CHAPTER 1

Introduction

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**See Chapter 2 for more detail on CCSP goals and deliverables.*

About the Strategic Plan

This Strategic Plan for the Climate Change Science Program describes a strategy for developing knowledge of variability and change in climate and related environmental and human systems, and for encouraging the application of this knowledge. The strategy seeks to optimize the benefits of research that is conducted, sponsored, or applied by 13 agencies and departments of the U.S. government. These agencies coordinate their research through the Climate Change Science Program (CCSP), which incorporates the U.S. Global Change Research Program (USGCRP) and the Climate Change Research Initiative (CCRI).

Scientists and research program managers from the 13 participating agencies and the Climate Change Science Program Office drafted the Strategic Plan. It reflects a commitment by its authors to high-quality science, which requires openness to review and criticism by the wider scientific community. The process by which the plan was drafted proceeded with the transparency essential for scientific credibility.

External comments have played a key role in revising the initial draft of the plan. Significant input was received during the CCSP workshop held in December 2002, in Washington, D.C., which was attended by 1,300 scientists and stakeholders. Written comments on the *Discussion Draft Strategic Plan* were submitted during a public comment period. When collated, these comments amounted to nearly 900 pages of input from scientists and stakeholders. In addition, a special committee of the National Research Council (NRC) reviewed the draft plan at the request of the CCSP. The NRC committee also will submit a final report on both the content of the plan and the process used to produce it.

This document is not a detailed blueprint for conducting specific research projects or applying research results. Research strategies and implementation plans for specific areas of science are the focus of detailed planning documents that have already been prepared for some research elements, and are under preparation for others. These implementation plans spell out agency roles and provide added detail on the prioritization and sequencing of research activities. Annual budget information will continue to be provided through the program's annual report to Congress, *Our Changing Planet*. As a baseline reference for this Strategic Plan, the overall program budget is assumed to continue at the level of the FY2004 President's Budget Request. Actual budget commitments will be made on an annual basis.

While this document provides overviews of research, it does not report in detail on past or expected scientific conclusions.

Summaries of the current state of scientific knowledge are available in a series of reports, evaluations, and assessments conducted by international and national scientific bodies, as well as in the open scientific literature.

Brief definitions of the terms used throughout this chapter are listed in Box 1-1. For a more complete listing of the definitions used throughout the plan, refer to Annex D.

Vision and Mission of the Climate Change Science Program

Climate and climate variability play important roles in shaping the environment, natural resources, infrastructure, economy, and other aspects of life in all countries of the world. Potential human-induced changes in climate and related environmental systems, and the

BOX 1-1

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
Climate can be defined as the statistical description in terms 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 to 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, and the biosphere, and the interactions among 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 El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), and the Pacific Decadal Variability (PDV).

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 (Climate Change)
An intervention to reduce the causes of change in climate. 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 (Climate)
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 (Climate)
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 causes (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.
It is measured in terms of parameters such as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation.

options proposed to adapt to or mitigate these changes, may also have substantial environmental, economic, and societal consequences. Because of the pervasiveness of the effects of climate variability and the potential consequences of human-induced climate change and response options, citizens and decisionmakers in public and private sector organizations need reliable and readily understood information, including a clear understanding of the reliability limits of such information, to make informed judgments and decisions. Over the past 15 years, the United States has invested heavily in scientific research, monitoring, data management, and assessment for climate change analyses to build a foundation of knowledge for decisionmaking. The seriousness of the issues and the unique role that science can play in helping to inform society's course give rise to CCSP's 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.

The core precept that motivates CCSP is that the best possible scientific knowledge should be the foundation for the information required to manage climate variability and change and related aspects of global change. Thus the CCSP mission is to:

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

CCSP will add significant integrative value to the individual Earth and climate science missions of its 13 participating agencies and departments, and their national and international partners. A critical role of the interagency program is to coordinate research and integrate and synthesize information to achieve results that no single agency, or small group of agencies, could attain.

CCSP Goals

CCSP will develop knowledge that addresses the following basic questions:

How will variability and potential change in climate and related systems affect natural environments and our way of life? How can we use and improve this knowledge to protect the global environment and to provide a better living standard for all?

Five CCSP goals have been identified to focus and orient research in the program to ensure that knowledge developed by the participating agencies and research elements can be integrated and synthesized to address these broad questions.

CCSP 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

Climate conditions change significantly over the span of weeks, seasons, years, decades, and even longer time scales. CCSP research will improve understanding of natural oscillations in climate on time scales from weeks to centuries, including improving and harnessing ENSO forecasts, a large-scale climate oscillation with implications for resource and disaster management. Research will sharpen qualitative and quantitative understanding of climate extremes, and whether any changes in their frequency or intensity lie outside the range of natural variability, through improved observations, analysis, and modeling. The program also will expand observations, monitoring, and data/information system capabilities and increase confidence in our understanding of how and why climate is changing. Fostering improved interactions and connectivity between research and ongoing operational measurements and activities will be another important aspect of the program's work.

GUIDING VISION FOR THE CCSP

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.

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

Combustion of fossil fuels, changes in land cover and land use, and industrial activities produce greenhouse gases (GHGs) and aerosols and alter the composition of the atmosphere and physical and biological properties of the Earth's surface. These changes have several important climatic effects, some of which can be quantified only poorly at present. Research conducted through CCSP will address reducing uncertainty in the sources and sinks of GHGs; aerosols and their precursors; the long range atmospheric transport of GHGs and aerosols and their precursors; and the interactions of GHGs and aerosols with global climate, ozone in the upper and lower layers of the atmosphere, and regional-scale air quality. It will improve quantification of the interactions among the carbon cycle, other biological/ecological processes, and land cover and land use to better project atmospheric concentrations of key greenhouse gases and to support improved decisionmaking. The program will also improve capabilities for developing and applying emissions scenarios in research and analysis, in cooperation with the Climate Change Technology Program (CCTP).

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

While a great deal is known about the mechanisms that affect the response of the climate system to changes in natural and human influences, many questions remain to be addressed. There is also a high level of uncertainty regarding precisely how much climate will

change overall and in specific regions. A primary objective of CCSP is to develop information and scientific capacity needed to sharpen qualitative and quantitative understanding through interconnected observations, data assimilation, and modeling activities. CCSP-supported research will address basic climate system properties, and a number of "feedbacks" or secondary changes that can either reinforce or dampen the initial effects of greenhouse gas and aerosol emissions and changes in land use and land cover. The program will also address the potential for future changes in extreme events and uncertainty regarding potential rapid or discontinuous changes in climate. CCSP will also build on existing U.S. strengths in climate research and modeling and enhance capacity for development of high-end coupled climate and Earth system models.

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

Seasonal to annual variability in climate has been connected to impacts on ecosystems and many aspects of human life. Longer time scale natural climate cycles and human-induced changes in climate could have additional effects. Improving our ability to assess potential implications on ecosystems and human systems of variations and future changes in climate and environmental conditions could enable governments, businesses, and communities to reduce damages and seize opportunities by adapting infrastructure, activities, and plans. CCSP research will examine the interactions of multiple interacting changes and effects (e.g., the carbon dioxide "fertilization effect," deposition of nitrogen and other nutrients, changes in landscapes that affect water resources and habitats, changes in frequency of fires or pests) to improve knowledge of sensitivity and adaptability to climate variability and change. CCSP research will also improve methods to integrate our understanding of potential effects of different atmospheric concentrations of greenhouse gases and to develop methods for aggregating and comparing potential impacts across different sectors and settings.

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

Over the last decade, the scientific and technical community has developed a variety of products to support management of risks and opportunities related to climate variability and change. CCSP will foster additional studies and encourage evaluation and learning from these experiences in order to develop decision support processes and products that use knowledge to the best effect, while communicating levels of uncertainty. CCSP will develop resources (e.g., observations, databases, data and model products, scenarios, visualization products, scientific syntheses, assessments, and approaches to conduct ongoing consultative mechanisms) to support policymaking, planning, and adaptive management.

Core Approaches

CCSP will employ four core approaches in working toward its goals, including:

1) *Scientific Research*. Plan, sponsor, and conduct research on changes in climate and related systems
2) *Observations*. Enhance observations and data management systems to generate a comprehensive set of variables needed for climate-related research
3) *Decision Support*. Develop improved science-based resources to aid decisionmaking
4) *Communications*. Communicate results to domestic and international scientific and stakeholder communities, stressing openness and transparency.

Each of these approaches is essential for achievement of the CCSP's goals. The first two of these approaches will rely heavily on existing programmatic strengths and mechanisms, while the latter two approaches will require development of new capabilities and initiatives over the coming years.

Approach 1: Plan, sponsor, and conduct research on changes in climate and related systems

Fundamental, long-term research on a broad range of global change issues.

Over the past 15 years, the USGCRP element of CCSP has provided planning and sponsorship of the world's most extensive program of scientific research, monitoring, data management, and assessment for climate change analyses.

Results of this program include the first ever global characterization of many aspects of the Earth's environment; the development of decadal-scale global observations of a limited number of environmentally important variables; detailed knowledge of a variety of processes important in the functioning of the Earth system; the development of ENSO forecasts and derived products used in management, planning, and emergency preparedness; and significant improvement in the capability of models used to project the future evolution of the Earth system, as evidenced by improvements in their ability to simulate variability in the present and recent past. USGCRP accomplishments are evidenced by large numbers of peer-reviewed scientific papers and other reports; unique data archives; contributions of U.S.-based scientists to the body of work produced by the Intergovernmental Panel on Climate Change (IPCC) and other assessment activities; and increased public awareness of issues associated with climate variability and change.

A substantial percentage of future CCSP budgets will be devoted to continuing this essential investment in scientific knowledge, facilitating the discovery of the unexpected and advancing the frontiers of research. CCSP agencies will coordinate their work through seven interdisciplinary research elements that have evolved from the framework for research presented in *Global Environmental Change: Research Pathways for the Next Decade*, a report from the National Research Council that lays out advances in knowledge needed to improve predictive capability in Earth system science (NRC, 1999a).

The following "snapshot" of CCSP research elements depicts their foci at the time of the preparation of this Strategic Plan. The program will encourage evolution of these research elements over the coming decade in response to new knowledge and societal needs. Over time, a greater degree of integration across the research elements and a greater degree of involvement with users are expected.

Atmospheric Composition. The atmosphere creates a protective envelope for life on Earth, providing key ingredients for respiration and

photosynthesis and shielding the planet from harmful incoming radiation. It transports materials globally on rapid time scales, yet it can retain some pollutants for centuries or longer. Changes have been observed in relative quantities of key constituents that affect climate and in processes that affect the composition of the atmosphere itself (e.g., self-cleansing of pollutants). CCSP-supported research focuses on how the composition of the global atmosphere is altered by human activities and natural phenomena, and how such changes influence climate, ozone, ultraviolet radiation, pollutant exposure, ecosystems, and human health. Specific objectives address processes affecting the recovery of the stratospheric ozone layer from reduced ozone levels observed in recent decades; the properties and distributions of greenhouse gases and aerosols; long-range transport of pollutants and implications for regional air quality; and integrated assessments of the effects of these changes. Atmospheric composition issues involving interactions with climate variability and change—such as interactions between the climate system and stratospheric water vapor and ozone, or the potential effects of global climate change on regional air quality—are of particular interest at present.

Climate Variability and Change. Climate is a crucial aspect of the physical environment. The historical record of climate shows evidence of variability on multiple time scales, as well as rapid change. CCSP-supported research on climate variability and change focuses on how climate elements that are particularly important to human and natural systems—especially temperature, precipitation, clouds, winds, and storminess—are affected by changes in the Earth system. Specific objectives include improved predictions of seasonal to decadal climate variations (e.g., ENSO); improved detection, attribution, and projections of longer term changes in climate; the potential for changes in extreme events at regional to local scales; the possibility of abrupt climate change; and development of approaches (including characterization of uncertainty) to inform national dialogue and support public and private sector decisionmaking.

Global Water Cycle. Water is crucial to life on Earth. Water changes phase from solid to liquid to gas through a natural cycle that also transports and converts energy. Water in its different phases affects the Earth's radiative balance (e.g., changes in water vapor, clouds, and high-latitude ice formations are important climate feedbacks). Humans depend on predictability in the water cycle (e.g., water works are engineered to operate within certain tolerances of precipitation, evaporation, flow, and storage), and changes beyond expectations can have serious implications. CCSP-supported research on the global water cycle focuses on how natural processes and human activities influence the distribution and quality of water within the Earth system, whether changes are predictable, and on the effects of variability and change in the water cycle on human systems. Specific areas include identifying trends in the intensity of the water cycle and determining the causes of these changes (including feedback effects of clouds on the global water and energy budgets as well as the global climate system); predicting precipitation and evaporation on time scales of months to years and longer; and modeling physical/biological and socioeconomic processes to facilitate efficient water resources management.

Land-Use/Land-Cover Change. Land cover and use influence climate and weather at local to global scales. Land surface (cover) characteristics affect the exchange of greenhouse gases, including water vapor, between the land surface and the atmosphere, the radiation balance of the continents, the exchange of sensible heat between continents and the atmosphere, and the uptake of momentum from the atmosphere. Land-cover characteristics are key inputs to climate models. Land cover and use also affect water runoff, infiltration, and quality; biogeochemistry (including the carbon and nitrogen cycles); the distribution of microorganisms, plants, and animals; and other factors. Understanding and projecting observed and future states of land cover and land use will require close integration of the natural and social sciences. Research within this program element will focus on the interactions among changes in land use and land cover, global change, and socioeconomic factors, including the predictability of land-use and land-cover change. Specific foci will identify and quantify the human drivers of land-use and land-cover change; improve monitoring, measuring, and mapping of land use and land cover, and the management of these data; and develop projections of land-cover and land-use change under various scenarios of climate, demographic, economic, and technological trends.

Global Carbon Cycle. Although water vapor is the most significant greenhouse gas, increased atmospheric concentration of carbon dioxide in recent decades is the largest single forcing agent of climate change. Methane is also a significant contributor. Evidence of increases in the atmospheric concentrations of these gases since pre-industrial times is unequivocal. The natural carbon cycle involves several reservoirs (the oceans, the biosphere, and the atmosphere) and is in approximate balance. Relatively small human perturbations can have major impacts, however, and our knowledge of these and their implications for environmental change is insufficient to manage carbon effectively. CCSP-supported research on the global carbon cycle focuses on identifying the size, variability, and potential future changes to reservoirs and fluxes of carbon within the Earth system, and providing the scientific underpinning for evaluating options to manage carbon sources and sinks. Specific programs and projects focus on North American and oceanic carbon sources and sinks; the impact of land-use change and resource management practices on carbon sources and sinks; projecting future atmospheric carbon dioxide and methane concentrations and changes in land-based and marine carbon sinks; and the global distribution of carbon sources and sinks and how they are changing.

Ecosystems. Ecosystems provide a variety of environmental goods and services that are necessary to sustain life. For the purposes of this research plan, ecosystems include agricultural lands, commercial forests, and other ecosystems that are essential to human survival and a desirable quality of life. Provision of essential resources depends on a variety of physical and chemical inputs and is affected by climate variability and change, and by human influences such as introduction of nutrients and pollutants and fragmentation of landscapes. Improving projections of future climate and global changes depends on developing improved understanding of ecosystem processes under multiple natural and human influences. CCSP-supported research on ecosystems focuses on: (1) how natural and human-induced changes in the environment interact to affect the structure and functioning of ecosystems (and the goods and services they provide) at a range of spatial and temporal scales, including those ecosystem processes that in turn influence regional and global environmental changes; and (2) what options society may have to ensure that desirable ecosystem goods and services will be sustained

or enhanced in the context of still uncertain regional and global environmental changes. Among the specific focus areas are the cycling of nutrients, such as nitrogen, and how these nutrients interact with the carbon cycle; key processes that link ecosystems with climate; and options for managing agricultural lands, forests, and other ecosystems to sustain goods and services essential to societies.

Human Contributions and Responses. Human activities are an important influence on the global environment. Human responses to change, through adaptation and mitigation, will strongly influence whether environmental changes have positive or negative effects on society. CCSP-supported research on human contributions and responses to global change focuses on the interactions of changes in the global environment and human activities. The current focus of this research is on the potential effects of climate variability and change on human health and welfare; human influences on the climate system, land use, and other global environmental changes; analyses of societal vulnerability and resilience to global environmental change; decisionmaking under conditions of significant complexity and uncertainty; and integrated assessment methods.

Enhanced short-term focus on reducing key scientific uncertainties to support informed public review of adaptation and mitigation strategies. President Bush created the CCRI in June 2001, and directed that it focus on short-term (i.e., within 5 years) actions to reduce high-priority scientific uncertainties about global climate change where possible, and to synthesize the available scientific information to support public discussion of global climate change response strategies. CCSP manages CCRI activities jointly with its management of the long-term USGCRP studies, using the same interagency management and scientific working group structures.

Enhanced modeling capacity to accelerate incorporation of new knowledge into comprehensive climate models and to develop model products for decision support. Models are an essential tool for synthesizing observations, theory, and experimental results to investigate how the Earth system works and how it may be affected by human activities. Comprehensive climate models represent the current imperfect state-of-the-science understanding of the major components of the climate system and the transfer of water, energy, chemicals, and mass among them. CCSP will foster two complementary streams of climate modeling activities. The first is a research activity that will support continued model experiments and accelerate incorporation of new knowledge into comprehensive climate and Earth system models. Closely associated with the research activity will be the sustained and timely delivery of predictive model products for assessments and other decision support resources.

The challenge is that of balancing fundamental long-term Earth system research with an enhanced short-term focus on climate change uncertainties. CCSP will focus attention on key climate change issues that are important for public discussion, while maintaining sufficient breadth to facilitate scientific discovery on a broad range of global environmental changes. Establishing a careful balance between focus and breadth is essential and will require input from both decisionmakers and the science community. The NRC has already played a significant role in shaping the program through a series of reports and evaluations of the program and is expected to help establish this balance through future interactions and evaluations.

Approach 2: Enhance observations and data management systems to generate a comprehensive set of variables needed for climate-related research

Since the early years of the USGCRP, an expanded program of global observations has been developed to characterize climate variability and change on a global and regional basis. These observations have come from a variety of sources, including paleoclimate studies interpreting climate parameters over thousands of years, satellite remote-sensing systems, and numerous *in situ* systems at the terrestrial surface (including the polar regions), in the atmosphere, and in the surface and deep oceans. The suite of available observations includes long-term observations associated with the National Oceanic and Atmospheric Administration's satellite monitoring program and global weather observations, which have not historically been considered as part of the USGCRP; several long-term surface-based measurement networks operated by the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration, Department of Energy, and other agencies; and several long-running NASA research satellite series, as well as a large number of limited-duration measurements obtained during research programs. Satellite observations made under the USGCRP have provided wide-scale, synoptic measurements and data sets of the global distribution of important environmental parameters and their spatial and temporal variability.

Prior and current investments in new observations will significantly enhance our knowledge of a number of environmental parameters in the coming years as the promise of these investments is realized. But two considerations have created a need for enhanced attention to global and regional observation and data management systems: (1) The large quantity and diverse format of available observations requires a major expansion of the capacity to prioritize, quality assure, archive, disseminate (in useful format), and assimilate the elements of this extensive record; and (2) the importance of integrated evaluation of climate and ecosystem parameters calls for the development of new requirements for integrated observation systems, followed by system design and implementation. This will enable the research community to address additional research issues including ecosystem and land-use/land-cover forcing and feedback relationships with other climate parameters, and impacts of climate variability and change on terrestrial and marine ecosystem dynamics, productivity, and biodiversity.

The United States has taken a leading role in fostering the development of a more broadly defined and integrated global observing system for all Earth parameters (e.g., including geological as well as climate information). The United States is hosting a ministerial-level Earth Observation Summit in July 2003, with participation by many developed and developing nations as well as many intergovernmental and international non-governmental organizations. This summit will initiate a 10-year commitment to design, implement, and operate an expanded global observing system that builds on the major observational programs currently operated by the United States and many other governments and international organizations. CCSP agencies have provided the leadership, definition, and support for the Earth Observation Summit, and CCSP will closely integrate the U.S. observation and data management programs with the international programs launched at the summit.

CCSP relies on both research and operational systems. The former are designed principally to address research questions, both those posed by CCSP as well as those posed by other federal environmental research efforts—for example, those of other subcommittees of the Committee on Environment and Natural Resources (see the CCSP Background and Management Overview section later in this chapter). A set of fundamental geophysical parameters must be measured to describe Earth system processes. A subset of these parameters is measured on an operational basis to serve other needs such as weather forecasting. CCSP uses measurements from the best available sources. CCSP working groups and participating agencies must explicitly include both research and operational systems in implementation planning. As many CCSP scientific objectives require long-term data records, facilitating the transition of responsibility for mature research observations to operational systems is a key element of the CCSP observing strategy. CCSP will also adhere to NRC climate monitoring principles, as well as the Global Climate Observing System (GCOS) climate monitoring principles for satellites.

Approach 3: Develop improved science-based resources to aid decisionmaking

Since the earliest years of the USGCRP and its counterparts around the world, the use of available scientific information to address key questions about changes in climate and related systems has continuously grown in importance. The available scientific record has been used for many years to improve understanding of a range of questions, from detecting climate change and attributing it to particular causes, to applying satellite and ground-based observations and related analyses in resource management applications. CCSP will build on this record and respond to significant new demands for additional information resources to support adaptive management of natural resources, planning, and policymaking. The program will improve approaches for sustained interactions with stakeholders that consider needs for information from a "user perspective." It will encourage development of new methods, models, and other resources that facilitate economic analysis, decisionmaking under conditions of complexity and uncertainty, and integration and application of information from the natural and social sciences in specific decision contexts.

Critical to the success of CCSP's contributions to decision support are partnerships with a variety of federal and non-federal entities that rely on the outcomes and products of global change research. These include the Climate Change Technology Program, subcommittees of the Committee on Environment and Natural Resources, and agencies with charters to provide essential public services, such as weather forecasting, disaster preparedness and response, management of resources, and enhancement of agricultural efficiency.

Evaluation and communication of uncertainty and levels of confidence is a crucial issue for the development of credible decision support resources. Uncertainties can arise from lack of knowledge, from problems with data, models, terminology, or assumptions, and from other sources, creating room for considerable misunderstanding. CCSP research will contribute to reduction of uncertainty, although research can also unexpectedly increase uncertainty. Because uncertainty can never be completely eliminated, CCSP will develop systematic approaches for assessing and updating levels of confidence and uncertainty and communicating this information in ways that are appropriate to the particular decision at hand. This will enable decisionmakers to understand the uses and limits of the information they are seeking to apply. CCSP will develop and employ transparent and systematic approaches for decision support under conditions of uncertainty, and for evaluating and reporting levels of confidence and uncertainty, including when uncertainties expand unexpectedly as the result of research. In addition, CCSP will strive to improve clarity in understanding how and when uncertainty is likely to be reduced by different research initiatives.

Approach 4: Communicate results to domestic and international scientific and stakeholder communities, stressing openness and transparency

The domestic and international communities addressing global climate change are already well developed. This is evident in publications in the scientific literature, IPCC collaborations, and many other scientific forums; in policy discussions in Washington and other world capitals; and in the media throughout the world. CCSP has a major responsibility to communicate with interested partners in the United States and throughout the world, and to learn from these partners on a continuing basis. Because of the large commitment of public resources to CCSP activities, CCSP also has a responsibility to report its findings in the form of educational materials suitable for use at various educational and public information levels, so that the dissemination of its findings will be effective.

Global climate change is complex and often subject to disputed interpretations even among scientists. Further, the economic and policy dimensions of the issue often give rise to even greater debates among individuals with different policy views. Controversy about climate change can sometimes be characterized as "public debate by headlines"—selective citations from the scientific literature, advocacy-oriented quotations from interested persons (often citing their own expertise), and other debating tactics. As an essential part of its mission, CCSP undertakes the significant responsibility of enhancing the quality of discussion by stressing openness and transparency in its findings and reports.

CCSP will employ four methods to ensure the credibility of its reported findings: (1) use of structured analyses (usually question-based) for CCSP scientific synthesis, assessment, and projection reports; (2) use of transparent methodologies that openly report all key assumptions, methods, data, and uncertainties; (3) continuous use of web-based and other forms of information dissemination so that CCSP information is freely available to all interested users; and (4) frequent use of "draft for comment" methods to seek external review before completion of each key document. CCSP will also continue to urge all of its sponsored researchers to seek publication of their findings in the peer-reviewed scientific literature.

Some of these credibility-enhancing steps have already been introduced through the public dissemination and review of the CCSP *Discussion Draft Strategic Plan* in November 2002, the open public workshop with 1,300 participants in December 2002, the subsequent public comment period, and the invited review by a committee of the NRC.

CCSP Prioritization

Research priorities of USGCRP and now CCSP have progressed over time as the fundamental scientific issues have evolved. Prioritization is an ongoing process in the program and reflects changes in needs and scientific progress and opportunity. The CCSP priorities will be reviewed on an annual cycle through the budget process.

Initial CCSP priorities have developed in response to a report requested by the Administration of a National Academies' NRC committee. The NRC report, *Climate Change Science: An Analysis of Some Key Questions*, characterized areas of uncertainty in scientific knowledge concerning climate change, and identified research areas that will advance the understanding of climate change. In particular, the report concluded that "predictions of global climate change will require major advances in understanding and modeling of (1) the factors that determine atmospheric concentrations of greenhouse gases and aerosols, and (2) the so-called "feedbacks" that determine the sensitivity of the climate system to a prescribed increase in greenhouse gases." The report also noted the limitations of current observing systems as well as the inadequacy of computational resources. Finally, the report called for an enhancement of the research enterprise dealing with environmental change and environment-society interactions in order to address the consequences of climate change and better serve the nation's decisionmakers. This includes "support of (a) interdisciplinary research that couples physical, chemical, biological, and human systems; (b) improved capability to integrate scientific knowledge, including its uncertainty, into effective decision support systems; and (c) an ability to conduct research at the regional or sectoral level that promotes analysis of the response of human and natural systems to multiple stresses."

In response to this NRC report, the Administration established the CCRI "to study areas of uncertainty [about global climate change] and identify priority areas where investments can make a difference." CCRI represents a focusing of resources and enhanced interagency coordination of ongoing and planned research on those elements of USGCRP that can best address major gaps in the understanding of climate change.

Initially, CCRI prioritizes research on three sets of uncertainties highlighted by the NRC: (1) atmospheric concentrations and effects of aerosols; (2) climate feedbacks and sensitivity, initially focusing on polar feedbacks; and (3) carbon sources and sinks, focusing particularly on North America in the immediate term. These priorities are discussed more completely in CCRI text boxes found in Chapter 3 (aerosols), Chapter 4 (climate feedbacks and sensitivity), and Chapter 7 (carbon cycle).

In addition, CCRI will focus on climate observing systems including efforts to: (a) document historical records; (b) improve observations for model development and applications; (c) enhance biological and ecological observing systems; and (d) improve data archiving and information system architectures. These activities involve substantial collaboration with the international climate science community and with several ongoing international monitoring development programs. Details on these efforts are highlighted in Chapters 12 and 13.

Development of state-of-the-art climate modeling that will help us better understand the causes and impacts of climate change is also a CCSP priority. Based on recommendations in several NRC reports on U.S. climate modeling (NRC 1999b, 2001d) and USGCRP evaluations (see, e.g., USGCRP, 2000), CCSP agencies are prioritizing new activities to strengthen the national climate modeling infrastructure. Details on these efforts are included in Chapter 10.

Finally, in the area of decision support resources, CCSP has identified over 20 synthesis and assessment products that will focus on key uncertainties and decisionmaking issues. These are described in Chapter 2. In addition, through CCRI, the program will develop additional resources to support national discussion and planning, adaptive management, and policymaking. Chapter 9 includes a description of research to develop new methods for use of scientific information under conditions of complexity and uncertainty, and Chapter 11 describes CCSP's decision support activities more broadly.

CCSP Criteria for Prioritization

As the program evolves in response to emerging needs and scientific opportunities, CCSP will employ the following overall criteria in establishing priorities for work elements selected for support:

1) Scientific or technical quality
   - The proposed work must be scientifically rigorous as determined by peer review.
   - Implementation plans will include periodic review by external advisory groups (both researchers and users).
2) Relevance to reducing uncertainties and improving decision support tools in priority areas
   - Programs must substantially address one or more CCSP goals.
   - Programs must respond to needs for scientific information and enhance informed discussion by all relevant stakeholders.
3) Track record of consistently good past performance and identified metrics for evaluating future progress
   - Programs addressing priorities with good track records of past performance will be favored for continued investment to the extent that time tables and metrics for evaluating future progress are provided.
   - Proposed programs that identify clear milestones for periodic assessment and documentation of progress will be favorably considered for new investment.
4) Cost and value
   - Research should address CCSP goals in a cost-effective way.
   - Research should be coordinated with and leverage other national and international efforts.
   - Programs that provide value-added products to improve decision support resources will be favored.

CCSP Background and Management Overview

CCSP Background

CCSP was created by the President in February 2002, as part of a new cabinet-level management structure (see Figure 1-1) to oversee public investments in climate change science and technology. The new structure also includes CCTP, which is responsible for climate

change-related technology research and development. Joint oversight of CCSP and CCTP is intended to increase the degree of coordination and integration, and to apply the knowledge created by CCSP to technology development decisionmaking. CCSP and CCTP report through the Interagency Working Group on Climate Change Science and Technology (IWGCCST) to the cabinet-level Committee on Climate Change Science and Technology Integration (CCCSTI). The IWGCCST membership includes deputy secretary and deputy administrator level representatives of the relevant cabinet departments and agencies, and representatives of the Executive Office of the President including the Office of Management and Budget (OMB), the Council on Environmental Quality (CEQ), and the Office of Science and Technology Policy (OSTP). IWGCCST meets regularly, supplemented with ad hoc meetings as needed. This structure oversees a combined annual budget exceeding $3 billion.

CCSP integrates federal research on global change and climate change, as sponsored by 13 federal departments and agencies (the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, the Interior, State, and Transportation; together with the Environmental Protection Agency, the National Aeronautics and Space Administration, the National Science Foundation, the Agency for International Development, and the Smithsonian Institution). OSTP, CEQ, OMB, and the National Economic Council (NEC) provide oversight. By leveraging the complementary strengths of the 13 agencies, CCSP integrates the planning of research and applications that are implemented by the participating agencies.

In addition to the new management structure instituted by the President, the National Science and Technology Council and its subsidiary bodies—the Committee on Environment and Natural Resources and the Subcommittee on Global Change Research (SGCR)—continue to coordinate climate and global change research. Agency representation on the SGCR and CCSP is identical to ensure coordination.

CCSP integrates USGCRP and CCRI. The USGCRP was established in 1989, and codified in the Global Change Research Act of 1990 as a high-priority national research program to address key uncertainties about natural and human-induced changes in the Earth's global

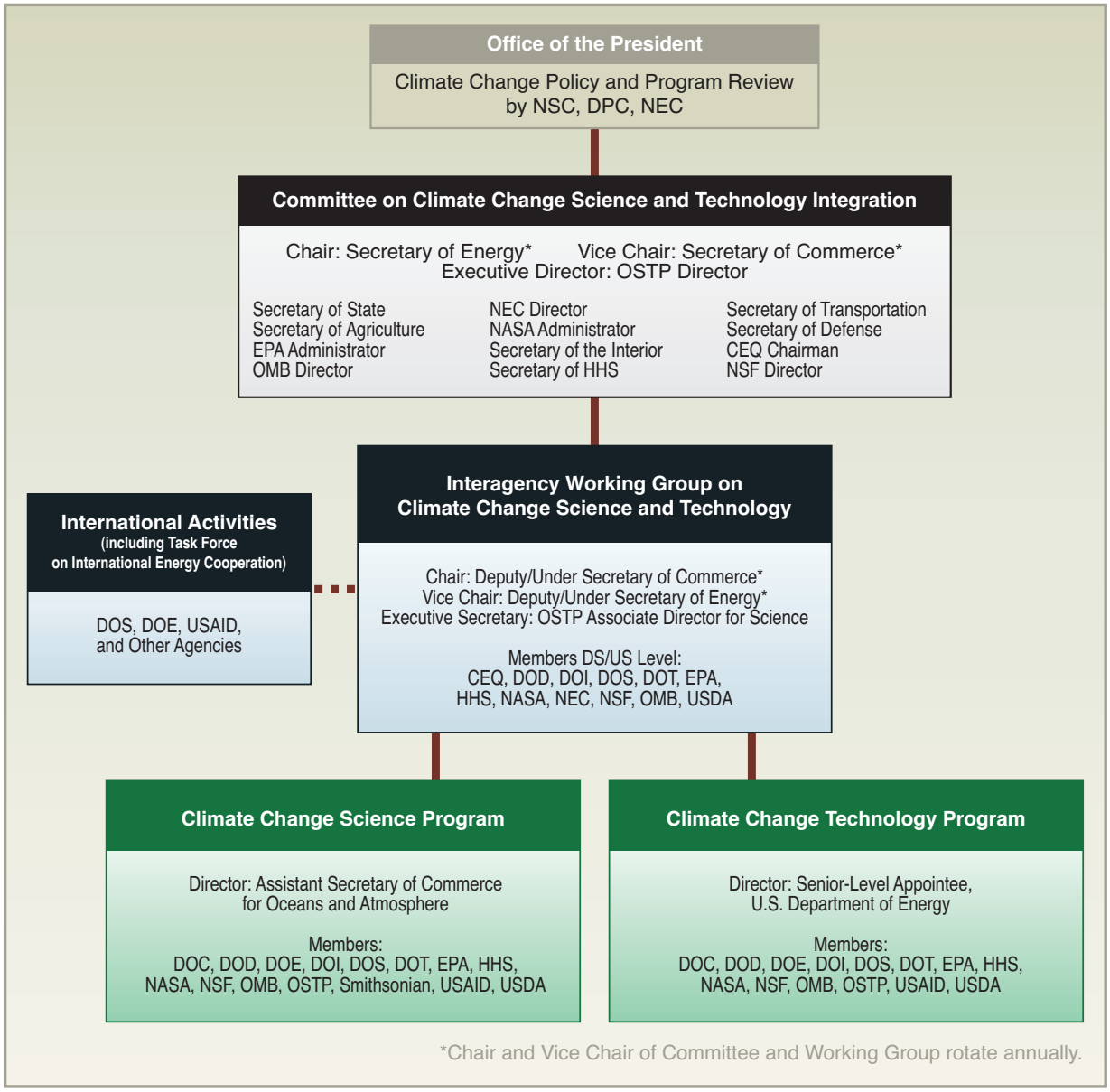

Figure 1-1: The Climate Change Science and Technology Programs are overseen by a cabinet-level management structure of the U.S. government.

environmental system; to monitor, understand, and predict global change; and to provide a sound scientific basis for national and international decisionmaking. The rationale for establishing the program was that the issues of global change are so complex and wide-ranging that they extend beyond the mission, resources, and expertise of any single agency, requiring instead the integrated efforts of several agencies. USGCRP is organized into a set of linked research program elements, which together support scientific research across a range of interconnected issues of climate and global change. As previously described, CCRI was created in June 2001, by the President in response to a report prepared by the National Academy of Sciences at the request of the Administration. The goal of CCRI is to reduce key uncertainties in climate science and measurably improve the integration of scientific knowledge, including measures of uncertainty, into effective decision support systems and resources. Specific examples of research proposed as part of CCRI in the FY04 President's Budget Request are highlighted throughout relevant chapters of this plan.

Management Overview

The CCSP approach to management 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—IWGCCST/CCSP/SGCR Representatives*
  Overall priority-setting, program direction, management review, and accountability to deliver program goals.
- *Agency Implementation—CCSP-Participating Departments and Agencies*
  Conducting research, developing and operating observing systems, and producing CCSP-required products, often in collaboration and often as defined or refined in interagency working groups.
- *Interagency Planning and Implementation—Interagency Working Groups*
  Coordinated planning and implementation to align agency programs with CCSP priorities.
- *External Guidance and Interactions—Advisory Groups*
  External guidance, oversight, and interactions to ensure scientific excellence, credibility, and utility.
- *Program Support—CCSP Office*
  Value-added staffing and day-to-day coordination of CCSP-wide program integration, strategic planning, product development, and communications.

Interaction among the groups responsible for these five mechanisms is essential, especially to prioritize research efforts and decision support activities. A more complete description of each of these five mechanisms and the CCSP management approach can be found in Chapter 16, Program Management and Review.

Roadmap for the Strategic Plan

The strategy describes the goals of the CCSP and its component programs and elements, the products that are expected to result, and the approaches and criteria that will be adopted to implement the program. The products include data sets, geographic information systems and other approaches for visualization of data, model studies, scientific publications, state-of-science reports, assessments, comparative evaluations of response options (including "If…, then…" scenario analyses), and other decision support resources. The plan also identifies enhancements needed in observing systems, data and information capabilities, modeling, and decision support resources to meet the program's goals.

Following this introduction, Chapter 2 describes the approach of CCSP for planning and sponsoring research on variability and change in climate and related systems. This approach is based on five overall CCSP goals and a set of interdisciplinary and interagency research elements. Integration of research from agency programs and research elements is an essential component of the development of synthesis products and assessments that address CCSP goals. The chapter introduces the cross-cutting goals, as well as related CCSP deliverables.

Chapters 3-9 provide a more detailed description of the research elements of the plan. These research elements focus on crucial components and interactions within the Earth system and have evolved from recommendations of the research community and the NRC. Each of these chapters describes research questions; provides an overview of the current state of knowledge; outlines milestones, products, and benefits from the research; and identifies needed inputs from and linkages with other national and international programs.

Chapters 10 and 12-13 describe the cross-cutting issues of modeling, observations, and data management. These are all areas where CCSP has substantial existing capabilities, but in which additional capacity will be developed to achieve the goals that have been set. Chapter 11 focuses on decision support. This chapter lays out the goals and strategy for participating in state-of-the-science syntheses and assessments, and for developing additional resources to support policymaking, planning, and adaptive resource management.

Chapters 14-16 describe communications, international cooperation, and management issues that cut across all areas of the program.

This plan was drafted by scientists and research program managers from the participating CCSP agencies and the Climate Change Science Program Office.

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