Review of the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.3, "Weather and Climate Extremes in a Changing Climate"

Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.3, National Research Council

ISBN: 0-309-11005-X, 60 pages, 8 1/2 x 11, (2007)

Review of the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.3, "Weather and Climate Extremes in a Changing Climate"

Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.3

Board on Atmospheric Sciences and Climate

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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

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

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report is funded in part by a contract from the National Oceanic and Atmospheric Administration under grant number DG133R-04-CQ-009, TO#27. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its subagencies.

International Standard Book Number-13: 978-0-309-11004-4
International Standard Book Number-10: 0-309-11004-1

Copies of this report are available from the program office:
Board on Atmospheric Sciences and Climate
500 Fifth Street, N.W.
Washington, DC 20001
(202) 334-3512

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

Printed in the United States of America

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles Vest are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

COMMITTEE TO REVIEW THE U.S. CLIMATE CHANGE SCIENCE PROGRAM'S SYNTHESIS AND ASSESSMENT PRODUCT 3.3

JOHN GYAKUM (*Co-Chair*), McGill University, Montreal, Quebec
HUGH WILLOUGHBY (*Co-Chair*), Florida International University, Miami
CORTIS COOPER, Chevron, San Ramon, California
MICHAEL J. HAYES, University of Nebraska, Lincoln
GREGORY JENKINS, Howard University, Washington, DC
DAVID KAROLY, University of Oklahoma, Norman
RICHARD ROTUNNO, National Center for Atmospheric Research, Boulder, Colorado
CLAUDIA TEBALDI, National Center for Atmospheric Research, Boulder Colorado
and Visiting Scientist, Stanford University, Stanford, California

NRC Staff

CURTIS H. MARSHALL, Study Director
KATHERINE WELLER, Senior Program Assistant

BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

Acknowledgments

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

Walter F. Dabberdt, Vaisala Inc., Boulder, Colorado
Jennifer Phillips, Bard College, Annandale-on-Hudson, New York
Robert Maddox, University of Arizona, Tucson
Roland Madden, Scripps Institution of Oceanography, La Jolla, California
John Molinari, The State University of New York, Albany

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 George L. Frederick, Falcon Consultants LLC, Georgetown, Texas. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Summary

The committee reviewed draft Synthesis and Assessment Product 3.3, *Weather and Climate Extremes in a Changing Climate*, focusing on the extent to which the document meets the requirements set forth in its prospectus and using guidelines developed by the U.S. Climate Change Science Program in conjunction with the National Research Council. The committee finds that the draft provides a good and thorough assessment of the important issues regarding extreme events over North America and how they may change in the context of a changing climate. The document may be improved by considering several recommendations regarding its content and format outlined later in this review.

From an architectural and formatting perspective, the document needs significant improvement. The continuity and cohesion among the chapters could be improved by greater coordination among the chapter authorship teams and a concerted effort to consolidate the material. The Executive Summary should clearly and concisely state the major recommendations, which should be contained and discussed in Chapter 4 and not scattered among the chapters. The Preface should focus on the "big-picture" issues and not contain technical material, as it now does.

In the case of tropical cyclones, the material presented is beyond what is necessary or desirable for an assessment document; this material should be reduced significantly and is too detailed for the target audience. Although the content of the Abstract and Executive Summary is written appropriately for their target audience(s), the alarmist tone of the Abstract is inconsistent with the tempered language used elsewhere in the document and is not entirely consistent with the scientific evidence provided. The discussion of drought and ecological impacts should be strengthened and consistent with related statements in the Abstract and Executive Summary. In many cases, particularly for drought and tropical cyclones, claims of trends are not necessarily supported by the available evidence and the underlying statistical methods to assess those trends are unclear or problematic.

Although the committee recommends significant revisions that are intended to lead to an improved final product, the scope, content and scientific rigor of the current draft provide a solid basis for the final version of Synthesis and Assessment Product 3.3.

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 (SAPs) that address its highest priority research, observation, and decision-support issues. 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 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 focus of SAP 3.3 (see Box 1-1 for document outline), the subject of this document, is the identification of key variables or indices that can provide important information on weather and climate extremes and their socio-economic and environmental impacts. The Product seeks to identify recent changes and trends in these variables, and outline potential future changes. Key variables and parameters discussed include droughts, heavy precipitation events, heat waves, damaging freezes, tropical and extra-tropical cyclone frequency and intensity, ice storms, snow cover, snow depth, hail, and severe thunderstorms. This Product focuses on extreme events across Canada, Mexico, and the United States, including its territories and does not address extreme weather and climate events on a global scale.

In a review of the U.S. CCSP Strategic Plan, the National Research Council (NRC) recommended that SAPs should be produced with independent oversight and review from the wider scientific and stakeholder communities (NRC 2004). As part of its

efforts to meet this goal, National Oceanic and Atmospheric Administration (NOAA) requested that the NRC provide an independent review of SAP 3.3. The NRC appointed an ad hoc committee composed of 10 members (Appendix C) to provide this review. The committee's Statement of Task is included in Appendix D.

The committee conducted its work by first carefully reading the draft SAP 3.3 document *Weather and Climate Extremes in a Changing Climate* (draft dated February 27, 2007). The committee then met with the authors, who provided in-depth presentations of their research and material used to formulate the draft document. During this meeting, the co-chairs of the authoring committee also outlined for the NRC review committee NOAA and CCSP requirements and expectations for SAP 3.3. This present document constitutes the committee's peer review of SAP 3.3, resulting from its careful study of the draft document and its interactions with those present at the meeting. This review includes the committee's findings, recommendations, suggestions, and options for the authors to consider in finalizing SAP 3.3. In conducting its review, the committee focused on substantive matters of content and did not proofread the document for grammatical or typographical errors.

BOX 1-1
Outline of CCSP Synthesis and Assessment Product 3.3

The main body of the assessment product is presented in four chapters:

Chapter 1: Why Weather and Climate Extremes Matter
- 1.1. Why are extremes important?
- 1.2. Defining extremes in relation to social, economic, and environmental impacts.
- 1.3. Measures of weather and climate extremes and their data limitations

Chapter 2: Observed Changes of Weather and Climate Extremes
- 2.1. Observed changes and variations in weather and climate extremes
- 2.2. Key uncertainties related to measuring specific variations and changes

Chapter 3: Do We Understand the Causes of Observed Changes in Extremes and What are the Projected Future Changes?
- 3.1. What are the physical mechanisms of observed changes in extremes?
- 3.2. Attributing observed changes to external forcing
- 3.3. Projected future changes in extremes, their causes, mechanisms, and uncertainties

Chapter 4: Recommendations for Improving our Understanding

2

Major Comments

In this chapter, the committee provides its major comments on the draft Synthesis and Assessment Product (SAP) document. In some cases, the specific comments the committee provides on the separate sections of the draft SAP (see Chapter 3 of this report) offer detailed suggestions on how to address the major concerns outlined here.

1. The authors have provided a broad and useful assessment of this important issue. The review committee commends the U.S. Climate Change Science Program (CCSP) and the authors of the draft SAP 3.3 for producing a broadly formulated and generally solid assessment of the scientific underpinnings of this most important topic. Indeed, the committee agrees that potential changes in extreme weather and climate events resulting from global climate change have serious socio-economic and environmental implications. In seeking to address this important issue, the authors have provided a document that addresses the goals, objectives, and intended audiences, including scientists, policymakers, resource managers, stakeholders of climate change science, the media, and the general public, as set forth in the document prospectus; all should benefit from the information provided in this Product.

2. The Abstract and Executive Summary are inconsistent with the document content. The Abstract and the Executive Summary are disconnected from the material presented in the four chapters of the document in tone and scope. The Abstract in particular takes an overly alarmist tone. The authors should ensure that the language is tempered to reflect the implications of changes in extreme events only as supported by the scientific material presented elsewhere in the document. The committee understands that the front material should be understandable and readable for a lay audience with a high school education; however the scope of this material falls short of that target. The committee suggests that the technical level could be increased and the readability would remain appropriate.

3. The content is weighted excessively toward tropical cyclones. The committee understands that trends in tropical cyclones (intensity, number of storms, and other characteristics) are an important topic of considerable interest to many audiences; however, in the context of this SAP, they are but one of several types of extreme events with significant socio-economic consequences. Please see specific comments on the relevant sections of the draft document for the committee's suggestions on how to reduce and consolidate the discussion of tropical cyclones.

4. Some claims of trends in extreme events are insufficiently supported. In some cases trends are inferred and trend lines are drawn on figures when the data do not appear to justify it. Key issues are whether a given time series is long enough to infer or deduce a trend, whether the underlying data are of sufficient homogeneity to draw conclusions, and whether the trend is statistically significant. In the case of the latter, there are many instances where small changes in the start time for the time series produce changes in the magnitude of the trend that are probably non-significant. One notable example of this is the apparent difference in the trend for Atlantic tropical cyclones when the start time is 1880 versus 1900. In this case and others, such a difference may reflect a problem with the trend assessment technique rather than an actual signal.

In general, the word "trend" is used too loosely and often interchanged with "variation" or "increase." These words should be associated with precise statistical definitions. Furthermore, when statements are made, the authors should indicate whether the claim is based on rigorous statistical analysis of a particular dataset (or datasets), expert elicitation, or the informed judgments of the authors.

5. The levels of uncertainty inherent in the trends should be discussed in more detail. The levels of uncertainty associated with trends (both observed and projected) in various types of extreme events should be elaborated upon. For an observed trend in a particular type of extreme event or variable, please discuss the underlying scientific and technical reasons for that uncertainty, and discuss its implications for projected trends in the extreme event or variable in question. When feasible, compare and contrast the issue for a particular variable to the underlying issues for other variables. As an example, consider that it is reasonable to assert that more is known about observed trends in temperature than trends in heavy precipitation, and even less is known about trends in the frequency and/or intensity of tropical cyclones. What are the technical reasons for this and what are the implications for projected trends?

6. Some cited material is not yet published. Some key literature cited in the report was not available to the peer review committee. In many cases the literature in question was cited as "to be submitted." The committee understands that all literature cited and used as scientific evidence in SAP 3.3 should have reached at least "in press" status by August 2007. The authors of the SAP should ensure that all cited works are publicly available before the public release of the SAP. The committee further recommends that the authors use caution in drawing too heavily on papers and information that are not yet scientifically mature. The authors should minimize reliance on "grey literature" and non-refereed works.

7. The discussion of drought should be strengthened. The discussion of drought is not consistent among the chapters and sometimes contradictory (in terms of observed trends). In some cases apparent trends for particular geographic regions are used to make statements on broader geographic trends that are not justified. This discussion could be strengthened by including a figure for precipitation analogous to Figure 2 in Chapter 1. Notwithstanding the discussion of observed trends and projections, the background information on droughts should better define the different

types of drought (e.g., meteorological, hydrological, agricultural, etc…) and the uncertainties associated in quantifying drought severity using the Palmer Drought Severity Index (PDSI) and other indices. We note that PDSI is the only index discussed in the draft document. Furthermore, the document should address the uncertainty associated with climate model design (e.g., the model treatment of land-surface processes and parameters) and its impact on model representation of drought conditions.

8. The discussion of ecological impacts should be expanded. The draft briefly describes ecological impacts. It would be helpful to expand on these and carry them through with brief pointers, elsewhere in the document, particularly in discussions of future impacts in Chapter 3. The committee recognizes CCSP SAP Goal 4 addresses the subject of impacts in detail, but those SAPs address impacts of climate change in the broader sense and do not necessarily address *per se* the impacts of extreme events. SAP 3.3 should acknowledge the impacts addressed in other SAPs and incorporate some by example. Impacts to consider by example include wildfires and heat stress, which are "compound impacts" of temperature and moisture extremes.

9. The continuity and cohesion among the chapters needs improvement. The individual chapters read as stand-alone documents. They should be connected with some common themes and examples that are carried through (not just in terms of impacts as discussed in 8 above). There is a considerable amount of overlap and repetition, particularly between Chapters 2 and 3. Each chapter authorship team should coordinate with the other three teams to ensure that redundancies are eliminated.

10. The recommendations are not properly organized. Recommendations, and statements that are in effect recommendations but are not labeled as such, are scattered among the chapters. Some of these are repeated in Chapter 4 and some are not. Recommendations should be combined and contained only in Chapter 4 and a highlighted (bold) short sentence corresponding to each recommendation should appear in the Executive Summary.

11. The preface should not contain scientific or technical material. The Preface should contain "big-picture" information on the CCSP and the Synthesis and Assessment Products, and some background on the process and motivation pertaining to SAP 3.3. From a technical writing perspective, a preface is the appropriate location for framing and context; it should not contain technical information that is presented elsewhere in the report. Please see Chapter 3 of this review for more specific suggestions for content.

12. The content is limited in geographical scope. The rationale behind the minimal coverage of regions outside the North American mainland (e.g. "Hawaii, Caribbean, and U.S. Pacific Islands") should be explained. The SAP focuses heavily on North America, but the prospectus and the title suggest some appreciable coverage of other geographic locations.

3

Review of Individual Sections

This chapter provides detailed comments on the front matter (Abstract, Preface, and Executive Summary) and the four chapters of the draft Synthesis and Assessment Product (SAP). The review of each section begins with the committee's overarching thoughts, followed by a list of specific suggestions. The overarching thoughts at the beginning of the review of each section/chapter generally relate the review to the issues raised in the Major Comments (Chapter 2 of this peer review report). In some cases, the specific suggestions that follow the overarching thoughts further relate to issues raised in the Major Comments; in other cases, these specific suggestions are targeted and the committee considers the issue a relatively minor one.

ABSTRACT, PREFACE, AND EXECUTIVE SUMMARY

Abstract

The Abstract should read as a summary of the Executive Summary or a "one-pager" for policymakers. In its current form, the Abstract provides a sufficient summary of the key issues; however, the tone is inconsistent with the balanced and objective tone projected elsewhere in the document. The authors of the document's four chapters should ensure that the language of the revised abstract is not alarmist and that statements are supported by the scientific content provided.

Specific Suggestions:

- Line 10: Make this sentence consistent with the Intergovernmental Panel on Climate Change (IPCC) language it alludes to and refer to the source IPCC material. For example, begin the sentence with "The IPCC 4th assessment concluded…" In addition, replace "planet's" with "Earth's atmosphere and oceans," or a similar phrase.

- Line 11: The second or third sentence should state that, unlike the IPCC assessment, the SAP focuses on North America (this information is currently withheld until Line 17).

- Line 16: The committee feels that it is unjustified to refer to trends in drought since 1950 over North America. If the authors of the SAP disagree, they should

justify disregarding data prior to 1950. The observational record over North America is sufficient to infer trends beginning prior to the 1930s, when the most significant drought in the record occurred.

- Line 18: Please see comment on Line 220 regarding the use of the phrase "hurricane activity."

- Line 21: Longer duration aggravates the impacts of heat waves, droughts, downpours, and to some extent tropical cyclones. This paragraph should be modified to reflect this consideration, consistent with statements in the body of the SAP.

- Lines 29-30: Erosion and inundation of coastal lands are arbitrary selections of impacts. The committee suggests either removing these two impacts or expanding the list.

- The Abstract should mention conclusions made within the body of the report on mid-latitude cyclones (blizzards or "nor'easters"), severe thunderstorms, and tornadoes. All other phenomena discussed in the report are mentioned in the abstract.

Preface

The committee suggests that a preface should not contain scientific or technical material; rather, it should provide background information and outline the process that led to the formulation of the document. In this case, the background information should outline purpose and goals of the U.S. Climate Change Science Program (CCSP) and the SAPs, and provide a brief summary of the purpose of SAP 3.3. The Preface in its current form does address the purpose of SAP 3.3; however background on the CCSP is absent. Remaining material of a technical nature should be moved to other sections of the document.

Specific Suggestions:

- Display and discuss Figure 1 in Chapter 1 and in the Executive Summary, but not in the Preface.

- Place Figure 2 in a "Box" and compare it to the analogous table in the IPCC assessments, by displaying the IPCC figure or via a description of that figure.

- Acknowledge the similar Figure included in SAP 5.2, which was originally conceived to provide guidance for communicating uncertainty in the formulation of other SAPs. Note that SAP 5.2 is currently under revision but should be released publicly before SAP 3.3 is finalized.

Executive Summary

The Executive Summary is more balanced in tone than the Abstract; however, the committee notes several instances where statements in the Executive Summary are not well-supported in the four chapters. The committee does not necessarily disagree with these statements, but only recommends that the authors ensure they are supported if they are included in the Executive Summary. In particular, and in keeping with Major Comments 4 and 5, claims of trends (increases or decreases), which are listed at length, should be rooted consistently in statistical significance and the underlying uncertainties summarized.

The Executive Summary contains several sections with seemingly random, single-sentence paragraphs that should be consolidated, when possible, into coherent themes. Section 6 should be revised to concisely and adequately reflect the recommendations provided in Chapter 4 (see Major Comment 10).

Specific Suggestions:

- Lines 26-29: This paragraph is vague and may be interpreted as alarmist; it should focus on some specific extremes that definitely appear to be changing (e.g., maximum temperatures and precipitation intensity). At a minimum, the committee suggests inserting "some" before "extremes" on line 26.

- Line 66: This sentence on problems of climate models simulating extremes is correct, but it is not obviously related to the previous two sentences, which describe that changes in climate averages imply changes in the tails of the distribution and hence in climate extremes. Perhaps a more direct connection could be made or the sentence put in a separate paragraph where the difficulties for models in simulating extremes are elaborated a little, including both resolution and process limitations.

- Line 87: What is the conclusion of this paragraph?

- Line 113: What does "are likely to be attributable to" mean? Does it mean that they have been attributed to, or does it mean they would be attributed to, but the relevant studies haven't been done yet? There are no formal attribution studies that attribute the global changes in these phenomena to anthropogenic forcing. There is a single attribution study on these by Christidis et al. (2005) but it only considers limited global coverage, as there are no data in many regions.

- Line 118: In this case there are a number of studies that have detected and attributed observed changes in Sea Surface Temperature (SST) to increasing greenhouse gases. Does this statement refer to global average SST or regional SST in the tropics?

- Line 120: There is a new study by Christdis et al. (2007) that attributes observed increases in growing season length (GSL) (based on a simple temperature threshold to define GSL) globally and in North America to increasing greenhouse gases. The main changes are associated with earlier spring onset and are consistent with observed changes in the frost-free period. This should be mentioned as it is just as robust as the other attribution studies on changes in temperature extremes.

- Line 121: Sections 2.3 and 3.1 list societal and ecological impacts for some forms of severe weather but not others. All paragraphs could benefit from some examples of impacts.

- Line 164: There appears to be no basis for this statement in Chapter 2 on observed changes.

- Line 170: If the authors agree that the material presented elsewhere in the document illustrates increases in extreme precipitation, substitute "increases" for "changes."

- Lines 192-197: These statements concerning drought are acceptable, but they are inconsistent with the Lines 202-203, "… it is likely that the increasing temperatures are already contributing to droughts that are longer and more intense." The committee could find no evidence in the material presented (the observed record) of longer, more intense droughts relative to the 1930s and 1950s droughts over North America. These statements also do not comport with the perception conveyed in the Abstract that drought is increasing over North America since 1950.

- Line 205: Section 4.3 boldly asserts increased evapotranspiration and decreased spring runoff in the mountains without providing any compelling evidence. First, it is likely that *potential* evapotranspiration will increase because of warmer air temperatures but actual evapotranspiration will decrease because of decreased soil moisture. Second, the authors state elsewhere (Lines 182-183) that increased spring snowmelt (in higher latitudes) may contribute to extremes in river flooding. Does the first assertion apply only to mountains at low latitudes? Does the second apply only to lowlands at high latitudes? Please clarify this. The peak in spring snow melt run-off is likely to occur earlier, exacerbating the problems of summer water availability, but it unlikely to decrease in magnitude.

- Line 220: This section concludes that it is "very likely" that hurricane *activity* is increasing. The case seems weaker in light of the general uncertainty in the database and Figure 2.30. Moreover, hurricane activity is defined here specifically in terms of frequency and destructive power yet the phrase is used throughout the document in seemingly less definitive ways. The authors should

ensure that when the phrase "hurricane activity" is used anywhere in the document, it refers to a precise and consistent concept.

- Line 227: If the significance of the trends in hurricane frequency is sensitive to a small change in the start date of the period, it may mean that the statistical estimation of the trend significance has not been performed correctly or that assumptions in the noise model are inappropriate. The data do not appear to support a real significant trend in hurricane frequency. This sentence is not appropriate for the Executive Summary.

- Line 245: Over what time period?

- Line 248: The document provides a case for increasing *severity* of hurricanes but the case for increasing frequency is much less compelling. Thus the changes in *activity* (see comment above) may reflect changes in severity.

- Line 302-303: This trend is not supported by an analysis for statistical significance.

- Lines 310-315: The authors state that data are not adequate to make definitive statements on observed changes in tornadoes and severe thunderstorm (Lines 310-312). Then, in an apparent contradiction, they state (lines 312-313) that data related to severe thunderstorms 'are reliable' (suggesting that the presence or absence of trends in *conditions* can be determined). The trends in *conditions* for severe thunderstorms (lines 313-315) have not been shown in the text, and in fact are inconsistent with material presented in Chapter 2 (Lines 144-145; 154-157). Unless the trends in conditions are shown, this statement should be restricted to simply state that the data are not adequate to make definitive statements about trends in severe thunderstorms and tornadoes.

- Lines 327-329: This paragraph does not specify a particular region within the Pacific basin. It seems unlikely that the statement applies to the entire basin. Furthermore, this paragraph relies on Figure 5 to justify its conclusions. If Figure 5 applies globally, the authors should briefly state why this figure supports their conclusion regarding increased extra-tropical cyclone severity. Chapter 2 suggests extra-tropical cyclone severity off the U.S. east coast has decreased because the tracks have shifted northward. The authors should comment on whether this trend is expected to continue.

- Line 379: The inflation-adjusted curve in Figure 1 does not compellingly support the notion extreme events are changing because of a changing climate. If 2005 (Katrina) is removed, there is no significant upward trend. Moreover, any increase in damage (in terms of dollars) could be attributed to increased vulnerability (e.g., expanding infrastructure and population near the coastlines) as much as changes in extreme events. The report needs something more compelling. One possible alternative is to disaggregate the data by phenomenon

(e.g., provide inflation-adjusted trends corresponding to the parameters presented in Figures 2-5).

CHAPTER 1

Why Weather and Climate Extremes Matter

Weather and climate extremes matter primarily because of their socio-economic and environmental impacts, yet the Chapter does not discuss socio-economic impacts in any significant detail. A good starting place for such a discussion would be to include an improved version of Figure 1 from the Executive Summary in this chapter (see above for specific suggestions on how to improve this figure). The authors should also consider providing supporting material for an improved Figure 1. Supporting material could include facts and figures illustrating the migration of the U.S. population to vulnerable coastal areas and time series of deaths due to extreme weather events.

Chapter 1 provides material on many topics but the topics are not well connected. The lack of cohesion is apparent in the architecture of the sub-sections, wherein there are multiple one-sentence paragraphs that do not always support a more general theme. One remedy would be to combine these short paragraphs; another is to enhance each of them by developing a stronger lead sentence and providing supporting material. In addition, the boxes at the end should be integrated into the chapter rather than grouped together. In some cases, these boxes could be moved into other chapters (e.g., Box F could be moved to Chapter 2).

Specific Suggestions:

- Line 31: This is an excellent recommendation but it should be augmented to explain why it is important. For example, Chapter 4, Figure 1, which states "Mitigation of adverse impacts through better planning and decision making." The recommendation on Line 31 should include language to this effect.

- Line 66: This sentence is unclear and Figure 1 is not very effective. Figure 1 should be removed or revised to differentiate between natural and human systems.

- Line 68: This chapter should emphasize a key point: Changes in extremes are key mechanisms by which climate change affects society and the environment. IF these changes can be forecast reliably society can adapt to minimize their impacts. This point could be the lead-in sentence to the paragraph starting on line 68. The authors should consider moving the resulting paragraph to the beginning of the chapter.

- Line 83: Section 1.3 is a summary but not a catalogue of extreme event indicators. Moreover, there probably should be a catalogue to help explain what extremes were considered and why. This report should provide a first pass at

such a catalogue, as the authors imply that future work should refine a catalogue based on dialogue with the stakeholder community (lines 34-37 and Chapter 4, lines 255-258).

- Line 103: The authors should replace "determine the probability" with "estimate."

- Line 109: Insert "some" before "extreme events".

- Line 110: Figure 2 is a valuable figure but its value is diminished because of the lack of discussion. The authors should walk the reader through the figure more carefully, perhaps looking at some specific numbers and examples (e.g. in the previous climate the probability of seeing a 10º temperature was 10%. When the mean shifts, the probability becomes 20%.)

- Line 127: The title of Section 1.1.2 is ambiguous. One possibility might be to rename it, "Important Characteristics of Extremes."

- Line 133: The authors raise important points but then illustrate them with examples that are relatively unimportant. For example, it may not be important that the tornado season shifts if season duration is unchanged. More important examples might include: (a) time of the first snow melt (earlier in the Sierras means longer dry season with far reaching impacts on the ecology); (b) time of the wild-fire peak (earlier might pose threats to certain species).

- Line 144: The authors introduce the term "morphology" and use it very ambiguously throughout the report. The authors seem to define morphology to mean the detailed characteristics and properties of an extreme. The authors could in some cases employ more direct terminology; perhaps "characteristics" or "properties" would suffice.

- Line 151: The details of this discussion are quite good but the organization needs improvement. One possibility is to move Sections 1.1.3-4 into 1.2 since these sections focus largely on vulnerabilities.

- Line 167: "Enormous" may be an overstatement if one considers the numbers of deaths resulting from other natural hazards and disasters (e.g., the Indian Ocean Tsunami).

- Line 170: Consider combining sections 1.1.3 and 1.1.4.

- Line 208: This sentence fails to summarize the important point. Consider replacing "the relationship between climate and society" with a phrase similar to "calculating losses due to extremes". In addition, "statistics" can be deleted.

- Line 212: This is a powerful statement but the authors offer no justification or evidence to support it.

- Line 222: Consider substituting "probability of extremes" for "magnitude of the exposure to which the system is subjected" if this statement refers to extremes but not vulnerability.

- Line 243: The authors should point out that there is a lack of quantitative proof that adaptation and mitigation saves money. Many decision makers will not support the cost of mitigation unless the cost-benefit relationship is known.

- Line 272: The concept of a binary classification is introduced yet it is not employed elsewhere in the report (e.g., in the boxes at the end of this chapter other chapters). Consider employing the concept elsewhere in the report. Please clarify the concept when it is first introduced and explain how a binary tree would work.

- Line 325: The last six words are emphatically policy prescriptive and should be removed altogether. The authors should not recommend courses of action for policymakers.

- Line 355: This paragraph should be re-written using simpler terminology. At a minimum, "evolutionary" in first sentence should be replaced with "behavioral." The present paragraph implies that while some species have shown behavioral adaptation to on-going climate change, there are no species that have shown genetic adaptations (presumably because they have not had time to evolve). If that is true then the paragraph deserves its own section and would not belong in Section 1.2.3 on Thresholds.

- Line 500: A recent study in press in the Proceedings of the National Academy of Sciences (PNAS) with Tom Knutson as a co-author has attributed the observed increase in coral bleaching in the Caribbean to anthropogenic forcing (Donner et al. 2007). This could be mentioned in this box.

- Line 562: The sentence beginning on this line could be interpreted as a value judgment that compares human worth and suffering to animal or plant worth and should be deleted or phrased more precisely.

CHAPTER 2

Observed Changes of Weather and Climate Extremes

In this chapter the authors address the key issues set forth in the document's prospectus regarding what is known about observed changes in extreme events. In several cases, however, the authors overstate the case for an observed trend. Such claims

should be supported by the data, provided here or elsewhere in the peer-reviewed literature, with uncertainties quantified and the analyses of datasets subjected to tests for statistical significance. If the claims are based on expert elicitation and not data per se, this should be noted explicitly.

The material on tropical cyclones is too lengthy. The committee provides several specific comments to indicate what material should be retained and what should be omitted in the revised SAP. In considering these comments, the authors should strive to capture the dimensions of the ongoing scientific debate vis-à-vis trends in tropical cyclones and climate change, while considering the need to limit the length of the discussion.

Specific Comments and Suggestions:

- Line 69: This finding is inconsistent with earlier statements about drought (Line 17 of the Abstract and Line 193 of the Executive Summary).

- Line 89: The change in start time from 1880 to 1900 is a small percentage of the overall length of the time series. Such a relatively small change should not impact the trend in a statistically significant manner. This difference likely reflects a problem with the trend assessment technique more than a difference in any actual trend in nature.

- Line 103: There is no quantitative discussion accompanying the phrase "very unlikely" of the key uncertainties related to measuring the decadal variability.

- Line 121: This does not rise to the level of a "key" finding.

- Line 141: This key finding is repeated on line 1551 without any evidence. Please provide citations (if they exist) to support this.

- Line 164: Are these regime changes associated with climate change issues? Is there evidence for a naturally varying climate system? Please provide citations (suggestion: Bell and Halpert 1995)? (Note: this would be a good location for Box F from Chapter 1).

- Line 182: Delete "exactly." As is, the sentence implies that exactness is the norm or at least is not rare.

- Line 184: What is meant quantitatively by "above to much above?" The National Oceanic and Atmospheric Administration (NOAA) defines these terms quantitatively. What are these definitions?

- Line 187: Insert anomalies after temperature[s].

- Line 224: This statement may be inconsistent with lines 242-243. How do "very extreme" heat episodes differ quantitatively from "warm spells?" (Note: Peterson et al. 2007 is not yet published). These data do not support the tone of certainty projected by sentence that begins on line 12 of the Abstract.

- Line 261: To minimize confusion, please characterize all changes in terms of either frost day occurrence or length of the frost season, but not both.

- Line 338: Define Palmer Drought Severity Index (PDSI). Provide a reference. Discuss its strengths and weaknesses.

- Line 424: Please quantify what is meant by "disproportionately" or strike it.

- Line 426: It would be useful to note parenthetically that 101.6 millimeters is equivalent to 4 inches. If there are other instances in the document where seemingly random metric quantities relate to "round" English system numbers, please provide the equivalents.

- Line 491: Cavazos 2007 is not yet published and may not yet have even been submitted.

- Line 539: Please better define "90-days duration precipitation episode." This may be a misstatement (e.g., 90-day accumulation may be the intended phrase).

- Line 544: How is the temporal behavior similar? Does the comment refer to multi-decadal variability?

- Line 643: The annual-average global total of 90 with a variance of approximately 10 is consistent with Poisson statistics, and indeed a range of studies provide no compelling evidence to reject a Poisson model (Gray 1968; Katz 2002; Frank and Young 2007). Since the process of tropical cyclogenesis involves many disturbances each with low probability of becoming a storm one would expect this sort of model to work reasonably well. This should be acknowledged.

- Line 656: The more commonly quoted damage total for Katrina is $80B; $110-120B is the generally quoted cost for the entire 2005 season (NHC 2006).

- Line 676: The discussion of data limitations on pp. 27-30 is generally balanced and accurate. Note that routine reconnaissance began in 1944 (not in 1945 as stated on line 715), and the National Weather Service (NWS) attributed the limited loss of life ashore in the "Great" Hurricane of that year to this reconnaissance.

- Lines 744: Although cyclone-size data are invaluable for many aspects of impacts modeling, this discussion is not essential here and could be removed. At

a minimum, the concluding statement of this paragraph is inflammatory ("failure of governments to take seriously…") and should be removed.

- Lines 754: The discussion of spectra of hurricane occurrence is not essential to the thrust of this chapter. It should be reduced to mention El Niño/Southern Oscillation's (ENSO) modulation of Atlantic activity and the existence of substantial multidecadal component.

- Lines 773: Please define the Power Dissipation Index (PDI) and comment that statistical significance of PDI trends is dependant upon corrections applied to the records, listing all references. The detailed accounts of dueling corrections will make a fascinating review paper at some point, but they do not contribute to the message here. The assessment of the science is that eminently qualified investigators cannot yet forge a solid consensus. Nevertheless, the paragraphs that begin on lines 798 and 804 should be retained verbatim.

- Line 812: The material beginning here and ending on line 891 reflects a level of detail entirely appropriate for a review article, but not for the document at hand. The readers (at the level of a "Scientific American" readership) need not know the details of the argument, but need to know that different, but reasonable detrending strategies can yield either large trends or trends at the margins of detectability.

- Line 906: This paragraph provides too much detail for the proposed audiences.

- Line 924: This section should be condensed into one page or less, incorporating key references that span the range of evidence and informed opinion. The committee does not necessarily disagree with the statements in this section but that the level of detail is not appropriate for a SAP. These are issues that should mature in the peer-reviewed, technical literature before they are presented in an assessment document.

- Line 930: Figure 2.27 would be improved if it showed tropical cyclone numbers subject to different adjustment strategies and resulting uncertainties in the trends, such as is shown in 2.30 (note: Figure 2:30 is "in preparation") .

- Line 965: The literature documents that historical SST data for these time periods constitute a well maintained database with clearly defined, acceptably small errors. Again, this is a point that would be essential in a review targeted at a professional audience, but it does not serve the purpose here.

- Line 998: The lack of an increasing trend in landfalling Atlantic tropical cyclones is important. The committee recommends that the material on observed trends in Chapter 3 (e.g., Pielke) be combined with this material and that it all be placed here in Chapter 2. The lack of trend due to signal-to-noise problems has implications for projection into the future. The message is that landfalls may be described by a Poisson process, thus a low mean implies a larger standard

deviation relative to the mean and hence a large stochastic component, regardless of any trends with basin-wide numbers and intensities.

- Line 1069: Fig 2.30 contributes significantly. A paragraph based upon lines 1069-1086, but without the details of the significance testing should be retained.

- Line 1087: The material presented from here through line 1165 should be reduced because it is largely redundant with the discussion that begins on line 976.

- Line 1166: The review panel endorses the recommendation to pursue paleotempestology; it is a promising method to extend the short, heterogeneous instrumental record. Historical investigations of existing, but obscure, written archives also show promise. However, this section could probably be reduced to a paragraph or two. (Note: please clarify here or elsewhere that as used in the SAP, "paleo" refers primarily to the Holocene).

- Line 1227: The discussion of the climatic role is interesting, but it may not belong in this document. This is about extreme events, not about the maintenance of the general circulation by hurricanes.

- Line 1247: Is Hart et al. 2006 yet published?

- Line 1296: The committee believes that in fact there are data over the central North Pacific to analyze extratropical cyclones; it may be limited, but it exists.

- Line 1352: This statement is not supported by Figure 2.36, which indicates no trends whatsoever.

- Line 1355: It would help to insert a sentence or two on the importance of increasing sea level as it relates to the 'perfect storm' nor'easter.

- Line 1475: Table 2 should indicate whether there are significant trends, despite the textual reference to the five largest wave occurrences each year.

- Line 1573: Please clarify what is meant by W-shaped. Does this refer to a figure in the Changnon and Karl reference?

- Line 1612: If there is not a trend, please reconcile this with the statement that severe weather environments have increased and then decreased (Lines 314-315 of Executive Summary and Figure 2.42).

- Line 1630: These changes do not appear to be significant and may just be natural variations. The results here may be the justification for the statement in Exec Summary lines 313-315 but since the trends are likely not significant, they do not justify being brought forward to the Executive Summary.

- Line 1648: Please clarify what is meant by the climate shift in 1976-77. If this shift is important, why is it not discussed elsewhere?

- Line 1639: Enhance this section with follow-up discussion from lines 662-752 of Chapter 1. The discussion should relate suppression of hurricane activity in the Atlantic to the enhanced ENSO index. The observed changes that have occurred in Pacific-North America pattern (PNA) and North Atlantic Oscillation (NAO) are related to the surface storm track that you have already discussed earlier (lines 1249-1354).

- Line 1768: This section could be moved to Chapter 3. It is about projections (not the observed record) and combining models to predict future extremes.

CHAPTER 3

How Well Do We Understand the Observed Changes in Extremes, and What Are the Projected Future Changes?

The authors provide a good assessment of the scientific understanding of extremes and projected future changes; however, the chapter is too long. Moreover, the discussion on tropical cyclones is excessively lengthy while drought receives less attention than it should. The committee understands that although hurricanes are of considerable interest to a wide variety of audiences, the socio-economic implications of increases in droughts and heat waves are also very serious. Consider, for example, tens-of-thousands who died in the European heat wave of summer 2003, or the 739 excess deaths in Chicago during the 1995 heat wave. Given these implications, the committee believes that the SAP 3.3 should expand the discussion of drought, particularly in regards to projections and uncertainties in those projections.

The authors should coordinate with the authors of Chapter 2 to eliminate the many redundancies with Chapter 3. Much of the detection section (3.2) should be moved to Chapter 2 to reduce redundancies. The authors should discuss the differences among detection in observed changes and their implications for projections. If these differences and the causes for them are presented adequately in Chapter 2, the discussion of attribution in Chapter 3 would flow more logically than in the present structure of the document.

To reduce the material on tropical cyclones, the authors should focus on significantly reducing Subsections 3.2.4 and 3.3.3. Subsection 3.2.4 is twice as long as all other parts of Section 3.2 and reads as a text on mechanisms. Much of this material is not appropriate for an assessment. The revised versions of these subsections should outline the basic arguments and summarize the range of informed opinion without providing the fine details of every researcher's arguments, in keeping with a style and

level of detail appropriate for a *Scientific American* readership. The committee provides some specific suggestions in the comments below.

Specific Comments and Suggestions:

- Line 36: The number of key findings (34) dilutes the effectiveness of each. The authors should reduce the number.

- Line 43: What period of time is being referenced in the first two bullets?

- Line 48: The paper by Christidis et al. (2007) supports a stronger conclusion for the attribution of GSL reductions in North America and globally over the last 50 years.

- Line 73: What is meant by "tropical cyclone activity"? Does activity refer to a combination of intensity, number of storms, and other characteristics, or something more specific?

- Line 108: Increased *frequency* of droughts is not supported by the evidence provided in this document. Insert "potential" before evapotranspiration.

- Line 128: Is this statement supported by published literature or is it based on expert elicitation? The conventional wisdom in the hurricane community is that shear is a bigger factor in the Atlantic and that as a result, Atlantic hurricanes often form under marginally favorable conditions. Thus, hurricane activity in the Atlantic is sensitive to small changes in environment near the threshold of formation. Other basins may exhibit similar sensitivity, but this sensitivity is geographically larger and less influenced by mid-latitude windshear (apart from the northern Indian Ocean).

- Line 135: If this is a key finding based on one study that provides an ensemble mean of climate model output, the uncertainty (spread of the ensemble) should be discussed. This statement on the changes in vertical wind shear appears to be based on the ensemble mean model result from one study. Given the likely poleward shift in the mid-latitude jets and the large variability between different models, there may be good reasons for being less confident about this statement.

- Line 198: Mesoscale models (used in a regional climate modeling mode) can be used to help address these issues. The committee suggests explicitly mentioning this in this recommendation.

- Line 261: In Table 1, it may be incorrect to assert better than even odds that *global* drought is attributable to anthropogenic forcing considering that this information is (1) based only on one study; (2) based only on one model, (3) the

reference isn't available in the published literature; and (4) is based only on the PDSI, which has its limitations.

- Line 301: This reference is not listed. The U.S. Climate Extremes Index (CEI) uses annual mean maximum and minimum temperatures, not daily temperatures, so the observed increase in the U.S. CEI is largely due to an increase in the area of the U.S. with much above normal mean maximum and minimum temperatures and an increase in the area of the U.S. experiencing a much greater than normal proportion of precipitation from heavy one day events.

- Line 324: This paragraph is a little misleading, as the main external forcing of the observed global precipitation changes is the volcanic forcing. This should be stated explicitly, as elsewhere in this chapter, the main forcing is the increase in anthropogenic greenhouse gas and aerosol concentrations.

- Line 427: In addition to comparing observations to the ensemble mean of climate model output, these types of comparisons should address ensemble spread and differences in the spatial patterns among ensemble members. All that is required for the observations to be consistent with the model ensemble is that the observed trend and spatial pattern of change lies within the full range of the model ensemble members, but not necessarily close to the ensemble mean. It appears that the authors may be neglecting to take account of the contribution of internal climate variability to the spatial pattern of observed changes, which could be very large regionally.

- Line 482: This result only applies globally, but there can be large spatial variations in the decrease in duration or frequency of precipitation events, with some locations having increases.

- Line 766: Insert "observational" before "studies."

- Line 1024: This section needs more subheadings. Some suggestions include frost, snow, drought, and lake effect snow. In the current format, all of these events are lumped under "precipitation" and "temperature."

- Line 1041: The uncertainty ranges (shaded sigma bounds) are plotted incorrectly in Figure 1. It may be that the authors did not assess the trends in the control runs and eliminate models with significant control run drift before assessing uncertainty ranges in the projections.

- Line 1043: The statements on effects of soil moisture change are difficult to follow. Consider simplifying them to state that changes in soil moisture and land-surface parameters may differently affect changes in extremes for maximum and minimum temperature.

- Again, the comparison of the observed spatial pattern of warming and decrease in frost days in Figure 2 with the ensemble mean pattern from models seems to expect the observed pattern of change to be close to the ensemble mean. However, consistency with the model forced changes plus natural internal variability just requires that the observed pattern of change be well correlated with at least one member of the model ensemble, not necessarily with the ensemble mean. Differences in the spatial patterns are likely due to natural climate variations at regional scales.

- Line 1262: The introductory material is excellent, although here and elsewhere, the authors should reconcile the disconnect between model predictions of reduced tropical cyclone numbers due to increased shear with the subset of the observations that support increased numbers.

- Line 1271: At some point, either here or (preferably) in the discussion of middle latitude cyclones and storm surge (Chapter 2), the authors should quote the amount of historical sea-level rise as measured by instruments like tide gauges. Note the apparent acceleration detected with satellite altimetry, and mention scenarios (e.g., West Antarctic Ice Sheet, Greenland Ice Sheet, reduction in formation of Atlantic Intermediate Water) that could lead to acceleration (Alley et al. 2005; Shepherd and Wingham 2007).

- Line 1318: This citation is not in the references section. Is it yet published?

- Lines 1362: It would be useful to quote the intensity increases in terms of wind speed in addition to (or instead of) pressure. Wind speed is more meaningful to a broader readership and also avoids the issues of ambient environmental pressure and pressure-wind relationships.

- Line 1425: The discussion of modeling lapses into far too much detail near this location. From here through line 1466, it needs to be condensed and simplified.

- Line 1467: The material from here through line 1506 could be reduced to one or two paragraphs. The intensity changes per degree Celsius should be quoted in terms of velocity and pressure fall, or at least consistently in terms of one or the other.

- Line 1542: Beginning here, the material presented in Subsection 3.3.3 could be condensed.

- Line 1600: The caption for Table 3 is incorrect. The table provides percentages of 20th Century occurrence, not percentage changes.

- Line 1636: The summary that extends through should be reduced to a few lines and appended to the paragraph beginning on line 1675, which should be retained,

because these paragraphs are to a large extent redundant with the discussion that begins on line 1599.

- Line 1642: The material beginning here and through line 1655 should be removed because it addresses non-tropical cyclone convection over the oceans. While this connection may be real, it is too speculative for inclusion here.

- Line 1694: The authors probably mean accumulated rainfall at a locality in the storm's path. Radar meteorologists use the term "total storm-lifetime precipitation," but for broad readership it implies a Lagrangian (not Eulerian) concept.

- Line 1702: A citation to personal communication may be problematic, given the requirements of the prospectus.

- Line 1725: Subsection 3.3.3.5 is well-written but the scientific support for it is perhaps the weakest subsections of 3.3.3. This committee suggests that this subsection in particular should be greatly condensed.

CHAPTER 4

Recommendations for Improving Our Understanding

The committee generally concurs with the recommendations of the authors but offers several specific comments to sharpen their impact. From a formatting perspective, the committee recommends that the authors consolidate all recommendations scattered among the chapters into Chapter 4. Stylistically, using both bold face and italics for the entire text of a recommendation statement dilutes its impact. Each numbered recommendation statement (e.g., line 115) should begin with a concise, high-impact sentence (in bold) followed by supporting (plain) text. Each of these first sentences should appear verbatim in the Executive Summary.

The committee noted that although the draft document devotes a considerable amount of space to tropical cyclone issues, there are no recommendations regarding this topic. Notwithstanding the recommendation to reduce the amount of discussion within the chapters, the committee suggests that the authors add a recommendation to support research that seeks to improve our understanding of what governs hurricane intensity. Current theory (e.g., the Maximum Potential Intensity) does not adequately explain the correlation between higher sea-surface temperature and hurricane intensity. The mechanisms that govern intensity must be understood better in order to understand better the potential impacts of a warming world on hurricane intensity.

Specific Comments and Suggestions:

- Line 11: The sentence beginning on this line should be deleted. It's a parenthetical remark without much meaning that detracts from the point of the paragraph.

- Line 30: Substitute "approximate" for "produce" (also on line 59). Producing a completely homogeneous time series is impossible.

- Line 57: This is a particularly balanced statement on the ongoing scientific debate and could be included in the Executive Summary.

- Lines 74: Is there a reference that supports this conclusion (in Chapter 2 or 3 of the draft SAP)?

- Line 77: The authors may mean 1905 instead of 2005.

- Line 96: Please see comment on line 74.

- Line 109: Please see comment on line 74.

- Line 119: Why is this recommendation applied only to severe thunderstorms and tornadoes? Do observations of other types of events not suffer from inconsistent standards of data collection?

- Line 123: The authors could add to line 123 "Recover, digitize" before "homogenize." In the four recommendations surrounding this line, there is nothing about digitization or recovery of data

- Line 129: Recommendation 3 does not rise to the level of generality as the other recommendations and could be incorporated into recommendation 2, which should emphasize long term analysis of observational data. This combined recommendation should be sufficiently overarching and include a statement to the effect that many improvements are needed in many types of observing systems in order to address the issues set forth in the SAP. In a combined and broader recommendation, extra-tropical Cyclones (ETCs) and extreme wave heights could be mentioned as two types of extremes for which better analysis of long-term data is required. If the authors are raising ETCs and extreme wave heights for a particular reason and they wish for Recommendation 3 to remain separate, then those particular reasons should be further elucidated.

- Line 133: This recommendation should be broadened to included paleo datsets that can be used to infer time series of extreme hydrologic flows (paleogeological datasets) and droughts (tree rings and other paleohydrologic datasets). These datasets could provide information in addition to time series of temperature and precipitation.

- Line 140: The sentence beginning on this line should be a dependent clause of the one that immediately follows. Please provide a reference.

- Line 144: The acronym is WGCM, not WGNE.

- Line 167: What is "this" resolution, in kilometers?

- Line 177: The Hurricane Rainband and Intensity Change Experiment (RAINEX) results show that approximately 2km may be adequate (Houze et al. 2007).

- Line 184: In this recommendation, replace "with only minor modifications" with "within the same conceptual framework." Insert "of weather and climate extremes" after predictions. Insert "to enhance spatial and time resolution" before "to recreate." In addition, this recommendation should be consistent with what appears in the document (see text beginning on line 175 of the Executive Summary) and should further recommend use of, or consideration of, *regional* climate models.

- Line 192: A better first sentence could be "We recommend that modeling groups make available data at the highest spatial and temporal resolution from existing simulations of the climate of the 20th and 21st century."

- Line 240: This example has been explored adequately in previous chapters. The committee suggests deleting the sentence on lines 240-241, and everything from "threshold" in line 244 through the end of the paragraph on line 247.

- Line 242: What changes are "these" changes?

- Line 250: Remove "Considering the rapid pace of climate change," because this sentence is a statement of fact regardless of the current or future pace of climate change.

- Line 259: The summary, while it is a straightforward statement of what needs to be done, needs editing to make it more vigorous and emphatic. Also, need to emphasize the need not only for scientists and users to communicate, but in this case, the weather and climate communities need to learn to talk to one another.

- Line 329: Figure 1 would be improved if the text in the boxes is replaced with single words, such as "Observations", "Models", "Understanding", "Impacts", "Adaptation and Mitigation".

REFERENCES

Alley, R.B., P.U. Clark, P. Huybrechts, and I. Joughin. 2005. Ice-Sheet and Sea-Level Changes. *Science* 310: 456-460.

Bell, G.D., and M.S. Halpert. 1995. Atlas of intraseasonal and interannual variability, 1986–1993. NOAA Atlas No. 12, Climate Prediction Center, NOAA/NWS/MNC, Washington, DC.

Christidis, N., P.A. Stott, S. Brown, D.J. Karoly, and J. Caesar. 2007. Human contribution to the lengthening of the growing season during 1950-1999. *Journal of Climate*, in press.

Christidis, N., P.A. Stott, S. Brown, G. Hegerl, and J. Caesar. 2005. Detection of changes in temperature extremes during the second half of the 20th century. *Geophysical Research Letters* 32: L20716.

Donner S.D., T.R. Knutson, and M. Oppenheimer. 2007. Model-based assessment of the role of human-induced climate change in the 2005 Caribbean coral bleaching event. *Proceedings of the National Academy of Sciences* 104(13): 5,483-5,488.

Frank, W.M., and G.S. Young. 2007. The interannual variability of tropical cyclones. *Monthly Weather Review* 135, in press.

Gray, W.M. 1968. Global view of the origin of tropical disturbances and storms. *Monthly Weather Review* 96: 669-700.

Houze, R.A., S.S. Chen, B.F. Smull, W.C. Lee, and M.M. Bell. 2007. Hurrican Intensity and Eyewall Replacement. *Science* 315: 1235-1239.

Katz, R.W. 2002. Stochastic modeling of hurricane damage. *Journal of Applied Meteorology* 41: 754-762.

National Hurricane Center. 2006. Tropical Cyclone Report: Hurricane Katrina. Available at http://www.nhc.noaa.gov/pdf/TCR-AL122005_Katrina.pdf.

National Research Council (NRC). 2004. Implementing Climate and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Plan. Washington, DC: The National Academies Press.

Shepherd, A. and D. Wingham. 2007. Recent Sea-Level Contributions of the Antarctic and Greenland Ice Sheets. *Science* 315: 1529-1532

Appendixes

A

CCSP Synthesis and Assessment Products

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/>.

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.

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>.

B

Prospectus for Synthesis and Assessment Product 3.3

Weather and Climate Extremes in a Changing Climate

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

The impact of climate extremes can be severe and wide-ranging. Extremes affect all sectors of the economy, including agriculture, utilities, transportation, water resources, and the insurance industry. The costs of weather-related disasters can be considerable. The U.S. National Climatic Data Center maintains a web page (<http://www.ncdc.noaa.gov/oa/reports/billionz.html>) that describes those events that have had the greatest economic impact in the U.S. since 1980. During the period 1980-2005, the U.S. experienced 67 weather-related disasters in which overall damages exceeded $1 billion at the time of the event (and subsequently adjusted in terms of constant dollars).

Clearly, the direct impact of extreme weather and climate events on the U.S. economy is substantial. However, the evidence for increases in extreme weather and climate events varies, depending on the event of interest (e.g., changes in heavy and extreme precipitation, frost days, heavy snow events, etc.).

A workshop convened in Bermuda in October, 2005 assembled climate scientists and insurers/reinsurers to assess the current state of knowledge of climate extremes. A summary of the meeting is available in EOS (Vol. 87, No. 3, January 17, 2006). The meeting addressed anticipated changes in the frequency of extreme events in response to global warming; whether these changes could be bounded; and the observations needed to improve our knowledge, i.e., improve models and the statistics of extremes. Hurricanes were of particular interest because of recent, very active seasons and the large impact on the insurance industry. The workshop recognized the importance of both observations and models to accurately quantify risk. The need to better understand the natural and anthropogenic drivers of changes in climate extremes was underscored.

Recent and ongoing Intergovernmental Panel on Climate Change (IPCC) Assessments have evaluated extreme weather and climate events in the context of climate change on a global basis. However, there has not yet been specific focus on those events in North America, where observing systems are among the best in the world.

There is also environmental evidence that changes in weather and climate extremes have important biological impacts for both natural and managed ecosystems. In addition, there are

prospects from climate model simulations that a gradually warming world will be accompanied by changes in the variability and frequency of weather and climate extremes. For all these reasons monitoring changes and variations in weather and climate extremes and assessing what we know and do not know regarding future changes is important for both socio-economic and environmental interests. Therefore, it is timely to undertake an in-depth assessment of the state of our knowledge for North America, where we live, work, grow much of our food, etc.

Extreme weather and climate events span many weather and climate variables, and an important aspect of this synthesis and assessment report will be to identify those key variables or indices that may provide important information related to socio-economic or environmental impacts. Identifying recent changes and trends in these parameters will be a focus of the report, as well as identifying what can be said about future changes. Examples of some of the key variables include temperature-related parameters (severe freezes, heat waves), precipitation-related parameters (wet spells, heavy precipitation events, droughts), tropical and extra-tropical storm frequency and intensity, ice and hail, snow cover and depth, etc. Since extreme weather and climate events on a global scale are regularly addressed in international assessments, this CCSP Synthesis and Assessment Report will focus on weather and climate extremes primarily across Canada, Mexico, and the United States, including its territories.

In accordance with CCSP guidelines, the synthesis and assessment products are intended to support informed discussion and decision-making regarding climate variability and change by policy makers, resource managers, stakeholders, the media, and the general public. This report also should have particular value to ongoing free-trade agreements (Canada, U.S., and Mexico) and bi-lateral and multi-lateral agreements related to the management of natural resources in North America.

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

The National Oceanic and Atmospheric Administration (NOAA) is the lead agency for this synthesis and assessment product. Relevant agency personnel are presented in the following table:

CCSP Member Agency	Agency Leads
Department of Commerce (NOAA)	Thomas Karl, Christopher Miller
Department of Energy	Anjuli Bamzai
National Aeronautics and Space Administration	Don Anderson, Tsengdar Lee
U.S. Geological Survey	Tom Armstrong

3. Lead Authors: Required Expertise of Lead Authors and Biographical Information for Proposed Lead Authors

The author team for this Product will be constituted as a Federal Advisory Committee in accordance with the Federal Advisory Committee Act (FACA) of 1972 as amended, 5 U.S.C. App.2. Each author team member shall be appointed for a term of two years, and will serve at the discretion of the Under Secretary of Commerce for Oceans and Atmosphere. Appointments are renewable for additional terms. Committee members will include non-Federal experts and

Federal officials who are also experts and who may remain on the committee should they leave Federal service. Non-federal employee committee members will be subject to the ethical standards applicable to Special Government Employees and to Departmental and FACA vetting procedures. The Committee Charter, a list of Committee members, and meeting announcement information will be made available to the public on a dedicated web page. Committee meetings will also be announced in the *Federal Register* at least 15 days in advance and these meetings will be open to the public. All materials made available to the Committee, as well as meeting reports, will be made available to the public unless subject to exemption under the Freedom of Information Act.

The list of author team nominees presented in Appendix A is proposed based on their records of interest and accomplishment in framing the core issues related to changes, trends, and uncertainties in the occurrence of extreme climate events and their impacts, advancing relevant scientific arguments, and contributing to increased understanding of the behavior of respective components of the end-to-end system that provides the required data sets. Past contributions to relevant scientific assessments, publication records in refereed journals, and committee balance and diversity are among the measures used in the selection process. Dr. Thomas Karl, the Director of the National Climatic Data Center, and Dr. Gerald Meehl, of the National Center for Atmospheric Research, are nominated as co-Chairs of the FACA Committee. Once the nominations have been approved and vetting has been completed, the chapter assignments proposed in Section 5 of this Prospectus will be confirmed.

4. Stakeholder Interactions

An initial workshop was held in July 2005 to bring together a number of leading scientists in the area of climate extremes and members of key segments of the stakeholder community. The primary objective of this workshop was to help frame the critical issues related to this synthesis and assessment. This framework included various aspects of the science, impacts, and stakeholders' concerns related to the changes and variations of weather and climate extremes. A specific outcome was an outline of an action plan to produce the required CCSP product, i.e., an assessment report on weather and climate extremes. A second workshop, this one focusing more on the impacts of extreme weather and climate events for a specific stakeholder community occurred in October 2005. The output from the second workshop was used to help refine critical issues the report will address.

In summary, the general objectives of these workshops were to: (1) identify a framework to define climate weather and extremes with particular ecological or economic impact; (2) assess the state of the science in the historical and contemporary measurement of weather and climate extremes; (3) examine and clarify our ability to report on observed changes and variations; (4) examine what, if anything, we can say about future changes suggested by climate models or other relevant information, including changes in the frequency, intensity, and duration of extremes; and (5) define the measurements, analyses, and other actions required to improve our understanding of future variations and changes in weather and climate extremes. These issues will be the focus of the CCSP Synthesis and Assessment Product 3.3.

5. Drafting, Including Materials to Be Used in Preparing the Product

The lead NOAA focal point, Dr. Thomas Karl, is the Editor-in-Chief. The assistant NOAA focal point, Dr. Christopher Miller, serves as the Associate Editor. This report will be prepared in compliance with the Federal Advisory Committee Act and the report development team will be constituted and operated under FACA guidelines. The report will be written in a style consistent with major international scientific assessments [e.g., IPCC assessments, and the Global Ozone Research and Monitoring Project (WMO, 1999)].

The main body of this report will be presented in four chapters, the contents of which will be summarized in an Executive Summary (ES):

Chapter 1. Why weather and climate extremes matter
- 1.1 Why are extremes important?
- 1.2 Defining extremes in relation to social, economic and environmental impacts.
- 1.3 Measures of weather and climate extremes and their data limitations.

Proposed Convening Lead Author (CLA): Thomas Peterson
Proposed Lead Authors (LA): David Phillips, Camille Parmesan, John Stone (also ES), David Anderson, Miguel Cortez, Richard Murnane (also ES), Roger Pulwarty, Stewart Cohen (also ES)

Chapter 2. Observed changes of weather and climate extremes
- 2.1 Observed changes and variations in weather and climate extremes.
- 2.2 Key uncertainties related to measuring specific variations and changes.

Proposed Convening Lead Author (CLA): Kenneth Kunkel
Proposed Lead Authors (LA): David Levinson, Tereza Cavazos, Arthur Douglas, Harold Brooks, David Easterling, Kerry Emanuel, Charles Watson, Pavel Groisman, Richard Smith, Peter Bromirski, Paul Komar

Chapter 3. Do we understand the causes of observed changes in extremes and what are the projected future changes?
- 3.1 What are the physical mechanisms of observed changes in extremes?
- 3.2 Attributing observed changes to external forcing.
- 3.3 Projected future changes in extremes, their causes, mechanisms and uncertainties.

Proposed Convening Lead Author (CLA): William Gutowski
Proposed Lead Authors (LA): Linda Mearns, Greg Holland, Gabriele Hegerl, Francis Zwiers, Ronald Stouffer, Peter Webster, Thomas Knutson (also ES)

Chapter 4. Recommendations for Improving our Understanding:
Proposed Convening Lead Author (CLA): David Easterling
Proposed Lead Authors (LA): Thomas Peterson (also ES), Kenneth Kunkel (also ES), William Gutowski (also ES)

Executive Summary
Proposed Convening Lead Authors (CLA): Gerald Meehl, Thomas Karl
Proposed Lead Authors (LA): Thomas Peterson, Kenneth Kunkel, William Gutowski, David Easterling, Rick Murnane, Stewart Cohen, Thomas Knutson, John Stone

Under the leadership of the convening lead author for each of the main report chapters, the lead authors and contributors will prepare the scientific/technical analysis section of the synthesis and assessment report. They will draw upon published, peer-reviewed scientific literature in the drafting process, complemented, if necessary and if approved by the CCSP Principals, with information that has not yet been published in the peer-reviewed literature.

The synthesis and assessment product will include an Executive Summary that will present key findings from each of the report chapters. It will be written by a team consisting of the Executive Summary convening lead authors assisted by the convening lead authors from each of the chapters. The synthesis and assessment product will strive to reach consensus on the issues covered and will seek to avoid the need to include disparate views in the report chapters and in the Executive Summary. It also will include a recommendation on steps to better understand the frequency and severity of future climate extremes and improve the predictions and projections of those extremes.

The strategy for proceeding from the initiation of the effort, through the sequence of draft versions, to the final version will be in accordance with "Climate Change Science Program Guidelines for Producing CCSP Synthesis and Assessment Products" as presented on the U.S. Climate Change Science Program web page.

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 3.3 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 decision makers.

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. Related activities: Coordination with Other National or International Assessment Processes

This CCSP synthesis and assessment product will be coordinated internationally through the planned direct involvement of international participants in the author and stakeholder groups. In addition, the synthesis and assessment product is expected to complement the IPCC Fourth Assessment Report, that is also due for release in 2007. The IPCC Report will focus on the behavior of extremes from the global perspective, while the CCSP report will emphasize extremes as experienced primarily on the North American continent.

8. Communications

The first (peer review version), second (public comment version), and third (post-public comment version) drafts of the product will be posted on the CCSP web site.
Once the NSTC approval has been obtained and the product is finalized, NOAA, the lead agency, will produce and release the completed product using a standard format for all CCSP synthesis and assessment products. The final product, the comments received during the expert review (without attribution unless specific reviewers agree to attribution), the responses to the expert review comments, and the comments received during the public comment period will be posted on the CCSP web site.

In addition to the formal dissemination requirements listed above, the lead authors will be encouraged to publish their findings in the scientific literature.

9. Chronology

CY 2005

1) Aspen Workshop: "North American Weather and Climate Extremes – Progress in Monitoring and Research" – July 15-21
2) November CCSP Stakeholder Workshop - November 14-16

CY 2006

3) Draft Prospectus Submitted to CCSP Interagency Committee for Approval – March 3
4) Draft Prospectus Approved – April 4
5) Draft Prospectus Released for Public Comment – April 12
6) Public Comment Period Completed - May 12
7) Draft FACA Charter Submitted for Approval - May 20
8) Revised Prospectus Submitted to CCSP Interagency Committee for Approval - July 1
9) Prospectus Approved by CCSP Interagency Committee - July 15
10) Draft Prospectus, Public Comments, and Final Prospectus Posted on CCSP Website - July

20

CY 2007

11) First Draft of the Synthesis and Assessment Product Report Submitted for Expert Review – February 15
12) Expert Review of the Synthesis and Assessment Product Report Completed - May 15
13) Second Draft of the Synthesis and Assessment Product Report Released for Public Comment –August 15
14) Second Draft Public Comment Period Completed –October 1
15) Third Draft of the Synthesis and Assessment Product Report Completed and Submitted to CCSP for posting and Interagency Committee Review – December 20

CY 2008

16) CCSP Interagency Committee Review of Third Draft Completed - January 15
17) Third Draft Report Submitted to NSTC for Final Review and Approval – January 31
18) Web Version of the Synthesis and Assessment Product Report Posted on CCSP Website – February 28
19) Hardcopy of the Synthesis and Assessment Product Report Published – April 15

10. List of Lead Authors

David M. Anderson, NOAA's National Climatic Data Center; Director, World Data Center for Paleoclimatology; Associate Professor, Adjoint at the Institute of Arctic and Alpine Research at the University of Colorado, Boulder.

Peter D. Bromirski, Assistant Project Scientist, Integrated Oceanography Division at Scripps Institution of Oceanography, UCSD, La Jolla.

Harold Brooks, Research Meteorologist and Head of the Mesoscale Applications Group, NOAA's National Severe Storms Laboratory.

Tereza Cavazos, Assistant Professor, Department of Physical Oceanography, CICESE, Ensenada, Baja California, Mexico.

Stewart J. Cohen, Research scientist, Adaptation and Impacts Research Group (AIRG), Environment Canada; Adjunct Professor, Sustainable Development Research Institute (SDRI), University of British Columbia (UBC), Vancouver.

Miguel Cortez, Climatologist and Lead of the Climate Section, Mexican National Meteorological Service; Lecturer, Department of Geography, National University of Mexico.
Arthur Douglas, Professor and Chair, Environmental and Atmospheric Sciences, Creighton University.

David Easterling, Chief, Scientific Services Division, NOAA's National Climatic Data Center.

Kerry Emanuel, Professor of Atmospheric Science, Massachusetts Institute of Technology.

Pavel Ya. Groisman, UCAR Project Scientist at the NOAA/NESDIS National Climatic Data Center.

William J. Gutowski, Jr., Professor of Meteorology, Iowa State University, Ames.

Gabriele Hegerl, Associate Research Professor, Duke University.

Greg Holland, Director Mesoscale and Microscale Meteorology Division, National Center for Atmospheric Research.

Thomas R. Karl Director, NOAA's National Climatic Data Center; Program Manager, NOAA's Climate Observations and Analysis Program; Director, NOAA's Climate Change Data and Detection Applied Research Center.

Thomas Knutson, Research Meteorologist, NOAA's Geophysical Fluid Dynamics Laboratory.

Paul Komar, Emeritus Professor of Oceanography, Oregon State University, Corvallis.

Kenneth E. Kunkel, Director, Center for Atmospheric Sciences, Illinois State Water Survey, a division of the Illinois Department of Natural Resources and an affiliated agency of the University of Illinois at Urbana-Champaign; Adjunct Professor, Department of Atmospheric Sciences, University of Illinois.

David Levinson, Physical Scientist, Climate Monitoring Branch, NOAA's

National Climatic Data Center.

Linda Mearns, Senior Scientist and Director, Institute for the Study of Society and the Environment, National Center for Atmospheric Research.

Gerald A. Meehl, Senior Scientist, National Center for Atmospheric Research.

Richard J. Murnane, Associate Research Scientist, Bermuda Biological Station for Research; Program Manager, Risk Prediction Initiative (RPI).

Camille Parmesan, Assistant Professor, University of Texas, Austin.

Thomas C. Peterson, Research Meteorologist, NOAA's National Climatic Data Center.

David Phillips, Senior Climatologist, Environment Canada.

Roger S. Pulwarty, Research Scientist, NOAA-CIRES Climate Diagnostics Center and University of Colorado

Richard L. Smith, Mark L. Reed III Distinguished Professor of Statistics, University of North Carolina, Chapel Hill.

John Stone, Executive Director (Climate Change) Canadian Department of Environment (retired).

Ronald J Stouffer, Climate Scientist, NOAA's Geophysical Dynamics Laboratory (GFDL) in Princeton, NJ. He is a member of the CMIP (Coupled Model Intercomparison Project) panel and PMIP (PaleoModeling Intercomparison Project) panels. He has served on a number of WCRP (World Climate Research Project) committees involving climate modeling. Stouffer has been a lead author in the past 2 Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment reports and is a lead author in the current IPCC report under development. His research interests include projections of future climate change and the study of past and present climates. Relevant publications include:

Charles C Watson Jr., Director Research and Development of Kinetic Analysis Corporation,

Peter Webster, Professor of Earth and Atmospheric Sciences and Environmental Engineering, Georgia Institute of Technology.

Francis Zwiers, Senior Research Scientist and Chief, Canadian Centre for Climate Modelling and Analysis; Adjunct Professor, University of Victoria.

C

Committee and Staff Biographies

John Gyakum is a Full Professor in Synoptic and Dynamic Meteorology at McGill University in Montreal, Quebec. His research focuses on the dynamical processes associated with tropical cyclones that ultimately affect the Atlantic Canada provinces. These cases typically transform from a warm-core convectively driven disturbance into a cold-core extratropical system. During this latter phase, however, these cyclonic systems are often responsible for copious amounts of rainfall in the Atlantic provinces. Work is in progress investigating the processes by which the cyclones transform from tropical to extratropical systems. Additional research is being conducted on the roles that surface fluxes of heat and moisture play in the evolution of these extratropical transformations.

Hugh Willoughby is a Distinguished Research Professor in the Department of Earth Sciences at Florida International University, where he teaches in the newly established academic track in Atmospheric Sciences. His research interests include analysis of instrumented aircraft observations of hurricanes and formulation of theoretical models of tropical–cyclone motion and intensification. Until December 2002 he was a Research Meteorologist at the Hurricane Research Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory, where he had worked since 1975 and served as director 1995-2002. He has made more than 400 research and reconnaissance flights into the eyes of typhoons and hurricanes. During his time at HRD, Dr. Willoughby occupied the G. J. Haltiner Visiting Research Chair at the Naval Postgraduate School (January–July, 1991); was a Visiting Research Scientist at the Bureau of Meteorology Research Centre in Melbourne, Australia (June–July, 1988); and was a Visiting Lecturer at the Shanghai Typhoon Institute (December 1985), where he visited again during the winter of 2004. Before joining HRD, Dr. Willoughby was a commissioned officer in the U. S. Navy. He served as a flight meteorologist in Airborne Early Warning Squadron ONE (1970–1971) and on the Military faculty of the Naval Academy (1971–1974), where he taught meteorology, oceanography, geology, and computer science. He left active duty as a Lieutenant (O3). Dr. Willoughby has the following academic degrees: Ph.D. (1977, Atmospheric Science) from the University of Miami, M.S. (1969, Meteorology) from the Naval Postgraduate School, and B.S. (1967, Geophysics–Geochemistry) from the University of Arizona. He is a fellow of the American Meteorological Society and of the American Association for the Advancement of Science, and a member the American Geophysical Union and Sigma Xi. He is past chair the AMS Committee on Hurricanes and Tropical Meteorology.

Cortis Cooper has been actively involved in ocean research and development since receiving his BSc and MSc in Engineering at MIT in 1977. He later returned and obtained his Ph.D. from the University of Maine in 1987. Dr. Cooper is an oceanographer in the energy technology company of Chevron. He is also a Chevron Fellow, one of 6 scientists and engineers chosen for their technical contributions to the company. His research efforts have included leading the first comprehensive velocity surveys of the Loop Current in the Gulf of Mexico in the early 1980s and developing a hurricane current model whose results were later adopted as the industry standard. Dr. Cooper has initiated and lead six Joint Industry Projects (JIP) one of them included 32 companies and another 25. These JIPs have successfully resolved major technical questions and established industry standards in some cases. He has been a contributing author of six books, published 14 journal articles, and 32 conference papers. A former member of the Ocean Studies Board, he served on the NRC Committee on Oil in the Sea: Inputs, Fates, and Effects and the Review of JSOST Research Priorities Plan; and has been a frequent advisor to government agencies including NOAA, USGS, U.S. Navy, and the Minerals Management Service (MMS).

Michael J. Hayes is a climate impacts specialist for the National Drought Mitigation Center (NDMC) and associate professor in the School of Natural Resources at the University of Nebraska, Lincoln (UNL). Since coming to UNL in 1995, Dr. Hayes has been mostly associated with the climate and bio-atmospheric sciences and human dimensions program areas and work in outreach and extension. His main research interests are precipitation indices, drought mitigation, drought impacts, drought vulnerability, risk analyses and remote sensing. Dr. Hayes received a bachelor's from the University of Wisconsin-Madison in Meteorology and his master's and doctorate from the University of Missouri-Columbia in Atmospheric Sciences

Gregory Jenkins is an associate professor in the Department of Physics and Astronomy and the graduate director for the Howard University Program in Atmospheric Sciences (HUPAS). He has numerous research interests with an emphasis on regional climate change and precipitation processes in West Africa, anthropogenic and natural sources of tropospheric ozone in the tropics, and studies in paleoclimate. Dr. Jenkins joined Howard University during 2003 after spending 10 years at Penn State University as a faculty member and researcher in the Department of Meteorology and the Earth System Science System. He spent 2 years at the National Center for Atmospheric Research in Boulder, Colo. after finishing his doctoral research in atmospheric and space sciences at the University of Michigan. Dr. Jenkins is a member of the American Meteorological Society, the American Geophysical Union (AGU), is an associated editor for AGU-Journal of Geophysical Research and serves as a member on several national committees.

David Karoly is Williams Chair Professor of Meteorology at the University of Oklahoma. He joined the School of Meteorology faculty in January 2003 from Monash University, Melbourne, Australia, where he was Professor of Meteorology and Head of

the School of Mathematical Sciences. From August 1995, he was Director of the Cooperative Research Centre for Southern Hemisphere Meteorology at Monash University until it closed in June 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 committees, including the WMO/CLIVAR Expert Team on Climate Change Detection and Indices and the WCRP Working Group on Coupled Modeling. He was Review Editor of the chapter "Understanding and Attributing Climate Change" in "Climate Change 2007: The Physical Science Basis" and is a lead author of the chapter "Assessment of Observed Changes and Responses in Natural and Managed Systems" in "Climate Change 2007: Impacts, Adaptation and Vulnerabilities", two volumes in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In 1993, Professor Karoly received the Meisinger Award from the American Meteorological Society, 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 American Meteorological Society for outstanding contributions to the atmospheric sciences over a substantial period of years. Dr. Karoly also served on the Climate Research Committee from 2003 to 2006.

Richard Rotunno received his Ph.D. in Geophysical Fluid Dynamics from Princeton University in 1976. He has spent most of the past 30 years at the National Center for Atmospheric Research in Boulder, Colorado, where he has been a Senior Scientist since 1989, and Assistant Director of the Microscale and Mesoscale Meteorology Division since 1999. He has worked on the fluid dynamics of atmospheric flows, in particular tornadoes, and the rotating thunderstorms that produce tornadoes known as supercells, squall lines, hurricanes and polar lows, midlatitude cyclones and fronts, density-stratified flow past mountains, sea breezes, and variety of related problems such as the dynamics of density currents, internal bores and hydraulic jumps. Through a combination of theory and numerical modeling, his work is directed at the understanding needed to make progress in the forecasting of mesoscale weather phenomena. In 2004 he was the recipient of the American Meteorological Society's Jule G. Charney Award.

Claudia Tebaldi obtained her Ph.D. in Statistics from Duke University in 1997. Since then she has been at the National Center for Atmospheric Research, in Boulder, CO, first as a post-doc in the Geophysical Statistics Project and then as a Project Scientist. She is currently a visiting scientist at Stanford University. Her appointment is shared by three divisions: the Institute for the Study of Society and Environment, the Climate and Global Dynamics Division and the Institute for Mathematics Applied to the Geosciences. She focuses on statistical analysis of observational and modeled data within studies of climatic variability and change. Dr. Tebaldi has contributed to the current IPCC-AR4, WG1, in Chapter 11 on Regional Projections, and some of her recent work is cited in both Chapter 10 (Global Projections) and Chapter 11.

Curtis H. Marshall is a Program Officer with the Board on Atmospheric Sciences and Climate. He received B.S. (1995) and M.S. (1998) degrees in meteorology from the University of Oklahoma, and a Ph.D. (2004) in Atmospheric Science from Colorado State University. His Doctoral research examined the impact of anthropogenic land-use change on the mesoscale climate of the Florida peninsula. Prior to joining the staff of BASC in 2006, he was employed as a research scientist in the National Oceanic and Atmospheric Administration, where he focused on the development of coupled atmosphere – land surface models.

Katherine Weller is a Senior Program Assistant for the Board on Atmospheric Sciences and Climate (BASC) and the Polar Research Board (PRB). In 2004, she received her B.S. from the University of Michigan in Biopsychology. She is currently working toward a master's degree in Environmental Science and Policy from Johns Hopkins University.

D

Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.3 STATEMENT OF TASK

The National Research Council will appoint a committee to provide a peer review the U.S. Climate Change Science Program's (CCSP) draft Synthesis and Assessment Product (SAP) 3.3, Weather and Climate Extremes in a Changing Climate. The committee appointed for this work will address the following issues related to this draft document:

1. Are the goals, objectives and intended audience of the product clearly described in the document? Does the product address all questions outlined in the prospectus?

2. Are any findings and/or recommendations adequately supported by evidence and analysis? In cases where recommendations might be based on expert value judgments or the collective opinions of the authors, is this acknowledged and supported by sound reasoning?

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

4. Are the document's presentation, level of technicality, and organization effective? Are the questions outlined in the prospectus addressed and communicated in a manner that is appropriate and accessible for the intended audience?

5. Is the document scientifically objective and policy neutral? Is it consistent with the scientific literature?

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

7. What other significant improvements, if any, might be made in the document?