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

Lead Agency: National Oceanic and Atmospheric Administration

Supporting Agencies: National Aeronautics and Space Administration
Department of Energy
National Science Foundation

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 Technology Program (CCTP) and the Climate Change Science Program (CCSP) process, updated scenarios of long-lived greenhouse gases and their atmospheric concentrations are being developed by Synthesis and Assessment Product 2.1.

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 scenarios of long-lived greenhouse gas emissions and atmospheric concentrations developed by SAP 2.1a. These scenarios and their resulting long-lived greenhouse gas concentrations were generated by 3 unified assessment models employing economic optimization techniques to develop the least costly emission paths to a range of stabilized radiative forcings for 2100.
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 to mitigate to control air pollution.

This product is part of a larger suite of CCSP analyses: Product 2.1a (Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations); Product 2.3 (Aerosol properties and their impacts on climate); Product 3.1 (Climate Models: An Assessment of Strengths and Limitations for User Applications); Product 4.3 (Analyses of the effects of climate change on agriculture, biodiversity, land, and water resources); Product 4.5 (Effects of Climate Change on Energy Production and Use in the United States); and Product 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 emission scenarios for both long-lived and short-lived radiative species. Besides the climate projections resulting from the stabilization scenarios developed by the SAP 2.1a for long lived greenhouse gases, SAP 3.2 will examine potential climate impacts of methane emission scenarios, as well as emission 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 Intergovernmental Panel on Climate Change 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 lead 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 methane and short-lived specie which, while part of the current reviewed literature, were not a specific focus of IPCC-4.

The intended audiences of this CCSP product are decision makers 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 emission 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 decision maker.

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

The SAP 2.1a emission scenarios for long-lived trace gases stabilizing at approximately 750 ppm, 650 ppm and 550 ppm CO2 fall within the envelope of emission scenarios A1B and B1 considered by IPCC. First the 2.1a scenarios will be compared with each other, and then they will be interpolated between the A1B and the B1 IPCC emission scenarios. We will then use energy balance models as a tool for interpolating climate projections for the SAP 2.1a emission scenarios from the climate projections resulting from the existing GFDL and GISS integrations for the A1B and the B1 emission scenarios. If similar interpolation options are available for other IPCC climate model simulations, they will also be considered

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

1) Assume that the spatial (and seasonal) pattern of the warming, divided by the global mean, annual mean warming is the same for both scenarios.
2) Fit the time dependence of the global mean temperature in one's control scenario with a simple energy balance model, in which the equilibrium climate sensitivity and the effective heat capacity are parameters.
3) 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 and is only relevant if the well-mixed greenhouse gases dominate the response. 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 emission scenarios can be reasonably estimated from the existing IPCC climate simulations which were performed for the A1B and B1 IPCC emission scenarios. If necessary, full climate model simulations will be performed. We will also explore the possibility of regional model downscaling for North American climate projections

The following questions will be addressed:

1. Do SAP 2.1a emission scenarios differ significantly from IPCC emission scenarios?

2. If the SAP 2.1a emission scenarios do fall within the envelope of emission scenarios previously considered by the IPCC, can the existing IPCC climate simulations be used to estimate 50 -100 year climate responses for the CCSP 2.1 CO2 emission 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 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 emission 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 emission 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 methane and the short-lived species on climate.

For this section we propose two integrations of 3 member ensembles with the Geophysical Fluid Dynamics Laboratory (GFDL) and Goddard Institute for Space Studies (GISS) climate models from 2000 to 2050 with, if time permits, 1 member integrated to 2100. One integration will employ the complete IPCC A1B emission 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 3 member ensembles 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. Other climate models that participated in IPCC-4, such as the NCAR Community Climate Model (CCM), will be invited to participate in this study. This idealized study is 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 expect this section of SAP 3.2 to promote future research which would explore a range of emission 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 considered in Product 2.1?

2. How do the impacts of short-lived species compare with those of the well-mixed green house gases (GHG) 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 Science Workshop

Funding permitting, we will organize an open science workshop to discuss the results of the 1.2 study and to prepare a draft paper for submission to the reviewed science literature. Besides the 3 SAP 3.2 authors and interested scientists from the three major US global climate modeling centers (GFDL, NCAR, NASA/GISS), we will solicit representatives from Synthesis and Assessment Products 2.1a, 2.3, and 3.1. This workshop will also 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 are presented in the following table:

Agency	Contact	Email	Telephone
DOE	Anjuli Bamzai	anjuli.bamzai@science.doe.gov	(301) 903-0294
NASA	Donald Anderson	danders1@hq.nasa.gov	(202) 358-1432
NOAA	Ants Leetmaa	ants.leetmaa@noaa.gov	(609) 452-6502
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 the National Center for Atmospheric Research, the Geophysical Fluid Dynamics Laboratory, the Goddard Institute for Space Studies, and the Department of Energy. Expertise and experience in global atmospheric chemistry modeling, atmospheric chemistry-climate interactions, and regional down-scaling 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 there are 3 authors working on the Prospectus. We expect to identify several more authors for the final report as the outline develops (the various chapters) and through the workshop.

The authors of the Prospectus are:

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

4. Stakeholder Interactions

The wider intended audiences for this CCSP product are decision makers 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 the 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 emission 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 decision maker.

Stakeholder input will be solicited through the public comment period for this prospectus, through the public workshop to discuss and assess the climate impacts of methane and 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 will be drafted based on scenarios developed for the CCSP product 2.1a. The core will be interpolated model simulations of the climate response to the radiative forcing/CO2 stabilization scenarios developed under 2.1a and evaluation of those scenarios and climate responses in comparison with the existing set of IPCC simulations of future climate. Energy balance models are expected to be the primary tools used, with full climate model simulations to be performed for any emission 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, National Oceanographic and Atmospheric Administration 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 emission scenarios for short-lived radiatively active gases and aerosols

This will be drafted based on model simulations of the climate response to the IPCC A1B emission scenario. For one ensemble, the short-lived species will follow the A1B emission 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. These distributions will then be provided to climate models, including at least those from NOAA GFDL and NASA GISS, to evaluate the resulting climate response. We will solicit the participation of other global climate models, such as the NCAR CCM, and expect that all participating groups will also participate in the science workshop and in the drafting of a scientific paper 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 as a way of summarizing and documenting the analysis carried out in support of this effort.

As the lead agency, the National Oceanographic and Atmospheric Administration also 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 NRC, (2) a second draft released for 45 days for public comment, (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 boards and committees of the National Research Council. 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 the National Science and Technology Council 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 emission scenarios for both long-lived and short-lived radiative species. Besides the climate projections resulting from the stabilization scenarios developed by the 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 represents one part of a larger suite of CCSP scenario analysis products that includes Product 2.1a (Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations), Product 2.3 (Aerosol properties and their impacts on climate), Product 3.1(Climate Models: An Assessment of Strengths and Limitations for User Applications), Product 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 1st draft of the report has an inherent uncertainty. The proposed schedule is also contingent on approval of the prospectus by September 2006 as well as completion of review deadlines following completion of the draft products.

6/06	Prospectus submitted to CCSP
7/06	Prospectus posted on CCSP web site for public comment (30 days)
9/06	Final prospectus posted on the CCSP web site
7/1 -9/1/06	Climate interpolation for 1.1 and climate model integrations for 1.2
9/06	Science workshop for 1.2 study
10/06-4/07	Completion of assessment of 2.1 scenario driven climates based on IPPC-4 analysis for 1.1 and completion of draft science paper for 1.2
4/30/07	Draft #1 of SAP 3.2 provided to NRC for expert peer review (120 days)
9/1/07	Draft #2 of SAP 3.2 prepared [15 days]
9/15/07	Draft #2 of SAP 3.2 made available for public comment (45 days)
11/1/07	Draft #3 of SAP 3.2 prepared [15 days]
11/15/07	Draft #3 of SAP 3.2 submitted to CCSP interagency committee for review and processing through NSTC
12/30/07	Final SAP 3.2 report posted on CCSP web site

Appendix. 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.