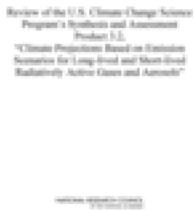

Review of the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.2, "Climate Projections Based on Emission Scenarios for Long-lived and Short-lived Radiatively Active Gases and Aerosols"

Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.2, National Research Council

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Board on Atmospheric Sciences and Climate

Division on Earth and Life Studies

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Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the 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:

Radford Byerly, Jr., University of Colorado, Boulder
Judith A. Curry, Georgia Institute of Technology, Atlanta
Sonia Kreidenweis, Colorado State University, Fort Collins
Donald J. Wuebbles, University of Illinois, Urbana-Champaign
Chien Wang, Massachusetts Institute of Technology, Cambridge

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 William Randel, National Center for Atmospheric Research, Boulder, Colorado. 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 the draft Synthesis and Assessment Product (SAP) 3.2, focusing on the extent to which the draft document meets the requirements set forth in the prospectus. The current draft was clearly written for an audience of researchers involved in assessment efforts. The product provides initial information regarding the influence of short-lived radiatively active species on future climate and has shown that these short lived species are significant in forcing climate. However, the current draft needs revision to make the document easier to read even by subject experts. Many of the figures and captions do not convey the information intended and comparison of figures is difficult because different scales are employed. In addition, the document needs to distinguish between the types of models, especially for the benefit of non-specialists. Also, in the technical sections of the report, more details about the models used and statistical methods employed need to be included (see specific chapter reviews).

Although the assessments community should find this document extremely helpful, understanding the impact of short-lived species on future climate is critical and should be explained to all stakeholders of climate change science as outlined in the SAP prospectus. In this sense, the current draft of SAP 3.2 falls short of the requirements set forth in the prospectus. The draft does not address all of the specified audiences, particularly "policymakers, decision-makers, and members of the media and general public with an interest in developing a fundamental understanding of the issue." Chapter 3 does not describe the state-of-the-science, the problems in methodology adopted in the current models, and the most uncertain factors in the current research regarding the effect of short-lived species on climate.

1

Introduction

The U.S. Climate Change Science Program (CCSP) was established in 2002 to coordinate climate and global change research conducted in the United States. Building upon and incorporating the U.S. Global Change Research Program of the previous decade, the program integrates federal research on climate and global change, as sponsored by 13 federal agencies and overseen by the Office of Science and Technology Policy, the Council on Environmental Quality, the National Economic Council, and the Office of Management and Budget. A primary objective of the CCSP is to provide the best possible scientific information to support public discussion and government and private sector decision making on key climate-related issues. To help meet this objective, the CCSP is producing a series of synthesis and assessment products that address its highest priority research, observation, and decision-support needs. The CCSP is conducting 21 such activities, covering topics such as the North American carbon budget and implications for the global carbon cycle, coastal elevation and sensitivity to sea-level rise, trends in emissions of ozone-depleting substances and ozone recovery and implications for ultraviolet radiation exposure, and use of observational and model data in decision support and decision making. Each of these documents has been / will be written by a team of authors selected on the basis of their past record of interest and accomplishment in the given topic. A list of the CCSP SAPs is provided in Appendix A.

The National Oceanic and Atmospheric Administration (NOAA) is the lead agency for CCSP Synthesis and Assessment Product (SAP) 3.2. NOAA's stated purpose for SAP 3.2 is to provide information to those who use climate model outputs to assess the potential effects of human activities on climate, air quality and ecosystem behavior. (see Appendix B for full prospectus). SAP 3.2 is comprised of two components that assess the climate projections resulting from SAP 2.1a scenarios in the context of existing IPCC climate projections and isolate and assess the future climate impacts resulting from future emissions of short-lived species.

According to the guidance provided in the prospectus, SAP 3.2 is to be written in a style consistent with major international scientific assessments. To address these purposes and audiences, SAP 3.2 was given eight key questions to address (see Box 1).

In a review of the U.S. CCSP Strategic Plan, the National Research Council (NRC) recommended that synthesis and assessment products should be produced with independent oversight and review from the wider scientific and stakeholder communities (NRC, 2004). To meet this goal, NOAA has requested an independent review of SAP 3.2 by the NRC. The NRC appointed an ad hoc committee composed of eight members (Appendix C). The committee's Statement of Task is included in Appendix D.

The committee conducted its work by first carefully reading the draft SAP 3.2 report "Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols" (draft dated May 9, 2007). The committee then met with the lead authors to ask questions about the authoring team's research and formulation of the draft document. During this meeting, the committee also interacted with NOAA personnel, who outlined for the committee their expectations for SAP 3.2. This present document constitutes the committee's review report, resulting from its careful study of the draft SAP 3.2 document and its interactions with those present at the aforementioned meeting. Herein the committee provides its review findings, and recommendations, suggestions, and options for the authors to consider in revising the draft SAP 3.2. In its review, the committee focused on substantive matters of content and did not proofread the document for grammatical or typographical errors.

BOX 1-1

Questions to be Addressed by CCSP Synthesis and Assessment Product 3.2

According to guidance in the CCSP prospectus outlining the purpose of SAP 3.2, the report will consist of two components.

1. Climate projections for research and assessment based on the range of stabilization scenarios of long-lived greenhouse gas emissions and atmospheric concentrations developed by SAP 2.1a. These stabilization scenarios and their resulting long-lived greenhouse gas concentrations were generated by three unified assessment models.
2. An assessment of the sign, magnitude, and duration of future climate impacts due to changing levels of short-lived gaseous and particulate species that may be subject to future mitigation actions to address air quality issues.

SAP 3.2 is intended to provide information to those who use climate model outputs to assess the potential effects of human activities on climate, air quality, and ecosystem behavior. The key questions to be addressed by SAP 3.2 are:

1. Do SAP 2.1a emissions scenarios differ significantly from IPCC emissions scenarios?
2. If the SAP 2.1a emissions scenarios do fall within the envelope of emissions scenarios previously considered by the IPCC, can the existing IPCC climate simulations be used to estimate 50-to 100-year climate responses for the CCSP 2.1 CO2 emissions scenarios?
3. What would be the changes to the climate system under the scenarios being put forward by SAP 2.1a?
4. For the next 50 to 100 years, can the time-varying behavior of the climate projections using the emissions scenarios from SAP 2.1a be distinguished from one another or from the scenarios currently being studied by the IPCC?
5. What are the impacts of the radiatively active short-lived species not being reported in SAP 2.1?
6. How do the impacts of short-lived species compare with those of the well-mixed green house gases as a function of the time horizon examined?
7. How do the regional impacts of short-lived species compare with those of long-lived gases in or near polluted areas?
8. What might be the climate impacts of mitigation actions taken to reduce the atmospheric levels of short-lived species to address air quality issues?

2

Key Issues

Computer models of the coupled atmosphere-land surface-ocean-sea ice system are essential tools for understanding past climates and making projections of future climate resulting from radiative forcing changes, both natural and anthropogenic. Projections of future climate require estimates (e.g. scenarios) of future emissions of long-lived greenhouse gases, aerosols, and other short-lived gases. A number of standard scenarios have been developed for the Intergovernmental Panel on Climate Change (IPCC) assessment process, and the future impacts of these have been explored. As part of the Climate Change Science Program (CCSP) process, updated scenarios of long-lived greenhouse gases and their atmospheric concentrations were developed by the Synthesis and Assessment Product 2.1 team and served as a basis for SAP 3.2.

Understanding the impact of short-lived radiatively active species on future climate is critical and recently has become an active area of research in the reviewed literature. These types of studies encompass a realistic time frame over which available technological solutions can be employed, and focuses on those gas and aerosol species whose future atmospheric levels are also subject to mitigation to control air pollution. Thus the Climate Change Science Program's (CCSP) Synthesis and Assessment Product (SAP) 3.2 will potentially be very beneficial to all stakeholders of climate change science. The committee commends CCSP and the National Oceanic and Atmospheric Administration (NOAA) for emphasizing the need to address this important topic.

This chapter outlines the major issues that, from the point of view of the review committee, the authors should strongly consider addressing in the revised version of SAP 3.2. In some cases, findings are simply noted without explicit recommendations. In other cases, the committee provides either a direct recommendation or alternatives for the authors to consider as they address the review findings. In subsequent chapters of this report, the committee provides further overarching thoughts on the draft document and then findings and recommendations specific to individual chapters of the draft. Comments regarding key issues follow.

This assessment provides initial information regarding the influence of short-lived radiatively active species on future climate out to 2100. The authors had to work with existing models that did not treat all parameters consistently. Despite this challenge, they have shown that these short lived species are significant in forcing climate.

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

   - The committee finds that the lack of a non-technical executive summary hinders its accessibility to the audiences named in the prospectus. A concise and readable summary of the document, including key findings and recommendations, would enable all audiences -- producers of synthesis and assessment products, scientific researchers, decision-makers, media, and the general public -- to glean the main points and to locate further information that may be of interest to them. The document should include a short executive summary for a non-technical reader, such as congressional staff, local and regional governmental decision makers. The summary should not be merely descriptive, but informative on the main points of the document. The summary should use plain language to describe the goals of the report, the principal findings and why it is critical to understand the impact of short-lived species on future climate. The summary should point out that these types of studies encompass a realistic time frame over which available technological solutions can be employed, and that this study in particular, focuses on those gas and aerosol species whose future atmospheric levels are also subject to mitigation to control air pollution. The summary should define briefly but clearly the line between “long-lived” and “short-lived”, not just described as “(carbon dioxide)” and “(soot)”. An alternative approach could be to add a box consisting of a chart with temporal vs. spatial scales of various species, added by general model resolutions used in such a practice as a reference.

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

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

- A clear concise description of the models employed in the study needs to be included. This description should clearly outline the strengths, weaknesses, and critical assumptions for each model. The models should be referred to by what they do, not necessarily by the name of the team that developed it. For example, explain what the GFDL, GISS, and the two NCAR models do when they are referred to in the document. This could either go in the introduction or in Chapter 3.

2. **Introductory material is lacking.** The draft would be improved if the introduction section provided a clear framework and context for the rest of the document. At present the scope of and motivation for the study are not well explained. The authors could clearly state what this study does and does not address in terms of responses, relative feedbacks and species. In its current form, the transition to technical material is far too abrupt. Specific ways to improve the introduction follow.

   - The authors could define what a scenario is, describe the models used in the study and differentiate between the different types of models.

   - The introduction section could outline the charge to the authors as they perceived it, and clearly define the goals and objectives of the document.

   - As an alternative, this material could be included in a foreword. The foreword or introduction could also state explicitly what the document does *not* address.

   - There could also be a description of how adequate the adopted methods in the 3 models are in comparison to the current findings regarding the related processes.

   - A discussion explaining the coupling between climate effects of long- and short-lived species is needed in the introduction. A reader with less technical background might wonder specifically about the relationship between the predictions for the well-mixed greenhouse gas scenarios and the predictions where these are combined with the short-lived species. Are effects adding? What changes in climate response, and on what time and space scales, when they are considered together?

3. **Details about the models used are lacking.** In addition to a general description of model functions, many details about the models used in this assessment are not

stated. Model resolution, inputs, reactive chemical mechanisms, emissions assumptions, and removal mechanisms, and residence times should be more clearly presented. In addition, there is insufficient detail about how the experiments were run. It is not possible to decipher what radiatively active species are predicted (emissions) vs. those prescribed (concentrations) and how they vary temporally and spatially. The technical detail could either be included in a table in Chapter 3 or described in the text of Chapter 3. The more general information about the models used could be included in the introduction (see reviews of specific chapters for suggestions).

4. **Details about statistical methods employed are lacking.** At present there is no discussion about how statistical significance was determined. The statistical significance of certain trends is discussed and judgments are made about the relative significance, yet there is no description of how this was calculated. This information could be provided in an appendix and should clearly describe the statistical approaches used to determine the relative significance of trends and explain the rationale behind why judgments were made.

5. **Many of the figures and captions presented could be improved for ease of interpretation**. The figures presented in the report do not have similar scales or projections, which makes comparison of the data difficult. In addition, key points that are made in the discussion are not necessarily obvious from the present figures. For example, it is not entirely clear that the pattern of temperature response to short-lived species is of similar magnitude and distribution as the pattern of long-lived species. A graphic comparison of the temperature response to short-lived species vs the response to long-lived species should be presented.

3

Stylistic Issues

The committee notes several stylistic issues, which, if addressed, could significantly improve the overall accessibility of the document for a wider audience and improve the coherence of the document. Specific instances will be noted in the sections of this report that provide reviews of individual chapters of the draft. Broadly, these issues are:

- *Jargon and definitions*: The language suffers from excessive use of jargon and a lack of definitions of terms that may have multiple meanings to multiple readers. For example, certain terms such as, “very likely”, and “likely” are used with the “specific IPCC connotations”. These connotations should be defined, or the text translated so that they are accessible to the non-technical reader, particularly in the “key findings”. In addition, the authors should expand the glossary for less commonly understood terms and phrases.

- *Acronyms*: There are many instances in which undefined acronyms are used or defined at a later point. In general acronyms are over used to the point that they interfere with the flow of the document.

- *Content arrangement*: The document would be improved by relegating supporting text that is not central to the study to boxes. For example, the authors could consider revising Chapter 2 to focus more on the climate implications of emissions scenarios developed in SAP 2.1a, and move the summary of results of the IPCC WGI AR4 to a box.

4

Review of Individual Chapters

This chapter provides specific comments on the eight individual chapters of draft Synthesis and Assessment Product (SAP) 3.2. In some cases, these specific comments relate to the overarching comments provided in the previous two chapters of this review. In the other cases, these specific comments are generally minor in nature. The review of each chapter includes a statement that summarizes the committee's overall thoughts. For some chapters, there are enumerated comments that follow this statement to provide suggested editorial changes or other details for the authors to consider during the revision process.

Chapter 1

Introduction

General remarks:

Chapter 1 needs similar revision to the document as a whole to make it easier to read. The committee is concerned that this chapter is not written so that it can easily be understood by the non-specialist. In particular, readability is impaired by frequent use of acronyms and abbreviations. These concerns are especially relevant to this chapter, as it sets the stage for (and provides a summary of) the other chapters. For example, there are many instances in which undefined acronyms are used or defined at a later point. In general, acronyms are over used and detract from the flow of the material. Certain terms (for example, "very likely", "likely" etc) are used with the "specific IPCC connotations". These connotations should be defined, or the text translated so that they are accessible to the non-technical reader, particularly in the "key findings".

The document should be revised by including explanations and use plain language that make the results more easily interpretable to a non-technical audience. Some specific examples are to explain the following:

- What is an integrated assessment model?
- What is a scenario?

- Explain how IAMs differ from climate models

- Explain why the IAMs differ from each other, and why it is important to use more than one

- Explain why Radiative Forcing is an important concept.

The "Historical Overview" section is useful and well-written. The overview of the IPCC reports (beginning at line 414) could benefit from a very brief statement of what the IPCC is as well as the scope of IPCC assessments (i.e., review of current literature; there is a common misconception that IPCC performs research). At lines 434-441 it could be noted that the models are moving toward finer resolution that can include some topographic features that are important to U.S. climate. Finer resolution in the ocean now allows some important atmosphere-ocean coupling processes such as ENSO to be represented in some AOGCMs (see e.g., van Oldenborgh et al. 2005; Wittenberg et al. 2006).

The three AOGCMs and modeling groups should be briefly introduced in this chapter. Care should be taken to distinguish the AOGCMs from the IAMs, especially for the benefit of non-specialists. Text (perhaps a box) describing these types of models and functions as an introduction to a non-technical reader should be included.

An indication should also be given as to whether the AOGCMs used in the study are appropriate to the task at hand. This need not be a detailed performance evaluation; it would be adequate simply to state that intercomparison studies have shown that the performance of these models is comparable to other state of the art climate models.

Finally, the methodology and its limitations should be made clearer at the outset and should also explain why new emissions scenarios are needed. . .

Minor issues:

L428-429: "model" should be plural, "models"

L506: Methane is reactive not only in the troposphere but also in the stratosphere (being a main source of water vapor in the upper stratosphere).

Chapter 2

Climate Projections from Well-Mixed Greenhouse Gas Stabilization Scenarios

General remarks:

The committee feels that the chapter contains much useful material that serves to fulfill the mandates of the prospectus. It also feels that the chapter can be improved in several regards.

First, the chapter needs revisions to make it easier to read. It also assumes the reader to be a technical expert, and should either have a summary for non-technical reader, or be identified as such at the beginning.

As presently written, the chapter is presented in two parts. Material from the beginning of the chapter to page 39 describes work that examines the climate implications of emissions scenarios developed in SAP 2.1a. Particular emphasis is placed on the combined roles of the Kyoto and non-Kyoto short-lived gases. The chapter notes that all of the scenarios are contained within the range of the scenarios examined by IPCC Working Group I (WGI) in the Fourth Assessment Report (AR4). (Though, one of the attributes of the SAP 2.1a is that it contains stabilization scenarios that fall outside of the range of the SRES scenarios on the low side.) The chapter then argues that because the range of climate scenarios associated with the SAP 2.1a falls within the range of scenarios examined in the IPCC WGI AR4 that the same general conclusions follow. The chapter then proceeds to summarize the IPCC results in the second half of the chapter, Pages 39-51.

The committee recommends that the authors consider revising the chapter to focus more on the first material, moving the summary of results of the IPCC WGI AR4 to a box, and adding a section that identifies the role of the short-lived species that could serve as motivation for and transition to Chapter 3.

The motivation for and important conclusions arising from the section on regional climate models needs to be clarified. The committee speculated that the intent was to show the similarities in surface temperature change and ozone change between the global and regional models, but was left wondering if there was more to the section. The committee agrees that more research is clearly needed to assess if downscaled RCM simulations improve our ability to characterize climate change (lines 1132-1145), but this statement might be better suited for Chapter 4.

Minor issues:

Figures 2.1, 2.2, 2.3, 2.4: Show the three SAP 2.1a reference cases as well as the stabilization cases. Also note that in addition to the SRES cases that a commitment run is also shown. (The latter is what allows the assertion that the IPCC work contains the SAP 2.1a.)

Figures 2.1, 2.2, 2.3, 2.4: In general it would be good to provide a table for year 2100 values. This would make it easier for the reader to get a sense of the absolute differences between cases.

L27642-643: How can the lower bound of the 5-95% range (i.e., 0.19 m) be less than the minimum of the entire range (0.28 m)? Please clarify.

L28655-658: ENSO and the AMOC are two different phenomena. Lumping them together risks creating a misleading association in the minds of non-experts.

L29688-690: This is right for one model, MERGE. It is a formal optimization model. The other two models are recursive. However, the two recursive models adopted two assumptions that resulted in results being similar to that of a formal optimization model. Both assumed that all regions of the world and all economic activities faced the same price of carbon, though each model adopted their own treatment of the non-CO_2 greenhouse gases. Only MERGE was a true optimization frame. The MiniCAM adopted the assumption that the price of carbon rose at the rate of interest plus the rate of net loss of carbon from the atmosphere to the ocean-terrestrial system. This is consistent with intertemporal cost optimization for carbon. The IGSM used a similar assumption, namely that the price of carbon rises at the rate of interest. For the purposes of this report it should be adequate to simply state that, "All of the groups developed pathways to stabilization targets designed around economic principles. However, each group used somewhat different approaches to stabilization scenario construction."

L30694-695: "...trajectories ... were produced...". Would a non-expert know what this phrase means?

L30696: Change "optimization process" to "scenario definitions".

L31724: What are "F-gases"?

L32739: Note that the MiniCAM uses MAGICC as its representation of carbon cycle and the atmosphere.

L34786:Some discussion of the methodology employed to link MERGE output to MAGICC, particularly in the carbon cycle is needed. The MERGE model appears to have adjusted its ocean to reproduce essentially the same behavior as the other two models' combined ocean and terrestrial system models. This sparks the question of how was this case run so that it is true to the underlying MERGE approach?

L35805-806: committee is skeptical that EPPA runs a 200-year trajectory to stabilization. This assertion should be checked.

L35800-816: It is important to note that in general all of the models hit their targets with their own carbon cycle and atmosphere models. Thus, failure to hit targets in MAGICC is not the same thing as failing to meet the stabilization target for the model. The methodology employed to get the radiative forcing and transient temperature changes were to have each model use the MAGICC atmosphere. However, the models did hit the target using their own atmospheric representations. Thus, when results differed when all used the MAGICC atmosphere, this would seem to be a reflection of underlying uncertainty in the carbon cycle models, which, as we all know, is substantial.

L36823-825: It seems odd to replace the BC and OC from the MiniCAM and MERGE models with arbitrary trajectories.

L36836: What does “later for MiniCAM” mean? The comment is unclear.

L37842-843: This statement should be checked. Is it really true that SO_2 emissions are invariant across the scenarios as indicated? How could SO_2 emissions not vary with dramatic reductions in fossil fuel use? EPPA assumes lots and lots of CO_2 capture and storage, which means almost complete clean up of S, so SO_2 emissions should decline as the stabilization level tightens.

L 371132-1145: Downscaled information is necessary for more than air quality; in particular, it is needed for hydrologic and agricultural uses (among many others).

Chapter 3

Climate Change from Short-Lived Emissions Due to Human Activities

General Remarks:

The committee thought that Chapter 3 was the most substantive. They believed that this chapter should more clearly identify what the major take-home messages are and should also consider including additional analysis of the mechanisms involved.

The authors’ main point, that the short-lived greenhouse gases are important factors in projections of future climate, is well supported. However, the climate models do not use consistent forcing scenarios for the short-lived species, nor do they use consistent natural emissions of primary aerosols and ozone and aerosol precursors or consistent removal mechanisms for the short-lived species. This makes comparison of the model results challenging.

Additional discussion of the difference between uncertainties in processes and uncertainties in future emissions is needed. Uncertainties in chemical and physical processes represent the state of our current knowledge. The fact that one modeling group chooses to include a process while another group chooses not to shows that our knowledge about short-lived species is still evolving. Eventually, with further research, uncertainties in chemical and physical processes can be ironed out. Uncertainties in future emissions, however, will never be completely erased. What modelers can do is choose consistent emission scenarios to bracket possible future outcomes.

The authors need to emphasize that the magnitude and signs of effects of the short-lived species on climate may be totally different using different projected emissions in the same models. Also, the committee thinks that following the A1B emission scenarios for the precursors of short-lived species all the way out to 2100 may result in unrealistically large surface concentrations of pollutants. The committee recommends inclusion of a figure showing the monthly mean surface ozone, BC, and OC at 2100. A caveat should then be added that such large abundances are not likely to be tolerated.

The committee recommends the addition of a table that includes descriptions of each of the models, including resolution, inputs, reactive chemical mechanisms, emissions assumptions, removal mechanisms, and residence times. In the accompanying discussion, sufficient detail should be provided for each experiment regarding what radiatively active species are predicted (emissions) vs. those prescribed (concentrations) and how they vary temporally and spatially so that the reader can understand exactly what was done. Discussion of this table should include some analysis of the differences between model results produced by the different parameterizations.

A graphic comparison of the temperature response to short-lived species vs the response to long-lived species should be presented. In this way, readers can appreciate 1) the contribution of the short-lived species to future climate change and 2) the similarities (or differences) of the responses to the short-lived vs long-lived species. Past work investigating the climate response to heterogeneous forcing should be discussed.

Many of the plots showing future changes provide only the annual mean. Because the short-lived species have large seasonal trends, plots showing seasonal forcings and temperature responses are essential. Much information could be lost in the mean. This is true of course for the surface temperature response, but also especially important for the response of precipitation to changes in aerosol. It could be that the seasonal precipitation response would have much greater statistical significance than the annual mean precipitation response.

Regional changes, particularly surface temperature, appear to be important, and the committee recommends that considerably more attention, discussion, and analysis be paid to this, including a comprehensive treatment of uncertainty. For example, a summertime 2^{o}C increase over the central United States by 2100 would have large consequences for both human health and the economy.

Results on how temperature responded to changes in short-lived species would be greatly strengthened by additional sensitivity studies that could help to establish causes and mechanisms. For example, in the GISS model, how much warming did the declining trend in the indirect effect contribute to the climate response and where? How would the GISS results differ if dust had not been permitted to take up sulfur dioxide? Determining the relative importance of these and other processes to the climate response would help prioritize the gaps in our knowledge. In addition, a discussion of how the system might respond to controls on short-lived species and the possible feedbacks, and what the impact of climate changes might be on short-lived species would be helpful. At this point, there is sufficient information from present study and previous ones to get an approximate idea of what the feedbacks and control sensitivities are on the system to get a first order estimate of what controls on short-lived species and their precursors might do to climate. While the committee notes that the present document would benefit from these additional analyses, it may not be feasible given time and potential monetary constraints; in such a case, a recommendation for future analyses should be included in Chapter 4.

Discussion and citation of previous studies is insufficient. The authors need to show that their work builds on what has already been done. Also, citing previous work will enrich the study by making clear where various model agreements and disagreements lie, and will help clarify how robust the current findings are.

All of the methods used to calculate statistical significance should be described in detail either within this chapter or in an appendix.

The authors should emphasize that the impacts of climate change on the short-lived species were not included in this exercise, except for the methane/isoprene simulations. The authors should refer to other studies that show the relative importance of these climate impacts, and briefly describe how including such impacts might affect their results.

It is not clear how the model simulations were set up, and why the authors made the choices they did. How were the time-slice monthly chemical fields of ozone and aerosol implemented in the transient climate simulations? Were the future composition simulations performed with present-day climate? How were the effects of long-lived species implemented in the models, as forcings or concentrations? The description of ensemble runs needs clarification for the lay audience.

The methane text leads to many questions. Was three years a sufficient length of time to calculate the methane response to changing climate and chemistry? How much did OH concentrations further decline when the biogenic emissions of methane and isoprene were permitted to interact with the changing climate? What chemical mechanism was used for isoprene oxidation? (The choice of mechanism could make a difference in the outcome. Given that the fate of isoprene oxidation products is a major issue among air quality modelers, this has importance. See *Wu et al.,* 2007.) Was OH also allowed to respond to changing water vapor concentrations? How did changes in NOx emissions impact OH? This section also neglects much previous work looking at the effect of changing emissions and/or climate on methane abundances, e.g., *Wild et al.*, 2001; *Wigley et al.*, 2002; *Stevenson et al.,* 2006.

The methane text should not be a box, but a separate section. The result here, that including biogenic chemistry-climate impacts increases methane concentrations and thus climate forcing, has importance and should be included in the chapter summary.

The methane section could end with a brief description of other chemistry-climate feedbacks that could play a major role in the future climate. Processes involved in the feedbacks include: lightning NOx emissions, land cover change, changes in convection and transport, and changes in absolute humidity.

The current practice to include tropospheric chemistry in global models has a common problem in methods, i.e., the simplified representation of subgrid-scale processes (e.g., fast chemistry affecting species from nitrogen oxides and isoprene to ozone, nucleation of aerosols). The authors are encouraged to make a comment on the consequences of using coarse-grid models to describe fine-scale chemistry.

Minor issues:

The bullets at the beginning of the chapter could be revised to ensure that key points are highlighted. The first bullet in the Introduction and Key Findings section, line 1328, is awkward. Bullet 2, line 1333, infers that short-lived species are emitted when actually some of the most important (ozone and sulfate) are formed in the atmosphere.

Line 1500. It's more appropriate to use "amount of sulfate and ammonia" instead of "amount of sulfate". Note that the added detail that a lognormal distribution is assumed for all aerosols is not needed for this audience.

Line 1572: Why would the treatment of natural and biomass burning emissions affect sulfur dioxide emissions to such a large extent?

Lines 1606-1608. Nitrate can be a dominant component of aerosol during the winter, and may therefore play an important role in climate at that time of year. Therefore, the reviewers are not convinced that nitrate has a "minimal effect" and that it doesn't matter that only GISS includes nitrate aerosol. Further, as sulfate concentrations decline, and ammonia increases (as estimates suggest will be the case), nitrate may become an even bigger player.

Many of the Figure captions are not clear. E.g., in Figure 3.2, what is being shown here in what units, and for what time period? "Other" in the NCAR bar should be defined differently in the labels. Most of the captions are not "stand-alone." The reader needs to burrow through the text to know what is going on in this plot.

Table 3.3. The term "model production efficiency" is confusing, since it resembles the well-known but differently defined term ozone production efficiency. The reviewers suggest employing a different term, such as burden-emission ratio (BER). Alternatively, what would be lost if the authors instead just looked at species lifetimes?

Also in Table 3.3, the GFDL ozone production efficiency declines dramatically between 2000 and 2030 (7.19 to 2.24). Why is this? In the A1B future, volatile organic compounds go up and NOx goes down, which would typically lead to a higher OPE. The authors need to explain this large jump.

Line 1650. This paragraph describes several trends in aerosol production efficiencies. The authors need to attempt to explain the reasons for these trends. Could trends in wet and dry deposition of sulfate, nitrate, BC, OC and other aerosols and precursor gases matter?

Line 1651 What does "are more effective" mean? Please clarify.

Paragraph beginning with Line 1720. The reviewers are surprised that OC is not considered a more major player. Could the authors comment on this small contribution?

A better figure and table of the radiative forcing of each of the different short-lived greenhouse gases for each model would be helpful (Figure 3.3)

Color-coding the tables to emphasize the sign and magnitude of the differences in burden and emissions would be helpful.

Consistent scales and map projections would be helpful in Figures 3.4 and 3.7.

Figure 3.4. The reviewers suggest including maps of radiative forcing from both long-lived and short-lived greenhouse gases for the same time periods.

Lines 2176-2177. The authors state that uncertainties in socio-economics dominate "uncertainties in physical sciences." Here chemical mechanisms should also be mentioned because of important chemical reactions for sulfate and ozone formation.

Line 2248-2250. This sentence concerning the possible impact of future air-policy decisions in Asia on U.S. climate change is loaded with importance and needs more discussion.

Table 3.8 The table of radiative forcing impacts from regional sector perturbations is interesting, but needs more explanation in the caption. What are the perturbations? Give them in the table caption or footnote.

Lines 2276-80: use 0.01 W rather than 10 mW (and not 10 MW!)

Paragraph beginning with line 2293. This paragraph assumes that reducing surface transportation emissions of short-lived species and their precursors is done by reduced fuel consumption. This is not necessarily the case. Indeed, some controls might increase fuel consumption.

Chapter 4

Issues, Opportunities, and Recommendations

General remarks:

The title provides a nice paradigm for the chapter as it suggests that issues, opportunities and recommendations will be discussed. However, few issues, opportunities or recommendations are apparent in the organization or presentation of the chapter material. The committee offers the following suggestions for reorganization within the chapter:

1. Introduce this chapter with a *restatement* of what the scope of this SAP is, *why* the scope has been so defined (what was seen to have highest priority

and why; what it was possible to do at the time), and what is not being addressed in this SAP;

2. Avoid jargon and acronyms; use more functional descriptions of models (with model names in parentheses). Otherwise, the text is seen as inaccessible and thus detail-dense information is largely lost;

3. Refer back to new table(s) added to chapter 1 (Introduction) in which the different model configurations are described; possibly add figures to clarify steps taken/model process and use examples from chapter 3 (perhaps even show one of the figures (e.g. 3.1 bottom) again in this chapter) to highlight findings/conclusions drawn in this SAP;

In addition the chapter would be improved by the addition of a section recapitulating the highpoints of the study. Some suggestions are.

1. The SAP model scenarios for long-lived species produce projections that are within the IPCC range, although it should be noted that the SAP response range tends to be lower than all but the IPCC "commitment scenario".

2. The most important uncertainties in characterization in short lived species were found to be emissions and the indirect effect.

3. Part of the reason for the different emission inventories used here and in the IPCC studies was that the Integrated Assessment Models did not recognize that these species were necessarily important when the scenarios were first constructed. Clarification of the challenges associated with emissions projections (not a simple matter of improving quantitative skill, as these are a function of difficult-to-anticipate socioeconomic choices) should also be included;

4. Natural aerosols are also important and their emissions differed greatly between the models, with consequences to the role of anthropogenic emissions. The inconsistencies between models should be reconciled in future studies.

5. Calculation of the indirect effect is potentially the single most important deficiency in the study. The modeling community as a whole cannot as yet produce a credible characterization of the climate response to aerosol/cloud interactions. All models (including those participating in this study) are currently either ignoring it, or strongly constraining the model response. Using a box to highlight this issue is recommended. Additional referencing of work on aerosol indirect effects is also recommended.

6. The results suggest that the short-lived species do matter to the climate in the long term (e.g. out to 2100). The presence of radiatively active short-lived species can significantly change the regional surface temperature

response (for example over the continental US). It is noteworthy and surprising however that the response location is not local to the forcing.

7. The 3 model frameworks participating in the study produced different outcomes. Each model represents a thoughtful, but incomplete characterization of the driving forces and processes that are believed to be important to the climate. Much work remains to be done before there can be confidence that the climate response to short-lived species is well understood.

At present, a list of the priorities and opportunities for future work is not presented in the chapter. This is unfortunate; because the result of this report clearly illustrated that there are many needs for future research.

Additional regional modeling studies could provide information on local effects of short-lived species on regional climate. For example, the local impacts of aerosol forcing on surface temperature and precipitation could be significant. In addition, there is a need for modeling studies with finer resolution models, both at regional and global scales, to determine the resulting impacts on derived effects from short-lived emissions

This SAP examines only a subset of processes controlling short-lived species and their interactions with clouds. Other processes might be important but have not been addressed such as ice clouds and their interactions with short lived species and the climate system

There is evidence that future biomass burning and land cover change could have a large effect on the climate response.

To conclude the document, a reflective assessment of the product would be useful. For example, – what lessons were learned during these experiments, what would be done differently if the experiments were to be repeated? How should other experiments be set up to answer the key questions generated by this study?

Minor Issues:

Page 15 of the executive summary introduces a different chapter 4 than exists and raises expectations regarding a long list of other potentially important short-lived species and anthropogenic impacts (land use change, reactive nitrogen deposition and ecosystem responses, changing VOC emissions, changing oxidant and SOA formation).

A more-detailed discussion of the impact of fire (biomass burning) on aerosols and hydroxyl is needed. A concern was raised that 2-3 year runs are not long enough to capture the impact of ENSO-related fires in the tropics (like the 1997-1998 Indonesian fires). This may be an issue where current capabilities restrict a thorough treatment as part of this effort. If so, this should be stated in Chapter 3, and this issue should be raised as a future need in Chapter 4;

L2642: This line seems to all of a sudden pop in here, yet is potentially rather important in regards to results in Chapter 3. Given that NH3 comes from a rather large number of processes, some rather disconnected to N2O production, this seems a stretch.

L2750 "five different RCMs" should be "***six*** different RCMs…"

L 2755-2756 The sentence beginning "Future IPCC…" should be corrected to "The IPCC A1B scenario is used in this intercomparison study." (i.e., only A1B will be used and not A2)

L 2790: "The future sources of *most of*

L 2800: They need to be more specific as to what is meant by biofuel, and also need to show it is CO2 neutral. In many cases, it is not.

L 2841: This last sentence is rather weak and equivocating. From what is presented, reducing NOx will reduce tropospheric ozone. Reducing tropospheric ozone should reduce radiative forcing. The report should have a strong ending.

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Appendixes

A

CCSP Synthesis and Assessment Products

CCSP-5

U.S. CLIMATE CHANGE SCIENCE PROGRAM

CCSP Synthesis and Assessment Products

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

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

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

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

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

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

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

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

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

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

January 2006

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

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

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

Steps of the Process[1]

Planning the Process and Preparing a Prospectus

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

Additional Stakeholder Interactions, if Needed

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

Drafting/Reviewing the Products

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

Approving, Producing, and Releasing the Products

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

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

PARTICIPANTS AND THEIR ROLES

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

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

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

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

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

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

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

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

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

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

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

ccsp synthesis and assessment products

Summary of Synthesis and Assessment Products*

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

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

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

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

B

Prospectus for Synthesis and Assessment Product 3.2

U.S. CLIMATE CHANGE SCIENCE PROGRAM

Prospectus for Synthesis and Assessment Product 3.2

Climate Projections Based on Emissions Scenarios for Long-Lived Radiatively Active Trace Gases and Future Climate Impacts of Short-Lived Radiatively Active Gases and Aerosols

1. OVERVIEW

The Earth's climate system derives its energy from the Sun and any variations in the balance between energy received and emitted by the Earth can change the climate. Variations can be caused by natural factors, such as changes in solar output and volcanic eruptions, or by anthropogenic changes in atmospheric concentrations of long-lived greenhouse gases, aerosols, and other radiatively active short-lived species.

Computer models of the coupled atmosphere-land surface-ocean-sea ice system are essential tools for understanding past climates and making projections of future climate resulting from radiative forcing changes, both natural and anthropogenic. Projections of future climate require estimates (e.g. scenarios) of future emissions of long-lived greenhouse gases, aerosols, and other short-lived gases. A number of standard scenarios have been developed for the Intergovernmental Panel on Climate Change (IPCC) assessment process, and the future impacts of these have been explored. As part of the Climate Change Science Program (CCSP) process, updated scenarios of long-lived greenhouse gases and their atmospheric concentrations are being developed by the Synthesis and Assessment Product 2.1 team.

Synthesis and Assessment Product (SAP) 3.2, in conformance with the intent of the *Strategic Plan for the U.S. Climate Change Science Program*, will have two components:
1) Climate projections for research and assessment based on the range of stabilization scenarios of long-lived greenhouse gas emissions and atmospheric concentrations developed by SAP 2.1a. These stabilization scenarios and their resulting long-lived greenhouse gas concentrations were generated by three unified assessment models.
2) An assessment of the sign, magnitude, and duration of future climate impacts due to changing levels of short-lived gaseous and particulate species which may be subject to future mitigation actions to address air quality issues.

The first component was identified in the CCSP Vision document and has also been an important focus of the latest IPCC study. The second component was also identified in the CCSP Vision document, has been identified by the IPCC as a critical area for continuing study, is an active area of research that is being reported in the reviewed literature, represents a time frame over which available technological solutions can be realistically employed, and focuses on those gas and aerosol species whose future atmospheric levels are also subject to mitigation to control air pollution.

This product is part of a larger suite of CCSP analyses: SAP 2.1a, *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*; SAP 2.3, *Aerosol Properties and Their Impacts on Climate*; SAP 3.1, *Climate Models: An Assessment of Strengths and Limitations for User Applications*; SAP 4.3, *Analyses of the Effects of Climate Change on Agriculture, Biodiversity, Land, and Water Resources*; SAP 4.5, *Effects of Climate Change on Energy Production and Use in the United States*; and SAP 4.6, *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems*.

SAP 3.2 will also contribute to and enhance the ongoing and iterative international process of producing, analyzing and assessing climate projections based on a range of emissions scenarios for both long-lived and short-lived radiative species. Besides the climate projections resulting from the stabilization scenarios developed by SAP 2.1a for long-lived greenhouse gases, SAP 3.2 will examine potential climate impacts of emissions scenarios for short-lived radiatively active gases and particles that are influenced, if not determined by, local and regional air quality issues. The resulting climate projections will then be made available to the general community concerned with potential climate impacts as well as climate and air quality policy.

This process of climate projection and analysis will include, among others, both international efforts undertaken by the IPCC and national efforts of the Climate Change Technology Program, Federal research laboratories at the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Department of Energy (DOE), and Environmental Protection Agency (EPA) and the joint university-National Science Foundation (NSF) effort led by the National Center for Atmospheric Research (NCAR). SAP 3.2 will assess the climate projections resulting from SAP 2.1a scenarios in the context of existing IPCC climate projections and will isolate and assess the future climate impacts resulting from future emissions of short-lived species which, while part of the current reviewed literature, were not a specific focus of the IPCC Fourth Assessment Report.

Intended audiences of this CCSP product are decisionmakers and researchers who use climate model output as input to studies or analyses in their respective disciplines, both climate and non-climate (e.g., ecosystem science, air quality issues, hydrology and water resources, economics, human health, and agriculture and forestry).

The intended use of this CCSP product is to provide information to those who use climate model outputs to assess the potential effects of human activities on climate, air quality, and ecosystem behavior. A discussion of potential interactions between climate and emissions controls driven by local and regional air quality issues will be included. The product will address scientific issues on a comprehensive, objective, open, and transparent basis. While based on the peer-reviewed scientific literature, it will be written to be accessible and useful to the well-informed general reader and decisionmaker.

1.1. Climate Projections Based on Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations from SAP 2.1a

Three of the four SAP 2.1a emissions scenarios for long-lived trace gases—stabilizing at approximately 750 ppm, 650 ppm, and 550 ppm CO_2—fall within the envelope of emission scenarios A1B and B1 considered by IPCC. First, the 2.1a scenarios will be compared with each other, then they will be interpolated between the appropriate results. We will then use energy balance models as a tool for interpolating climate projections for the SAP 2.1a emissions scenarios from the climate projections resulting from the existing AOGCM integrations.

A simple approach to using the temperature response in a given scenario to predict the response to a second scenario is as follows:

- Assume that the spatial (and seasonal) pattern of the warming, divided by the global mean, annual mean warming is the same for both scenarios.
- Fit the time dependence of the global mean temperature in any given emissions scenario case with a simple energy balance model, in which the equilibrium climate sensitivity and the effective heat capacity are parameters.
- Use the same energy balance model to predict the global mean response to the altered radiative forcing and apply the same spatial pattern to this scenario as well.

The conventional wisdom is that this procedure works better for temperature than for precipitation. Variants of this procedure are described and evaluated in the literature.

Based on the existing scientific literature, we expect that the climates resulting from SAP 2.1a long-lived trace gas emissions scenarios can be reasonably estimated from the existing IPCC climate simulations. If necessary, full climate model simulations will be performed.

The following questions will be addressed:

1) Do SAP 2.1a emissions scenarios differ significantly from IPCC emissions scenarios?
2) If the SAP 2.1a emissions scenarios do fall within the envelope of emissions scenarios previously considered by the IPCC, can the existing IPCC climate simulations be used to estimate 50-to 100-year climate responses for the CCSP 2.1 CO_2 emissions scenarios?
3) What would be the changes to the climate system under the scenarios being put forward by SAP 2.1a?
4) For the next 50 to 100 years, can the time-varying behavior of the climate projections using the emissions scenarios from SAP 2.1a be distinguished from one another or from the scenarios currently being studied by the IPCC?

1.2. Climate Impacts of Future Emissions Scenarios for Short-Lived Radiatively Active Gases and Aerosols

Ozone and aerosols are all radiatively important short-lived trace species, whose concentrations have increased dramatically since pre-industrial times and are projected to continue to change in the future. The specified anthropogenic aerosols include black carbon, organic carbon, nitrate, and sulfate aerosols. Recent calculations suggest that the tropospheric burden of ozone has increased by over 50%, and sulfate and carbonaceous aerosol burdens have increased by factors of 3 and 6, respectively, since pre-industrial times. Natural aerosols include volcanic emissions, sea salt, and dust. In this study we will not address future changes in aircraft emissions, the direct anthropogenic component of dust emission, climate change-induced changes in dust and sea salt emissions, changes in contrails, and indirect effects of aerosols on clouds and cloud radiative properties.

Global chemical transport models are used to create scenarios of future time-dependent three-dimensional distributions of these radiatively active species (gases and aerosols) from their emissions scenarios. Projected tropospheric ozone changes over the next century range from -5 to +34%, depending on the emissions scenario, in recent studies. Sulfate concentrations are projected to increase for the next several decades, but then to decrease by 4 to 45% by 2100, again with values highly sensitive to the emissions scenario. Variations can be even larger at regional scales. These time-dependent distributions are then used to drive climate models to assess the effect of short-lived species on climate.

For this section, we propose two integrations of three-member ensembles with the Geophysical Fluid Dynamics Laboratory (GFDL) and Goddard Institute for Space Studies (GISS) climate models and single member simulations with the National Center for Atmospheric Research (NCAR) model from 2000 to 2050 with, if time permits, at least one member integrated to 2100. One integration will employ the complete IPCC A1B emissions scenario including long-lived greenhouse gases and short-lived greenhouse aerosols and gases. In the second integration, short-lived greenhouse gases and aerosols will be fixed at present values throughout the integration. The climate differences between the two three-member ensembles and the one single pair of integrations will be ascribed to the impact of future levels of short-lived aerosols and gases. The A1B scenario is an upper limit to the 2.1a stabilization scenarios and represents a realistic middle-of-the-road IPCC scenario. An additional set of simulations will examine the impact of 30% reductions in anthropogenic emissions of short-lived species precursors from specific economic sectors in North America and in developing Asia. These idealized studies are seen as a first step in examining the climate impact of potential actions taken to mitigate air pollution which would reduce radiatively active short-lived species.

We will also compare a regionally downscaled climate projection that relies on the A1B scenario with the above global climate simulations. The regional downscaled climate simulation, which would focus on the 2050 projections and the North American domain, provides projected changes in temperature and precipitation at a higher spatial resolution. These downscaled results can also be aggregated up to a similar spatial and temporal scale as the global climate models for direct comparison. Regional simulations of ozone and aerosol have also been developed, based on this A1B regional downscaled simulation for 2050, and can be compared to the short-lived species concentrations used in the climate simulations.

We expect this section of SAP 3.2 to promote future research that would explore a range of emissions scenarios for short-lived gases and aerosols. These scenarios would be driven by future air quality actions taken around the globe and would include a wide range of socio-economic and development pathways.

Part B will explore the following questions:
1) What are the impacts of the radiatively active short-lived species not being reported in SAP 2.1?
2) How do the impacts of short-lived species compare with those of the well-mixed green house gases as a function of the time horizon examined?
3) How do the regional impacts of short-lived species compare with those of long-lived gases in or near polluted areas?
4) What might be the climate impacts of mitigation actions taken to reduce the atmospheric levels of short-lived species to address air quality issues?

1.3. Workshop

We will organize a workshop, open to the public, to discuss the results of the work described in subsections 1.1 and 1.2, and to prepare a draft paper or papers for submission to the reviewed science literature. Besides the three SAP 3.2 authors and interested scientists from the three major U.S. global climate modeling centers (GFDL, NCAR, NASA/GISS), we will solicit representatives from the SAP 2.1a and 3.1 author teams and/or agency leads. This workshop will be announced publicly and open to any interested parties who wish to attend.

2. Contact Information

NOAA is the lead agency for this product. DOE, NASA, and NSF are supporting. Agency contacts follow:

NOAA	Ants Leetmaa ants.leetmaa@noaa.gov (609) 452-6502
DOE	Anjuli Bamzai anjuli.bamzai@science.doe.gov (301) 903-0294
NASA	Donald Anderson danders1@hq.nasa.gov (202) 358-1432
NSF	Jay Fein jfein@nsf.gov (703) 292-8527

3. Lead Authors

Authors will primarily be drawn from participating modeling teams that have records of successful development, evaluation, and/or use of global (coupled ocean-atmosphere-sea ice-land) climate models. Examples are those climate models developed and maintained by NCAR, GFDL, GISS, and DOE. Expertise and experience in global atmospheric chemistry modeling, atmospheric chemistry-climate interactions, and regional downscaling will also be sought, including from these same centers. In addition, the authors should have a track record of publications in professional refereed journals, specifically in the use of global and/or regional models for the projection and analysis of climate and atmospheric chemistry.

To facilitate expeditious completion, direct participation in SAP 3.2 will be limited to models and groups that meet the criteria above, though all relevant published research will apply. Currently, the writing team consists of the three authors who developed this prospectus (see Appendix A):
- Dr. Alice Gilliland, ARL/NOAA in partnership with EPA Office of Research and Development

- Dr. Hiram Levy II, GFDL/NOAA
- Dr. Drew Shindell, GISS/NASA

Several more authors will be added as the outline is developed and via the workshop.

4. Stakeholder Interactions

The wider intended audiences for this CCSP product are decisionmakers and researchers who use climate model output as input to studies or analyses in their respective disciplines, both climate and non-climate (e.g., ecosystem science, air quality issues, hydrology and water resources, economics, human health, and agriculture and forestry). While SAP 3.2 inputs and outputs will be global, there will be a focus on those outputs relevant to North America. The intended use of this CCSP product is to provide information to those who use climate model outputs to assess the potential effects of human activities on climate, air quality, and ecosystem behavior. An examination of potential interactions between climate and emissions controls driven by local and regional air quality issues will be included. The product will address scientific issues on a comprehensive, objective, open, and transparent basis. While based on the peer-reviewed scientific literature, it will be written to be accessible and useful to the well-informed general reader and decisionmaker.

Stakeholder input will be solicited through the public comment period for this prospectus, through the workshop to discuss and assess the climate impacts of the SAP 2.1 scenarios as well as short-lived greenhouse species, and through the public comment period for the draft final report.

5. Drafting

5.1. Climate Projections Based on Scenarios of Long-lived Greenhouse Gas Emissions and Atmospheric Concentrations from SAP 2.1a

This report will be drafted based on scenarios developed for SAP 2.1a. The core will be simulations of the climate response to the radiative forcing/CO_2 stabilization scenarios developed under 2.1a employing MAGICC and evaluation of those scenarios and climate responses in comparison with the existing set of IPCC simulations of future climate. MAGICC is expected to be the primary tool used, with full climate model simulations to be performed for any emissions scenarios that depart substantially from those already used to drive existing IPCC simulations and analysis.

The final report will include a summary section that addresses issues important for interpreting and using the projections, including a discussion of key uncertainties surrounding them. While the forcings and climate projections are global, the analysis, to the degree possible, will focus on North America.

As the lead agency, NOAA will be responsible for disseminating this product with respect to meeting the requirements of the Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies [see Federal Register, Vol. 67, No. 36, February 22, 2002].

5.2. Climate Impacts Resulting from Emissions Scenarios for Short-Lived Radiatively Active Gases and Aerosols

This report will be drafted based on model simulations of the climate response to the IPCC A1B emissions scenario. For one ensemble, the short-lived species will follow the A1B emissions scenario and for the other ensemble they will be fixed at their 2000 values. A global chemical transport model incorporating transport and the chemical and phase transformations within the atmosphere will be used to create temporally and spatially varying distributions of these short-lived trace species for the A1B emissions scenario. Simulations will be performed by individual chemistry-aerosol modeling groups, then provided to the climate models of those same groups. Participants will include NOAA GFDL, NASA GISS, and NCAR, all of whom will evaluate the resulting climate response.

Idealized simulations of the response of short-lived species to 30% reductions in their anthropogenic precursor emissions in specific sectors (industrial, transport, and domestic/power) for two regions (North America and developing Asia) will also be performed by NCAR and NASA GISS. These are sensitivity studies with no assumptions as to time frame. The climate impacts of these responses will also be assessed for the report.

All three modeling centers will participate in the simulations, in the workshop, and in the drafting of a scientific paper(s) for submission to the reviewed literature. However, no non-Federal participants will be authors of SAP 3.2.

The final report will include a summary section that addresses issues important for interpreting and using the climate projections, including a discussion of key uncertainties surrounding them. Each modeling team may produce an independent background report to summarize and document the analysis carried out in support of this effort.

As the lead agency, NOAA will be responsible for disseminating this product with respect to meeting the requirements of the Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies [see Federal Register, Vol. 67, No. 36, February 22, 2002].

6. Review

SAP 3.2 will follow the process described in the *Guidelines for Producing CCSP Synthesis and Assessment Products*: (1) a first draft for expert peer review organized by the National Research Council (NRC); (2) a second draft released for 45 days for public comment; and (3) a third draft for final review and approval through the CCSP interagency committee and the National Science and Technology Council (NSTC).

The expert peer review process will consist of independent written reviews from five to ten expert peer reviewers. The lead and supporting agencies will develop an appropriate charge for the reviewers in collaboration with the relevant NRC boards and committees. After receiving the reviews, the lead authors will revise the report as appropriate and prepare a response to the reviewers' comments. The peer review processes will be consistent with the final Information Quality Bulletin for Peer Review [see Federal Register, Vol. 70, No. 10, January 14, 2005].

The report and response to reviewer's comments will then be posted for public review. Using the public comments, the lead authors will revise the report as appropriate and prepare a response to those reviewers' comments.

Following the expert and the public reviews and subsequent revisions as necessary, the products will be passed to the CCSP interagency committee and NSTC for final approval and dissemination.

7. Related Activities

SAP 3.2 will contribute to and enhance the ongoing and iterative international process of producing, analyzing, and assessing climate projections based on a range of emissions scenarios for both long-lived and short-lived radiative species. Besides the climate projections resulting from the stabilization scenarios developed by SAP 2.1a for long-lived greenhouse gases, SAP 3.2 will examine potential climate impacts of future emissions of short-lived radiatively active gases and particles that are influenced, if not determined by, local and regional air quality issues.

The resulting climate projections represent one part of a larger suite of CCSP scenario analysis products that includes SAP 2.1a (*Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*), SAP 2.3 (*Aerosol Properties and Their Impacts on Climate*), SAP 3.1 (*Climate Models: An Assessment of Strengths and Limitations for User Applications*), and SAP 4.5 (*Effects of Climate Change on Energy Production and Use in the United States*).

8. Communication

Hardcopies of the product will be published using the standard format for all CCSP synthesis and assessment products. The final product and the comments received during the expert review and the public comment period will be posted on the CCSP web site. The number of hardcopies and the process for their dissemination will be determined as part of the development of this product.

9. Timeline

The following schedule is proposed for the completion of this product. Because this product may require substantial new modeling, the deadline for the first draft of the report has an inherent uncertainty. The proposed schedule is contingent on meeting review deadlines.

June 2006
Prospectus submitted to CCSP

July 2006
Prospectus posted on CCSP web site for public comment (30 days)

July-September 2006
Climate interpolation for Section 1.1 and climate model integrations for Section 1.2

October 2006
Final prospectus posted on the CCSP web site

October 2006
Workshop

October 2006 - April 2007
Completion of assessment of 2.1 scenario-driven climates based on IPCC Fourth Assessment Report analysis for Section 1.1 and completion of draft science paper(s) for Sections 1.1 and 1.2

30 April 2007
Draft #1 of SAP 3.2 provided to NRC for expert peer review (120 days)

1 September 2007
Draft #2 of SAP 3.2 prepared

15 September 2007
Draft #2 of SAP 3.2 made available for public comment (45 days)

1 November 2007
Draft #3 of SAP 3.2 prepared

15 November 2007
Draft #3 of SAP 3.2 submitted to CCSP interagency committee for review and processing through NSTC

30 December 2007
Final SAP 3.2 report posted on CCSP web site

Appendix A. Biographical Information for Authors

Dr. Alice Gilliland is a supervisory physical scientist at the Air Resources Laboratory [ARL]/National Oceanic and Atmospheric Administration. She received a Ph.D. in Atmospheric Sciences from Georgia Institute of Technology in 1997 with a focus on interannual variations in interhemispheric transport, and she then continue to work with global chemical transport modeling during her post-doctoral work at Duke University. She joined ARL's Atmospheric Sciences Modeling Division as a federal employee in 1999, became a Supervisory Physical Scientist in 2004, and is the chief of the Model Evaluation and Applications Research Branch. Her branch is responsible for evaluating the Community Multiscale Air Quality (CMAQ) regional scale model, which is used in regulatory rulemaking by the EPA and for NOAA air quality forecasts. She is also leading a study of climate impacts on air quality where regionally downscaled climate projections are used to study the sensitivity of air quality to climate change scenarios. Results from this study will contribute to the SAP 4.6. She has written or co-authored approximately 25 papers related to atmospheric chemical transport modeling on regional and global scales. Her NOAA Division is working in partnership with the EPA Office of Research and Development in Research Triangle Park, NC, which gives her a unique position to provide insight into regulatory aspects relevant to the study of climate and air quality interactions.

Dr. Hiram Levy II is a Senior Research Scientist at the Geophysical Fluid Dynamics Laboratory [GFDL]/National Oceanic and Atmospheric Administration. He received a Ph.D. in Chemistry from Harvard University in 1966. After post-doctoral work in theoretical chemistry at Massachusetts Institute of Technology and working as a Research Scientist in atomic and molecular physics at the Smithsonian Astrophysical Observatory, he joined GFDL in 1973. He has been a government scientist since 1975, a Senior Research Scientist since 1998, and is Leader of the Biospheric Processes Group studying the interactions and feedback of the earth's biosphere with its climate and assessing the impact of natural variability and past, present, and future human activities. He has been a visiting Professor at the University of Michigan and the University of Iowa. He has written or co-authored more than 70 papers on global change, atmospheric chemistry and atomic and molecular physics. He has served on numerous National Academy of Sciences panels, as an Editor of EOS and as an Associate Editor for the Journal of Geophysical Research. He is also a Lecturer in the Atmospheric and Oceanic Science Program at Princeton University, where he has taught Atmospheric Chemistry since 1987. He was named a Fellow of the American Geophysical Union in 1998.

Dr. Drew T. Shindell is a physicist at the NASA Goddard Institute for Space Studies (GISS). He received a Ph.D. in Physics from the State University of New York, Stony Brook, in 1995. He joined GISS in 1995, under a NASA EOS postdoctoral fellowship through Columbia University. He has been a government scientist since 2000, leading a research group studying atmospheric composition and climate. He has been a visiting scientist at Imperial College, London and at the Max-Planck Institute for Meteorology, Hamburg. He has written or co-authored about 60 papers on climate modeling, climate change, and atmospheric chemistry. He has served as an expert reviewer for the Intergovernmental Panel on Climate Change, co-author of the World Meteorology Organization's Ozone Assessments and the US National Assessment, and consultant for the American Museum of Natural History. He is also a Lecturer in the Department of Earth and Environmental Sciences at Columbia University, where he has taught Atmospheric Chemistry since 1997. He was named one of the top 50 scientists of 2004 by Scientific American magazine.

C

Committee and Staff Biographies

Mary Anne Carroll (Chair) is director of the Program for Research on Oxidants: Photochemistry, Emissions and Transport (PROPHET), executive director of the Biosphere-Atmosphere Research and Training Program (BART), and a professor of Atmospheric, Oceanic and Space Sciences,Chemistry, and Geological Sciences at the University of Michigan. Her areas of interest include oxidant photochemistry, distribution, and trends; atmosphere-forest exchange of reactive nitrogen (a factor in carbon storage); and the impacts of air pollutants on ecosystem function and emissions. She served as editor for the Journal of Geophysical Research-Atmospheres from 1997 to 2000, is a past member of the NRC's Committee on Geophysical and Environmental Data, the Committee on Atmospheric Chemistry, and the Board on Atmospheric Sciences and Climate. Dr. Carroll received her Sc.D. in atmospheric chemistry from the Massachusetts Institute of Technology.

Raymond W. Arritt is a Professor at Iowa State University’s Department of Agronomy. His research emphasis is on regional-scale atmospheric processes, focusing on regional climate modeling and atmospheric processes affecting warm-season precipitation. Dr. Arritt is a member of the American Geophysical Union (AGU) and the American Meteorological Society (AMS). He is an Associate Editor of *Journal of Hydrometeorology*, and has served on the AMS’s Committee on Mountain Meteorology and the AGU’s Committee on Clouds and Precipitation. He served as a Contributing Author to the Third and Fourth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC). He received his PhD from Colorado State University and his MS and BA from the University of Virginia.

James A. Edmonds is a Senior Staff Scientist and Technical Leader of Economic Programs at the Pacific Northwest National Laboratory's (PNNL) Joint Global Change Research Institute, a collaboration with the University of Maryland on the College Park campus. Dr. Edmonds heads an international global change research program at PNNL with active collaborations in more than a dozen institutions and countries around the world. He is the principal investigator for the Global Energy Technology Strategy Program to Address Climate Change, an international public-private research collaboration. Dr. Edmonds is well known for his contributions to the field of the integrated assessment of climate change and the examination of interactions between energy, technology, policy and the environment. He has expounded extensively on the subject of global change including books, papers, and presentations. His publications include ***Global Energy: Assessing the Future***, with John Reilly (Oxford University Press) and ***A Primer on Greenhouse Gases*** (Lewis Publishing and scientific book of the year at the Lawrence Livermore National Laboratory). He has served as a Lead Author for all three major assessments of the Intergovernmental Panel on Climate Change and numerous interim assessment reports. He has frequently testified before Congress and briefed the Executive Branch of the United States Government, and has prepared and conducted numerous briefings and lectures to a wide range of audiences. His received his Ph.D. and M.A. in economics from Duke University and his B.A. in economics from Kalamazoo College.

Loretta J. Mickley is a research associate in the Division of Engineering and Applied Sciences at Harvard University. She primarily investigates the complex relationship between climate change and tropospheric ozone and aerosols. Dr. Mickley's work addresses an array of chemistry-climate questions such as: how human activity has changed the composition of the atmosphere, the effect of tropospheric ozone on climate change, causes of pollution episodes, the influence of future climate change on air quality. Dr. Mickley received her master's degree in chemistry from the University of Illinois at Chicago and her Ph.D. in geophysical sciences from the University of Chicago.

Phillip Rasch is a Senior Scientist in the NCAR Climate and Global Dynamics Division's (CGD) Climate Modeling Section. His main focus has been on understanding the connections between clouds, chemistry and climate of the Earth system. Work in this broad area has required basic contributions in numerical methods for atmospheric models, as well as contributions in the representation of cloud processes, and processes that control the transport, production, and loss of trace constituents in the atmosphere. He is a member of the development team for the NCAR Community Atmosphere Model (CAM), and the Community Climate System Modeling (CCSM) project, and has contributed in the above mentioned areas to that model. He was the principal architect of MATCH (Model for Atmospheric Transport and Chemistry) at transport model used by researchers worldwide. Rasch is the co-Chair of the Atmospheric Model Working Group within the CCSM project, facilitating research within a group of scientists numbering in the hundreds around the country. He oversees the day to day activitives of the group's model development and helps in coordinating the planning of future versions. He is a chair of the International Global Atmospheric Chemistry project (IGAC), and an organizer of the IGBP/WCRP activity called Atmospheric Chemistry and Climate (AC&C). He has served in various editorial positions for international journals, served on advisory panels for NSF, DOE, and NASA, and is a member of numerous science teams on NASA projects. He has been a contributing author to NASA,World Meteorological Organization, and International Panel on Climate Change assessment documents. He has served and/or chaired organizing committees for NATO Advanced Study Institutes and World Climate Research Programme workshops. He was a member of the NSF Science and Technology Center for Clouds, Chemistry and Climate (C4), and was chair of the modeling activity within that center.

Armistead G. Russell is the Georgia Power Distinguished Professor and Coordinator of Environmental Engineering at the Georgia Institute of Technology. Professor Russell has expertise in air quality engineering, with particular emphasis in air quality modeling, air quality monitoring and analysis. He earned his M.S. and Ph.D. degrees in Mechanical Engineering at the California Institute of Technology in 1980 and 1985, conducting his research at Caltech's Environmental Quality Laboratory. His B.S. is from Washington State University (1979). Dr. Russell has been a member of a number of the National Research Council's committees, including chairing the Committee to Review EPA's Mobile Model and chairing the committee on Carbon Monoxide Episodes in Meteorological and Topographical Problem Areas, and serving on the committee on Tropospheric Ozone Formation and Measurement, the committee on ozone forming potential of reformulated fuels and the committee on Risk Assessment of Hazardous Air Pollutants. Recently, he served on two EPA SAB subcommittees: the CASAC subcommittee on the National Ambient Air Monitoring Strategy and the subcommittee on Air Quality Modelling Subcommittee of the Advisory Council on Clean Air Compliance Analysis. He was also a member of the EPA FACA Subcommittee on Ozone, Particulate Matter and Regional Haze, the North American Research Strategy for Tropospheric Ozone and California's Reactivity Science Advisory Committee. Previously he was on the Office of Science, Technology and Policy's Oxygenated Fuels Program Review and various National Research Council program reviews, and a committee to review a Canadian NRC program.

Joellen L. Russell is an assistant professor of geosciences at the University of Arizona and previously worked as a research scientist at Princeton University's Geophysical Fluid Dynamics Laboratory. Her primary research focus is on the role of Southern Ocean intermediate and mode waters in the global carbon cycle, ocean circulation, and heat budget. Dr. Russell received her Ph.D. in Oceanography from the University of California, San Diego and her BA in Environmental Geoscience from Harvard University.

Lisa C. Sloan is Professor of Earth and Planetary Sciences at the University of California at Santa Cruz. Her research interests focus on understanding the processes that have controlled past climates, environments, and surficial processes in Earth history. Her research has concentrated primarily on Cenozoic events and processes, with primary emphasis on the warm and transitional intervals of that era of Earth history. Dr. Sloan's research involves examining marine and terrestrial geologic records of climatic and environmental change and investigating the driving forces behind such changes. Dr. Sloan was elected Associate Fellow of Canadian Institute for Advanced Research in 1999 and has served as National Secretary of the American Geophysical Union's Ocean Sciences Section (Marine Geology and Geophysics). She received her Ph.D. in Geosciences from Pennsylvania State University, her M.S. in Geology from Kent State University, and her B.S. in Geology from Allegheny College.

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

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

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Committee to Review the U.S. Climate Change Science Program's Synthesis and Assessment Product 3.2

Statement of Task

This committee will review the U.S. CCSP's draft Synthesis and Assessment Product 3.2 entitled "Climate Projections Based on Emissions Scenarios for long-lived radiatively active trace gases and future climate impacts of short-lived radiatively active gases and aerosols". The purpose of the CCSP SAP 3.2 is to provide information to those who use climate model outputs to assess the potential effects of human activities on climate, air quality and ecosystem behavior. The role of the National Academies committee will be to provide a peer review of CCSP SAP 3.2. The committee will address the following issues:

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