CCSP Synthesis and Assessment Product 3.2

SAP-3.2

Prospectus for

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

U.S. Climate Change Science Program

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National Oceanic and
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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:

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NASA Donald Anderson
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NSF Jay Fein
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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.