# Review of the U.S. Climate Change Science Program's Synthesis and Assessment Product 1.3: Reanalyses of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change

Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 1.3

Board on Atmospheric Sciences and Climate

Division on Earth and Life Studies

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

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This material is based upon work supported by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA) under NSF grant number ATM-0455946. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of NSF, of NOAA, or any of its sub agencies.

Copies of this report are available from the program office:
Board on Atmospheric Sciences and Climate
500 Fifth Street, N.W.
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Printed in the United States of America

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# Acknowledgments

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

Mary Anne Carroll, University of Michigan, Ann Arbor
Peter R. Leavitt, Weather Information Company, Newton Centre, Massachusetts
Elizabeth L. Malone, Joint Global Change Research Institute, College Park, Maryland
Joellen L. Russell, University of Arizona, Tucson
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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 Lynne D. Talley, Scripps Institution of Oceanography, La Jolla, California. Appointed by the National Research Council, she 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

# Summary

A primary objective of the Climate Change Science Program (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 that address its highest priority research, observation, and decision-support needs. The National Oceanic and Atmospheric Administration (NOAA) is the lead agency on Synthesis and Assessment Product (SAP) 1.3 "Reanalyses of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change". The objective of this product is to provide an expert assessment of the capability and limitations of state-of-the-art climate reanalyses to describe past and current climate conditions, and the consequent implications for scientifically interpreting the causes of climate variations and change.

As part of the CCSP process, NOAA has requested an independent review of SAP 1.3 by the National Research Council (NRC). The NRC appointed an ad hoc committee of climate scientists who engage in reanalysis efforts to review the draft SAP 1.3 focusing on the extent to which the draft document meets the requirements set forth in the prospectus. The current draft was clearly written for an audience of researchers involved in assessment efforts. The product assesses the capability of current reanalysis for quantifying climate variations and long-term trends. The authors rightly state that substantial efforts are needed to correct biases and discontinuities in various observational data before they are assimilated into reanalyses. The committee commends the authors for clearly stating their goals and their intended audience and for their fidelity in following the prospectus. However, the current draft needs revision to better link reanalysis and attribution. This connection is often missing and attribution is not tied to reanalysis directly. In addition, the document needs to better explain how reanalysis fits into climate science and include a general description of how climate science is done and how the models, observations, and theories are related to the ultimate goal of reanalysis, especially for the benefit of non-specialists. Also, in the technical sections of the report, more details about the models used and statistical methods employed need to be included (see specific chapter reviews).

Although the assessments community should find this document extremely helpful, understanding the present level of scientific confidence and remaining uncertainties in identifying and describing how the climate system has varied over approximately the last half-century is critical and should be explained to all stakeholders of climate change science as outlined in the SAP prospectus. In this sense, the current draft of SAP 1.3 falls short of the requirements set forth in the prospectus. The draft does not address all of the specified audiences, particularly "policymakers, decision-makers, and members of the media and general public with an interest in developing a fundamental understanding of the issue." Chapters 2 and 3 do not necessarily describe the state-of-the-science, the problems in methodology adopted in the current models, and the most uncertain factors in the current research regarding reanalysis and attribution. Much of the data in the product is original research. The authors should explicitly distinguish the findings from the peer-reviewed literature from those derived from original work. The report should give precedence to peer-reviewed literature whenever possible.

# 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 upon 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 that address its highest priority research, observation, and decision-support needs. The CCSP is conducting 21 such activities, covering topics such 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 has been / will be 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.

The National Oceanic and Atmospheric Administration (NOAA) is the lead agency for CCSP Synthesis and Assessment Product (SAP) 1.3 “Reanalyses of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change”. NOAA’s stated purpose for SAP 1.3 is to provide an expert assessment of the capability and limitations of state-of-the-art climate reanalyses to describe past and current climate conditions, and the consequent implications for scientifically interpreting the causes of climate variations and change.

The Prospectus (Appendix B) describes the topic, audience, intended use, and questions to be addressed by SAP 1.3, as summarized here:

*This proposed CCSP report will be in the form of a synthesis and assessment product that (a) summarizes the present status of national and international climate reanalysis efforts, and (b) discusses key research findings on the strengths and limitations of the current reanalysis products for describing and analyzing the causes of climate variations and trends that have occurred during the time period of the reanalysis records (roughly the past half-century). The proposed report will describe how reanalysis products have been used in documenting, integrating, and advancing our knowledge of climate system behavior, as well as in ascertaining significant remaining uncertainties in descriptions and physical understanding of the climate system.*

*By identifying key limitations of the current generation of reanalyses, the report will be useful to policymakers in identifying and understanding the causes for remaining uncertainties, and for climate program managers in developing priorities for future observing, modeling, and analysis systems required to advance national and international efforts to describe and attribute causes of observed climate variations and change. The assessment of the capabilities and limitations of current reanalysis products for different applications will also be of value to users of reanalysis products.*

*The assessment of present uses and limitation of reanalysis products for attribution of causes of observed climate variations and trends will provide a basis for decision makers and policymakers to understand the present level of confidence and uncertainties in describing how the climate system has varied in the recent historical past, and how this has enabled, and in some cases limited, our ability to identify the causes of such variations. The report will also provide useful information to help the scientific community and public to understand the causes of past climate variations, especially for those events that have high societal, economic, or environmental impacts, such as large and prolonged droughts.*

According to the guidance provided in the prospectus, SAP 1.3 is to be written in a style consistent with major international scientific assessments. To address these purposes and audiences, SAP 1.3 was given 10 key questions to address (see Box 1). In a review of the U.S. CCSP Strategic Plan, the National Research Council (NRC) recommended that synthesis and assessment products should be produced with independent oversight and review from the wider scientific and stakeholder communities (NRC, 2004). To meet this goal, NOAA has requested an independent review of SAP 1.3 by the NRC. The NRC appointed an ad hoc committee composed of 7 members (Appendix C). The committee's Statement of Task is included in Appendix D.

The committee conducted its work by first carefully reading the draft SAP 1.3 report "Re-analyses of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change" (draft dated August 20, 2007). The committee then met with the lead authors to ask questions about the authoring team's research and formulation of the draft document. During this meeting, the committee also interacted with NOAA personnel, who outlined for the committee

their expectations for SAP 1.3. This present document constitutes the committee's review report, resulting from its careful study of the draft SAP 1.3 document and its interactions with those present at the aforementioned meeting. Herein the committee provides its review findings, with recommendations, suggestions, and options for the authors to consider in revising the draft SAP 1.3. In its review, the committee focused on substantive matters of content and did not exhaustively proofread the document for grammatical or typographical errors.

**BOX 1-1**

**Questions to be addressed by CCSP Synthesis and Assessment Product 1.3**

According to guidance in the CCSP prospectus outlining the purpose of SAP 1.3, the report will consist of two components.

1. *Descriptions of Past Climate Variations and Trends*. This section will focus on the strengths and limitations of current reanalysis systems for identifying and describing past climate variations.
2. *Attribution of the Causes of Climate Variations and Trends*. This section will assess present uses and limitations of reanalysis products for attributing the causes of observed climate variations and trends over North America during the time period (1948 to present) included in present-generation reanalyses. Emphasis will be placed on advances in our understanding of the causes of major climate variations over this region and period subsequent to work included in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report published in 2001.

SAP 1.3 is intended to provide a summary of the present level of scientific confidence and remaining uncertainties in identifying and describing how the climate system has varied over approximately the last half-century. The discussion of limitations of current reanalyses will provide valuable information for developing priorities for data recovery and quality control efforts and future requirements for improving models, data assimilation methods, and observing systems to reduce uncertainties and improve our ability to describe past and ongoing climate variability and change. SAP 1.3 will also provide recommended steps to improve future analyses and reanalyses of the climate system, and discuss how this information can be developed and applied more effectively to increase confidence and reduce uncertainties in interpreting the causes for past and ongoing climate variations and change.

The key questions to be addressed by SAP 1.3 are:

1. What is a climate reanalysis, and what role does reanalysis play within a comprehensive climate observing system?
2. What can reanalysis tell us about climate forcing and the veracity of climate models?
3. What is the capacity of current reanalyses to help us identify and understand major seasonal-to-decadal climate variations, including changes in the frequency and intensity of climate extremes such as droughts?
4. To what extent is there agreement or disagreement between climate trends in surface temperature and precipitation derived from reanalyses and those derived from independent data?
5. What steps would be most useful in reducing spurious trends and other major uncertainties in describing the past behavior of the climate system through reanalysis methods? Specifically, what contributions could be made through improvements in data recovery or quality control, modeling, or data assimilation techniques?
6. What is climate attribution, and what are the scientific methods used for establishing attribution?
7. What is the present understanding of the causes for North American climate trends in annual temperature and precipitation during the reanalysis record?
8. What is the present understanding of causes for seasonal and regional differences in U.S. temperature and precipitation trends over the reanalysis record?
9. What is the nature and cause of apparent rapid climate shifts, having material relevance to North America, over the reanalysis record?
10. What is our present understanding of the causes for high-impact drought events over North America over the reanalysis record?

# 2

# Key Issues

Reanalysis is an important and relatively new method in climate science that can provide a context in which to put new climate observations. The reanalysis technique integrates a diverse array of observations within a physical model of the climate system (or of one of its components, such as the atmosphere, ocean, or land surface) to describe past conditions over an extended time period, typically several decades. An important goal of reanalysis is to provide comprehensive, consistent long-term climate data sets that are reliable on hourly to decadal and longer time scales. Another important aspect of reanalysis is that it is three dimensional through at least the depth of the atmosphere (Kistler et al., 2001). SAP 1.3 deals primarily with global reanalyses, however, regional reanalyses are becoming ever more common (e.g., the North American Regional Reanalysis http://www.emc.ncep.noaa.gov/mmb/rreanl/).

By comparing recent surface observations with the corresponding atmospheric dynamical fields estimated by reanalysis we can begin to assess whether current conditions are unusual, whether they are part of a long-term trend, or a result of climate variability that may be expected to reverse over months, seasons, or years. In addition, reanalysis can help determine whether similar or related changes are occurring in other parts of the globe and help identify the processes and mechanisms that can explain current conditions, and how are they similar to, or different from, what has occurred in the past.

This report addresses the strengths and limitations of current reanalysis products in documenting, integrating, and advancing our knowledge of the climate system. It also assesses current capabilities and remaining uncertainties in our ability to attribute causes for climate variations and trends over North America during the reanalysis period (1948-present), and discusses the uses, limits and opportunities for improvement of reanalysis data applied for this purpose.

While current reanalysis products provide a foundation for climate research, reanalysis data are now used in an increasing range of commercial and business applications, such as energy (supply/demand analysis, assessing locations for wind power generation), agriculture, water resource management, insurance and reinsurance. Thus the Climate Change Science Program's (CCSP) Synthesis and Assessment Product (SAP) 1.3 will potentially be very beneficial to all stakeholders of climate change science. The committee commends CCSP and the National Oceanic and Atmospheric Administration (NOAA) for emphasizing the need to address this important topic.

This chapter outlines the major issues that, from the point of view of the review committee, the authors should strongly consider addressing in the revised version of SAP 1.3. In some cases, findings are simply noted without explicit recommendations. In other cases, the committee provides either a direct recommendation or alternatives for the authors to consider as they address the review findings. In subsequent chapters of this report, the committee provides further overarching thoughts on the draft document and findings and recommendations specific to individual chapters of the draft. Comments regarding key issues follow.

The committee finds that in general, the authors nicely summarize the capability of current reanalysis for quantifying climate variations and long-term trends. SAP 1.3 appears to be scientifically objective and policy neutral. In cases where the results of SAP 1.3 are compared with existing peer-reviewed literature, the SAP 1.3 results are consistent with existing data. However, a significant fraction of the SAP 1.3 results is not compared with peer-reviewed literature and the authors are encouraged to compare their results with the peer-reviewed literature whenever possible. The authors correctly point out that the strength of current atmospheric reanalysis is its global coverage and complete description of atmospheric states, and that the reanalysis is best used for quantifying atmospheric processes at synoptic to decadal time scales (including describing the El Niño-Southern Oscillation (ENSO) and the spatial patterns of atmospheric modes such as the Pacific-North America Oscillation (PNA), the North Atlantic Oscillation (NAO)) , but not appropriate for longer-term changes (for example trends in precipitation, atmospheric water vapor or even surface air temperature). The authors rightly state that substantial efforts are needed to correct biases and discontinuities in various observational data before they are assimilated into reanalysis. The committee commends the authors for clearly stating their goals and their intended audience and for their fidelity in following the prospectus.

The primary issues identified by the committee focus on the effectiveness of the document's presentation, level of technicality and organization, as well as accessibility of the document to its target audiences. The committee identified the following issues and offers suggestions on how to improve the document.

1. **The title and contents of the document are not entirely consistent.** The title of the present draft, "Reanalyses of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change," correctly suggests that reanalysis data is useful for attributing the causes of observed climate change. This link, however, is often missing and attribution is not tied to reanalysis directly. All

elements of the document (title, table of contents, chapters and recommendation) fail to link reanalysis to attribution to various degrees. In particular, there is a mismatch between chapters 2 and 3. The document would greatly benefit from tying these two chapters together more strongly. This could be accomplished by the following.

The document should stress that climate science needs a more quantitative way to bring multiple lines of evidence together, and that reanalysis provides an important means to do so. This point should be the theme throughout the report and should be evident in the abstract, preface, summary, introduction and in each chapter and recommendation, as appropriate. Highlighting this point often will help emphasize the message of the report.

The document should clearly explain why reanalysis is needed and how reanalysis is connected to attribution. This discussion should emphasize what aspects of this work, such as diagnosing and assessing climate model output, both in terms of model veracity and aspect of simulated climate change and variability, could not have been done without reanalysis.

The document should highlight the difficulties in connecting attribution to reanalysis and what data and steps are needed to overcome these challenges. For example, the attempt at attribution with reanalysis surface variables appears to indicate that model based reanalysis does not aid in the attribution problem. This may indicate a real need to better assimilate the available surface data in order to address the surface attribution problem. Other challenges include assimilation of analyzed surface data such as gridded temperature and precipitation data into the reanalysis, minimizing spurious changes in the reanalysis data due to changes in input data, and improved data quality control for raw observations assimilated into the reanalysis.

2. **The document is not accessible to all intended audiences.** The committee finds that the draft is written largely for a technical audience. The intended audiences as outlined in the prospectus include those people engaged in scientific research, the media, policymakers, and the general public. Policy and decision-makers in the public sector (e.g., congressional staff) need to understand the implications of reanalysis and its role in attribution, in contrast to the research science community, who may be more interested in the actual outcomes. The draft would benefit from including more information for an audience of non-technical readers, particularly information that could be used as guidelines for effective communication techniques. In general, the draft would greatly benefit from revisions to highlight the essential points of the document. Some specific suggestions follow.

   The committee was informed by the authors that a major goal for this document was to provide education for both a general audience and a scientific audience. The education function of this document could be improved by explicitly stating why reanalysis is needed in plain language. The document should clearly state how climate science is done and how reanalysis fits in a more broad perspective. Risk type language may be a better

way to attribute causes of climate change and the committee suggests using a probabilistic approach to explain uncertainties. This could be illustrated in call out boxes illustrating these scientific concepts, which may improve communication without interrupting the flow of the document.

The committee finds that the medical analogy was not helpful and in some ways misleading, and suggests that a concrete example to illustrate how attribution is done in a step by step manner should be substituted. This approach would be beneficial to policy makers and to scientific program managers.

Although this is primarily an agency-written government report, a key mission of many federal agencies is to provide education and outreach for their programs. At present, the document does not clearly mention the academic community, which is a key audience and principal contributor to reanalysis work.

An example of explaining the benefits of using reanalysis and attribution in conjunction is highlighted in Recommendation A2 (An important focus for future attribution research should be on developing capabilities for better explaining climate conditions at regional to local scales, including the roles of changes in land cover/use and aerosols, as well as changes in greenhouse gases, sea surface temperatures, and other forcing factors.) This recommendation illustrates the benefits of combining reanalysis and attribution for societal benefit and should be mentioned in the introduction.

The organization of the report could be improved by a stronger tie between chapters 2 and 3. It is important to explain how these chapters fit together and why the reanalysis period was chosen. The key findings are summarized at the beginning of Chapters 2 and 3, and also in the Executive Summary, which helps the flow of information, but the summaries are not consistent. The consistency needs to be improved, bearing in mind that many readers will consult the individual chapter summaries for additional detail after the executive summary. The main points of the chapters should be highlighted in these summaries.

The committee finds that the lack of a non-technical executive summary hinders the document's accessibility to the audiences named in the prospectus. A concise and readable summary of the document, including key findings and recommendations, would enable all audiences -- producers of synthesis and assessment products, scientific researchers, decision-makers, media, and the public -- to glean the main points and to locate further information that may be of interest to them. The document should include a short executive summary for non-technical readers, such as congressional staff, local and regional governmental decision makers. The summary should be clearly labeled as such (non-technical or other indication) and not be merely descriptive, but informative on the main points of the document. The summary should use

plain language to describe the goals of the report, the principal findings and why reanalysis is important to attribution, as well as to highlight the strengths and limitations of reanalysis. It may also be beneficial to explain to the lay reader that it is the limitations of reanalysis that drive future research directions. *An alternate approach could be to add a box explaining the differences between these topics and explaining how climate science is done within the current executive summary.*

A technical summary written for an informed general scientific audience should be included. This should be written using clearly defined technical language (without acronyms) so that the general scientific community, not just atmospheric scientists, can understand the goals, findings and relevance of the study.

If some chapters are to use technical language, the introduction chapter should contain a section with advice on "How to read this document" – a paragraph that describes the intent of each chapter and its target audience. For instance, the paragraph may state: Chapter 1 provides an introduction to the study and relevant findings from previous studies and is intended to provide all audiences with a general overview. Chapters 2 and 3 provide detailed technical information about specific models, model runs and trends and are intended primarily for the scientific community. Chapter 4, which is intended for all audiences, provides a summary of the major findings and identifies new opportunities for future research.

3. **Introductory material is lacking.** The draft would be improved if the introduction section (either the preface or Chapter 1) provided a clear framework and context for the rest of the document. At present, the scope of and motivation for the study are not well explained. The authors should stress that the topic is directly related to some of the most basic and frequently asked questions by the public and decision-makers. For example: What do we know about past climate? What are our uncertainties? What do we know about the causes of climate variations and change? What are our uncertainties on causes? Reanalysis addresses science challenges at the heart of CCSP Goal 1: **"**Improve knowledge of the Earth's past and present climate environment, including its natural variability, and improve understanding of the causes of observed variability and change." This topic is directly relevant to core questions on our current scientific abilities to detect and attribute causes of climate variability and change. Some specific suggestions follow.

   At present the public perception of reanalysis is woefully inadequate. The introduction would benefit from a discussion of the usefulness of reanalysis in understanding climate variation, which is a compelling national need that is of vital interest to the nation and society. The introduction should educate the reader about how reanalysis fits into climate science and include a general description of how climate science is done and how the models, observations, and theories are related to the ultimate goal of reanalysis. The introduction should ultimately highlight the benefits and limitations of reanalysis and

should provide information to all readers, including the public, congressional staff, science program managers and, hopefully, a new generation of students. In the current draft of the document, the transition to technical material is far too abrupt. Specific ways to improve the introduction follow.

The introduction should explain what analysis is, distinguish reanalysis from climate data analysis, and explain how reanalysis fills in a data and knowledge gap. The strengths and limitations of the reanalysis approach should be stated and the unique contributions that reanalysis makes over existing climate analyses should be highlighted. It should stress that reanalysis may in some cases be the best tool for obtaining information about critical aspects of the climate system. In addition, the document should clearly state what is needed to be done to make reanalysis more powerful.

The introduction needs to clearly explain the motivation for ad hoc choices such as why the German rainfall data was used in Chapter 2. The introduction should also clearly convey the limitations of current reanalysis and that reanalysis could be used for future studies provided specific improvements were made. It is also important to mention that reanalysis has the potential to be an effective way of assessing long-term climate change.

The introduction should also highlight that because society needs to have the clearest picture of climate, reanalysis activities should continue in order to provide a way to evaluate the majority of climate information. In addition, there is a need to explain why there are no more effective options for such evaluation.

The introduction (either the preface or Chapter 1) should outline the charge to the authors as they perceived it, and clearly define the goals and objectives of the document. The foreword or introduction should also state explicitly what the document does *not* address.

4. **Details about the methods, data sources and assumptions used are lacking.** Specific details about the methods, data and assumptions used in this assessment need to be provided within the document to enable a meaningful interpretation of the data, especially those that are not compared to the peer-reviewed literature. The committee suggests that the report be revised to rely more on the published literature as opposed to the authors' original research. At present there is no discussion about how statistical significance was determined. The statistical significance of certain trends is discussed and judgments are made about the relative significance, yet there is no description of how this was calculated. This is particularly important for the unpublished results calculated by the authors. This information could be provided in an appendix and should clearly describe the statistical approaches used to determine the relative significance of trends and explain the rationale behind why and how judgments were made. The committee suggests that technical details regarding the previously-unpublished calculations and syntheses of climate model output in Chapter 3 either be included in the text of Chapter 3 or in a separate appendix to

enable an interested and motivated reader to draw his/her own conclusions. More general information about the methods, data sources and assumptions used could be included in the introduction (see reviews of specific chapters for suggestions).

5. **The document heavily relies on original research and does not include sufficient peer-reviewed literature**. Although the committee finds that the results presented in the document are consistent with scientific literature and that the document appears to be objective, the document relies too heavily on original, non-peer-reviewed work. The authors should include more discussion of findings in the scientific literature and how the unpublished findings compare with previously published findings (especially for sections 3.1 through 3.3). While the authors provide compelling evidence supporting their recommendations, greater lengths are needed to distinguish their work from peer-reviewed literature. At present, it is difficult to determine how much of the document is collective opinioned. The authors should explicitly distinguish the findings from the peer-reviewed literature from those derived from original work. The report should give precedence to peer-review literature whenever possible.

6. **The document and its language should be clarified.** The committee notes that the document lacks a suitable table of contents and that section and subsection headings are generally too wordy. At the level of language, the phrasing regarding attribution is awkward. It is more correct to say that one attributes climate variations to particular causes, not that one attributes causes to climate variations. Also, one should speak of causes of variations, not causes for variations.

# 3

# Review of Individual Chapters

This chapter provides specific comments on the four individual chapters of draft Synthesis and Assessment Product (SAP) 1.3. In some cases, these specific comments relate to the overarching comments provided in the previous two chapters of this review. In the other cases, these specific comments are generally minor in nature. The review of each chapter includes a statement that summarizes the committee's overall thoughts. For some chapters, there are enumerated comments that follow this statement to provide suggested editorial changes or other details for the authors to consider during the revision process.

## ABSTRACT

**General remarks:**

The abstract has two paragraphs summarizing the attribution section, and no paragraphs summarizing the reanalysis section. The abstract would benefit from a better balance.

The use of "variations in global sea surface temperatures" can be misconstrued as referring to temporal variations in the global-mean sea surface temperature. The committee suggests deleting "global" wherever it appears in this context.

**Specific remarks:**

L61-63: Wording implies that sea surface temperature variations are independent of anthropogenic forcing.

## PREFACE

**General remarks:**

The committee finds the tables corresponding to treatment of uncertainty on Page 11 unhelpful without more context or specific examples. While it makes sense to use terms consistent with IPCC, the quantitative probabilities can only be interpreted in the context of the models that are used to estimate them. A note should be added here that the

specific context will always be made clear throughout the document. One way to improve Table P1 would be to add column headings and include a category for $0.33<p<0.50$.

**Specific remarks:**

L 131, 138: "climate" should be replaced with "weather and climate"

L225: "for" should be replaced with "with"

L226: Delete "up through"

L229: "supercede" should be replaced with "supersede"

## EXECUTIVE SUMMARY

**General remarks:**

Most of the key findings on attribution listed on P18-21 regarding surface temperature and rainfall trends are based on surface observations and climate model simulations, and thus can be assessed without reanalysis directly. The committee finds that most of the conclusions appear to be independent of reanalysis and that the authors need to strengthen the case that reanalysis is in fact critical in reaching these conclusions, for example by stressing the indirect use of reanalysis for the attribution of climate variability and in testing the Global Circulation Models (GCMs).

Page 20: need some statements regarding the fact that the SST changes may be due to anthropogenic forcings.

There is some confusion about the usage of "change". One suggestion is to replace "a change has occurred" (or similar wording) with "an anthropogenic change has occurred" on L418 & throughout: Changes caused by solar variability would be called changes by this document, yet they are natural. Later (lines 3044-3046), for example, changes are partly attributed to natural causes. This language needs to be much more precise.

**Specific remarks:**

L278-279: "conditions and, more generally, conditions of other" should be replaced with "conditions, including various";

L278-279: "the oceans" should be replaced with "the atmosphere, oceans"

L312: "consistent" should be replaced with "internally consistent"

L329: "synoptic (weather)" should be replaced with "regional"

L378-383: This evidence is among the weakest on this point in the relevant chapter.

L423-426: Quotation of "some published evidence" does not rise to the level of scientific confidence meriting inclusion in the Executive Summary.

## CHAPTER 1

## INTRODUCTION

**General remarks:**

Chapter 1 needs to be revised so that it fulfills the educational component of the document. The committee is concerned that this chapter is not written so that it can easily be understood by the non-specialist and that it does not adequately explain reanalysis and attribution and how these techniques are related. These concerns are especially relevant to this chapter, as it sets the stage for (and provides a summary of) the other chapters. The document should be revised by including explanations and use plain language that make the results more easily interpretable to a non-technical audience. Finally, the authors should clearly explain the methodology and its limitations at the outset and the authors should also explain why new reanalysis is needed. Some specific examples are the following:

The committee feels that the medical analogy does not work. It describes a process analogous to that done by climate scientists in creating a surface temperature reconstruction such as that shown in Fig. 1.3, but this is not a reanalysis as it is correctly defined in Chapter 2.

The same applies to the accident reconstruction analogy. Both are missing the defining characteristic of a reanalysis, which is integrating data into a self-consistent, multivariate representation spanning a long period of time. Simply collecting or retrieving the data and examining it does not capture this essence.

L584-585: The interaction effect is an important consideration, but through the rest of the document this effect is ignored and causes are presumed to be linearly additive. For example, more than half of the change is likely to be due anthropogenic effect. A paragraph should be added to discuss the importance of combined effects and should address caveats about the fact that we cannot separate linear trends from natural variability.

It is becoming increasingly apparent that reanalysis should also include reanalysis of the chemical state of the atmosphere. There is great need for a skillful reanalysis using a global air quality model, for various reasons: understanding of aerosol-climate interactions, understanding of global transport of air pollution, provision of boundary conditions for regional photochemical simulations, etc. This issue should be addressed in the introduction and throughout the report as applicable.

**Specific remarks:**

There are inconsistencies in the use of italics/bolds throughout the text.

L484: "variable for a specific time and" should be replaced with "variable or set of variables, for a specific time, level, and"

L489 and(Ghil and Robertson, 2002; Yeh and Kirtman, 2007) throughout: Improve legibility of reproduced figures.

L493-494: "and surface station locations" should be replaced with "and a subset of surface station locations with observations"

L500-501: "there are fewer upper-air observations than surface observations, and that there is also" should be replaced with "there is" (since only a subset of surface observations are plotted, such that the number of visible surface and upper air observations are similar, this is not a good place to mention this)

L507: Add at end of sentence: "…using data that for the most part had already been analyzed earlier for weather forecasting purposes."

L528: "attribution" should be replaced with "attribute"

L529: "Webster's II" is not the "author".

L593: Delete "becoming increasingly"

L595-600: This is hardly a broad list of various major areas of meteorological research. All fall into the single major category of climate change and variability. If it's difficult to find major areas that don't use reanalysis data, as the draft states, it can't be too hard to find more than one major area that does.

L609-610: "one measure of uncertainty" should be replaced with "a measure of part of the uncertainty"

L610: "phenomena" should be replaced with "identifying phenomena"

## CHAPTER 2

## REANALYSIS OF HISTORICAL CLIMATE DATA FOR KEY ATMOSPHERIC FEATURES

**General remarks:**

The committee feels that the chapter contains much useful material that serves to fulfill the mandates of the prospectus. It also feels that the chapter can be improved in several respects. First, the chapter must be revised to make it easier to read. It also

assumes the reader to be a technical expert, and should either have a summary for non-technical reader, or clearly state at the beginning that the chapter is intended for a technical audience.

The discussion of temperature trends and reanalysis needs to be improved. This discussion should include a description of the usual climate data sets, surface temperature and precipitation and an evaluation of present capabilities of reanalysis. For example, the Observing System is mentioned in the captions of Fig. 1.2 and Fig. 2.4 and on pages 37, 40, 46. Observations play a crucial role in the reanalysis process and the text would benefit from the addition of a synthesis table where all different types of observations used in reanalysis would be listed, along with notes on their spatial and temporal coverage and also the year that they started being included in the model. This would be a very useful for the general public and the data user.

The committee believes that the authors should emphasize that long-term climate data sets derived directly from surface and/or satellite observations (such as those for surface air temperature, precipitation, atmospheric water vapor, etc.) will continue, at least for the near-term (5-10yr), to be the main tool for quantifying decadal and long-term climate changes. The authors should also emphasize that reanalysis data will continue to be used largely for studying atmospheric processes and synoptic to interannual variations. Thus, the climate community should continue to invest in producing, updating and maintaining these long-term climate data sets, which should be assimilated into the reanalysis data (e.g., on a daily or monthly basis).

The section on Key Findings in Chapter 2 contains several contradictions. The value of reanalysis is promoted, but then several paragraphs outline the uncertainties in everything from the models themselves to the quantity and quality of the underlying observations. A more reasonable finding might have been to acknowledge that reanalysis is a work in progress and then extol the *potential* that reanalysis offers to describe the current state of the atmosphere in 3 dimensions and to improve the predictability of climate change.

This chapter should also emphasize that atmospheric reanalysis should try to make better use of historical records of surface observations (of temperature, precipitation, humidity, pressure and winds) from land stations and marine platforms. This will enable the reanalysis to be truly useful for climate change analyses. The reanalysis can make use of the existing climate analysis data (such as those for daily or monthly air temperature, pressure, humidity, precipitation, and cloudiness), instead of going back to the raw observations and trying to repeat the data quality control processes already done by the climate analysis people.

The chapter would benefit from some discussions or reference to other parts of the report on how to improve the quality of the reanalysis data for long-term climate change studies. For example, it would be helpful to make suggestions on how to improve the reanalysis temperature and precipitation in future versions of reanalysis. Some expert opinions on the technical aspects of reanalysis are needed in addition to the mostly user aspects presented in the report. For example, the ERA-40 and JRA-25 have already

applied many techniques to correct biases and homogenize surface and satellite data. The report should address these technical aspects and what the U.S. efforts should do in future reanalysis projects.

The authors should note the need for systematic treatment of representation error, i.e., the variability in the observations due to those physical causes for which the model cannot account. It is possible to establish confidence limits on the hypothesis that the final product be consistent with its underlying assumptions about model and observation errors, and it is essential that these statistical tests be performed. Any statements of confidence derived from such non-parametric tests should be consistent with the statements of confidence that would be obtained from conventional significance tests on time series with Gaussian statistics. One finds, for example, that when a trend is estimated with ordinary least squares regression and tested for significance, the p-value of a zero trend is 0.0 rather than the 0.5 that the non-parametric test is inferred to yield. In general, the confidence levels defined for the non-parametric test seem much too high. Differences between observed and modeled values should, within confidence limits, be consistent with the error models used in the reanalysis. In filtering schemes such as the Kalman filter, the sequence of analysis increments (also called "innovations") should be white. In variational methods, the ending value of the cost function should be a random variable with chi-square distribution. In filtering schemes such as variants of the Kalman filter, a well-known quantity derived as a quadratic function of the innovations should be subjected to the chi-square test.

The model biases are very important and need to be considered when interpreting trends, evaluating trend significance, and attempting attribution. For these reasons, model biases should perhaps be given a paragraph in this chapter, where they would be defined and briefly discussed, or this could be included in a text box.

The committee finds that the report is relatively silent on the developing coupled data assimilation CFS reanalysis reforecast project. The report should acknowledge that this project is in the process of being launched and it should also mention the development of the Ensemble Kalman filter technique used by Geophysical Fluid Dynamics Laboratory (GFDL).

The committee is concerned that the document suggests that reanalysis was used to help understand the surface temperature/precipitation trends over North America (specifically using the 500 mb heights) because the reanalysis data does not characterize all regions correctly. This should either be explained in the document or another example used.

**Specific remarks:**

The committee notes inconsistencies in the use of italics/bolds throughout the text.

There are also many editorial errors that need to be corrected. For example, many of the papers cited in the text are not in the Reference list (e.g., Folland et al. 1986, cited on page 60, Table 2; Straus and Shukla 2004, cited on p. 67, line 1341; Mo et al.

1998, line 1350; Feldstein et al. 2002, 2003, p. 67, line 13341; etc.). Also, some of the figure captions need to be corrected (e.g., the citation in the caption for Fig. 2.9 is incorrect).

Page 34: when listing all the key findings, it would be useful to also include reference to the main section(s) that these findings refer to.

Page 37, section 2.1.2: 'analysis' is introduced. The second sentence refers to "accomplishing *this purpose*". This paragraph should be rephrased.

L711: There is a double (period) "surface.." at the end of the sentence.

L756: Delete "Nevertheless"

L892: "physical relationships" - useful to provide one or two examples of such relationships, and how they provide "memory" for observations.

L899: this paragraph is a little confusing. "Initial atmospheric conditions" were introduced in ~1970s, but what were the numerical weather predictions systems using before that? Also, the "detailed quantitative analyses" are obtained by the use of numerical models, not directly by using initial atmospheric conditions. I just find this paragraph unclear.

L922: "evolution" should be replaced with "evolution potentially"

L981: "of the quantities that" should be replaced with "of which quantities"; "those that" should be replaced with "which"

L957: the bias should be defined more clearly (bias between …)

L1030: "in principle" should be replaced with "ideally"

L1030: "can forecast or simulate **all** aspects of the atmosphere". "all" is very strong and should be replaced by "many".

L1052: Delete "about"

Figure 2.7 caption, L1100: "The top panels are *form* the *observations*", should be replaced by "The top panels are *from* the *NCEP NCAR R1 observations*". It should also be kept in mind that reanalysis fields are not observations.

L1126, 1127: an example would be very useful here.

L1137-1139: a diagram would be very useful in making the point here.

L1172: "new parameter estimation techniques" - since these methods are mentioned, perhaps the text should also give a very brief description of such techniques.

Table 2.2, page 60: What is meant by link between atmosphere and ocean and how is this assessed? Consistency column should include citations.

L1217: Concerning the title listed in the figure "Impact", it would be better to show the percentage of explained variance to provide more of an impact.

Figure 2.8: What season? What is the contour interval for the heights? Why is correlation used? Why not use regression to indicate amplitude?

L1325: "reanalyses" should be replaced with "global reanalyses"

L 1407 year missing in Madden and Julian citations.

L1520: Delete "our"

L1525: "they" should be replaced with "reanalyses"

L1557-1562: Why is AMIP the only approach? What about pace-maker? What coupled efforts? Predictions?

L1822: The GISS plot needs to be updated.

Page 95: The need to deal with systematic errors in observations and the introduction of false trends into observations by changes in instrument systems both reflect deficiencies in the form of the measurement functional, the statistical model of measurement errors, or both. A similar comment applies to the inhomogeneities noted on lines 1927-1929, p97.

L 1953-56: This is an encouraging example of diagnosis of systematic errors at their source.

Page 99, Figure 2.19: The hemispheric asymmetry in number of observations is probably understated by this figure since all panels are for the austral summer.

L1987-1990: Not clear. Wouldn't one normally expect a data compilation covering 30 more years to have much more data in it?

L1993: This error should be cast in terms of errors in some familiar quantity like thermocline depth, and compared to other sources of error.

Page 100, Figure 2.20: Note from this figure the episodic nature of ocean observations: Note that the number of observations decays sharply after 1973, and again after 1992. Is there a specific reason for these changes in observational coverage? Compare this to figure 2.11 that indicates for the atmosphere that, at any given latitude, the number of observations increases with time.

There are no counterparts of GARP or FGGE in operational oceanography. For this reason, analysis of the ocean will lag analysis of the atmosphere for some time to come.

Figure 2.20 points out, if only indirectly, the scarcity of observations of the deep ocean. Diagnosis of the influence of the deep circulation on climate must remain in the realm of speculation. The influence is probably not among the greatest on decadal time scales, but errors in estimates of the deep circulation will not be diagnosed for some time.

L2041-2044: What is a "reanalysis observation?" Please explain "merged dataset"

L2064: What has been (or will be) the tangible benefit of improved reanalysis resolution for climate studies?

L2071-2074: Delete sentence. Not relevant to paragraph on false trends.

L 2072-2074: Formulation of forecast error models is particularly important in this context.

L 2076-2089 The point of this paragraph is uncertain, particularly last sentence. One-way coupling is confusing language – does this mean forced ocean simulations with no feedback onto the atmosphere?

L2079-2080: The question of how to do one-way coupling is far from settled. Two-way coupling is harder still.

L2086-2087: Also, fully coupled systems have fairly coarsely resolved ocean model components due to resource limitations.

L2089 needs to mention coupled activities at EMC, GFDL and JPL.

Page 109: Besides assumptions 1) and 2), most data assimilation systems make assumptions of near linearity and Gaussianity

Pages 109-110: The authors are correct in pointing out the need for bias correction and for better covariance models.

L2130-2131 gives the impression that the state of the art of correction of systematic errors is more advanced than it actually is; methods for doing this are under development, and there are few examples.

L2139-2149 more text about ongoing coupled efforts (e.g., at EMC, GFDL and JPL) needs to be included.

## APPENDIX A

## DATA ASSIMILATION

**General remarks:**

It should be noted that data assimilation is an exercise in the calculation of conditional probabilities. Assumptions of Gaussianity reduce the explicit evaluation of conditional probability to formulas involving covariances. It should be emphasized that all data assimilation methods are based on statistical error estimates.

**Specific remarks:**

L2847: "Observational increments" are known as "innovations" in the engineering literature, and are occasionally referred to as such in the data assimilation literature.

L2854: Quadratic cost functions can be constructed without assumptions about the underlying distributions, but interpretation of the results is not so straightforward as it is in the Gaussian case.

L2863-4: Straightforward implementations of the Ensemble Kalman Filter cannot incorporate future data; that's why it's called a filter, according to standard terminology in time series analysis. The analysis produced by 4DVAR at any given time can be influenced by observations at subsequent times. This property defines 4DVAR as a smoother.

## APPENDIX B

## AN EXAMPLE OF SOME OF THE OUTPUT FIELDS FROM REANALYSIS

**Specific remarks:**

L2906: replace “/s” with “1/s”

L2942, 2959, 2954, 2958: clarify units.

L2976, 2984: clarify “layers”

L2975: for consistency, replace “m**2” with “m2”.

# CHAPTER 3

## ATTRIBUTION OF THE CAUSES OF CLIMATE VARIATIONS AND TRENDS OVER NORTH AMERICA DURING THE MODERN REANALYSIS PERIOD

**General Remarks:**

The committee understands that the goal of chapter 3 is to document how reanalysis is currently an essential tool for rigorous attribution of regional climate variations, and could be used in the future for climate-change attribution. This message should be stated clearly at the beginning of chapter 3 in order to provide a bridge with the previous chapter for the multiple intended audiences. For example, while the chapter will be of considerable interest to climate scientists, as it is presently written, the committee is unsure what policy makers could take away from it.

This chapter relies heavily on original, non-peer reviewed work. The authors should emphasize that although much of the work in this chapter has not been done before, that they are drawing on previous work (especially in sections. 3.4 and 3.5, which are primarily a review of the relationship between drought and climate shift). The authors should clearly identify what is their own original work. In general the committee believes that the authors should rebalance their work by including more the peer reviewed literature. The authors are encouraged to add relevant references, especially with respect to climate variations that are included in the attribution sections.

The chapter would be greatly improved by referring to a detailed appendix that explains the methodology of the non-peer reviewed material, such as how smoothing was accomplished, identification of which years were generated by original research or if details can be obtained from a website; how the “obs” figures were constructed, how the PDSI was computed, how the “natural variability” time series were constructed. The committee believes that this Appendix should be peer reviewed. This peer review could be conducted either prior to or during the public comment period. Some suggestions follow to help improve this chapter.

It would be useful to document studies that have made use of reanalysis data for analyzing climate shifts. The so-called transition around 1976 might be an instructive example.

On L4405-4409 the authors state “There is evidence of abrupt changes of ecosystems in response to anthropogenic forcing that is consistent with tipping point behavior over North America (Adger et al. 2007), and some elements of the physical climate system including sea ice, snow cover, mountainous snow pack, and streamflow have also exhibited rapid change in recent decades (IPCC, 2007).” It would valuable to summarize and critique these lines of evidence, especially in view of the difficulties in detecting purely meteorological shifts. Has reanalysis data been used in an auxiliary role? What might be its likely potential?

Quantifying the ability of reanalyses to reproduce droughts ought to be a key part of this report. The authors state on page 214: “The indications for drought itself, such as

the PDSI or precipitation, are not derived from reanalysis data, but from the network of surface observations." Why is this so? How can one have objective confidence in determining the mechanisms of drought from reanalyses if one doesn't even know if the reanalysis captures the drought? This should be addressed.

From a statistical point of view, it would be worth stressing the extreme difficulty of detecting and defining a rapid climate shift from very short noisy climatic time series. It may be helpful to distinguish between the statistical signal detection aspect of the definition and the physical aspects. Statistical significance has to be assessed against a red-noise null-hypothesis. The intractability of the purely statistical problem makes it imperative to consider the physical plausibility of any "shift" detected, and it would be here that suitable reanalysis data could play a potentially important role. This point might well be illustrated by a figure or a table.

There are some poorly-worded (and therefore incorrect) attribution statements, such as "the spatial variations in observed North American surface temperature change since 1951 are unlikely due to anthropogenic forcing alone" (p. 178). The statement should be revised, since SST's and natural variability are known to influence spatial variations of North American surface temperatures, so it is impossible (or at best exceptionally unlikely) that the spatial variations of the change are due to anthropogenic forcing alone.

In formulating these attribution statements, the authors have ignored sources of error in the observed record, such as observation uncertainty (changes in siting, instrumentation, etc.); analysis uncertainty (as discussed in the example shown in Ch. 2 of differences among analyses); and sampling bias (carrying out a trend analysis partially because the last 10 years have been so unusual). In essence, the authors have neglected the uncertainty of the observed trend and the uncertainty that models have as much or more century-scale natural variability as the real climate system. These factors should be addressed.

While the committee appreciates the need for a non-parametric confidence test, the standard for "detecting a change" is so weak that an observed fall of 0.05 degrees C would merit an inference of "moderate confidence" that an upward change had been detected. Any statements of confidence from non-parametric tests should include reference to the results of application of such tests to a well-behaved time series, to which conventional tests of statistical significance could be applied. This would facilitate critical evaluation of the level of confidence that a change had, or had not been detected.

Spatial variations in summertime surface temperature change are *unlikely* the result of anthropogenic forcing alone.

This chapter is predominantly oriented toward treating drought as an "event", so it fails to discuss the importance of long-term local precipitation trends in altering the rainfall PDF and thereby producing more or fewer drought events of greater or lesser severity. In addition, Section 3.5.4.2 fails to consider/discuss any anthropogenic influences besides greenhouse gases, such as changes in irrigation,

deforestation/reforestation, and radiative and microphysical effects of aerosols. The analysis of Indian/WPac SST's in 3.5.4.2 seems to leave unconsidered the likely relevance of SST changes in that region independent of other changes (Rossby wave forcing) compared to SST changes occurring simultaneously everywhere (no Rossby wave forcing, but strong anthropogenic influence).

**Specific remarks:**

The source of "obs" analyses should be identified.

More complete definitions of Atmospheric Model Intercomparison Project (AMIP) and Coupled Model Intercomparison Project (CMIP) are needed throughout the chapter.

The authors should avoid the tendency to "explain away" differences between observed and AMIP long-term trends, while ignoring other possibilities in instances where the observed and AMIP agree (for example p. 177, p. 192).

In the Attribution summary of Chapter 3, the authors use italics to highlight "likely – unlikely" but the definitions of these terms are not explained. It would be helpful to refer back to the table in the preface with footnote, or add the numbers parenthetically and explain how these numbers were estimated.

L4301-4303: "A retrospective assessment of [abrupt shifts] may offer insights on mitigation strategies that are consistent with the known frequency and severity of impacts related to rapid climate shifts." Due to their rarity, any retrospective analysis of impacts would be very difficult. This sentence understates its complexity.

L4356: Do the authors mean "proxy" climate records rather than historical?

L4361: "3.4.4.1 Abrupt Natural External Forcings Since 1950" Are these external forcings (aerosols, GHGs etc) included in any of the reanalyses? *The discussion of abrupt natural external forcings such as volcanic eruptions needs to be framed in the context of reanalyses. Specifically, the report should clearly state which "external" forcings, including natural and anthropogenic aerosols and greenhouse gases, are included in current reanalyses, and what are the potential implications for the role of reanalysis datasets in attribution. The question of uncertainties in estimating these forcings also needs to be addressed. Implications and recommendations for future reanalyses should also be given.*

L4432-4433: "Some rapid climate transitions in recent decades appear attributable to chaotic natural fluctuations." Again definition of what is meant by a "rapid transition" is problematic: one person's transition is another person's climate noise. A "wave-particle duality" analogy between episodic and oscillatory views of atmospheric variability has been discussed recently, and this may be helpful here to the intended audience (Ghil and Robertson 2002).

L4446: An “apparent” rapid transition might be more accurate.

Page 219: Mentioning “billion-dollar weather disasters” should not be done without discussing increased vulnerability and inflation.

L3034: “2 C warming” Is this a linear trend? Is it per century? The number should be given.

L3042-3045: See comment for L3908 and L3916.

L3056-3061: See comments for L3908 and L3916.

L3071 & 3075: The terms “short-term” and “long-term” are not defined anywhere.

L3087: “may be” should be replaced with “are”

L3093: “record-setting 2006 US warmth”: This term should be used with caution. The committee suggests “unusual” instead.

L3096: Delete “the source for”

L3117: “gold-standard”: This term is confusing and potentially ambiguous. More explanation is needed. Does this imply that this standard is something that is assumed to be error-free by definition or does this mean the best available measurement? {This last sentence isn't clear in itself (distinction between what and what?), and probably isn't necessary.}

L3133: “immediate cause(s)”: The committee disagrees with this terminology. The immediate cause of a temperature change pattern is some combination of changes in advection, land surface characteristics, cloud cover, etc. A teleconnection is at best an intermediate cause.

L3139: Figure 3.1 does not have a clear flow and the relationship of the graphs to the rest of the figure is unclear. The figure also brings up the potential for confusion between the term “attribution” defined in the broader sense in this report, and its narrower but, by now, familiar usage in the climate-change community. This needs to be kept in mind throughout the document.

L3222: Use consistent method of citing IPCC reports.

L3370: See 1217.

L3377-3378: Some text is missing here.

L3458: “jointly” has a specific statistical meaning that is probably not intended here.

L3793: Figure 3.6 and many figures that follow use non-conformal projections. This should generally be avoided, but it should especially be avoided here because the

spatial average of the plotted field and how much different areas contribute to that spatial average are very important.

L3871-3872: Delete “the observed”; replace “detected,” with “detected in observations,”

L3875-3877: The text gives the impression that where the observed pattern agrees with models with greenhouse gas forcing, the models are correct, and where the observed pattern disagrees, the models are deficient. No, the models are deficient everywhere, and the disagreement in the Southeast US suggests that part of the agreement elsewhere may be fortuitous.

L3907-3908: Given what we know about the climate system, it is *impossible* that any sub-century spatial variations in observed surface temperature change could be due to anthropogenic forcing alone. The authors must mean to say something different, such as it is unlikely that the spatial variations are due *predominantly* to anthropogenic forcing.

L3915-3918: Given what we know about the climate system, it is *certain* that any sub-century spatial variations are influenced by observed SST variations. The authors must mean something different, such as, it is likely that the spatial variations are predominantly associated with sea surface temperature variations.

L3924: “much” should be replaced with “many”

L3951: “in producing should be replaced with “to produce”

L3958: Delete “explaining”

L4000-4002: See comment regarding L3907-3908.

L4034-4039: It is equally true that the U.S. also experienced warm conditions during the end of the 20$^{th}$ Century, and it is partly for that reason that the 1951-2006 observed trends are not smaller. The passage could perhaps be justified if the trend starting at 1951 is less than one would obtain starting earlier or later, however this is not the case. It appears that any trend starting between 1925 and 1950 would yield an even lower trend.

L4081-4087: If “natural cooling” can explain the discrepancy with anthropogenically-forced warming in the Southeast, then it is equally plausible that “natural warming” can explain part of the apparent agreement with anthropogenically-forced warming elsewhere. In fact, since the cooling is related to teleconnection patterns, there must be natural warming elsewhere.

L4097: “20004” should be replaced with “2004”

L4137: “High” should be replaced with “Very high” ???

L4140-4144: See comments for L4034-4039. Texas, for example, has smaller trends 1921-2006, 1931-2006, and 1941-2006 than 1951-2006. Of all the available starting dates for trend assessment, 1951 produces a trend estimate that falls close to the median of the other estimates.

L4144: “mid-spread” should be replaced with “wide-spread”

L4208: Spell checker Freudian slip.

L4241: “decadal-like”?

L4466: “appearnence” should be replaced with “appearance”

L4494: “phenomena’s” should be replaced with “phenomenon’s”

L4509-4510: Moisture demand from PET exceeding supply from precipitation is the definition of a “dryland”, not a “drought”. Otherwise, the Colorado Basin would be in drought even in the wettest year.

L4553: “and” should be replaced with “and an average of”

4554: “drought” should be replaced with “severe drought”

L4554: Delete “index”.

L4558: In Fig. 3.20, what is the red line?

L4588: Droughts (6) and (7) are a single event.

L4596: The fractional “variability relative to the average precipitation should be shown in Fig. 3.22”, because this is the key parameter in the discussion.

L4610: “conditons” should be replaced with “conditions”

L4651: “influence for the” What does this phrase mean?

L4656-4659: Is this in reference to the western US or the northwestern US? It seems to hop around.

L4700: “upstream” should be replaced with “downstream”?

L4712: “have also been linked” should be replaced with “have been linked to”

L4769: What is the bottom panel of Fig. 3.23?

L4783-4794: The discussion is missing a logical link: a demonstration that the absolute magnitude of the Indian Ocean temperature is the factor that matters, rather than an anomaly with respect to surrounding SSTs. The correlation found by Lau et al. might be solely due to short-term variability, based on the information presented.

L4804: This line of text is awkward.

L4872-4873: If there is an initial soil moisture deficit, the drought has already started. Change to "…subsequently amplified by local soil moisture conditions, and in some…"

L4877: Delete "an"

Page 137 – move last bullet to second bullet on page 136.

L3094-3103: This text appears to be a discussion of the prediction/predictability question. How does attribution differ from predictability?

L3149 "places"

Figure 3.1 has too many arrows and the point being made is unclear, however the text on page 3274-3284 is quite clear.

Figure 3.2 contour interval.

L3392: It is not clear what aspect of figure 3.1 is referenced.

Page 170: Use of AMIP does not include changes in forcing other than SST. May explain why magnitude weak, but also a weakness in the comparisons.

L3822-3825: This assessment seems incomplete for the CMIP models.

L3852 "And I remains unclear how SST" should be "And it remains unclear how SST."

L4018-4022: This needs to be stated earlier also.

L4101: "series in" should be changed to "series is"

L4459: Latif and Barnett not the best reference here.

L4493: This statement does not appear to be accurate; we do prediction all the time without understanding the mechanisms.

Figure 3.22 shouldn't a ratio be plotted?

L4761: Yeh and Kirtman (2007) reference should be cited

L4763-4788: non-Gaussian behavior assumed – no change in La Niña?

Figure 3.23: The committee does not understand the bottom panel.

# CHAPTER 4

# RECOMMENDATIONS

## General remarks:

The title provides a nice paradigm for the chapter as it suggests that issues, opportunities and recommendations will be discussed. The committee finds that the opportunities and recommendations are apparent in the organization and presentation of the chapter material; however the connection between reanalysis and attribution needs to be strengthened. The committee offers the following suggestions to improve this connection:

Introduce this chapter with a *restatement* of what the scope of this SAP is, *why* the scope has been so defined (what was seen to have highest priority and why; what it was possible to do at the time, what was not done and why), and describe the motivation for this SAP.

Refer back to text added to chapter 1 (Introduction) in which the connections between reanalysis and attribution are described; highlight the steps taken/model process and use examples from chapter 3 (perhaps even show one of the figures) to highlight findings/conclusions drawn in this SAP.

Mention that the goal of the chapter is to provide high-level recommendations aimed at improving the scientific and practical value of future climate analysis and reanalysis. This discussion should clearly state that these recommendations will help reduce uncertainties in climate attribution and will develop ways of realizing the benefits of reanalysis data in supporting policy decisions.

The introduction of Chapter 4 needs to better explain variability and trends. The meaning of attribution should be clearly defined and should be discussed/interpreted in a probabilistic manner. This will further enhance the education function of the document. The introduction should also mention that although some researchers prefer the use of all available data in reanalysis, there is a basic, unavoidable need for verification of reanalyses using an independent data set.

L5838-5843: Questions such as “What was the cause for the Nation’s record setting 2006 warmth?” are ill-posed. Since the intended audience of this report includes policy-makers, the report misses an opportunity to explain why such questions are ill-posed. As mentioned somewhere else in the report, the key policy-relevant questions are: “How much has the probability of warmth such as 2006 changed, and would this probability be expected to undergo further change in the future?” or a related question: “What is the net contribution of anthropogenic forcings to the 2006 warmth, and what is the marginal contribution of each forcing?” Both questions are relevant for adaptation, and the latter question is also relevant for mitigation.

As mentioned earlier, reanalysis should also include reanalysis of the chemical state of the atmosphere. A skillful reanalysis using a global air quality model is

necessary for various reasons: understanding of aerosol-climate interactions, understanding of global transport of air pollution, provision of boundary conditions for regional photochemical simulations, etc. This issue should be addressed in the final chapter as well as in the introduction.

**Specific remarks:**

Some of the recommendations need further clarification.

The designation of recommendations by "R" and "A" for reanalysis and attribution, respectively, further enhances the separation/discontinuity between these techniques. The committee suggests that all recommendations that blend reanalysis and attribution issues be combined.

The biggest challenge with reanalysis is the model and the authors are silent on the fidelity of the model. A discussion of how the model should assimilate temperature and precipitation should be included in the recommendations.

R2 needs to be more specific. What does "optimized for climate purposes" mean? Does this mean detection and attribution? There should be some discussion of the fact that there is a range of climate purposes, and different purposes demand different, incompatible, reanalysis configurations. For example, if one wants a trend-free reanalysis, one uses a sparse subset of the current data, but if one wants the most accurate representation of the atmospheric state at any given time, one uses as much data as possible. This discussion would tie reanalysis and attribution sections together better.

R6 states that it is beneficial to go beyond present ad hoc project efforts to a more coordinated and effective national program in climate analysis and reanalysis. How this approach would be beneficial to improve coordination is unclear from this recommendation. What is the scope of this coordination? What is the rationale behind this recommendation? Would the goal be to coordinate better, have a better use of existing resources? There is a US national interest to continue to do reanalysis – does this recommendation mean that a program should go beyond the current program? Will this approach make better use of existing climate data sets? For example, surface trend problems are evidence that we need to do better – will this be accomplished through a national program? Capability may be a better word that does not necessarily imply new infrastructure.

L5400 "… efforts should include a focus on …"

L5454: Recommendation A1: Is Program for Climate Model Diagnosis and Intercomparison (PCMDI) addressing this need?

# References

Ghil, M. and Robertson, A. W., 2002: "Waves" vs. "particles" in the atmosphere's phase space: A pathway to long-range forecasting? Proceedings of the National Academy of Sciences of the United States of America, 99: 2493-2500.

Kistler, R., E. Kalnay, W. Collins, S. Saha, G. White, J. Woollen, M. Chelliah, W. Ebisuzaki, M. Kanamitsu, V. Kousky, H. van den Dool, R. Jenne and M. Fiorino, 2001: The NCEP-NCAR 50 –year reanalysis: Monthly means CD-ROM and documentation. *Bull. Amer. Meteorol. Soc*. 82, 247-267.

Yeh, S. W. and Kirtman, B. P., 2007: ENSO amplitude changes due to climate change projections in different coupled models. Journal of Climate, 20: 203-217.

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# Appendixes

# A

# CCSP Synthesis and Assessment Products

CCSP-5

U.S. CLIMATE CHANGE SCIENCE PROGRAM

## CCSP Synthesis and Assessment Products

According to the National Research Council, "an essential component of any research program is the periodic synthesis of cumulative knowledge and the evaluation of the implications of that knowledge for scientific research and policy formulation." The U.S. Climate Change Science Program (CCSP) will help meet that fundamental need through a series of 21 "synthesis and assessment" (S&A) products. A key component of the *CCSP Strategic Plan* (released July 2003), they will integrate research results focused on important science issues and questions frequently raised by decision makers.

The S&A products will support informed discussion and decisions by policymakers, resource managers stakeholders, the media, and the general public. They also will help define and set the future direction and priorities of the program. The products help meet the requirements of the Global Change Research Act of 1990. The law directs agencies to "produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to the effects of global change" and to undertake periodic scientific assessments.

Designated CCSP agencies or departments will take the lead in generating each S&A product. The CCSP also will continue to participate in the principal international science assessments, including the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report scheduled for completion in 2007, and the World Meteorological Organization (WMO)/United Nations Environment Programme (UNEP) assessments of stratospheric ozone depletion and associated environmental impacts.

The *CCSP Strategic Plan* sets forth general principles for the S&A products:

- Analyses structured around specific questions
- Early and continuing involvement of stakeholders
- Explicit treatment of uncertainties
- Transparent public review of analysis questions, methods, and draft results
- Flexible approach, building on lessons learned.

As the CCSP progresses with the S&A products, it will learn from experience and adjust its approach accordingly.

To help ensure adherence to those principles, the program has published guidelines for producing the S&A products. These guidelines establish a broadly standardized methodology that will facilitate involvement of the research community and the public; ensure focused and useful products; and meet the highest standards of scientific excellence. The guidelines also encourage transparency by providing public access to information about the status of the products through the *Federal Register*, the CCSP web site, and other means. The guidelines address three steps required to produce S&A products:

1) Developing a prospectus
2) Drafting and revising the document
3) Final approval and publication of each product.

The guidelines set forth the roles of participants and the steps in the process (see page 2).

The first S&A product—*Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*—will be issued by CCSP in early 2006. Others are in various stages of development. For more information on the products, process, and schedule, visit the Synthesis and Assessment products portion of the CCSP web site at <www.climatescience.gov/Library/sap/>.

January 2006

## INFORMATION QUALITY ACT (IQA) AND FEDERAL ADVISORY COMMITTEE ACT (FACA)

The S&A products are subject to the IQA and most also fall under FACA. Each product must meet the IQA guidelines of the lead agency responsible for the product. In particular, the lead agency must ensure compliance with peer review requirements established under IQA for "highly influential scientific assessments." This requires producing and implementing a peer review plan for each product. Where a product falls under FACA, the lead agency forms an advisory committee to which authors are appointed. The lead agency produces a draft charter outlining the committee's mission and specific duties. The charter is made available for public review, and subsequently a final charter is produced by the lead agency and approved by the CCSP Interagency Committee. Each FACA committee must adhere to its charter and must:

- Arrange meetings for reasonably accessible and convenient locations and times
- Publish adequate advance notice of meetings in the Federal Register
- Open advisory committee meetings to the public (with some exceptions)
- Make available for public inspection, subject to the Freedom of Information Act, papers and records, including detailed minutes of each meeting
- Maintain records of expenditures.

### STEPS OF THE PROCESS[1]

#### Planning the Process and Preparing a Prospectus

1) The lead and supporting agencies solicit input from users and other stakeholders, plan preparation of the product, and summarize the proposed process in a draft prospectus.
2) The CCSP Interagency Committee reviews and approves the draft prospectus for public comment.
3) Expert reviewers and stakeholders review the draft prospectus over a period of at least 30 days.
4) Lead and supporting agencies revise the draft prospectus and finalize recommendations for individuals to serve as authors.
5) The CCSP Interagency Committee approves the revised prospectus.
6) The CCSP Office posts the draft prospectus comments and the final prospectus on the CCSP web site.

#### Additional Stakeholder Interactions, if Needed

7) Lead authors may solicit additional input from users and other stakeholders to assist in the development of the product. The process for soliciting additional input is open and is described in the prospectus. The results from additional stakeholder interactions are publicly available in summary or more extensive forms through publication on the CCSP web site.

#### Drafting/Reviewing the Products

8) Lead authors prepare the first draft, including a technical section and a summary for interested non-specialists.
9) The lead and supporting agencies organize and facilitate an expert peer review of the first draft. All comments submitted during the expert peer review are publicly available.
10) Lead authors prepare the second draft of the product.
11) The CCSP Office posts the second draft for public comment for not less than 45 days. All comments are publicly available.
12) The lead authors prepare a third draft of the product.

#### Approving, Producing, and Releasing the Products

13) Lead agencies certify that the product complies with the Information Quality Act, and submit the third draft and comments received to the CCSP Interagency Committee.
14) If the CCSP Interagency Committee review determines that no further action is needed, the product is submitted to the National Science and Technology Council (NSTC) for approval. Otherwise, the Committee's comments are sent to the lead and supporting agencies for consideration and resolution by lead authors.
15) If needed, the National Research Council (NRC) can be asked to provide additional scientific analysis.
16) Once any remaining concerns are addressed, the CCSP Interagency Committee submits the final draft to NSTC for review and approval. Approval requires the concurrence of all Committee on Environment and Natural Resources (CENR) members.
17) Once NSTC approval has been obtained and the product is finalized, the lead agencies produce and release the completed product.
18) The CCSP Office widely disseminates the product through its web site and other mechanisms.

[1] A more detailed description is available on the CCSP Web site at <http://www.climatescience.gov/Library/sap/sap-guidelines.htm>.

## PARTICIPANTS AND THEIR ROLES

**CCSP Interagency Committee**
CCSP's Interagency Committee is chaired by the CCSP Director (DOC appointee) and includes representatives of 13 participating departments/agencies that have mission or funding responsibilities in climate and global change research:

- Department of Agriculture (USDA)
- Department of Commerce / National Oceanic and Atmospheric Administration (DOC/NOAA)
- Department of Defense (DOD)
- Department of Energy (DOE)
- Department of Health and Human Services (HHS)
- Department of the Interior / U.S. Geological Survey (DOI/USGS)
- Department of State (DOS)
- Department of Transportation (DOT)
- Agency for International Development (USAID)
- Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Science Foundation (NSF)
- Smithsonian Institution (SI).

The committee also includes liaisons from the Executive Office of the President (EOP). Membership on the CCSP Interagency Committee is joint with the Subcommittee on Global Change Research (SGCR) of the Committee on Environment and Natural Resources (CENR) of the President's National Science and Technology Council (NSTC).

**Lead Agencies/Departments**
A single CCSP agency or department will take the lead in producing each product. Among the lead agency's responsibilities is ensuring compliance with the Information Quality Act (PL 106-554, §515 (a)). Each S&A Product must meet the lead agency's Information Quality Guidelines. In so doing, lead agency must ensure compliance with peer review requirements. The lead agency also is responsible for ensuring that the report is produced in accordance with the Federal Advisory Committee Act.

**Lead and Contributing Authors**
Lead and contributing authors are individuals with appropriate technical expertise. They may be citizens of any country and be drawn from within or outside the Federal government. Lead authors are responsible for producing the S&A reports.

**Federal Advisory Committee Act (FACA) Committees**
If FACA is applicable to a particular product, a FACA committee is formed. In general, if non-Federal scientists serve as lead authors, the authors are constituted as an advisory committee under the Federal Advisory Committee Act. After substantive deliberations on the product, the committee submits the finished report to the lead agency.

**Interagency Working Groups**
The CCSP's research-oriented interagency working groups (IWGs) consist of agency program managers who have budget authority within their agencies to implement CCSP research programs. IWGs may help the lead agencies with any product-related task. Current IWGs focus on Atmospheric Composition, Climate Variability and Change, Global Water Cycle, Land-Use/Land-Cover Change, Global Carbon Cycle, Ecosystems, Human Contributions and Responses to Global Change, Decision Support, Modeling, Observations and Monitoring, International, and Data Management.

**Expert Reviewers**
Expert reviewers are scientists or individuals selected by the lead agencies/departments based on expertise, balance, and independence criteria. In accrediting the experts, the lead agencies/departments ensure that there is no perceived conflict of interest. Reviewers may be citizens of any country and be drawn from within or outside the Federal government (e.g., universities or other public or private sector organizations).

**Stakeholders**
Stakeholders are individuals or groups whose interests (financial, cultural, value-based, or other) are affected by climate variability, climate change, or options for adapting to or mitigating these phenomena. Stakeholders participate during the "scoping" process by providing information that helps define the audience and potential uses of a product. In addition, stakeholders provide comments on the prospectus, and on the product during the public comment period.

**National Research Council**
The National Academy of Sciences/National Research Council will provide advice on an as-needed basis to the lead agencies. The NRC may be asked to provide additional scientific analyses to help bound the uncertainty associated with these issues.

**National Science and Technology Council**
The NSTC is responsible for final review and approval. Approval will require written concurrence from all members of the NSTC's Committee on Environment and Natural Resources, which consists of 15 agency and department representatives on the Assistant Secretary or Deputy Assistant Secretary level. The committee also includes liaisons from the Executive Office of the President, and other Executive organizations, departments, and agencies as the co-chairs may, from time to time, designate.

ccsp synthesis and assessment products

## Summary of Synthesis and Assessment Products*

| | | |
|---|---|---|
| **CCSP GOAL 1** | Extend knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed changes | |
| **Product 1.1** | Temperature trends in the lower atmosphere: steps for understanding and reconciling differences | NOAA |
| **Product 1.2** | Past climate variability and change in the Arctic and at high latitudes | USGS |
| **Product 1.3** | Re-analyses of historical climate data for key atmospheric features: implications for attribution of causes of observed change | NOAA |
| **CCSP GOAL 2** | Improve quantification of the forces bringing about changes in the Earth's climate and related systems | |
| **Product 2.1** | Scenarios of greenhouse gas emissions and atmospheric concentrations and review of integrated scenario development and application | DOE |
| **Product 2.2** | North American carbon budget and implications for the global carbon cycle | NOAA |
| **Product 2.3** | Aerosol properties and their impacts on climate | NASA |
| **Product 2.4** | Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure and climate change | NOAA |
| **CCSP GOAL 3** | Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future | |
| **Product 3.1** | Climate models: an assessment of strengths and limitations for user applications | DOE |
| **Product 3.2** | Climate projections for research and assessment based on emissions scenarios developed through the Climate Change Technology Program | NOAA |
| **Product 3.3** | Climate extremes including documentation of current extremes: prospects for improving projections | NOAA |
| **Product 3.4** | Risks of abrupt changes in global climate | USGS |
| **CCSP GOAL 4** | Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes | |
| **Product 4.1** | Coastal elevation and sensitivity to sea-level rise | EPA |
| **Product 4.2** | State-of-knowledge of thresholds of change that could lead to discontinuities (sudden changes) in some ecosystems and climate-sensitive resources | USGS |
| **Product 4.3** | Analyses of the effects of global change on agriculture, biodiversity, land, and water resources | USDA |
| **Product 4.4** | Preliminary review of adaptation options for climate-sensitive ecosystems and resources | EPA |
| **Product 4.5** | Effects of global change on energy production and use | DOE |
| **Product 4.6** | Analyses of the effects of global change on human health and welfare and human systems | EPA |
| **Product 4.7** | Within the transportation sector, a summary of climate change and variability sensitivities, potential impacts, and response options | DOT |
| **CCSP GOAL 5** | Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change | |
| **Product 5.1** | Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions | NASA |
| **Product 5.2** | Best-practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decision making | TBD |
| **Product 5.3** | Decision support experiments and evaluations using seasonal-to-interannual forecasts and observational data | NOAA |

* The righthand column provides the S&A product lead agency for IQA and FACA purposes.

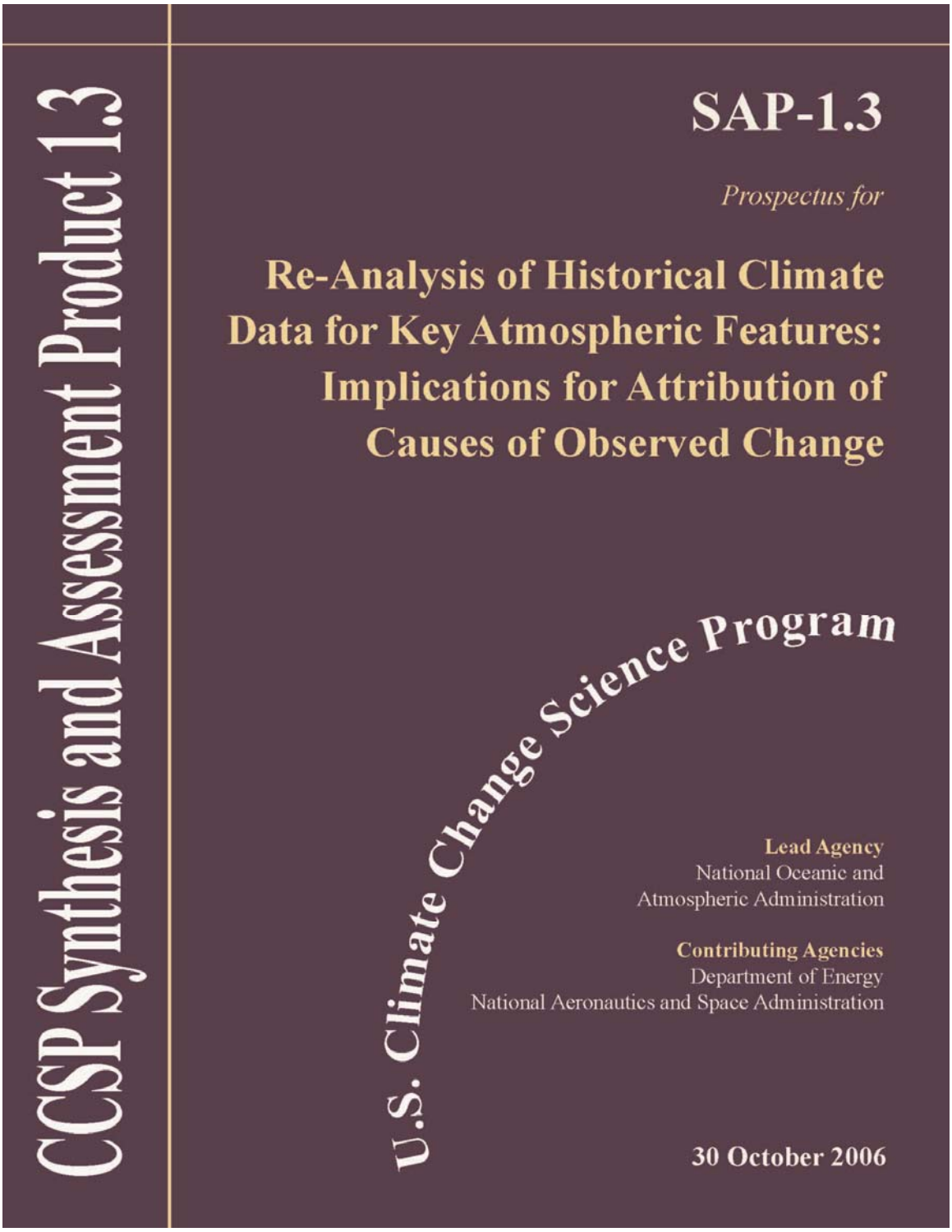
This fact sheet was generated by the Climate Change Science Program Office in collaboration with an interagency working group composed of representatives of the 13 Federal agencies participating in the U.S. Climate Change Science Program.

For further information, see <www.climatescience.gov>.

4

# B

# Prospectus for Synthesis and Assessment Product 1.3



**Agency Leads**
**Randall M. Dole**
National Oceanic and Atmospheric Administration
**Tsengdar Lee**
National Aeronautics and Space Administration
**Rick Petty**
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This prospectus has been prepared according to the *Guidelines for Producing Climate Change Science Program (CCSP) Synthesis and Assessment Products*. The prospectus was reviewed and approved by the CCSP Interagency Committee. The document describes the focus of this synthesis and assessment product, and the process that will be used to prepare it. The document does not express any regulatory policies of the United States or any of its agencies, or make any findings of fact that could serve as predicates for regulatory action.

U.S. CLIMATE CHANGE SCIENCE PROGRAM

*Prospectus for Synthesis and Assessment Product 1.3*

## Re-Analysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change

### 1. Overview: Description of Topic, Audience, Intended Use, and Questions to be Addressed

This prospectus provides a plan for developing and producing CCSP Synthesis and Assessment Product 1.3, *Re-Analysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change*. Re-analysis (henceforth, reanalysis) is the process of reconstructing a long-term climate record by integrating carefully quality-controlled data obtained from disparate observing systems together within a state-of-the-art model to create a comprehensive, high-quality, temporally continuous, and physically consistent climate analysis data set. Over the past several years, reanalysis data sets have become a cornerstone for research in advancing our understanding of how and why climate has varied over roughly the past half-century. Increasingly, reanalysis data sets and their derived products are also being used in a wide range of climate applications.

The proposed report is intended to provide an expert assessment of the capability and limitations of state-of-the-art climate reanalyses, as defined above, to describe past and current climate conditions, and the consequent implications for scientifically interpreting the causes of climate variations and change. The information in the report will provide a basis for decisionmakers and policymakers to understand the present level of confidence and uncertainties in describing how the climate system has varied in the recent historical past, and how this has enabled, and in some cases limited, our ability to identify the causes of such variations. The report will conclude with a discussion of steps that could be taken to improve future analyses and reanalyses of the climate system, and how this information can be developed and applied more effectively to increase confidence and reduce uncertainties in interpreting the causes for past and ongoing climate variations and change.

This proposed CCSP report will be in the form of a synthesis and assessment product that (a) summarizes the present status of national and international climate reanalysis efforts, and (b) discusses key research findings on the strengths and limitations of the current reanalysis products for describing and analyzing the causes of climate variations and trends that have occurred during the time period of the reanalysis records (roughly the past half-century). The proposed report will describe how reanalysis products have been used in documenting, integrating, and advancing our knowledge of climate system behavior, as well as in ascertaining significant remaining uncertainties in descriptions and physical understanding of the climate system. By identifying key limitations of the current generation of reanalyses, the report will be useful to policymakers in identifying and understanding the causes for remaining uncertainties, and for climate program managers in developing priorities for future observing, modeling, and analysis systems required to advance national and international efforts to describe and attribute causes of observed climate variations and change.

This report will focus on the strengths and limitations of current reanalysis products in addressing two primary issues of interest to policymakers and the public.

ccsp product 1.3 prospectus

### 1.1. Descriptions of Past Climate Variations and Trends

As one of their central applications, reanalysis data sets have been employed extensively in research to identify and describe climate variations over times extending from approximately the mid-20th century to the present. This work has led to many important scientific advances. However, limitations of past and current observations, models, and data assimilation systems have also contributed to uncertainties in representing past climate system behavior or, in some cases, even to spurious climate "discontinuities" or shifts. This section of the report will focus on the strengths and limitations of current reanalysis systems for identifying and describing past climate variations. The "first-generation" of reanalyses focused only on the atmospheric component, and includes the NCEP/NCAR reanalysis, the NCEP/DOE reanalysis, the NASA/DAO and GMAO reanalyses, and the European Center for Medium Range Weather Forecasts (ECMWF) ERA-40 reanalysis. Because of the relatively greater maturity and more extensive use of these atmospheric reanalyses, they will constitute the primary focus of this report. However, efforts are now advancing to create reanalyses for the ocean, land surface, and the coupled climate system, and so emerging capabilities and initial findings will also be discussed for these areas.

The primary questions to be addressed in this section of the report are:

- What is a climate reanalysis, and what role does reanalysis play within a comprehensive climate observing system?
- What can reanalysis tell us about climate forcing and the veracity of climate models?
- What is the capacity of current reanalyses to help us identify and understand major seasonal-to-decadal climate variations, including changes in the frequency and intensity of climate extremes such as droughts?
- To what extent is there agreement or disagreement between climate trends in surface temperature and precipitation derived from reanalyses and those derived from independent data?
- What steps would be most useful in reducing spurious trends and other major uncertainties in describing the past behavior of the climate system through reanalysis methods? Specifically, what contributions could be made through improvements in data recovery or quality control, modeling, or data assimilation techniques?

The primary value of this section of the report will be as a summary of the present level of scientific confidence and remaining uncertainties in identifying and describing how the climate system has varied over approximately the last half-century. The discussion of limitations of current reanalyses will provide valuable information for science program managers for developing priorities for data recovery and quality control efforts and future requirements for improving models, data assimilation methods, and observing systems to reduce uncertainties and improve our ability to describe past and ongoing climate variability and change. The assessment of the capabilities and limitations of current reanalysis products for different applications will also be of value to users of reanalysis products.

### 1.2. Attribution of the Causes of Climate Variations and Trends

The second section of the report will assess present uses and limitations of reanalysis products for attributing the causes of observed climate variations and trends. The assessment will be limited to the time period included in the present-generation reanalyses, which is from 1948 to the present, and will focus on climate variations and changes over the North American region. The emphasis of this section will be on advances in our understanding of the causes of major climate variations over this region and period subsequent to work included in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report published in 2001.

Questions to be considered in this section follow:

- What is climate attribution, and what are the scientific methods used for establishing attribution?

- What is the present understanding of the causes for North American climate trends in annual temperature and precipitation during the reanalysis record?
- What is the present understanding of causes for seasonal and regional differences in U.S. temperature and precipitation trends over the reanalysis record?
- What is the nature and cause of apparent rapid climate shifts, having material relevance to North America, over the reanalysis record?
- What is our present understanding of the causes for high-impact drought events over North America over the reanalysis record?

The primary audience for this section is policymakers, who would have an improved basis for ascertaining the present state-of-knowledge, as well as uncertainties, in our scientific understanding of the causes of major U.S. climate trends over roughly the last half-century. The scientific community and public would also benefit from a report assessing our present understanding of the causes of past climate variations, especially for those events that have high societal, economic, or environmental impacts, such as large and prolonged droughts.

## 2. Contact Information for Responsible Individuals at Lead and Supporting Agencies

NOAA is the lead agency for this CCSP deliverable, with NASA and DOE the supporting agencies. Because NOAA is the lead agency, the product will be subject to NOAA guidelines implementing the Information Quality Act (IQA). Contact information for responsible individuals at lead and supporting agencies follow:

NOAA (Lead) Dr. Randall M. Dole
NOAA Earth System Research Laboratory
Physical Sciences Division
325 Broadway
Boulder, CO 80305
Email: Randall.M.Dole@noaa.gov
Phone: 303-497-5812

NASA Dr. Tsengdar Lee
Email: Tsengdar.J.Lee@nasa.gov
Phone: 202-358-0860

DOE Dr. Rick Petty
Email: Rick.Petty@science.doe.gov
Phone: 301-903-5548

## 3. Lead Authors: Required Expertise and Biographical Information

Appendix A provides brief biographies for each of the proposed authors. As needed, additional authors will be added to the team in order to ensure comprehensive and balanced subject matter expertise, in conformance with requirements for the Federal Advisory Committee Act (FACA). The author team will also depend extensively on solicitation of relevant information from experts in the Federal and academic research community during the preparation of this report.

### *3.1. Lead Authors*

Dr. Siegfried Schubert (NASA, Global Modeling and Assimilation Office) is the proposed lead author for Section 1 of this report, and Dr. Martin P. Hoerling (NOAA, Earth System Research Laboratory) is the proposed lead author for Section 2.

### *3.2. Contributing Authors*

Proposed contributing authors follow:

- Dr. Phil Arkin (University of Maryland)
- Dr. James Carton (University of Maryland)
- Dr. Gabriele Hegerl (Duke University)
- Dr. Eugenia Kalnay (University of Maryland)
- Dr. David Karoly (University of Oklahoma)
- Dr. Randal Koster (NASA, Global Modeling and Assimilation Office)
- Dr. Arun Kumar (NOAA, Climate Prediction Center)

- Dr. Roger Pulwarty (NOAA, Climate Program Office)
- Dr. David Rind (NASA, Goddard Institute for Space Sciences).

## 4. Stakeholder Interactions

Stakeholder interactions have been initiated and additional opportunities are proposed throughout the process. In April 2005, the National Research Council (NRC) Climate Research Committee (CRC) was briefed on planning efforts on the nature and scope of the synthesis and assessment product. Informal comments received from CRC members at the meeting provided useful input toward development of this product. At the American Geophysical Union (AGU) Spring 2005 meeting, two special sessions directly related to this CCSP synthesis and assessment product were held to brief the scientific community and discuss relevant recent research. The two sessions were "The Strengths and Limitations of First-Generation Reanalyses for Understanding Climate Variability and Trends" and "Attribution of Climate Variability During The Last 100 Years." Talks presented during these sessions have provided useful background about the current state of knowledge. Following the Spring AGU meeting, a more specialized workshop was convened in September 2005 on "The Development of Improved Observational Data Sets for Reanalysis: Lessons Learned and Future Directions". Additional sessions related to this report are planned for the AGU Fall 2006 meeting and the American Meteorological Society (AMS) Annual Meeting to be held in January 2007. Input provided by scientists, decisionmakers, and other interested parties during the public comment periods will also be used to inform product development. In addition, the lead authors will solicit input from other experts, the applications community, and other stakeholders throughout the preparation of the synthesis report.

## 5. Drafting

The lead authors will draft answers to the key questions in their respective sections. They will also prepare an introductory section to describe the topic, the audience, and the intended use of this product. The coordinating lead author for each section may assign primary responsibility for drafting the text associated with a question to a specific contributing author. The lead authors will be responsible for incorporating materials from contributing authors in the draft product.

After the product is drafted, the lead authors (or coordinating lead author and the authors responsible for each of the questions) will write a non-technical summary. Lead and contributing authors will base their writing on published, peer-reviewed scientific literature. Where appropriate, the product and its non-technical summary will identify disparate views.

## 6. Review

The CCSP Synthesis and Assessment Products are classified as "highly influential" under the terms of the Office of Management and Budget's Final Information Quality Bulletin for Peer Review (issued 16 December 2004). The review process will be conducted in accordance with the OMB guidelines, which include making the peer review plan web accessible.

NOAA, the lead agency for this product, plans to present Synthesis and Assessment Product 1.3 to the NRC for scientific review. The reviewers, who will be selected by the NRC, will be charged to focus on the scientific and technical content of the draft report to ensure that the report adequately answers the questions posed in the approved prospectus, that the report is objective, unbiased, and does not contain policy recommendations, and that the report is written at a level appropriate for the intended audience that will include government and private sector managers and decisionmakers.

Upon receipt of the expert review comments, all comments will be considered and addressed. The lead agency will disseminate the peer review report, including the agency's response to the review, on the agency's web site. A second

draft of the product will be prepared and released for a 45-day public comment period. The lead authors will prepare a third draft of the product in response to the public comments, incorporating changes, as appropriate.

The third draft of the document will be submitted to the CCSP Principals for final review and subsequent submission to the National Science and Technology Council (NSTC) for approval for release.

## 7. Communications

Once NSTC clearance has been obtained, NOAA will coordinate publication and release of the synthesis and assessment product. The published report will follow the standard format for all CCSP synthesis and assessment products.

## 8. Proposed Timeline

| Step | Expected Completion Date |
|---|---|
| *Prospectus* | |
| Drafting | June 2005 |
| CCSP Review | December 2005 |
| Public Comment | January 2006 |
| Revised Draft | September 2006 |
| Clearance | November 2006 |
| *Stakeholder Interactions* | |
| Reanalysis Workshop | September 2005 |
| AGU Session | December 2006 |
| AMS Special Session | January 2007 |
| *Drafting* | |
| Initial Draft | June 2007 |
| Final Draft | February 2008 |
| *Review* | |
| NRC Review | December 2007 |
| Public Comment | February 2008 |
| CCSP Review | March 2008 |
| NSTC Clearance | May 2008 |
| *Communications* | |
| Communications Plan | May 2008 |
| Hardcopy Production | June 2008 |
| Web Production | June 2008 |
| Dissemination | July 2008 |

## Acronyms

| | |
|---|---|
| AGU | American Geophysical Union |
| CCSP | Climate Change Science Program |
| DAO | Data Assimilation Office (NASA) |
| DOE | Department of Energy |
| ECPC | Experimental Climate Prediction Center |
| ENSO | El Niño-Southern Oscillation |
| ERA-40 | 40-year European Reanalysis |
| GMAO | Global Modeling and Assimilation Office (NASA) |
| NASA | National Aeronautics and Space Administration |
| NAO | North Atlantic Oscillation |
| NCAR | National Center for Atmospheric Research |
| NCEP | National Centers for Environmental Prediction |
| NCO | NOAA Climate Office |
| NOAA | National Oceanic and Atmospheric Administration |
| NSTC | National Science and Technology Council |

## Appendix A. Biographical Summaries for Proposed Authors

**Phillip Arkin**
Dr. Arkin is Deputy Director and Senior Research Scientist at the Earth System Science Interdisciplinary Center (ESSIC) of the University of Maryland. He helps to administer ESSIC and conducts research into the observation and analysis of precipitation and other aspects of the hydrological cycle of the global climate system. Until January 2002, he served as Program Manager for Climate Dynamics and Experimental Prediction in the Office of Global Programs at NOAA, where he managed the Applied Research Centers that provide the research and development that enable NOAA to provide better climate forecasts. From 1998-2000, he served as the Deputy Director of the International Research Institute for Climate Prediction (IRI) at Columbia University. He has spent the last 25 years working at NOAA as a research scientist and administrator in various parts of the climate community, including the Climate Prediction Center, the Office of Global Programs and the National Centers for Environmental Prediction. He invented the GOES Precipitation Index, a method for estimating rainfall from geostationary satellite observations, and led the Global Precipitation Climatology Project from 1985-1994. His B.S. in mathematics and M.S. and Ph.D. in meteorology are from the University of Maryland. Dr. Arkin has published more than 50 refereed papers in scientific journals, 22 atlases and chapters in books, and has had more than 100 non-refereed publications. He has served as a member of many national and international scientific panels, and has presented invited papers at more than 100 workshops and scientific meetings.

**James Carton**
Professor Carton is director of the graduate program and Associate Chair of the Department of Atmospheric and Oceanic Science at University of Maryland. His research includes the ocean's role in tropical climate variability on seasonal to decadal timescales. He received an undergraduate degree in Electrical Engineering from Princeton, an MS in Oceanography from University of Washington, and MA and PhD degrees from Princeton's program in Atmospheric and Oceanic Sciences, graduating in 1983. He was a postdoctoral fellow at Harvard until 1985 when he joined the faculty at University of Maryland. Professor Carton's research has had two major foci in the past decade. The first is to understand the sources of climate variability in the tropical Atlantic sector. The countries of the tropical Atlantic are subject to floods and droughts with substantial interannual and decadal variability. Evidence suggests that part, perhaps much of the memory in this system reflects the ocean's ability to store and redistribute heat. Work on this subject is summarized in a book last year, "Earth's Climate: the Ocean-Atmosphere Interactions", co-edited by Professor Carton. The second focus is his SODA effort to develop reanalyses of ocean circulation to complement the atmospheric reanalyses. Professor Carton has an active teaching program that has produced 9 PhDs and 22 Masters Degrees. Professor Carton is also active in international science, currently serving on the steering committees of the Community Climate System Science effort, the JASON altimeter and US CLIVAR.

**Gabriel Hegerl**
Professor Hegerl is an Associate Professor in the Earth and Ocean Sciences Division at Duke University. Her primary areas of research are the detection and attribution of climate variations and change due to natural and anthropogenic changes in radiative forcing (such as greenhouse warming, climate effects of volcanic eruptions and changes in solar radiation). Dr. Hegerl is also

an expert in the application of statistical techniques for climate research. Dr. Hegerl serves as a coordinating lead author for the chapter on "Detection and Attribution" for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, as well as on committees for the National Research Council and US CLIVAR.

**Martin P. Hoerling**
Dr. Hoerling is a research meteorologist in the NOAA Earth System Research Laboratory located in Boulder, Colorado. His research interests include climate variability on seasonal to centennial time scales, focusing on air-sea interactions such as related to El Nino/Southern Oscillation, and the role of oceans in decadal climate variation and climate change. He received his Bachelors, Masters, and Ph.D. degrees from the University of Wisconsin-Madison, graduating in 1987. He is principal investigator on several research projects to understand the causes and origins for seasonal to centennial global climate variations, including North Atlantic climate change since 1950 (CLIVAR-ATL), and the factors controlling low frequency North Pacific-North American climate variations (CLIVAR-Pacific). He is also active in research on seasonal climate predictability and predictions, working in collaboration with operational prediction centers at the National Centers for Climate Prediction, Lamont-Doherty's International Research Institute, and the NASA Seasonal-to-Interannual Prediction Project (NSIPP). Dr. Hoerling has led a NOAA-funded program to explore and develop regional climate services. He has served as project manager for the climate component of NOAA's Regional Integrated Science Assessment on Water, Climate and Society in the Interior Western United States that is studying the region's sensitivity and responses to climate variations, and the need for climate information by regional decision makers. Dr. Hoerling has served as Editor for the American Meteorological Society's *Journal of Climate*.

**Eugenia Kalnay**
Professor Kalnay became a Distinguished University Professor at the University of Maryland in 2002 after chairing the Department of Meteorology for 3 years. Previously she was the Lowry Professor at the University of Oklahoma (1999-2000), Director of the Environmental Modeling Center (EMC) of the NOAA National Centers for Environmental Prediction (1987-1996), and a member and later Head of the 911 Branch at NASA/Goddard that later became the GMAO (1979-1986). While she was director of EMC many improvements of the numerical models and methods of data assimilation were developed and implemented, including the widely used NCEP-NCAR Reanalysis. She has written about 100 peer reviewed papers, and published a book, *Atmospheric Modeling, Data Assimilation and Predictability* (2003), which is on its third printing. She has received several gold medals from NASA and NOAA, the Charney Award from the AMS, and was elected member of the National Academy of Engineering in 1995.

**David Karoly**
Professor Karoly is Williams Chair Professor of Meteorology at the University of Oklahoma. He joined the University of Oklahoma in January 2003 from Monash University, Melbourne, Australia, where he was Professor of Meteorology and Head of the School of Mathematical Sciences. He was Director of the Cooperative Research Centre for Southern Hemisphere Meteorology at Monash University from 1995-2000. He is active in research into the dynamics of the large-scale circulation of the atmosphere and its variability on time scales from days to

decades. Specific research interests include climate change, stratospheric ozone depletion and interannual climate variations due to the El Nino-Southern Oscillation. He is a member of a number of international and national committees, including the World Meteorological Organization Expert Team on Climate Change Detection, Monitoring and Indices, the Council of the American Meteorological Society (AMS), and the UCAR University Relations Committee. He was Coordinating Lead Author of the chapter "Detection of Climate Change and Attribution of Causes" in the third scientific assessment of climate change prepared by the Intergovernmental Panel on Climate Change. He is a Lead Author for the chapter "Assessment of Observed Changes and Responses in Natural and Managed Systems" in the IPCC Fourth Assessment report to be published in 2007. In 1993, Professor Karoly received the Meisinger Award from the AMS, with citation "for contributions to the understanding of the role of Rossby wave propagation in atmospheric teleconnections and to greenhouse climate change research." In 1999, he was elected a Fellow of the AMS for outstanding contributions to the atmospheric sciences over a substantial period of years. He is currently a member of the NRC's Climate Research Committee.

**Randal Koster**
Dr. Koster joined NASA/GSFC in 1987 upon receiving his Sc.D. from M.I.T. His early work focused on the analysis of global water isotope geochemistry. Most of his professional career, though, has focused on the development of improved treatments of land surface physics for atmospheric general circulation models and on the analysis of interactions between the land and atmosphere using these models. With the advent of the Global Modeling and Assimilation Office in 2003, Koster was given the responsibility of coordinating the many disparate land surface modeling activities at GSFC. He has authored or co-authored over 70 refereed papers, and he currently serves on panels or subpanels for WCRP, CLIVAR, and GEWEX. He has served for the last several years as a lecturer for the climate program at George Mason University.

**Arun Kumar**
Dr. Arun Kumar received his PhD in Meteorology from Florida State University in 1990. Since October 2002, he has been the Deputy Director of Climate Prediction Center, National Centers for Environmental Prediction. Dr Kumar's research interests include analysis of climate variability and predictability, attribution of the causes for climate variability, analysis of climate models, and seasonal climate predictions. His research collaborators include scientists from the Climate Diagnostics Center, International Research Institute, Geophysical Fluid Dynamics Laboratory, and University of Washington, among others. He has published more than 50 research papers in peer-reviewed journals. He currently holds the position of Secretary for the Atmospheric Physics & Climate section of the American Geophysical Union. He has been a member of the science advisory boards of several research groups and has participated in several review panels.

**Roger S. Pulwarty**
Dr. Roger S. Pulwarty is a research scientist for the NOAA Climate Program Office, and is leading a Climate Project Office in Boulder, CO to develop a "National Integrated Drought Information System". Dr. Pulwarty received his Ph.D. in 1994 from the University of Colorado. His research expertise is on the design of effective services to address weather and climate-related risks. Dr. Pulwarty's publications have focused on (1) hydroclimatic variability and

change, 2) assessing social vulnerability and capacity to respond to climatic variations and weather extremes, and (3) the use of research-based information in natural resources policy and decision-making in the Western U.S., Latin America, and the Caribbean. From 1998 to 2002, Dr. Pulwarty led the development of the NOAA/Office of Global Programs/Regional Integrated Sciences and Assessments (RISA) Program. In addition to federal agencies and the National Research Council, Dr. Pulwarty has acted in advisory capacities to the Organization of American States (Sustainable Development Unit), the World Bank, the governments of Venezuela, Fiji, CARICOM (the Caribbean Economic Community) countries, and the Western Governors Association. Dr. Pulwarty chairs the American Meteorological Society's Board on Societal Impacts, is Deputy Director of the Western Water Assessment Project, and directs the vulnerability assessment component of the World Bank/GEF funded multi-country project on Mainstreaming Adaptation to Climate in the Caribbean. He is a lead author on chapters in the IPCC Fourth Assessment Report Working Group 2 and in the Millennium Ecosystem Assessment. Dr. Pulwarty is also a member of the U.S. Inter-Agency Water Sciences Committee and the North American Regional Reanalysis Advisory Group.

**David H. Rind**
Dr. David Rind is a staff scientist at the NASA Goddard Institute for Space Sciences in New York, NY. Dr. Rind's expertise is in the application of observations and theory together with advanced climate models to ascertain causes of past changes and implications for future changes. Dr. Rind's work encompasses time scales ranging from paleoclimate variations to present climate and projections of future changes. Recent studies by Dr. Rind and colleagues include a review of water vapor feedbacks in climate models, examination of the roles of tropospheric and stratospheric changes on large-scale modes of climate variability like the Artic Oscillation/North Atlantic Oscillation, relative influences of solar and anthropogenic forcing, and impacts of sea ice on climate.

**Siegfried D. Schubert**
Dr. Siegfried D. Schubert received his Ph. D. in Meteorology from the University of Wisconsin-Madison in 1983. His research interests include climate variability and predictability, droughts, hydrological cycle, extreme events, and reanalysis. Dr. Schubert has authored or co-authored 60 papers in peer reviewed journals. He is currently the head of the Sub-Seasonal-to-Decadal group at the Global Modeling and Assimilation Office at NASA/Goddard Space Flight Center. He organized and directed NASA's first reanalysis projects. He has served on the science working group of the North American Monsoon Experiment, and has been a member of international APEC Climate Network (APCN) working group. He has served as an Editor for the *Journal of Climate*.

# C

# Committee and Staff Biographies

**Dr. David H. Bromwich** is a Professor with the Atmospheric Sciences Program of the Department of Geography and a Senior Research Scientist with the Polar Meteorology Group of the Byrd Polar Research Center at the The Ohio State University. Dr. Bromwich received his Ph.D. in Meteorology from the University of Wisconsin, a M.Sc. in Meteorology from the University of Melbourne, Australia, a Diploma of Meteorology, from the Bureau of Meteorology, Australia, and a B.Sc. Honors in Physics from the University of Sydney, Australia. His research centers on the roles of the polar regions in global climate variability and change using both numerical modeling and observational approaches. He currently serves as a member of the Polar Research Board and has previously served on the following NRC Committees: Planning Committee for the International Polar Year, Committee on Geophysical and Environmental Data, and the Scientific Committee on Antarctic Research.

**Dr. Aiguo Dai** is a Scientist with the Climate and Global Dynamics Division at NCAR. He received his Ph.D. in Atmospheric Science from Columbia University and NASA Goddard Institute for Space Studies. His research includes climate variability and change, such as changes in precipitation, cloudiness, humidity, droughts, river run-off, and diurnal temperature range by analyzing various climate data. He also has evaluated climate models and analyzed climate model simulations. Dr. Dai has done research and published on many other areas, including ENSO-induced climate variations, diurnal variability of the climate system (such as tidal variations in surface pressure fields, diurnal variations in winds and divergence, diurnal variations in precipitation, cloudiness, and convection), climate-biosphere interactions, and climatic impacts on the global carbon cycle and trace gases (CO2, CH4, etc.) emissions.

**Dr. Ioana M. Dima** is a Research Scientist at AIR-Worlwide, a Boston based research and modeling company. Dr. Dima's general interests are in the general circulation of the atmosphere, climate variability and climate change. Her research has focused on the low latitude variability in the upper troposphere, with emphasis on the mean meridional circulation, angular momentum budget, eddy and transient momentum fluxes and the horizontal and vertical structure of the tropical stationary waves, both in anomaly and climatology fields. Special emphasis was given to variability related to the annual cycle, ENSO and MJO. Presently she is interested in investigating the climatological interaction between smaller scale (tropical cyclones) and larger scale (Equatorial Stationary Waves, El Nino/Southern Oscillation, etc) patterns of variability in the tropics. Other interests include low latitude troposphere-to-stratosphere exchanges and tropics-extratropics interactions. Dr. Dima received her PhD in Atmospheric Sciences from the University of Washington, Seattle, her MS in Atmospheric Sciences from the University of Washington, Seattle, and her MS in Atmospheric Physics from the University of Bucharest.

**Dr. John W. Nielsen-Gammon** is a professor of Meteorology and Texas State Climatologist at the Department of Atmospheric Sciences with Texas A&M University. Dr. Nielsen-Gammon received his Ph.D. from Massachusetts Institute of Technology in Meteorology in 1990, a S.M. from Massachusetts Institute of Technology in Meteorology in 1987 and a S.B. from Massachusetts Institute of Technology in Earth and Planetary Sciences in 1984. His professional interests include synoptic-scale dynamic meteorology, weather forecasting and numerical weather prediction, air pollution meteorology, dynamics of weakly-forced precipitating systems, and land surface inhomogeneities and local circulations. Much of Dr. Nielsen-Gammon's recent work in air pollution meteorology and as Texas State Climatologist has involved issues of data quality and consistency for surface and upper-air measurements in inhomogeneous networks.

**Dr. Benjamin Kirtman** is an Associate Research Scientist with COLA. He received his Ph.D. from the University of Maryland. Dr. Kirtman is working on the development of simple and complex coupled ocean atmosphere general circulation models which are used to investigate the predictability of the coupled system on interannual and intraseasonal time scales, to study the influence of tropical predictability on mid-latitude predictability and to assess how the annual cycle affects intraseasonal and interannual predictability. Current areas of interest include: El Nino prediction, dynamics and low frequency variations; impact of atmospheric stochastic forcing on coupled climate variability; El Nino-Monsoon interactions; and the maintenance of the inter-tropical convergence zone.

**Dr. Robert Miller** is a Professor at the College of Oceanic and Atmospheric Sciences at Oregon State University. Dr. Miller's current research includes application of

methods developed in meteorology and engineering to ocean prediction; validation of these methods with observed and computer-synthesized data; and application to prediction of transient currents in the North Pacific. Dr. Miller received a MS from California Institute of Technology in Applied Mathematics and a PhD from the University of California, Berkeley in Mathematics.

**Dr. Andrew W. Robertson** came to the International Research Institute for Climate Prediction (IRI) in November 2001 from the Department of Atmospheric Sciences at UCLA, where he was principal investigator on NOAA and DOE research grants concerned with climate variability on interannual-to-interdecadal time scales. His work at UCLA focused on the phenomenology of climate variations (intrinsic modes of atmospheric variability, the impact of SST variations, ocean-atmosphere interaction) using data and GCM experiments, and applications-relevant research (planetary-flow regimes and local daily weather, streamflow predictability). After graduating from the University of Leeds, U.K., with a B.Sc. in geography and mathematics, Dr. Robertson received his Ph.D. in atmospheric dynamics from the University of Reading in 1984 under the supervision of Professor Brian Hoskins. He has held postdoctoral and research positions at the Universities of Paris and Munich. Dr. Robertson is interested in the mechanisms, particularly ocean-atmosphere interaction, that give rise to predictable aspects of interannual-to-interdecadal regional climate variability, and the use of GCM experiments to isolate them. He is interested in probabilistic modeling of relationships between local daily weather statistics and large-scale climate processes. At IRI, Robertson will seek to advance understanding of short-term regional climate predictability and to develop useful seasonal-to-interannual predictions of applications-relevant quantities with small spatial and temporal scales. He will work to forge the link between climate research and its application.

**Maria Uhle** has been a Program Officer with the Polar Research Board at the National Research Council since April of 2005. Prior to joining the NRC, she was the Jones Assistant Professor of Environmental Organic Geochemistry in the Department of Earth and Planetary Sciences at the University of Tennessee. At UT, Dr. Uhle mentored several graduate students in various scientific disciplines including Quaternary climate studies, salt marsh ecology, reconstruction of biomass burning events throughout geologic history, organic contaminate remediation and Antarctic biogeochemistry. Dr Uhle received her B.S. from Bates College, M.S. from the University of Massachusetts and Ph.D. from the University of Virginia. At the NRC, she has directed several studies including *Assessment of the U.S. Coast Guard Polar Icebreakers Roles and Future Needs*, *Exploration of Antarctic Subglacial Aquatic Environments: Environmental and Scientific Stewardship*. She continues to work with the U.S. National Committee

on the International Polar Year developing interagency communications and public outreach and education projects.

**Rob Greenway** is a Senior Program Assistant at the National Academies Board on Atmospheric Sciences and Climate. He has worked on NRC studies that produced the reports *Assessment of the Benefits of Extending the Tropical Rainfall Measuring Mission: A Perspective from the Research and Operations Communities, Review of NOAA's Plan for the Scientific Stewardship Program, Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services*, and *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*, among others. He received his A.B. in English and his M.Ed. in English education from the University of Georgia.

# D

# Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 1.3

## Statement of Task

This committee will review the U.S. CCSP's draft Synthesis and Assessment Product 1.3 entitled "Reanalyses of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change". The purpose of the CCSP SAP 1.3 is to provide an expert assessment of the capability and limitations of state-of-the-art climate reanalyses, to describe past and current climate conditions, and the consequent implications for scientifically interpreting the causes of climate variations and change. The role of the National Academies committee will be to provide a peer review of CCSP SAP 1.3. The committee will address the following issues:

1. Are the goals, objectives, terminology, 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? How do the conclusions and general approaches for addressing uncertainty compare with those embraced by other treatments of the topic (e.g., IPCC, NRC activities)? Are differences supported by explicit and sound reasoning?
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?