REVIEW OF CCSP DRAFT SYNTHESIS AND ASSESSMENT PRODUCT 5.3: DECISION-SUPPORT EXPERIMENTS AND EVALUATIONS USING SEASONAL TO INTERANNUAL FORECASTS AND OBSERVATIONAL DATA

Panel to Review CCSP Draft Synthesis and Assessment Product 5.3:
Decision-Support Experiments and Evaluations
Using Seasonal to Interannual Forecasts and Observational Data

Committee on the Human Dimensions of Global Change
Center for Economic, Governance, and International Studies
Division of Behavioral and Social Sciences and Education

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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This study was supported by Contract/Grant No. DG133R07SE2248 between the National Academy of Sciences and the Department of Commerce. Support of the work of the Committee on the Human Dimensions of Global Change is provided by a consortium of federal agencies through a NASA Contract No. NNH07CC79B from the National Aeronautics and Space Administration and a grant from the National Science Foundation (Number 0436369). Any opinion, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-11568-1
International Standard Book Number-10: 0-309-11568-X

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet <http://www.nap.edu>.

Printed in the United States of America

Suggested citation: National Research Council. (2008). *Review of CCSP Draft Synthesis and Assessment Product 5.3: Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data*. Panel to Review CCSP Draft Synthesis and Assessment Product 5.3: Decision-Support Experiments and Evaluations, Committee on the Human Dimensions of Global Change, Center for Economic, Governance and International Studies, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Panel to Review CCSP Draft Synthesis and Assessment Product 5.3: Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data

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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 NRC's RRC. 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: Richard G. Lawford, Global Energy and Water Cycle Experiment (GEWEX), Silver Spring, MD; Kathleen A. Miller, Institute for the Study of Society and Environment, National Center for Atmospheric Research; and Alex Rothman, Department of Psychology, University of Minnesota.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Roger E. Kasperson, George Perkins Marsh Institute, Clark University, Worcester, MA. Appointed by the National Research Council, he was 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

The U.S. Climate Change Science Program, in its effort to provide the best possible scientific information to support decision making on key climate-related issues, is producing 21 synthesis and assessment products (SAPs) that address its highest priority needs. This report reviews a draft of SAP 5.3, which attempts to synthesize lessons learned in decision-support efforts in the water resource management sector.

The draft that was presented for review was, as the authors explained, in a fairly early stage of development, and the authors already had plans for significant revision and reorganization. This review examines the draft as given, with the understanding that it is not presented as near final. Thus, this review focuses on major issues of coverage and organization and other substantive comments but offers few comments at fine levels of detail, such as would be appropriate for a more polished draft.

The panel concludes that the draft SAP is appropriately objective and policy neutral and that data, when relevant, are handled appropriately. Its summary mainly recapitulates the key findings from the chapters, so it raises the same issues as the full draft. This summary emphasizes the major issues we think deserve attention in the revision of the draft SAP. Other issues are raised throughout the report.

A major issue is the need for some disconnects between different sections of the report to be resolved in revision. In particular, we suggest that the authors give explicit consideration to **two assumptions we see as implicit in the report, or in sections of it, that we find problematic or inconsistent with assumptions implicit elsewhere**.

ASSUMPTION 1: More forecast skill implies more forecast value

Parts of the document, particularly in Chapter 1, **seem to assume implicitly that forecasts that have greater skill or higher resolution in time and space will necessarily be better for decision support,** whereas other parts of the document do not make these assumptions. **Assuming that skill improves usefulness** leads to recommendations to invest in improved forecast skill and resolution; not assuming this leads to recommendations to invest in improving networks that link forecast producers and potential users. These sets of recommendations are likely to compete with each other in a tight-budget environment, but the draft does not note or address this issue. The sections emphasizing the need to improve networks are more consistent with the language in the Executive Summary, and also with available scientific evidence about the use of scientific information (National Research Council, 2007), than the sections **assuming that more skill means more value**. We suggest that the revised document discuss the evidence on the skill-value assumption and discuss its implications for meeting the objectives of making climate information more decision-relevant and more commonly used in the water resource management sector.

ASSUMPTION 2: Most useful form of information

Another assumption that is implicit, at least in Chapter 1, is that the most useful form of scientific information is a projected expected future value of some outcome parameter with a distribution reflecting uncertainty. This assumption is not supported by sufficient scientific evidence. Other kinds of scientific outputs (e.g., sets of plausible scenarios; models that could simulate the implications of forecasts) might more closely fill the needs of some decision makers in the water management sector. Building knowledge-action networks, as the draft SAP recommends, is advisable in part as a way to learn what would be useful. Also, Chapter 3 presents a serial flow chart as a model of innovation. We urge the authors to consider a continuous improvement model that is circular in nature.

Other important issues needing attention

In terms of coverage, the draft explicitly addresses all but two of the questions raised in the prospectus. Some are addressed in more than one place, when issues are raised in particular chapters. However, we note that Chapter 3, which addresses innovation and offers useful insights, does not draw on the research literature on innovation processes. Incorporating concepts from this literature may help to better conceptualize the operational insights and their implications and strengthen the evidentiary base for findings. Chapter 4 includes discussions of climate change issues, although the focus of the report is mainly on climate variability, which can pose different issues for modeling and for decision support. The document should clarify what it does and does not cover, distinguish clearly between discussions of climate change and of variability, and better justify the inclusion of material on climate change if the authors wish to include it. Responses to questions in the prospectus related to communication of forecasts, operationalization of tools, and evaluation should be elaborated. The discussion of evaluation, a major area of interest for the policy maker audience, is quite limited. If this is due to a lack of published materials, this should be stated.

In terms of the adequacy of evidentiary support for findings and recommendations, we note that very little evidence and analysis are available regarding decision-support efforts in the water sector, with the implications that findings must be based on the relatively weak grounding provided by case study evidence and that recommendations must be based largely on judgment. These points could be made more explicitly in the document.

Although the research priorities and general recommendations are all reasonable and generally supported by argumentation, they are stated in vague language that is hard to contradict and that does not offer clear guidance about the relative importance of different objectives or activities. The arguments raised in the document allow for persuasive arguments to be made for giving some of these ideas higher priority than others and for making some of the recommendations more pointed. For example, the recommendations for improving forecast skill could target areas ripe for improvement, such as realistic land-atmosphere interaction and cryospheric processes. The recommendation to support dense hydrologic monitoring networks is far stronger than the supporting text, which may need to be strengthened in support of this recommendation.

Chapter 2 claims **several potential benefits for knowledge-action networks without providing the sources of research or illustrative examples to substantiate each claim**. It should make a stronger case for wealth as a key variable affecting the use or nonuse of climate forecasts, or else revise this claim. It presents a relatively strong discussion of knowledge about “science citizenship” but does not clearly link it to the idea of using climate information in decisions. In Chapter 4, some of the key findings seem to depend on an analysis of lessons implicit in the case studies, but the case studies do not always include the type of information needed to support the findings.

The appropriate balance of roles between governmental and private efforts deserves more careful consideration. The case has not generally been made that private-sector organizations or local and state governments will not undertake the research priorities, so that the federal government must. An exception is the argument that, although private organizations may provide tailored decision-support products to those who can afford them, the government should provide useful information for general use by those who may not be able to afford customized information and/or are not requiring it (e.g., smaller water districts, towns, rural areas). We suggest that the document give consideration to an approach to climate forecast development that includes public-private partnerships in funding and developing needed information.

1

INTRODUCTION

The U.S. Climate Change Science Program (CCSP) was established in 2002 to coordinate climate and global change research conducted in the United States. Building on and incorporating the U.S. Global Change Research Program of the previous decade, the program integrates federal research on climate and global change, as sponsored by 13 federal agencies and overseen by the Office of Science and Technology Policy, the Council on Environmental Quality, the National Economic Council, and the Office of Management and Budget. A primary objective of the CCSP is to provide the best possible scientific information to support public discussion and government and private-sector decision making on key climate-related issues.

To help meet this objective, the CCSP is producing a series of synthesis and assessment products (SAPs) that address its highest priority research, observation, and decision-support needs. The CCSP is conducting 21 such activities, covering such topics as the North American carbon budget and implications for the global carbon cycle, coastal elevation and sensitivity to sea-level rise, trends in emissions of ozone-depleting substances and ozone recovery and implications for ultraviolet radiation exposure, and use of observational and model data in decision support and decision making. Each of these documents is written by a team of authors selected on the basis of their past record of interest and accomplishment in the given topic. A list of the CCSP SAPs is provided in Appendix A; additional information is available at <http://www.climatescience.gov/Library/sap/sap-summary.php>.

SYNTHESIS AND ASSESSMENT PRODUCT 5.3

The National Oceanic and Atmospheric Administration (NOAA) is the lead agency for CCSP Synthesis and Assessment Product 5.3: "Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data". Although the title of the SAP does not mention specific sectors, the prospectus for the SAP states that it "will concentrate on the water resource management sector" (U.S. Climate Change Science Program, 2006:2). NOAA's stated purpose for SAP 5.3 is to focus on the water resource management sector to allow for detailed synthesis of lessons learned in decision-support experiments in that sector. The term "experiments" in this context refers to novel initiatives for providing resources to better inform decision makers in that sector, rather than to the use of experimental methodology.

It is intended that the lessons learned from this product will be relevant, transferable, and essential to support decisions in other climate-sensitive resource management sectors. According to the guidance provided in the prospectus, SAP 5.3 is intended to inform (1) decision makers about others' experimental uses of seasonal and interannual forecasts and other observational data; (2) climatologists and social scientists about how to advance the delivery of decision-support resources that use the most recent forecast products, methodologies, and tools; and (3) science managers as they plan for future investments in research related to forecasts and their role in decision support. The authors of the document were asked to address a series of issues and questions (see Box 1-1).

Like the other synthesis and assessment products, SAP 5.3 is being produced with independent oversight and review from the wider scientific and stakeholder communities, as recommended by the National Research Council (NRC) review of the U.S. CCSP Strategic Plan (National Research Council, 2004b). NOAA as the lead agency asked the NRC to perform the independent review of SAP 5.3, and our panel was created to perform the task.

The Panel to Review CCSP Draft Synthesis and Assessment Product 5.3: Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data was asked to address the following review criteria:

1. Are the goals, objectives and intended audience of the product clearly described in the document? Does the product address all questions outlined in the prospectus?
2. Are any findings and/or recommendations adequately supported by evidence and analysis? In cases where recommendations might be based on expert value judgments or the collective opinions of the authors, is this acknowledged and supported by sound reasoning?
3. Are the data and analyses handled in a competent manner? Are statistical methods applied appropriately?
4. Are the document's presentation, level of technicality, and organization effective? Are the questions outlined in the prospectus addressed and communicated in a manner that is appropriate and accessible for the intended audience?
5. Is the document scientifically objective and policy neutral? Is it consistent with the scientific literature?
6. Is there a summary that effectively, concisely and accurately describes the key findings and recommendations? Is it consistent with other sections of the document?
7. What other significant improvements, if any, might be made in the document?

THE REVIEW PROCESS

The panel received a draft of SAP 5.3 report “Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data” when it was completed on July 5, 2007. A table of contents for the draft appears in Box 1-2. The draft was prepared by a team of authors working over a 6-month period. We met on July 17 with three of the lead authors—Helen Ingram, the product lead author, and Nathan Mantua and David Feldman, two of the convening lead authors—to ask questions about the authoring team’s research and formulation of the draft document. During this meeting, we also interacted with NOAA personnel, who outlined their expectations for SAP 5.3.

Nancy Beller-Simms of NOAA described the document as “very much a first draft” and asked us for comments that would help the authors make revisions to strengthen it. Ingram said that the authoring group recognized the draft as needing reorganization—for one thing, it was written in subgroups that separated the natural scientists from the social scientists, so that integration was as yet unsatisfactory to the authoring group. She and the other authors present mentioned some of their ideas for reorganization. They also said that they expected that, in revision, the concluding chapter would expand and that it would address the idea of a climate service. The authors did not see the draft as requiring major additional writing, however.

Panel members engaged in fairly extensive discussion with the authors present, raising points of interest to individuals on the panel. The authors present were very open to receiving comments, expressing the hope that the review would direct them in some of the ways they were already heading. In short, the draft was presented to us as very much a work in progress and in flux.

The panel then met in closed session to discuss reactions to the draft product and to develop its assessment of the draft. In these discussions and this review, we have focused on the draft document that we received on July 5, 2007, and have presumed nothing about ways the draft might subsequently change. After discussions were finished, individual panel members and the chair were assigned to draft a set of overview comments and review comments specific to each chapter. These were circulated among the panel members, compiled, and revised until the panel produced a draft that reflected our collective judgment. The draft was then independently reviewed following procedures established by the National Academies' Report Review Committee.

GUIDE TO THE REPORT

This report is organized around the seven review criteria given to us, although for reasons of exposition, we do not take them up in numerical order. Chapter 2 addresses Review Criteria 3, 5, 6, and 7; Chapter 3 addresses Review Criterion 1; Chapter 4 addresses Review Criterion 2; and Chapter 5 addresses Review Criterion 4.

BOX 1-1
Questions To Be Addressed in Synthesis and Assessment Product 5.3

The prospectus for SAP 5.3 indicates that the document will address, among others, each of the following questions or issues. They are numbered here for reference purposes.

Section I: A Description and Evaluation of the Forecast/Data Products

1. (a) What are the seasonal to interannual forecast/data products currently available and (b) how does a product evolve from a scientific prototype to an operational product?
2. What steps are taken to ensure that this product is needed and will be used in decision support?
3. (a) What is the level of confidence of the product within the science community and within the decisionmaking community; (b) who establishes these confidence levels and how are they determined?

Section II: Decision-Support Experiments
Within the Water Resource Management Sector

4. What types of decisions are made related to water resources?
5. What is the role that seasonal to interannual forecasts play and could play?
6. How does climate variability influence water resource management?
7. What seasonal to interannual (e.g., probabilistic) forecast information do decisionmakers need to manage water resources?
8. (a) How do forecasters convey information on climate variability and (b) how is the relative skill and level of confidence of the results communicated to resource managers?
9. What are the obstacles and challenges decisionmakers face in translating climate forecasts and hydrology information into integrated resource management?
10. What are the barriers that exist in convincing decisionmakers to consider using risk-based hydrology information (including climate forecasts)?
11. What is the role of probabilistic forecast information in the context of decision support in the water resources sector?
12. What challenges do tool developers have in finding out the needs of decision makers?
13. How much involvement do practitioners have in product development?
14. What are the measurable indicators of progress in terms of access to information and its effective uses?
15. How is data quality controlled?

Section III: Analysis of Present and Past Decision-Support
Experiments and a Look Toward the Future

16. identify critical components, mechanisms, and pathways that have led to successful utilization of climate information by water managers.
17. discuss how these findings can be transferred to other sectors.

18. discuss options for (a) improving the use of existing forecasts/data products and (b) identify other user needs and challenges in order to prioritize research for improving forecasts and products.

SOURCE: U.S. Climate Change Science Program (2006).

Box 1-2
Contents of "Synthesis and Assessment Product 5.3: Decision-Support Experiments and Evaluations Using Seasonal to Interannual Forecasts and Observational Data"

SOURCE: U.S. Climate Change Science Program (2006).

2

OVERVIEW ISSUES

We begin our review by addressing some of the review criteria that raise overview questions about the document. We find the document generally adequate in most of these respects.

Review Criterion 3: Are the data and analyses handled in a competent manner? Are statistical methods applied appropriately?

To the extent that this pair of questions refers to quantitative data, it is most applicable to Chapter 1. The data, the analyses, and the statistical methods are appropriately reviewed and presented there.

Review Criterion 5: Is the document scientifically objective and policy neutral? Is it consistent with the scientific literature?

With a few exceptions, the document is objective and policy neutral. We note some use of prescriptive language, particularly in Chapter 2 (such terms as “must,” “essential,” “ought to,” etc.). The main body of the chapter should describe what is known, with judgments, recommendations, suggestions, and the like concentrated at the end of sections or the chapter and labeled as such, with some direct connection to the basis of the comment (e.g., based on increasing awareness of ___, we recommend that ___).

The document is generally consistent with the scientific literature. However, there are some matters on which different scientific literatures lead thinking about decision support in different directions. We discuss this issue below in relation to other improvements that can be made in this document (under Review Criterion 7). We also have a few chapter-specific comments related to consistency with the scientific literature.

In Chapter 1, more emphasis should be placed on the more recent work, due to the rapidly changing state of knowledge. This is particularly true for forecast methodologies and operational practices.

Chapter 2 should draw on a much broader array of sources. For example, on the impact of water shortages on poor populations, only one forthcoming study by Lemos is cited. The authors should draw on the recent Intergovernmental Panel on Climate Change Working Group II reports regarding climate change impacts, adaptation, and vulnerability, which include a report specifically on water resources. In revising the document, it might be worthwhile to do a quick literature search on each of the major topics, especially as they relate to water resource management (knowledge-action networks, equity implications, framing, etc.).

Chapter 3 includes very little discussion of published research. It gives limited attention to models of innovation other than the one presented, and it includes scant discussion of how the model presented, or any other model of innovation, might provide useful insight for those attempting to integrate climate information into water resource decision making.

Review Criterion 6: Is there a summary that effectively, concisely and accurately describes the key findings and recommendations? Is it consistent with other sections of the document?

The Executive Summary begins with a good general statement of the concept of decision support and its evolution over time. This statement is actually more coherent than what appears in the chapters that follow, which were written, as already noted, in subgroups that separated the natural scientists and the social scientists and therefore comes across as somewhat lacking in integration. We discuss this issue further in the next section of this chapter. We recommend that when the report is revised, the chapters are made more consistent with this section of the Executive Summary. It is our understanding that this is the authoring group's intent.

The bulk of the Executive Summary simply recapitulates the key findings from the chapters. We discuss these in Chapter 4, in the context of assessing Review Criterion 2, about support for the document's findings and recommendations.

Review Criterion 7: What other significant improvements, if any, might be made in the document?

As noted, we see some disconnects between different sections of the report that should be resolved in revision. In some cases, these reflect different implicit assumptions in different sections of the report. We suggest that the authors give explicit consideration to a few assumptions we see as implicit in the report, or in sections of it, that we find problematic or inconsistent with assumptions implicit elsewhere. We suggest that the revised report reconcile such inconsistencies and explicitly state which assumptions are being made on the following matters, provide justification for making them, and, if some assumptions apply only to certain parts of the report, state where the assumptions are and are not being applied.

Assumptions about the relationship between quality of forecasts and usefulness for decision support: Parts of the document, particularly in Chapter 1, seem to assume implicitly that forecasts that have greater skill or higher resolution in time and space will necessarily be better for decision support. Climate information is assumed to be useful, and better information is therefore assumed to be more useful. These assumptions support recommendations to invest in improved forecast skill and resolution. Other parts of the document focus on the need to improve networks linking forecast producers and users and do not make these assumptions. These parts of the report lead to recommendations to invest in improving networks. The thrust of these two parts of the report are in somewhat inconsistent directions; moreover, it is the sections emphasizing networks that are more consistent with the language in the Executive Summary.

Recommendations to support improved forecast skill and to improve networks are likely to be in competition with each other in an environment of limited resources: priorities need to be set between investing in forecast skill and investing in networks and communication. The document advocates both types of investment and does not address relative priority or relative levels of investment needed. We suspect that this was not a conscious decision, but rather an inadvertent outcome of a division of labor in which Chapter 1 was written by climate scientists who are much concerned about forecast skill and resolution, and Chapters 2 and 4 were written by social scientists who were more concerned with forecast utility. The recommendations seem to have been simply compiled in the completed draft. The apparent disconnect in thrust between the chapters and their recommendations should be addressed in the revision.

Available scientific evidence mainly fails to support the assumption that forecasts that are better scientifically are more likely to be used and is therefore consistent with the emphasis on network building in the Executive Summary. Some of this evidence is summarized in Chapter 2 of a new National Research Council report, *Research and Networks for Decision Support in the NOAA Sectoral Applications Research Program*, released in September 2007. That study concludes that there is no evidence that forecasts that are better are therefore more likely to be used, for several reasons, including that forecasts are not useful unless they provide outputs that matter for decisions. Improving the quality of forecasts that do not provide such outputs adds no value for decision making, whatever value it has for science. Although the SAP 5.3 draft could not cite the new report, the final SAP 5.3 report could. More importantly, we suggest that the revised document discuss the evidence covered there and follow that evidence through by discussing its implications for how to proceed toward the twin objectives of making climate information more decision-relevant and more commonly used in the water management sector. We also note the potential for users under some circumstances to attribute greater skill to climate projections than they actually have, and then to lose confidence in the entire enterprise when they act on a projection that yields an expectation inconsistent with subsequent events.

Assumptions about the kinds of climate information that decision makers need. Related to the assumption that forecasts that are scientifically better are therefore more useful is another assumption that is implicit, at least in Chapter 1—namely, that the most useful form of scientific information is the kind now usually provided: a forecast or projection in the form of an expected future value of some outcome parameter with a probability distribution reflecting uncertainty.

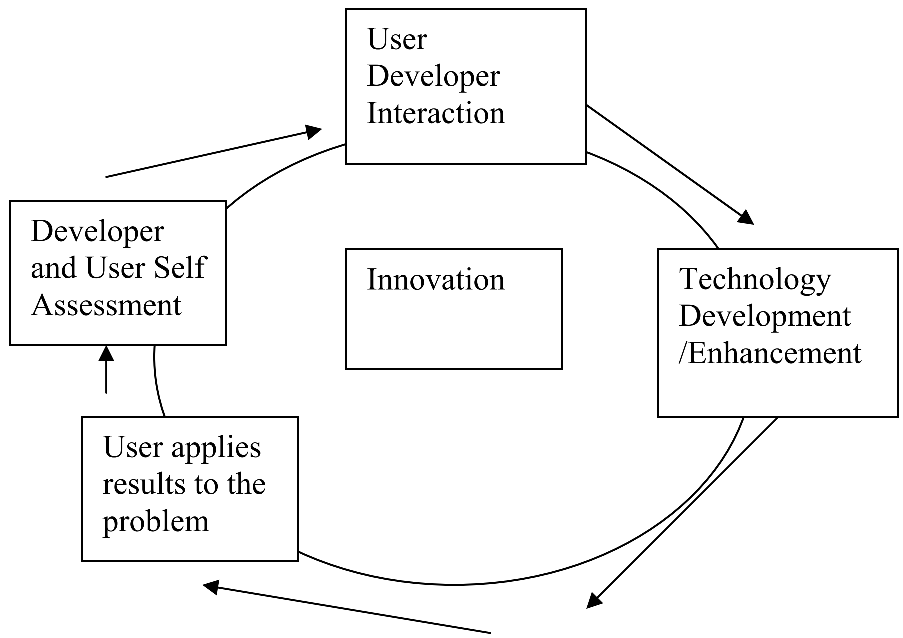
We think it is a mistake to assume that the most useful form of scientific output is already known. Other kinds of scientific outputs might more closely fill the needs of some decision makers in the water management sector. For example, instead of standard forecasts, some users might prefer a set of drought or streamflow scenarios, each of which is considered sufficiently probable on the basis of scientific knowledge about climate and hydrology to be worth considering for purposes of planning and emergency preparedness. Some users might prefer outputs that link simple water demand forecasts for outdoor urban or agricultural water use to streamflow forecasts based on climate scenarios. What we are suggesting is that the most useful kind of scientific output might not be a forecast but a package based on forecast information, perhaps combining forecasts with some simple way of ascertaining their implications for what a water manager does.

The tasks of determining which forms of scientific output are needed, and more generally of identifying and meeting decision makers' information needs, may be performed in part by continuing discussions in groups involving producers and users of climate information, along with intermediaries or information integrators working in such programs as the Regional Integrated Science Applications Program and the Sector Applications Research Program, both recently established by the National Oceanic and Atmospheric Administration. These are logical entities to coordinate the different actors that must interact to generate and disseminate appropriate sets of end-to-end decision-support products for particular sectors in their respective regions. Research can also play a role—for example, in testing pilot scientific outputs on representative samples of target user groups.

Assumptions about the nature of innovation. In the discussion of innovation (now in Chapter 3), the authors should consider whether a linear innovation flow chart, as described in words or implied by the hourglass Figure 3.1, is the correct model of innovation. We urge the authors to consider a continuous improvement model that is circular in nature. Figure 2-1 presents one potential description of this process.

Climate data needs. Finally, we suggest that the report explicitly address needs for collecting and maintaining data related to climate as it affects the water management sector. These data needs, which have been identified in numerous previous studies (e.g., National Research Council, 1999a, 2000, 2004a; Trenberth et al., 2002), include maintenance of stream gauges and adequacy of observation coverage in situ in mountainous regions of the Western United States where climatic variables most directly affect water supply. In revising the report, the authors should consider ways that these needs might be met by coordinated efforts among federal agencies, possibly including both space-based and in situ observations.

Figure 2-1 A model of innovation showing feedbacks.



3

RESPONSIVENESS TO PROSPECTUS QUESTIONS

This chapter considers Review Criterion 1, which consists of two subquestions: Are the goals, objectives and intended audience of the product clearly described in the document? Does the product address all questions outlined in the prospectus?

GOALS, OBJECTIVES, AND INTENDED AUDIENCE

The product's goals and objectives are described with adequate clarity. However, the audience for the document and its recommendations is not made explicit. As the document was created as part of a process of the U.S. Climate Change Science Program (CCSP) with the National Oceanic and Atmospheric Administration (NOAA) acting as lead agency, it seems reasonable to presume that the intended audience consists of the CCSP agencies, including but not restricted to NOAA. It would help to make the audience more explicit, and then to address recommendations as much as possible to specific parts of that audience.

RESPONSIVENESS TO QUESTIONS IN THE PROSPECTUS

The prospectus called on the authors to address numerous questions and issues (see Box 1-1). Most of these are addressed in more than one place in the document; two do not seem to be addressed explicitly at all. We suggest that, in the revision, the authors make it easier for readers to locate the places where the prospectus questions are answered. We organize our comments by chapter, to make them easier to address in a revision, and then by question within each chapter.

Chapter 1: A Description and Evaluation of Forecast and Data Products

Chapter 1 covers the issues identified in Section I of the product as described in the prospectus and has the same title as that section.

Prospectus Question 1(a): *What are the seasonal to interannual forecast/data products currently available?* Chapter 1 covers this question extensively, providing valuable information based on the literature. However, there should be some clarification about what is "currently available." All the centers mentioned, in addition to the National Centers for Environmental Prediction (NCEP)—the International Research Institute for Climate Prediction (IRI), the Climate Diagnostics Center at NOAA (CDC), and the Experimental Climate Prediction Center at the Scripps Institution of Oceanography (ECPC)—do have products of potential interest, but they are quite different in what they offer. Although NCEP is working toward more objective forecasts, only IRI offers a synthesized product—skill-filtered, objective multimodel, with some additional final subjective filtering based on response to potentially erroneous predictions of sea surface temperature (SST). CDC and ECPC essentially produce raw model outputs. Our understanding is that CDC doesn't post actual model predictions; instead, after analyzing the models' historical responses to imposed SSTs, it statistically, and linearly, estimates what the models' responses should be to the currently predicted SSTs.

Prospectus Question 1(b): *How does a product evolve from a scientific prototype to an operational product?* Chapter 1 provides little or nothing on the evolution from prototype (i.e., experimental research inside or outside government agencies) to operational products. One pathway is discussed in Chapter 3. The revision should address the roles in this evolution of a variety of nongovernmental actors, including academia and private-sector organizations. The report would be strengthened by providing a brief overview of the evolution of seasonal predictions. It is worth highlighting that methodologies are becoming more objective, centers are working on providing products with greater information content (more flexible), and the models are improving in their physics and by moving to higher resolution.

Prospectus Question 2: *What steps are taken to ensure product is needed and will be used in decision support?* Chapter 1 says little on this topic because there has been little conversation with users of information about what they require when designing forecast products. Some empirical reports are relevant to the issue, however (e.g., National Research Council, 2005b; Hartmann et al., 2002; McNie et al., 2007; Rayner et al., 2005). Some of this work is discussed in other chapters, but the findings are not integrated into the discussions of the usefulness of forecast information in Chapter 1.

Prospectus Question 3(a): *What is the level of confidence of the product within the science community and within decisionmaking community?* This question seems to be addressing forecast quality. There are three possible interpretations of quality, all of which are addressed to some degree in the chapter. First, information is given on sources of skill in seasonal climate and hydrological forecasts. The fact that a signal in the forecast can be attributed to a physically reasonable process helps give confidence in the forecast product.

Second, the level of confidence in a particular forecast is implicit in the probabilities assigned to particular outcomes, as climate forecasts (and an increasing number of hydrological forecasts) are probabilistic. We caution against strong suggestions in the report that the spread of ensemble members for a particular climate model gives a meaningful estimate of confidence. Forecast probabilities are much more reliable (i.e., mean what they say) after the historical response of the model ensemble has been appropriately recalibrated to the observed climate variability. Although they provide some insight into decision-making criteria, climate projections based on scenarios should also be distinguished clearly from probabilistic forecasts.

Third is the issue of overall quality of prediction tools. This is addressed, but not adequately. Only accuracy, which is a feature only of deterministic forecasts, was addressed. Probabilistic skill measures, such as reliability and resolution, are also important. The World Meteorological Organization (WMO) has developed a set of recommendations on forecast verification: the Standardised Verification System for Long Range Forecasts (SVSLRF). We recommend that WMO efforts in this regard be reviewed, consulted, or at the very least mentioned. However, we note that although the WMO-SVSLRF set of metrics gives a more complete view of forecast quality, it still may not address quality concerns that decision makers may have, such as frequency of errors exceeding a certain magnitude. The report would be improved by covering these issues and particularly by emphasizing the need for forecasts and projections to use metrics of importance to users if they are to gain their confidence.

Prospectus Question 3(b): *Who establishes these confidence levels and how are they determined?* Chapter 1 implicitly answers this question. Confidence is defined primarily by the community that produces the forecast information. This so far one-sided approach can be improved. It maybe helpful for the report to recommend that the communities of forecast producers and users work together to develop mutually useful measures of forecast quality. Such a recommendation would be more consistent with the way decision support is defined in the Executive Summary.

Chapter 2: Moving Knowledge to Action

The contents of Chapter 2 are most relevant to Section II of the document as described in the prospectus. This chapter, which focuses on the social, cultural, and political contexts in which decisions take place, addresses several of the specific prospectus questions. Emphasis is placed on the changing context for decision making in the water resources arena. The chapter reviews the difficulty of integrating seasonal to interannual forecasts into existing decision-support systems. With knowledge of these difficulties, policy makers and decision makers can consider new processes or systems of information production and delivery. The chapter suggests ways to use emerging structures for integrating climate information to improve decision making. It might be helpful to have authors reference specific difficulties in proposing their recommendations (e.g., "based on what we know about issues related to inequity in use of climate forecasts . . .").

Prospectus Question 5: *What is the role that seasonal to interannual forecasts play and could play?* This chapter reviews the emerging venues or forums (e.g., knowledge-to-action networks, "science citizenship") that may facilitate the use of climate information in water resource decisions. It also reviews the equity questions related to the use of forecasts. Overall the presentation is balanced and addresses this question well.

Prospectus Question 7: *What seasonal to interannual (e.g., probabilistic) forecast information do decisionmakers need to manage water resources*? The chapter reviews research regarding the difficulties water resource managers experience in using climate forecasts. It would be helpful to have these difficulties presented in the summary, as it might help to focus discussions in Chapter 4.

Prospectus Question 9: *What are the obstacles and challenges decisionmakers face in translating climate forecasts and hydrology information into integrated resource management?* The chapter considers this topic in depth, bringing together concepts regarding decision contexts, emerging venues, and equity issues (e.g., unequal distribution of knowledge and unequal benefits from climate forecasts) in relation to the usefulness of climate information for decision makers. It points to such issues as barriers to innovation in water resource management, the low visibility of water supply as a policy issue, and the need for citizens "to alter their perceptions of climate risks and uncertainties" (p. 126), in addition to equity issues.

Prospectus Question 11: *What is the role of probabilistic forecast information in the context of decision support in the water resources sector?* The chapter considers how the changing social, political, and cultural contexts affect the use of climate change information as well as how emerging governance structures may change the way water resources decisions are made.

Prospectus Question 13: *How much involvement do practitioners have in product development?* The chapter describes the rise of science citizenship and knowledge-to-action networks as potential sources of deep involvement by practitioners. These concepts should be expanded on and referenced in Chapter 4 when thinking about practitioner involvement.

Chapter 3: Managing Innovation: Ensuring Success in Joining Research and Operations

Chapter 3 provides an interesting discussion of different kinds of innovation from an operational perspective. A brief description is given for the various ways that current operational forecast environments attempt to improve and streamline. The chapter provides a useful discussion of the responsibilities placed on operational units and the resources that they possess to innovate. In this context, the discussion focuses on distinguishing between innovation resources that are centralized and those that are distributed among regional offices. It provides a comparison of the advantages and disadvantages of centralized and standardized versus distributed and individualized systems. The role of users in this process is also described, followed by a discussion of challenges of garnering institutional support for innovation.

While the material in this chapter is highly relevant to the overall goal of SAP 5.3, it lacks references from the literature. We appreciate the challenge, as most of the operational issues covered are not of a type that can be written up for submission to a peer-reviewed journal. The issues are mostly based on the experience of those engaged in the operational units. We think that much of the content is highly relevant and useful and should be presented in the final product in perhaps a modified form (i.e., incorporating the chapter material into other parts of SAP 5.3). As already noted, the chapter does not draw on the research literature on innovation processes generally. Incorporating concepts from this literature may help conceptualize the operational insights and their implications.

The discussions provided in Chapter 3 address a number of the specific questions in the prospectus, as discussed below.

Prospectus Question 1(b): *How does a product evolve from a scientific prototype to an operational product*? This is the major focus of this chapter. There are some difficulties with layout and content. It would help to focus this discussion as much as possible on what is known about how climate information has been transformed by users into operational products. There have been reviews that suggest how climate information can be integrated into existing decision routines (e.g., McNie et al., 2007, on NOAA's Regional Integrated Science Applications Program). Such work could provide examples of the use of climate information in existing decision routines in the water resources sector. The report should present and cite existing evidence on the role of users in the transformation of scientific information into operational products.

Also, as already noted, the conceptual framework used to discuss innovation in this chapter is rather deterministic in nature (i.e., the innovation itself determines its construction, use, etc.) and may give the impression that innovations mainly affect those who adopt them. Some of questions that deserve attention are: How do producers receive feedback on products they produce? How are ideas for new products generated, particularly by users? What about any "fixes" to the innovation? We recommend that the writing team to take a harder look at other models for thinking about technological change (e.g., Rip and Kemp, 1998).

Prospectus Question 2: *What steps are taken to ensure that this product is needed and will be used in decision support?* In our experience, science-based agencies of the federal government often lack a true understanding of the role of users and struggle with how to appropriately integrate the user community so as to increase the chances that they produce science that is accepted as useful. For example, during the National Academies' review of the National Weather Service's Advanced Hydrological Prediction Service (AHPS; National Research Council, 2006), the review committee heard that the NWS had only marginally considered a user integration strategy both for agency employees and potential external users. It was reported that AHPS, a suite of tools to enhance the river forecast centers, was virtually unknown by the floodplain management community, a key potential user. NWS has made efforts and some progress on addressing these issues since the AHPS report was published. However, it is important to realize that this sort of lack of user integration can be found in many science-based agencies. Typically, scientists are content with data collection and analysis or perhaps coming forth with a new innovation based on analysis of science-driven questions, but they do not fully appreciate the importance of truly engaging the user community. Due to the writing style used (the posing of questions), it was difficult to determine whether or not the writing team was expressing concerns that science users are not effectively incorporated into the process.

An unaddressed issue in relation to making climate forecasts useful is the likelihood of increased need for information about climate variability and change because of larger changes going on in the society. These include population growth, increasing population density in vulnerable areas, and so forth—changes that will increase the importance of decisions that could be informed by climate forecasts and projections. These changes may make social systems more sensitive to climate variability in the short term and to climate change over longer time scales. Such changes may result in additional layers of complexity and increased uncertainties in estimates of future climate effects. The model of innovation in seasonal to interannual climate forecasting as driven by scientists looking to improve model accuracy, which is implied in much of the Chapter 3 discussion, falls short of what will be needed. Perhaps user demand will force change in this approach. The document needs to provide some context related to demographic and other societal changes as background to discussing the kinds of innovation needed.

Prospectus Question 5: *What is the role that seasonal to interannual forecasts play and could play?* The chapter reviews a limited range of innovation models that might be relevant, but it does not address this question directly.

Prospectus Question 6: *How does climate variability influence water resource management?* This issue is addressed obliquely in discussions related to issues of scale in hydrologic decision making. It could be addressed more directly by considering what kinds of innovations in water management might be advantageous, given the development of some skill in forecasting climate variability.

Prospectus Question 9: *What are the obstacles and challenges decisionmakers face in translating climate forecasts and hydrology information into integrated resource management?* The chapter considers how patterns of integrating innovation in organizations may pose obstacles to the use of climate forecasts and hydrologic information.

Prospectus Question 10: *What are the barriers that exist in convincing decisionmakers to consider using risk-based hydrology information (including climate forecasts)?* Chapter 3 reviews how limits and constraints to the adoption of innovation in organizations, particularly state and federal agencies, create barriers to use of risk-based information.

Prospectus Question 16: *Identify critical components, mechanisms, and pathways that have led to successful utilization of climate information by water managers.* Chapter 3 describes models of innovation but does not provide analytical descriptions of any successful utilization.

Prospectus Question 18: *Discuss options for (a) improving the use of existing forecasts/data products and (b) identify other user needs and challenges in order to prioritize research for improving forecasts and products.* This chapter suggests ways to use emerging structures for integrating climate information, such as consistent databases, to improve decision making (especially section 3.6.3).

Chapter 4: Decision-Support Experiments Within the Water Resource Management Sector

This chapter addresses a number of questions identified in the prospectus and goes beyond the prospectus in bringing in numerous examples of climate change needs. However, it is important for this report to clearly indicate that the focus is meant to be on seasonal and interannual forecasts—climate variability, not climate change. While these are related processes, it is helpful to the readers that the distinction is made, because they can pose significantly different issues for decision support, as well as for climate prediction. For example, seasonal forecasts provide probabilities and skill assessments based on observations, model predictions, and expert judgment, whereas climate change projections offer ranges based on scenario inputs built up from a set of plausible, coherent narratives that many would like to see revised. Engaging the climate change discussion would also require consideration of a broader literature than is currently covered. It is important that the study clarify what it does and does not cover and better justify the inclusion of material on climate change, if the authors wish to include it. Section 4.6 briefly mentions that it includes climate change experiments as useful analogues, but it is not clear that they are useful analogues, since there is no equivalent prediction or decision history. Some clarification as to the intended focus, throughout the document, would be helpful.

Responses to questions related to communication of forecasts, operationalization of tools, and evaluation should be elaborated. The discussion of evaluation, a major area of interest for the policy maker audience, is quite limited. If this is due to a lack of published materials, then it should be mentioned.

We offer brief comments below on how specific issues in the prospectus are addressed.

Prospectus Question 1(b): *How does a product evolve from a scientific prototype to an operational product?* While implicitly covered in places, it maybe helpful to address the role of NOAA’s Transition of Research Applications to Climate Services program. It may also be helpful to be explicit about the roles of NOAA and other CCSP agencies in the cases presented.

Prospectus Question 2: *What steps are taken to ensure that this product is needed and will be used in decision support?* The question is addressed most directly in prescriptive discussions of boundary organizations and end-to-end tool design processes. Several case experiments describe collaborative approaches now in process.

Prospectus Question 3: *What is the level of confidence of the product within the science community and within the decisionmaking community; who establishes these confidence levels and how are they determined?* Chapter 4 focuses on confidence as it relates to credibility, trust, and risk perception. In doing so, it usefully broadens the discussion of the types of confidence involved in decision making beyond the narrower technical definition that might be inferred from the term "confidence levels" and from the treatment of the issue in Chapter 1. Still, it would be appropriate to add discussion of work, such as that by Hartmann et al. (2002), which address the importance and value of different skill measures to decision makers. The Red River case study included in this chapter gives a great deal of attention to how deterministic forecasts may be perceived by user groups, but this discussion is not well integrated with the main body of the text.

Prospectus Question 4: *What types of decisions are made related to water resources?* Section 4.2 provides an overview and a table of general examples (Table 4.1). It would be helpful to link this discussion more closely with the presentation of forecasts and forecast uses in Chapter 1, where some specific products are mentioned.

Prospectus Question 5: *What is the role that seasonal to interannual forecasts play and could play?* The discussion in first part of Chapter 4 overlaps in some ways with the Chapter 1 discussion of forecasts. Table 4.1 includes listings of general types of decisions that might include forecast information. Some decision makers are using the forecasts as suggested in Table 4.1, and examples of uses are provided in later case studies. However, they are not referenced in the table. Better integration of these discussions with more detailed material in section 4.6 would strengthen the report.

Section 4.5.1.1, under a title on climate variability, includes a summary of climate change issues drawing primarily on materials from the Intergovernmental Panel on Climate Change. This section would be a better fit earlier in a discussion of impacts and influence of climate on decision makers. This is an example of a place where the distinction between climate variability and climate change should be drawn more carefully.

Comparing decision maker needs (discussed in section 4.3.1 and Figure 4.1) against the availability of forecasts (Table 1.3) highlights the generality of available information related to decision maker needs and the potentially enormous number of context-specific decisions. Perhaps this is where the point about the need for more integrators could be advanced more forcefully.

Prospectus Question 6: *How does climate variability influence water resource management*? This topic is covered well and additional research needs are identified.

Prospectus Question 7: *What seasonal to interannual (e.g., probabilistic) forecast information do decisionmakers need to manage water resources?* Chapter 4 stresses the diversity of circumstances and possible information needs. The case studies give specific examples of needs. Table 4.1 indicates general decision areas and decision makers. Processes for determining needs are reviewed. The text also addresses the importance of the timing of forecasts but not the spatial scale of needs.

Prospectus Question 8: *How do forecasters convey information on climate variability and how is the relative skill and level of confidence of the results communicated to resource managers?* The issue of how to communicate information through collaborative engagement with decision makers receives a great deal of well-documented attention. Other work on communicating risk and uncertainty, such as covered in past National Research Council reports (e.g., 1989, 1996, 1999b) reports, should be elaborated.

Prospectus Question 9: *What are the obstacles and challenges decisionmakers face in translating climate forecasts and hydrology information into integrated resource management?* Chapter 4 considers this topic in depth, although the discussion is somewhat fragmented across sections. This concern can easily be addressed in the final version.

Prospectus Question 10: *What are the barriers that exist in convincing decisionmakers to consider using risk-based hydrology information (including climate forecasts)?* The question is addressed well at the agency, institutional, and individual levels.

Prospectus Question 11: *What is the role of probabilistic forecast information in the context of decision support in the water resources sector?* The case studies provide discussion relevant to this question.

Prospectus Question 12: *What challenges do tool developers have in finding out the needs of decision makers?* Major issues related to this question are raised in the discussion of challenges to building collaborative relationships.

Prospectus Question 13: *How much involvement do practitioners have in product development?* Chapter 4 takes a prescriptive approach to this question by calling for end-to-end involvement of practitioners in development and dissemination of tools as an alternative to the "loading dock model" that is still used in some cases. The case studies presented do not describe the collaborative processes, perhaps because so little of the kind of literature that is available regarding public involvement practices is available in this topic area. Strategies for achieving the long-term involvement seen as essential to building these collaborative relationships offer indirect insights.

Prospectus Questions 14 and 15: *What are the measurable indicators of progress in terms of access to information and its effective uses? How is data quality controlled?* There is very little discussion of these topics in this chapter. Even though the peer-reviewed literature may be sparse, the value of this document for policy makers could be enhanced by expanding this discussion, perhaps by suggesting indicators that might be appropriate to use. Some examples might be generated by examining reports of consultations between agencies and potential forecast user communities.

Prospectus Question 16: *Identify critical components, mechanisms, and pathways that have lead to successful utilization of climate information by water managers.* This issue is addressed in numerous ways, including discussion of various approaches, such as development of boundary institutions, long-term collaboration, and end-to end forecasts, as well as discussions of individuals' perceptions of risks and of the case of the Regional Integrated Sciences and Assessment centers.

Prospectus Question 17: *Discuss how these findings can be transferred to other sectors.* This issue is not addressed in the document in any detail.

Prospectus Question 18: *Discuss options for (a) improving the use of existing forecasts/data products and (b) identify other user needs and challenges in order to prioritize research for improving forecasts and products.* The closing discussion of research needs includes several important items, but it does not address issues of communicating uncertainty that are seen as priorities in the recent NRC reports, *Decision Making for the Environment* (2005) and *Completing the Forecast* (2006). The document will be greatly enhanced by addressing more clearly the need for vulnerability assessments. Only one of the case studies included to support the discussion in section 4.6 addresses issues of vulnerability. There is much more literature that could be introduced to support this case. Similarly, the discussion of barriers and obstacles might note a lack of information on the implications of smaller scale tailored products.

4

SUPPORT FOR FINDINGS AND RECOMMENDATIONS

This chapter considers the document in relation to Review Criterion 2, which contains two subquestions: Are any findings and/or recommendations [in the report] adequately supported by evidence and analysis? In cases where recommendations might be based on expert value judgments or the collective opinions of the authors, is this acknowledged and supported by sound reasoning?

OVERALL COMMENTS

The central subject matter of this document—decision-support "experiments" in the water sector—is one for which very little evidence and analysis are available. Thus, findings must necessarily be based on the relatively weak grounding provided by case study evidence, and recommendations must necessarily be based largely on judgment. These points could be made more explicitly in the document. Nevertheless, despite the weakness of the available evidence base, it remains worth assessing the strength of the support and reasoning underlying the authoring group's judgments. In addition, we encourage the authors to look outside the federal government and even outside the U.S. experience for evidence on the effects of decision support activities in the water sector.

The main findings and recommendations in the document appear in Chapter 5. We focus first on these and then turn to the key findings from the other chapters. Chapter 5 identifies seven research priorities and three general recommendations. To support these, the document should ideally demonstrate that (a) the recommended activities deserve higher priority than other activities and (b) that they deserve action by the document's audience group.

The research priorities and general recommendations are all reasonable ideas and are generally supported by the argumentation in the document. However, they are stated in vague language that is hard to contradict and yet does not offer clear guidance to agencies about the relative importance of different objectives or activities. Given the arguments raised in the bulk of the document, we think that persuasive arguments could be made for giving some of these ideas higher priority than others and for making some of the recommendations more pointed.

Evidence or argumentation should be presented that Climate Change Science Program agencies should pursue the recommended activities. The case has not generally been made that private-sector organizations or local and state governments will not undertake these research priorities, so that the federal government must. An exception is in the discussion of the recommendation to "adopt appropriate roles for private enterprise," in which the argument is made that although private organizations may provide tailored decision-support products to those who can afford them, the government should provide a "baseline level" of useful information for general use by those who may not be able to afford customized information or are not requiring it (e.g., smaller water districts, towns, rural areas). Many such users may be able to take advantage of web-based resources.

The appropriate balance of roles between governmental and private efforts deserves more careful consideration. Considering the pessimistic outlook for discretionary federal funding, the future of climate programs may absolutely require the infusion of corporate funding. The document might therefore give consideration to an approach to climate forecast development that includes public-private partnerships in funding and developing needed information.

It is worth noting that some priorities and recommendations appear to have a broader audience than federal government agencies. One is the recommendation to adopt appropriate roles for private enterprise, which implicitly calls for action by businesses. Another is the priority of improving understanding of water resources vulnerability. Presumably, it is water resource managers and not only federal agencies that need this better understanding.

COMMENTS ON INDIVIDUAL CHAPTERS

Chapter 1: A Description and Evaluation of Forecast and Data Products

There are four key findings and recommendations in Chapter 1 (pp. 111-112).

1. Continued support for efforts to improve the skill in climate forecasting are crucial for improving the skill in hydrologic forecasting at seasonal lead times. This summary/ recommendation points to the need for further strengthening of climate and hydrologic forecasts. There is perhaps a perception that seasonal to interannual forecast skill (as measured by accuracy) is at a plateau. We recommend that the revised document indicate what advances are likely in forecast quality with increased investment (examples might be more reliable probabilistic forecasts, higher spatial resolution information, statistics of weather within climate, etc.). Needless to say, the models have room for further improvement. Examples of areas with most relevance to the coupling of climate and hydrology that are not being accounted for in dynamical models are realistic land-atmosphere interaction and cryospheric processes.

2. Support for the maintenance, expansion, and integration of dense hydrologic monitoring networks is paramount in supporting hydrologic and water resources forecasts. This conclusion is an important one, but it is far stronger than the text in the associated section in the chapter. The text may need to be strengthened with some additional references in support of this recommendation.

3. Support for coordinated efforts to standardize and quantify the skill in hydrologic forecasts is needed. This recommendation implies the evolution of hydrologic forecasts from deterministic to probabilistic but then advocates accuracy metrics. In support of the latter, discussion of the literature of available metrics of "quantitative estimates for the forecast uncertainty" is necessary.

4. New efforts are needed to extend "forecasts of opportunity" beyond those years when anomalous ENSO conditions are underway. It is not clear what is intended by "extending forecasts of opportunity beyond ENSO years." However, probabilistic forecasts may still offer information beyond "climatology," such as indicating more extreme outcomes having a lower probability of occurrence. A clear discussion indicating that decadal trends provide additional skill to the seasonal forecasts is perhaps necessary.

We note again a sense of disconnection between these recommendations, which come from and propose investments to improve climate science, and the rest of the document, which is about decision support. Also, these recommendations may go beyond the charge to the authors, which calls for evaluating "seasonal to interannual forecasts and observations currently available for use by decisionmakers." Some of these recommendations speak to needs for improved forecast skill beyond what is available; more importantly, the recommendations do not make specific reference to improvements that will make model outputs more closely meet decision makers' needs.

Chapter 2: Moving Knowledge to Action

This chapter includes six key findings but no recommendations. The primary message is to call for promotion of science citizenship to improve decision-making processes. The discussion provided in this chapter supports this overall message and the findings (key findings in this and the other chapters are listed verbatim below in italics). However, it would be worthwhile for the authors to seek and cite additional evidence supporting the proposition that citizen science leads to improved responses to climate forecasts.

1. The social, cultural, and political contexts in which climate variation and change forecasts are considered has changed dramatically in the past twenty years, enhancing the likelihood that such information will be incorporated into innovative water management. Although section 2.2 (New Understanding of Climate Variability and Change, p. 126) starts out with a quote about rising interest in the visibility of climate change, the text seems to be more about the changing context of water resource management than new understanding of climate variability. The claim that climate information may be integrated into the innovative water management regimes is not supported by reference to existing research.

2. Water issues are being framed as more salient and as integral to sustainability. It would be helpful to provide a summary statement about what role reframing takes in policy and behavioral change. The section on issue frames could describe how such issues as climate change come to be seen as important for public policy, so that decision support becomes an issue for government attention. However, the processes of framing are not clearly described for readers unfamiliar with the concept.

The framing of water as an "ecosystem service" (p. 134) is no longer "emergent"—it is widely accepted in the science and policy arenas—see the publications of the Ecological Society of America, the Millennium Ecosystem Assessment (2005), and the Intergovernmental Panel on Climate Change (2007). A discussion of how ecosystem functions (such as the provision of water) are being reframed as services (ultimately for humans) is an interesting example of how the visibility and legitimacy of issues can be shaped by political and scientific reframing processes.

3. New venues or forums for discourse and decision making are emerging. New venues are indeed emerging, including some not mentioned in the draft. They include local governance structures, such as watershed councils, water banks, and nongovernmental organizations dedicated to water issues, especially in the developing world. Some of these are emerging as major players in local water resource management. There is no discussion in Chapter 2, however, of a major difficulty with the new venues: the mismatch between local decision venues and climate science products, which are produced at regional, national, and global scales (although this is discussed in Chapter 1).

4. *Knowledge-to-action networks that cut across levels of government and include public and private actors facilitate communication and information exchange across organizational boundaries. Knowledge-to-action networks that include locally based actors are important to implementation of innovative ideas.* A more detailed discussion is needed of what knowledge-to-action networks are, how they differ from other venues or institutions (e.g., collective action, governance), their strengths and limitations, and their potential role in integrating climate science in water resource management. The definition of knowledge-action networks in this draft is too vague to be useful in thinking through how the examples pertain to more general points of the discussion. For example, why are water markets or banks considered an example of a knowledge-action network and not a new governance structure? Also, why are rebates provided for water conservation not just an example of a commonly used policy tool (i.e., incentives)? The following website describes a "knowledge network on vulnerability and adaptability to climate change" on water resources hosted by the United Nations Environment Programme: http://ncsp.vanetwork.org/section/resources/resource_water. Is this an example of a knowledge-action network? Can the authors offer an example of a knowledge-action network that integrates "scientific knowledge into societal beliefs," as claimed on p. 143?

Finally, the document claims that knowledge-action networks have the potential to (a) get issues recognized and make action on them legitimate, (b) integrate local knowledge, (c) translate and integrate scientific information in decision and policy making, and (d) build social capital. It would be helpful to provide sources of research and illustrative examples to substantiate each claim.

5. *Equitable distribution of the benefits of water-related climate variation and change forecasts depend upon effective two-way communication to disadvantaged, vulnerable populations, and provision of sufficient resources to them to enable meaningful response.* It is not clear that the problems of communication pertain only to poor and/or less technologically sophisticated users of seasonal climate forecasts. The document claims (lines 2637-2640) that "utility and value [of forecasts] is often hampered by factors such as poor communication, inequitable distribution of knowledge, institutional barriers, and most critically, the inability of many of the targeted populations to respond to forecasts because of their lack of financial and human resources." Some of these issues would seem to apply to all potential users of seasonal forecasts. The document should make a stronger case that lack of financial resources is a key variable affecting the use of the forecasts—or else revise the claim.

6. *Water resource management has great unrealized potential for the inclusion of science citizenship that involves enhanced citizens' understanding of water related climatic risks; citizen participation in the development of knowledge and knowledge-to-action networks; and citizen cooperation in producing water management innovations.* The document presents a relatively strong discussion of knowledge about science citizenship but does not clearly link it to the idea of using climate information in decisions. It also does not link the discussion of citizenship to the one about the use or nonuse and levels of understanding of climate information by nonexperts (including agency staff and members of the public). If citizens take interest in

climate, is there evidence to support the assumption that they will they see existing climate information as useful or usable for informing their long-term decisions?

Chapter 3: Managing Innovation: Ensuring Success in Joining Research and Operations

This chapter includes five key findings but no recommendations. For the most part, the key findings are not directly supported by discussion in the chapter. Relevant evidence sometimes appears in Chapter 2 or 4. Depending on the overall revision strategy adopted by the authoring team, some of these findings and accompanying discussions may be incorporated into other chapters and hence may be supported more strongly by the revised text. By whatever method of revision, the findings should be linked more closely to the discussions that support them.

1. There are many ways in which forecasts can improve. Skill is only one dimension of quality, whereas timeliness, understandability, and relevance are among some of the others. This is an interesting and important concept that is of direct concern to potential users; however, it does not appear to be very well supported in this chapter. There is support available for it in research and also in some of the case material discussed in Chapter 4. The support for this finding should be gathered in the same chapter as the finding itself.

2. Climate forecasting generally has a national organization structure, whereas hydrologic forecasting is focused on a more regional scale. This finding probably does not need detailed support. However, its implications for the use of climate information in decision making are not developed either here or in Chapters 2 and 4, where scale mismatch is also mentioned.

3. For change to be attractive, improvement must be expected. Without a framework for comparing the quality of the existing system to its alternatives, the pursuit for better forecasts has been largely unstructured and based on qualitative impressions of expected benefits. Information to support this finding is included in section 3.9 (and some in section 3.7), although the conclusion regarding a framework for comparison is not strongly supported by the information provided.

4. Incompatibility with existing forecasting systems can be a major obstacle to adopting new technology into operational practice. Few resources exist among researchers or forecasters to foster this compatibility. The evidence of incompatibility is basically not found in the chapter. There is no discussion of what resources would foster compatibility or of their extent among researchers or forecasters.

5. Although known to be an effective product development tool, structured user testing is rarely done. In particular, almost no research is done on effective seasonal forecast communication. Instead, users are commonly engaged only near the end of the product development process. No support for is offered for this finding in Chapter 3.

Other Comments: Several other statements in Chapter 3 deserve comment:

Page 163, line 3007: The statement that "Water management decisions can strongly benefit from better seasonal forecasts" sounds good, but it should at least be qualified, considering Key Finding #1 from this chapter, that skill is not the only dimension of quality in forecasts and also considering that benefits should be weighed against costs.

Page 165, line 3046: The statement that innovation leads to lower cost is not substantiated and may not hold up to scrutiny. Quite often, innovations have initial incremental costs. The ultimate result may be a more valuable output, so that the cost is justifiable, but that is not the same as lower cost.

Page 168, line 3113: Reference is made to the employment of a schoolteacher in the summer to generate regression equations. This is not documented. More importantly, it is not clear whether this example, contrasted to "hydrologists using computers," is related to staffing qualifications, technology, or both.

Page 173, line 3199: The statement: "There is evidence supporting a system-wide decline in water supply forecast skills . . ." could be clarified. It could be read to indicate that in 1970 there were better educated, trained, and more intuitive personnel than those working today. If decreases in skill are due to changes in the timing of precipitation as claimed, the import of this change needs explanation. For example, can the skill be regained simply by adding in better information about precipitation, or has there been a fundamental change in precipitation timing brought about, for example, by climate change?

Section 3.5 demonstrates and contrasts regionally versus centrally developed methods, user interfaces, etc. The discussion implies a preference for regionally developed applications. For example, in one location it is suggested that one of the driving forces for a national application look and feel is that of "branding." Perhaps a more compelling consideration is the fact that users interested in multiple regions are better served if they can operate within the same look and feel on a website, and so forth. Another is that most agencies are required to provide summary reports and findings, which are made easier with common formats. The issue of regional versus national development should be viewed through the lens of decision-support needs.

Page 193, line 3640: The characterization of a motive for innovation as "laziness" here and elsewhere invites unwarranted criticism of forecasters and agencies. The motive might as easily be characterized as "efficiency."

Page 198: The discussion of user interaction in development in this section seems to endorse a prototype-and-test method that gives inadequate consideration to user requirements and goes against the recommendations in Chapters 2 and 4 regarding involvement of users/practitioners in developing climate science. As the software industry has learned, user requirements must be emphasized throughout the entire development process if an application is to be successful. Users need to be able to explain what they want, and at the same time be shown examples of the look and feel of a product so they can gain some sense of the possibilities.

Section 3.11 has an anti-innovation tone. It is important to recognize cost and risk, but also to balance these considerations with return. Benefits are discussed elsewhere; editing could usefully bring the discussions together.

Chapter 4: Decision-Support Experiments Within the Water Resource Management Sector

This chapter includes six key findings or recommendations. The material covered in the chapter generally supports the findings; however, this material and the key findings should be more tightly integrated. Reference to the many case studies, which provide much of the evidence for the document's findings, should be integrated into the text and vice versa, so that the case studies are clear illustrations supporting the analysis and key findings. Some of the key findings seem to depend on an analysis of lessons implicit in the case studies, and the case studies do not always include the type of information needed to support the findings.

While the findings call for end-to-end studies, the discussion does not explicitly address the communication of forecasts and operationalization issues that are part of the authoring team's charge.

The six key findings are:

1. Effective integration of climate information in decisions requires sustaining long-term collaborative research and application of decision-support outcomes. Most "experiments" in the use of climate information are relatively young, and it remains to be seen whether they can be sustained. This point comes through mainly in the case studies. It seems to rely heavily on the South Florida water management case, one of 11 cases presented. The background on the other case studies does not always provide information on how long the effort has been developing. The analysis of cases that support this finding could be more effectively summarized and presented.

2. A critical mass of scientists and diverse decision-makers is needed for collaboration to succeed, and there are currently an inadequate number of "integrators" of climate information for specific applications. Other than in findings and summaries, the term "critical mass" appears only in the case study of the Regional Integrated Science and Assessment centers. The definition of critical mass appears in the conclusions on page 327. This point could be supported more strongly by addressing and highlighting this issue in the case studies and in the text, where the emphasis is more often on broad inclusiveness. The claim that there are not many people working as "integrators" is plausible but not well supported in the main text.

3. Forums and other means of stakeholder engagement must be adequately funded and supported by decision-makers and scientists. The finding on forums seems to be supported most strongly by the discussion in Chapter 2. In Chapter 4, it is embedded in the discussion of boundary organizations. Given the emphasis placed on the value and potential of boundary organizations, is not clear why this seemingly narrower point appears among the key findings, whereas a finding about boundary organizations does not. The need for funding of other forms of stakeholder engagement also needs additional support, either from the experience of the authoring group or from other sources. For example, the section that calls for balance of funding might be elaborated. Additional material is needed explain to the reader why this finding is labeled as key.

4. Effective decision support tools must be "end-to-end" useful, meaning that they engage a range of participants, including those who generate them and those who translate them into predictions for decision-maker use. This point is a bit confusing as written. Presumably it is decision-support systems that should be useful from end to end, not decision-support tools, and the people who "translate" climate information to make it useful are more likely to be producing decision-support tools than translating them. If the finding is correctly interpreted in this manner, it is illustrated and supported in Chapter 4, although that support could be strengthened by better integration of the case experiments with the main text.

5. *Good seasonal forecasts are an important tool for bringing scientists and water decision makers together.* The tone of this statement is entrepreneurial, as though seasonal forecasts open the door to a new market. Perhaps this point relates to the first conclusion, about long-term collaboration. There are many examples in which seasonal forecasts have served as a topic of mutual interest for scientists and decision makers and collaborations have developed around them.

6. *Customizable tools—rather than generic services—are the most important products needed by decision-makers.* This statement implies that decision makers need tools they can customize. Research and the text suggest that they also need scientists and boundary organizations—in fact, it may be scientists and boundary organizations rather than the users that customize climate information, thereby creating tools to meet users' needs. The comments about the need for efforts that allow communities and other groups to develop their own capacity are mentioned but not developed in this chapter.

Other Comments:

Page 229, lines 4342 to 4346, lists a number of consequences of changes in streamflow. The connection is not clear to NOAA's seasonal or interannual forecasts, in the sense that it is not clear that improved forecasts from NOAA will do much to help with these issues.

Page 240 lists four major challenges to decision-support systems: lack of integrated decision-support systems, lack of coordinating institutions, lack of stakeholder participation, and overspecialization of science and engineering education. The evidence that these are important challenges is not made explicit. Also, this list does not address the claim about wealth made in Chapter 3. The claim that decision-support information providers have difficulty communicating with each other (lines 4593-4594) contravenes the experience of some such scientists. The document also fails to make clear which of these challenges are most profound and enduring, or which can be addressed effectively by the actions of federal agencies.

Pages 246 (bottom) and 247 (top) identify three reasons that managers may not use climate forecasts. There is documentation for these reasons but no discussion of another potentially important reason: that the expected payoff from using the forecast is relatively small. This might be the case, for example, if a manager does not see climate as a hazard, if the forecast lacks skill in relation to decision-relevant parameters, or if the expected benefit is too small to justify using the forecast.

The case studies of "decision support experiments" are characterized on page 257, line 4837, as being on "employing climate information." However, the first example of the Rio Grande Silver Minnow is about how climate information might help in the analysis, not how it was employed. Also, the Delaware River Basin example is about the potential of the use of climate information, not in its actual use. Such examples should be reconsidered and not used unless they add to the main points of the chapter.

The discussion of how climate variability influences water resource management (pages 238-239) actually addresses only the effects of climate change and cites only Intergovernmental

Panel on Climate Change reports as sources. There is a large number of more geographically detailed studies of the impact of climate change on hydrology and water resources (e.g., in the Western United States) that might be worth examining for this section if indeed it should be including discussion of the effects of climate change. In California, the studies suggest that with climate change, there will be more water when it is not needed, in the early spring, and less when it is needed, during the summer irrigation season. Vicuña and Dracup (2007) review over 60 of these articles.

5

ORGANIZATION AND ACCESSIBILITY

This chapter considers the document in relation to Review Criterion 4, which contains two subquestions: Are the document's presentation, level of technicality, and organization effective? Are the questions outlined in the prospectus addressed and communicated in a manner that is appropriate and accessible for the intended audience? We respond to these questions first for the report overall and then chapter by chapter.

OVERALL COMMENTS

When we met with members of the authoring team, they told us that they were not satisfied with its organization and were already planning to reorganize it. Our comments on organization are based on the July 5 draft and do not take into account the authors' plans as of our meeting July 17.

After Chapter 1, much of the rest of the document seems to confuse the ideas of climate variability and climate change and of predictions (or forecasts) and projections.

The division of content between Chapters 2 and 4 can be confusing. The flow might be improved by putting the discussion of context in Chapter 2 and the findings from decision-support experiments Chapter 4. With the Chapter 3 material moved into another chapter or an appendix, this could considerably improve the presentation.

COMMENTS ON THE INDIVIDUAL CHAPTERS

Chapter 1: A Description and Evaluation of Forecast and Data Products

In this chapter, the level of technicality is varied. There is occasional jargon, much of it mentioned in specific comments below. The organization needs work, and the chapter could definitely be shortened—perhaps by half. The communication is appropriate and accessible but, due to the current length and organization, some messages may get lost.

Distinguish the time scales of forecasts/projections. It would help to have clear descriptions of how forecasts of different timescales are made—different inputs are necessary to determine "signal" (predictability). For example, weather forecasts need initial atmospheric state; seasonal forecasts may need initial atmospheric state in the first month but rely more on sea surface temperature data at longer lead times; climate change forecasts are influenced by changing atmospheric composition (e.g., CO_2); decadal forecasts, which don't really exist yet, will need data on both atmospheric composition and initial state of the oceans. All these predictions use dynamical models—perhaps the same ones—but they are initialized and run differently. The climate community is slowly moving toward "seamless" prediction, but it is not there yet.

It would be helpful to provide a more explicit link between seasonal to interannual climate variability and climate change, since there is so much emphasis on climate change in the rest of the document. Some relevant points to consider:

- The value of seasonal to interannual decision-support systems to climate change adaptation. In theory, awareness and preparation for seasonal to interannual variability can contribute to adaptation to climate change. However, it would be useful to specify the decisions that seasonal to interannual forecasting does not address that require longer time-scale information and to be clearer about the relevant time scales: 10 years? 50 years?
- Expectations of skill may be erroneous, that is, for low-frequency variations predicted in year-to-year operations. While seasonal to interannual predictions show greater skill for temperature variability than precipitation, they have not done a good job at capturing the widespread increases in above-normal temperatures over the United States. Although precipitation would appear to be more difficult to predict, many seasonal to interannual predictions did a reasonable job capturing the multiyear drought from 1998 to 2001 (prediction review of the Predictability, Prediction & Applications Interface Panel, U.S. CLIVAR).
- There are important similarities and differences in the current approaches to predictions versus projections (e.g., no greenhouse gas changes in seasonal to interannual predictions).

Shorten the discussion of forecast skill. This discussion currently takes up two-thirds of the chapter and has a lot of repetition that could be eliminated with tighter organization.

- Section 1.4.1.1, Some Basic Concepts Regarding Forecast Skill, could be dropped. This is 4 pages long, and much of what it says is repeated later. This could potentially be replaced by a short section on the metrics of forecast skill that describes correlation and perhaps something probabilistic, as well as the differences between real and potential predictability. Those tangents later detract from the discussion.
- Information in section 1.4.4 should be absorbed into 1.4.3 and not be a separate section.
- There is a lot of repeated information between 1.4.2, Sources of Hydrologic Forecast Skill, and 1.4.5.1, Skill of Seasonal Water-Supply Forecasts. Perhaps it would be more economical to not separate "sources of skill" from "skill" but have those be a single section—one section for climate and one for hydrology.
- The section Skill of Climate Forecast-Driven Hydrologic Forecasts also has much redundancy. Skill of forecasts is the same concept, whether they are statistical or dynamically driven. If these really need to be broken out into separate subsections, at least have one follow the other.
- The section on skill of long-term climate projections has little on skill assessment, so the section could be shortened quite a bit.
- Why does climate come after the hydrology in section 1.4? It would seem to make more sense for climate to come first.

Overemphasis on forecast accuracy. Forecast accuracy is a deterministic measure, but much of the discussion of the use of forecasts emphasizes their probabilistic nature. The discussion of skill should include the concept as applied to probabilistic forecasts.

Expand the section on skill of seasonal climate forecasts: This section is only two sentences long and contains nothing that states or shows actual skill levels of seasonal climate forecasts. Yet there are some relevant sources, regarding International Research Institute forecasts or Climate Prediction Center forecasts, even though the systems have changed since those articles. Also, the Goddard et al (2006) article shows an example of seasonal forecast skill from the predictions of a large collection of dynamical models both atmosphere with predicted sea surface temperatures and coupled global circulation models, including the Climate Forecast System (see Figure 5-1).

Improve the section on observational networks and data products. This section is currently quite short, and not as powerful as the summary/recommendation point. The section doesn't need to be long, just more specific and compelling.

Reduce the number of tables and figures:

- F1.1 and F1.2 could be dropped or replaced by something available from CPC (a modified version of that is pasted below). Specifically, on F1.1, "lead time" is the time between release of the forecast and the start of the forecast target period. This is about 3-10 days for medium range and only 1-12 months for season to interannual forecasts. Also, the weather-climate boundary is between medium range and season to interannual, not between short and medium range.
- Table 1.2 doesn't add much to the discussion.
- F1.3 is not particularly useful. The link above it leads to a potentially confusing list of products, none of them accompanied by any description. It might be better just to keep F1.4 and F1.5 and add URLs to their captions.
- F1.6 caption should make clear that this is a "POE Map" (add URL?) or else interested parties will never find it on the Climate Prediction Center site.
- F1.7 could be deleted. The F1.8 caption could indicate that the Probability of Exceedance graphs are based on climate division data.
- F1.9 and F1.10 could be deleted.
- F1.15-F1.18 all show examples of hydrological forecasts with associated uncertainties. Could they be combined into a single 4-panel figure, which then illustrates similarities and differences of hydrological forecast presentation? Or do they actually make different points?
- F1.20 is valuable and helps make several relevant points in the text.
- F1.25 is confusing and doesn't add much to the discussion.

Chapter 2: Moving Knowledge to Action

This chapter focuses on the context of decision making. Although these issues are critical, they aren't all captured in this chapter. For example, risk perceptions and risk communication strategies, both discussed in Chapter 4, are also part of the context of decision making. These concepts are not fully developed in the Chapter 4 discussions. For example, what is known about how the framing of climate change as a public policy issue may affect how water resource managers utilize climate information?

The discussion of the "prior appropriation doctrine" is not very clear. A further discussion is needed of overappropriated streams that create problems due to junior rights holders who have claims to any water not claimed by the senior rights holder (the issued is not that the senior rights holder uses "virtually all the water"). Water conservation schemes have to be agreements among all users, or senior rights holders have to sell or lease rights to another user. Water markets and banks in the West are still highly controversial, especially among landowners/water users, and a market solution for water shortages is still some distance in the future.

In discussing the communication of climate science to and with varying audiences, the authors reference the "deficit model" but don't talk about other communication models and research. There are several recent articles in *Public Understanding of Science* (e.g., Weingart, Engels, and Panescrau, 2000). An older review of risk communication research is the National Research Council report, *Improving Risk Communication* (1989), including an appendix by Baruch Fischhoff.

The discussion of institutional response, adaptation, and learning in relation to climate science opens with reference to the work of Baumgartner and Jones (p. 129) but does not follow up very systematically. (*Water Resources Research* has published some interesting work regarding water resource agencies).

Chapter 3: Managing Innovation: Ensuring Success in Joining Research and Operations

This chapter focuses on innovation in the context of federal agencies responsible for developing climate forecasts. Much of the chapter does not directly engage with the insights developed in other chapters about various kinds of disconnects between what forecasters produce and what users want or need. As written, the material on innovation is too nonspecific to engage researchers concerned with applications to water resources and much too lengthy to engage executive readers. Despite the level of detail, the chapter doesn't fully cover the range of innovation models that may help explain why climate information is or is not integrated into existing or emerging decision systems. Managing innovation may be a critical component to understanding decision systems, but the document does not make a compelling case.

Much of the chapter seems more like a sidebar than part of the main flow of the argument about decision-support needs and experiments. The information on innovation in federal agencies might be placed appropriately in an appendix, with other text moved to Chapter 4, condensed and sharpened to relate more clearly to the rest of the chapters. In particular, sections 3.2 and 3.4 are too detailed and should be seriously shortened or moved to an appendix. Section 3.6 is a list of rhetorical questions, the value of which to the report is unclear. Similarly, the value of section 3.8 is not evident.

The kinds of innovation that are the focus of this chapter—innovations in forecasting apparently developed without direct connection to user needs—do not fit well with the issues raised in Chapters 2 and 4. Such innovations in forecasting may have served the nation well in an era when climate change and variability were issues of lesser concern, but this is no longer the case. Now, forecast information related to climate variability on a 1- to 10-year time horizon may be of profound interest to agribusiness, natural resource managers and industries, water supply managers, and others. Decadal projections will be of interest to these groups and others, such as those making long-term investment decisions (e.g., the oil and gas industry in Alaska, which has long operated on ice roads constructed according to historic permafrost conditions that may now be changing). Moreover, the projected growth of the U.S. population by nearly 100 million people in the next 40 years will cause additional demand on resources that will be affected by climate variability and change. Discussion of user needs in the document, in whatever chapter, should provide some context related to demographic changes (population, geographic density, immigration and risk, etc.) that may further change needs for climate projections, particular on long time scales, and perhaps also for better characterization of uncertainty in the projections.

Until near the end, the chapter proceeds without recognition that (as noted elsewhere in the document), federal science agencies often lack understanding of the needs of users and of how to appropriately integrate them. For example, a recent National Research Council (2006b) review of the Advanced Hydrologic Prediction Service showed that the National Weather Service had only marginally considered a user integration strategy. The Advanced Hydrologic Prediction Service, a suite of tools to enhance the river forecast centers, was virtually unknown by the floodplain management community, a key potential user. Innovation by forecasters may have little to do with making climate information more useful to decision makers, but this possibility is barely addressed or considered in this chapter. The way this chapter is written makes it difficult to determine if the authors are raising concerns related to the ineffective incorporation of users into the process or continuing to write from a model that does not fully recognize the challenges of user engagement.

There are some apparent references to comments made by attendees at a workshop or conference. It would be helpful to know more about the methods used to collect information, including at the workshop or conference. However, such anecdotal information cannot substitute for a discussion of the published research on this topic.

Chapter 4: Decision-Support Experiments Within the Water Resource Management Sector

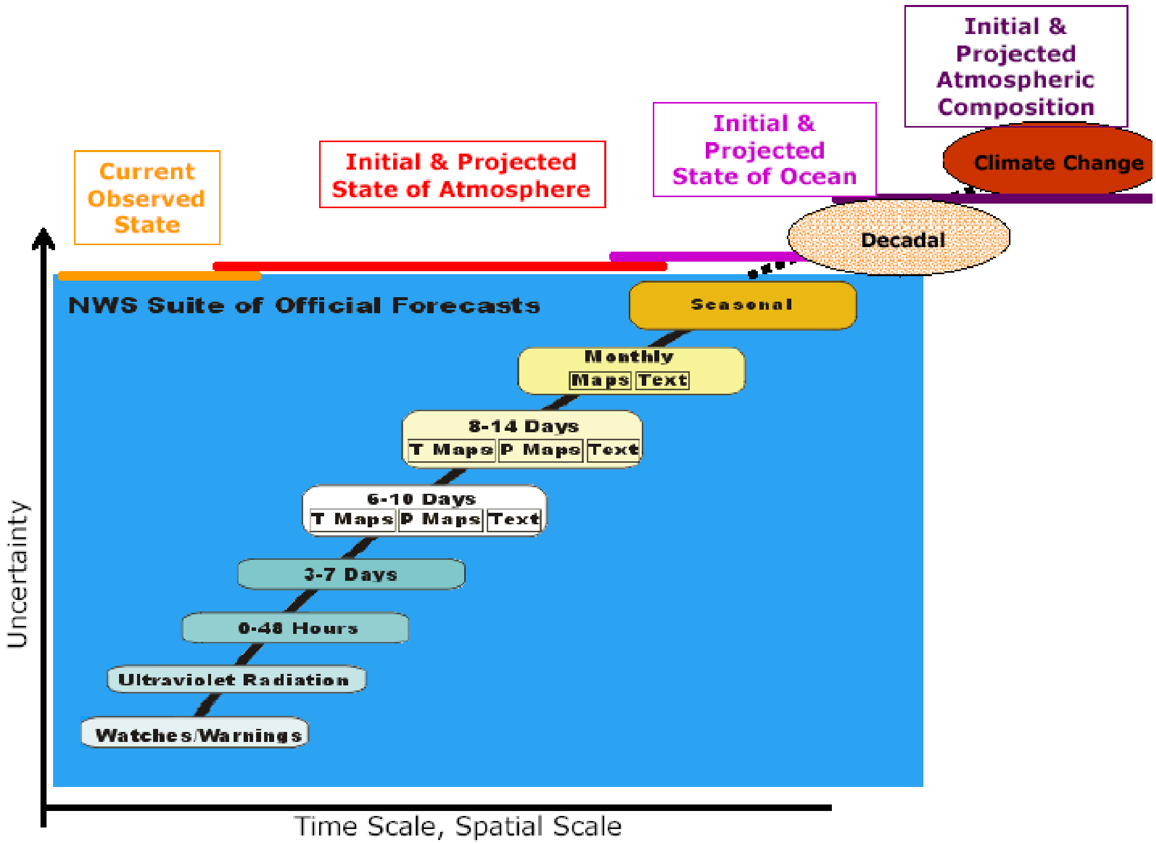
The organization of Chapter 4 needs to be revisited to reduce redundancies and treatment of the same topics in multiple places. In addition, in several instances, the contents of the sections do not correspond closely to the central questions identified in the subheadings. The case studies do not make a clear effort to develop the major themes and observations made in the text or to support the key findings of the chapter.

The language needs careful review for consistency and accuracy, so that climate variability and climate change do not appear to be used interchangeably and so that projections are not confused with forecasts.

This chapter suffers from too much technical jargon that is not clearly related to the context of water resources. For example, does “adaptive management” as used in this chapter mean anything more than simply changing strategies as new information becomes available? If more is meant, the meaning should be made clear.

The term “decision-support system” should be given a clear definition for the water resource management context. The term is critical in Chapter 4 but should be defined early in the report. How the authors see the term as being defined for water resource management would be an important contribution. The term is often used to refer to a computerized system for making decisions or that aids the process of decision making. Clearly, the authors sometimes are using a broader meaning. They are now able to refer to the discussion of the term in a new NRC (2007) report, *Research and Networks for Decision Support in NOAA's Sectoral Applications Research Program.*

Figure 5-1 An example of seasonal forecast skill.



SOURCE: Modified by L. Goddard, based on NCEP-CPC schematic from http://www.cpc.ncep.noaa.gov/products/forecasts.

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APPENDIX A

Topics for Synthesis and Assessment Products of the U.S. Climate Change Science Program

1-1 Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences.
1-2 Past Climate Variability and Change in the Arctic and at High Latitudes
1-3 Re-analyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change.
2-1 Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Application.
2-2 North American carbon budget and implications for the global carbon cycle.
2-3 Aerosol properties and their impacts on climate.
2-4 Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure.
3-1 Climate Models: An Assessment of Strengths and Limitations for User Applications.
3-2 Climate projections for research and assessment based on emissions scenarios developed through the CCTP.
3-3 Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific islands.
3-4 Abrupt Climate Change.
4-1 Coastal elevation and sensitivity to sea level rise.
4-2 Thresholds of Change in Ecosystems.
4-3 The effects of climate change on agriculture, biodiversity, land, and water resources.
4-4 Preliminary review of adaptation options for climate-sensitive ecosystems and resources.
4-5 Effects of Climate Change on Energy Production and Use in the United States.
4-6 Analyses of the effects of global change on human health and welfare and human systems.
4-7 Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study.
5-1 Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions.
5-2 Best practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decision making.
5-3 Decision support experiments and evaluations using seasonal to interannual forecasts and observational data.

APPENDIX B

Biographical Sketches of Panel Members and Staff

SOROOSH SOROOSHIAN (*Chair*) is distinguished professor of civil and environmental engineering and of earth system science at the University of California, Irvine. His research focuses on surface hydrology, primarily in the area of rainfall-runoff modeling. He has devoted much of his effort to model identification and calibration issues and has developed special estimation criteria to account for the uncertainties of calibration data. He also consults on problems related to surface hydrology and flood forecasting. He is a member of the National Academy of Engineering (NAE) and has been a member of several NRC committees. He is currently chair of the Global Energy and Water Cycle Experiment Panel. He has a B.S. in mechanical engineering and an M.S. in operations research from California Polytechnic State University and a Ph.D. in systems engineering from the University of California, Los Angeles.

KIRSTIN DOW is associate professor in the Department of Geography at the University of South Carolina. She is also a senior research fellow at the Stockholm Environmental Institute, where she serves on the Advisory Committee on the Poverty and Vulnerability Program. Her areas of interest include environmental change, hazards and vulnerability, climate risks and decision making, and environmental justice. Her research projects address vulnerability and decision making with respect to climate variability, climate change, and water resources. She has authored and coauthored many journal articles and book chapters along with peer and book reviews. In 2005 she was awarded the Zayed prize for scientific and technical achievement. She has M.A. and Ph.D. degrees in geography from Clark University.

JOHN A. DRACUP is professor in the Department of Civil and Environmental Engineering at the University of California, Berkeley. Previously he served on the faculty of the University of California, Los Angeles. His research interests include hydroclimatology; analysis of large-scale water resource systems and hydrologic and environmental systems; engineering economics of water resources systems; and surface water hydrology. He served as lieutenant with the U.S. Army Corps of Engineers from 1957 to 1958. He has a B.S. from the University of Washington an M.S. from the Massachusetts Institute of Technology, and a Ph.D. from the University of California, Berkeley.

LISA GODDARD is a research scientist at the International Research Institute for Climate and Society. She has been working for the International Research Institute (IRI) at Columbia University since 1995, developing and improving IRI's climate forecasts. Her research interests are aimed at improving the quality and content of seasonal climate predictions. This goal is approached with a focus on climate diagnostics and climate predictability. Research areas include El Niño/La Niña and their impact on climate variability and predictability; methodologies for identifying the relative importance of regional SSTs to regional climate variability; and, assessment of climate prediction tools. She has a B.A. from the University of California, Berkeley, an M.A. from Princeton University, and a Ph.D. in atmospheric and oceanic sciences from Princeton University.

MICHAEL HANEMANN is professor of agricultural and resource economics at the University of California, Berkeley. His research interests include nonmarket valuation, environmental economics and policy, water pricing and management, demand modeling for market research and policy design, the economics of irreversibility and adaptive management, and welfare economics. His current project focuses on testing and calibrating the measurement of nonmarket values for oil spills via the contingent valuation method. He has an M.A. in public finance and decision theory and a Ph.D. in economics, both from Harvard University.

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