scientific advances of the last few decades and are deepening our understanding of the interplay of natural and human-caused forces, their implications, and response options. CCSP is developing information to facilitate comparative analysis of different approaches for adapting to and mitigating climate change. CCSP also promotes capacity development among scientists and information users—both in the developed and the developing world—to address the interactions between climate change, society, and the environment.

CCSP MISSION

Facilitate the creation and application of knowledge of the Earth's global environment through research, observations, decision support, and communication.

CCSP Goals and Analysis of Progress Toward These Goals

At the highest conceptual level, five goals have been identified to provide focus and facilitate programmatic integration (see box on page 4). These goals encompass the full range of climate-related issues.

The program's detailed objectives, milestones, and products and payoffs complement these overarching goals, and are articulated in the program's *Strategic Plan*. CCSP-participating agencies and departments coordinate their work through discipline-related "research elements," which together support scientific research across a wide range of interconnected issues of climate and global change.

The goals address the most common questions concerning climate change which include:

- To what extent and how is the climate system changing?
- What are the causes of these changes?
- What will the future climate be like and what effects will a changed climate have on ecosystems, society, and the economy?
- How can we best apply knowledge about ongoing and projected changes to decisionmaking?

This section of the *Our Changing Planet FY 2008 - Preview* provides a high-level overview of progress made toward the program's goals in the 12 to 18 months prior to the preparation of this report. Because of the program's breadth and wide-ranging progress, this overview gives only a sampling of

CCSP GOALS

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.

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

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

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

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

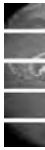
the advances made. In addition, this section does not purport to provide a thorough assessment of climate change or the extent of the scientific uncertainties that remain. Instead, it provides examples that illustrate the scope and significance of the progress that CCSP has made in expanding and applying understanding of climate.

The primary focus of U.S. climate research has historically been on Goals 1 through 3, which emphasize improvements in fundamental understanding of the climate system, its driving forces, and the tools to make predictions of short-term climate variability and potential long-term climate change more reliable. As the science matures and its societal utility becomes more evident, the importance of Goals 4 and 5 has become more significant. Examples of progress provided under each of the goals are often the result of coordinated research activities from many disciplines conducted or supported across the participating CCSP agencies.

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.

Analyses based on observations provide a solid foundation for the program. These analyses contribute to improved understanding of Earth system processes, help determine the extent of climate variations, and provide true comparisons to test and advance model veracity. In the past year, analyses have enabled several important advances in understanding the nature and variability of the Earth system. The

illustrative examples of progress toward CCSP's Goal 1 are drawn from and integrate a variety of different CCSP research elements.



One example of these integrated analyses is illustrated by the progress made in understanding climate change at high latitudes. Temperature and moisture patterns over North America and Europe are experiencing an earlier transition from winter to summer. The warmer spring temperatures produce earlier springtime green-up of vegetation and longer growing seasons.[2] Satellite, airborne, and ground-based observations suggest significant changes occurring in the mass balance of Greenland and Antarctic ice sheets that are inferred to be caused by warming at high latitudes.[3,4] Climate model simulations suggest that the global pattern of regional temperature and moisture trends is more readily explained by estimated human activity and natural climate forcing[5] than by internal variability alone. These wide-ranging sets of analyses tie together findings from traditionally disparate disciplines including hydrology, glaciology, and ecology.

Progress has been made in understanding changes in atmospheric ozone through observations and comparisons with models of the atmosphere. Satellite observations have shown that the large ozone decreases over Antarctica have been accompanied by significant but smaller summertime ozone increases at higher levels of the Antarctic atmosphere. A chemical-climate model confirms these observations.[6] Other related modeling research has shown that warming of the tropical lower atmosphere due to increased greenhouse gases may accelerate the large-scale motions of the stratosphere and thus alter the global distribution of ozone.[7]

In the past decade, measurements have been made from a variety of platforms including satellites and ocean buoys, showing the top layers of the oceans to be warming with strong evidence that the warming is due to increases in human-produced greenhouse gases.[1] Ocean heat storage is the largest component of the Earth's climate system for storing the energy imbalance between the sources and sinks of thermal energy. Even though the methods of observations are quite different, the matching magnitude and annual variability of the satellite-derived energy imbalance and the ocean heat storage is considered to be quite remarkable and lends confidence to the interpretation of the underlying climate process.[8]

Although CCSP Goal 1 is focused on basic research, it is often quite relevant to society. An example is work on identifying relationships between climate variability and change and hurricane activity. Studies suggest that increasing tropical sea surface temperatures are associated with more intense, but not necessarily more frequent, hurricanes.[9] However, the conclusion that there has been a detectable global trend in hurricanes has been questioned due to uncertainty in the observational tropical cyclone databases used for trend detection.[10] Model results indicate that observed sea surface temperature

changes in the Atlantic and Pacific regions where tropical storms are formed are due to a combination of natural variability and forcing caused by human activities.[11,12] A recent study indicates that the extensive cooling observed over the subtropical North Atlantic during the summer of 2006 appears to be related to variations in the Saharan dust transported to that region. The study suggests that the causes for the reduced number and intensity of Atlantic hurricanes during the summer of 2006 (compared to forecasts for 2006) may include both Saharan dust transport and El Niño.[13]

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

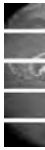
In making long-term climate projections, an understanding of the factors responsible for global environmental change is necessary. These forcing factors include greenhouse gases, land cover changes, tiny airborne particles (aerosols), and solar variability. As in the previous Goal, the following examples of progress toward CCSP Goal 2 result from the integrated focus of multiple CCSP research elements.

Recent climate warming has been particularly intense in boreal and Arctic regions, leading to concern that increasing air temperature in these ecosystems may indirectly increase the incidences of forest fires. Beyond the emission of carbon dioxide (CO_2) and other greenhouse gases from fires, understanding the consequences of large-scale fires on climate is challenging due to the many additional ways in which they influence the atmosphere and surface. A recent study in Alaska found that there was intensification in the climate warming in the first year after a major fire but a slight decrease in the climate warming when averaged over the 80 years of the study. The long-term result, which was primarily due to plant re-growth increasing the summertime reflectivity of the burn-scarred surface, appears to be more significant than the fire-emitted greenhouse gases.[14] The result implies that future increases in boreal fires may not further intensify long-term climate warming.

CCSP's interdisciplinary research on the carbon cycle has produced a set of analyses utilizing long-term observations of several new and mature forests. Results from this work show that forest carbon storage has been increasing in these ecosystems and is not in balance with the carbon lost by respiration and decay. This result is contrary to the contemporary concept of near balance of carbon sources and sinks in mature forests.[15] The gain in forest carbon is typical of findings from the U.S.-based large-scale networks, as well as observations made in mature forests in China. Evidence is therefore mounting that these sinks for atmospheric CO_2 offer significant potential for modulating the rate of atmospheric CO_2 increase.[16]

Incorporation of the sub-surface water table into regional climate models is important since land cover changes produce significant effects on the water table and the hydrologic cycle. Shallow water tables

can be either a sink or source of water to the surface soil depending on the relative balance of infiltration versus evaporation.[17] Recent studies using detailed observations and regional climate models have found that the fraction of rainfall that either recharges groundwater or ends up as stream flow tends to decrease when the fraction of land devoted to agriculture increases. This result suggests that intense agriculture can amplify surface water stresses, particularly during drought conditions.[18]



In western states, large changes in land cover and land use have occurred over the past century with rapidly expanding urbanization along the Pacific coast and extensive agricultural development inland. Researchers exploring the effects of urbanization and agriculture on regional climate have found that irrigated agriculture in California tended to lower mean and maximum surface air temperatures, while conversion of natural vegetation to urban areas tended to increase ground temperatures. The surface temperature changes and their associated effects on the atmosphere also caused changes to the regional airflow. Overall, it was found that conversion of natural vegetation to irrigated agriculture has likely had a larger effect on California's climate than urban growth, but increased conversion of irrigated land to urban/suburban development could alter this conclusion.[19]

Scientists are concerned that increased permafrost thawing due to warming in Arctic regions could cause the release of substantial amounts of carbon long held in the frozen tundra. There appears to be two potential mechanisms for the carbon to reach the atmosphere: drainage of the carbon-rich river flow into the Arctic Ocean with subsequent emission, and direct respiration or recycling of the newly thawed carbon. Measurements made in the Yukon River basin in northern Canada have shown that the latter process predominates.[20]

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

The accuracy of estimates of future Earth system conditions at time scales ranging from months to centuries and at spatial scales ranging from regional to global has been significantly improved by CCSP research. The primary tools for Earth system prediction and projection are computer models that reflect the best available knowledge of Earth system processes. The following examples demonstrate the integration of observations and modeling necessary to contribute to the progress being made in CCSP Goal 3.

For a model to produce a realistic climate requires that it include realistic representations of physical processes such as cloudiness, precipitation, and solar energy. Recent innovative studies using newly

developed, detailed models of cloud processes that are coupled with a global climate model provide results that are significantly more consistent with observations.[21] The incorporation of improved cloud representation in climate models is expected to reduce the uncertainty in predictions of the global and regional water cycle and surface climate.

Sunlight not reflected back to space provides the driving energy to Earth's weather and climate systems. Clouds are a major component in the global reflectance of sunlight. Year-to-year variability in the global reflectance is dominated by the variability of cloudiness in the tropics.[22] On the other hand, scientists have recently found that the year-to-year variability of reflectance at middle and high latitudes has had little change despite decreases in the highly reflective snow and sea-ice cover. This fascinating result appears to be due to the compensating increase in cloud cover balancing the decreasing surface level reflectance. Clouds continue to provide the largest source of uncertainty in model estimates of climate sensitivity, although a recent study finds evidence that in most climate models used in the Working Group I contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) clouds provide a positive feedback.[23]

Analyses of climate model simulations generated for the IPCC Fourth Assessment Report have identified several additional characteristics of the climate change projections that are common to all of the models.[24] Examples of these robust model projections include strong subtropical drying, weakening of large-scale tropical atmospheric motions, and expansion of the poleward upper atmospheric wind pattern known as the Hadley circulation.

In another study, several models were used to investigate the effects of the input of freshwater from melting ice and glaciers on the currents in the North Atlantic.[25] These currents are important due to their large-scale transport of heat. The study concluded that in response to expected levels of freshwater input in the northern North Atlantic, the average modeled large-scale deep ocean current weakens by about 30% by the end of the century. All models simulate some weakening of this deep circulation, but no model simulates a complete shutdown of it.

CCSP researchers also use the geological record to test and apply climate models, particularly in cases where that knowledge has a bearing on climate change processes relevant to current society. One such analysis involves the largest known extinction in Earth's history that took place approximately 250 million years ago at the Permian-Triassic boundary, where approximately 95% of marine and 75% of terrestrial species were lost. In this study, a climate model simulation indicated that the elevated levels of CO_2 during this period led to climatic conditions inhospitable to both marine and terrestrial life.[26] It is hypothesized that a critical level of high-latitude warming was reached where the connection

of oxygen-rich surface waters to the deep ocean was dramatically reduced, thus leading to a shutdown of marine biologic activity, which in turn led to increased atmospheric CO_2 and accelerated warming.

The historical record provides a broader set of observations to test and apply climate models to help reduce uncertainty in their future projections. A recent study has used a simple model to attempt to reproduce paleoclimate reconstructions of Northern Hemisphere temperature over the past 7 centuries in response to estimated solar, volcanic, and greenhouse gas forcing during this period.[27] This study suggests that, for the current century, very high climate sensitivities predicted by some models for greenhouse gas concentration doubling are less likely than previously thought.

Projections made by CCSP research pertain not just to physical climate, but also to other components of the Earth system, including atmospheric chemistry. Continuing research has provided an estimate that the recovery of the Antarctic ozone hole will occur approximately 10 to 20 years later than the previous estimate of 2050.[28] As a result of the Montreal Protocol and its amendments, the use of ozone depleting substances (ODSs) has been greatly reduced. Improved understanding of atmospheric dynamics now give 2001 as a better estimate of when the ODS peak occurred in the Antarctic stratosphere. This date is later than had been previously estimated and results in a longer projected time scale for recovery back to pre-1980 (unperturbed) levels of ODSs.

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

Significant advances have been made in understanding the potential impacts of climate change. One of the characteristics of CCSP research is the use of many different sources of information, including analyses utilizing prehistoric information, direct observations, and model-based projections. Recent research also accounts for the dynamic nature of the response of human and natural systems to climate change. This research encompasses a wide range of potential impacts on societal needs such as water, health, and agriculture, as well as potential impacts on natural terrestrial and marine ecosystems. The integrated approach to developing the understanding sought in CCSP Goal 4 is illustrated in the following examples.

Tools and research resulting from carbon cycle science are highly relevant to carbon management as demonstrated by a recent study that estimated the spatial variability of net primary production and potential biomass accumulation over the conterminous United States.[29] This study's model-based predictions indicate a potential to remove carbon from the atmosphere at a rate of 0.3 GtC yr^{-1}

through afforestation[30] of low production crop and rangeland areas. This rate of carbon sequestration[31] would offset about one-fifth of the annual fossil fuel emissions of carbon in the United States.

The changing adaptability of coastal marshes is illustrated by a study of a coastal ecosystem. In a Chesapeake Bay marsh ecosystem, rising sea level, increasing CO_2, and high rainfall were shown to interact and improve the growth of a relatively tall bulrush at the expense of a hay-like cordgrass that grows in thick mats.[32] Such changes in species composition, caused by interacting global change factors, may influence the capacity of coastal marshes to rise in elevation at the pace required to keep abreast of sea-level rise because of species-specific differences in their ability to trap sediment and organic material.

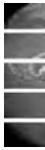
Another example of the ecological consequences of climate change affecting adaptability involves the devastation of millions of acres of western U.S. and Canadian pines by Bark beetles during the warmth and drought of 2000-2004. Recent modeling and observations revealed that beetles invading northernmost Lodgepole Pine trees are now only a few miles from previously pristine Jack Pine populations.[33] This may create a direct pathway of invasion to valued pine forests in the eastern United States and Canada.

CCSP's integrated approach to understanding the sensitivity and adaptability of natural ecosystems to climate change has also been applied in remote regions. The West Antarctic Peninsula is experiencing some of the largest, most rapid warming on Earth, which is causing loss of sea ice and increased snow precipitation. In turn, these changes are having major contrasting impacts on the adaptability of different penguin species. For example, during the last 3 decades in the region, populations are shifting south, so that local abundance of the ice-dependent and snow-intolerant Adélie penguins decreased (-65%), while abundance of Chinstraps and Gentoos increased (+2730% and +4600%, respectively).[34] Climate warming in the Canadian Arctic has caused significant declines in total cover and thickness of sea ice and progressively earlier ice breakup in some areas. These changes impact the polar bear populations causing them to extend their normal fast for longer periods during the open-water season.[35]

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

A substantial investment in basic research focused on global environmental variability and change has provided a significant set of opportunities for applying this knowledge in local and regional planning. To explore and communicate the potential uses and limits of this knowledge, CCSP is taking the following

three approaches: the development of scientific syntheses and assessments; exploration of adaptive management and planning capabilities; and development of methods to support climate change policy inquiries. A few noteworthy examples of the progress made by CCSP in pursuing these approaches and actively working with the user community to apply this knowledge to manage risks and opportunities are described below.



CCSP scientists developed and documented a "water supply stress index" that calculates water shortage risks across the conterminous United States. The index is based on models and observations that integrate the effects of climate, land cover, and current water uses by municipalities and industries on water supply.[36] The water supply stress index and the methods associated with it will be used by local and regional decisionmakers to quantify the likelihood of future water shortages under changing climate, water, and land uses, for determining mitigation practices.

An example of regional decision support is the work carried out by the Consortium for Atlantic Regional Assessment (CARA), which is providing data and tools to help decisionmakers understand how outcomes of their decisions could be affected by potential changes in both climate and land use. On an interactive, user-friendly website, CARA has organized data on climate (historical records and future projections for seven global climate models), land cover, and socioeconomic and environmental variables to help inform local and regional decisionmakers.[37] The CARA tools and tutorials are designed to help in understanding the issues related to land use and climate change by gathering, organizing, and presenting information for evaluating alternative strategies.

A workshop involving scientists and managers, co-led by several CCSP agencies under the auspices of the U.S. Coral Reef Task Force, resulted in publication of *A Reef Manager's Guide to Coral Bleaching*.[38] The combined research results among state/territorial, federal, academic, non-governmental, and international scientists concluded that warming sea-surface temperatures are a key factor in mass coral bleaching events. The *Guide* provides managers with strategies that support the natural resilience of coral reefs in the face of climatic change.

CCSP researchers have developed new metrics for estimating greenhouse gas emissions and carbon sequestration in the agricultural and forestry sectors.[39] These sectors can reduce atmospheric greenhouse gas concentrations by increasing carbon sequestration in biomass and soils, by reducing fossil fuel emissions through use of biomass fuels, and by substituting agricultural and forestry products that require less energy than other materials to produce. The Department of Energy's National Greenhouse Gas Registry is utilizing the new metrics as the basis for reporting greenhouse gas information from the agricultural and forestry sectors.[40]

Program Management

CCSP's coordination of scientific research is through the research elements described in the following section. The management approach as described in the *CCSP Strategic Plan* 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 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 Interagency 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 modeling tools, 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.

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. Chapters 3 to 15 of the *CCSP Strategic Plan* contain more detailed discussions of the discipline-specific research elements, as well as elements that cut across all areas of the program. A brief summary of each of these research and cross-cutting elements is provided below, as well as a few highlights of planned activities. These and other activities will be described in more detail in the full volume of *Our Changing Planet FY 2008 – Annual Report*.

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 soil biogeochemical processes. 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*.

Atmospheric Composition – The composition of the atmosphere on global and regional scales influences climate, air quality, stratospheric ozone, and precipitation. Consequently, this impacts human health and the vitality of ecosystems. Research and observational activities coordinated and supported by CCSP are being used to assess how human activities and natural processes affect atmospheric composition, and how that understanding may be used to inform decisionmaking in the United States and abroad. In FY 2008, emphasis will be given to studies of interactions between aerosols and non-CO_2 gases, enhanced measurements of atmospheric water vapor, and interactions of pollutants with climate change. Special emphasis will be given to the climate impacts of pollutants associated with aviation.

Climate Variability and Change (including Climate Modeling) – Recognizing that the climate system operates seamlessly across a wide spectrum of time scales, CCSP-supported research encompasses both short-term climate variability and longer term climate change. Addressing the interaction of climate processes across time scales poses challenges not only in designing observation systems to monitor the climate system adequately, but also in constructing models that can properly reproduce its past, and confidently project its future behavior. Earth system models, in combination with global Earth observations, must produce internally consistent maps of atmospheric, oceanic, land

surface, and ice conditions both in near real-time and retrospectively. These maps, or "analyses," will provide decisionmakers with tools to visualize the evolving state of the full climate system over the entire planet, and researchers with the ability to better explain observed changes in the climate system.

Global Water Cycle – Research associated with this element involves studies of the crucial role the water cycle plays both in climate variability and change, and climate and variability have on aspects of the global water cycle upon which society and nature critically depend. The ultimate goal of this water cycle research is to provide a better foundation for decisions and investments by policymakers, managers, and individuals. Achieving this goal requires a program of activities that test predictions and data products in real decision contexts, demonstrate techniques and their effectiveness to potential users, and provide tools and strategies to transfer the science from the experimental realm to operations.

Land-Use and Land-Cover Change – Land use and land cover are linked to climate and weather in complex ways and are critical inputs for modeling greenhouse gas emissions, carbon balance, and ecosystems. Land-use and land-cover change (LULCC) studies have provided critical inputs to large-scale biomass and forest cover assessments; future LULCC goals include reducing uncertainties in biomass estimates, understanding regional heterogeneities in changes, and quantifying linkages and feedbacks between LULCC, climate change, and other human and environmental components. Research that examines historic, current, and future LULCC, its drivers, feedbacks to climate, and its environmental, social, economic, and human health consequences is therefore of utmost importance and often requires interagency and intergovernmental cooperation. Research plans focus on how management practices may change as climate and conservation policies change, and feedbacks among these systems.

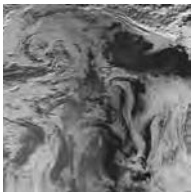
Global Carbon Cycle – Increasing levels of atmospheric CO_2 and methane (CH_4) are major drivers of climate change. The global carbon cycle element of the CCSP seeks to better quantify and understand the dynamics of the global carbon cycle that determine CO_2 and CH_4 fluxes and carbon storage in terrestrial and oceanic ecosystems. Carbon cycle processes depend on climate, and thus linking carbon cycle and climate change analyses is critical. Carbon cycle research involves multiple disciplines and extends over a broad range of spatial and temporal scales. Major multi-agency activities include the North American Carbon Program (NACP), an effort to describe and reduce uncertainties about the North American carbon budget and underlying processes, and the Ocean

Carbon and Climate Change (OCCC) Program, an effort for oceanic research aimed at determining how climate change will affect the future behavior of the oceanic carbon sink. In FY 2008, NACP will address key gaps and uncertainties in the synthesis developed previously (Synthesis and Assessment Product 2.2), and aspects of OCCC and NACP will be coordinated to better quantify and understand the roles of adjacent ocean basins in the North American carbon budget. NASA will launch the Orbiting Carbon Observatory (OCO) to provide for the first time consistent atmospheric carbon observations globally from space, and carbon data assimilation systems will begin to derive estimates of carbon sources and sinks from these measurements.

Ecosystems – This research element studies the potential effects of global change on goods and services provided by aquatic and terrestrial ecosystems, using observations, experiments, modeling, and syntheses to focus on critical emerging questions. Newly initiated projects in terrestrial ecosystems are addressing cause-and-effect relationships between climatic variability and change, and the distribution, abundance, and productivity of native and invasive organisms. Further, research is continuing into understanding how increasing CO_2 levels affect plants and microorganisms. Research in a Chesapeake Bay ecosystem is generating data to evaluate and forecast effects of warming, changes in fishing pressure, and eutrophication on economically important estuarine ecosystems. In the ocean, coral reef research is helping scientists and managers identify climatic and non-climatic stressors and thereby better manage these important ecosystems.

Decision-Support Resources Development and Related Research on Human Contributions and Responses – Decisionmakers and other interested citizens need reliable science-based information to make informed judgments regarding policy and actions to address the risks and opportunities of variability and change in climate and related systems. A wide variety of CCSP decision-support resources and related research on human contributions and responses is targeted at that objective. The outcomes of these activities are intended to inform public discussion of climate-related issues and scientifically assess and expand options for mitigation of and adaptation to climate variability and change. The most prominent of CCSP's ongoing decision-support activities is its synthesis and assessment process that involves the generation of 21 different products intended to support public discussion of climate science issues of particular importance to U.S. decisions. CCSP's research on human contributions and responses to global environmental variability and change includes analyses of human drivers of change and their potential impact, societal resilience and ways of reducing vulnerability, approaches for improving the ability of decisionmakers to utilize scientific information, and the effects of global environmental change on human health. CCSP's research is paying particular attention to

aspects of global change that have greatest relevance to society including drought and extreme or abrupt climate events.



Observing and Monitoring the Climate System – CCSP provides active stewardship for observations that document the evolving state of the climate system, allow for improved understanding of its changes, and contribute to improved predictive capability for society. Some of these observations however are not part of the CCSP budget (such as operational satellites) but are crucial to its success. A core CCSP activity is U.S. participation in the broad-based strategy of the international Global Climate Observing System (GCOS) in monitoring atmospheric, oceanic, and terrestrial domains with an appropriate balance of *in situ* and remotely sensed observations. In 2007-2008, GCOS-related observing activities by CCSP agencies will focus on observing the polar climate as part of the International Polar Year (IPY) series of international cooperative studies. IPY plans to advance polar observations by establishing a variety of new multidisciplinary observatories using the latest technologies in sensor web (network of spatially distributed sensor platforms that wirelessly communicate with each other) and power-efficient designs. Data from these as well as more traditional surface- and space-based observatories will provide high-quality records needed to detect potential future climate change. The United States plans to increase its efforts on observations of the polar atmosphere, ice, and ocean, as well as leverage its investments in polar research with international partners. A continuing challenge to CCSP agencies is ensuring the long-term integrity and understandability of data products provided by remote-sensing and *in situ* observing systems.

Communications – CCSP's member agencies support a broad array of communications initiatives. CCSP has developed a strategy and implementation plan for helping to coordinate and facilitate these activities. These efforts are intended to improve public understanding of climate change research by disseminating the results of CCSP activities credibly and effectively, and by making CCSP science findings and products easily available to a diverse set of audiences. CCSP facilitates communication of the results of individual agencies, as well as providing coordination in communicating the results of climate activities of the Federal Government.

International Research and Cooperation – CCSP, through its working groups including the Interagency Working Group on International Research and Cooperation, participates in and provides input to major international scientific and related organizations on behalf of the U.S. Government and scientific community. CCSP also provides support to maintain the central infrastructure of

several international research programs and international activities that complement CCSP and U.S. Government goals in climate science.

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 sought guidance from the National Academies. CCSP is funding a National Research Council (NRC) committee to provide high-level, independent, integrated advice on the strategy and evolution of the program. Specific topics the committee will address in its first two reports are outlined below:

- The first committee report will include findings and recommendations on the process for evaluating progress toward the five CCSP goals and a preliminary assessment of progress to date.
- The second report will identify priorities to guide the future evolution of the program in the context of established scientific and societal objectives.

At the request of CCSP, the NRC recently produced a report on global change assessments that is briefly described in a later section of this *Preview*.

CCSP will continue to rely on other mechanisms for scientific guidance and advice, including other NRC committees that focus on particular components of the climate system (e.g., the Climate Research Committee and the Committee on the Human Dimensions of Global Change). CCSP will also continue to utilize scientific advisory groups that support individual agencies, scientific steering groups organized to coordinate different CCSP research elements, and open dialogue with the domestic and international scientific and user communities interested in global change issues.

Key Interagency Implementation Activities

The program's long-term vision, mission, goals, and objectives are described in the Strategic Plan. Implementation of this long-term plan occurs through agency activities that often benefit significantly from ongoing coordination facilitated by CCSP. CCSP has identified several key areas for FY 2008 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-participating agencies 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 National Research Council committees. CCSP's annual implementation priorities are logical evolutions of the program's interagency approaches to the priorities established in the *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, which requires sustained, ongoing support to achieve its full set of objectives. The focus areas are listed here in a similar order as 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.

Development of an Integrated Earth System Analysis Capability – By combining global observations of the atmosphere, ocean, land, biosphere, and ice-covered areas with models that dynamically couple these components of the Earth system, it will be possible to produce internally consistent maps (i.e., "analyses") of the state of the planet. Time series of such analyses will allow researchers to better explain observed changes in the climate system and will allow decisionmakers to develop more informed options to deal with future changes. Building upon progress in successfully modeling the ocean and atmosphere as coupled components, activities in FY 2008 will work toward constructing a high quality "reanalysis" of the ocean-atmosphere system from the start of the satellite era (late 1970s). Further advances in producing integrated Earth system analyses will require progress in ongoing efforts to construct models that properly simulate the interactions among the physical and biogeochemical processes in the climate system.

Carbon Cycle Research Integration – CCSP's carbon cycle research element will integrate the research efforts of the North American Carbon Program and relevant aspects of the Ocean Carbon and Climate Change Program to better quantify and understand the carbon budget of North America and adjacent ocean basins, including terrestrial, freshwater, oceanic, and atmospheric sources and sinks, the underlying processes, and the dynamics that determine influences on atmospheric CO_2 and CH_4. This integration will clarify and reduce uncertainties about the North American carbon budget and provide better information for the decisionmaking processes of carbon management. Improved observations, methods,

and understanding of carbon cycling will be integrated into global models and analysis systems to provide more reliable capabilities for studying and predicting future changes in atmospheric CO_2 and CH_4 and carbon storage by terrestrial and oceanic ecosystems.

Abrupt Changes in a Warming Climate – Paleoclimate research indicates that major shifts in regional and global climate have occurred on time scales as short as decades, severely impacting rainfall patterns, droughts, ecosystems, and human civilizations. Assessing the potential for future abrupt changes and implementing the capability to diagnose and predict their development will require concerted efforts to improve Earth system analysis, decadal forecasting capabilities, reconstructions of past abrupt climate change, and understanding of societal impacts. Activities in FY 2008 will emphasize (1) model experiments designed to test potential mechanisms for abrupt change, and (2) paleoclimate research on patterns, causes, and impacts of past abrupt climate events. Both activities will help set priorities for enhanced monitoring toward developing an abrupt change early warning system.

Potential Effects of Climate Change on the Biodiversity and Productivity of Ecosystems – Research will include new activities on two topics of urgency: (1) vulnerability of coastal ecosystems, both terrestrial and aquatic, to climate-related changes, including sea-level rise, increased sedimentation and runoff, increased storm frequency or intensity, saltwater intrusion, and oceanic warming; and (2) warming-induced changes in high-latitude and high-elevation ecosystems, including changes in species compositions, alterations in the timing of water availability, migration of the tree line, retreat of glaciers, and loss of permafrost and sea ice. Both these topics require additional research on underlying ecological processes and development of models linking geophysical and ecological phenomena.

Integration of Water Cycle Observations, Research, and Modeling – The FY 2008 interagency priority for the global water cycle is the initiation of a multi-year activity that is planned to include a series of integrated projects, each building upon the experience gained from previous years. FY 2008 activities will focus on the evolution of an observing system aimed at measuring key elements required to close the terrestrial water cycle budget on a regional scale such as a river basin or watershed. Enabling links with other projects will be explored through the Hydrological Information System portal, including data/product delivery to the National Integrated Drought Information System (NIDIS). In future years, an expansion in scope is envisaged to encompass time scales from seasonal to inter-annual, and spatial scales from local to regional to global. This activity is designed to benefit both the broader research community as well as the operational applications community through a more accurate quantification of the water cycle and improved mathematical formulations of physical processes. Results will be incorporated into climate and hydrological prediction models.

Land-Use and Land-Cover Change and Climate: Interactions and Critical Observations – Land-use and land-cover priorities include: understanding historic, current, and potential future land-use and land-cover change patterns, dynamics, and drivers; understanding the mutual effects and feedbacks between climate variability and land-use/land cover; and forecasting environmental, social, economic, and human health consequences. All of these land-use and land-cover change priority questions directly influence climate, by affecting atmospheric trace gas composition and surface reflectance, and are thus critical to a broad spectrum of CCSP interests. The collection, archival, and subsequent scientific use of global Landsat data from 2005-2006 is a priority for FY 2008, through the "mid-decadal Landsat data collection effort." The FY 2008 priority also includes support for the ongoing Landsat Data Continuity Mission to continue the collection of global Landsat data. Without these satellite observations, the current pace of discovery and innovation in global land-use and land-cover change climate research would not be possible.

Understanding Aerosol Forcing and Interactions with Clouds and Non-CO_2 Trace Gases – The key objectives of this set of activities are to quantify the effects of atmospheric aerosols (tiny airborne particles) on radiation and on clouds, to quantify the modification of the radiation balance by non-CO_2 greenhouse gases, and to quantify the influence of the chemistry of the lower atmosphere on both aerosols and non-CO_2 greenhouse gases. Research will include use of newly initiated and enhanced measurements of water vapor in the upper troposphere and the lower stratosphere and water vapor's role in altering climate directly and via its influence on aerosols, cirrus clouds, and chemical composition. Initial studies on the potential contributions of air pollution, including that from aviation, to global climate forcing will be started. In addition, field missions are planned to understand the transport and properties of absorbing aerosols and their precursors to the Arctic polar region as a part of the International Polar Year in an effort to quantify the contribution of absorbing aerosols to the melting of the Arctic ice.

Coping with Drought through Research and Regional Partnerships – Building trust and collaborative efforts with stakeholders to help them take advantage of climate information, especially in the area of drought planning, is a long-term effort that requires consistent and continual interactions. Research in this area will focus on the development of methods, models, and mechanisms for integrating climate information into analyses of the social and economic ramifications of drought as well as the policy and decisionmaking processes in the face of drought. Scientific data products will include paleoclimatic and historical information about drought and its impacts, seasonal-to-interannual observations and predictions of drought, and longer term projections of decadal-to-centennial variability and change. Social and economic impact analyses including historical perspectives and near-term trends such as projections of water conflicts, water demand, population changes, and land-use changes will be used to augment the physical-science analyses. This effort is linked to the National Integrated Drought Information System.

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 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 and setting the future direction and priorities of the program. The synthesis and assessment products constitute an important new form of topic-driven integration of U.S. global change assessment efforts. These CCSP products will be U.S. Government disseminations, subject to the provisions of the Information Quality Act (Section 515 of the Treasury and General Government Appropriations Act of 2001) and the Federal Advisory Committee Act Amendments of 1997 (PUB. L. 105-153, SEC. 2(A), (B), DEC. 17, 1997, 111 STAT. 2689).

The synthesis and assessment products are generated by researchers in a process that involves review by experts, public comment from stakeholders and the general public, and final approval by the departments/agencies involved in CCSP. Formal endorsement of the products by the Federal Government will enhance their value for decisionmakers and the public at large. The program has prepared guidelines that describe steps to be followed in each of three phases of the preparation process: developing the prospectus, drafting and revising, and final approval and publication. This methodology for product development facilitates involvement of the research community and user groups in ensuring that the products are focused in a useful fashion and meet the highest standards of scientific excellence. The guidelines also encourage transparency by ensuring that public information about the status of the products will be provided through the Federal Register, on the CCSP website, and other means throughout the review and clearance process. If further clarification of specific issues is required, the NRC will provide advice on an as-needed basis to the lead agency responsible for the preparation of each product.

The first product (1.1) has been completed and several others are nearing completion. Up-to-date information on the status of all Synthesis and Assessment products can be obtained from <http://www.climatescience.gov/Library/sap/default.htm>, including information on opportunities for public comment on draft products. A listing of each of the 21 Synthesis and Assessment products by CCSP Goal is provided as Appendix B.

"Lessons Learned" in Decision Support and Assessment

To build on the experiences of earlier assessment activities, CCSP requested that the National Research Council carry out an analysis of global change assessments that have addressed topics broadly similar to those encompassed by CCSP. The study, which was released in early 2007, included a comparative analysis of past assessments that address issues directly related to the science and technical issues of CCSP. The committee concluded that global change assessments are critical for informing decisionmakers. In identifying essential properties of a successful assessment it stressed that future assessment processes must communicate relevant information to the user, address the technical quality of the information, and demonstrate fairness and impartiality in the assessment process. The report identifies a number of essential elements that increase the probability that an assessment will effectively inform decisionmakers and other target audiences. CCSP will take into account the findings of the NRC in its future assessment activities.

Final Note

It is hoped that this *Preview* provides a useful perspective on CCSP's recent progress and plans for FY 2008. The full *Our Changing Planet – Annual Report* describing the program in greater detail will be published later in 2007.

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Appendix A. Climate Change Science Program

The Climate Change Science Program (CCSP) integrates federally supported research on global change and climate change, as conducted by 13 U.S. Government departments and agencies:

- Department of Agriculture (USDA)
- Department of Commerce (DOC)
  - National Oceanic and Atmospheric Administration (NOAA)
  - National Institute of Standards and Technology (NIST)
- 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).

In addition, the Executive Office of the President and other related programs have designated liaisons that 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).

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 hydrologic and satellite land-cover observations from USGS; and NOAA's future satellite measurement programs. Without input from activities such as these, CCSP would be unable to fulfill its mission.

CCSP is closely allied with other major interagency programs that observe and study particular aspects of the Earth system and related societal dimensions. Foremost among these is the CCTP, which develops and studies technological options for responding to climate change. CCSP is also closely linked to ongoing Federal ocean science and technology strategic planning under the auspices of the Joint Subcommittee on Ocean Science and Technology, which recently released a set of integrating decadal-scale priorities in a document entitled *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy*. A key observational linkage is with the U.S. Integrated Earth Observation System, which contributes to the international Global Earth Observation System of Systems (GEOSS). 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.

The CCSP incorporates and integrates the U.S. Global Change Research Program (USGCRP) with the Administration's U.S. Climate Change Research Initiative (CCRI). CCSP budget requests are coordinated through interagency research working groups and other mechanisms, but ultimate budget accountability resides with the participating departments and agencies. As a result of its interagency composition, the activities of CCSP-participating agencies are funded by Congress through nine of the 13 annual Appropriations bills. The CCSP budget will be described in the soon-to-be-released *Federal Climate Change Expenditures Report to Congress for FY 2008*. A more complete breakdown of the CCSP, CCRI, and USGCRP budgets will be provided in *Our Changing Planet FY 2008 – Annual Report*.

Appendix B. Synthesis and Assessment Products by CCSP Goal

CCSP GOAL 1	Extend 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.
1.1	Temperature trends in the lower atmosphere: Steps for understanding and reconciling differences.
1.2	Past climate variability and change in the Arctic and at high latitudes.
1.3	Re-analyses of historical climate data for key atmospheric features: Implications for attribution of causes of observed change.
CCSP GOAL 2	Improve quantification of the forces bringing about changes in the Earth's climate and related systems.
2.1	A. Scenarios of greenhouse gas emissions and atmospheric concentrations. B. Global change scenarios: Their development and use.
2.2	North American carbon budget and implications for the global carbon cycle.
2.3	Aerosol properties and their impacts on climate.
2.4	Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure.
CCSP GOAL 3	Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.
3.1	Climate models: An assessment of strengths and limitations for user applications.
3.2	Climate projections based on emissions scenarios for long-lived radiatively active trace gases and future climate impacts of short-lived radiatively active gases and aerosols.
3.3	Weather and climate extremes in a changing climate: Regions of focus – North America, Hawaii, Caribbean, and U.S. Pacific Islands.
3.4	Abrupt climate change.
CCSP GOAL 4	Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.
4.1	Coastal elevations and sensitivity to sea-level rise.
4.2	State-of-knowledge of thresholds of change that could lead to discontinuities (sudden changes) in some ecosystems and climate sensitive resources.
4.3	The effects of global change on agriculture, biodiversity, land, and water resources.
4.4	Preliminary review of adaptation options for climate-sensitive ecosystems and resources.
4.5	Effects of climate change on energy production and use in the United States.
4.6	Analyses of the effects of global change on human health and welfare and human systems.
4.7	Impacts of climate variability and change on transportation systems and infrastructure: Gulf coast study.
CCSP GOAL 5	Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.
5.1	Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions.
5.2	Best-practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decisionmaking.
5.3	Decision-support experiments and evaluations using seasonal-to-interannual forecasts and observational data.

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The Climate Change Science Program incorporates
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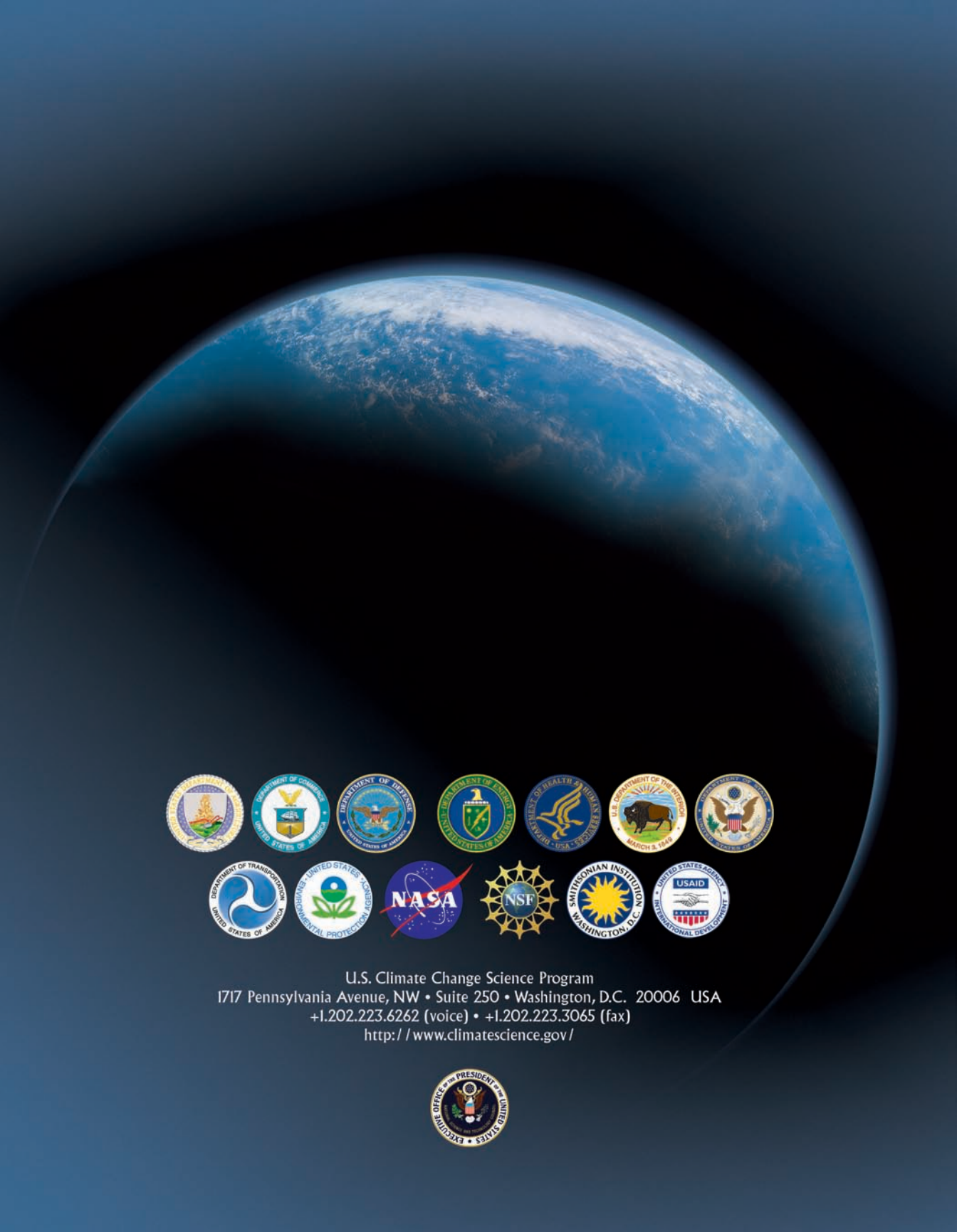

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