Response to NRC Review of
CCSP Synthesis and Assessment Product 1.3:

Reanalysis of Historical Climate Data for Key Atmospheric Features:
Implications for Attribution of Causes of Observed Change

The authors of CCSP Synthesis and Assessment Product (SAP) 1.3 thank David Bromwich, chair of the NRC review committee, and all of the committee members for a very thoughtful and thorough review of the draft report. The authors have carefully considered all of the comments and recommendations in the report and have made significant revisions in response to the NRC review comments. The authors have paid particular attention to the key issues identified for the overall document and in specific chapters. All typographical and other editorial errors noted in the specific remarks have been corrected. The author team responses are provided below following the NRC review sections.

Key issues

1. The title and review contents are not entirely consistent.

The authors understand this comment on the title as a question on the extent to which reanalysis and attribution must be linked throughout the entire document and, in particular, between Chapters 2 and 3. As discussed below and in the Chapter responses, considerable efforts have been made to strengthen the linkages between reanalysis and attribution throughout the document. The connections between reanalysis and attribution, as well as challenges in doing so, are addressed in Chapter 1. While it is difficult to convey the report contents completely within the title, it is the SAP 1.3 prospectus itself that provides essential details on what is to be contained in the report. In this sense, the SAP 1.3 team appreciates the NRC committee comment that commends the authors for their fidelity in following the SAP 1.3 prospectus, which we have taken as our fundamental charge.

2. The document is not accessible to all intended audiences.

In the revisions, the authors have made great efforts to simplify the language throughout the report, although some technical discussion is probably unavoidable. Major emphasis has been placed on revising the Preface, Executive Summary, and Chapter 1 (Introduction) in light of this comment. In addition, Chapter 1 has been revised to provide more of an educational role. The authors agree that risk type language has the potential to be a much better way to communicate attribution findings and, indeed, our discussion under our final recommendation in Chapter 4 (now listed as Recommendation 9) makes this same point. At this time, however, few studies have yet to adopt this approach. The approach taken in the report is consistent with the conventions of the IPCC and other CCSP SAP reports.

3. Introductory material is lacking.

The first chapter has been revised extensively to address this comment. Other general introductory material is also contained in the Preface and, to a lesser extent, in the Executive Summary. Introductions are also provided in each of the subject chapters.

4. Details about the methods, data sources and assumptions used are lacking.

More details have been added where required in the different chapters, and in particular in chapter 3. An Appendix section has been added that gives an inventory of the observational and model data sets used. It provides the references to those data, all of which are accessible via public domain access. The methods of data analysis are described, emphasizing that, while new analyses are shown in the Chapter 3, they are derived using standard statistical procedures that have been extensively used in prior climate research, are completely reproducible through publicly available data sets, and received prior approval for inclusion through the required CCSP process.

5.The document heavily relies on original research and does not include sufficient peer-reviewed literature.

This comment is directed at Chapter 3, which includes references to nearly 150 peer-review publications; in short, peer review publications were used extensively. To address the questions in the SAP prospectus, the authors of Chapter 3 at times found it necessary to re-draft figures from peer-review literature, or in some cases to perform additional analysis. In all cases, the new analyses followed standard and well-accepted scientific procedures, were performed on publicly available data sets, and were approved for inclusion through the required CCSP process, as stated above. As the NRC review noted, the results presented in the document, while in some cases new, are consistent with the published scientific literature. The additional detail provided in these analyses, for example on regional scales over the U.S., was deemed essential to address the specific questions in the prospectus and to better serve the needs of the intended audience.

Abstract

Add more on reanalysis for balance

The abstract has been revised to have better balance. In particular, a paragraph has been added on reanalysis. Wording has been changed in response to the other two remarks.

Preface

The tables on uncertainty are unhelpful without further context.

The authors believe it is appropriate to continue to use the IPCC tables on uncertainty, consistent with other SAP reports. A note has been added and the table revised slightly to

address the comments. Other minor comments have all been addressed. As this is a Preface, we are reluctant to put in a more extensive discussion on uncertainty that includes illustrative examples. The specific context is contained within the chapters.

Other specific comments were addressed during the revisions.

Executive Summary

General remarks:

Strengthen the case that reanalysis is critical to conclusions on attribution

As discussed in the report (e.g., Chapters 1 and 4), reanalysis is one of the methods used in establishing attribution, but not the only one. The final key finding on reanalysis in the Executive Summary states that "the integrated and comprehensive nature of the reanalysis data provide a quantitative foundation for increasing the understanding of the processes that lead to climate trends. These qualities make reanalysis useful for attributing the causes of observed climate change beyond what can be determined from a dataset of a single variable, such as surface temperature or precipitation." In short, even if specialized, single variable data sets are (at this time) superior for climate change detection, they are of much more limited value for attributing the causes of any detected changes. Use of reanalysis data helps to ensure that the right answer is obtained for the right reason i.e., the comprehensive nature of the data is much more informative in identifying the relevant processes. This is crucial to providing the proper attribution. Key attribution findings in the ES also note that changes in the atmospheric circulation patterns have led to many of the patterns of regional surface temperature changes and that the connections between wind and temperature changes are established through reanalysis data. In short, we have indicated many areas where reanalysis is important to attribution, but have also indicated that this is just one methods used (reanalyses, of course, have many other applications as well).

State that SST changes may be due to anthropogenic forcings.

We agree that the SST changes may be due in part to anthropogenic forcings, and a statement has been added to this effect. The report finds, however, that many of the changes in regional patterns in temperatures and precipitation can be related to changes in spatial variability of the SSTs, and in the models used in the assessment, these regional SST changes have not been systematically reproduced in runs forced by anthropogenic greenhouse gases and aerosols. This makes it difficult to attribute the observed patterns of SST changes (e.g., different regional patterns of warming or cooling) to anthropogenic forcing, although the possibility cannot be ruled out, either. This is a big research and modeling challenge.

Revise language on "change".

Language on change has been modified. We quite agree that the fact that "a change has occurred" does not say whether it is natural or anthropogenic. However, it is for this reason it would be inappropriate to follow the review recommendation to replace "a change has occurred" with "an anthropogenic change has occurred" everywhere. In cases where the assessed evidence implicates anthropogenic forcing, the terms "human caused" or "human induced" are now used.

Specific remarks have been addressed in the revisions.

Chapter 1

General remarks:

Strengthen educational component

Chapter 1 has been extensively revised to fulfill the educational component of the document (note that the Preface also provides an educational role). Reanalysis and attribution are defined and discussed in their own sections, and another section discusses the links between reanalysis and attribution.

Remove analogies

The medical and accident reconstruction analogies have been removed, although several non-specialists (as well as specialists on and off the authors' team) that commented on the draft thought the analogies were helpful.

Interaction effect

The discussion on interactions is included. The ability to separate linear trends from natural variability is variable-dependent, so we are reluctant to make such a broad assertion as in the review "that we cannot separate linear trends from natural variability" (we do fully agree that climate variability and climate change are linked, if that is was is meant). We are also reluctant to accept the general statement that "For example, more than half of the change is likely to be due to anthropogenic effect."

Reanalysis of the chemical state of the atmosphere

We agree with the statement "reanalysis should also include reanalysis of the chemical state of the atmosphere". Indeed, adding chemical constituents in future reanalyses was contained explicitly within Recommendation 5 in the reviewed draft. It is continued as a major recommendation in this report. However, the authors do not believe that this should be part of Chapter 1, which is intended to provide an introduction to fundamental concepts, rather than recommendations for future work.

Other specific remarks have been addressed in the revisions.

Chapter 2

The authors of Chapter 2 would like to thank Dave Bromwich, chair of the NRC review team, and the team members for providing very helpful comments on improving Chapter 2 (Reanalysis). The following provides a summary of how the authors of chapter 2 have addressed the main concerns and recommendations of the NRC review team.

1. The authors should provide a better link between reanalysis and attribution, and description of how the models, observations, and theories are related to the ultimate goal of reanalysis, especially for the benefit of non-specialists.

Numerous changes have been made to address these issues (see the responses to Chapter 1 and Chapter 3). In chapter 2, we have addressed this by including a new call out box (2.2) that describes for the non-specialist the complementary roles of reanalysis and model simulations in attribution studies and in the broader context of climate science.

2. The chapter should be revised to make it easier to read or should have a summary for the non-technical reader.

The chapter has been revised substantially to make it easier to read by a non-specialist. Our goal in this chapter (and for this SAP in general) is to make it useful to both the technical and non-technical reader. In that regard, we targeted the executive summary as providing a non-technical summary that serves both to give the non-technical reader an overview of the basic findings and the technical reader an easy entry into the more technical and detailed aspects of the report. See also response to (1) above.

3. It would be helpful to add a synthesis table where all different types of observations used in reanalysis would be listed.

A new table (2.2) has been added.

4. The authors should emphasize that long-term climate data sets derived directly from surface and/or satellite observations will continue for some time to be the main tool for quantifying decadal and long-term climate changes.

This has been added to the discussion in section 2.4.3

5. 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.

While we understand the reviewers' concerns, we do not believe that this is a contradiction, especially in the context of the full report. Uncertainties are in fact inevitable in science, including both observations and models; reanalysis based on data assimilation has as a central goal to minimize the joint uncertainty between observations and models in order to optimally estimate the states of past (and present) climate. We believe that the current report provides is a balanced assessment of what has already been achieved (see chapter 1 for an overview of the numerous applications and broad user base) with current reanalyses, and remaining challenges that need to be addressed to obtain the full potential of reanalyses. The revised document now has links to the relevant sections for each key finding to help the reader find the relevant supporting material.

6. More emphasis should be placed on bias issues and improving the quality of the reanalysis products

Bias in reanalysis products is clearly an important problem and the report touches on this and related issues in a number of places. This is specifically addressed in section 2.5, where the reader will find discussions on bias estimation and correction, the use of reduced observing systems, and the need for improvements to the input observations. Model bias issues are discussed in sections 2.2.2, 2.2.3, 2.3.2.3, 2.4.2 (see also Fig 2.4.5).

7. The report is relatively silent on the developing coupled data assimilation CFS reanalysis reforecast project (CFSRR). 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).

Coupled data assimilation is now discussed at end of section 2.5.2 (includes mention of CFSRR, GFDL and GMAO efforts). A new call out box describes the CFSRR effort. We agree that the CFSRR is a very important step forward, as discussed in Chapter 4. However, it should be noted that the CFSRR project is not yet complete (now scheduled for completion in 2009), and therefore it is not yet possible to assess results from this project.

Specific Remarks:

All of the specific remarks have been addressed. In particular, we have corrected the editorial errors in the references and citations, and we have included the links to the specific sections for each key finding. All typographical and other editorial errors have been corrected.

Chapter 3

The authors of Chapter 3 thank Dave Bromwich, chair of the NRC review team, and the team members for providing constructive comments on improving the readability of Chapter 3 (Attribution), and better integrating with Chapter 2 (Reanalysis).

We focused our attention on three major recommendations of the NRC review team:

1. ***Enhance integration of reanalysis with attribution***
2. ***Enhance accessibility to a broader audience***
3. ***Detail methods/statistical procedures used in Ch. 3***

Below are the major steps that have been taken to improve the CCSP 1.3 along the lines recommended.

1. Enhance integration

a. A more extensive discussion now appears in the "Fundamental Concepts" (Chapter 1), where the connections between reanalysis and attribution are more extensively described. In particular, section 1.3.2 provides a new discussion, intended for a broad audience, on the connection between a climate reanalysis and attribution as currently exists in the climate science.
b. The Chapter 3 Introduction now begins with a new summary of the data sets and strategies for performing attribution. This is focused on guiding the reader through the various stages of attribution illustrated schematically in Figure 3.1. For each stage, the discussion focuses on the principle tools and the role of reanalysis.
c. A specific example showing the use of reanalysis for attribution has been added in the form of Box 3.1: Assessing model suitability. A principle tool for testing and diagnosing the efficacy of surmised cause-effect relationships is with models. In almost all cases, these models are themselves first evaluated for their capacity to generate realistic statistical properties of climate and its variability, and reanalysis is the yardstick against which those properties and models are judged.

2. Enhance accessibility

The revisions to Chapter 3 include 5 new call-out boxes that capitalize upon numerous opportunities to enhance the accessibility of the material to a broad readership. The boxes, in addition to making the document more accessible to all intended audiences, also address several general concerns raised by the review panel, as indicated below. The subject matters covered by each box are:

Box 3.1: Assessing Model Suitability (section 3.1)
-provides an illustration of the use of reanalysis for attribution.

Box 3.2: Forcing a Climate Model (section 3.1)
-clarifies the manner of "forcings" being considered cause-effect linkages.

Box 3.3: Choosing the Assessment Period (section 3.2)
-places the post-951 period into a context of 20th Century climate variability.

Box 3.4: Use of Expert Assessment (section 3.2)
-explains use of peer-reviewed work (as available), methods, and new analyses.

Box 3.5: Drought Attribution and the Use of Reanalysis Data (section 3.5).
-state how reanalysis data is (and is not) used for attribution of drought.

3. Explain methods and procedures

As recommended, an Appendix section has been added. This gives an inventory of the observational and model data sets used. It indicates the references to those data, all of which are accessible via public domain access. The methods of data analysis are described, emphasizing that, whereas new analyses are show in the Chapter 3, they are derived using standard statistical procedures that have been extensively used in prior climate research.

We also wish to thank the NRC review team for their specific comments on Chapter 3. These have been addressed in the revised draft of CCSP 1.3.

Chapter 4

In the introduction, restate the scope of the SAP, explain climate variability and trends, discuss the meaning of attribution, and add other components.

The authors appreciate the intent of this overall recommendation, but are concerned that it would add unduly to an already long report. This Chapter is focused on providing high-level recommendations along with a supporting rationale, drawing on findings from the previous chapters and other sources. We agree, for example, that probabilistic attribution is required. This is discussed in the final recommendation of the report. We also agree that reanalysis of the chemical state of the atmosphere is important, and this contained within Recommendation 5 of the report.

Other specific remarks:

Combine reanalysis and attribution recommendations

Done.

Discuss fidelity of the model and add discussion of how to assimilate temperature and precipitation

Model development is beyond the scope of this report. We fully agree that assimilation of temperature and precipitation are important, but believe this is more specific than needed for a high-level recommendation (significant progress is being made in both these areas now, e.g., at ECMWF, as well as precipitation in NARR).

Make R2 (now 2) more specific.

Done.

R6 (now 6). Provide details on the scope of coordination of a national program in climate analysis and reanalysis and its rationale.

The current recommendation states: "There is a pressing need to develop a more coordinated, effective, and sustained national capability in analysis and reanalysis to support climate research and applications." Whether developing this national capability is through a program or by other means is beyond the purview of this report. At present, there is no national program, but as discussed, a set of activities undertaken by different agencies without close coordination (although it should be noted that there have been significant efforts in this area in recent years through the CCSP, which have helped increase interagency coordination over what is was previously.) A discussion of the rationale for multi-agency coordination is provided under this recommendation: "To be truly successful such a program must include multiple agencies, since it requires resources and expertise in a broad range of scientific disciplines and technologies beyond that of any single agency (*e.g.*, atmosphere, ocean, land surface and biology, observations and modeling, measurements, computing, data visualization and delivery). It also will need strong ties with the Earth science user community, to ensure that the analysis and reanalysis products satisfy the requirements of a broad spectrum of users and provide increasing value over time."

Other minor changes have been made to address the specific remarks.

Again, the CCSP SAP 1.3 author team expresses our sincere thanks to David Bromwich and all of the members of the NRC Review Committee for their thoughtful and thorough review of the draft report. We have made extensive revisions throughout the draft to address the Review Committee's comments and recommendations. We believe that the final report will be substantially improved as a result.