Planning Climate and Global Change Research: A Review of the Draft U.S. Climate Change Science Program Strategic Plan

Committee to Review the U.S. Climate Change Science Program Strategic Plan, National Research Council

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PLANNING CLIMATE AND GLOBAL CHANGE RESEARCH

A REVIEW OF THE DRAFT U.S. CLIMATE CHANGE SCIENCE PROGRAM STRATEGIC PLAN

Committee to Review the U.S. Climate Change Science Program Strategic Plan
Division on Earth and Life Studies
Division of Behavioral and Social Sciences and Education
Division on Engineering and Physical Sciences

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Preface

On September 17, 2002, Assistant Secretary of Commerce for Oceans and Atmosphere James R. Mahoney wrote to Bruce Alberts, president of the National Academy of Sciences, to request that the National Academies undertake a fast-track review of the U.S. Climate Change Science Program's (CCSP's) draft strategic plan for climate and global change studies. The letter (see Appendix D) asked the National Academies to form a committee to review both the discussion draft of the strategic plan and the final strategic plan after it has been revised. The letter also requested that the National Academies examine the CCSP's strategic planning process, focusing on the program's efforts to solicit input from the scientific and stakeholder communities between November 2002 and January 2003. In response the 17-member Committee to Review the U.S. Climate Change Science Program Strategic Plan (see Appendix B for committee biographies) was formed. This report is the committee's assessment of the discussion draft strategic plan dated November 11, 2002 and addresses phase I of the committee's statement of task (see Box P-1). A second report by this committee will review the final strategic plan after it has been released, addressing phase II of the committee's task (see Appendix E).

A challenging aspect of the committee's work has been to come to a clear understanding and agreement about the intended scope of the CCSP; that is, does the program focus exclusively on issues of "climate change"—as one might infer from the name of the *Climate Change* Science Program itself and its constituent, the *Climate Change* Research Initiative—or does it encompass all, or some, other global changes—as one might infer from the name of the CCSP's other constituent, the U.S. *Global Change* Research Program? While climate change has clearly been the major focus of past work by the GCRP and current work of the CCSP, the answer to this question has implications for the program's future. Specifically, it will determine which research areas belong in the program and, accordingly, the level of resources needed. In terms of the committee's work the answer to this question has a profound effect on how the committee responds to its task statement, in particular, to the question, "Is the plan responsive to the nation's needs for information on *climate change and global change*, their potential implications, and comparisons of the potential effects of different response options?"

The natural place to look for insights on this question was the draft strategic plan itself, which clearly indicates that the program is not designed to focus exclusively on climate change issues. For example, the title of the introductory chapter is "Climate and Global Change: Improving Connections Between Science and Society," and two of the five "climate and global change issues" to be informed by the program explicitly mention global changes other than climate change.[1] What is not clear in the draft plan is whether the program is designed to address all or some subset of issues pertaining to global change. As discussed in Chapter 2 of this report, part of the problem is that the draft strategic plan does not present a clear, concise statement of vision for the program.

Without that clear vision the committee developed its own working understanding of the intended scope of the CCSP. The committee believes that it will be important for the CCSP to consider those processes (1) that interact with climate change to produce significant impacts of societal relevance and therefore must be integrated into research to understand impacts and to develop adaptation and mitigation approaches, and (2) that have large feedbacks to climate change. In this report the committee uses the term "climate and associated global changes" as a general term encompassing those global changes included in the two categories above.

The CCSP will need to consider whether these or other criteria will determine the program's coverage of various global change processes. This is important from a planning perspective because the number of factors identified for CCSP's attention is likely to grow as the program's work

[1] In particular, "How much have *climate and other aspects of the Earth system* changed since the industrial revolution…?" and "What is the sensitivity of natural and managed ecosystems to *climate and other global changes*" (CCSP, 2002, p. 4-5, emphasis added).

with decision makers expands. Many decision makers deal with climate change as only one of a suite of factors affecting the people, economy, and ecosystems of an area. Not all of these factors will necessarily be appropriate for the CCSP's attention. An obvious tradeoff will be between depth and breadth, and the risk is a program spread so thin that it fails to make meaningful progress in core research areas. The CCSP's decisions about scope will have important implications for the portfolio of research to be funded initially, and for how this portfolio evolves over the program's lifetime.

The committee was asked to review the draft strategic plan by focusing on nine questions (see Box P-1). Five of the first six questions, which apply to the draft strategic plan as a whole, are addressed in Part I of this report. The last three questions, which apply to each major section of the plan, are addressed in Part II of this report.

The third question in the statement of task ("Is there an appropriate balance (1) between short-term (2-5 years) and longer-term goals, (2) among substantive research areas, and (3) between research and nonresearch activities, such as observations, modeling, and communicating results?") is not addressed explicitly in this report. One way to assess these elements of balance would be through budget data accompanied by cost estimates for the underpinnings of individual research components (e.g., supercomputers, satellite instruments, socio-economic surveys) and categorized as in the task statement (e.g., short-term versus longer-term, research versus nonresearch). The draft strategic plan does not include such data, nor was it possible for the committee or the CCSP to generate it in the time available. Even if available, these data would reflect only the current balance of the program and not the future directions outlined in the draft plan (e.g., whether new activities, such as those in decision support, applied climate modeling, and land-use and land-cover change, will be supported through new funding or by redirecting funds currently devoted to other research areas). The fiscal year 2004 budget request for the CCSP provides some insights into the CCSP's plans for the program, but it also was not available in time for detailed analysis at the time this report was written. Another way to assess issues of balance would be from clearly stated program goals and priorities, which are not well articulated in the draft. Therefore, the committee was not able to evaluate the balance of the plan in a detailed way. Chapter 3 of this report provides some insights on balance issues by identifying elements of the draft plan that are appropriate short-term and longer-term objectives, and by pointing out areas needing additional research. The committee will address the balance question in its second report, when the draft has been revised and relevant budget data are available.

This report is not the only mechanism through which the CCSP has received input on the draft strategic plan. On December 3-5, 2002, the CCSP held a major workshop in Washington, D.C., to obtain input from scientific and other stakeholder communities. The workshop was attended by over 1000 scientists, agency representatives, and other stakeholders who participated in breakout sessions focused generally on the strategic plan chapters and selected crosscutting themes (see <http://www.climatescience.gov/events/workshop2002/>). In the second phase of this study the committee will assess the effectiveness of this workshop as a mechanism for gathering scientists' and other stakeholder's comments on the draft plan, as directed in the statement of task. The CCSP also provided a mechanism for interested parties to submit written comments on the draft strategic plan. The committee was able to examine comments received by the CCSP before its last meeting on January 8-10, 2003, and this report is written in light of those viewpoints.

The committee held three meetings to gather information and prepare this report. The first meeting was held on November 22, 2002, in Washington, D.C. At this meeting James R. Mahoney and Richard Moss, executive director of the U.S. Global Change Research Program, presented an overview of the draft strategic plan and the strategic planning process. Representatives from participating departments and agencies also discussed with the committee their agency's strategic planning process and how their agency's research relates to the CCSP program. We thank the following individuals who participated in this meeting: James R. Mahoney, U.S. Climate Change Science Program; Richard Moss, U.S. Global Change Research Program; Mary Glackin, National Oceanic and Atmospheric Administration; Jack Kaye, National Aeronautics and Space Administration; Jerry Elwood, Department of Energy; Ari Patrinos, Department of Energy; Michael Slimak, Environmental Protection Agency; Steve Shafer, Department of Agriculture; Daniel Reifsnyder, Department of State; Harlan Watson, Department of State; Martha Garcia, U.S. Geological Survey; James Andrews, Office of Naval Research; Karrigan Bork, Department of Transportation.

Members of the committee attended the CCSP planning workshop on December 3-5, 2002, and then held a second meeting in Washington, D.C., on December 6, 2002. At this meeting the committee discussed the CCSP workshop and began to develop this report. In addition Robert Marlay, director of the Department of Energy's Office of Science and Technology Policy Analysis, briefed the committee on the Climate Change Technology Program. The committee's third meeting was held on January 8-10, 2003, during which the committee prepared this report.

The committee called upon a number of National Academies boards and standing committees with expertise in issues of climate and global change. In the short period of time available these boards and standing committees and their staffs produced very thoughtful summaries of the strengths and weaknesses of the draft strategic plan. The committee acknowledges the efforts of the following individuals who took the lead in preparing the materials on

behalf of these units:

- Board on Atmospheric Sciences and Climate: Eric Barron, Pennsylvania State University, University Park, and Amanda Staudt, National Research Council (NRC) staff;
- Ocean Studies Board: Jay McCreary, University of Hawaii, Manoa, and Morgan Gopnik, NRC staff;
- Polar Research Board: Richard Alley, Pennsylvania State University, University Park, and Chris Elfring, NRC staff;
- Climate Research Committee: Tony Busalacchi, University of Maryland, College Park, and Amanda Staudt, NRC staff;
- Committee on Human Dimensions of Global Change: Tom Dietz, George Mason University, Fairfax, Virginia, Tom Wilbanks, Oak Ridge National Laboratory, Tennessee, and Paul Stern, NRC staff; and
- Committee on Earth Studies: Michael Freilich, Oregon State University, Corvallis, and Arthur Charo, NRC staff.

The committee also received comments on the draft plan from several members of the Committee on Geophysical and Environmental Data and its staff director, Anne Linn. The contributions from these boards and committees were extremely useful in informing the committee's deliberations. Though these individuals provided many useful insights and suggestions, many of which are reflected in the report, they did not participate in the committee's closed session discussions and are not responsible for the final content of this report.

This study differs from most National Academies studies in three respects. First, the timeline for this first report was limited—approximately three months from the committee's first meeting to the deadline for delivery of this report. This timeline was driven by the CCSP's ambitious push to publish a final plan by the end of April 2003. Second, the committee was asked to review both a preliminary draft of the strategic plan and the final strategic plan, enabling the committee to provide advice at a stage in the strategic planning process when it could be most useful. Third, as discussed above, the CCSP convened a major workshop and solicited public comments on the draft plan while the study was underway. As a result, a number of the issues raised in this report have already been brought to the attention of CCSP leadership and recognized by them (see <http://www.climatescience.gov/Library/workshop2002/closingsession>).

The committee gratefully acknowledges the NRC staff who worked hard to facilitate its deliberations and the preparation of this report. Gregory Symmes and Amanda Staudt made major contributions to the report, at considerable personal sacrifice. Kristen Krapf was instrumental in coordinating input to the report from the committee and the NRC boards and committees. Byron Mason and Elizabeth Galinis were an extremely effective team in ensuring that the committee's meetings and report production went smoothly.

The committee has worked diligently to make this report as useful as possible to the CCSP. We wish the CCSP leadership well as it takes on the challenging task of revising the draft strategic plan to enhance the usefulness of the program to the decision makers who need to better understand the potential impacts of climate change and make choices among possible responses. In the opinion of many of the committee members the issues addressed by the CCSP are among the most crucial of those facing humankind in the twenty-first century.

Thomas E. Graedel, Chair

Box P-1 STATEMENT OF TASK FOR PHASE I

An ad hoc committee will conduct an independent review of the U.S. Climate Change Science Program's strategic plan for global change and climate change studies, giving attention also to the program's strategic planning process. This review will be carried out in two phases.

Phase I

In the first phase, the committee will review the discussion draft of the plan. The review will address the following questions about the draft plan as a whole:

- Is the plan responsive to the nation's needs for information on climate change and global change, their potential implications, and comparisons of the potential effects of different response options?
- Are the goals clear and appropriate?
- Is there an appropriate balance (1) between short-term (2-5 years) and longer-term goals, (2) among substantive research areas, and (3) between research and nonresearch activities, such as observations, modeling, and communicating results?
- Are mechanisms for coordinating and integrating issues that involve multiple disciplines and multiple agencies adequately described?
- Does the plan adequately describe the roles of the public, private sector, academia, state/local governments, and international communities, and linkages among these communities?
- Does the written document describing the program effectively communicate with both stakeholders and the scientific community? Is the question format for driving the research program effective?

The review also will address the following questions for each of the plan's major topical areas:

- Does the plan reflect current scientific and technical understanding?
- Are the specific objectives clear and appropriate?
- Are expected results and deliverables (and their timelines) realistic given the available resources?

In its review, the committee will consider the scientific and stakeholder community comments at the U.S. Climate Change Science Program's workshop and other comments received by the program during the public comment period. If time permits, the committee also will comment on any significant process issues related to the workshop that could affect how the program revises the draft plan. The results of phase I will be provided in a report to be delivered no later than February 28, 2003.

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

James Anderson, Harvard University, Cambridge, Massachusetts
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Susanne C. Moser, Union of Concerned Scientists Cambridge, Massachusetts
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W. Richard Peltier, University of Toronto, Ontario, Canada
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Susan Solomon, NOAA Aeronomy Laboratory, Boulder, Colorado
B.L. Turner, II, Clark University, Worcester, Massachusetts
Robert M. White, Washington Advisory Group, Washington, D.C.
Oran R. Young, University of California, Santa Barbara

Although the reviewers listed above have provided constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Richard M. Goody (Harvard University) and Robert A. Frosch (Harvard University). Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Executive Summary

For the last century human activities have been altering the global climate. Atmospheric abundances of the major anthropogenic greenhouse gases (carbon dioxide, methane, nitrous oxide, and tropospheric ozone) reached their highest recorded levels at the end of the twentieth century and continue to rise. Major causes of this rise have been fossil fuel use, agriculture, and land-use change. Observations show that Earth's surface warmed by approximately 0.6 ^{o}C (1.1 ^{o}F) over the twentieth century. This warming has been attributed in large part to increasing abundances of greenhouse gases, though it is difficult to quantify this contribution against the backdrop of natural variability and climate forcing uncertainties. The emerging impacts of this change on natural systems include melting glaciers and ice caps, sea level rise, extended growing seasons, and changes in the geographical distributions of plant and animal species. Because the Earth system responds so slowly to changes in greenhouse gas levels, and because altering established energy-use practices is difficult, changes and impacts attributable to these factors will continue during the twenty-first century and beyond. Uncertainties remain about the magnitude and impacts of future climate change, largely due to gaps in understanding of climate science and the socio-economic drivers of climate change.

Research to understand how the climate system might be changing, and in turn affecting other natural systems and human society, has been underway for more than a decade. Significant advancement in understanding has resulted from this research, but there are still many unanswered questions, necessitating a continuance of this effort. As society faces increasing pressure to decide how best to respond to climate change and associated global changes, there is a need to focus at least part of this effort on more applied research in direct support of decision making. In particular, research efforts are needed to explore response options and evaluate the costs and benefits of adaptation and mitigation.

The U.S. Climate Change Science Program (CCSP) was formed in 2002 to coordinate and direct U.S. efforts in climate change and global change research. The CCSP builds upon the decade-old U.S. Global Change Research Program (GCRP). Since its inception the GCRP has reported hundreds of scientific accomplishments and, together with other major international partners and programs, has been responsible for improving the understanding of climate change and associated global changes. The CCSP incorporates the GCRP and adds a new component—the Climate Change Research Initiative (CCRI)—whose primary goal is to "measurably improve the integration of scientific knowledge, including measures of uncertainty, into effective decision support systems and resources" (CCSP, 2002, p.15). A draft strategic plan for the CCSP was released to the scientific community and the public in November 2002. At the request of the CCSP, the National Academies formed a committee to review this draft strategic plan; the results of this review are reported herein. The committee's statement of task can be found in Appendix E of this report.

STRENGTHS OF THE DRAFT CCSP STRATEGIC PLAN

The committee commends the CCSP for undertaking the challenging task of developing a strategic plan. The current draft of the plan represents a good start to the process, particularly in that it identifies some exciting new directions for the program while building on the well-established foundation of the GCRP. Further, the CCSP has made genuine overtures to researchers and the broader stakeholder community to gain feedback on the draft strategic plan and how to improve it. These efforts indicate a strong interest on the part of the CCSP in developing a plan that is consistent with current scientific thinking and is responsive to the nation's needs for information on climate and associated global changes.

The CCRI portion of the plan introduces an admirable emphasis on the need for science to address national needs, including support for those in the public and private sectors whose decisions are affected by climate change and variability. For example, the discussion of applied climate modeling in the draft plan insightfully articulates a much-

needed new direction for U.S. climate-change modeling, reaching out beyond the "business as usual" approach of the GCRP to provide tangible decision support resources, particularly tested and trusted projections (or "forecasts") of future climate. The draft plan correctly identifies the need to enhance research on options for adaptation to climate change. In addition, the plan appropriately recognizes that there are some short-term products that can and should be delivered by the program.

The committee finds that the draft plan identifies many of the cutting-edge scientific research activities that are necessary to improve understanding of the Earth system. For example, the acceleration of research on aerosols and the carbon cycle is consistent with priorities of the scientific community. Indeed, the GCRP portion of the plan clearly builds upon the substantial and largely successful research programs of the last decade. The call for greatly improved observational capabilities reflects a well recognized priority for increasing understanding of climate and associated global changes. Further, the plan takes positive steps towards improved interdisciplinary research opportunities. Overcoming the substantial hurdles associated with the highly interdisciplinary nature of research on climate and associated global changes will continue to be a fundamental challenge for the program.

In general, the draft plan provides a solid foundation for the CCSP. With suitable revisions, the plan could articulate an explicit and forward-looking vision for the CCSP and clearly identifiable pathways to successful implementation.

Recommendation: The draft plan should be substantially revised to: (1) clarify the vision and goals of the CCSP and the CCRI, (2) improve its treatment of program management, (3) fill key information needs, (4) enhance efforts to support decision making, and (5) set the stage for implementation.

CLARIFY VISION AND GOALS

The committee found that the draft strategic plan lacks the kind of clear and consistent guiding framework that would enable decision makers, the public, and scientists to clearly understand what this research program is intended to accomplish and how it will contribute to meeting the nation's needs. The draft plan lacks most of the basic elements of a strategic plan: a guiding vision, executable goals, clear timetables and criteria for measuring progress, an assessment of whether existing programs are capable of meeting these goals, explicit prioritization, and a management plan. Many candidates for vision and goals are scattered throughout the draft strategic plan and in references to other documents, yet neither an explicitly stated vision nor a coherent set of goals are consistently presented. The draft plan lists a multitude of proposed activities, but does not identify which of these activities are higher priorities than others (either across the CCSP as a whole or within individual program areas of the CCRI or the GCRP) nor does it provide an explicit process for establishing such priorities. Finally, the plan lacks the kind of straightforward comparison of current programs to projected needs that will be essential to guide the plan's implementation. A systematic and coherent strategic plan is especially necessary when, as in the CCSP, the institutional environment is diverse and fragmented and when the program involves new directions and collaborations. Such a plan would provide a common basis for planning, implementation, and evaluation and would protect against a continuation of the *status quo*.

Recommendation: The revised strategic plan should articulate a clear, concise vision statement for the program in the context of national needs. The vision should be specific, ambitious, and apply to the entire CCSP. The plan should translate this vision into a set of tangible goals, apply an explicit process to establish priorities, and include an effective management plan.

The revised strategic plan also must present clear and consistent goals for the CCRI. The draft plan states that to be included in the CCRI, a program must produce both significant decision or policy-relevant deliverables within two to four years and contribute significantly to one of the following activities: improve scientific understanding; optimize observations, monitoring, and data management systems; and develop decision support resources. The decision support activities described in Chapter 4 of the draft plan are generally consistent with the above criteria. In fact, the committee considers the CCRI's emphasis on scientific support for decision makers one of the most promising and innovative features of the draft plan. Unfortunately, the plan's descriptions of decision support as a two to four year activity give the false impression that decision support is needed only in the near-term. While short-term deliverables are possible in this arena, decision support also will be needed as an ongoing component of the program. In addition, many of the activities described in Chapters 2 and 3 of the draft plan are not consistent with the CCRI focus on decision support and are not likely to produce deliverables within four years. This is not to say that these activities are unimportant, but simply that they are not consistent with the goals for CCRI as given in the draft plan. The committee believes that it is important for the program to correct these inconsistencies while maintaining a strong emphasis on near-term, ongoing decision support in the CCRI. The revised strategic plan also needs to describe more clearly how the research activities included in the GCRP support the decision support needs of the CCRI. Indeed, there should be a "rolling linkage" between the two programs, with CCRI objectives periodically redefined as a result of new scientific input from the GCRP.

Recommendation: The revised strategic plan should: (1) present clear goals for the CCRI and ensure that its activities are consistent with these goals; (2) maintain CCRI's strong emphasis on support for near-term decisions as an ongoing component of the program; and (3) include an explicit mechanism to link GCRP and CCRI activities.

IMPROVE PROGRAM MANAGEMENT

The management of an interagency program involving 13 agencies, each with a separate mission and a long history of independent research on climate and associated global changes, is a challenging task. The GCRP has been criticized in the past for being unable to do much beyond encouraging multi-agency cooperation and support because it lacked the authority to redirect long standing programs and mandates of individual agencies. The creation of a cabinet-level committee with the authority to shift resources among agencies to meet the goals of the CCSP is an improvement over past approaches to managing the GCRP. However, the interagency approach to managing the program may not be enough to ensure that agencies cooperate toward the common goals of the CCSP because no individual is clearly identified in the draft plan as having responsibility for managing the program as a whole.

Recommendation: The revised strategic plan should describe the management processes to be used to foster agency cooperation toward common CCSP goals. The revised plan also should clearly describe the responsibilities of the CCSP leadership.

The plan does not describe the responsibilities and authorities of contributing agencies, such as which agencies will be responsible for implementing the work. Defining responsibilities is particularly important for new areas of research that have not been significant program elements of the GCRP in the past, such as land-use and land-cover change and decision support. It is also important for crosscutting research elements, notably water cycle and ecosystems research, which are carried out within multiple agencies. Another management challenge for the CCSP is to foster the participation of mission-oriented agencies in the strategic planning process. The committee believes that mission-oriented agencies—such as the Federal Emergency Management Agency, water resources and land management agencies within Department of the Interior, the Army Corps of Engineers, and the extension and farm program agencies within U.S. Department of Agriculture—could make important contributions to identifying research needs, collaborating on research problems, and testing research and modeling results.

Recommendation: The revised strategic plan should more clearly outline agency responsibilities for implementing the research. In addition, the CCSP should encourage participation of those agencies whose research or operational responsibilities would strengthen the ability of the program to deliver products that serve national needs.

The Climate Change Technology Program (CCTP) is an interagency program parallel to the CCSP and created to coordinate and develop technologies for stabilizing and reducing greenhouse gas levels in the atmosphere. The committee is concerned that the existing management and program links between the CCSP and the CCTP may not be extensive enough to take advantage of the synergies between these two programs. This may be due in part to the CCTP's early stage of development. Generally speaking, a program to define and understand a massive problem (i.e., the CCSP) and a program to develop options for solution to the problem (i.e., the CCTP) should be guided by a common strategy. At the very least the results from each program should be used as extensive guidance for the project portfolio of the other. For example, technology options should be pursued for the highest-risk problems and informed by the most robust knowledge of those problems. Likewise, the global change effects of implementation of various solutions (e.g., sequestration impacts) should be identified and studied as an integral part of technology programs.

Recommendation: The CCSP should assess the scientific implications of technologies under consideration by the CCTP and develop realistic scenarios for climate and associated global changes with these technologies in mind. The program management chapter of the revised CCSP strategic plan should clearly describe mechanisms for coordinating and linking its activities with the technology development activities of the CCTP.

The plan currently describes scientific planning committees that will be composed of independent experts to help the agencies plan specific program elements, as has been done for the carbon cycle, the water cycle, climate observations, climate modeling, and elsewhere. The committee supports this approach. Nonetheless, the committee believes that the most difficult research management challenges will occur at the level of the CCSP program itself. Scientific and other stakeholder guidance will be needed for the whole program to establish and communicate clear priorities, evaluate progress toward meeting the overarching goals, and ensure that the inevitable trade-offs in resources and allocation of time are done so as to meet the overall program goals. Otherwise, the individual needs and priorities of the agencies will tend to take precedence over the needs of the entire program.

Recommendation: The CCSP should establish a standing advisory body charged with independent oversight of the entire program.

FILL KEY INFORMATION NEEDS

The committee identified several weaknesses in the draft strategic plan that need to be addressed if the CCSP is to meet the nation's needs for information on climate and associated global changes. First, there is now a strong need to augment the GCRP research of the last decade, which focused on national- to global-scale phenomena, with research that applies an understanding of the global scale to developing an understanding of the variability and change unique to regional scales. Such information would be useful to international, federal, state, and local decision makers facing environmental problems, including drought, flooding, or other climate impacts. Insufficient detail is provided in the draft plan about how current work on large-scale climate models will be adapted and combined with information to address regional issues and seasonal-to-interannual timeframes. Particularly important and challenging will be analyses and modeling of future regional climate and related effects on social, economic, and ecological issues. The need to develop regional research products is not adequately emphasized throughout the strategic plan or integrated through all program elements.

Recommendation: The revised strategic plan should more fully describe how models and knowledge that support regional decision making and place-based science will be developed.

The next decade of research must also support an increase in understanding the potential impacts of climate change on human societies and ecosystems, and related options for adaptation and mitigation. The need for research and applications in these areas logically follows from the CCSP's new emphasis on decision support. The plan's treatment of human dimensions and ecosystems, however, has several important gaps. It lacks research into consumption, institutions, and social aspects of technology as causes of climate and associated global changes. Further, the draft plan does not propose any research into the costs and benefits of climate change and related response options. Finally, the research plan for ecosystems needs a more cohesive and strategic organizational framework that places a clear priority on predicting ecosystem impacts and on providing the scientific foundation for possible actions and policies to minimize deleterious effects and optimize future outcomes. The committee finds that, while the draft strategic plan does address these topics to some extent, its coverage is insufficient to provide adequate input into the models and analyses necessary to reduce or clarify uncertainties, or to meet current and anticipated needs of decision makers.

Recommendation: The revised plan should strengthen its approach to the human, economic, and ecological dimensions of climate and associated global changes to ensure it supports the research necessary to project and monitor societal and ecosystem impacts, to design adaptation and mitigation strategies, and to understand the costs and benefits of climate change and related response options.

The draft strategic plan does a better job of identifying links between chapters and crosscutting themes than in the past, but, overall, the coordination among many individual program components is poor. Examples include the generally weak integration of the human dimensions, ecosystems, and water cycle issues across the plan; the nearly complete disconnect among the atmospheric composition, ecology, and land-use and land-cover chapters; and the uneven consideration of the role of the ocean in climate. The draft plan also does not adequately consider the interactions and synergies of climate change with other global changes. Climate change operates in concert with other significant changes, such as those related to land-use dynamics and hydrological cycles. Therefore, most scientists and decision makers typically do not find themselves dealing with climate change in isolation but rather as one of many factors affecting the people, economy, and ecosystems of an area.

Recommendation: The CCSP should strengthen the treatment and integration of crosscutting research areas in all substantive chapters. The revised strategic plan should address the interactions and synergies of climate change with other associated global changes.

The draft plan makes repeated reference to *the* global climate observing system, and yet to date the system is only a patchwork of observational networks maintained by various agencies within the United States and by other nations. Careful planning and major investments are needed to maintain and expand an integrated observing system that will support monitoring and modeling of climate and associated global changes. A critical weakness in the draft plan is that it does not adequately explain how existing observation systems will be integrated with a plan for expansion of them to add key climate-related ecological, biogeochemical, geophysical, and environmentally relevant socio-economic measurements. Especially for systematic integrated measurements, interagency and international cooperation could bring major advances. An integrated global climate observing system should also have a plan to make scientific products widely available in useful formats for climate-system researchers and for decision makers, to ensure continuity of observations, and to accommodate flexibility in response to changing scientific questions and societal needs.

Recommendation: The revised strategic plan should better describe a strategic program for achieving an integrated observing system for detecting and understanding climate variability and change and

associated global changes on scales from regional to global.

The committee believes that the draft plan misses an opportunity to develop a forward-looking strategy for improving international research and observation networks, exchanges of knowledge, and joint assessments. There is little discussion in the draft plan of how and whether the CCSP will participate in such international efforts. The overall sense of insularity in the plan could hinder efforts to improve linkages with the international community. International collaboration is especially valuable for building better *in situ* calibration and validation of satellite observations, for obtaining more globally distributed measurements, and for building synergy and reducing redundancy in the deployment of observation assets. Scientifically, there is a danger that the emphasis on U.S. issues and resources in the plan will result in agencies choosing not to work in geographic regions outside the United States that are significant for understanding particularly important processes.

Recommendation: The revised strategic plan should clearly describe how the CCSP will contribute to and benefit from international research collaborations and assessments.

A manifestation of the general insularity of the draft plan is that it fails to place sufficient weight on the need for the global and long-term historical context in observing, understanding, modeling, and responding to climate variability and change. This lack of context is not consistent with the global and long time-scale research perspectives of many climate scientists. The plan does not take into account, for example, how climate variability and change in North America is influenced by global variability involving the land surface, atmosphere, ocean, and cryosphere in regions remote to North America. A better presentation in the plan of the time and space scales associated with climate change also would point to the value of paleoclimate data as a descriptor of past natural variability.

Recommendation: The global and long-term historical context of climate change and variability should receive greater emphasis in the revised strategic plan.

STRENGTHEN DECISION SUPPORT CAPABILITY

The committee views the definition and development of decision support resources as a critical short-term goal of the CCSP. Although the draft strategic plan has incorporated general language about decision support in many places, it is vague about what this will actually mean. The draft plan fails to adequately distinguish between research to develop new decision support tools and understanding on the one hand, and operational decision support activities, on the other. It then does not successfully identify state-of-the-art undertakings in both. A significant problem with the draft plan is that an explicit connection to decision-making problems—both anticipated decision-making needs and past experiences—is absent. Indeed, the plan does not recognize the full diversity of decision makers and does not describe mechanisms for two-way communication with stakeholders.

Recommendation: The revised strategic plan should identify which categories of decision makers the CCSP serves and describe how the program will improve two-way communication with them. The revised plan also should better describe how decision support capabilities will be developed and how these efforts will link with and inform the program's research to improve understanding of climate and associated global changes.

The draft strategic plan's description of applied climate modeling is quite insightful, reasonably well focused, and well grounded with respect to the priorities for climate modeling research and applications over the next decade. Even so, the treatment of this topic does not adequately address several substantial challenges to meeting the ambitious goals it sets forward: (1) the optimistic, and likely unrealistic, objective of fully understanding cloud feedbacks and therefore significantly reducing climate sensitivity uncertainties within two to four years; (2) the challenge of making connections between the applied climate modeling results and the climate-impacts research community, and on to policy makers, resource managers, and other consumers of climate-change information; (3) how the current modeling community's efforts will support multiple objectives (e.g., producing scenarios for the Intergovernmental Panel on Climate Change, reducing climate sensitivity, evaluating regional impacts); (4) the lack of new resources to build the needed supercomputing and human resource capacity; and (5) the limitations of existing observation records for testing models.

Recommendation: The discussion of applied climate modeling should be revised to better describe how models will be incorporated into the broader suite of decision support activities and to better address the key challenges to attaining the applied climate modeling goals set forward in the plan.

The draft strategic plan identifies the reduction of uncertainty as a top priority for the CCSP and the CCRI. It recognizes three important points about uncertainty: (1) uncertainty is inherent in science and decision making and therefore not in itself a basis for inaction; (2) decision makers need to be well informed about uncertainty so that decisions can be made more knowledgeably; and (3) accelerated research should focus on those uncertainties

that are important for informing policy and decision making. Unfortunately, having recognized these principles of decision making under uncertainty, the draft plan does not apply a systematic process to identify the key scientific uncertainties and to ascertain which of those are most important to decision makers. Thus, the plan's research objectives intended to address decision making under uncertainty are not necessarily those of optimum use to decision makers. Further, the plan does not adequately articulate the utility of better characterizing uncertainty. The draft plan also does not build upon existing knowledge in the areas of risk estimation, assessment, perception, communication, and management.

Recommendation: The revised strategic plan should identify what sources and magnitudes of reductions in key climate change uncertainties are especially needed and where an improved characterization of uncertainty would benefit decision-making, and should use this information to guide the research program.

The draft strategic plan does not adequately use many prior assessments and consensus reports that have provided scientific information to decision makers. While the plan does refer to some of these reports with regard to scientific issues relating to the physical climate, it fails to build upon past experience in applied climate studies, including regional impacts, or in interactions with a wide range of user communities. In these facets the plan must build on lessons learned from the U.S. National Assessment of the Potential Impacts of Climate Variability and Change, the Third Assessment Report of the Intergovernmental Panel on Climate Change, the World Meteorological Organization/United Nations Environment Programme ozone assessments, and other environmental assessments.

Recommendation: The revised strategic plan should build upon the lessons learned in applied climate studies and stakeholder interaction from prior environmental and climate assessment activities.

SET THE STAGE FOR IMPLEMENTATION

The draft strategic plan calls for a multitude of research and decision support advances, including a greatly strengthened climate modeling infrastructure to address local, regional, national, and international needs; increased collaboration on key scientific challenges; a significantly upgraded global climate observing system that includes climate-quality data management; and a suite of sophisticated informational products for decision makers who in many cases are new to climate change science. It is not apparent that the CCSP has carefully evaluated the size, scope, and training of the appropriate researcher and stakeholder communities that will be needed to address these issues or how best to take advantage of those resources that do exist. The committee believes that the CCSP faces major challenges in "capacity building": systematically developing institutional infrastructure; growing new multidisciplinary intellectual talent; nurturing "networking" of diverse perspectives and capabilities; and fostering successful transition from research to decision support applications.

Recommendation: The revised strategic plan should explicitly address the major requirements in building capacity in human resources that are implied in the plan.

Another type of capacity building is necessary to acquire the computing, communication, and information management resources necessary both to conduct the extensive climate modeling called for in the draft strategic plan and to process and store the large amounts of data collected from a greatly expanded observation network. Applied climate modeling and especially the crucial regional-to-global scale climate change scenarios will require substantially enhanced supercomputer power. Improvements realized in research models need to be tested before transition to operational models; this testing requires substantial computing resources. The draft plan says nothing about what these computing requirements might be or how the CCSP might obtain them.

Recommendation: The revised strategic plan should provide details about how the CCSP will acquire the computing resources necessary to achieve its goals.

Because the draft strategic plan does not include details about present and projected levels of support for each program element and because the fiscal year 2004 budget request was not available to the committee during its deliberations, the committee had limited information to evaluate whether the "results and deliverables are realistic given available resources," one of its task statements. However, it is clear that the scope of activities described in the draft strategic plan is greatly enlarged over what has been supported in the past through the GCRP. Implementing this expanded suite of activities will require significant investments in infrastructure and human resources and therefore will necessitate either greatly increased funding for the CCSP or a major reprioritization and cutback in existing programs.

Shortly after this report entered National Academies review, the President's fiscal year 2004 budget request was made publicly available. It includes $182 million for the CCRI (compared to the fiscal year 2003 budget request of $40 million) within a total CCSP budget request of $1749 million (compared to the fiscal year 2003 budget request of $1747 million). The committee has not had the opportunity to analyze the fiscal year 2004 budget request in detail. Even so, a cursory review of the proposed budget indicates that the CCSP has chosen to increase funding for CCRI at the expense of existing GCRP program elements (or simply

relabeled some activities previously considered part of the GCRP as CCRI activities) and has shifted funds from one agency to another. Even if program funding increases, CCSP management will continue to be faced with many funding decisions, such as which new programs should be initiated (and when), whether any existing programs should be scaled back or discontinued, how to balance short-term and longer-term commitments, and how to balance support for international and U.S. programs. These resource allocation decisions must be based on the goals and priorities of the program, which should be clearly described in the revised strategic plan. The independent advisory body recommended by the committee also should be used to inform such decisions. The committee believes it is essential for the CCSP to move forward with the important new elements of CCRI while preserving crucial parts of existing GCRP programs.

Recommendation: The CCSP should use the clear goals and program priorities of the revised strategic plan and advice from the independent advisory body recommended by the committee to guide future funding decisions.

1

Introduction

The issues addressed by the U.S. Climate Change Science Program (CCSP) are among the most crucial of those facing humankind in the twenty-first century. Given increasing evidence of how humans have modified the Earth's climate over the last century, it is imperative for the nation to continue directing resources toward better understanding of what form future changes in climate and climate variability may take, the potential positive and negative impacts of these changes on humans and ecosystems, and how society can best mitigate or adapt to these changes.

Over the twentieth century the global mean surface temperature increased by 0.6±0.2°C (1.1±0.4°F) (IPCC, 2001c). Indeed, the 1990s was very likely the warmest decade for the planet since the mid-1800s. An increasing body of observations gives a collective picture of other climate changes including the widespread retreat of non-polar glaciers and the rise of global mean sea level by 10 to 20 cm during the twentieth century. The hydrology and ecosystems in many regions of the world also have been affected by changes in the climate. For example, the growing season in the Northern Hemisphere has lengthened, particularly at high latitudes, and plant and animal ranges have shifted poleward and toward higher elevations.

The role that human activities have played in causing these climate changes has been a subject of debate and research for more than a decade. There is no doubt that humans have modified the abundances of key greenhouse gases in the atmosphere, in particular carbon dioxide, methane, nitrous oxide, and tropospheric ozone (IPCC, 2001c). These gases are at their highest recorded levels. In fact, the ice-core records of carbon dioxide and methane show their twentieth century atmospheric abundances to be significantly larger than at any period over the past 400,000 years. The increase in these greenhouse gases is primarily due to fossil fuel combustion, agriculture, and land-use changes. Recent research advances have led to widespread acceptance that the human-induced increase in greenhouse gas abundances is responsible for a significant portion of the observed climate changes, though it is difficult to quantify against the backdrop of natural variability and climate forcing uncertainties.

Because the Earth system responds so slowly to changes in greenhouse gas levels, and because altering established energy-use practices is difficult, changes and impacts attributable to these factors will continue during the twenty-first century and beyond. Current models indicate a large potential range for future climates, with global mean surface temperature warming by 1.4 to 5.8°C (2.5 to 10.4 °F) by 2100 (IPCC, 2001c). This range, which many consider to be too wide to guide policy making, is due to gaps in understanding of climate science and the socio-economic drivers of climate change. Research under the CCSP is critical to improve this basic understanding so as to make it possible to produce more reliable projections (or "forecasts") of future climate and associated global changes. Such tested and trusted "forecasts" of future climate would be of great use to a broad spectrum of stakeholders, ranging from national policy makers deciding whether to ratify international agreements to reduce greenhouse gas emissions, to regional water managers deciding how much river flow to allocate to irrigation, to individuals choosing which car or appliance to purchase.

Given the above, setting new strategic directions for the CCSP is particularly important. This new program must complement the research of the last decade, which focused on building an understanding of the Earth system, with research to explicitly support decision making. To do so, it will be necessary to continue research into the physical, chemical, and biological aspects of climate and associated global changes, and to add research that will enable decision makers to understand the potential impacts ahead and make choices among possible response strategies. Further, new collaborations among scientists, policy makers, and other stakeholders will be essential to developing a research agenda that is responsive to the nation's needs.

HISTORICAL CONTEXT OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM

A multidisciplinary approach to researching Earth's biogeochemical system was first considered in the mid-1970s, when scientists became aware that humans might be perturbing the climate, as well as the biology, physics, and chemistry of the global environment. A number of reports published during the 1980s (e.g., by the U.S. Department of Energy [DOE, 1977, 1980], the National Research Council [e.g., NRC, 1983, 1986], the National Aeronautics and Space Administration [NASA] Earth System Sciences Committee [ESSC 1986, 1988]), suggested that a coordinated national research effort was needed to effectively observe and study the Earth system. The first efforts at a coordinated government research strategy came in late 1986, when NASA, the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF) began developing parallel global change programs. In 1987 eight agencies formed the federal interagency Committee on Earth Sciences (now known as the Committee on Environment and Natural Resources [CENR]). When the U.S. Global Change Research Program (GCRP) was created by a presidential initiative in 1989, CENR formed a Subcommittee on Global Change Research (SGCR)[1] to provide leadership and coordinate the activities of this new program.

The U.S. Global Climate Research Act of 1990 codified the existing interagency relationships. According to the act the GCRP was to be "aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes" (see Appendix C). The act specifically called for a 10-year research plan to be submitted to Congress at least every three years specifying "the goals and priorities for Federal global change research which most effectively advance scientific understanding of global change and provide usable information on which to base policy decisions relating to global change." Other requirements of the 10-year research plan include descriptions of activities necessary to meet the plan's goals, identification of existing federal programs that contribute to the GCRP, description of the role of each federal agency and department in implementing the plan, recommendations for international coordination of research activities, and estimates, to the extent practical, of federal funding for the activities in the plan.

In addition to the responsibility for planning and coordinating national global change research, the Global Change Research Act mandated that the GCRP produce periodic scientific assessments of the research results, prepare an annual report to Congress summarizing the program's activities, and coordinate with other nations. In 2001 the GCRP published its first assessment of results from the research program and implications for the United States (NAST, 2001). The Act also states that the GCRP should retain the NRC to "evaluate the scientific content of the plan" and to provide information and advice, in particular about "priorities for future global change research" (see Appendix C). The NRC has provided ongoing advice to the GCRP through many reports and has convened numerous public meetings of the several NRC boards and committees that focus on global change.

Since its creation in 1990, the GCRP has made substantial investments in the following general areas of climate change and global change research: measurements of the physical, chemical, and biological processes responsible for changes in the Earth system; documentation of global change; studies of past changes in the Earth system; prediction and simulation of global environmental processes; and research initiatives to understand the nature of and interactions among global change processes. The GCRP reports numerous scientific insights and accomplishments of the program in the annual publication of its report to Congress titled *Our Changing Planet* (e.g., GCRP, 2002, 2003). The program did not release publicly any ten-year plans for global change research before the draft plan this committee is reviewing. The annual publication of *Our Changing Planet* provides some indication of the GCRP's future plans and vision. For the most part, however, the GCRP has comprised atmospheric, oceanic, and land-surface research activities conducted by the individual agencies, which coordinate with each other in differing degrees.

During the late 1990s the GCRP began to develop a comprehensive ten-year research plan. It held three planning meetings with agency representatives and the science community between 1998 and 2001. The NRC was asked to provide guidance in the form of a report describing the scientific issues of global change, the key scientific questions that should be addressed by the GCRP, and research approaches to address these questions. In response to this request the NRC Committee on Global Change Research (CGCR) produced *Global Environmental Change: Research Pathways for the Next Decade* (NRC, 1999b). The CGCR also discussed a draft GCRP draft ten-year plan at a public meeting on January 23, 2001.

[1] The membership of the Subcommittee on Global Change Research has since grown to 13 agencies and departments: NASA, NOAA, NSF, Environmental Protection Agency, DOE, Department of State, Department of Defense, Department of the Interior/U.S. Geological Survey, U.S. Department of Agriculture, Department of Transportation, Health and Human Services, U.S. Agency for International Development, and the Smithsonian Institution. The Office of Science and Technology Policy and the OMB provide oversight on behalf of the Executive Office of the President.

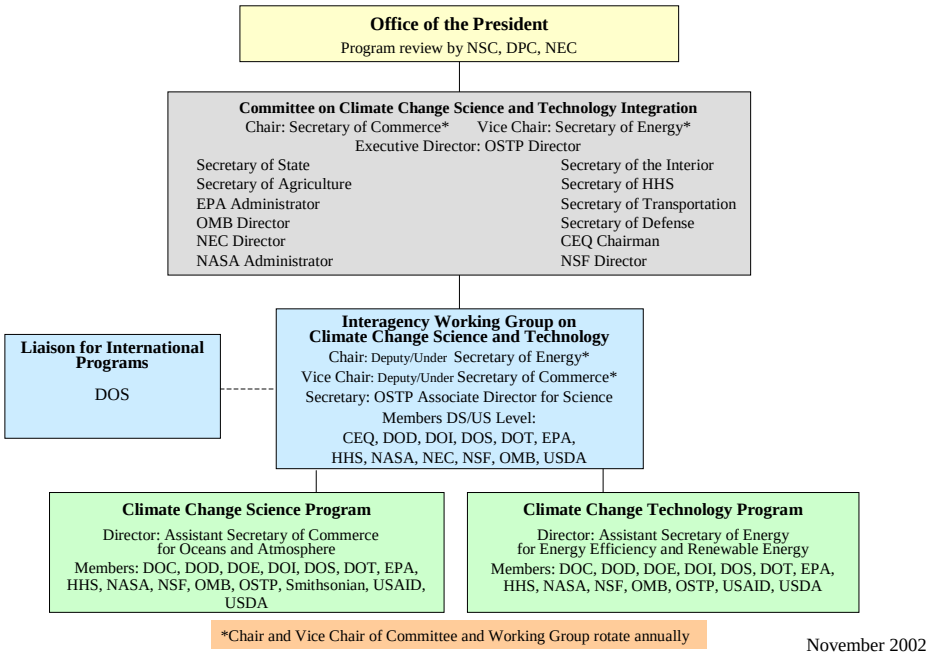

FIGURE 1-1 Climate Science and Technology Management Structure**.** Source: Available online at <http://www.climatescience.gov>.

In 2001 the new presidential administration reviewed U.S. climate change policy. Its review included another request to the National Academies to help identify "the areas in the science of climate change where there are the greatest certainties and uncertainties" and to provide "views on whether there are any substantive differences between the IPCC reports and the IPCC summaries." In response the NRC published *Climate Change Science: An Analysis of Some Key Questions* (NRC, 2001a). Days after receiving the report President George W. Bush announced the creation of the new Climate Change Research Initiative (CCRI). In his announcement the President directed that priorities be established for climate change research, including a focus on identifying the scientific information that can be developed within two to five years to assist the nation in the development of strategies to address global change risks. The President also called for improved coordination among federal agencies to assure that research results are made available to all stakeholders, from national policy leaders to local resource managers.

In February 2002 President Bush announced the formation of the U.S. Climate Change Science Program (CCSP), a new management structure that would incorporate the work of the GCRP and the newly launched CCRI. The CCSP is intended to be a single interagency committee responsible for the entire range of science projects sponsored by the two programs.[2] The Assistant Secretary of Commerce for Oceans and Atmosphere was named director of the CCSP. The interagency CCSP retains the responsibility for compliance with the requirements of the Global Change Research Act of 1990, including its provisions for annual reporting of findings and short-term plans, scientific reviews by the National Academies, and periodic publication of a 10-year strategic plan for the program. At the same time a Climate Change Technology Program (CCTP) was created to coordinate and develop interagency research efforts focused on developing new technologies related to climate change and its mitigation. The Assistant Secretary of Energy for Energy Efficiency and Renewable Energy was named the director of the CCTP. As illustrated in Figure 1-1, oversight for both the CCSP and the CCTP is provided by the Interagency Working Group on Climate Change Science and Technology, which in turn reports to a high-level Committee on Climate Change Science and Technology Integration.

The initial activities of the CCSP included an inventory of global change research activities at the 13 participating agencies. The fiscal year 2002 budget included $1670 million officially part of the GCRP plus an additional $1210 million in related and supporting research activities

[2] The SGCR retains responsibility for overseeing the GCRP in name, however the membership and leadership of the SGCR and the CCSP are identical.

at the agencies. The fiscal year 2003 request for the CCSP was $1747 million and that for the newly established CCRI was $40 million. The fiscal year 2004 requests for CCSP and CCRI are $1749 million and $182 million, respectively.

Soon after the inventory was completed the CCSP began drafting a 10-year strategic plan for global change research. The discussion draft of the plan, *Strategic Plan for the Climate Change Science Program* (CCSP, 2002), was released on the CCSP website (<http://www.climatescience.gov>) on November 11, 2002. According to the draft plan's foreword, the plan was "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," Executive Director of the GCRP.

This plan was the subject of extensive discussion by over 1,000 scientists, agency representatives, and other stakeholders at a major planning workshop in Washington, D.C., on December 3-5, 2002. The CCSP also requested that the National Academies undertake a fast-track review of the discussion draft of the strategic plan (see Appendix E for statement of task). This report represents the results of the committee's review of the November 11, 2002, draft strategic plan. This committee will issue a second report reviewing the final strategic plan and the CCSP's planning process.

Part I

Overarching Issues

2

Clarifying Vision and Goals

Are the goals clear and appropriate?

Whether the draft plan's goals are clear and appropriate is really a question of whether it succeeds as a strategic plan. Unfortunately, it does not. The document is not a coherent strategic plan, because it lacks most elements of a strategic plan, including:

- Clear and ambitious guiding *vision* of the desired outcome;
- Unambiguous and executable *goals* that address the vision and broadly describe what the program is designed to accomplish;
- Clear *timetable* for accomplishing the goals and *criteria for measuring progress*;
- *Assessment* of whether existing programs are capable of meeting these goals, thereby identifying required program changes and unmet needs that must be addressed in subsequent implementation planning;
- Set of explicit *prioritization criteria* to facilitate program design and resource allocation; and
- *Management plan* that provides mechanisms for ensuring that the goals are met and for coordinating, integrating, and balancing individual program elements and participating agencies.

A coherent strategic plan containing these elements is especially critical when, as in the CCSP, the institutional environment is diverse and fragmented and when the program involves new directions and collaborations. Such a plan would provide a common basis for planning, implementation, and evaluation and would protect against a continuation of the *status quo*. Unfortunately, these elements are either weakly identified, poorly developed, or missing altogether in the draft plan.

The information provided to the committee suggests that the draft plan was produced through a "bottom up" process in which individual committees designed plans for components of the program. While input from several scientific advisory committees guided some of these efforts, they also appear to have been influenced by existing programmatic responsibilities and funding priorities. The committee certainly recognizes that the involvement of federal program managers in the development of the draft plan will greatly facilitate the future implementation of the final plan. However, the result is that the overall CCSP plan does not articulate a clear and consistent guiding framework to enable policy makers and the public, as well as scientists, to understand what this research program is intended to accomplish and how it will contribute to meeting the nation's needs.

The committee recognizes the difficulty of producing an organization's first strategic plan and applauds the CCSP for taking on the challenge of drafting a plan that encompasses such diverse players and disciplines, particularly given the history of limited integration within the GCRP (NRC, 2001d). As the first step in a maturing strategic planning process, the draft plan successfully lays out parts of the guiding framework that should shape the final document, but they are scattered throughout the document.

ELEMENTS OF A STRATEGIC PLAN

Vision

The vision for a large government research program like the CCSP should address such national aims as understanding how humans affect global change; implementing efforts to minimize the most harmful effects; reducing vulnerability to global change; and protecting public health and natural resources. Indeed, the GCRP's authorizing legislation identifies as its purpose "to assist the Nation and the world to understand, assess, predict, and

respond to human-induced and natural processes of global change" (see Appendix C).

In the view of the committee, perhaps the clearest vision for the CCSP was given by President Bush in announcing his Clear Skies and Global Climate Change Initiatives on February 14, 2002.

> America and the world share this common goal: we must foster economic growth in ways that protect our environment. We must encourage growth that will provide a better life for citizens, while protecting the land, the water, and the air that sustain life. We must also act in a serious and responsible way, given the scientific uncertainties. While these uncertainties remain, we can begin now to address the human factors that contribute to climate change. (Bush, 2002)

A guiding vision similar to this but specific to the CCSP should be succinctly stated in the final strategic plan.

In crafting its vision, the CCSP will need to explicitly consider the scope of the program; that is, does the program focus exclusively on issues of "climate change"—as one might infer from the name of the *Climate Change* Science Program itself and its constituent, the *Climate Change* Research Initiative—or does it encompass all, or some, other global changes—as one might infer from the name of the CCSP's other constituent, the U.S. *Global Change* Research Program? The answer to this question has implications on the research areas that belong in the program and, accordingly, the level of resources needed. The committee believes that it will be important for the CCSP to consider those processes (1) that interact with climate change to produce significant impacts of societal relevance and therefore must be integrated into research to understand impacts and to develop adaptation and mitigation approaches, and (2) that have large feedbacks to climate change. In this report the committee uses "climate and associated global changes" as a general term encompassing those global changes included in the two categories above.

The CCSP will need to consider whether these or other criteria will determine the program's coverage of various global change processes. This is important from a planning perspective because the number of factors identified for the CCSP's attention is likely to grow as the program's work with decision makers expands. Many decision makers deal with climate change as only one of a suite of factors affecting the people, economy, and ecosystems of an area. Not all of these factors will necessarily be appropriate for the CCSP's attention. An obvious tradeoff will be between depth and breadth, and the risk is a program spread so thin that it fails to make meaningful progress in core research areas. The CCSP's decisions about scope will have important implications for the portfolio of research to be funded initially, and for how this portfolio evolves over the program's lifetime.

Goals

Numerous potential goals for the CCSP, CCRI, and GCRP can be inferred from the draft plan (see Box 2-1). Many come from related legislation or recent presidential announcements. The text does not highlight most as overarching program goals, however. Whereas several might be quite appropriate for CCSP, in light of the absence of an overarching vision, it is unclear whether they are necessary or adequate goals for the program.

Whatever goals that CCSP selects for the final plan, they should be associated with clear time targets, as well as criteria for success and for selecting programs to meet the goals. Clear links should exist between these goals and specific deliverables identified in the plan.

Prioritization Criteria

The draft plan lists many proposed activities, yet it does not identify which of these activities have higher priorities than others, either across the CCSP as a whole or within individual program areas of the CCRI or GCRP, nor does it describe a process for establishing priorities.[1] The mismatch between these multiple proposed activities and the resources currently devoted to the program implies that not all of the projects will be pursued with the same intensity. Numerous participants in the CCSP public workshop held in December 2002 were concerned that without priority setting, resources would not be directed toward important new research areas.

The committee inferred possible CCSP priorities from the draft plan, such as those activities included in the CCRI, or that have deliverables in two to four years. Thus, the document's criteria for including activities in the CCRI implies prioritization, specifically whether the activity will (1) produce significant decision or policy-relevant deliverables within the next two to four years and (2) contribute substantially to one or more of the CCRI goals of reducing uncertainty, improving global observation capabilities, and developing resources to support policy- and decision making. Also, although no prioritization rationale is clearly stated, some process presumably took place in choosing which products and payoffs to include for each program element in the GCRP portion of the plan.

The committee believes that the revised strategic plan would be greatly improved if it provided specific prioritization criteria or outlined an overarching prioritization process for the CCSP. Key considerations

[1] The draft plan states that activities would be identified for "early action and support" using "agreed-upon criteria" in the following areas: relevance/contribution, scientific merit, readiness, deliverables, linkages, and costs (CCSP, 2002 p. 165).

BOX 2-1 Candidates for CCSP's Overarching Goals that Can Be Inferred from the Draft Strategic Plan, (CCSP, 2002).

CCSP GOALS:

- "balance the near-tem (2 to 4-year) focus of the CCRI with the breadth of the GCRP, 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" (p. 2).

- "inform public debate on the wide range of climate and global change issues necessary for effective public policy and stewardship of natural resources" (p. 4).

- "[establish] and [apply] priorities for climate change research so the Nation can address and evaluate global and climate change risks and opportunities" (p. 149).

CCRI GOALS:

- "measurably improve the integration of scientific knowledge, including measures of uncertainty, into effective decision support systems and resources" (p.).

- "reduce significant uncertainties in climate science" (p. 2; p. 8).

- "[a]ddress key and emerging climate change science areas that offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible" (p. 15).

- "improve global climate observing systems" (p. 2; p. 8).

- "[o]ptimize observations, monitoring, and data management systems of 'climate quality data'" (p. 15).

- "develop resources to support policymaking and resource management" (p 2).

- "develop resources to support policy- and decision-making" (p. 8).

- "[d]evelop decision support resources including scenarios and comparisons; quantification of the sensitivity and uncertainty of the climate system to natural and anthropogenic (human-caused) forcings through the implementation and application of models; and structured information for national, regional, and local discussions about possible global change causes, impacts, benefits, and mitigation and adaptation strategies" (p. 15).

- "synthesiz[e] scientific results and produc[e] decision support resources responsive to national and regional needs" (p. 38).

GCRP GOALS:

- "address key uncertainties about changes in the Earth's global environmental system, both natural and human-induced" (p. 55).

- "monitor, understand, and predict global change" (p. 55).

- "provide a sound scientific basis for national and international decision-making" (p. 55).

might include the relative importance of an activity for meeting the program's goals, cost, positioning and leverage relative to the private sector and other U.S. and international research entities, and sequencing and scheduling considerations. Ideally the CCSP should make its funding decisions by carefully and explicitly considering which activities best meet the program's vision and goals and when particular research products are required. These future decisions need to be informed by the CCSP's overarching vision, rather than only by the considerations of individual agencies as they implement the plan. This will be particularly important, for example, in developing budget support for new programs and for crosscutting issues that are of high strategic importance but currently lack a strong institutional home or span multiple agencies and congressional appropriation committees (e.g., water cycle, decision support).

Assessment of Current Programs and Resources

The CCSP took an important step in mid-2002 when it inventoried federal activities related to global change research (<http://www.climatescience.gov/Library/Inventory_budgetsummary_26Aug02.pdf>). This inventory provides a baseline for the CCSP to assess, as a part of the strategic planning process, whether current programs are sufficient to accomplish the goals, performance metrics, and timelines that will be identified in the final strategic plan. Any gaps or unmet needs for information, capacity, or resources to address the program's goals and vision that are identified through this process will be a key input to implementing the plan. To be successful and to provide a clear map for the implementation phase that follows, the final strategic plan will need to include a more rigorous assessment that evaluates the match of existing programs and resources to the vision, goals, and priorities identified during the revision process.

Management Plan

A management plan describes the organizational structures and approaches to be used to ensure that program goals are met and to coordinate, integrate, and balance program elements. Chapter 15 of the draft strategic plan constitutes a preliminary management plan for the CCSP and describes at a general level the management structures and processes that will be used to coordinate and integrate federal research and technology development in climate and associated global change. As will be discussed in Chapter 4 of this report, the basic management structure appears sound and could provide a useful general framework for the management of the program. However, the chapter does not provide sufficient detail for the committee to have confidence that the management plan will be effective. A detailed management plan is especially important for the CCSP, because it is new and it is charged with coordinating and integrating the activities of 13 agencies, each with a separate mission and a long history of independent research on climate and associated global changes.

Recommendation: The revised strategic plan should articulate a clear, concise vision statement for the program in the context of national needs. The vision should be specific, ambitious, and apply to the entire CCSP. The plan should translate this vision into a set of tangible goals, apply an explicit process to establish priorities, and include an effective management plan.

RELATIONSHIP BETWEEN THE GCRP AND THE CCRI

The draft plan states that to be included in the CCRI, "a program must produce both significant decision or policy-relevant deliverables within two to four years and contribute significantly to one or more of the following activities: (1) address key and emerging climate change science areas that offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible, (2) optimize observations, monitoring, and data management systems of 'climate quality data' […], and (3) developing decision support resources" (CCSP, 2002, p. 15). Focusing part of the CCSP on short-term investigations oriented principally toward decision support is a welcome addition to the longer-term research carried out under the GCRP.

The decision support activities described in Chapter 4 are generally consistent with the CCRI objectives. In fact, the committee considers this emphasis on scientific support for decision makers one of the most promising and innovative features of the draft plan. While there are valuable short-term deliverables in this arena, the committee feels that the CCSP should also commit to a long-term investment in decision support as an on-going component of the program. It is important for the revised plan to make clear how a decision support function in the CCSP will continue well beyond the current two- to four-year effort of the CCRI.

Many of the activities described in Chapters 2 and 3 of the draft plan, however, are not consistent with the CCRI focus on decision support and are unlikely to produce deliverables within four years. This is not to say that these activities are unimportant, but simply that they are not consistent with the CCRI objectives given in the draft plan. Most if not all of the science activities identified to address key and emerging climate change science areas in Chapter 2 seem to better meet an objective of accelerating efforts to understand well-defined, priority scientific questions that may or may not be of direct relevance for decision making. Those activities proposed in Chapter 3 to optimize observations, monitoring, and data management systems

appear to be directed at "jump starting" a major new capacity-building initiative in a crosscutting element. These efforts will have few short-term deliverables but significant long-term benefits.

In revising the strategic plan there are a number of ways that the CCSP could address the major inconsistencies between the activities described in Chapters 2 and 3 and the stated goals for the CCRI. One approach would be to revise the objectives of the CCRI to be more consistent with the apparent objectives mentioned above for the activities currently included in Chapters 2 and 3 of the draft plan. This revision would tend to de-emphasize the importance of decision support within the CCRI. An alternative approach would be move those activities in Chapters 2 and 3 of the draft plan that are not directly linked to near-term decision making to the relevant GCRP sections of the plan. Decision support activities would then likely become the primary focus of the CCRI. The committee believes that it is important for the program to correct these inconsistencies while maintaining a strong emphasis on near-term decision support in the CCRI.

In addition to addressing these inconsistencies, the revised strategic plan also needs to more clearly describe how the research activities included in the GCRP support the decision support needs of the CCRI. The revised plan should clearly describe how the program intends to enable the transition of research results into operations and decision making. Indeed, there should be a "rolling linkage" between the two programs, with CCRI objectives periodically redefined as a result of new scientific input from GCRP.

Recommendation: The revised strategic plan should: (1) present clear goals for the CCRI and ensure that its activities are consistent with these goals; (2) maintain CCRI's strong emphasis on support for near-term decisions as an ongoing component of the program; and (3) include an explicit mechanism to link GCRP and CCRI activities.

3

Meeting the Nation's Needs for Climate and Global Change Information

Is the plan responsive to the nation's needs for information on climate change and global change, their potential implications, and comparisons of the potential effects of different response options?

The nation has diverse information needs on climate and associated global changes, their implications, and different response options. These needs arise from decision makers across the public and private sectors dealing with issues ranging from energy to public health and the environment and operating at the local, state, national, and international levels. A major weakness of the draft strategic plan is that it does not adequately identify these diverse needs or use them to target the scientific studies that it proposes. In general the description of the Climate Change Research Initiative (CCRI) in the draft plan does a better job of addressing a relatively short list of the major policy decisions that are pending at a national level. Even at this level the plan specifies that one of the objectives of the CCRI will be to identify "national-level decisions and [use] that list to develop decision support activities as well as to help prioritize climate change research" (CCSP, 2002, p. 40).

The draft strategic plan does identify at a general level four areas that will be important to meeting the needs of decision makers.[1]

- *Improve the global climate observation system.* Both the CCRI ("optimize observations, monitoring, and data management systems of 'climate quality data,'" CCSP, 2002, p. 15) and the U.S. Global Change Research Program (GCRP) ("monitor, understand, and predict global change," CCSP, 2002, p. 55) call for improved global observing and information systems.

- *Improve understanding of climate and associated global changes.* The draft plan states that "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" (CCSP, 2002, p. 4). The committee considers the wide range of climate change and associated global change issues to encompass Earth system processes (physical, biological, chemical, and societal), impacts on human societies and ecological systems, and the scientific underpinnings of potential response options.

- *Reduce key uncertainties.* The CCRI seeks to "reduce significant uncertainties in climate science" (CCSP, 2002, p. 2; p. 8). Likewise, the GCRP seeks to address "key uncertainties about changes in the Earth's global environmental system, both natural and human-induced" (CCSP, 2002, p. 55).

- *Develop decision support resources.* Creating "resources to support policymaking and resource management" (CCSP, 2002, p. 2) is a major new undertaking included in the CCRI portion of the plan. This objective appears to be multifaceted, calling for developing "scenarios and comparisons; quantification of the sensitivity and uncertainty of the climate system to natural and anthropogenic forcings through the implementation and application of models; and structured information for national, regional, and local discussion about possible global change causes, impacts, benefits, and mitigation and adaptation strategies" (CCSP, 2002, p. 15).

In addition to these information needs the committee notes a related need that can be inferred from the plan, though it is not explicitly stated.

- *Build capacity to implement the strategic plan.* The ambitious objectives of the draft strategic plan require substantial investments in training new researchers, building linkages across disciplines and between researchers and stakeholders, and in computing and data storage capabilities.

[1] As discussed in Chapter 2, although these general themes are expressed repeatedly throughout the draft plan, they are not explicitly identified as overarching program goals, and therefore are not identified as such in this report.

This chapter assesses the extent to which the draft plan addresses these areas without commenting on whether this list comprises the full set of information needs that the final CCSP plan should address. Developing that fuller list should be part of the process by which the draft plan is revised.

THE GLOBAL CLIMATE OBSERVATION SYSTEM

The draft plan correctly identifies the need for a global observing system for climate and climate-related variables. Such a system would include observations of physical, chemical, and biological parameters of the ocean, atmosphere, and land systems, and it would incorporate relevant socio-economic data needed to understand the factors that influence the causes of climate change. Its goals would be to supply the scientific basis for detecting climate and associated global changes and for testing and calibrating the climate system models, and to develop data products of use to decision makers. To provide climate-quality data, the observation strategy would need to be long-term, subject to careful calibration and validation, and be flexible enough to accommodate new understanding and evolving needs (NRC, 1999a; 2000b). The draft strategic plan could be improved by providing a structured program for establishing such a global climate observing system and a strategy for coordinating observation needs that cross disciplinary and national boundaries. The existing climate observing system is a patchwork of observation networks, which are not well coordinated. Large investments are needed in maintaining and expanding an integrated observing system that will support monitoring, diagnosis, and modeling of climate and associated global changes.

Many research needs in observations, monitoring, and data management systems are identified in Chapter 3, Chapters 5-11, and Chapter 12 of the draft plan. The observation goals are generally appropriate and reasonably complete, although they would benefit from some coarse prioritization or implementation schedule. A major weakness in the plan, however, is that it does not describe how existing observation systems will be integrated, nor does it offer a pathway to expansion of observation systems to include key climate-related ecological, biogeochemical, geophysical, and socio-economic measurements. A great need exists for systematic integrated measurements, where interagency and international cooperation could bring major advances. For example, significant changes in natural and managed ecosystems are already occurring in response to climate variability and changes, yet a clear strategy for obtaining the necessary observations is lacking. A more integrated approach to ecosystem observations would include ground-based monitoring of biogeochemical and other ecosystem processes (e.g., carbon dioxide flux at distributed reference sites and nutrients in stream, river, estuarine, and coastal systems and large-scale patterns of disturbance and fire) and monitoring of the distribution and abundance of key species in a range of regional terrestrial and marine ecosystems. The global climate observing system would provide datasets to explore the coupling of major cycles (e.g., carbon, water, nitrogen, energy). Better integrating relevant socio-economic observations—including changes in land use, location and intensity of economic activities that alter atmospheric chemistry, and social conditions that alter vulnerability to climate change—into this observation system could be of great use in understanding the importance of various drivers of climate change.

Major issues associated with creating and implementing an integrated, global climate observing system need more attention in the draft plan to make it clear how the selection of observation systems and sites would be guided by an overarching observation strategy. It is important that the revised strategic plan address the following:

- The role that the CCSP will play in implementing and maintaining national- to global-scale observing systems that require interagency and international cooperation.
- How the program will develop an appropriate range of space-based and *in situ* observing systems with an adequate overlap to allow the calibration necessary to maintain data quality.
- Efforts to observe important local and regional variability (such as due to local orography, local coastline structure, or land-sea temperature differences not otherwise resolved) that are necessary to meet the CCSP's goals of providing information to decision makers. Design of local or regional observation arrays will need to be responsive a variety of users' needs while being consistent in accuracy and practice so that they feed data into the global array.
- How climate modeling and observation activities will be coordinated, including the use of models to aid in the design of improved climate observing systems and the deployment of observation networks appropriate for testing climate models.
- The challenges associated with the transition of research observations to operational platforms and to measurements involving *in situ* and space-based instruments (NRC, 2000a). Although the plan refers to making climate observations accessible, it would be more effective if it conveyed an overall vision for climate services as discussed in various recent reports (e.g., NRC, 2001b).
- The requirements to ensure that observations for weather have value for climate studies (NRC, 1999a; 2000b; 2000c).

Chapter 3 of the plan identifies a number of observation activities that CCSP considers of higher

priority for decision making, therefore warranting their inclusion in the CCRI portion of the plan. Although the activities chosen are appropriate, the observation approach within the CCRI lacks a clear strategy for implementing the system. Chapter 3 of the plan largely sidesteps the fundamental overhaul and large national and international capacity-building required to establish the needed observation programs. It is clear that the observing system objectives listed in Chapter 3 of the plan are long-term programs with most benefits accruing well beyond two to four years. This does not necessarily mean that new initiatives to improve observations, monitoring, and data management are inappropriate for the CCRI. Rather, if they are to remain as part of the CCRI, the plan should more clearly describe what will be accomplished in two to four years, how these results will improve decision making, and how these short-term initiatives relate to longer-term progress on observations, monitoring, and data management that will be carried out under the GCRP.

Recommendation: The revised strategic plan should better describe a strategic program for achieving an integrated observing system for detecting and understanding climate variability and change and associated global changes on scales from regional to global.

IMPROVE UNDERSTANDING OF CLIMATE AND ASSOCIATED GLOBAL CHANGES

The scientific research program presented by the draft plan is of mixed quality. In general, the better developed parts of the plan build upon the substantial and largely successful research programs of the last decade. Also, those elements of the research plan that were based on the advice and reports of specialized scientific steering groups (e.g., the carbon cycle, the water cycle, climate observations, and climate modeling) benefited from a sustained and close interaction with their scientific community and the relevant federal program managers. In contrast, several of the crosscutting program elements—such as regional studies, ecosystems, the human dimensions, and the role of oceans in climate—need the greatest improvement. This is largely because these content areas are not as well developed, too narrowly constrained in the existing GCRP structure, or fall across multiple program elements.

Thus, the committee finds that, although existing GCRP activities provide a reasonably sound foundation for the CCSP strategic plan in areas of historical strength, this approach also has important shortcomings. It potentially perpetuates: the weak coordination that has existed among program elements; the adherence to agency-specific foci that, in the past, has hindered the development of comprehensive research programs in some areas; and the difficulty in supporting new crosscutting initiatives. The enhanced focus of the CCSP on decision support is likely to bring these shortcomings into sharp relief, as decision makers who need to understand impacts and develop response strategies call for new kinds of information that have historically received relatively little attention from the GCRP.

In the following pages the committee discusses several weaknesses in the research activities presented by the plan. A more detailed analysis of each chapter of the draft plan is provided in Part II of this report.

Regional Studies to Facilitate Decision Making

A need now exists to use understanding of global-scale phenomena to develop predictive information on regional and smaller scales. Such information is essential for federal, regional, and local decision makers and resource managers addressing such issues as public health and economic development, water use planning, the condition of forests and fisheries, and endangered species. The CCSP highlights the need to investigate regional problems, devoting a section in Chapter 4 of the draft plan to "Decision Support Resources for Regional Resource Management" (CCSP, 2002, p. 41-43) and identifying some regional modeling products and payoffs designed to improve interactions between producers and users of climate variability and change information (CCSP, 2002, p. 77-78). Insufficient detail, however, is provided in the draft plan about how the program anticipates scaling down its current efforts to address regional issues.

Scaling down from global to regional and local scales is an important research endeavor that the CCSP must address. Particularly important and challenging will be analyses and models of future regional climate and related effects on social, economic, and ecological issues of concern to regional decision makers. The committee believes that regional or place-based studies provide important opportunities to calibrate models with specific *in situ* measurements, evaluate global mechanisms, address the tangible impacts of climate change on societies and ecosystems, and develop models for providing climate information to stakeholders and thus better engage them in the decision-making process. Regional studies are also a critical element of the global climate observing system, providing key information for improving climate system models. Pursuing regional studies can also provide scientific understanding of scale interactions that translate local climate and associated global changes to global impacts.

Most routine resource management decisions are made on a daily, seasonal, interannual time scale (e.g., agricultural planting and risk management, water management, energy resources for heating and cooling, etc.), yet these time scales are under-represented in the CCSP. To maximize the utility of decision support activities, the nature and time frame of the relevant

decisions need to be clearly identified, and appropriate tools need to be developed. This concept has been well articulated in the western water "decision calendar" developed by NOAA's Regional Integrated Sciences and Assessments (RISA) in Boulder, Colorado. The calendar depicts the annual reservoir management decision timeframes so that climate information can be provided to managers when it is most useful to them. The preliminary success of El Niño-Southern Oscillation (ENSO) forecasts, as discussed in the draft plan (CCSP, 2002, p. 6), and the achievements of pilot regional assessments in delivering useful climate information to stakeholders demonstrate the societal and economic benefits that can accrue from such efforts. The successful prediction of long-term climate change at regional scales, however, is a significant challenge facing the CCSP.

On an international level the development of regional specific studies and networks of scientists is an opportunity to leverage the U.S. program with international contributions while building a broader community of scientists outside the United States. Regional and local networks of on-the-ground science efforts will enhance the reliability of the outputs from the program and provide key links with global satellite observations.

Recommendation: The revised strategic plan should more fully describe how models and knowledge that support regional decision making and place-based science will be developed.

Human, Economic, and Ecological Dimensions of Climate Change

While the last decade of climate change research focused on how the climate is changing, the next decade must also support an increase in understanding of the potential impacts of climate change on human societies and ecosystems and related options for adaptation and mitigation. The need for research in these areas logically follows from the CCSP's new emphasis on decision support, and is identified in the draft strategic plan.[2] Strong and strategic research programs on human dimensions and ecosystems and better integration of economic concepts would enable CCSP to meet this need. However, the committee finds that the draft plan's coverage of these topics (primarily in Chapters 10 and 11) is sufficiently weak that it raises serious questions about CCSP's ability to meet current and future needs of decision-makers at local, state, regional, and national levels or to provide adequate input into the models and analyses needed to reduce or clarify uncertainties. These flaws create critical weaknesses that translate across the draft strategic plan, because so many connections should exist between the plan's other research areas and research on human dimension and ecosystems, and because economic analysis is so integral to decision-making.

The plan's treatment of human dimensions has several important gaps. It does not include, for example, research on the role of institutions (e.g., property rights and markets) or of consumption (e.g., per capita water consumption) in driving future patterns of environmental change and resource supply and demand. Nor does it recognize the importance of deliberative interactions with stakeholders and the value of research on human preferences as input into policy decisions. Importantly, Chapter 11 fails to address the need for basic social science research into human-environment interactions or for more applied research into questions about mitigation and adaptation.

A key gap in the draft plan is research that might lead to better understanding of the costs and benefits of climate change. Measuring and monetizing the costs and benefits of climate change is a fundamental intellectual problem. A wide range of potential costs and benefits needs to be considered, including the direct and indirect costs and benefits of mitigation, the costs and benefits of public and private adaptation, and the costs and benefits of adjustment from one climate to another. Generating estimates of the impacts from climate change, which involves both market and nonmarket effects, is a continuing research challenge. Improving the economic research in the draft plan could be of great value to policymakers whose choices will hinge on the broadly construed costs and benefits of alternative actions.

The research plan for ecosystems needs a more cohesive and strategic organizing framework that places a clear priority on predicting ecosystem impacts and on providing the scientific foundation for possible actions and policies to minimize deleterious effects and optimize future outcomes. Overall, the draft plan devotes insufficient attention to understanding the interplay between climate change and the ecological patterns and processes that sustain the capacity of ecosystems to deliver goods and services desired by society (e.g., the diversity, distribution, and dynamics of species and ecological communities; large scale ecosystem processes like disturbance and hydrology; the spatial configuration and connections among ecosystems; and evolutionary processes) (NRC, 1999d). Targeted research in these areas will be essential for ensuring that managed and natural ecosystems continue to provide food, clean water, wildlife, germplasm resources, and other benefits. Insights from this research will be of use, for example, to farmers and public land agencies for designing and choosing among competing management approaches, to county agencies for developing land-use plans, and to policy makers for evaluating the full benefits and risks of adaptation and mitigation strategies.

[2] For example, "How readily can adaptation take place in different natural and socio-economic systems?" (CCSP, 2002, p. 8), and "What are the projected costs and effects of different potential response strategies to manage the risks of long-term climate change?" (CCSP, 2002, p. 5).

Recommendation: The revised plan should strengthen its approach to the human, economic, and ecological dimensions of climate and associated global changes to ensure it supports the research necessary to project and monitor societal and ecosystem impacts, to design adaptation and mitigation strategies, and to understand the costs and benefits of climate change and related response options.

Integration of Critical Crosscutting Issues and Associated Global Changes

While the draft strategic plan does a better job of identifying links between chapters and crosscutting themes than did previous draft GCRP plans, overall, the coordination among many program components is poor. Chapter 8 of the draft plan on land use and land cover is a notable exception by presenting a problem-driven approach that integrates natural science and social science research on environmental change. This chapter frames its research strategy by identifying and analyzing the agents of change in the system in question, improving the ability to characterize and predict environmental changes and improving understanding of the links and feedbacks between the environmental systems. Chapter 6 of the plan provides an overarching discussion of climate variability and change with questions that would motivate efforts that span present elements of the GCRP, but it does not indicate how such crosscutting themes would be addressed.

There are many examples where coordination is lacking in the plan. Ecosystems and human dimensions are weakly integrated across the draft plan. The carbon cycle strategy in Chapter 9 would be greatly strengthened if it included a more comprehensive plan for research on the human dimensions of the carbon cycle and if it addressed the full range of interactions with ecological systems. The plan's treatment of water resource issues would be strengthened by greater linkages between the water cycle chapter and the addressing decision support, carbon, and land use and land cover. The apparent disconnect among the chapters on atmospheric composition, the water cycle, ecology, and land use and land cover is another manifestation of a problem with plan integration.

Certain crosscutting topics that ought to come up in multiple parts of the plan are surprisingly absent. One already mentioned is the general lack of economic approaches across the plan. Another example is the oceans. The plan provides uneven coverage of ocean-related issues and impacts, despite the well-documented role of the ocean in climate change and variability. The oceans store and transport freshwater, nutrients, heat and carbon, and as such are a critical component of the climate system; they are also an important source of livelihood, recreation, and food and directly impact the majority of the world's population.

The CCSP needs to address another kind of linkage in addition to those among existing program elements, specifically the interactions and synergies between climate and associated global changes. The committee believes that it will be particularly important for the CCSP to consider those processes (1) that interact with climate change to produce significant impacts of societal relevance and therefore must be integrated into research to understand impacts and to develop adaptation and mitigation approaches, and (2) that have large feedbacks to climate change.

The draft plan makes an important step in this direction through its inclusion of land use and land cover change as a new core program element. The committee believes that the CCSP should consider expanding its coverage of two other interacting processes of global change. First, major shifts are now occurring in global nutrient cycles, which can have important feedbacks with the climate system. Of particular concern is the widespread elevation in environmental nitrogen due to greatly increased use of nitrogen, especially in agriculture. Second, major translocations are now occurring in the world's biota. Species invasions and alterations in the structure and functioning of many ecosystems, already on the rise due to other factors, are expected to increase in response to a changing climate. In turn, these ecological shifts (such as increases in fire frequency due to invasions of fire prone plants) are likely to alter the set of feasible options for adapting to climate change.

Recommendation: The CCSP should strengthen the treatment and integration of crosscutting research areas in all substantive chapters. The revised strategic plan should address the interactions and synergies of climate change with other associated global changes.

Global and Long-Term Context for Climate Science

The global and long-time scale perspectives of climate researchers have provided a valuable context in observing, understanding, modeling, and responding to climate variability and change (e.g., NRC, 1999b). This context is not clearly conveyed in the draft plan. Further, the plan does not acknowledge how variability and change in North America is strongly affected by the global atmosphere, ocean, and cryosphere. It is the global, three-dimensional ocean circulation that introduces long-time scales (decades to centuries) into climate variability and change and it is the basin-scale patterns of coupled ocean and atmosphere variability that introduce interannual and decadal variability in North America. The plan should better reflect the role of large-scale and global variability: the global nature of the ocean and atmosphere circulation and their associated time scales; the large storage capacity and slow sequestration of heat, carbon and other constituents in important reservoirs; and the ability of remote regions to affect climate in North America.

The draft plan could be improved by establishing the setting of the Earth located in space, receiving solar radiation from the Sun, with large-scale processes in the atmosphere and ocean then governing the distribution of heat and freshwater about the globe. The influence of the large-scale setting on regional variability and change needs to be a recurring theme in all the chapters of the draft plan. To do so would motivate the need for an integrated global climate observing system and explain why climate science research in the United States must include studies of processes and variability at sites remote from North America. This would also help justify to stakeholders who seek improved local prediction why they should support long-term, global climate observations and research.

A better presentation of the time scales associated with climate change would also point to the value of paleoclimate data as a descriptor of past natural variability, including past abrupt climate changes (NRC, 2002). While paleoclimate data is noted at times in the draft plan, its value becomes more clear when one is aware of the large-scale patterns of variability of the climate system. It should be made clear that paleoclimate data provides long records of the time scales and range of variability that have been dominant in the past and an essential context for present studies of forced climate change combined with natural variability.

Recommendation: The global and long-term historical context of climate change and variability should receive greater emphasis in the revised strategic plan.

ADDRESSING KEY UNCERTAINTIES

The draft strategic plan identifies reducing uncertainty as a top priority for the CCSP, and the CCRI in particular (for example, see CCSP, 2002, p. 2). Addressing uncertainty is the subject of one of the three guiding principles for the CCSP.

> 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, 2002, p. 11).

Chapter 2 of the draft strategic plan titled "Research Focused on Key Climate Change Uncertainties," describes research areas that address "key and emerging climate change science areas that offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible" (CCSP, 2002, p. 15; p. 17). These statements indicate that the CCSP realizes three important points about uncertainty: (1) uncertainty is inherent in science and decision making and therefore not necessarily a basis for inaction; (2) decision makers need to be well informed about uncertainty to allow more knowledgeable decisions to be made; and (3) accelerated research on uncertainties should focus on those uncertainties that are important for informing policy and decision making. However, the draft plan does not present a systematic process to identify the key scientific uncertainties and to ascertain which are most important to decision makers. The draft plan would be more useful in sequencing a set of problem-driven research activities if such a process had been applied. Further, the committee believes that the draft plan understates the level of our current understanding and overstates the level of uncertainty in some places, possibly because parts of it so closely resemble preceding GCRP plans. Thus, the resources put into the GCRP over the last decade appear to be undervalued, despite the significant advances in understanding of climate and global change achieved by the program. The connections between what the plan promises to do for the coming years and what has been accomplished over the last decade should be strengthened in the revised plan.

The CCRI goal of reducing significant uncertainties within two to four years may only be achievable incrementally for the topics identified in Chapter 2 of the draft plan (i.e., aerosols, North American carbon cycle, and cloud and polar feedback processes). Such incremental reductions in uncertainty in these areas could be realized within longer-term national and international research efforts. Thus, because addressing key uncertainties for decision makers is a high priority for the CCSP in the next two to four years, the program should set goals for near-term reporting of progress. Additionally, the CCRI could focus on better characterizing uncertainties and on uncertainties that are more amenable to a short-term solution. These include questions that can be addressed using "if, then" scenarios and improvements to climate models that can be accomplished with existing data and collaborations among current researchers.

Characterizing and Reducing Uncertainty

All important decisions are made under conditions of uncertainty. Indeed, uncertainty will never be resolved fully. This points to the importance of providing the most accurate representation of uncertainty and points of scientific disagreement. The CCSP recognizes this point in choosing a guiding principle that "CCSP analyses should specifically evaluate and report uncertainty" (CCSP, 2002, p. 11), but the draft strategic plan neither clearly describes the different types of uncertainties nor articulates the value of characterizing uncertainty to decision makers. For example, inherent uncertainty in the climate system (e.g., the chaotic motions of Earth's atmosphere and oceans) is not clearly distinguished from uncertainty due to a lack of

understanding. Yet, it is important for decision makers to understand the source, magnitude, and nature of uncertainty, as well as areas of insufficient scientific understanding and of scientific disagreement. Is the uncertainty due to a lack of knowledge about causal processes? Are causal processes known, but the parameters cannot be accurately estimated because of lack of data, imprecision in the data, or inadequate computing power? Is uncertainty traced to broken links in the separate but interacting systems that drive climatic dynamics and other global processes? The precise characterization of the bases of uncertainty can target areas of further investigation. It can also help decision makers judge whether additional knowledge might improve decisions in the near future.

Systematic Identification of Key Uncertainties for Decision Making

Chapter 2 of the strategic plan accurately identifies three research questions related to significant remaining uncertainties in the physical, chemical, and biological understanding of the Earth system. The plan does not explain how these questions were selected or how the results of these research activities will lead to improved decision making in two to four years. It is not apparent that the CCSP systematically considered the value of these activities for decision making. Instead, the draft plan states that the research areas are selected from recommendations of the NRC report *Climate Change Science: An Analysis of Some Key Questions* (NRC, 2001a). Because the recommended research areas in this report were intended to answer, "What are the specific areas of science that need to be studied further, in order of priority, to advance our understanding of climate change?", this list of research areas may be different from one optimized for providing useful information to decision makers. Relying on the recommendations for priority research from the *Climate Change Science* report is inadequate for meeting the nation's broader needs for global change information to support a wide range of decisions.

Key uncertainties should be identified more systematically, in consultation with decision makers to learn what decisions they need to make. A research agenda focused on making better decisions can then be generated by carefully considering what information is most critical for making those decisions, and then identifying the information that is most uncertain. In many ways this process is similar to the strategic planning process outlined in Chapter 2 of this report. Rigorous processes of this sort are routinely used in other areas of applied research associated with substantial uncertainty (e.g., the rate of spread of a communicable disease).

As noted above, uncertainty is an unavoidable feature of climate and global environmental policy choices. Many techniques to estimate risk, the probability of an impact in the face of uncertainty, are available. There is a sizable and rapidly growing literature in the field of risk analysis that can inform climate and global change decisions, such as how to respond to the threat of drought, flooding, or crop failures. Risk analysis addresses not only the estimation and assessment of risks but also risk perception, risk communication, and risk management—knowledge useful to a wide variety of decisions. For example, the framing of risks and the means of communicating information about risk are highly influential in how risks are perceived by laypersons and experts (NRC, 1996).

Recommendation: The revised strategic plan should identify what sources and magnitudes of reductions in key climate change uncertainties are especially needed and where an improved characterization of uncertainty would benefit decision making, and should use this information to guide the research program.

DECISION SUPPORT RESOURCES

The CCRI portion of the plan introduces an admirable emphasis on the need for science to provide decision support for those in the public and private sectors whose policy decisions are affected by climate change and variability. The CCRI's call for building decision support resources is one of the most innovative and promising features of the draft plan. Building and using this capacity means commitments to capitalize on available information and existing decision support tools, to collect new information to address gaps in understanding, to develop new tools and capacity for decision making, and to engage stakeholders. The committee views the development of decision support resources as the most critical short-term goal of the CCSP. Strong incentives exist for decision makers to use the results of CCSP research when this information is developed and communicated in an accessible and timely manner. The overall objectives identified in the draft plan are certainly amenable to significant short-term progress.

Although the draft strategic plan has incorporated the general language about decision support in many places, it is vague about what this will actually mean. In some cases the strategic plan does not reflect the current state of knowledge relative to decision support and recent science decision-making experiences. Of particular importance is that the plan needs to better identify decision makers and their individual needs, as discussed in Chapter 5 of this report.

Decision Support Research and Operational Activities

The discussion of decision support in the draft plan is weakly developed, in particular the section "Resources for Risk Analysis and Decision Making under Uncertainty" on pages 52-53 of the draft plan. The draft plan does not

adequately distinguish between *research* to develop new decision support tools or understanding, on the one hand, and *operational* decision support activities, on the other. It then does not identify state-of-the-art undertakings in both. Decision support research includes (1) natural and social science research to address gaps in information needed by decision makers (e.g., scenarios, applied modeling); (2) research on processes to improve decision making by effectively translating scientific information into policy options; and (3) research on developing public participation processes. The operational end of decision support focuses on building specific mechanisms or tools for connecting with the wide range of stakeholders, ranging from deliberative processes to identify user needs to application of decision support tools in an operational mode.

Research on processes to improve decision making should comprise activities to tailor available tools for decision support and risk analysis, the transfer of tools across context, and the development of tools customized for climate and global change decision making. The draft plan identifies a number of existing approaches for evaluating longer-term risks in multivariable systems, including game theory, preferences elicitation, and decision sequencing (CCSP, 2002, p. 53); and scenarios, comparisons, applied climate modeling, and historical data analysis (CCSP, 2002, p. 43-52). On the other hand, as described previously, the plan could call for more efforts in the areas of risk assessment and estimation, risk perception, risk communication, and risk management. In identifying research activities in decision support the plan should emphasize products that can be used at appropriate scales and in the context of all the factors influencing environmentally relevant decisions, as well as the opportunities to produce these products in cooperation with stakeholders and the private sector.

The plan does not adequately elaborate upon the processes it will employ for deliberation and adaptive learning. The effectiveness of decision-making tools and risk analyses is fully dependent upon the procedures adopted for their use, in particular how scientists, decision makers, and other stakeholders are engaged in the process. Deliberation should be devoted to determining user needs for decision-relevant scientific information, to the selection of appropriate tools, to the application of those tools in support of decisions, and to the inclusion of all stakeholders in the process. A clearly articulated program of deliberation processes, called analytic deliberation, is contained in the NRC report *Understanding Risk: Informing Decisions in a Democratic Society* (1996).

Recommendation: The revised strategic plan should better describe how decision support capabilities will be developed and how these efforts will link with and inform the program's research to improve understanding of climate and associated global changes.

Applied Climate Modeling

The "Applied Climate Modeling" section of the draft plan (CCSP, 2002, p. 47-52) articulates a much needed new direction for U.S. climate change science, reaching out beyond the business-as-usual approach of the GCRP to provide tangible decision support resources. This section is insightful, reasonably well focused, and well grounded with respect to the priorities for climate modeling research and applications over the next decade. It also shows considerable understanding of the research required to produce some of the key mandated improvements in climate modeling skill, particularly in quantifying climate sensitivity, as well as a keen awareness of the growing but embryonic multi-organization collaborative efforts in applied and theoretical climate change modeling.

The applied climate modeling discussion could be improved by strengthening its treatment of several substantial challenges to meeting the ambitious goals it sets forward.

- The rigidly stated four-year deadline to produce a substantial reduction in climate sensitivity uncertainty is optimistic and likely unrealistic, mostly because of the daunting challenges remaining in understanding and modeling the physics of cloud-radiation feedbacks.
- This section sidesteps the challenge of making connections between the applied climate modeling results and climate impacts researchers, decision makers, resource managers, and other consumers of climate change information. Serious capacity building is necessary, particularly with respect to increasing the capability and number of researchers producing and receiving the model results. In addition, this section does not adequately address how the applied climate modeling activities will be coordinated with the more theoretical model improvements called for under the GCRP.
- The draft plan is unclear about how the National Center for Atmospheric Research-Geophysical Fluid Dynamics Laboratory partnership will be directed (e.g., will its focus be on conducting Intergovernmental Panel on Climate Change (IPCC) projections; facilitating the transition of research results into operational code; refining projections so as to reduce uncertainties in climate sensitivity; preparing model projections for local, regional, and national decision makers; or some combination of these?). The current modeling community will not be able to make substantial near-term progress on all of these fronts, and prioritization will be necessary.
- The section does not adequately address the serious mismatch between existing supercomputer resources and those needed to implement the proposed applied modeling program. Neither the draft plan nor *Our Changing Planet* (GCRP, 2003) indicate that the CCSP intends to seek sufficient funding to address these limitations in the ability to produce and utilize climate projections.

- The discussion of "Testing Against the Climate Record" understates the challenges in these endeavors. Operational satellites have had difficulty in producing reliable measurements of atmospheric temperature trends (NRC, 2000d). The CCSP should strive to ensure that future satellite systems improve upon the recognized climate monitoring deficiencies of the existing system (NRC, 2000b; 2000c). The proposal to test contemporary climate-change models against the paleoclimate record needs to be more specific to overcome ongoing data and interpretive challenges with this type of analysis.

Recommendation: The discussion of applied climate modeling should be revised to better describe how models will be incorporated into the broader suite of decision support activities and to better address the key challenges to attaining the applied climate modeling goals set forward in the plan.

Existing Decision Support Assets

The draft strategic plan does not adequately utilize many prior assessments and consensus reports that have provided scientific information to decision makers. There are numerous examples of GCRP research supporting assessments and interactions with decision makers and industry on environmental issues. While the plan refers to some of these reports with regard to natural science issues relating to the climate, these reports are not used as examples of success or failure in applied climate studies, including efforts to assess regional impacts, or in interactions with a wide range of user communities. In this respect the plan might build on lessons learned from the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (NAST, 2001), the IPCC process (e.g., IPCC, 2001a, b), and other environmental assessment undertakings. The draft plan deals with many issues that were addressed in the U.S. National Assessment, but the document is not referenced, nor is it used fully in the human dimensions and decision support sections of the draft plan (e.g., scenario development). No matter what the evaluation of the U.S. National Assessment, there were many valuable lessons learned from it in terms of regional impact studies and interactions with stakeholders. These lessons should not be ignored in the CCSP strategic plan.

The plan does not use as a model what the United Nations Environment Programme/World Meteorological Organization (UNEP/WMO) or IPCC assessments have accomplished in terms of decision support, applied science, and stakeholder participation. The UNEP/WMO ozone assessments have had fifteen years of highly successful interaction with governments as Parties to the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. While the IPCC assessments are referenced and used to justify the CCSP, the lessons learned, among others the outstanding success in communicating with governments around the world, are overlooked. For example, the IPCC aviation assessment (IPCC, 1999) was successful in involving scientists, industries, governments, and intergovernmental regulators (i.e., International Civil Aviation Organization) in evaluating options for future aviation. In many aspects climate science has already succeeded in communicating with stakeholders and in being used in policy decisions, but the CCSP does not take advantage of these successes.

In identifying the relevant decision makers and their needs the CCSP also should build on decades of work in this area by various government agencies, such as the Energy Information Administration, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service and Office of Global Programs, the U.S. Department of Agriculture's Natural Resources Conservation Service, and the National Aeronautics and Space Administration's (NASA's) various ozone assessments. Research needs regarding vulnerability, key risk areas, and interactions with stakeholders can be gleaned from the regional and sectoral findings of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (NAST, 2001), the IPCC report from Working Group II, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (IPCC, 2001a), and the experiences of past GCRP programs that have supported research and delivery of information to stakeholders, such as NOAA's Regional Integrated Sciences and Assessments (RISA), NASA's Regional Earth Science Application Center, and NSF's Science and Technology Center programs. In particular, the RISA program has dealt with climate impacts and delivery of regional climate and environmental information on all time scales to stakeholders in various regions of the United States, while the International Research Institute for Climate Prediction (the IRI), in cooperation with U.S. Agency for International Development has encouraged similar capacity building in developing countries. These programs could form the kernel of a future "research-to-operations" system that would be focused on understanding the decision context and informing decisions at regional scales.

Recommendation: The revised strategic plan should build upon the lessons learned in applied climate studies and stakeholder interaction from prior environmental and climate assessment activities.

CAPACITY BUILDING TO IMPLEMENT THE STRATEGIC PLAN

The draft strategic plan calls for many research and decision support advances, including a greatly strengthened climate modeling infrastructure to address local, regional, national, and international needs; increased collaboration on key scientific challenges; a significantly upgraded global climate observing system, including climate-quality data

management; and a suite of sophisticated informational products for decision makers who in many cases are new to climate change science. The draft plan does not evaluate the size, scope, and training of appropriate research and stakeholder communities necessary to address these issues or approaches for taking advantage of resources that do exist. The infrastructure requirements to support the transition from research results to operational prediction are also not addressed. For example, support will be needed to bring together in one facility diverse researchers, including observers, process study scientists, modelers, computer programmers, social scientists, and those who represent end users. The committee believes that the CCSP faces a major challenge in systematically developing institutional infrastructure, growing new cross-disciplinary intellectual talent, nurturing networks of diverse perspectives and capabilities, and fostering successful transition from research to decision support applications. In general this capacity building is a long-term activity, but significant progress can be made in the short term with strategic investments.

In both the social sciences and the natural sciences there is considerable knowledge that has the potential to make major contributions to the current and long-term goals of the CCSP, however that knowledge has not yet been fully applied to these goals, nor has the broad set of interfaces between these disciplines been addressed. The necessary personnel to execute an enhanced level of research cannot be assumed to exist, particularly for research problems that cross disciplinary boundaries. In a number of fields, particularly in the social sciences, there are relatively few researchers in the position to undertake climate research. Furthermore, it takes years to increase workforce capacity. The achievement of these capacity-building goals will require systematic investments over a long period of time.

A second capacity-building challenge for the CCSP is to educate the stakeholder community so that it can effectively use the CCSP research products. This key aspect of the linkage between the scientific community and stakeholders is addressed further in Chapter 5 of this report.

Recommendation: The revised strategic plan should explicitly address the major requirements in building capacity in human resources that are implied in the plan.

Another type of capacity building is necessary to acquire and develop the computing, communication, and information management resources necessary both to conduct the extensive climate modeling called for in the draft strategic plan and to process and store the large amounts of data to be collected from a greatly expanded observation network. Applied climate modeling and especially the crucial regional-to-global scale climate change scenarios will require substantially enhanced supercomputer powers. Improvements in research models need to be tested before transition to operational models; this testing requires substantial computing resources. Further effort would be required to develop products responsive to decision makers and other users. The draft plan says nothing about what these computing requirements might be or how the CCSP might obtain them. This omission in the plan comes despite its reference to how two recent NRC reports (NRC, 1998 and 2001c) identified the hardware and software challenges facing the U.S. climate modeling capabilities (CCSP, 2002, p. 139).

Recommendation: The revised strategic plan should provide details about how the CCSP will acquire the computing resources necessary to achieve its goals.

FINANCIAL RESOURCES FOR IMPLEMENTING THE PLAN

The committee was asked to consider whether the results and deliverables identified in the draft strategic plan are realistic given available resources. Because the draft strategic plan does not include details about present and projected levels of support for each program element and because the fiscal year 2004 budget request was not available to the committee during its deliberations, it had limited information to evaluate this question. Nonetheless, it is clear that the scope of activities described in the draft strategic plan is greatly enlarged over what has been supported in the past through the GCRP. It includes a greatly strengthened climate modeling infrastructure increased collaboration; a significantly upgraded global climate observing system; and a suite of sophisticated informational products for decision makers. As discussed in the previous section, implementing this expanded suite of activities will require significant investments in infrastructure and human resources and therefore will necessitate either greatly increased funding for the CCSP or a major reprioritization and cutback in existing programs.

Shortly after this report entered National Academies' review, the President's fiscal year 2004 budget request was made publicly available. It includes $182 million for the CCRI (compared to the fiscal year 2003 budget request of $40 million) within a total CCSP budget request of $1749 million (compared to the fiscal year 2003 budget request of $1747 million). The committee has not had the opportunity to analyze the fiscal year 2004 budget request in detail. Even so, a cursory review of the proposed budget indicates that the CCSP has chosen to increase funding for CCRI at the expense of existing GCRP program elements (or simply relabeled some activities previously considered part of the GCRP as CCRI activities) and has shifted funds from one agency to another.

Even if program funding increases, CCSP management will continue to be faced with many funding decisions, such as which new programs should be initiated (and when),

whether any existing programs should be scaled back or discontinued, how to balance short-term and longer-term commitments, and how to balance support for international and U.S. programs. As discussed in Chapter 2 of this report, these resource allocation decisions must be based on the goals and priorities of the program, which should be clearly described in the revised strategic plan. The independent advisory body recommended by the committee in Chapter 4 of this report also should be used to inform such decisions. The committee believes it is essential for the CCSP to move forward with the important new elements of CCRI while preserving crucial parts of existing GCRP programs.

Recommendation: The CCSP should use the clear goals and program priorities of the revised strategic plan and advice from the independent advisory body recommended by the committee to guide future funding decisions.

4

Managing and Guiding the Program

Are mechanisms for coordinating and integrating issues that involve multiple disciplines and multiple agencies adequately described?

Chapter 15 of the draft strategic plan describes the management structures and processes that have been established to coordinate and integrate federal research and technology development in the area of global climate change. The management structure (see Figure 1.1) includes the following major components:

- A cabinet-level Committee on Climate Change Science and Technology Integration;
- An Interagency Working Group on Climate Change Science and Technology;
- An interagency Climate Change Science Program (CCSP) whose draft strategic plan is the subject of this report; and
- An interagency Climate Change Technology Program (CCTP).

Chapter 15 of the draft plan also describes several management processes that will be used to implement, evaluate, and guide the program (see CCSP, 2002, p. 162-166), and calls for the development of a new mechanism to improve the integration of program elements that are not central to the core missions of participating agencies.[1] In the sections that follow, the committee examines elements of this management framework and offers advice on how they could be improved in the revised strategic plan.

INTERACTIONS BETWEEN CLIMATE CHANGE SCIENCE AND TECHNOLOGY

The committee is concerned that the existing management and program links between the CCSP and CCTP may not be sufficient to take advantage of the synergies between these two programs. This may be due in part to CCTP's early stage of development. Generally, a program to define a massive problem (i.e., the CCSP) and a program to develop options for solution to the problem (i.e., the CCTP) should be guided by a common strategy, and this does not appear to be the case for the CCSP and CCTP yet. At the very least the results from each program should be used to guide the project portfolio of the other. Elements of the CCTP program will need to build upon the findings of the CCSP program. Technology solution options should be pursued for the highest-risk problems and informed by the most robust knowledge of those problems. Likewise, the impacts of implementing various solutions (e.g., sequestration, hydrogen-based fuels) should be studied as an integral part of technology development. On the other hand, there are many human dimensions, economic analysis, and decision support functions in the CCSP that critically depend on a deep understanding of the technologies and options that are being developed to address climate and associated global changes. These include the rate of diffusion of new technologies, the cost and impact of new technologies or policy drivers, and the development of realistic scenarios for anything other than business-as-usual baselines for the next 5 to 10 years.

The Interagency Working Group on Climate Change Science and Technology is responsible for coordinating the CCSP with the CCTP at the highest level, and this group may be able to foster some of the synergies described above. The committee believes that more potential benefits of these types of synergies would be realized if there were

[1] "The past decade has shown that research on climate and global change often includes components that do not fall neatly into the core mission of any one of the participating agencies, are entirely new program needs, or are key to the integration of separate agency activities…One necessary approach for addressing such integrating activities is to develop a mechanism that allows functions that are not central to the core missions of the participating agencies, but that are highly relevant, to be fostered" (CCSP, 2002, p. 165).

also direct coordination of some individual components of the CCSP and CCTP.

Recommendation: The CCSP should assess the scientific implications of the technologies under consideration by the CCTP and develop realistic scenarios for climate and associated global changes with these technologies in mind. The program management chapter of the revised CCSP strategic plan should clearly describe mechanisms for coordinating and linking its activities with the technology development activities of the CCTP.

INTERAGENCY MANAGEMENT

The management of an interagency program involving 13 agencies, each with a separate mission and history of independent efforts on issues of climate and global change, is a challenging task. The GCRP has been criticized in the past for being unable to do much beyond encouraging multi-agency cooperation and support because it lacked the authority to redirect long standing programs and mandates of individual agencies (NRC, 2001d). The new CCSP management structure announced by President Bush in February 2002 is designed to address this problem by providing a level of accountability and direction that was missing from the GCRP. In particular, the cabinet-level Committee on Climate Change Science and Technology Integration is responsible for providing "recommendations concerning climate science and technology to the President, and if needed, recommend the movement of funding and programs across agency boundaries" (GCRP, 2003, p. 11). An Interagency Working Group on Climate Change and Technology, composed of departmental and agency representatives at the deputy secretary level, reports to the cabinet-level committee and is responsible for making recommendations about the "funding level and focus" of the CCSP and the CCTP (CCSP, 2002, p. 162-163). The CCSP itself, an interagency group composed of representatives from all agencies that have a research mission in climate and global change, reports to the deputy-secretary level working group and is responsible for "effective management of the coordinated interagency research program" (CCSP, 2002, p. 163). Interagency committees of program managers for each major research element are responsible for interagency coordination and implementation at the program element level.

Responsibility for Managing the Program

The creation of the cabinet-level committee with the authority to shift resource among agencies to meet the goals of the CCSP (if necessary) is an improvement over past approaches to managing the GCRP. However, the interagency approach to managing the program at all levels, from the cabinet-level committee to the individual program element, may not be enough to ensure that agencies cooperate toward the common goals of the CCSP because no individual is clearly identified in the draft plan as having responsibility for managing the program as a whole. Of particular importance are those crosscutting program elements that involve multiple agencies. Chapter 15 of the draft plan on "Program Management and Review" does not describe the responsibilities and authorities of the CCSP leadership adequately.

Recommendation: The revised strategic plan should describe the management processes to be used to foster agency cooperation toward common CCSP goals. The revised plan also should clearly describe the responsibilities of the CCSP leadership.

Descriptions of Agency Responsibilities

The plan does not describe the specific responsibilities and authorities of contributing agencies, such as which entity will be responsible for implementing the work. Defining responsibilities is particularly important for new areas of research that have not been supported by the GCRP in the past, such as land-use and land-cover change and decision support. This also is important for crosscutting research elements, notably water cycle and ecosystems research, which are currently carried out within multiple agencies. The plan includes no clear delineation of which agency will do what, and in particular, which agency(ies) or program(s) will lead the proposed expansion of these crosscutting research areas.

Recommendation: The revised strategic plan should more clearly outline agency responsibilities for implementing the research.

Participation of Mission Agencies

Another management challenge for the CCSP is to foster the participation of mission-oriented agencies in the strategic planning process. The committee believes that mission oriented agencies—such as the Federal Emergency Management Agency, water resources and land management agencies within Department of the Interior, the Army Corps of Engineers, and the extension and farm program agencies within U.S. Department of Agriculture—could make important contributions to identifying research needs, collaborating on research problems, and testing research and modeling results. Because these agencies apparently played little, if any, role in the creation of the current strategic plan, the plan overlooks resources that might be available to its ambitious agenda.

Recommendation: The CCSP should encourage participation of those agencies whose research or operational responsibilities would strengthen the ability of the program to deliver products that serve national needs.

EXTERNAL GUIDANCE

The draft plan describes how the CCSP intends to use scientific steering committees composed of outside experts to help guide program elements. Advisory committees already exist for most of the agency science programs and some interagency programs (e.g., the carbon cycle and the water cycle). Such committees are especially useful for new program elements. There is also a stated desire to continue to receive advice and review from appropriate NRC committees and boards. These processes are valuable for scientific guidance on program goals, research approaches, and evaluating the usefulness and credibility of products.

Notwithstanding the value of these activities, the committee believes that the most difficult of the research management challenges will occur at the level of the CCSP program itself. Thus, there will be a need for scientific and other stakeholder guidance at the level of the program to ensure that clear priorities are established and communicated, that progress toward meeting the subsequent goals can be evaluated, and that the inevitable trade-offs in resources and allocation of time can be done with an eye toward meeting the most important of the overall program goals. Otherwise there will be a tendency for the individual needs and priorities of the agencies to take precedence over the needs of the entire program.

Recommendation: The CCSP should establish a standing advisory body charged with independent oversight of the entire program.

SUMMARY

Successful coordination and integration of CCSP activities will require clearly delineated lines of authority, requisite accountability by participating agencies, and appropriate staffing and funding. As the implementing and coordinating body for this effort, the CCSP will need the ability to direct other agencies' efforts and hold them accountable for performance and coordination. The success of the CCSP will also require the support and oversight of the Committee on Climate Change Science and Technology Integration and the Interagency Working Group on Climate Change Science and Technology, as well as the continued guidance of independent advisory bodies.

5

Enhancing Linkages and Communication

Does the plan adequately describe the roles of the public, private sector, academia, state/local governments, and international communities, and linkages among these communities?

Does the written document describing the program effectively communicate with both stakeholders and the scientific community?

Is the question format for driving the research program effective?

The committee addresses these questions in the context of its analysis of the Climate Change Science Program's (CCSP's) efforts to establish linkages with and outreach to various stakeholder groups including the scientific community. The strategic plan itself does not include explicit statements articulating the program's view of the roles of the public, private sector, academia, state and local governments, and international communities, so one answer to the first part of the first question above would be "no." Based on references in the draft plan to these stakeholder groups (e.g., CCSP, 2002, p. 149ff), the committee inferred the CCSP's view of their respective roles. This chapter starts by addressing the first two questions above for each of the following major stakeholder groups: (1) decision makers, (2) the international community, (3) the public, and (4) scientists; the third question is addressed later in this chapter. The committee will provide more detailed analysis of the strategic planning process, including its analysis of the December planning workshop, in its second report.

DECISION MAKERS

As discussed in Chapter 3 of this report and as identified repeatedly at the December planning workshop, one overarching weakness of the draft strategic plan is its treatment of decision support. Whereas the plan frequently refers to decision support resources, these resources are not defined beyond "providing the needed information" to policy and other decision makers. This approach implies strongly that the role of decision makers is primarily as passive recipients of information. For example, Chapter 13 of the draft plan focuses on describing one-way communication from researchers to various end users who may or may not have previously identified these information needs. This general weakness of the plan applies to decision makers of all types and can be addressed in the revised plan by drawing on lessons learned in previous assessment activities (see Chapter 3 of this report).

The plan lacks specificity about which decision makers it serves, how the CCSP will connect with them, and what types of decisions they will need to make. There are many different stakeholders both inside and outside of the federal government whose needs may vary considerably. When decision makers are mentioned in the plan, however, only two general communities of decision makers are mentioned (e.g., see CCSP, 2002, p. 41-42): federal policy makers with responsibility for emission mitigation decisions and officials (at what government level is unclear) in charge of natural resource management decisions. These two groups have different information needs; the first group requires knowledge of the projected costs and benefits of different emissions control scenarios, while the second is more concerned with understanding climate variability so as to develop adaptation strategies and to respond to current climate conditions, such as in water resource management. The plan needs to clearly indicate how its research activities will support both of these types of decisions, as well as those for a broader suite of stakeholders.

The strategic plan does not adequately consider the participation of state and local officials. Users of climate information at the local, state, and regional levels rely primarily on local officials and experts, not on federal

officials. If the CCSP's outreach endeavors are to be successful, it is important for federal agencies to work closely with regional and state climate institutions that can directly help educate and interact with state government, the private sector, and the general public. Indeed, some mission agencies (e.g., those under the Department of the Interior) already have state and local officers addressing climate issues, but these agencies do not yet participate in the CCSP (see Chapter 4 of this report).

The plan's treatment of the private sector is also limited. Many sectors of the U.S. economy stand to be affected seriously or even restructured by policies employed to respond to climate change. Others can benefit greatly from improved climate information (e.g., from seasonal to interannual forecasts) and from new opportunities in adaptation to and mitigation of climate change (e.g., through developing new climate mitigation technologies). In addition, commercial development and implementation of most of the technology to address climate change will be carried out by the business community. Yet the plan barely mentions the private sector and when it does, its role is solely as a passive recipient of information generated by the program (e.g., CCSP, 2002, p. 151). Government decisions based on information to be provided by the CCSP are likely to be more successful if the private sector is engaged throughout the research and planning process.

Although the text in places recognizes the importance of engaging stakeholders in the preparation and review of long-term strategic plans, the plan needs to state explicitly that stakeholders should be included where appropriate throughout the research planning, execution, and results review process. Furthermore, the draft plan does not capitalize on the NRC report *Making Climate Forecasts Matter* (NRC, 1999c), which includes recommendations for using the decision sciences to communicate climate issues to stakeholders and other interested parties. Without employing two-way and deliberative communication the plan presents an outmoded and unsuccessful model of stakeholder engagement and public involvement.

Recommendation: The revised strategic plan should identify which categories of decision makers the CCSP serves and describe how the program will improve two-way communication with them.

INTERNATIONAL COMMUNITY

The committee believes that the draft plan misses an opportunity to develop a forward-looking strategy for improving international research networks and assessments. These concepts are mentioned in Chapter 14 of the draft plan, but not in a strategic way. The value of multi-national research networks has been demonstrated in several ongoing agency programs and in international organizations. For example, research conducted under the GCRP during the last 10 years has demonstrated considerable science leadership in international global change programs, particularly the International Geosphere-Biosphere Programme (IGBP), the International Program on Human Dimensions of Global Environmental Change (IHDP), and the World Climate Research Programme (WCRP). The issue for the CCSP is how to leverage the many governmental and nongovernmental organizations to develop capacity and ongoing regional networks of international scientists collaborating with U.S. scientists. Without a defined strategy it is unlikely that the full benefits of such approaches will be achieved.

International collaboration is needed for building better *in situ* calibration and validation of observations, for obtaining more globally distributed measurements, and for building synergy and reducing redundancy in the deployment of observation assets. The meteorological community offers a good example of international collaboration, with assignment of responsibilities for making measurements and data-sharing protocols arranged at an intergovernmental level under the World Meteorological Organization. The climate community lacks a similar structure. The U.S. climate community has not even identified which agency serves as the central contact for international partners on climate research issues, including coordinated observing arrays, intercalibration, capacity building, and data and product sharing.

Most of the world community recognizes that the Intergovernmental Panel on Climate Change (IPCC) approach to involving governments directly in the scientific assessments has been a success. It has acted to denationalize scientific knowledge, an objective that individual national assessments cannot always meet. The value of international assessments over national assessments lies in three factors: (1) by engaging a majority of the world's experts on the relevant scientific questions, such assessments can attain higher scientific quality and are better able to withstand partisan attacks; (2) national assessments risk the perception or actuality of being subordinated to national policy priorities; and (3) by rendering competing parallel assessments scientifically superfluous, well done international assessments control the risk that minor or unintentional disparities in coverage, emphasis, or tone between parallel national assessments are exploited to exaggerate scientific disagreement in policy negotiations. The CCSP should acknowledge such successes in science-policy interactions in its revised strategic plan.

The overall sense of insularity of the plan itself may hinder efforts to improve linkages with the international community. In particular, portions of the draft plan focus so strongly on decision support in the United States, on land cover in the United States, on the carbon cycle in the United States, and so forth that it is not at all clear what the balance may be between focusing on the United States itself and sponsoring research that is relevant to the rest of the world.

Of most concern is that the plan does not discuss how it intends to provide information to the IPCC. While there is no evidence of any such nationalism in the GCRP research community, the perception of insularity in the draft plan is of concern to the committee on two fronts. Scientifically, there is a danger that the emphasis on U.S. issues and resources will result in agencies choosing not to work in geographic regions outside the United States that are significant for understanding particularly important processes. The second issue relates to participation in international climate change research. The United States has been the source of about half the global research investment historically and a leader in many activities internationally, yet there is little discussion in the draft strategic plan of how and whether the U.S. program will participate in international arenas. This insular approach could alienate international contributions to U.S. science.

Recommendation: The revised strategic plan should clearly describe how the CCSP will contribute to and benefit from international research collaborations and assessments.

PUBLIC

The draft strategic plan appropriately recognizes the importance of efforts to communicate with the public and to promote outreach for K-12 education. Chapter 13 of the draft plan accurately describes the need for improved public understanding of climate change, and lists a number of mechanisms that could be used for this purpose. Though important, the recommendations for action in Chapter 13 of the plan are so broad and without prioritization that it will be difficult to accomplish all or even many of them. The revised chapter on communications and outreach should better identify which recommendations have the highest priorities and which agency has the responsibility for ensuring that they are carried out.

The committee notes that the draft plan itself, with its dense prose, is not easily accessible to intelligent nonexperts, and certainly not to laypersons. The draft plan would communicate with the public much more effectively if it included clearly articulated vision, goals, and priorities for the program, as discussed in Chapter 2 of this report.

SCIENTISTS

The draft strategic plan makes clear that the scientific community will play important roles in carrying out research and in advising the program through scientific advisory processes. The program has established strong linkages and two-way communication with the scientific community in general. An indication of this was the strong representation of the scientific community at the December planning workshop, with the exception of some areas of science that have not traditionally received funding from the GCRP. The document itself is generally effective in communicating with the scientific community about problems and research areas. As discussed in Chapter 2 of this report, however, the plan could be more effective in conveying to the scientific community an integrated, reasoned "strategic plan" for climate change and associated global change science.

EFFECTIVENESS OF QUESTION FORMAT

The committee commends the authors for focusing each chapter on a short list of questions or problems, and believes that this should be done consistently throughout the strategic plan. The committee found the question format particularly effective in dealing with well-specified tasks related to improved understanding of physical and chemical processes. The format was less effective in dealing with issues that cross several chapters, such as those related to human dimensions and decision support tasks, which should be better integrated into relevant chapters.

CONCLUDING REMARKS

The committee commends the CCSP for undertaking the challenging task of developing a strategic plan, an important first step in enhancing how the program communicates with its wide range of stakeholders. The current draft of the plan represents a good start to the process. Further, the CCSP has made genuine overtures to researchers and the broader stakeholder community to gain feedback on the draft strategic plan and how to improve it. The planning workshop in December 2002 attracted hundreds of attendees. The workshop summaries presented by the program's leaders (see <http://www.climatescience.gov/Library/workshop2002/closingsession>) indicated that they were attentive to the issues raised by the workshop participants. In addition to the workshop, the CCSP established a mechanism for interested parties to submit written comments on the draft plan. These efforts indicate a strong interest on the part of the CCSP to develop a plan that is consistent with current scientific thinking and is responsive to the nation's needs for information on climate and associated global changes.

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Part II

Detailed Comments

6

Comments on Individual Chapters

INTRODUCTION

In this part of the report the committee provides a more detailed analysis of each chapter of the Climate Change Science Program's (CCSP) draft strategic plan. This part of the committee's review therefore is more disciplinary in nature than part 1 of the report. The committee has used the results of these chapter-by-chapter assessments as the basis of the overarching conclusions and recommendations presented in part 1. The main elements of the Climate Change Research Initiative (CCRI) are described in Chapters 2-4 of the draft plan, the main elements of the U.S. Global Change Research Program (GCRP) are described in Chapters 5-12 of the draft plan, and the program's activities in the areas of communications and outreach, international research and cooperation, and program management are described in Chapters 13-15 of the draft plan.

The committee was asked to address the following three questions for each "major topical area" of the plan:

1. Does the plan reflect current scientific and technical understanding?
2. Are the objectives clear and appropriate?
3. Are results and deliverables realistic given available resources?

The committee has used these questions as an organizing framework for its review of Chapters 2-12. Because these questions are not directly relevant to the issues covered in Chapters 13-15, the committee has organized its comments on these chapters into "General Comments" and "Specific Comments."

A general issue that applies to all chapters is that the draft strategic plan does not include details about present and projected levels of support for each program element. The fiscal year 2004 budget request for the CCSP also was not available until this report entered National Academies' review. The committee therefore had limited information to evaluate whether the "results and deliverables are realistic given available resources," the third question above. Even so, the committee attempts to provide insights into this question wherever possible, using its knowledge of the scientific challenges that need to be overcome to achieve the stated results, historical levels of support, and its knowledge of the approximate levels of resources that would be required to achieve the anticipated results. The strategic plan would be a much more useful planning document if it included estimates of the funding that would be required to achieve each result and deliverable. One approach for doing so would be to list short-term and longer-term "products and payoffs" together with an assessment of how much it will cost to achieve the product or payoff within the given time frame.

CHAPTER 2: "RESEARCH FOCUSED ON KEY CLIMATE CHANGE UNCERTAINTIES"

This chapter is organized around three questions: (1) What aerosols are contributing factors to climate change and what is their relative contribution to climate change? (2) What are the magnitudes and distributions of North American carbon sources and sinks, and what are the processes controlling their dynamics? and (3) How much of the expected climate change is the consequence of feedback processes?

General Comments

This chapter selects some very specific research areas as being key to reducing uncertainties in climate change.

The CCSP has made a compelling case that it needs to reduce uncertainty in climate projections ("forecasts") for a wider audience, and the research areas selected in this chapter represent the science community's view of the some of the largest sources of such uncertainty. The problem with the specific research programs proposed in Chapter 2 is that the draft plan has not shown a clear path as to how these foci will lead to improved climate projections in two to four years. While substantial progress in our scientific understanding would be gained by CCRI support of these four efforts, it is not clear that these will coordinate and drive a significant breakthrough in climate-change science at the level of the CCSP goals in Chapter 1 of the draft plan. This raises questions about whether research activities described in Chapter 2 of the draft plan might be more appropriate for the GCRP, and the intended relationship between the GCRP and the CCRI more generally (see discussion in Chapter 2 of this report).

One possible model for the CCRI-GCRP relationship might be taken from some recent environment assessments in which an applied program (NASA Aeronautics) has some high-level questions (e.g., what will a supersonic civil-aviation fleet do to stratospheric ozone and climate?) that require both an acceleration of knowledge and a synthesis across a wide range of baseline science programs (NASA Earth Science researchers plus aircraft manufacturers). The high-level questions not only drive a new synthesis of current scientific understanding but also define some new research priorities for the baseline programs. By analogy, CCRI questions for aerosols, carbon-cycle science, and feedbacks should be at a level that could significantly improve climate projections (e.g., what is the role of anthropogenic aerosols in altering clouds globally?). The stated objective of reducing key uncertainties in climate-change projections will be difficult to achieve in the short term and cannot be guaranteed, but realistic short-term milestones could be identified. For example, the CCRI could make a significant contribution by convening workshops to assess and synthesize the state-of-the-science available to address priority policy questions.

Does the plan reflect current scientific and technical understanding?

The plan's response to Question 1 is reasonably well balanced and reflects the current state of aerosol science and recent interagency steering group reports, such as the National Aerosol-Climate Interactions Program (NACIP). It focuses correctly on the need to develop a history of aerosol forcing that includes indirect effects on clouds and the hydrological cycle. The budgeted details (e.g., aircraft fly-overs and algorithm development) are not coordinated, not necessarily high on the scientific priority list, and look more like specific preexisting agency interests. Elements of this aerosol science project are clearly among the top GCRP-type science priorities in terms of climate change and uncertainties, and they should stand out in the relevant chapters of the draft plan (i.e., Chapters 5, 6 and 11), but a more comprehensive CCRI synthesis of aerosol-climate interactions is needed to address Chapter 2 goals.

Question 2 also presents a well-designed scientific program for the atmospheric component of the North American Carbon Program (NACP). The research is compelling, but it addresses only one aspect of understanding atmospheric carbon dioxide. The "Research Needs" focus on atmospheric measurements to identify surface sources and sinks only over North America (admittedly an important task), but not on the ecosystem research needed to understand the mechanisms driving these sources and sinks and how they may change in a future climate. This work would appear to be excellent GCRP-type research receiving high priority in Chapters 9 and 11, but by itself it is unlikely to significantly reduce the uncertainty in projecting atmospheric carbon dioxide abundances and, as for aerosols, a more comprehensive CCRI synthesis of the global carbon cycle is needed.

Question 3a fails to capture the broad scope of the water cycle and its associated feedbacks. The land surface processes, including runoff, absorption, collection, and release of water vapor from the soil and plants, are not mentioned. Neither is the ocean, which plays a large role in moisture transport and cloud formation. The plan also fails to indicate clearly that we are challenged to understand and model clouds and moisture transports, so how these factors respond to climate change does not yet have a firm foundation. The lack of understanding is related to fundamental processes, and thus the complaint of poor resolution in current computer models is overemphasized relative to the need for better observations and understanding.

Question 3b does a good job of summarizing the processes and issues. It would be better to change the emphasis to the "polar regions" rather than individually identifying specific Arctic and Antarctic issues.

Are the specific objectives clear and appropriate?

For question 1 the objectives are generally clear, but perhaps too grand to be answered readily. The "Products and Payoffs" are just too numerous and could be more focused.

For Question 2 the objectives are clear but the "Products and Payoffs" are limited and may not answer the big question. The objective to understand the "systems" affecting carbon sources and sinks is not supported by the necessary research into understanding these systems (e.g., ocean, ecosystems, and human dimensions). For both Questions 1 and 2, achieving the larger objective of reducing key uncertainties would require a much broader synthesis and support from a wide range of GCRP research.

For Question 3a, the apparent objective, "Basic understanding of the processes that control atmospheric water vapor and clouds must be improved and incorporated in models," has high merit and has been a goal for many years. Consequently, it is unrealistic to expect that it will be met in the first CCRI time window of two to four years. However, appropriate milestones could be identified within the cloud and water vapor feedback question (e.g., process studies of characteristic cloud types and regimes to develop the physical understanding of cloud formation, variability, and roles of surface and atmospheric processes; tests of the realism of boundary layer and cloud parameterizations against *in situ* data using process-resolving models) that would be a good match to the stated time line and products of the CCRI.

For Question 3b the objectives are clear and appropriate, but some tuning is needed to make the objectives complete and robust (e.g., see CCSP, 2002, p. 23, "Determination of polar sea ice thickness, concentration, extent, and albedo, including in the marginal seas, on an ongoing basis to observe change and initialize models"). Also, space-borne salinity measurements in cold, polar waters may be more difficult than anticipated and relying on new, not-yet-flown satellites for the first two to four years of CCRI is too optimistic.

Are expected results and deliverables realistic given the available resources?

The answer for all questions is: No. No resources have been identified at the time of this review, and the time of two to four years is barely adequate, even if the scope of GCRP research in these areas is expanded. For example, it is unlikely that the NACIP or NACP will be able to acquire the observations, much less analyze or produce answers in two to four years. Similarly, some of the "Products and Payoffs" of Question 3b (e.g., measuring sea surface salinity from space, assessing the likelihood of polar changes to contribute to abrupt climate change) are major research challenges that are unlikely to be achieved in two to four years. The lack of a budget for these CCRI initiatives is more serious than for the GCRP research that already has a funding history. Resources thus depend not only on the CCRI budget augmentation but also on the commitments of the participating agencies.

For all the chapter objectives, additional observations and analyses are needed. In some cases these observations will focus on intensive, brief process studies to understand specific mechanisms. In other cases these observations will be based on collecting and re-analyzing existing data sets. In general, however, the detection of patterns of global change requires continuing observations—not restricted to a limited amount of time, as indicated in the plan. For the delivery of results during the first two to four years of CCRI, the observation requirements for the aerosol and carbon cycle questions are appropriate. For the feedbacks questions, however, the CCRI objectives could rest with the design and development of the climate observing system discussed in Chapter 3 of the draft plan.

CHAPTER 3: "CLIMATE QUALITY OBSERVATIONS, MONITORING, AND DATA MANAGEMENT"

This chapter is organized around five questions: (1) How did the global climate change over the past 50 years and beyond, and what level of confidence do these data provide in attributing change to natural and human causes? (2) What is the current state of the climate, how does it compare with the past, and how can observations be improved to better initialize models for prediction? (3) How real are the differences in surface and tropospheric temperature trends? (4) How do we improve observations of biological and ecological systems to understand their response to climate variability and change? and (5) How accessible is the climate record?

General Comments

The chapter is broad and descriptive. Although it mentions a number of specific observation activities, no connection is made between these activities and the overall goals of the CCRI, and no justification is given for the high priority attached to these activities. Finally, no strategy is proposed for achieving these observation goals; there appears to be broad agreement on the need for an integrated system to provide high-quality, long-term climate observations, but there is no clear strategy for what measurements are most critical in the near term and the long term, and how the current mostly research-grade observation systems can be transitioned into routine and continuous operational networks. The issue of intercalibration over the long term, both within and between sensors, is particularly important. The draft plan provides no strategy for establishing such a climate observing system, though several NRC reports have provided many relevant recommendations (NRC, 1999a; 2000c; 2000d).

A more balanced, comprehensive approach to observation systems is needed. The chapter reflects a strong bias toward satellite observations of the Earth system, but the complementary *in situ* observations are also needed. This is especially but not exclusively true of ocean and ecosystem observations (e.g., ground based, radio, buoys, aircraft). The draft plan does not address the human-dimension observations that are needed to understand climate change (e.g., emissions and land-use change).

Does the plan reflect current scientific and technical understanding?

For the most part the plan reflects current scientific and technical understanding of climate observation systems, but this part of the plan fails to identify opportunities for linkages between observations and modeling efforts (e.g., data-based evaluations of model simulations, model-based evaluation of proposed climate-relevant observing systems), and thereby does not reflect fully the current state of climate science.

To address Question 1 the plan proposes a program of data archaeology and reanalysis. At a general level such a program makes sense and would be relatively inexpensive and amenable to significant short-term progress. An improved reconstruction of historical climate would be useful in assessing the performance of numerical models and in relating regional climate variations to large-scale variations. This section could be improved if it paid more attention to four areas. First, there is a need to determine the most critical gaps in the historical record. For example, it may make sense to allocate climate reconstruction resources places where the historical record is particularly weak or especially critical variables, including those connected to external forcing. Second, there is a pressing need to link this activity with numerical modeling efforts, particularly if climate reconstruction data is to be used to assess model performance. Third, in addition to reconstructing recent climate there is a need to better characterize low-frequency natural variability in the climate system and to understand the processes responsible for specific climate events in the more distant past, such as the rapid cooling during the Younger Dryas. Lastly, paleoclimate data that may not be available much longer should be collected immediately (e.g., vanishing glaciers, old growth trees, and coral reefs).

To address Question 2 a number of activities are proposed to improve and expand modern climate observation systems. Again, at a general level, these are appropriate, but the motivation for attaching a high priority to specific observation programs is missing. The plan could be strengthened by making reference to the principles for ensuring the quality and usefulness of satellite observations for understanding climate (NRC, 1999a; 2000d). Attention must also be paid to the need for calibration both within and between sensor arrays. In terms of expanding the observation system there is a need for detailed optimization of the nation's climate observing program based on scientific information and budget constraints. This strategic design of the network should be done in coordination with other countries. In doing so it is important to press for an open exchange of data. Other major problems with this section include:

- The draft strategic plan says little about the need to improve analytical methods, including four- dimensional data assimilation, that convert raw observations into useful information.
- The priorities listed in the chapter are aimed almost entirely at global observations. Local information to support local decisions (e.g., about regional effects of climate change) also needs to be included in identifying high-priority observation programs.
- This section ignores the need for improved and expanded economic and other data necessary to assess the costs, benefits, and distributional effects of alternative decisions. These data are also critical to improving numerical projections of the potential impacts of future climate change, one of the stated motivations for improving and expanding climate observations.

Question 3 seems overly emphasized in the draft plan. Although resolving the difference between surface measurements and satellite measurements of tropospheric temperature is an important technical issue (e.g., see NRC, 2000e) of clear interest to policy makers, the draft plan seems to suggest that this question by itself is the key to determining whether the patterns of observed climate change are consistent with anthropogenic forcing. In fact, the underlying scientific question is far more complex and concerns variations in the vertical profile of temperature, including stratospheric cooling and specific geographic patterns of warming, a broader question that is not adequately addressed here or elsewhere in the draft plan.

The inclusion of Question 4 in Chapter 3 is appropriate and important and the issues addressed are generally on target. Nevertheless, the discussion of biological and ecological observations needs sharpening. For example, decisions about which variables to monitor need to be carefully considered so that they reveal information not only about spatial distribution, but also about the composition, structure, and functioning of natural and managed ecosystems. Moreover, this section of the plan needs to describe how the observation system could be linked to existing data systems (such as those for agriculture), which though developed for different purposes, could provide information of relevance to the proposed analyses. Efforts to evaluate data trends and project future conditions through biological and ecological modeling also need to be included in the revised plan. Importantly, design of this observation system needs to be dovetailed with planned research in the ecosystems, carbon cycle, human dimensions, land use and land cover change, and other chapters.

Are the specific objectives clear and appropriate?

At a general level the objectives spelled out in the chapter are clear, but the justification for focusing on these

five questions in terms of the overall goals of the CCRI is not clear. The draft plan does not provide an appropriate balance between satellite and *in situ* observations; among atmospheric, land-surface, and oceanographic observations; and between observations aimed at reconstructing climate in the recent and more distant past. Given the stated goals of the CCRI, a provision for collecting and analyzing economic and other social scientific observations should have been included.

Are the expected results and deliverables realistic given the available resources?

As there are few if any fundamental intellectual or technological obstacles, the plan seems generally realistic in what it states to achieve provided that adequate financial and management resources are available. However, the strategy for international cooperation is so poorly specified that it seems difficult to see major changes over the next 2-10 years in the currently fragmented and unsystematic way observations are currently made. To be realistic about making observations relevant to decision making there must be a plan to develop continuous, integrated space and *in situ* measurements and then a workable information system to make these observations available to decision makers as information in a form they can use on a regular and reliable basis.

CHAPTER 4: "DECISION SUPPORT RESOURCES"

Chapter 4 of the draft strategic plan is organized around four themes: (1) evaluations and syntheses for policy analysis and operational resource management; (2) analytical techniques for serving decision needs, (3) applied climate modeling; and (4) resources for risk analysis and decision making under uncertainty.

In this section of the report the committee first discusses the draft strategic plan's treatment of Themes 1, 2, and 4, which deal with broad issues of decision support resources. These themes are also addressed in Part I of this report (see sections on "addressing key uncertainties" and "decision support resources" in Chapter 3 of this report). The committee then discusses individually Theme 3 of Chapter 4 on applied climate modeling.

General Comments on Decision Support Resources (Themes 1, 2, and 4)

Chapter 4 introduces commendable emphasis on scientific support for public and private-sector decision makers who must deal with aspects of climate change, climate variability, and associated global changes. The committee considers this one of the most promising and innovative features of the draft plan. Building and using this capacity will require commitments to capitalize on available information and existing decision support tools, to collect new information to address gaps in understanding, to develop new tools and capacity for decision making, and to engage stakeholders.

Although the draft strategic plan incorporates general language about decision support in many places, it is vague about what this will actually mean. The draft plan does not do a very good job of identifying decision makers and their individual needs. Nor does it adequately distinguish between the research needed to develop new decision support tools and operational decision support activities, or how these two different types of activities relate to the longer-term research efforts of the GCRP.

Another significant weakness of Chapter 4's discussion of decision support resources is its failure to include any information as to which agency(ies) will be responsible for this new effort or the level of resources that will be required to achieve its objectives. This is particularly important in this case, because decision support is a new program element and because the levels of support for the types of research needed to achieve these objectives have been small in the past.

The section on analytical methods is a very good start on a very difficult topic. The committee is encouraged that for the first time the federal government has made a commitment to develop scenarios consistently. It is equally important to recognize that the chapter can go much further by drawing on past experience of federal programs in scenario development and in developing other analytical methods to support decisions. The plan would be strengthened by recognizing that scenarios and integrated assessments are only two tools for decision support. Other tools (such as elicitation of preferences and use of expert judgment, have also been useful and could be discussed more extensively in the plan.

Nearly all the other chapters in the draft strategic plan focus on four or five questions listed at the beginning of the chapter. Such questions were not included in Chapter 4, with the exception of the section on applied modeling. Chapter 4 would benefit from similarly focused questions.

Does the plan reflect current scientific and technical understanding? (Themes 1, 2, and 4)

The plan does not reflect the current state of knowledge in the broad area of support for environmental decision making. For example, a considerable part of the effort outlined in the plan is aimed at eliciting information needs from decision makers (e.g., "a new stakeholder-oriented process for ongoing identification of questions relevant to decision makers," CCSP, 2002, p. 46). Prior to embarking on a major new effort in this area the CCSP needs to assess and build on decades of work by various government agencies, such as the Energy Information Administration,

the Environmental Protection Agency (EPA), the U.S. Department of Agriculture's Natural Resources Conservation Service, National Aeronautics and Space Administration (NASA) (various ozone assessments), and the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service and Office of Global Programs. Identifying the research needs regarding vulnerability, key risk areas, and interactions with stakeholders can be gleaned from the regional and sectoral findings of the U.S. National Assessment of the Potential Impacts Climate Variability and Change (NAST, 2001). Additional important contributions of the National Assessment are the lessons learned about processes for stakeholder engagement, including the need for continuous stakeholder relationships that allow for trust building, funding mechanisms that allow for long-term commitments to join research projects, and new mechanisms for the federal government to engage local participants in assessments. Research needs also have been articulated clearly in the Intergovernmental Panel on Climate Change (IPCC) report from Working Group II, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (IPCC, 2001a), and the experiences of past GCRP programs that have supported research and delivery of information to stakeholders such as NOAA's Regional Integrated Sciences and Assessments, NASA's Regional Earth Science Application Centers, EPA's Global Change Research Program, and the National Science Foundation's Science and Technology Center programs. This is not to say that there is no need for additional effort in this area, only that such additional effort should build upon what is already available.

The scenario development section does not adequately describe the status of research or practice in this area. Rather, it reads as a tutorial on the nature of scenarios. There is by now a long national and international track record in scenario development. The plan could be improved if it built upon this track record by focusing on any areas of weakness and on the development of approaches to scenario use in decision making. In addition, the plan could be strengthened if it considered the development and use of socio-economic and ecological scenarios as a complement to the work on climate scenarios.

Are the specific objectives clear and appropriate? (Themes 1, 2, and 4)

The overall objectives of this part of the CCRI are clear and for the most part appropriate. The plan is weak on specifics, however, in part because of a failure to elucidate a framework for organizing research in this area. Such a framework could distinguish between (1) categories of decisions (e.g., mitigation *versus* adaptation) and (2) categories of decision makers (e.g., federal, state, and local governments, private firms, institutions, and individuals). The chapter does not adequately distinguish between research to develop new decision support tools or understanding and operational decision support activities. Operational needs have less research content but are very important to the success of the program and will probably require significant investments in human capacity. There is a need to distinguish between decision support at the national level regarding mitigation (choosing emissions control options, for example) and decision support at multiple scales for adaptation to the global changes that are already underway. The plan appears to focus entirely on decision making related to climate change. The scope for improved decision making related to seasonal-to-interannual climate variability (e.g., ENSO) also deserves attention.

Are the expected results and deliverables realistic given the available resources? (Themes 1, 2, and 4)

There are few specifics in this chapter regarding deliverables and timelines. Given that little decision support work for climate and global change is ongoing and the focus on decision support as a driver of the research agenda is relatively new, it is not clear which agency or funding stream will be used to initiate even the relatively modest short-term research agenda listed in the CCRI. Although NOAA's Office of Global Programs and EPA's Office of Global Change each have programs focused on developing the relationships, key questions, and scenarios described, these are small programs with limited support. These two offices are hardly in a position to bring about the increased emphasis in decision support. Because no description is given of how the CCRI will actually accomplish the products and payoffs, it is not clear that even these relatively modest short-term objectives of developing relationships and identifying key questions to drive the research agenda will be achieved.

For the scenario subsection of Chapter 4 the products and payoffs that are described are broad and vague. It would be possible to achieve well-defined portions of the products and payoffs described in two to four years, but overall the deliverables do not seem achievable in this time frame. An appropriate starting point would be to assess the successes and failures of past scenario building efforts, and then focus research efforts on gaps in knowledge.

Suggestions for Improving Subsection on Scenarios (Theme 2)

The committee offers five suggestions for improving Chapter 4's treatment of scenarios:

1. The section on scenarios for climate-change impacts could be improved by distinguishing between different applications. For example, the specificity and

detail needed for decision making by resource managers at the regional, state, and local levels and by the private sector may differ from that needed to support decision making at the national or international level.

2. Distinguish between the construction of climate-response scenarios (i.e., the climate change assuming a history of greenhouse gas and aerosol emissions and land-use changes) and climate-forcing scenarios (i.e., the socio-economic, ecological, and demographic scenarios that create the forcing). This is a serious research enterprise that the agencies must adequately support.

3. The program must be careful in establishing the legitimacy of the scenarios that it chooses to produce. The choice of scenarios is always subject to intense scrutiny for sources of potential bias. The developers of scenarios need to ensure that they can justify the assumptions they have made in their products, and that their products are the result of reasonable analysis.

4. The program will do itself a great service if it embraces the wealth of experience in decision support tools and scenario development that exists outside the government. Some of the best work on energy scenarios, for example, has been done in the private sector. There are many groups in university and research institute settings that have done extraordinary work in developing scenarios and other decision support tools.

5. The program could develop scenarios to complement on build on international efforts, such as those of the IPCC.

General Comments on Applied Climate Modeling (Theme 3)

The "Applied Climate Modeling" section of the draft plan (CCSP, 2002, p. 47-52) has articulated a much needed new direction for U.S. climate change science, reaching out beyond the business-as-usual approach of the GCRP to provide tangible decision support resources. This section is quite insightful, reasonably well focused, and well grounded with respect to the priorities for climate modeling research and applications over the next decade. In contrast to the treatment of other decision support activities in Chapter 4 of the plan, the applied modeling discussion is better developed and more specific.

This section does not adequately address several substantial challenges to meeting the ambitious goals it sets forward. First, it does not speak to the optimistic, and likely unrealistic, objective of substantially reducing climate sensitivity uncertainty in four years. Indeed, reducing this uncertainty substantially in the near future will require overcoming the challenges remaining in understanding the physics, and the quantitative modeling of that physics, in the cloud-radiation feedback problem. The challenges are even greater for those uncertainties associated with regional climate change projections.

Second, this section sidesteps an even greater challenge to the climate science community: to make connections between the applied climate modeling results and the climate impacts research community, and on to decision makers, resource managers, and other consumers of climate change information.This is much easier said than done (e.g., see *From Research to Operations in Weather Satellites and Numerical Weather Prediction: Crossing the Valley of Death* [NRC, 2002a]). The chapter would benefit from outlining how the different decision support activities would interact. The draft plan pays little attention to how the proposed improvements in applied climate modeling are to be connected to the current and future users of modeled regional climate projections. In addition, this section does not adequately address how the applied climate modeling activities will be coordinated with the more theoretical model improvements called for under the GCRP.

Third, the draft plan does not address the challenges associated with transitioning the current efforts at the National Center for Atmospheric Research (NCAR) and the Geophysical Fluid Dynamics Laboratory (GFDL) into an effective applied modeling program. For one thing, building a "common modeling infrastructure" (CCSP, 2002, p. 52) is not an easy task. Fortunately, NCAR, GFDL, Goddard Space Flight Center, and the Massachusetts Institute of Technology have achieved major progress over the past few years to develop a common modeling infrastructure in the Earth System Modeling Framework. This largely successful effort has set the stage to achieve a considerably enhanced capability for national and international cooperation in climate modeling, model output analysis, model intercomparisons, and improved climate assessments. A major outcome of these multiple-group efforts is a growing capacity to produce improved projections of climate change, as obtained from a range of groups with differing model formulations and different climate-forcing scenarios. An ongoing challenge is to provide fully interactive access and exchange from the "Two Centers" to other modeling groups, nationally and internationally. Particularly difficult is creating mechanisms by which researchers outside of the modeling centers can interface with the modeling efforts, for example to propose and test new parameterizations or to incorporate new observations. The draft plan is unclear about how the NCAR-GFDL partnership will be directed (i.e., will its focus be on conducting IPCC projections, facilitating the transition of research results into operational code, refining projections so as to reduce uncertainties in climate sensitivity, preparing model projections for local, regional, and national decision makers, or some combination of these?). It is unrealistic to expect the current modeling community to be able to make substantial near-term progress on all these fronts.

Lastly, the section does not adequately address the mismatch between existing computing resources and those needed to implement the proposed applied modeling program. The introduction to this section is vague in stating

the reason why the United States is lagging in its ability to produce more useful high-resolution climate model results (CCSP, 2002, p. 47). The real reason for this has been the lack of an accelerated U.S. investment in supercomputing power for higher-resolution climate models. The draft plan does not indicate that the CCSP will seek the necessary budget for such increases in supercomputing power, other than as an implicit "tax" on the limited U.S. supercomputing resources that are already being focused on key climate science challenges.

The section's focus on multiple Climate Process Teams (CPTs) (CCSP, 2002, p. 48) is a very important and promising new direction, as discussed in more detail in this report's comments on Chapter 6 of the draft plan. It is encouraging that the CCRI Fiscal Year 2003 budget request appears to have made genuine commitments in this area. It will be challenging to target these resources to be consistent with the dual climate-science and climate-impacts goals of the CCRI; thus it is important for the strategic plan to be more specific about how the CPTs will be focused. If already viable, the CPTs could serve as a critical anchor for accelerated cooperation in the attack on these difficult research challenges. If these teams do not yet exist, a description on how the teams are being constituted would be useful.

Does the plan reflect current scientific and technical understanding? (Theme 3)

Yes. This section is overall rather well thought out. It is based upon a generally impressive connection with state-of-the-art research understanding, as well as a keen awareness of the growing but embryonic collaborative efforts in applied and theoretical climate change modeling. There are some examples of the potential contributions being pushed a bit too hard in the context of the goals of the CCRI; they would have been quite reasonable in the context of the less directed scientific goals of the GCRP.

It is odd that aerosol data assimilation is offered as the key successful example of this technique (CCSP, 2002, p. 50). The NCEP/NCAR data assimilation and reanalysis datasets have been available for a number of years, well before such techniques were attempted in aerosol modeling. The draft does not make clear how such aerosol assimilation procedures are to be applied profitably to an external forcing term in transient climate runs.

Page 48, line 6 could better recognize that NCAR and GFDL are presently working cooperatively to explore the underlying reasons for these real model differences, thus providing a key anchor for the applied climate modeling part of the CCRI (CCSP, 2002).

"It will be important to identify the one or two largest sources of uncertainty in feedback processes currently represented in climate models," (CCSP, 2002, p. 48) does not reflect the current view that feedbacks associated with clouds is a major source of uncertainty. A remaining challenge is to better understand the uncertainty associated with the model representation of clouds and find new ways to reduce it.

Are the specific objectives clear and appropriate? (Theme 3)

For the stated climate science research objectives this section is one of the best in the draft plan. The section is much weaker, however, on how the prescribed emissions scenarios, and the climate model runs generated from them, will be used to enhance the needed information exchanges between the climate modeling community that produces the results and the climate-warming impacts communities who receive them. As discussed in Chapter 3 of this report considerable "capacity building" is needed to create the interactive community that will be required to facilitate the adaptive capability likely to be required.

The discussion of "Testing Against the Climate Record" (CCSP, 2002, p. 49) understates the challenges in these endeavors. Many of the observation networks that have provided measurements of climate variables over the past 25 years were not designed with the goal of collecting climate-quality data. Thus, these data were not subject to the calibration, accuracy, and continuity required to obtain reliable climate change information (NRC, 1999a). For example, the utility of archived temperature measurements from operational satellites is limited by differences among the multiple sensors and spacecraft deployed over the last 25 years (NRC, 2000c). The CCSP should work to ensure that future satellite series provide climate-quality data.

The proposal to test contemporary climate-warming models against the paleoclimate record (CCSP, 2002, p. 49) needs to be more specific to overcome ongoing data and interpretive challenges with this type of analysis. Paleoclimate records provide an important window on the natural variability of past climates. Unfortunately, they so far have been of rather limited value in the effort to provide the kinds of model evaluation tests necessary for constraining the uncertainties in quantifying future levels of climate warming for given scenarios of atmospheric aerosol and greenhouse gas concentrations. Simply put, the paleoclimate data are often of insufficient quality or quantity, the time scales of major epochs (e.g., ice ages) are often mismatched to today's climate change problem, and the governing phenomena in the paleo past can be quite different than those applicable today. The paleoclimate argument needs to be clarified here, with clear statements on how such data would be used improve climate models.

Are the expected results and deliverables realistic given the available resources? (Theme 3)

No. The four-year deadline to produce a substantial reduction in climate sensitivity uncertainty is unrealistic, mostly because of the substantial challenges remaining in understanding and modeling the physics of cloud-radiation feedbacks. The value of applied climate model projections is strongly limited by supercomputer resources, and by the capability and number of the climate impacts researchers receiving them. It is fair to say, however, that very relevant interim progress reporting is a major option for the managers of the CCSP.

CHAPTER 5: "ATMOSPHERIC COMPOSITION"

This chapter is organized around five questions: (1) What are the climate-relevant chemical and radiative properties and spatial and temporal distributions of human-caused and naturally occurring aerosols? (2) What is the current quantitative skill for simulating the atmospheric budgets of the growing suite of chemically active greenhouse gases and their implications for the Earth's energy balance? (3) What are the effects of regional pollution on the global atmosphere and the effects of global climate and chemical change on regional air quality and atmospheric chemical inputs to ecosystems? (4) What are the time scale and other characteristics of the recovery of the stratospheric ozone layer in response to declining abundances of ozone-depleting gases and increasing abundances of greenhouse gases? and (5) What are the couplings among climate change, air pollution, and ozone layer depletion, which were once considered separate issues?

General Comments

This chapter gives an excellent overview of atmospheric composition as being part of the broad, globally and regionally changing environment that has greater impact on society than just through climate change. The questions seem balanced and provide a suitable range of the top science priorities in the community as summarized below. The only major omission is the sources of trace gases and aerosols. In the committee's view a comprehensive research effort is needed to locate and quantify such emissions from natural and anthropogenic sources; the lack of a thorough inventory is possibly the overriding uncertainty in assessing human impacts on atmospheric composition today. Other topics not covered or emphasized in the chapter include improving the understanding of hydroxyl radicals, anthropogenic dust, connections between atmospheric composition and cloud microphysics, how oceans interact with the atmosphere, and dimethyl sulfide (DMS). The committee recognizes that this chapter is not intended to be a thorough review of all the science pertaining to atmospheric composition, and that these topics are included implicitly in the scientific problems addressed (and we hope in more detailed actions plans to follow).

This chapter could be improved by better describing how the research activities in it contribute to both the high-priority questions identified for the CCRI and the multiple critical crosscutting research areas. Understanding atmospheric composition should be at the core of many multistress and crosscutting environmental issues because its role in the Earth system extends well beyond being a vehicle for climate forcing. The links between atmospheric composition and human dimensions are obvious (both in terms of forcing and impacts), yet not adequately described in the draft plan. This relationship could be highlighted in the revised plan with a focus on developing the modeling capability to link atmospheric composition with human driving forces and human system impact at regional scales. The strong link of atmospheric composition with natural biogeochemical cycles, ecosystems, biomass burning, and the agricultural sector could be addressed in terms of the coupling between greenhouse gases and global nutrient cycles.

The draft plan does not make clear whether monitoring changes in atmospheric composition is a priority in the proposed observing system for climate and climate-relevant variables. Measurements of atmospheric composition are needed to quantify climate forcing and many impacts on human and natural systems beyond climate change (e.g., acid and nutrient deposition, air pollution, ozone depletion, and UV). The chapter on atmospheric composition in the revised plan could outline a major role for trace gas and aerosol measurements in the design of the proposed observing system.

Does the plan reflect current scientific and technical understanding?

Yes, the presentations at the CCSP planning workshop and at recent atmospheric chemistry workshops and steering committee meetings support the key topics raised here. The aerosol topic, Question 1, has been identified by the ad hoc scientific steering committee for the National Aerosol-Climate Interactions Program (NACIP). The budgets of key chemically reactive greenhouse gases such as methane, Question 2, are essential to projecting future climate change; and the recent variations in the methane growth rate pose a major challenge for the understanding of atmospheric composition. The connections between regional and global pollution and climate change, Question 3, have been identified recently as a major international, or at least hemispheric, issue with connections not only to the Framework Convention on Climate Change but also the Convention on Long-Range Transboundary Air Pollution. The recovery of the ozone layer, Question 4, remains a top interest; although improvements are expected over the next 50 years as chlorofluorocarbons decay in the atmosphere, there remains the threat of renewed ozone depletion at the

end of the century if methane and nitrous oxide abundances continue to increase. The relationship between climate change, ozone layer, and air pollution, Question 5, addresses the important linkage of atmospheric composition across a wide range of environmental problems that is now being recognized (e.g., IPCC [2001c]). The committee suggests that a new Question 6 should be added to address emissions of trace gases and aerosols.

Are the specific objectives clear and appropriate?

Generally, the objectives are clear, but they are not fleshed out. The detailed priorities and most critical linkages are not given in the draft plan. Rather than just quote linkages at the end, it would be more useful to describe each specific, top-priority research objective and how it involves linkages with climate change, water cycle, ecosystems, land use, carbon cycle, and human dimensions (both in terms of forcing and impacts). Most of these are implicit in the research needs as stated, but need to be explicit.

Are expected results and deliverables realistic given the available resources?

The timelines for scientific progress seem to be reasonable, but some payoffs are unclear as to whether the objective is to make major progress toward achieving them (a reasonable objective with previous GCRP resources) or to fully answer the big questions (an unrealistic objective requiring much greater resources).

CHAPTER 6: "CLIMATE VARIABILITY AND CHANGE"

This chapter is organized around five questions: (1) What is the sensitivity of climate change projections to feedbacks in the climate system? (2) To what extent can predictions of near-term climate fluctuations and projections of long-term climate change be improved, and what can be done to extend knowledge of the limits of predictability? (3) What is the likelihood of climate-induced changes that are significantly more abrupt than expected, such as the collapse of the thermohaline circulation and rapid melting of the major ice sheets? (4) Whether and how are the frequencies, intensities, and locations of extreme events, such as major droughts, floods, wildfires, heat waves, and hurricanes, altered by natural climate variations and human-induced climate changes? and (5) How can interactions between producers and users of climate variability and change information be optimally structured to ensure that essential information needed for formulating adaptive management strategies is identified and provided to decision makers and policy makers?

General Comments

Chapter 6 of the draft plan is well written and identifies many of the key research activities necessary to better understand climate variability and change. It appropriately attempts to provide an overview of the necessary progression from observations through modeling to production of decision aids for all of the CCSP. Ideally, this chapter would clearly articulate how research on individual elements of the Earth system will be integrated to develop a better understanding of climate variability and change. Chapter 6 does refer to other relevant chapters in several places, but does not adequately describe how research under climate variability and change and these other efforts will feed into each other. Of greatest concern are the linkages to the relevant elements of the CCRI (Chapters 2-4 of the draft plan) and the human contributions and responses to climate change (Chapter 11 of the draft plan). For example, the draft plan states, "Perhaps most fundamentally, we do not yet have a clear understanding of how these natural climate variations may be modified in the future by human-induced changes in climate" (CCSP, 2002, p. 69). This issue is vital to understanding both climate variability and climate change, yet the chapter does not specify any research that would improve understanding of the human activities that are changing climate systems. It calls for research that would make projections of climate futures based on assumptions about the human activities that drive climate change, but no research to put those assumptions on a more scientific footing.

Another linkage that is not sufficiently developed is with multiple ongoing internationally coordinated efforts. Several such programs are mentioned,[1] but no effort is made to describe how U.S. research activities will support them. This omission is striking considering that obtaining the observations necessary to improve understanding of climate variability and change requires international cooperation. The objectives of these international programs are closely parallel to those described in Chapter 6 of the plan. For example, a discussion of how the United States is contributing to and benefiting from CLIVAR, a 15-year effort dedicated to improving understanding and predictability of climate variability on seasonal to centennial time scales, would strengthen this chapter. It is

[1] "Moreover, internationally coordinated research programs such as the World Climate Research Programme (WCRP) and its projects Climate Variability and Predictability (CLIVAR), Stratospheric Processes and their Role in Climate (SPARC), Climate and Cryosphere (CliC), the Global Energy and Water Cycle Experiment (GEWEX); as well as the International Geosphere-Biosphere Programme (e.g., PAGES paleoscience project), are critical fordeveloping global infrastructure and research activities designed to ensure that global aspects of climate variability and change are addressed." (CCSP, 2002, page 79).

surprising the NOAA-sponsored and internationally supported International Research Institute for Climate Prediction (IRI) is not mentioned.

Does the plan reflect current scientific and technical understanding?

Generally yes. In some cases, however, the chapter does not sufficiently support specific claims (e.g., the statement that ocean mixing to a large degree controls the rate of projected global warming, CCSP, 2002, p. 71) or is incomplete (e.g., ice-albedo and vegetation feedbacks are not mentioned on page 71; the Antarctic Oscillation is neglected from the discussion on pages 72-74, CCSP, 2002).

Are the specific objectives clear and appropriate?

Generally yes. The chapter correctly identifies a need for Climate Process Teams (CPTs), a new strategy to bring key researchers together to rapidly improve the fundamental understanding of physical, chemical, and biological processes of the Earth system and how they are represented in models. The CPTs are intended to foster partnerships between scientists who specialize in observations, theory, and modeling so as to create an ongoing cycle of testing, verifying, and improving models in conjunction with research into climate processes. This new approach, and the general need to improve understanding of processes, could be better described in the plan, particularly by drawing from and referencing the CLIVAR science plan, where the idea was first presented.

The treatment of observations is uneven and in some cases weak. As discussed in Chapter 3 of this report the draft plan does not offer a structured program for building an integrated observing system for climate and climate-related variables. Indeed, it is awkward that the observation requirements are unclear until Chapter 12 of the draft plan. Chapter 6 of the plan does not explicitly identify the high-resolution observations necessary for process studies. In addition, it does not call for either an event-driven high-resolution observing program or a sustained high-resolution observation array to resolve the small spatial scales and fast time scales necessary to establish links between large-scale climate change and the strength of regional and local events. Chapter 6 does not adequately emphasize the role of data assimilation, reanalysis, and incorporation of remotely sensed observations in models. The reanalyses of the atmosphere by the National Centers for Environmental Prediction, the European Centre for Medium-Range Weather Forecasts, and other modeling centers provide consistent, gridded surface and atmospheric fields for 25 years that are increasingly used for climate research. With global climate observing systems being developed, such as the global ocean observing system, and new data available on land and in the ocean, this plan could be strengthened by including a clear U.S. strategy for producing atmosphere, ocean, land, and coupled system reanalyses.

Are the expected results and deliverables realistic given the available resources?

As discussed in the introduction to Part II of this report, this question is difficult to answer without detailed budget information. Nevertheless, the chapter does not adequately address the supporting research infrastructure needed to deliver the indicated products and payoffs. A fundamental gap in the U.S. research infrastructure exists in the transition of climate research tools, observations, and understanding to applications (e.g., NRC, 2000a). The plan could pay more attention to establishing ongoing, sustained mechanisms and computing resources for such transitions. This issue is particularly important in addressing question 5 in the draft Chapter 6, where two major challenges are not addressed: 1) the lack of ongoing partnerships between researchers and those producing operational model products; and 2) the interaction between the public and private sectors, particularly in terms of what climate products and services federally funded labs, investigators, and centers offer and what decision aids come from the private sector. Without the first it is difficult to see how a feedback loop would be established to improve the quality of model products. Without explicitly indicating the responsibilities of the public and private sectors it is difficult to assign any weight to the discussion of products and payoffs presented here.

CHAPTER 7: "WATER CYCLE"

This chapter is organized around five questions: (1) To what extent does the water cycle vary and change with time, and what are the internal mechanisms and external forcing factors, including human activities, responsible for variability and change? (2) How do feedback processes control the interactions between the global water cycle and other parts of the climate system (e.g., carbon cycle, energy), and how are these feedbacks changing over time? (3) What are the key uncertainties in seasonal to interannual predictions and long-term projections of water cycle variables, and what improvements are needed in global and regional models to reduce these uncertainties? (4) How do the water cycle and its variability affect the availability and quality of water supplied for human consumption, economic activity, agriculture, and natural ecosystems; and how do its interactions and variability affect sediment and nutrient transports, and the movement of toxic chemicals and other biogeochemical substances? and (5) What are the consequences of global water cycle variability and change at a range of temporal and spatial scales for human societies and ecosystems? How can the results of global water cycle

research be used to inform policy and water resource management decision processes?

General Comments

The water cycle chapter is very clear and well written. It is appropriately focused on integrating hydrologic research themes and producing research products that serve society. However, water resource issues are not integrated within other components of the strategic plan of most relevance, such as the decision support chapter (Chapter 4 of the draft plan). A key message that should be communicated is the potential for significant short-term benefits deriving from some aspects of the water cycle research, particularly as it relates to adaptation to climate change. Climate-related water tools and research products are currently available that could significantly decrease risk and increase economic benefits if they were shared with international, federal, state, and local decision makers more effectively. The plan could be strengthened by portraying the water cycle as an integrating feature with relevance to all program elements, in both the basic research and the evaluation of impacts and mitigation and adaptation options.

The treatment of water cycle science in the plan can be improved by enhancing the linkages between research on the water cycle, the carbon cycle, the nitrogen cycle, and land use land cover change in order to understand the important feedbacks that could affect society. More emphasis on the role of soil moisture and the evapotranspiration component of the water cycle will emphasize these linkages. The ocean component of the hydrologic cycle and the role of aerosols are also inadequately addressed. In the context of decision support the connections of water cycle forecasts to land resource management, such as controlling fires and managing agricultural activities, could be further emphasized.

In terms of program implementation there is great potential to economize (and improve results) by coordinating observations, modeling, and evaluations of management options in the context of the carbon, nitrogen, and water cycles (e.g., vegetative feedback, coordination of measurement and modeling efforts). Coordination of these efforts could produce important insights more rapidly, but would require increasing integration among participating agencies and bringing additional agencies into the CCSP.

Does the plan reflect current scientific and technical understanding?

Overall the chapter reflects current scientific and technical understanding. The research topics closely correspond to those outlined in *A Plan for a New Science Initiative on the Global Water Cycle* (Hornberger et al., 2001), with some additional research topics related to decision support. This addition is appropriate given the overall emphasis of the strategic plan. The key issues in this chapter are reducing (or at least clarifying) uncertainty, providing more accurate forecasts to decision makers, and improving the observation network to do a better job of identifying trends and increasing the accuracy of models.

The plan does not reflect current technical understanding in its discussion about the data needs of decision makers in the area of water, for example:

- Quantitative estimates of likely changes in runoff volumes, annual precipitation, snowpack conditions, average seasonal temperature (especially as related to snowmelt conditions, and other relevant variables), intense rain events and flooding, sea level, water consumption and evapotranspiration, water temperatures and water quality (especially as related to ecosystem management), and other relevant variables;
- Improved understanding of variability, trends, and predictions at the local level, using regional and watershed modeling; and
- Expanded ability to document financial incentives to develop and use better predictive capacity and evaluate value added when using better information (e.g., Riverware Decision Support Framework of the Bureau of Reclamation).

Are the specific objectives clear and appropriate?

Overall, the specific objectives of this chapter are clear, appropriate, and well organized. The chapter can serve as a basis for enhancing linkages with other programs, such as climate variability and change and human dimensions. One exception is that the plan does not identify the need for modeling advances to do accurate local and regional downscaling. Researchers do not have a cohesive dataset on the hydrologic system, which impedes their ability to close the water budget and, therefore, to conduct watershed modeling, however new measurement techniques make this an achievable goal in the near term.

The chapter could also focus more on short-term applications that could be developed in collaboration with water managers and private sector interests, *in situ* data collection, useful products from a regional perspective, and integrating work within the water, nitrogen, and carbon cycles.

Are expected results and deliverables realistic given the available resources?

The committee could not determine if the expected results and deliverables are realistic because adequate information was not available (1) about the nature, costs, and anticipated benefits of each agency's research projects that are considered to be part of the water cycle; (2) the magnitude of new resources required to implement the described agenda; and (3) the timelines for anticipated

completion of products. A higher degree of integration between the researchers within agencies and between agencies is imperative, although it is likely that the agencies will be reluctant to take on any additional coordination or new projects in the absence of new funding sources.

CHAPTER 8: "LAND USE/LAND COVER CHANGE"

This chapter is organized around five questions: (1) What are the primary drivers of land use and land cover change? (2) What tools or methods are needed to allow for better characterization of historic and current land use and land cover characteristics and dynamics? (3) What advances are required to allow for the projection of land-use and land-cover patterns and characteristics 10-50 years into the future? (4) How can projections be made of potential land-cover and land-use change over the next 10-50 years for use in models of impacts on the environment, social and economic systems, and human health? and (5) What are the combined effects of climate and land-use and land-cover change and what are the potential feedbacks?

General Comments

Land-use and land-cover change is a critical crosscutting component of the CCSP. Even so, the committee is pleased that the CCSP has recognized it as a program element in its own right. Chapter 8 is a model for problem-focused integration of research on biophysical and social processes, and is far ahead of many other chapters in that respect. The full range of human and other (e.g., climatic) influences on land-use and land-cover changes is recognized not only in the general language introducing the chapter but also in every part of the research agenda. The draft plan could be enhanced by clearly describing three roles for land-use and land-cover research: (1) as a driver of processes in other parts of the Earth system and thus in other parts of the CCSP; (2) as a global change in its own right requiring its own foundation of theoretical inquiry, measurement, and modeling; and (3) as the medium in which many impacts take place and where policy and decision-making levers exist (e.g., carbon sequestration).

The draft plan describes an ambitious program in land-use and land-cover change in Chapter 8, but the historical budget allocation for land-use and land-cover change is insufficient to meet these new goals. Furthermore, these objectives are not well integrated into other program elements. For example, Chapter 5 of the draft plan could pay more attention to how research in land-use and land-cover change is critical to understanding emission and uptake of greenhouse gases in the atmosphere. Similar interfaces exist with the other program elements in the GCRP portion of the plan, and are especially important for Chapter 6 on climate variability and change (e.g., to understand surface radiative properties), Chapter 9 on the carbon cycle, and Chapter 10 on ecosystem structure and function.

The study of land-use and land-cover change will require routine measurements, which are not clearly articulated in the draft plan. Methods and procedures now exist to make routine global observations of land cover, yet there is no such program in place. The plan would be significantly improved with a strategic focus on those critical measurements that would immediately enhance land-use and land-cover change research, with linkages to the chapters on observations and measurements. Adding this focus to the plan would also enable the plan to improve its treatment of international linkages, because proposed international efforts, such as the Global Climate Observing System and the Global Terrestrial Observing System, will need strong support from the U.S. global change community to be effective. A discussion of measurements would also tie neatly to decision-makers' needs, since land use and cover change observations may likely have some of the most immediate use.

The land-use and land-cover change element is new to the program, and a long time in coming. Several programs within the agencies (in particular, NASA, NOAA, and NSF) already include land-use and land-cover change in their global change programs. As well, the international global change programs (i.e., the International Geosphere-Biosphere Programme, the International Human Dimensions Programme on Global Environmental Change, and the World Climate Research Programme) have included this theme in their agendas, and have outlined the critical questions and methods. The CCSP would do well to review these existing programs and seek ways to enhance them. In turn, the revised plan could outline an approach for improved interagency collaboration on the topic of land use.

Does the plan reflect current scientific and technical understanding?

The chapter reflects the current scientific understanding and technical capabilities to the extent that it indicates a new readiness to tackle these questions. The committee believes the strategic plan itself could benefit from a closer examination of research questions relevant to land-use and land-cover change, perhaps through a process that engages the research community in close cooperation with relevant federal agencies.

Achieving systematic understanding of land-use and land-cover change is one of the grand challenges in the environmental sciences (NRC, 2000b). The draft plan focuses probably too much on empirical work with historical reconstruction and other measurement issues at the expense of the development of a science of land-use change. Key scientific issues include the spatial and temporal dynamics of land-use change, the role of

fragmentation and degradation, the role of multiple drivers, the role of institutions, and the synergy among drivers and types of land-use change. A community-wide science workshop could be used by the CCSP to better define these issues and the questions they pose.

Are the specific objectives clear and appropriate?

Generally, the specific objectives are clear and appropriate, however, the chapter could be better written and organized. The research questions listed under each topic are quite general and often vague. It is difficult to tell what has already been accomplished among the listed research needs, and some larger research questions are not specifically mentioned.

Of particular concern is that the distinctions among the five questions are confusing. For example, one of the products listed for Question 1 is long-term land-use and land-cover history, whereas one of the products listed for Question 2 is a national land-cover database. The first three research questions listed under Question 2, which is focused on methods, are related to a description of land-use and land-cover change rather than to method development. The introduction to Question 4 is the most tightly focused, and the research questions associated with that element are compelling. But, the research questions in Question 5 are similar to those posed in Question 4. A possible reorganization is: (1) description of current land use and rates of change; (2) studies of how different global change drivers affect land use and land cover; (3) studies of the feedback effects of land-use and land-cover change on climate variability and change; (4) data integration needs and requirements for new, more systematic observations; (5) model requirements; and (6) studies focused on improving the representation of processes in models.

More generally, it is important that the proposed program on land-use and land-cover change make provisions for process studies, observations, modeling and prediction, retrospective studies, research on impacts, and regional science networks and assessments. It may be useful to identify some longer-term targets for the program, in addition to the listed "Products and Payoffs," which necessarily tend to be more limited.

The role of land-use and land-cover change is an important crosscutting theme for climate and global change research. As such, the links to other program elements could be made clearer and more explicit. Cross-referencing with other chapters is necessary to emphasize key interactions with land-use and land-cover change.

As discussed in Chapter 2 of this report the CCRI and GCRP parts of the draft plan are not well integrated. In terms of land-use and land-cover change, improving the integration may require a refocusing of the CCRI issues to consider such topics as the convergence of multiple stresses from both climate and land-use changes, an issue highly relevant to decision making. Indeed, land-use and land-cover change is not only the "other" global change but also is a global change of immediate relevance to decision making.

Are the results and deliverables realistic given the available resources?

It seems unlikely that any of the "Products and Payoffs" identified in the draft plan that require new research will be delivered within two years given standard funding cycles. Even many of the four-year deliverables seem overly optimistic. The land-use and land-cover research agenda described in the draft plan is a long-term endeavor. A new and modestly funded program like this should not be expected or pressed to offer large numbers of useful outputs in the very short term. The CCSP should recognize that unlike some other elements with a 10-year head start, much of the first several years of the land-use and land-cover change program will be focused on research initiation. In the near term, results based on observations and measurements are more likely than those from model development, because the latter takes more time to develop. A few modeling activities, such as regional syntheses or case studies, may produce useful outputs in the first years.

CHAPTER 9: "CARBON CYCLE"

This chapter is organized around six questions: (1) What are the magnitudes and distributions of North American carbon sources and sinks and what are the processes controlling their dynamics? (2) What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time scales, and which processes control their dynamics? (3) What are the magnitudes and distributions of global terrestrial, oceanic, and atmospheric carbon sources and sinks and how are they changing over time? (4) What are the effects of past, present, and future land-use change and resource management practices on carbon sources and sinks? (5) What will be the future atmospheric carbon dioxide and methane concentrations, and how will terrestrial and marine carbon sources and sinks change in the future? (6) How will the Earth system and its different components respond to various options being considered by society for managing carbon in the environment, and what scientific information is needed for evaluating these options?

General Comments

Chapter 9 of the draft strategic plan gives an excellent overview of the major challenges in carbon cycle science. It appropriately recognizes that the carbon cycle is a core element of biogeochemistry and that studies of the carbon cycle cut across many disciplines of Earth system science,

including all the GCRP elements covered in Chapters 5-11 of the plan.

An important thrust of this chapter (that is also brought forward into Chapter 2 of the draft plan) is to refine estimates of the magnitudes and distributions of North American carbon sources and sinks (Question 1). While Question 1 could provide a very good test case of what to expect for land-based carbon storage and release over the next several decades of rising CO_2 abundances, it is limited and seemingly disconnected from the other questions that recognize the global scale of the problem. How will the North American intensive research translate into the improved global understanding that is well described in the Products and Payoffs? This focus on the North American carbon cycle is one example of the general insularity of the draft plan. In this effort regional atmospheric measurements of carbon dioxide (CO_2) and methane (CH_4) are correctly highlighted as essential to integrating sources and sinks, but such data are not unambiguous, and the projected advances rely heavily on anticipated improvements in atmospheric models (Chapter 5 of the draft plan).

In general the chapter would benefit from a broader perspective that better explores the global context of these studies, the links to human dimensions, and a fuller suite of sequestration options. For example, issues related to fossil fuel consumption patterns, emerging carbon markets, policy approaches for encouraging sequestration, and other mitigation options are touched upon only briefly in the chapter, although these areas offer rich opportunities for interdisciplinary research by natural and social scientists to understand the human dimensions of global change. The plan recommends research on various potential options for managing land and ocean ecosystems to mitigate the rise of CO_2 in Earth's atmosphere, and it may also need to consider the risks and benefits of such large-scale ecosystem manipulations.

The chapter underemphasizes the role of the oceans in the carbon cycle, giving much more attention to the terrestrial systems. For example, many detailed examples and research objectives from the terrestrial systems are given, while the role of the ocean is generally referred to in general sweeping statements when it is mentioned at all. This oversight is puzzling, as it is generally accepted that ocean processes regulate climate-related changes in atmospheric CO_2 over glacial-interglacial cycles, and oceans have a much larger inventory of carbon that is exchangeable with the atmosphere than do soils and the terrestrial biosphere. The plan would be greatly strengthened by providing a more detailed and comprehensive treatment of the role of oceans in the carbon cycle. In particular it could better address CO_2 uptake in the open ocean (not just coastal areas), the climate sensitivity of water column processes, and the carbon cycle below the thermoclime and in marine sediments.

The large-scale, long-term measurement campaigns and experiments in this plan will require significant multiyear funding commitment. More importantly, they are not just carbon cycle measurements but are also closely related to ecosystems research needs (Chapter 10 of the draft plan), and must be integrated with the global climate observing system (Chapter 3 of the draft plan). Success in the carbon cycle research requires the climate-quality observations, monitoring and data analysis shown in Chapter 3 of the draft plan.

Does the plan reflect current scientific and technical understanding?

Generally the chapter provides a good assessment of what is currently known and unknown about the global carbon cycle, and where research should be strengthened. Many of the recommendations in the draft strategic plan aim to improve our basic understanding of the global carbon cycle. This chapter draws heavily on *A U. S. Carbon Cycle Science Plan* (Sarmiento and Wofsy, 1999), which represents a broad consensus of the research priorities of the nation's scientists. Studies of biogeochemistry were also recognized as a research priority in *Grand Challenges in Environmental Sciences* (NRC, 2000b).

The draft plan perhaps overemphasizes a hot topic that recent evidence is deflating: the inability to balance the budget for CO_2 in the Earth's atmosphere, leading to an unresolved "missing sink" of carbon storage. In recent years various lines of direct (forest inventory) and indirect (atmospheric inversion) measurements have indicated that the missing sink for carbon lies in the forest biomass of the temperate zone, especially in North America (IPCC, 2001c). Estimates of the size of this missing sink differ markedly, but more recent work shows the value to be less than previously thought. This draft plan errs in assuming this sink is well known[2]; new, lower estimates of tropical deforestation do not require such a large uptake of carbon by temperate forests to balance the atmospheric CO_2 budget (IPCC, 2001c).

A major factor underplayed in this chapter is the human dimension (consumption and technology) in forcing of the carbon cycle. Although land-use change is well addressed (Question 4), the major driver, fossil fuel use, is not (also missing in Chapter 5 of the draft plan). Such human factors present a great uncertainty in projecting CO_2 abundances in the latter half of this century. The uncertainties in the carbon cycle addressed here are important, but they represent only a fraction of the projected human forcing (see IPCC, 2001c).

[2] "There is growing evidence of a current Northern Hemisphere terrestrial sink averaging 1.8 billion metric tons of carbon per year." (CCSP, 2002, p. 101)

Are the specific objectives clear and appropriate?

Yes, in the sense that the products and payoffs are excellent, clear, and appropriate objectives for the carbon cycle program. Unfortunately in many cases it is not clear how the research will lead to the products.

Research priorities could more transparently address the importance of the underlying background flux of carbon in the natural carbon cycle, as distinguished from human changes in the flux since the Industrial Revolution. For instance, only the net increment of carbon transport in rivers due to human activities is relevant to deducing the potential for an enhanced sink for carbon to mediate the rise of CO_2 in Earth's atmosphere. Similar arguments pertain to the storage of organic carbon in northern hemisphere boreal soils, the storage of inorganic carbon in desert soil carbonates, and the transfer of net production to the deep sea.

Are expected results and deliverables realistic given the available resources?

Almost uniformly, all of the scheduled products do not appear to be deliverable within two to four years. The plan exaggerates the pace of progress in scientific understanding that can be achieved. For example, the optimism ("Breakthrough advances in techniques to observe and model") is not true for the recent past, and seems to be a difficult achievement for the future. These products should remain high priority, but should be framed in terms of expected advances, rather than the described payoff.

CHAPTER 10: "ECOSYSTEMS"

This chapter is organized around three questions: (1) What are the most important linkages and feedbacks between ecosystems and global change (especially climate), and what are their quantitative relationships? (2) What are the potential consequences of global change for ecosystems and the delivery of their goods and services? and (3) What are the options for sustaining and improving ecosystem goods and services valued by societies, given projected global changes?

General Comments

Chapter 10 sets forth a broad and ambitious program on ecosystem research. This expanded emphasis, if adequately funded, would constitute a critical and much needed shift for the GCRP. Particularly important is the new focus on strategies for managing and sustaining ecosystems and the goods and services they provide amidst multiple global change processes (Question 3). Rapidly advancing science in this area will be essential to enable effective action before irreversible losses of ecosystem functions occur.

Although the general focus of Chapter 10 is good, much of the specific content is weaker, probably reflecting the small past role of ecosystem research in the GCRP and that most of the chapter covers new ground for the program. Nevertheless, it means that this part of the draft plan still needs to be thought through more thoroughly by a larger group of scientists and natural resource and ecosystem managers who match the chapter's breadth.

Overall the chapter would benefit from a more cohesive and strategic organizing framework that places a clear priority on predicting ecosystem impacts and on providing the scientific foundation for possible actions and policies to minimize the deleterious effects and optimize future outcomes. This framework should explicitly define "ecosystem goods and services," because this term is a core concept for organizing the chapter's research problems. The chapter's implied definition is appropriately broad, capturing public benefits ranging from food and fiber to biological diversity and aesthetic and cultural values. Unambiguous definition in the plan will be essential, though, to avoid misinterpretations such as a narrow focus on resource extraction.

The organizing framework needs to cogently address the diversity of ecosystems that it covers. Different research needs and priorities will arise from differences in vulnerability and response options, for example, between natural and semi-natural ecosystems and those intensively managed for agriculture and forestry. The framework should sequence the research in ways that reflect the urgency of information needs for decision makers, giving priority to approaches for enhancing ecosystem resilience, ecological systems most at imminent risk, and ecosystems where rapid, near-term changes are likely to have the greatest socio-economic effects.

Does the plan reflect current scientific and technical understanding?

The chapter's general scope and three questions are supported by current scientific and technical understanding. Because the chapter is short on scientific and technical detail and covers such a wide scope, it omits some important concepts, does not always build upon what is already known, and does not consistently target research toward the most pressing information gaps.

Two major weaknesses result. First, much of the chapter treats ecosystems as a "biophysical black box." The chapter lacks depth and misses important issues in its coverage of the interplay between climate and global change and the ecological patterns and processes that sustain the capacity of ecosystems to deliver goods and services desired by society. Such patterns and processes include: species and community diversity, distribution, and dynamics; ecosystem processes like disturbance, hydrology,

and fire; spatial configuration, connectivity, and corridors; and evolutionary processes. Targeted insights at this level will be essential to evaluate the benefits and risks of proposed mitigation and adaptation strategies and to inform resource management decisions that balance competing interests.

Similarly weak is the chapter's coverage of the many linkages between ecosystem condition and human societies and resulting research questions that integrate the natural and social sciences. The plan gives only passing attention to one of the key needs ahead: research on the economic valuation of ecosystems and the market and non-market goods and services that they provide in order to inform pending decisions about natural resources and risk management. Other gaps include the potentially significant feedbacks between ecosystem changes and human societies, such as the potential for ecosystem degradation to exacerbate or catalyze societal problems, and important researchable questions about the future effectiveness of current environmental laws and policies that seek to maintain recent ("natural") ecological conditions.

Are the specific objectives clear and appropriate?

The specific objectives are not clear and appropriate. The chapter identifies an assortment of general and specific research questions and needs, however, these objectives do not add up to a coherent, focused, and strategic science plan. Some of the research questions are important implementation issues, but the underlying science research needs have not been identified. Others confuse means with ends, calling for certain types of data or analytical frameworks without clearly specifying the underlying science objectives these tools should serve. For example, the section describing research to understand impacts (Question 2), focuses primarily upon remotely sensed data and ambiguously described analyses and experiments. What many decision makers will need, however, are results from robust models of climate and land use change at a regional scale linked to long-term experimental studies that examine how the composition, structure, and functioning of ecosystems will respond to multiple stressors.

The chapter's description of an ecosystem observing system has similar ambiguities. A clear picture of data needs and applications should inform the design of observation systems. Instead, the draft plan appears to simply link already existing and planned observation systems that were designed for different objectives. The first step should be to design an ecosystem observation system—to monitor the health of ecosystems, to serve as an early warning system for unanticipated ecosystem changes, and to verify approaches for modeling and forecasting ecosystem changes—and then to ask whether existing programs should be a part of this system.

The discussion of research on options for sustaining and improving ecosystem goods and services (Question 3) misses an important opportunity to consider integrating scientific analyses of ecosystem function into ongoing large-scale efforts to manage ecosystems for societal benefits. Much ecosystem management for the foreseeable future will proceed with imperfect knowledge about the impacts of multiple global change processes and about fundamental aspects of ecosystem structure and function. Thus, it will be experimental. Routine monitoring, scientific evaluation, and feedback to managers could enable adaptive shifts in management strategies as knowledge about an ecological system grows. At the same time, such "adaptive management" also could provide important opportunities for scientists to test hypotheses about ecosystem function and responses through large- scale manipulative experiments. Several private and public organizations have piloted this approach, and it has much promise for advancing both scientific research and natural resource management goals related to global change.

The chapter recognizes, as have previous NRC reports (e.g., NRC, 1999b) and the U.S. National Assessment of the Potential Impacts Climate Variability and Change (NAST, 2000), that climate change will interact with other global change processes to produce aggregate impacts on ecosystems and, further, that these interactions will affect the likely success of various response options. It does not, however, describe any program of research to better understand such interactions, nor does it identify which processes such a program would address. Two important interacting processes not well covered by the draft strategic plan, for example, are changes in global nutrient cycles, particularly the nitrogen cycle, and major changes now occurring in the world's biota due to species translocations and invasions.

Are the results and deliverables realistic given the available resources?

The chapter emphasizes near-term syntheses of existing knowledge, but these syntheses lack sufficient rigor to fulfill the chapter's research objectives. The chapter does not provide much clarity about longer-term deliverables and consequently falls short of the kind of content coverage that one would desire from a 10-year plan. Timelines for most deliverables seem ambitious.

While current resources might be sufficient for the near-term deliverables, they are clearly insufficient for implementing the expanded program of ecosystem research that matches the chapter's broad scope and the nation's needs. The plan will need to commit significant new resources, present a credible build-out plan, and/or provide a much more tightly organized and strategic focus if the CCSP is to achieve the longer-term objectives in the area of ecosystems. Implementing the plan also will require involvement of agencies with responsibilities for managing

ecosystems that have not previously been deeply involved in the GCRP (e.g., those dealing with federal lands, marine and estuarine reserves, agricultural conservation lands and wetlands).

Today's research and development infrastructure in and outside the federal government does not adequately support the development of technologies for managing ecosystems, particularly those outside production agriculture, forestry, and fisheries. Consequently, most federally supported ecosystem research has typically been only loosely linked to the federal government's significant responsibilities to manage and conserve biological resources in natural, semi-natural, and multiple-use ecosystems. The strategic plan needs to address this significant infrastructure and capacity gap.

CHAPTER 11: "HUMAN CONTRIBUTIONS AND RESPONSES"

This chapter is organized around four questions: (1) What are the magnitudes, interrelationships, and significance of the primary human drivers of change in atmospheric composition and the climate system, changes in land use and land cover, and other changes in the global environment? (2) What are the current and potential future impacts of global environmental variability and change on human welfare, what factors influence the capacity of human societies to respond to change, and how can resilience be increased and vulnerability reduced? (3) How can the methods and capabilities for societal decision making under conditions of complexity and uncertainty about global environmental variability and change be enhanced? and (4) What are the potential human health effects of global environmental change, and what tools and climate and environmental information are needed to assess and address the cumulative risk to health from these effects?

General Comments

Chapter 11 reflects many of the important research questions about human contributions and responses to global change. It does not provide an adequate assessment of the state of knowledge or provide specific priorities that might guide the implementation of research across federal agencies and other institutions. It is not well linked to most other chapters in the strategic plan, and lacks useful or detailed discussion of the links of the U.S. human dimensions research agenda with international activities such as those of the International Human Dimensions Programme on Global Environmental Change, IPCC, and the International Geosphere-Biosphere Programme. The revised plan will need to address the genuine challenge of supporting research that combines data, concepts, and analytical approaches from the social and natural sciences.

Does the plan reflect current scientific and technical understanding?

Generally the chapter does not adequately reflect current scientific and technical understanding. For each of the four questions the descriptions of the state of knowledge need to be greatly improved to better demonstrate what is known about the human contributions and responses to climate change and to indicate that the research funded to date has produced several significant results (see for example, NRC [1999b]; IPCC [2001a, b]; NAST [2001]; and articles in the journal *Global Environmental Change*). The chapter gives a false impression that all human dimensions research is more difficult or more uncertain than other aspects of the program. Some aspects of human activity are fairly predictable and their study can actually lead to reduced estimates of the uncertainty and severity of climate impacts (e.g., the analysis of resilient institutions and technologies, such as disaster response organizations or precision agriculture). There has been great progress in understanding regional vulnerabilities, multiple stresses, and possibilities for adaptation, especially in relation to seasonal climate variability independent of the uncertainty in longer-term climate projections.

Question 1 needs to include research on the role of institutions such as property rights in driving environmental change. Question 3 might recognize the importance of deliberative interactions with stakeholders and the value of research on human preferences as input into policy decisions. Question 4 appropriately focuses on the importance of research into impacts on human health, but suggests that this is of higher priority than other critical impact sectors such as water and agriculture. The chapter in general must recognize the need for basic social science research into human-environment interactions, the importance of economic analysis of the costs and benefits of mitigation and adaptation and the tradeoffs between different response options, and the importance of social science data collection as a basis for more specific research questions and empirical research results.

Because of their significance to human dimensions research and decision making, it is disappointing that this chapter pays little attention to research questions about mitigation and adaptation, environmentally significant consumption, human preferences, institutions, economic analysis, and decision support tools. The lack of attention paid to research on consumption is a problem throughout the draft strategic plan because understanding consumption (e.g., of resources such as fuel, water, chemicals) is critical to understanding the driving forces of land-use change (e.g., deforestation, agricultural intensification) and emissions. Consumption research is also important to understanding climate impacts and vulnerabilities, for example, the important role of per capita water consumption in understanding future patterns of water demand and supply. It has great payoffs in both the public and private sectors in

terms of informed decision making. Research into public perception and acceptance of alternative technologies (such as nuclear energy), public demand for low-mileage vehicles (such as sport utility vehicles), and local initiatives to promote energy conservation could provide scientific information needed for climate technology programs and for modeling emissions and land-use change.

As noted in Chapter 3 of this report there is a sophisticated range of social science tools for supporting decision making, understanding stakeholder needs, communicating uncertainty and risk, assessing both market and nonmarket costs and benefits, and providing outreach to the public and others. The strategic plan should be more explicit in Chapters 4 and 11 about the potential value of these social science tools and priorities for their improvement and incorporation across the whole strategic plan. The plan is very weak in the area of economics. Research progress has been made and should continue into the costs and benefits of impacts, mitigation, and adaptation; new economic instruments for responding to global change; the implications of global economic restructuring for contributions and responses to global change; and the full range of valuation (e.g., market and nonmarket). One of the most obvious gaps is the lack of attention to research on how institutions (markets, laws, property rights, formal organizations) influence the drivers of change (such as deforestation), the impacts of change (such as water scarcity), and the effectiveness of responses (such as emissions trading or climate technology).

Are the specific objectives clear and appropriate?

Chapter 11 is weaker than other chapters in terms of outlining products and payoffs in the short term, failing, for example, to highlight the potential of research on human vulnerability and response to climate variability and seasonal forecasts (e.g., El Niño-Southern Oscillation) to produce real economic benefits to U.S. and other stakeholders while providing insights into vulnerability and adaptation to longer-term climate change. There is considerable potential for short-term deliverables in the area of climate variability that will improve decision making and resource management while at the same time reducing uncertainties in understanding the human responses to longer-term climate change. The specific objectives of this chapter are not clear because the products and payoffs are stated so briefly and generally (with the exception of Question 4 on health) that it is difficult to understand what the priorities are and what might be achieved.

The strategic plan should be much more specific as to the different types of users and stakeholders for climate science and global change research with much greater sensitivity and disaggregation with regard to the scale of decisions (not just national and regional but finer scaled to state, city, watershed, ecoregion, and other management and administrative units), a sophisticated understanding of institutions, and the differentiated needs of the private and NGO sectors. Research can be (and has been) funded to create a fine-grained understanding of stakeholder needs and scales of decision making and could be established as an objective in either Chapter 4 or 11 of the draft plan.

Are the results and deliverables realistic given available resources?

The research program is described so broadly, and the description of products and payoffs so briefly that one is left with an unrealistic sense of what can be achieved in both the short and long term, especially given the modest budget for human dimensions research within the GCRP. More realistic and specific results and deliverables might include improved definition and understanding of climate vulnerability and adaptation at national and regional levels based on analysis of climate variability; guidelines for developing climate information of benefit to stakeholders and communicating uncertainty; development of socio-economic datasets for analyzing drivers of change and identification of relevant data gaps; and models of links between consumption, emissions and land-use change.

CHAPTER 12: "GRAND CHALLENGES IN MODELING, OBSERVATIONS, AND INFORMATION SYSTEMS"

This chapter is organized around three themes: (1) observations, (2) modeling capabilities, and (3) data and information management.

General Comments

Unlike the other chapters in the GCRP part of the strategic plan, titled simply "Carbon Cycle" or "Ecosystems," Chapter 12 carries the imposing title of "Grand Challenges in Modeling, Observations, and Information Systems." Its contents, however, are not so distinctive. The committee agrees with the report, *Improving the Effectiveness of U.S. Climate Modeling* (NRC, 2001) that one of the most important challenges for the CCSP is the evolving integration of modeling science, climate observations, and information into a decision support system. Chapter 12 does not articulate such an overarching vision for the CCSP's modeling, observations, and information systems.

The draft plan is unclear about the relationship between the objectives identified in this chapter, which apparently serve the GCRP program elements, and those identified in the CCRI, that is, in Chapter 3 (Climate Quality Observations, Monitoring, and Data Management) and in the applied climate modeling section of Chapter 4. Chapters

3 and 12 have substantial overlaps, and many of the modeling needs identified in Chapter 4 call on the same resources as those in Chapter 12. For these "grand challenges," it seems that a single overarching strategy into which the CCRI and GCRP objectives are integrated would be appropriate. As discussed further in Part I of this report most of the activities necessary to build global climate observing systems, greatly improve modeling capabilities, and advance data management system are long-term endeavors. Even so, certain well-placed investments can accrue short-term benefits suitable for the CCRI (see this report's discussion of the draft plan's Chapters 3 and 4).

This chapter, particularly in the observations and modeling sections, lists many "priorities." Indeed, 22 separate observational programs are given in the box on pages 134-135 (even while neglecting those pertaining to human contributions and responses to environmental change identified in Chapter 11 of the draft plan) and 33 separate modeling programs are listed in the box on pages 141-143 (CCSP, 2002). No apparent priority is given for either list, reflecting a more general problem with the draft plan. The "Observing System Prioritization Criteria" provided on page 136 are reasonable in the abstract, but it is difficult to discern how they will be applied in practice (CCSP, 2002). At the least the plan could indicate those items that are considered to be of very high, high, and moderate priority, or something similar.

Does the plan reflect current scientific and technical understanding?

For Theme 1 (observations) the list of observation challenges (CCSP, 2002, p. 132) is appropriately broad and reasonably complete. The observational needs identified in Chapter 11 of the draft plan ("Human Contributions and Responses to Environmental Change") are obviously missing in the box on pages 134-135 (CCSP, 2002). The sections on page 136 on "Integration and transition of experimental and operational systems" and "A Global Observing System" clearly fail to articulate and address the large challenges in these two realms (CCSP, 2002). As discussed in Part I of this report, transitioning research-grade observations to operational applications presents many significant infrastructure barriers. Likewise, the plan makes repeated reference to *the* global climate observing system, yet to date the system is only a patchwork of observation networks. Major investments are needed to maintain and expand an integrated observing system that will support monitoring, diagnosis, and modeling of climate and associated global changes. This chapter, as well as Chapter 3 of the draft plan, largely sidesteps the fundamental overhaul and large national and international capacity-building efforts that would be required to establish the needed observation programs.

For Theme 2 (modeling capabilities) the description of modeling capabilities is reasonably complete and generally accurate in assessing needs within the next decade. Useful research activities are clearly identified. This section, however, lacks the details that will enable smooth implementation of this plan.

For Theme 3 (data and information management) the challenge of integrating the large amounts of relevant data is well laid out. Receiving less attention, perhaps because they are addressed in Chapter 3, are the important issues of data quality assurance, data archiving, and data dissemination. The research needs are clearly described, and the inclusion of socio-economic data is particularly welcome.

Are the specific objectives clear and appropriate?

For Theme 1, the five objectives listed in "The Road Forward" section are very clear and quite appropriate, though they are rather general. Of greatest concern is that they do not address the larger issues relevant to establishing a global climate observing system, as discussed in Chapter 3 of this report. A major weakness in the plan is that it does not emphasize an integration of existing observation systems, nor does it offer a pathway toward expansion of observation systems to include key climate-related ecological, biogeochemical, geophysical, and environmentally relevant socio-economic measurements. A great need exists for systematic integrated measurements, where interagency and international cooperation could bring major advances. Chapter 12 in the plan is the appropriate place to describe how the necessary integration and expansion will be developed. For example, more specific criteria could be provided for strategically selecting observation sites and the correct mix of space-based and *in situ* measurements.

Another way that the section on observations could be strengthened would be to explicitly address the large investment in satellite observations. A longstanding criticism of the GCRP has been that it is too heavily biased toward space-based observations (e.g., NRC, 1999b). The most recent edition of *Our Changing Planet* (GCRP, 2002) indicates that approximately half of the GCRP budget is devoted to space-based observations. The lists of observational challenges and priorities in Chapter 12 seem reasonably balanced, but it is difficult for the committee to conduct an evaluation of this balance without detailed budget information. The committee believes that the strategic plan is an appropriate vehicle for describing the rationale for the expensive investment in satellite observations.

For Theme 2 the strategic plan lists two objectives: the first is described as a "research activity" and the second as a "quasi-operational" activity to provide a "sustained and timely delivery of model products that are required for

assessment and other needs" (CCSP, 2002, p. 139). Both are described only in general terms. Unlike the other sections of this chapter this section has no section devoted to "The Road Forward," "Research Needs," or "Products and Payoffs." This general discussion does not address the fact that these two activities require the same community of modelers to apply and develop their models to meet quite different objectives. Without clear priorities or even well-defined "Products and Payoffs" there is no clear pathway for implementation.

This general treatment of modeling sidesteps entirely the significant challenges associated with transitioning the current efforts at the National Center for Atmospheric Research (NCAR) and the Geophysical Fluid Dynamics Laboratory (GFDL) into an effective applied modeling program, while maintaining cutting-edge research programs (see also the discussion of Applied Climate Modeling in Part II of this report). "Maintaining collaborations with perhaps hundreds of external contributors" is an appropriate but very difficult objective. Chapter 12 needs to provide more details about how the NCAR-GFDL partnership will be directed (i.e., will its focus be on conducting IPCC projections; facilitating the transition of research results into operational code; refining projections so as to reduce uncertainties in climate sensitivity; preparing model projections for local, regional, and national decision makers; or some combination of these?). It is unrealistic to expect the current modeling community to be able to make substantial near-term progress on all of these fronts.

For Theme 3 the objectives are quite diffuse and address only a portion of the challenges of this activity.

Are expected results and deliverables realistic given the available resources?

As with most of the other chapters in this report an answer to this question is made difficult by the lengthy lists of results and deliverables, limited timelines, and the lack of information on available resources.

For Theme 1 a major increase in routine, opportunistic monitoring is required to inform models and interested stakeholders about the state of the Earth system (e.g., in space, on land, in the oceans). Long-term routine observation programs are particularly appropriate. These challenges can be met, but will require substantial funding and ongoing commitment.

For Theme 2 a large barrier to improved modeling, especially modeling that addresses regional and smaller scales, is supercomputing capacity. Addressing the substantial shortcoming in current computational power will require a significant commitment of funds, but the neither the plan or the most recent edition of *Our Changing Planet* (GCRP, 2003) indicate that such a commitment is forthcoming. In addition, producing the full suite of model products identified in the plan would require the efforts of large numbers of highly qualified personnel. Indeed, it is unrealistic to expect the existing community of climate modelers to accomplish all the relevant objectives listed in Chapter 6 (repeated in Chapter 12) and also to build substantial new applied climate modeling capabilities. As described in Part I of this report the plan does not address the significant capacity building that will be necessary to recruit, train, and retain a much increased community of climate modelers.

For Theme 3 the generation and maintenance of integrated datasets is extremely important, difficult to accomplish, and historically under funded. It will take a major long-term commitment to achieve the "seamless access to information" expressed in the CCSP.

CHAPTER 13: "REPORTING AND OUTREACH"

This chapter is organized around four themes: (1) inventory of existing agency activities; (2) reporting and outreach for decision makers; (3) reporting and outreach for the public; and (4) outreach for K-12 education.

General Comments

Effective outreach and reporting are pivotal to the success of the CCSP. The program cannot fulfill its mission of enabling the nation to address and evaluate global and climate change risks and opportunities without effective means of sharing information, reporting results, and engaging stakeholders. Chapter 13 of the draft strategic plan discusses critical reporting and outreach needs and mechanisms. Chapter 13 also addresses the promotion of public discourse and the use of decision support resources in establishing and choosing policy options. Its most glaring shortfall is the adoption of an outmoded, one-way, top-down mode of interacting with decision makers and other stakeholders.

The chapter defines two general stakeholder groups with complementary, but disparate needs, the first stakeholder group includes policy makers, resource managers, the scientific community, nongovernmental organizations (NGOs), and the international community, the second stakeholder group includes those involved in education of the general public, school children, the media, and educators. The specific information needs of each group and the mechanisms for incorporating their input into policy at all levels of government are not addressed.

The chapter summarizes very generally current federal agency reporting and outreach activities and commits the CCSP to specific activities for enhanced interagency coordination for decision makers, the public, and K-12 education. The chapter successfully identifies current problem areas and makes useful suggestions for correcting them. It falls short, however, when it fails to assign responsibility, establish time frames, and delineate budget and funding means. The recommendations for action, while

important, are so broad and lack prioritization; it will be very difficult to accomplish all or even a few of them. The chapter should better identify which recommendations are the highest priorities and who has responsibility for ensuring that they occur according to a specified time frame. The revised plan should also specify a time frame by which the CCSP develops a communication and outreach strategic plan that incorporates these elements.

Specific Issues

Theme 1 (inventory of existing agency activities) highlights a major problem with the myriad climate change research communication processes in the agencies. No current inventory of all federal government outreach activities exists. No interagency working group has been identified to specifically address outreach or to develop a plan that will maximize limited resources and assure much needed cooperation and coordination. Although the program assigns this vital responsibility to the CCSP, it needs to delineate more clearly what part of that institution will assume this responsibility, how it will be staffed and funded, and how it will ensure its goals are met. For example, the plan could call for reporting on a specified frequency (e.g., quarterly or annually) to the CCSP by all federal agencies listed in the plan. In addition, the plan could call for a mechanism to plan for and coordinate releases of research results and public announcements. To ensure that these coordination efforts are given appropriate emphasis, oversight of outreach and communication must be assigned to the upper echelons of the various agencies. Without senior management attention it is clear from the draft plan that competing resource needs and individual agency priorities will overwhelm the need for coordination.

Much of the chapter is focused on reporting after the fact rather than during the development of plans and research projects. Although it is clear from the text that the CCSP realizes the importance of engaging stakeholders in the preparation and review of long-term strategic plans, Chapter 13 needs to explicitly state that interested stakeholders should be included throughout the research planning, execution, and results review process. Guidance could be developed for inclusion of stakeholders at appropriate junctures in the process.

Although two general stakeholder groups are identified in Chapter 13, they include many subgroups with different needs and for whom different outreach approaches are appropriate. The outreach and communication plan must clearly identify stakeholders and the individual stakeholder's needs. In doing so the strategic plan should build upon prior efforts, such as the U.S. National Assessment (NAST, 2001). In addition, the revised plan could include a program to develop and incorporate an evaluation process to assess the success of these outreach efforts.

Theme 2 (reporting and outreach for decision makers) overlooks many decision makers in the section on "National Policymakers and the International Community." This section is focused on the international community and Congress without sufficient emphasis on other decision makers and staff in the Executive Branch. Without diminishing the importance of providing information to Congress and the international community, the plan's recommendations could be broadened to include briefings or other mechanisms for information sharing with agency officials. The recommendation to "provide information and briefings to international partners," (CCSP, 2002, p. 151) could be amended to include a specification of what partners, when, and by whom. This section generally suffers from lack of detail that will make it difficult to implement the recommendations.

For Theme 2 the section on "Local/Regional Governments, Businesses and NGO's" and the plan as whole, lacks recommendations for working with state decision makers. Given the increasing importance of regional issues, identified repeatedly at the December planning workshop, this document does not adequately acknowledge the participation of state officials, including governors, state assemblies, commissioners of state, departments of natural resources and environmental protection agencies, state agriculture secretaries, and state energy and transportation directors. The plan could provide more information on relationships with states. The CCSP could also consider working with the national associations that represent these entities, such as Environmental Council of the States, the National Governors Association, and the Association of State Highway and Transportation Officials.

This section could better acknowledge the importance of seasonal and interannual forecasts for outreach, education, and decision support. These forecasts often address regional issues of importance to decision makers and resource managers. The preliminary success of the El Niño-Southern Oscillation forecasts demonstrates the educational and decisional value of such announcements. Participants at the December planning workshop called for more emphasis on regional variability issues and regional climate change research. Such emphasis brings climate change issues down to a local scale with demonstrable impacts on specific populations. Therefore, regional outreach and communication should be a significant component of the plan. Such regional emphases also provide a valuable link between Congress and its constituents.

Inclusion of business and NGOs in the communication process needs to be better described in the plan. Implementation of many of the technologies identified in the Climate Change Technology Program will come from the business sector. Their needs could be better considered in this section. NGOs can be severely hampered by limited budgets, and recognition of this impediment and development of effective means of including them, could be

addressed. The recommendation to "facilitate regional identification of key stakeholders through regional workshops, regional integrated research and regional briefings" (CCSP, 2002, p. 151) lacks important details: What does this mean? How will this be done? By whom? After identifying the need to work with specific types of stakeholders, an appropriate next step would be evaluating whether to build on existing or past regional stakeholder networks (e.g., those created by the National Assessment), as well as evaluating whether the resources exist to maintain the relationships once established.

Theme 3 (reporting and outreach to the public) asserts that the public is the most important audience for the communication of reliable global change information. The section correctly asserts the value of informing key constituents about the importance of science's role in decision making. It suggests that CCSP and the federal agencies consider briefings for the general public through mechanisms like town meetings. Other mechanisms such as television programs, radio spots, and newspapers articles may be more effective in reaching a large community unless there is specific research or targeted regional research of particular relevance to a particular public. Participation by informed researchers or agency officials at specific forums, such as those sponsored by chambers of commerce, environmental groups, or others, may be another effective means of conveying information and engaging the community in a dialogue. There has been considerable progress in developing techniques for engaging members of the public in analytic deliberation processes over public policy issues, but these new techniques are not included in the plan. This section also discusses the need for a centralized, Internet-based clearinghouse of reliable information about global climate science. The committee concurs that such a clearinghouse would be useful to all stakeholders, but notes that the plan fails to specify the responsible authority, provide a timeline, or allocate a budget to this important need.

Theme 4 (outreach for K-12 education) summarizes some of the ongoing and valuable educational initiatives already underway, including the Climate Change Partnership Education Program. It further states that a greater emphasis on the quality of curricula and instruction is necessary, both for general studies and as relates to climate change. Although the recommendations generally seem consistent with the stated goals, there is clearly room for more imaginative and creative approaches. This chapter does not, however, address the needs of colleges and universities. It also misses the important role that university extension programs can plan in disseminating information and educating the public.

CHAPTER 14: "INTERNATIONAL RESEARCH AND COOPERATION"

This chapter is organized around six themes: (1) goals of international cooperation in climate science, (2) the international framework, (3) bilateral cooperation in climate change research and technology, (4) multilateral international cooperation in research and observation programs, (5) regional cooperation in global change research, and (6) U.S. plans and objectives for future international cooperation.

General Comments

The committee commends the CCSP for including a chapter on international research and cooperation, however this chapter does not fully convey a sense of what the CCSP will consider strategically important for strengthening international research and cooperation in global change. Chapter 14 does not describe how the CCSP plans to build upon existing international and national programs that have already begun to establish collaborations and partnerships. The Climate Variability and Predictability program (CLIVAR), a major international study under the World Climate Research Programme, is not mentioned in the chapter (though it is mentioned in Chapter 6 of the draft plan). The value of multi-national research networks has been demonstrated in several ongoing agency programs and in international organization. For example, research conducted under the GCRP during the last 10 years has shown considerable science leadership in international global change programs, particularly the International Geosphere-Biosphere Program (IGBP), the International Program on Human Dimensions of Global Environmental Change (IHDP), and the World Climate Research Program (WCRP). The draft plan therefore misses an opportunity to develop a strategy for improving international research networks, exchanges of knowledge, and joint assessments. On page 156 (CCSP, 2002) the strategic plan states that the main drivers for establishing cooperative research have been individual scientists identifying areas of opportunity and establishing international programs. This may be the best way to establish international cooperation, but it essentially abdicates any role for a central strategy in this area.

International cooperation is especially valuable for building better *in situ* calibration and validation of remote-sensed observations, for obtaining more globally distributed measurements, and for building synergy and reducing redundancy in the deployment of assets. The meteorological community offers an example of international collaboration, with assignment of regional responsibilities for making measurements and data-sharing protocols arranged at an intergovernmental level under the World Meteorological Organization. The climate community lacks a similar structure. The U.S. climate community has

not even identified which agency serves as the central contact for international partners on climate research issues, including coordinated observing arrays, intercalibration, capacity building, and data and product sharing.

International collaborations and interactions in the development of the science of climate and associated global changes is an essential component of the CCSP and where appropriate should be integrated into the substantive areas in the strategic plan (e.g., Chapters 8 and 11). Ideally, the information in these chapters would be linked to the CCSP framework for international research and cooperation in Chapter 14.

Specific Issues

Theme 1 (goals of international cooperation in climate science) lists several goals for international research. There are additional potential benefits to enhanced U.S. leadership in cooperative international research on global change, including

- shared international "ownership" of results and knowledge as a prerequisite for negotiation of shared solutions in the policy arena;
- capacity building in terms of educated stakeholders and strengthened institutions around the world;
- a much larger community of scientists trained and motivated to study the problems of global change;
- burden sharing on the costs and resources required for observation and study of global change; and
- access to broader observations across the globe for testing models and our understanding of global change.

The CCSP could enhance international cooperation by identifying clear research priorities, supporting projects in areas of the world that are critical for understanding climate change; and creating a managed approach to ensure maximum leverage of international efforts.

The revised strategic plan would be considerably improved if these potential benefits could be prioritized to a few important strategic objectives to be used by the CCSP to guide the development of international cooperation. By including this in the revised strategic plan CCSP could provide a strong signal concerning the importance of enhanced U.S. leadership in this area.

CHAPTER 15: "PROGRAM MANAGEMENT AND REVIEW"

Chapter 15 describes at a very general level the mechanisms and processes that have been established to manage the program in three broad areas: (1) scientific guidance, (2) interagency planning and implementation, and (3) program integration. The management structure includes the following major components

- a cabinet-level Committee on Climate Change Science and Technology Integration;
- an Interagency Working Group on Climate Change Science and Technology;
- an interagency Climate Change Science Program whose draft strategic plan is the subject of this report; and
- an interagency Climate Change Technology Program.

The chapter also describes at a very general level the processes that will be used to implement, evaluate, and guide the program (CCSP, 2002, p. 162-166) and calls for the development of a new mechanism to improve the integration of program elements.

General Comments

This basic management structure for the CCSP as described in Chapter 15 is sound and could provide a useful general framework for managing the program if implemented well. The details of the organizational structure and processes are not well developed in the draft plan, however. Successful coordination and integration of CCSP activities will require clearly delineated lines of authority, requisite accountability by participating agencies, and appropriate staffing and funding. As the implementing and coordinating body for this effort CCSP will require the ability to direct other agencies' efforts and hold them accountable for performance and coordination. The success of the CCSP also will require the support and oversight of the Committee on Climate Change Science and Technology Integration and the Interagency Working Group on Climate Change Science and Technology, as well as the continued guidance of independent advisory bodies. In the sections that follow, the committee provides general comments on the three main areas of program management covered in Chapter 15 (these topics are examined in more detail in Chapter 4 of Part I of this report). At the end of this section the committee offers some detailed comments on Chapter 15.

Chapter 15 describes the CCSP's plan to use scientific steering committees composed of outside experts to help plan specific program elements and to continue to receive advice and review from appropriate NRC committees and boards (CCSP, 2002, p. 163-164). Chapter 15 does not describe a similar advisory process for the program as a whole, however. The committee believes that the most difficult of the research management challenges will occur at the level of the CCSP program itself. Thus there will be a need for scientific and other stakeholder guidance at the level of the program to ensure that clear priorities are established and communicated, that progress towards meeting the subsequent goals can be evaluated, and that the inevitable tradeoffs in resources and allocation of time can be done with an eye toward meeting the most important of the overall program goals. Otherwise there will be a tendency for the individual needs and priorities of the

agencies to take precedence over the needs of the entire program.

Chapter 15 provides a very general overview of how the program will coordinate the efforts of the 13 agencies involved in the CCSP. The CCSP itself is responsible for interagency coordination at the program level, and interagency committees of program managers for each major research element are responsible for interagency coordination and implementation at the program element level. The Interagency Working Group on Climate Change and Technology is responsible for high-level funding and program decisions. This basic management structure is sound and should provide a useful general framework for coordination among agencies. The plan does not describe the specific responsibilities and authorities of contributing departments and agencies, such as which agencies will be responsible for implementing the work. This is of particular concern for new areas of research that have not been supported by the GCRP in the past, such as land use and cover and decision support, and for crosscutting research areas, such as ecosystems, water cycle, role of the ocean, human dimensions, and international activities. The draft plan does not make clear how agency responsibilities are defined or whether there is a central point of contact within the GCRP when interfaces to the international community, such as in observing global atmospheric and oceanic variability and change, are essential. The draft plan also does not describe a mechanism that could be used to foster the participation of mission-oriented agencies in the strategic planning process.

The draft strategic plan does not describe a mechanism for coordinating and integrating the activities supported by the GCRP with the needs of the CCRI. A more integrated strategic plan would reflect more consistency between the priorities of the GCRP and the short-term activities described in the CCRI parts of the plan. The program therefore must fill a major gap in the organizational structure to bring people together as needed to enable the transition of research results into operations and decision making. The draft plan also does not describe mechanisms to carry out and integrate research that are not central to the core missions of any participating agency, although it recognizes a need for such mechanisms.[3]

Specific Issues

The introductory section of Chapter 15 begins with a very brief description of the CCSP management structure. In general the descriptions do not adequately describe the roles, responsibilities, and relationships among the various organizational elements. The addition of an organizational chart would improve the chapter considerably.

The chapter does not clearly describe how the CCSP relates to the CCRI and the GCRP, or how the CCRI and the GCRP relate to each other.

The description of the Interagency Working Group on Climate Change Science and Technology does not identify the lead agency for this group.

The description of the Climate Change Science Program indicates that its membership consists of "representatives from all agencies that have a research mission in climate and global change," but does not indicate the level of responsibility of its members. As noted in Chapter 3 the committee recommends broader participation in the CCSP by agencies that are likely to be users of knowledge generated by the research programs and/or that work directly with decision makers and can therefore help identify decision makers' information needs.

The Climate Change Technology Program (CCTP) is mentioned in the plan, but its responsibilities, organization, and status relative to the CCSP are not described. In order for the CCSP and the CCTP to complement and enhance each other, the links of CCTP to CCSP need to be better identified (see discussion in Chapter 4 of Part I of this report).

The section of Chapter 15 on "CCSP Integration" states that "agreed-upon" criteria in certain areas will be used to determine the program's priorities. The section does not list these criteria or describe who will be involved in developing these criteria.

The section of Chapter 15 on "CCSP Integration" correctly recognizes that there will need to be a process for addressing functions that are not within the scope of any of the existing participating agencies. The section does not provide an indication of how that process will be developed, when it will be developed, or who will develop it, however.

[3] "One necessary approach for addressing such integrating activities is to develop a mechanism that allows functions that are not central to the core missions of the participating agencies, but that are highly relevant, to be fostered" (CCSP, 2002, p. 165).

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Appendixes

Appendix A

Acronyms

CCSP	U.S. Climate Change Science Program
CCRI	Climate Change Research Initiative
CCTP	Climate Change Technology Program
CENR	Committee on Environment and Natural Resources
CEQ	Council on Environmental Quality
CGCR	Committee on Global Change Research (NRC)
CLIVAR	International Climate Variability and Prediction Project
CPT	Climate Process [Modeling and Science] Teams
DMS	Oceanic Dimethylsulfide
DOC	Department of Commerce
DOE	U.S. Department of Energy
DOD	U.S. Department of Defense
DOI	U.S. Department of the Interior
DOS	U.S. Department of State
DOT	U.S. Department of Transportation
DPC	Domestic Policy Council
ENSO	El Niño-Southern Oscillation
EPA	U.S. Environmental Protection Agency
ESSC	Earth System Sciences Committee (NASA)
GCRP	U.S. Global Change Research Program
GFDL	Geophysical Fluids Dynamic Laboratory
HHS	U.S. Department of Health and Human Services
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Programme on Global Environmental Change
IPCC	Intergovernmental Panel on Climate Change
NACIP	National Aerosol-Climate Interactions Program
NACP	North American Carbon Program
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NEC	National Economic Council
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting
NRC	National Research Council
NSC	National Safety Council
NSF	National Science Foundation
OMB	Office of Management and Budget
OSTB	Office of Science and Technology Policy
SGCR	Subcommittee on Global Change Research
UNEP	United Nations Environment Programme
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

UV	Ultraviolet
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

Appendix B

Committee and Staff Biographies

Dr. Thomas E. Graedel (*Chair*) is a professor of industrial ecology at Yale University. He earned his Ph.D. in astrophysics in 1969 from the University of Michigan. His research interests include chemistry and physics of atmospheric gases and aerosols; effects of atmospheric contaminants on materials and electrical and mechanical equipment; and environmentally responsible industrial product and process design. His most recent research focuses on studies of the stocks and flows of materials in the industrialized society, especially in very large cities and in environmentally sensitive regions. This work explores aspects of resource availability, potential environmental impacts, opportunities for recycling and reuse, and resources policy initiatives. Dr. Graedel is a member of the NRC Committee on Material Flows Accounting of Natural Resources, Products, and Residuals and is a member of the National Academy of Engineering.

Dr. Linda Capuano is vice president of strategic marketing and business development for Honeywell Engines & Systems, a $5 billion aerospace business that provides propulsion engines, auxiliary power units, environmental control systems, engine controls and accessories, as well as electrical power. She is responsible for strategic planning, e-business, and mergers and acquisitions. Joining AlliedSignal in 1995, Dr. Capuano was the general manager of commercial air transport auxiliary power unit products. Previously, she was the vice president of operations and business development and part of the founding team of Conductus, a telecommunications superconductive electronics business in Sunnyvale, California. Dr. Capuano has also held product management positions in magnetic memory recording at IBM. She served on the Department of Energy Task Force on Alternative Futures for the DOE National Laboratories and chair of the National Research Council's Board on Assessment of NIST Programs. Dr. Capuano holds a B.S. in chemistry from State University of New York at Stony Brook, a B.S. in chemical engineering and an M.S. in chemistry from the University of Colorado, and an M.S. in engineering management and Ph.D. in materials science from Stanford University.

Dr. Elizabeth Chornesky is a freelance analyst and research associate at the University of California, Santa Cruz. For more than a decade, she has worked on integrating science into policies and practices related to the conservation of biological diversity and management of biological resources. Previously, as director of stewardship and then director conservation research at The Nature Conservancy, Dr. Chornesky oversaw the organization’s multi-million dollar research programs and led teams of extension scientists specializing in ecological management, monitoring, and restoration. Prior to that, she was a project director and analyst at the U.S. Congress Office of Technology Assessment working on national assessments related to invasive species and pesticide alternatives. Her early career was as a research scientist in marine ecology and systematics at the Smithsonian Institution and Lehigh University. Dr. Chornesky has consulted for the National Commission on Science for Sustainable Forestry, the Union of Concerned Scientists, and the Wallace Institute for Alternative Agriculture. She also serves on several national committees, most recently, a visioning initiative of the Ecological Society of America’s Governing Board and the NRC Committee on Opportunities in Agriculture. Dr. Chornesky holds a B.A. from Cornell University and a Ph.D. from the University of Texas at Austin.

Ms. Mary A. Gade is a partner in the environmental practice group in the law firm of Sonnenschein Nath & Rosenthal in Chicago, Illinois, where her work includes litigation, regulatory affairs, and compliance counseling. Before joining the firm, Ms. Gade was director of the Illinois Environmental Protection Agency from 1991 to 1999. She supervised a staff of approximately 1,400, which enforced the environmental laws and regulations of the state, conducted hazardous waste cleanups, responded to environmental emergencies, maintained environmental laboratories, provided financial assistance to local governments for pollution control facilities, and encouraged and supported pollution prevention programs. She received her law degree in 1977 from Washington University School of Law in St. Louis, Missouri, and her undergraduate degree in

environmental studies and Italian from the University of Wisconsin-Madison. She has been a fellow of the National Academy of Public Administration since 1996.

Ms. Katharine L. Jacobs is currently the special assistant for policy and planning for the Arizona Department of Water Resources (ADWR). She was the director of the Tucson Active Management Area of the ADWR from 1988 through 2001. Ms. Jacobs earned her M.L.A. in environmental planning from the University of California, Berkeley. Her expertise is in groundwater management and developing practical, appropriate solutions to difficult public policy issues. She has worked in many capacities for ADWR since 1981, verifying groundwater rights, developing mandatory conservation and enforcement programs, writing statewide rules requiring the use of renewable water supplies in new subdivisions, and working within the Tucson community building consensus solutions to serious water policy conflicts. She has facilitated development of groundwater recharge facilities and regional recharge policy. She served on the NRC's Committee on Assessing the Future Value of Ground Water, the Synthesis Team for the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, and has authored a number of publications on water management subjects.

Dr. Anthony C. Janetos is a senior research fellow at the H. John Heinz III Center for Science, Economics, and the Environment. Dr. Janetos earned his Ph.D. in biology from Princeton University. In 1999 he joined the World Resources Institute as senior vice president and chief of program. Previously he served as senior scientist for the Land-Cover and Land-Use Change Program in NASA's Office of Earth Science, and was program scientist for the *Landsat* 7 mission. He has many years of experience in managing scientific research programs on a variety of ecological and environmental topics, including air pollution effects on forests, climate change impacts, land-use change, ecosystem modeling, and the global carbon cycle. He was a cochair of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, and was an author of the IPCC Special Report on Land-Use Change and Forestry and the Global Biodiversity Assessment. Dr. Janetos recently served on the NRC Committee on Review of Scientific Research Programs at the Smithsonian Institution.

Dr. Charles D. Kolstad is currently the 3M Visiting Professor of Environmental Economics in the Department of Economics at Massachusetts Institute of Technology. Dr. Kolstad is also the Donald Bren Distinguished Professor of Environmental Economics and Policy at the University of California, Santa Barbara, where he is jointly appointed in the Department of Economics and the Bren School of Environmental Science and Management. For the decade prior to joining UCSB in 1993 he was on the faculty of the University of Illinois, Urbana-Champaign. He has been a visiting professor at MIT, Stanford, the Catholic University of Leuven (Belgium) and the New Economic School (Moscow). He received his Ph.D. from Stanford University (1982), his M.A. from the University of Rochester and his B.S. from Bates College. His research interests have been in the area of regulation, particularly environmental regulation. Recently he has also done work on environmental valuation theory in the role of information in environmental decision making and regulation, and the role of uncertainty and learning in controlling the precursors of climate change. His past work in energy markets has focused on coal and electricity markets, including the effect of air pollution regulation on these markets. Dr. Kolstad has served on several NRC committees, including the Committee on Building a Long-Term Environmental Quality Research and Development Program in the U.S. Department of Energy and the Board on Energy and Environmental Systems.

Dr. Diana M. Liverman is director of the Center for Latin American Studies, professor of geography and regional development, and a member of the Executive Committee of the Institute for the Study of Planet Earth (ISPE) at the University of Arizona. Dr. Liverman's research examines the social causes and consequences of environmental change, especially in Latin America. She is currently working on the impacts of climate variability and change on agriculture and water resources, and on the anthropogenic causes of changes in land use and land cover, both with a regional focus on Mexico. She
also studies environmental policy relating to the U.S.-Mexico border, the functioning of transnational research institutions, such as the Inter-American Institute for Global Change Research, and she is associated with UA-ISPE's Climate Assessment for the Southwest. Dr. Liverman received her Ph.D. from University of California, Los Angeles.

Dr. Jerry D. Mahlman is a senior research fellow at the national center for atmospheric research (NCAR) in Boulder, Colorado. He was director of the Geophysical Fluid Dynamics Laboratory at the National Oceanic and Atmospheric Administration in Princeton, New Jersey for 16 years before his retirement in 2000. He was also a professor of atmospheric and oceanic sciences at Princeton University for 28 years. Much of Dr. Mahlman's research career has been directed toward understanding the behavior of the stratosphere and troposphere. This has involved extensive mathematical modeling and diagnosis of the interactive chemical, radiative, dynamical, and transport aspects of the atmosphere, as well as their implications for climate and chemical change. Over the past decade he has occupied a central role in the interpretation of

climate change to policy makers and affected communities. Dr. Mahlman has served on numerous committees and boards, including the NASA Advisory Council and the Board on Sustainable Development of the National Research Council. In 1994 he received the prestigious Carl-Gustaf Rossby Research Medal from the American Meteorological Society and the Presidential Distinguished Rank Award, the highest honor awarded to a federal employee. He received his Ph.D. from Colorado State University.

Dr. Diane McKnight is professor of civil, environmental and architectural engineering at the University of Colorado. Her research focuses on interactions between hydrologic, chemical, and biological processes in controlling the dynamics in aquatic ecosystems. This research is carried out through field-scale experiments, modeling, and laboratory characterization of natural substrates. In addition, Dr. McKnight conducts research focusing on interactions between freshwater biota, trace metals, and natural organic material in diverse freshwater environments, including lakes and streams in the Colorado Rocky Mountains and in the McMurdo dry valleys in Antarctica. She also develops interactions with state and local groups involved in mine drainage and watershed issues in the Rocky Mountains. Dr. McKnight is a member of the NRC's Water Science and Technology Board and is a former member of the Polar Research Board. She received her Ph.D. in environmental engineering from the Massachusetts Institute of Technology.

Dr. Michael J. Prather is professor and Kavli Chair in the Earth System Science Department at the University of California, Irvine. He received his Ph.D. in astronomy from Yale University. His research interests include the simulation of the physical, chemical, and biological processes that determine atmospheric composition and the development of (1) detailed numerical models of photochemistry and atmospheric radiation, and (2) global chemical transport models that describe ozone and other trace gases. Dr. Prather has played a significant role in the IPCC second and third assessments and special report on aviation, and in the World Meteorological Organization's Ozone Assessments (1985-1994). He is a fellow of the American Geophysical Union and a foreign member of the Norwegian Academy of Science and Letters, and has served on several NRC committees, including the Panel on Climate Variability on Decade-to-Century Time Scales.

Dr. Eugene Rosa is professor of sociology and the Edward R. Meyer Distinguished Professor of Natural Resource and Environmental Policy in the Thomas S. Foley Institute for Public Policy and Public Service at Washington State University. Dr. Rosa also serves on the Advisory Board of the CIVICS (Consultative Institutions: Values and Information in a Changing Society) Network of the European Union. Dr. Rosa's research program has focused on environmental topics, particularly energy, technology, and risk issues, with attention to both theoretical and policy concerns. He has investigated the relationship between levels of energy consumption and societal well-being, public opinion about energy problems and policies, factors affecting the adoption of solar technologies and conservation practices, and public attitudes toward and acceptance of nuclear power and nuclear policies. Most recently his research is focused on two complementary topics: technological risk and global environmental change. His principal research activities associated with global change are devoted to specifying the anthropogenic causes of carbon dioxide loads and of ecological footprints, to the historical relationships between greenhouse gases and societal well-being, to the history of social thought on climate, and to testing theories of environmental impact. Dr. Rosa received his Ph.D. in social science from the Maxwell Graduate School of Syracuse University and completed postdoctoral work at Stanford University.

Dr. William H. Schlesinger is James B. Duke Professor of Biogeochemistry and dean of the Nicholas School of the Environment and Earth Sciences at Duke University. After completing his A.B. at Dartmouth (1972) and Ph.D. at Cornell (1976), he joined the faculty at Duke in 1980. He is the author or coauthor of over 150 scientific papers and the widely adopted textbook *Biogeochemistry: An Analysis of Global Change* (Academic Press, 2nd ed., 1997). He was elected a member of the American Academy of Arts and Sciences in 1995. Currently Dr. Schlesinger focuses his research on global change ecology. He is the co-principal investigator for the Free Air Carbon Dioxide Enrichment (FACE) Experiment in the Duke Forest, a project that aims to understand how an entire forest ecosystem (vegetation and soils) will respond to growth in elevated CO_2. He has also worked extensively in desert ecosystems and their response to global change. From 1991 to 2000 he served as principal investigator for the NSF-sponsored program of Long Term Ecological Research (LTER) at the Jornada Basin in southern New Mexico. His past work has taken him to diverse habitats, ranging from Okefenokee Swamp in southern Georgia to the Mojave Desert of California. His research has been featured on NOVA, CNN, NPR, and on the pages of *Discover*, *National Geographic*, *The New York Times*, and *Scientific American*. Schlesinger has testified before U.S. House and Senate Committees on a variety of environmental issues, including preservation of desert habitats and global climate change. He is a member of the Committee on Research and Exploration for the National Geographic Society. Schlesinger has been elected president of the Ecological Society of America for 2003-2004.

Dr. David L. Skole is professor of geography and director of the Center for Global Change and Earth Observations at Michigan State University. He received a Ph.D. in natural resources from the University of New Hampshire His research interests are on the role of land-use and land-cover change and its relation to global change and sustainable development. Much of his work involves remote sensing at continental scales in the tropical and temperate zones, including assessments of the rates and geographic patterns of tropical forest conversion and fragmentation. His research incorporates geographical information and geospatial information technologies in numerical models of natural and managed landscape change and its effect on biodiversity and biogeochemistry. Dr. Skole is past chair of the IGBP-IHDP Core Project on Land Use and Cover Change. He currently serves as chair of the Forest Cover Characteristics and Changes Implementation team of the United Nations Global Terrestrial Observing System program on Global Observations of Land Cover Dynamics, and has served on several advisory committees at federal agencies and the aerospace and geographic information system industries in the United States. Dr. Skole is currently chair of the U.S. National Science Foundation Advisory Committee on Environmental Research and Education and a member of NASA's *Landsat* 7 science team.

Dr. Andrew R. Solow is an associate scientist and director of the Marine Policy Center at Woods Hole Oceanographic Institution. His research interests include environmental and ecological statistics, time series analysis, spatial statistics, and applied Bayesian methods. His recent work has focused on population modeling with an emphasis on capturing the population effects of environmental variability. Dr. Solow is a former member of the NRC's Commission on Geosciences, Environment, and Resources and the Committee on Fifty Years of Ocean Discovery at the National Science Foundation. Dr. Solow earned his Ph.D. in geostatistics from Stanford University.

Dr. Robert A. Weller received his Ph.D. in 1978 from Scripps Institution of Oceanography. He is the director of the Cooperative Institute for Climate and Ocean Research at Woods Hole Oceanographic Institution; he has worked at WHOI since 1979. His research is on atmospheric forcing (wind stress and buoyancy flux), surface waves on the upper ocean, prediction of upper ocean variability, and the ocean's role in climate. He serves as the Secretary of the Navy Chair in Oceanography. He has been on multiple mooring deployment cruises and has practical experience with ocean observation instruments. Dr. Weller is currently serving on the NRC Committee on Utilization of Environmental Satellite Data: A Vision for 2010 and Beyond and the NRC Committee on Implementation of a Seafloor Observatory Network for Oceanographic Research.

Dr. Steve Wittrig is director of the Clean Energy: Facing the Future Program for BP, a program to invest $10 million in Chinese universities to develop and prove clean energy technologies for China and the rest of the world.He worked on the BP/Amoco merger, considering gas-to-liquids strategy and chemical technology strategy and implementation; and on special assignments for Amoco including leading the strategy development team for a program to convert gas to liquids and oxygenates. In prior assignments with Amoco, he managed the engineering and process evaluation group for new product development in chemicals; led a team developing new reactor technology for methane conversion to syngas; and worked with Amoco Oil on coal liquefaction, refinery research, and pollution control. He has a B.S. from the University of Illinois, Urbana, and a Ph.D. in chemical engineering from the California Institute of Technology.

National Research Council Staff

Dr. Gregory H. Symmes serves as associate executive director of the Division on Earth and Life Studies (DELS) of the National Academies, where he is responsible for managing the review of over 70 reports each year and coordinating the National Academies' global change activities, among other management duties. Prior to the formation of DELS in January 2001, he served as associate executive director of the National Academies' Commission on Geosciences, Environment, and Resources. In addition to his division-level management responsibilities, Dr. Symmes has directed National Academies' studies in the following areas of science policy: peer review processes and science and technology needs for the Department of Energy's radioactive waste management efforts; regulation of hardrock mining on federal lands; and competitive research within the U.S. Department of Agriculture. Before joining the NRC in 1995, Dr. Symmes served as a research assistant professor and postdoctoral associate in the Department of Earth and Space Sciences at the State University of New York at Stony Brook. He received his Ph.D. in geology from the Johns Hopkins University and his B.A. summa cum laude in geology from Amherst College.

Dr. Amanda Staudt is a program officer with the Board on Atmospheric Sciences and Climate of the National Academies. She received an A.B. in environmental engineering and sciences and a Ph.D. in atmospheric sciences from Harvard University. Her doctorate research involved developing a global three-dimensional chemical transport model to investigate

how long-range transport of continental pollutants affects the chemical composition of the remote tropical Pacific troposphere. Since joining the National Academies in 2001, Dr. Staudt has worked on studies addressing air quality management in the United States, research priorities for airborne particulate matter, the *NARSTO Assessment of the Atmospheric Science on Particulate Matter*, carbon monoxide episodes in meteorological and topographical problem areas, and weather forecasting for aviation traffic flow management. She also is the study director for the long-standing Climate Research Committee.

Ms. Kristen L. Krapf is a program officer with the National Academies' Board on Earth Sciences and Resources. She received her B.A. and M.S. degrees in environmental sciences from the University of Virginia. Prior to joining the National Academies, she was director of programs at the Renewable Natural Resources Foundation (RNRF) in Bethesda, Maryland. She provided staff support for several interdisciplinary and multidisciplinary programs that assessed renewable natural resources requirements and formulated public policy alternatives. She also edited RNRF's *Renewable Resources Journal*. While at the National Academies, Ms. Krapf has worked on studies involving new technologies in geographical information systems, coal waste impoundments, and geographical information for sustainable development in Africa. She is also the study director for the National Academies' Committee on Geography. She is a member of the Ecological Society of America and the Association of American Geographers.

Appendix C

Global Change Research Act of 1990

Public Law 101-606 [S. 169]; November 16, 1990
104 Stat. 3096-3104

An Act to require the establishment of a United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Global Change Research Act of 1990".

SECTION 2. DEFINITIONS.

As used in this Act, the term--

1. "Committee" means the Committee on Earth and Environmental Sciences established under section 102;

2. "Council" means the Federal Coordinating Council on Science, Engineering, and Technology;

3. "Global change" means 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;

4. "Global change research" means study, monitoring, assessment, prediction, and information management activities to describe and understand--

   A. The interactive physical, chemical, and biological processes that regulate the total Earth system;
   B. The unique environment that the Earth provides for life;
   C. Changes that are occurring in the Earth system; and
   D. The manner in which such system, environment, and changes are influenced by human actions;

5. "Plan" means the National Global Change Research Plan developed under section 104, or any revision thereof; and

6. "Program" means the United States Global Change Research Program established under section 103.

TITLE I--UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM

SEC. 101. FINDINGS AND PURPOSE.

(a) FINDINGS--The Congress makes the following findings:

1. Industrial, agricultural, and other human activities, coupled with an expanding world population, are contributing to processes of global change that may significantly alter the Earth habitat within a few human generations.

2. Such human-induced changes, in conjunction with natural fluctuations, may lead to significant global warming and thus alter world climate patterns and increase global sea levels. Over the next century, these consequences could

adversely affect world agricultural and marine production, coastal habitability, biological diversity, human health, and global economic and social well-being.

3. The release of chlorofluorocarbons and other stratospheric ozone-depleting substances is rapidly reducing the ability of the atmosphere to screen out harmful ultraviolet radiation, which could adversely affect human health and ecological systems.

4. Development of effective policies to abate, mitigate, and cope with global change will rely on greatly improved scientific understanding of global environmental processes and on our ability to distinguish human-induced from natural global change.

5. New developments in interdisciplinary Earth sciences, global observing systems, and computing technology make possible significant advances in the scientific understanding and prediction of these global changes and their effects.

6. Although significant Federal global change research efforts are underway, an effective Federal research program will require efficient interagency coordination, and coordination with the research activities of State, private, and international entities.

(b) PURPOSE--The purpose of this title is to provide for development and coordination of a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.

SEC. 102. COMMITTEE ON EARTH AND ENVIRONMENTAL SCIENCES.

(a) ESTABLISHMENT--The President, through the Council, shall establish a Committee on Earth and Environmental Sciences. The Committee shall carry out Council functions under section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651) relating to global change research, for the purpose of increasing the overall effectiveness and productivity of Federal global change research efforts.
(b) MEMBERSHIP--The Committee shall consist of at least one representative from—

1. The National Science Foundation;
2. The National Aeronautics and Space Administration;
3. The National Oceanic and Atmospheric Administration of the Department of Commerce;
4. The Environmental Protection Agency;
5. The Department of Energy;
6. The Department of State;
7. The Department of Defense;
8. The Department of the Interior;
9. The Department of Agriculture;
10. The Department of Transportation;
11. The Office of Management and Budget;
12. The Office of Science and Technology Policy;
13. The Council on Environmental Quality;
14. The National Institute of Environmental Health Sciences of the National Institutes of Health; and
15. Such other agencies and departments of the United States as the President or the Chairman of the Council considers appropriate.

Such representatives shall be high-ranking officials of their agency or department, wherever possible the head of the portion of that agency or department that is most relevant to the purpose of the title described in section 101(b).
(c) CHAIRPERSON--The Chairman of the Council, in consultation with the Committee, biennially shall select one of the Committee members to serve as Chairperson. The Chairperson shall be knowledgeable and experienced with regard to the administration of scientific research programs, and shall be a representative of an agency that contributes substantially, in terms of scientific research capability and budget, to the Program.
(d) SUPPORT PERSONNEL--An Executive Secretary shall be appointed by the Chairperson of the Committee, with the approval of the Committee. The Executive Secretary shall be a permanent employee of one of the agencies or departments represented on the Committee, and shall remain in the employ of such agency or department. The Chairman of the Council shall have the authority to make personnel decisions regarding any employees detailed to the Council for purposes of

working on business of the Committee pursuant to section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651).
(e) FUNCTIONS RELATIVE TO GLOBAL CHANGE--The Council, through the Committee, shall be responsible for planning and coordinating the Program. In carrying out this responsibility, the Committee shall--

1. Serve as the forum for developing the Plan and for overseeing its implementation;

2. Improve cooperation among Federal agencies and departments with respect to global change research activities;

3. Provide budgetary advice as specified in section 105;

4. Work with academic, State, industry, and other groups conducting global change research, to provide for periodic public and peer review of the Program;

5. Cooperate with the Secretary of State in--

   (A) Providing representation at international meetings and conferences on global change research in which the United States participates; and
   (B) Coordinating the Federal activities of the United States with programs of other nations and with international global change research activities such as the International Geosphere-Biosphere Program.

6. Consult with actual and potential users of the results of the Program to ensure that such results are useful in developing national and international policy responses to global change; and

7. Report at least annually to the President and the Congress, through the Chairman of the Council, on Federal global change research priorities, policies, and programs.

SEC. 103. UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM.

The President shall establish an interagency United States Global Change Research Program to improve understanding of global change. The Program shall be implemented by the Plan developed under section 104.

SEC. 104. NATIONAL GLOBAL CHANGE RESEARCH PLAN.

(a) IN GENERAL--The Chairman of the Council, through the Committee, shall develop a National Global Change Research Plan for implementation of the Program. The Plan shall contain recommendations for national global change research. The Chairman of the Council shall submit the Plan to the Congress within one year after the date of enactment of this title, and a revised Plan shall be submitted at least once every three years thereafter.
(b) CONTENTS OF THE PLAN--The Plan shall--

1. Establish, for the 10-year period beginning in the year the Plan is submitted, the goals and priorities for Federal global change research which most effectively advance scientific understanding of global change and provide usable information on which to base policy decisions relating to global change;

2. Describe specific activities, including research activities, data collection and data analysis requirements, predictive modeling, participation in international research efforts, and information management, required to achieve such goals and priorities;

3. Identify and address, as appropriate, relevant programs and activities of the Federal agencies and departments represented on the Committee that contribute to the Program;

4. Set forth the role of each Federal agency and department in implementing the Plan;

5. Consider and utilize, as appropriate, reports and studies conducted by Federal agencies and departments, the National Research Council, or other entities;

6. Make recommendations for the coordination of the global change research activities of the United States with such activities of other nations and international organizations, including--

   (A) A description of the extent and nature of necessary international cooperation;

(B) The development by the Committee, in consultation when appropriate with the National Space Council, of proposals for cooperation on major capital projects;
(C) Bilateral and multilateral proposals for improving worldwide access to scientific data and information; and
(D) Methods for improving participation in international global change research by developing nations; and

7. Estimate, to the extent practicable, Federal funding for global change research activities to be conducted under the Plan.

(c) RESEARCH ELEMENTS--The Plan shall provide for, but not be limited to, the following research elements:

1. Global measurements, establishing worldwide observations necessary to understand the physical, chemical, and biological processes responsible for changes in the Earth system on all relevant spatial and time scales.

2. Documentation of global change, including the development of mechanisms for recording changes that will actually occur in the Earth system over the coming decades.

3. Studies of earlier changes in the Earth system, using evidence from the geological and fossil record.

4. Predictions, using quantitative models of the Earth system to identify and simulate global environmental processes and trends, and the regional implications of such processes and trends.

5. Focused research initiatives to understand the nature of and interaction among physical, chemical, biological, and social processes related to global change.

(d) INFORMATION MANAGEMENT--The Plan shall provide recommendations for collaboration within the Federal Government and among nations to--

1. Establish, develop, and maintain information bases, including necessary management systems which will promote consistent, efficient, and compatible transfer and use of data;

2. Create globally accessible formats for data collected by various international sources; and

3. Combine and interpret data from various sources to produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to the effects of global change.

(e) NATIONAL RESEARCH COUNCIL EVALUATION--The Chairman of the Council shall enter into an agreement with the National Research Council under which the National Research Council shall--

1. Evaluate the scientific content of the Plan; and

2. Provide information and advice obtained from United States and international sources, and recommended priorities for future global change research.

(f) PUBLIC PARTICIPATION--In developing the Plan, the Committee shall consult with academic, State, industry, and environmental groups and representatives. Not later than 90 days before the Chairman of the Council submits the Plan, or any revision thereof, to the Congress, a summary of the proposed Plan shall be published in the Federal Register for a public comment period of not less than 60 days.

SEC. 105. BUDGET COORDINATION.

(a) COMMITTEE GUIDANCE--The Committee shall each year provide general guidance to each Federal agency or department participating in the Program with respect to the preparation of requests for appropriations for activities related to the Program.
(b) SUBMISSION OF REPORTS WITH AGENCY APPROPRIATIONS REQUESTS--

1. Working in conjunction with the Committee, each Federal agency or department involved in global change research shall include with its annual request for appropriations submitted to the President under section 1108 of title 31, United States Code, a report which--

(A) Identifies each element of the proposed global change research activities of the agency or department;
(B) specifies whether each element (i) contributes directly to the Program or (ii) contributes indirectly but in important ways to the Program; and
(C) states the portion of its request for appropriations allocated to each element of the Program.

2. Each agency or department that submits a report under paragraph (1) shall submit such report simultaneously to the Committee.

(c) CONSIDERATION IN PRESIDENT'S BUDGET.--

1. The President shall, in a timely fashion, provide the Committee with an opportunity to review and comment on the budget estimate of each agency and department involved in global change research in the context of the Plan.

2. The President shall identify in each annual budget submitted to the Congress under section 1105 of title 31, United States Code, those items in each agency's or department's annual budget which are elements of the Program.

SEC. 106. SCIENTIFIC ASSESSMENT.

On a periodic basis (not less frequently than every 4 years), the Council, through the Committee, shall prepare and submit to the President and the Congress an assessment which--

1. integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;

2. analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and

3. analyzes current trends in global change, both human- induced and natural, and projects major trends for the subsequent 25 to 100 years.

SEC. 107. ANNUAL REPORT.

(a) GENERAL.--Each year at the time of submission to the Congress of the President's budget, the Chairman of the Council shall submit to the Congress a report on the activities conducted by the Committee pursuant to this title, including--

1. a summary of the achievements of the Program during the period covered by the report and of priorities for future global change research;

2. an analysis of the progress made toward achieving the goals of the Plan;

3. expenditures required by each agency or department for carrying out its portion of the Program, including--

   (A) the amounts spent during the fiscal year most recently ended;
   (B) the amounts expected to be spent during the current fiscal year; and
   (C) the amounts requested for the fiscal year for which the budget is being submitted.

(b) RECOMMENDATIONS.--The report required by subsection (b) shall include recommendations by the President concerning--

1. changes in agency or department roles needed to improve implementation of the Plan; and

2. additional legislation which may be required to achieve the purposes of this title.

SEC. 108. RELATION TO OTHER AUTHORITIES.

(a) NATIONAL CLIMATE PROGRAM RESEARCH ACTIVITIES.-- The President, the Chairman of the Council, and the Secretary of Commerce shall ensure that relevant research activities of the National Climate Program, established by the National Climate Program Act (15 U.S.C. 2901 et seq.), are considered in developing national global change research efforts.
(b) AVAILABILITY OF RESEARCH FINDINGS.--The President, the Chairman of the Council, and the heads of the agencies and departments represented on the Committee, shall ensure that the research findings of the Committee, and of Federal agencies and departments, are available to--

1. the Environmental Protection Agency for use in the formulation of a coordinated national policy on global climate change pursuant to section 1103 of the Global Climate Protection Act of 1987 (15 U.S.C. 2901 note); and

2. all Federal agencies and departments for use in the formulation of coordinated national policies for responding to human-induced and natural processes of global change pursuant to other statutory responsibilities and obligations.

(c) EFFECT ON FEDERAL RESPONSE ACTIONS.--Nothing in this title shall be construed, interpreted, or applied to preclude or delay the planning or implementation of any Federal action designed, in whole or in part, to address the threats of stratospheric ozone depletion or global climate change.

TITLE II--INTERNATIONAL COOPERATION IN GLOBAL CHANGE RESEARCH

SEC. 201. SHORT TITLE.

This title may be cited as the "International Cooperation in Global Change Research Act of 1990".

SEC. 202. FINDINGS AND PURPOSES.

(a) FINDINGS--The Congress makes the following findings:

1. Pooling of international resources and scientific capabilities will be essential to a successful international global change program.

2. While international scientific planning is already underway, there is currently no comprehensive intergovernmental mechanism for planning, coordinating, or implementing research to understand global change and to mitigate possible adverse effects.

3. An international global change research program will be important in building future consensus on methods for reducing global environmental degradation.

4. The United States, as a world leader in environmental and Earth sciences, should help provide leadership in developing and implementing an international global change research program.

(b) PURPOSES--The purposes of this title are to--

1. Promote international, intergovernmental cooperation on global change research;

2. involve scientists and policymakers from developing nations in such cooperative global change research programs; and

3. promote international efforts to provide technical and other assistance to developing nations which will facilitate improvements in their domestic standard of living while minimizing damage to the global or regional environment.

SEC. 203. INTERNATIONAL DISCUSSIONS.

(a) GLOBAL CHANGE RESEARCH.--The President should direct the Secretary of State, in cooperation with the Committee, to initiate discussions with other nations leading toward international protocols and other agreements to coordinate global change research activities. Such discussions should include the following issues:

1. Allocation of costs in global change research programs, especially with respect to major capital projects.

2. Coordination of global change research plans with those developed by international organizations such as the International Council on Scientific Unions, the World Meteorological Organization, and the United Nations Environment Program.

3. Establishment of global change research centers and training programs for scientists, especially those from developing nations.

4. Development of innovative methods for management of international global change research, including--

   (A) use of new or existing intergovernmental organizations for the coordination or funding of global change research; and
   (B) creation of a limited foundation for global change research.

5. The prompt establishment of international projects to--

   (A) create globally accessible formats for data collected by various international sources; and
   (B) combine and interpret data from various sources to produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to possible adverse effects of global change.

6. Establishment of international offices to disseminate information useful in identifying, preventing, mitigating, or adapting to the possible effects of global change.

(b) ENERGY RESEARCH.--The President should direct the Secretary of State (in cooperation with the Secretary of Energy, the Secretary of Commerce, the United States Trade Representative, and other appropriate members of the Committee) to initiate discussions with other nations leading toward an international research protocol for cooperation on the development of energy technologies which have minimally adverse effects on the environment. Such discussions should include, but not be limited to, the following issues:

1. Creation of an international cooperative program to fund research related to energy efficiency, solar and other renewable energy sources, and passively safe and diversion-resistant nuclear reactors.

2. Creation of an international cooperative program to develop low cost energy technologies which are appropriate to the environmental, economic, and social needs of developing nations.

3. Exchange of information concerning environmentally safe energy technologies and practices, including those described in paragraphs (1) and (2).

SEC. 204. GLOBAL CHANGE RESEARCH INFORMATION OFFICE.

Not more than 180 days after the date of enactment of this Act, the President shall, in consultation with the Committee and all relevant Federal agencies, establish an Office of Global Change Research Information. The purpose of the Office shall be to disseminate to foreign governments, businesses, and institutions, as well as the citizens of foreign countries, scientific research information available in the United States which would be useful in preventing, mitigating, or adapting to the effects of global change.
Such information shall include, but need not be limited to, results of scientific research and development on technologies useful for--

1. Reducing energy consumption through conservation and energy efficiency;

2. Promoting the use of solar and renewable energy sources which reduce the amount of greenhouse gases released into the atmosphere;

3. Developing replacements for chlorofluorocarbons, halons, and other ozone-depleting substances which exhibit a significantly reduced potential for depleting stratospheric ozone;

4. Promoting the conservation of forest resources which help reduce the amount of carbon dioxide in the atmosphere;

5. Assisting developing countries in ecological pest management practices and in the proper use of agricultural, and industrial chemicals; and

6. Promoting recycling and source reduction of pollutants in order to reduce the volume of waste which must be disposed of, thus decreasing energy use and greenhouse gas emissions.

TITLE III--GROWTH DECISION AID

SEC. 301. STUDY AND DECISION AID.

(a) The Secretary of Commerce shall conduct a study of the implications and potential consequences of growth and development on urban, suburban, and rural communities. Based upon the findings of the study, the Secretary shall produce a decision aid to assist State and local authorities in planning and managing urban, suburban, and rural growth and development while preserving community character.
(b) The Secretary of Commerce shall consult with other appropriate Federal departments and agencies as necessary in carrying out this section.

The Secretary of Commerce shall submit to the Congress a report containing the decision aid produced under subsection (a) no later than January 30, 1992. The Secretary shall notify appropriate State and local authorities that such decision aid is available on request.

Appendix D

Letter from James R. Mahoney

September 17, 2002

Dr. Bruce Alberts
President
National Academy of Sciences
2101 Constitution Avenue, NW
Washington, DC 20418

Subject: Requested Review of the Updated U.S. Climate Change Science Program Strategic Plan by the National Academies

Dear Bruce:

I am writing in my role as Director of the U.S. Climate Change Science Program, involving the collaboration of thirteen federal agencies responsible for sponsoring research on climate change and global change issues. The Climate Change Science Program is responsible for reporting the results of the sponsored research in a manner that facilitates public debate about climate change policy issues, and that provides analyses useful for decision-making by natural resource and infrastructure managers throughout the United States. The Climate Change Science Program incorporates the work of the U.S. Global Change Research Program (USGCRP) authorized by Global Change Research Act of 1990 and the Climate Change Research Initiative (CCRI) launched by President Bush in June 2001.

Thanks very much for taking the time to discuss our plans for the formulation and public review of an updated strategic plan for the U.S. Climate Change Science Program during our recent meeting in your office. Confirming my verbal request during our meeting, the thirteen collaborating agencies in the Climate Change Science Program request that the appropriate elements of the National Academies appoint a committee to undertake a thorough review of the Program's draft strategic plan that is currently in development.

The approach to open scientific and stakeholder review of the Program's draft strategic plan is described in the *Announcement and Invitation for the U.S. Climate Change Science Program: Planning Workshop for Scientists and Stakeholders*, which is enclosed. This document describes a strategic planning process for research and reporting activities built around the following key dates:

- November 11, 2002: Discussion draft of the strategic plan available on the web.
- December 3 – 5, 2002: Open workshop held in Washington, DC.
- January 8, 2003: End of post-workshop public comment period (for written comments).
- April 1, 2003 (approximate): Publication of revised (final) plan.
- April 2003 through 2007: Various scheduled dates for publication of findings and related decision support information (as described in the strategic plan).

The U.S. Climate Science Program would like to engage the National Academies in a thorough review of the strategic planning process, with a focus on the following elements:

1. The discussion draft of the strategic plan, as posted on the www.climatescience.gov web site by November 11, 2002.
2. The comments and questions received at the workshop on December 3 – 5, 2002.
3. The comments received on the web site during the 30-day period after the workshop.
4. The process of publishing a discussion draft strategic plan for comment and discussion by the scientific and stakeholder communities at an open workshop, followed by a written comment period.

We would ask the Academy committee to prepare its comments by February 28, 2003, so that the committee comments can be used as input to the final version of the strategic plan due by April 1, 2003. Also, we note that the 1990 Global Change Research Act requires that the strategic plans of the science program be reviewed by the National Academy. Therefore we suggest that the same Academy committee remain in operation, and report its comments on the final version of the strategic plan after its publication in April 2003.

The Academy would be requested to comment on all of the topic areas listed in the section labeled "Workshop Topics" in the enclosed announcement. Noting that the topics "Scenario Development and Evaluation" and "Decision Support Tool Development" involve technology, cost, economic and energy supply questions, the coverage of the Academy review would include:

- Climate and ecosystem science questions.
- Human interactions questions.
- Control technology issues (a limited set)
- Cost and economic analyses
- Energy analyses
- Public communications and education issues

We also request that the Academy comment on additional crosscutting issues in the strategic plan as well as the individual subsections. For example, is there appropriate balance between short and long-term goals, and across substantive research areas? Does the plan adequately describe linkages with the public, private sector, state/local governments, and the international communities? Is the plan's approach to management of issues that involve multiple disciplines and multiple agencies effectively coordinated and integrated?

We look forward to continuing discussions with representatives of the Academy to review this letter, and to develop a plan for the requested Academy review.

With best regards,

/s/ *Jim Mahoney*

Enclosure

Appendix E

Statement of Task

Committee to Review the U.S. Climate Change Science Program Strategic Plan

An ad hoc committee will conduct an independent review of the U.S. Climate Change Science Program's strategic plan for global change and climate change studies, giving attention also to the program's strategic planning process. This review will be carried out in two phases.

Phase I

In the first phase, the committee will review the discussion draft of the plan. The review will address the following questions about the draft plan as a whole:

- Is the plan responsive to the nation's needs for information on climate change and global change, their potential implications, and comparisons of the potential effects of different response options?
- Are the goals clear and appropriate?
- Is there an appropriate balance (1) between short-term (2-5 years) and longer-term goals, (2) among substantive research areas, and (3) between research and non-research activities, such as observations, modeling, and communicating results?
- Are mechanisms for coordinating and integrating issues that involve multiple disciplines and multiple agencies adequately described?
- Does the plan adequately describe the roles of the public, private sector, academia, state/local governments, and international communities, and linkages among these communities?
- Does the written document describing the program effectively communicate with both stakeholders and the scientific community? Is the question format for driving the research program effective?

The review also will address the following questions for each of the plan's major topical areas:

- Does the plan reflect current scientific and technical understanding?
- Are the specific objectives clear and appropriate?
- Are expected results and deliverables (and their timelines) realistic given the available resources?

In its review, the committee will consider the scientific and stakeholder community comments at the U.S. Climate Change Science Program's workshop and other comments received by the program during the public comment period. If time permits, the committee also will comment on any significant process issues related to the workshop that could affect how the program revises the draft plan.

The results of phase I will be provided in a report to be delivered no later than February 28, 2003.

Phase II

In the second phase, the committee will provide an overall assessment of the revised (final) plan, with an emphasis on how the plan has evolved in response to NRC and other community input. The committee also will address the following

questions related to the processes used to solicit and consider input from the scientific and stakeholder communities throughout the strategic planning process:

- Were the mechanisms for input from the scientific and stakeholder communities throughout the program's strategic planning process adequate?
- Did the format of the workshop promote the open exchange of ideas and suggestions for improvement?
- Was the process used to make decisions on potential changes to the draft plan clearly communicated to workshop participants and others who submitted comments during the public comment period?
- Was this process consistent with generally accepted practices for considering community input during public comment periods?
- What specific improvements should be reflected in future planning efforts for the program?

The results of phase II will be provided in a report to be delivered to the program within 6 months after the revised (final) plan is published.