CHAPTER 1

INTRODUCTION

CLIMATE AND GLOBAL CHANGE: IMPROVING CONNECTIONS BETWEEN SCIENCE AND SOCIETY

from the

Strategic Plan for the Climate Change Science Program

By the agencies and staff of the
US Climate Change Science Program

Review draft dated 11 November 2002

Contents

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11 November 2002

Dear Colleague,

The Climate Change Science Program will hold the U.S. Climate Change Science Program Planning Workshop for Scientists and Stakeholders at the Marriott Wardman Park Hotel in Washington, D.C., from 3-5 December 2002. The purpose of the Workshop is to provide a comprehensive review of the discussion draft of the Strategic Plan for U.S. climate change and global change research. This Workshop will offer extensive opportunities for the scientific and stakeholder communities to provide comment and input to the Climate Change Science Program Strategic Plan. When finalized by April 2003, the Strategic Plan will provide the principal guidance for U.S. climate change and global change research during the next several years, subject to revisions as appropriate to respond to newly developed information and decision support tools.

We are writing to request your comments on the discussion draft of the Climate Change Science Program Strategic Plan. Comments on all elements of the plan from all communities are essential in order to improve the plan and identify gaps. In your review, we ask you to provide a perspective on the content, implications, and challenges outlined in the plan as well as suggestions for any alternate approaches you wish to have considered, and the types of climate and global change information required by policy makers and resource managers. We also ask that you comment on any inconsistencies within or across chapters, and omissions of important topics. For any shortcomings that you note in the draft, please propose specific remedies. To participate in the review it is not necessary that you review the entire plan.

We ask that comments be submitted by E-mail to <comments@climatescience.gov>. All comments submitted by 13 January 2003 will be posted on the <http://www.climatescience.gov> website for public review. While we are unable to promised detailed responses to individual comments, we confirm that all submitted comments will be given consideration during the development of the final version of the Strategic Plan.

Attached to this letter are instructions and format guidelines for submitting review comments. Following the instructions will ensure that your comments are properly processed and given appropriate consideration. If you wish to distribute copies of the plan to colleagues to participate in the review, please provide them with a copy of this letter as well as the attached instructions and format guidelines. We have posted the plan on the workshop website at <http://www.climatescience.gov>. PDF files for individual chapters of the plan can be downloaded from this site. If you have any questions, please contact: Sandy MacCracken at 1-202-419-3483 (voice), 1-202-223-3065 (fax), or via the address in the footer below.

We appreciate your contribution of time and expertise to this review, and look forward to your response.

Sincerely,

James R. Mahoney, Ph.D.
Assistant Secretary of Commerce for Oceans and Atmosphere, and
Director, U.S. Climate Change Science Program

Instructions For Submission of Strategic Plan Review Comments

Thank you for participating in the review process. Please follow the instructions for preparing and submitting your review. Using the format guidance described below will facilitate our processing of reviewer comments and assure that your comments are given appropriate consideration. An example of the format is also provided. Comments are due by **13 January, 2003**.

- Select the chapter(s) or sections of chapters which you wish to review. It is not necessary that you review the entire plan. In your comments, please consider the following issues:
  - **Overview**: overview on the content, implications, and challenges outlined in the plan;
  - **Agreement/Disagreement**: areas of agreement and disagreement, as appropriate;
  - **Suggestions** : suggestions for alternative approaches, if appropriate;
  - **Inconsistencies**: inconsistencies within or across chapters;
  - **Omissions** : omissions of important topics;
  - **Remedies**: specific remedies for identified shortcomings of the draft plan;
  - **Stakeholder climate information**: type of climate and global change information required by representative groups;
  - **Other:** other comments not covered above.
- Please do not comment on grammar, spelling, or punctuation. Professional copy editing will correct deficiencies in these areas for the final draft.
- Use the format guidance that follows for organizing your comments.
- Submit your comments by email to <comments@climatescience.gov> by 13 January, 2003.

Format Guidance for Comments

Please provide background information about yourself on the first page of your comments: your name(s), organization(s), area of expertise(s), mailing address(es), telephone and fax numbers, and email address(es).

- Overview comments on the chapter should follow your background information and should be numbered.
- Comments that are specific to particular pages, paragraphs or lines of the chapter should follow your overview comments and should identify the page and line numbers to which they apply.
- Comments that refer to a table or figure should identify the table or figure number. In the case of tables, please also identify the row and column to which the comment refers.
- Order your comments sequentially by page and line number.
- At the end of each comment, please insert your name and affiliation.

Format Example for Comments

I. Background Information

Name(s): John Doe
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II. Overview Comments on Chapter 5: Atmospheric Composition

First Overview Comment: (Comment)
Reviewer's name, affiliation: John Doe, University College

Second Overview Comment: (Comment)
Reviewer's name, affiliation: John Doe, University College

III. Specific Comments on Chapter 5: Atmospheric Composition

Page 57, Line 5: (Comment)
John Doe, University College

Page 58, Line 32 - Page 59, Line 5: (Comment)
John Doe, University College

Table 1-4, Row 3, Column 6: (Comment)
John Doe, University College

Please send comments by email to <comments@climatescience.gov>

Foreword

In February 2002 President George W. Bush announced the formation of a new management structure, the Climate Change Science Program (CCSP), to coordinate and direct the US research efforts in the areas of climate and global change. These research efforts include the US Global Change Research Program (USGCRP) authorized by the Global Change Research Act of 1990, and the Climate Change Research Initiative (CCRI) launched by the President in June 2001 to reduce significant uncertainties in climate science, improve global climate observing systems, and develop resources to support policymaking and resource management.

The President's Climate Change Research Initiative was launched to provide a distinct focus to the 13-year old Global Change Research Program. The CCRI focus is defined by a group of uncertainties about the global climate system that have been identified by policymakers and analyzed by the National Research Council in a 2001 report requested by the Administration.

The Climate Change Science Program aims to balance the near-term (2- to 4-year) focus of the CCRI with the breadth of the USGCRP, pursuing accelerated development of answers to the scientific aspects of key climate policy issues while continuing to seek advances in the knowledge of the physical, biological and chemical processes that influence the Earth system.

This *discussion draft* strategic plan has been prepared by the thirteen federal agencies participating in the CCSP, with input from a large number of scientific steering groups and coordination by the CCSP staff under the leadership of Dr. Richard H. Moss, to provide a vehicle to facilitate comments and suggestions by the scientific and stakeholder communities interested in climate and global change issues.

We welcome comments on this draft plan by all interested persons. Comments may be provided during the US Climate Change Science Program Planning Workshop for Scientists and Stakeholders being held in Washington, DC on December 3 – 5, 2002, and during a subsequent public comment period extending to January 13, 2003. Information about the Workshop and the written comment opportunities is available on the web site www.climatescience.gov. A specially formed committee of the National Research Council is also reviewing this draft plan, and will provide its analysis of the plan, the workshop and the written comments received after the workshop. A final version of the strategic plan, setting a path for the next few years of research under the CCSP, will be published by April 2003. We appreciate your assistance with this important process.

James R. Mahoney, Ph.D.
Assistant Secretary of Commerce for Oceans and Atmosphere, and
Director, Climate Change Science Program

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Scientists recognized the existence of a natural "greenhouse effect" and the possibility of human-induced changes in the Earth's climate and environment as early as the 19th century and, over time, this possibility has become widely accepted. In the last decades of the 20th century, public debate about the contribution of human activities to observed climate change and potential future changes in climate, and about courses of action to manage risks to humans and the environment, has been active and frequently contentious. These debates cover a range of both science and policy issues, including the extent to which global temperatures have in fact changed; whether most of the observed overall change in temperature of the last 50 years is attributable to human activities (principally the burning of fossil fuels and changes in land cover); how much climate might change in the future; and whether proposed response strategies, such as reductions in emissions or efforts to enhance natural carbon sequestration processes, would produce economic or other effects more detrimental than the effects of climate change itself.

Science-based information is required to inform public debate on the wide range of climate and global change issues necessary for effective public policy and stewardship of natural resources, including:

- How much have climate and other aspects of the Earth system changed since the industrial revolution, and how do recent rates and levels of change compare to those that resulted from the Earth's significant climate variability in more distant historical periods?

- What are the relative roles of natural and human-induced forces in bringing about change, and how might human-induced and natural forces interact in the future?
- How has the climate system responded to both natural and human-induced forces, and how might it respond to potential future forcing?
- What is the sensitivity of natural and managed ecosystems to climate and other global changes, and how will sensitive systems be affected by climate variability and changes in the future?
- What are the projected costs and effects of different potential response strategies to manage the risks of long-term climate change?

Developing the needed information will require addressing a wide-ranging set of fundamental science questions, significantly improving observations and data management, and implementing highly credible and transparent mechanisms for conveying research results in ways that are useful for decisionmakers and the public.

1. The Issues for Science and Society

Environmental systems on Earth are changing constantly. The climate system is highly variable, with conditions varying significantly over the span of seasons, years, decades, and longer timescales. Fluctuations in the amount of energy emitted by the Sun, slight deviations in the Earth's orbit, volcanic injections of gases and particles into the atmosphere, and natural variations in ocean temperatures and currents, all cause variability and changes in climate conditions.

Against the backdrop of these natural forces, humans have become agents of environmental change, at least on timescales of decades to centuries, even as living standards for billions of people have improved tremendously. Emissions of greenhouse gases and pollutants and extensive changes in the land surface (both tied to widespread development of modern living standards) have potential consequences for global and regional climate. They also influence air quality, the Earth's protective shield of stratospheric ozone, the distribution and abundance of water resources and many plant and animal species, and the ability of ecosystems to provide life-supporting goods and services.

The challenge is that discerning whether human activities are causing observed climatic changes and impacts requires detecting a small, decade-by-decade trend against the backdrop of wide temperature changes that occur on shorter timescales (seasons to years). A sound base of observations, as well as a solid understanding of how the Earth's environmental systems respond to different natural and human forces, is essential to detecting and attributing climate change to any specific cause. Currently, measurements taken at the Earth's surface, in various layers of the atmosphere, in boreholes, in the oceans, and in other environmental systems such as the cryosphere (frozen regions) indicate that the climate is warming. Further, in *Climate Change Science: An Analysis of Key Questions* (NRC, 2001a), the National Research

Council (NRC), the operational arm of the National Academy of Sciences (NAS), concluded that "the changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability." The NRC report elaborates on this point:

> "Because of the large and still uncertain level of natural variability inherent in the climate record and the uncertainties in the time histories of the various forcing agents (and particularly aerosols), a causal linkage between the buildup of greenhouse gases in the atmosphere and the observed climate changes during the 20th century cannot be unequivocally established. The fact that the magnitude of the observed warming is large in comparison to natural variability as simulated in climate models is suggestive of such a linkage, but it does not constitute proof of one because the model simulations could be deficient in natural variability on the decadal to century time scale. The warming that has been estimated to have occurred in response to the buildup of greenhouse gases in the atmosphere is somewhat greater than the observed warming. At least some of this excess warming has been offset by the cooling effect of sulfate aerosols, and in any case one should not necessarily expect an exact correspondence because of the presence of natural variability."

Apparently contradicting the evidence of warming are inconsistencies in the observational record, particularly related to the differences between temperature trends measured at the surface and measurements taken from satellite observations of the lower- to mid-troposphere, which show no significant warming trends in the last two decades of the 20th century. Reconciling these differences and improving observational capabilities remains an important challenge with significant potential implications for decisionmaking.

But the issues extend beyond those of "detection and attribution" to projecting how climate and other related environmental conditions could change in the future. Confidence in such projections is tied to knowledge of basic climate processes and natural variability, the ability of climate models to represent accurately these processes, and the ability of models to represent interactions of natural processes and any human-induced changes in the climate system.

Improving the capability to project future climate conditions would be of significant economic and social value. Consider, for example, the benefits of improved forecasts of the onset of the El Niño-Southern Oscillation (ENSO). ENSO is a large-scale climate oscillation in the equatorial Pacific Ocean that changes phase every few years. Its effects reverberate through the global climate system to affect precipitation and temperature in many regions of the world. Armed with a basic understanding of the processes involved, scientists intensified systematic observations and improved their models, and by the late 1990s could successfully forecast some conditions months in advance. While much additional work is required to improve ENSO forecasts, some climatic features can now be accurately predicted, with significant societal benefits. In the United States, decisionmakers are able to better estimate energy requirements, prepare for storms, manage water resources, anticipate where damage recovery efforts will be required, and foresee other potential impacts. In countries in South America, Africa, and other

regions of the world, resource planners and managers are applying model results to develop agricultural plans, anticipate potential food surpluses and shortages, and prepare for other impacts. Such planning has already reduced suffering and saved crops that would have otherwise been lost to drought and other ENSO effects.

Improving the ability to project long-term trends in climate and related conditions is important to understanding the effects of different types and amounts of natural and human forcing, such as that due to different levels of greenhouse gas and aerosol emissions. Therefore, anticipating how possible future forcing could affect the climate requires development of complex computer models that incorporate the many features of the climate system and their interactions. Such models have been under construction for decades, and require ongoing observations and research into basic processes to fuel their continued improvement. Already, large-scale features of climate can be simulated, but many significant uncertainties remain to be addressed. Current models project significantly different increases in the global average surface temperature, from approximately 1^{o}C during the 21^{st} century to more than 5^{o}C during the same period. This range of uncertainty incorporates both different estimates of climate sensitivity (the increase in temperature that results from a doubling of atmospheric concentrations of carbon dioxide (CO_2)) and a wide range in projections of future greenhouse gas emissions. Reducing uncertainty in climate models will involve improving understanding of the role of clouds in different parts of the atmosphere; improving characterization of the circulation and interaction of energy in the atmosphere and oceans; improving understanding of the Earth's natural carbon cycle; developing more detailed representations of features of and feedbacks from the land surface; incorporating additional types of forcing agents (e.g., "black carbon"); and making progress on other fundamental challenges. Improved projections of climate changes on decadal or longer timescales are also important for many areas of planning and resource management where decisions made today have implications for decades to come. However, at this point, modeled projections of the future regional impacts of global climate change are often contradictory and are not sufficiently reliable tools for planning.

Even if the scientific community were to develop a "perfect" model of the global climate, it would not be possible to predict the level and rate of future changes in climate resulting from human activities. This is because these activities are not predetermined, but rather depend on human choices, which will, in turn, affect future climate conditions. The activities in question—energy-related emissions of greenhouse gases; changing the surface of the land through clearing, conversion, and growth of different land covers; and the release of chemicals (both natural and human-made) that alter the productivity of the land and the oceans—all depend on a more basic set of human driving forces. These include population growth, living standards, characteristics of technology, and institutions (e.g., market conditions). While we cannot *predict* these conditions, we can use a different set of models to *project* the climatic and environmental consequences of different combinations of basic human driving forces. These models are useful for performing "If…, then…" scenario experiments that make it possible to begin to explore the potential implications of different technological and institutional conditions for future emissions, climate, and living standards.

Improving our ability to project potential future variations and changes in climate and environmental conditions, subject to assumptions about natural and human forcing, could enable governments, businesses, and communities to reduce damages and seize opportunities to benefit from changing conditions by adapting infrastructure, activities, and plans. But realizing this potential will require sustained research and improved understanding of the interactions among climate, natural and managed environmental systems, and human activities. Scientific research needs to address a range of issues, including:

- How might changes in climate, chemistry (e.g., the CO_2 "fertilization effect" (increased plant growth due to higher atmospheric CO_2 levels)), nitrogen deposition, and disturbance (e.g., fire, pest infestations) affect the water use efficiency, biomass allocation, and composition of natural and managed ecosystems over long periods of time?
- What is currently happening to ice sheets, sea ice, and permafrost, and what are the climatic, economic, trade, and strategic implications of future changes?
- How could climate change and sea level rise affect sediment flows, tides, waves, and biological functions of coastal areas?
- How readily can adaptation take place in different natural and socio-economic systems?

Research on such questions as these, and on development of adaptation options that are useful regardless of the origins of observed changes, will help clarify the importance of variations and potential changes in climate for the environment and society, and potentially broaden opportunities for management of risks and realization of benefits.

The complexity of the Earth's environmental systems, the unique conditions that they provide for life, and the state of these systems, including potential impacts on society, make climate and global change among the most important issues for our generation, and perhaps for generations to come. Given what is at stake, the Nation and the international community need the best possible science to inform public debate and decisionmaking in government and the private sector.

2. The Research Program

In February 2002, President George W. Bush announced the formation of a new management structure, the Climate Change Science Program (CCSP), to coordinate and provide direction to US research efforts in the areas of climate and global change. These efforts include the US Global Change Research Program (USGCRP), which began as a Presidential initiative in 1989 and was codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606), and the Climate Change Research Initiative (CCRI), which was announced by the President in June 2001 to reduce significant uncertainties in climate science, improve global climate observing systems, and develop resources to support policy- and decisionmaking. Departments and agencies of the US Government that participate in the CCSP include the Departments of

Agriculture, Commerce (the National Oceanic and Atmospheric Administration and the National Institute of Science and Technology), Defense, Energy, Health and Human Services, Interior (US Geological Survey), State, and Transportation; the US Environmental Protection Agency; the National Aeronautics and Space Administration; the National Science Foundation; and the Smithsonian Institution. The Office of Science and Technology Policy, the Council on Environmental Quality, and the Office of Management and Budget provide oversight on behalf of the Executive Office of the President.

The CCRI provides a distinct focus to the overall research program. This focus is defined by a set of uncertainties about the global climate system that have been identified by policymakers and analyzed by the NRC (NRC, 2001a). Areas addressed in the NRC report include climate observations, aerosols, North American carbon sources and sinks, climate feedbacks and modeling, scenarios of human-induced forcing, and development of methodologies for risk management. The CCRI is described more completely in Part I of this draft strategic plan.

The CCRI accelerates key areas of research that have been under development over the past thirteen years in the USGCRP. Over this period, the United States has made a large scientific investment—totaling almost $20 billion—in the areas of climate change and global change research. With these resources, research programs supported by the agencies that participate in the USGCRP, in collaboration with several other national and international science programs, have mounted extensive space-based, surface, and *in situ* (at fixed sites) systems for global observations and monitoring of climate and ecosystem variables; have documented and characterized several important aspects of the sources, sinks, abundances, and lifetimes of greenhouse gases; have begun to address the complex issues surrounding various aerosol species that may significantly influence climate; have advanced our understanding of global water and carbon cycles (but with major remaining uncertainties); and have developed several approaches to computer modeling of global climate. The program has been a comprehensive, interagency collaboration that has facilitated scientific discovery. Program results have revealed and addressed many of the complex interactions of climate and other environmental systems, and have started to lay the foundation for understanding the relationships between natural variability and human activities that may contribute to change. US researchers have developed fundamental insights into how the climate and Earth system functions: insights that are incorporated into advanced models throughout the world. The USGCRP is described more completely in Part II of this draft strategic plan.

CCSP's management will balance the CCRI's near-term focus on climate change with the USGCRP's breadth, creating a program that both accelerates development of answers to scientific aspects of key climate policy issues and supports advances in knowledge of the physical, biological, and chemical processes that influence the Earth system. This breadth is required to continue improving our understanding of the complex interrelationships among a broad set of systems that regulate climate and the global environment, as described in NRC's seminal report, *Global Environmental Change: Research Pathways for the Next Decade* (NRC, 1999a). The *Pathways* report lays out a framework of research questions that has

significantly influenced the development of this strategic plan. Other reports issued by several boards, committees, and panels of the NRC have advised the USGCRP on specific aspects of climate and global change research and have influenced specific components of its research strategy. Indeed, the program has benefited from extensive interaction with the NRC, which is responsible for evaluating the USGCRP periodically for scientific merit.

Research carried out under the auspices of the CCSP addresses a diverse set of topics including:

- Improving the understanding of the driving forces of climate and global change, including natural forces such as solar variability and human forces such as changes in land cover and emissions of greenhouse gases and aerosols;
- The atmosphere and its role in integrating climate forcing factors, including the roles of emissions of different atmospheric constituents;
- The climate system, which is regulated by complex interactions among its atmospheric, oceanic, and land surface components; which oscillates on time scales from seasons to decades; and which has experienced rapid and significant levels of change in the past (based on evidence from paleoclimate research);
- Changes in clouds in different parts of the atmosphere and their potential either to dampen or accelerate climate change, and alterations in other aspects of the "water cycle" of evaporation, precipitation, and storage that affect water resources;
- The "carbon cycle," which transfers carbon among different reservoirs in the atmosphere, on land, and in the oceans, and affects the amount of CO_2 emitted from human activities that remains in the atmosphere;
- Natural and managed ecosystems, which can dampen or accelerate forcing of climate change through their regulation of fluxes (flows) of carbon and nitrogen between soils and the atmosphere, and which constitute the Earth's basic life support system and are sensitive to changes in climate, atmospheric, and other conditions;
- The potential impacts of global change on human activities and health, and analysis of different courses of action that are available to manage risks and realize benefits; and
- The potential role of developing and recently-developed technologies in reducing net greenhouse gas emissions in the short and long term, including considerations of costs, effectiveness, and both intended and unintended consequences (in association with the Climate Change Technology Program, which has responsibility for research and development of engineered technologies for reducing and sequestering (storing) greenhouse gas emissions).

The challenge: By investigating a targeted yet comprehensive set of questions, the CCSP seeks to focus attention on key climate change issues that are important for public debate and decisionmaking, while maintaining sufficient breadth to facilitate the discovery of the unexpected. Establishing a careful balance between focus and breadth is essential if scientists are to develop knowledge of the interactions between natural variability and potential human impacts on the Earth system. This is an important management issue for the program and is a prerequisite for making as effective and productive use as possible of the significant resources allocated to this

purpose. Establishing this balance, and a rational sequencing of research priorities and potentials, will require input from both decisionmakers and the science community.

3. Guiding Principles for CCSP

To fulfill its mission as the publicly sponsored research program addressing climate change issues for the United States, the CCSP must continuously adhere to three guiding principles that underpin the objectivity, integrity, and usefulness of its research and reporting:

- **The scientific analyses conducted by the CCSP are policy relevant but not policy driven.** CCSP scientific analyses (including measurements, models, projections, and interpretations) are directed toward continually improving our understanding of climate, ecosystems, land use, technological changes, and their interactions. In developing projections of possible future conditions, the CCSP addresses questions in the form of "If…, then…" analyses. Policy and resource management decisions are the responsibility of government officials who must integrate many other considerations with available scientific information.
- **CCSP analyses should specifically evaluate and report uncertainty.** All of science, and all decisionmaking, involves uncertainty. Uncertainty need not be a basis for inaction; however, scientific uncertainty should be carefully described in CCSP reports as an aid to the public and decisionmakers.
- **CCSP analyses, measurements, projections and interpretations should meet two goals: scientific credibility and lucid public communication.** Scientific communications by the CCSP must maintain a high standard of methods, reporting, uncertainty analysis, and peer review. CCSP public reports must be carefully developed to provide objective and useful summaries of findings.

4. The Research Strategy

This draft strategic plan for the CCSP, incorporating both the USGCRP and the CCRI, is built around a carefully constructed set of questions and objectives for each of the major areas of the program. Primary research questions that focus on broad science issues are supported by more detailed questions and objectives that can be addressed in specific research initiatives and projects. For each major question addressed, the strategy includes a very brief description of the state of knowledge, subsidiary questions, descriptions of products and deliverables, information on activities and infrastructure needed to make progress, and the benefits or "payoffs" from research. For each major program area, linkages to important national and international research activities are also described.

The strategy for each major area of the program is described more fully in an accompanying set of white papers, which address these issues in greater depth.

Both the summary and the white papers should be considered as drafts subject to substantial revision through public comment and independent review by the NAS.

Following this introduction, Part I of the plan describes the components of the CCRI. These are organized into three broad programmatic areas:

- Research focused on key climate change uncertainties;
- Climate quality observations, monitoring, and data management; and
- Resources for decision support.

Part II of the plan describes major research questions about how the components of Earth's environmental system function, how the system may change in response to human and natural forcing, and what the implications of these changes may be for a variety of human activities and natural environments and resources. The specific topics addressed include:

- Atmospheric composition;
- Climate variability and change;
- The global water cycle;
- The global carbon cycle;
- Ecosystems;
- Land use and land cover change;
- Human contributions and responses to environmental change; and
- Grand challenges in modeling, observations, and information systems.

Part III of the plan describes communication, cooperation, and management issues that cut across all areas of the program, including:

- Reporting and outreach;
- International research and cooperation; and
- Program management and review.

References:

NRC, 1999a. Committee on Global Change Research, National Research Council, *Global Environmental Change: Research Pathways for the Next Decade* (Washington, DC: National Academy Press).

NRC, 2001a. National Research Council, Committee on the Science of Climate Change, *Climate Change Science: An Analysis of Some Key Questions* (Washington, DC: National Academy Press).