Preface

Motivation and Guidance for Using Synthesis and Assessment Product 3.2

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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 U. S. Climate Change Science Program (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 has identified an initial set of 21 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. The stated purpose for this report, Synthesis and Assessment Product (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.

In an examination 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. To meet this goal, NOAA requested an independent review of SAP 3.2 by the NRC. The NRC appointed an ad hoc committee composed of eight members who provided their review findings, and recommendations, suggestions, and options for the authors to consider in revising the first draft SAP 3.2. This second draft is in response to that review.

Background and Goals

The initial mandate for Synthesis and Assessment Product 3.2 (SAP 3.2), which is still listed on the official CCSP website [http://www.climatescience.gov/Library/sap/sap-summary.php], was to provide *"Climate Projections for Research and Assessment Based on Emissions Scenarios Developed Through the Climate Change Technology Program"*.

With the development of long-lived greenhouse gas scenarios by another Synthesis and Assessment Product (SAP 2.1a) our mandate evolved to *"Climate Projections for SAP 2.1a Emissions Scenarios of Greenhouse Gases"*. These emission scenarios[1] were for the long-lived[2] and therefore globally well-mixed greenhouse gases and were constrained by the requirement that their atmospheric concentrations stabilize within 100 – 200 years at specified levels more-or-less equivalent to 450, 550, 650, and 750 parts per million (ppm) of carbon dioxide. See the Box for additional details.

[1] Emission scenarios represent the future emissions based on a coherent and internally consistent set of assumptions about the driving forces (*e.g.* population change, socio-economic development, technological change) and their key relationships.

[2] Long-lived radiative species of interest have atmospheric lifetimes that range from 10 years for methane to more than 100 years for nitrous oxide. While carbon dioxide's lifetime is more complex, we think of it as being more than 100 years in the climate system. Due to their long atmospheric lifetime, they are well-mixed and evenly distributed throughout. Global atmospheric lifetime is the mass of a species in the atmosphere divided by the mass that is removed from the atmosphere each year.

Box P1: Stabilization Scenarios and Background from CCSP SAP 2.1a

Synthesis and Assessment Product 2.1 is an important precursor to this report. It explores different scenarios that lead to greenhouse gas emissions stabilizing at different (higher) levels in the future. Scenario analysis is a widely used tool for decision making in complex and uncertain situations. Scenarios are “what ifs”—sketches of future conditions (or alternative sets of future conditions), used as inputs to exercises of decision making or analysis. Scenarios have been applied extensively in the climate change context. Examples include greenhouse gas emissions scenarios, climate scenarios, and technology scenarios.

The scenarios in SAP 2.1a are called “stabilization emission scenarios” because they are constrained so that the atmospheric concentrations of the long-lived greenhouse gases level off, or stabilize, at pre-determined levels by the end of the 21st century. They explicitly treat the economic and technological drivers needed to generate each level of greenhouse gases.

Pre-industrial levels of carbon dioxide were approximately 280 part per million (ppm), and are currently around 380 ppm – a third higher than prior to the industrial era and higher than at any other time in at least the last 420,000 years (CCSP SAP 2.2). The four stabilization levels for 2.1a were constructed so that the carbon dioxide concentrations resulting from stabilization are roughly 450, 550, 650, and 750 ppm. While the Intergovernmental Panel on Climate Change (IPCC) has also examined greenhouse gas emission scenarios and those provided by SAP 2.1a are generally within the envelope of the IPCC scenarios, 2.1a is an alternative approach to developing a consistent set of long-lived greenhouse gas concentrations.

This report (3.2) explores the climate implications of such greenhouse gas “stabilization scenarios” via several different computer simulations. The results of these projections are presented in Chapter 2 of this report.

The SAP 2.1a scenarios did not explicitly address the direct influence of short-lived[3] drivers of climate: carbon and sulfate particles and lower atmospheric ozone. Therefore we expanded our mandate to include *"Future Climate Impacts of Short-lived Radiatively Active[4] Gases and Aerosols"*. These short-lived species are largely of human-caused origin, important contributors to large-scale changes in atmospheric temperature and climate in general and primarily controlled for reasons of local and regional air quality. Therefore, this added portion of the report is a critical first step in examining the climate impact of future actions taken to reduce air pollution.

The Prospectus for Synthesis and Assessment Product 3.2 contained two charges to the authors of this report:

1. Develop climate projections for a series of emission scenarios for long-lived greenhouse gases provided by Synthesis and Assessment Product 2.1 "Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Application";

2. Investigates the contributions of four short-lived pollutants in the lower atmosphere – ozone and three types of particles (soot/elemental carbon, organic carbon and sulfate) usually identified in scientific terms as aerosols[5].

[3] Short-lived radiative species of interest have atmospheric lifetimes that range in the lower atmosphere from a day for nitrogen oxides, from a day to a week for most particles, and from a week to a month for ozone. Their concentrations are highly variable and concentrated in the lowest part of the atmosphere, primarily near their sources.
[4] Radiatively active species absorb and re-emit energy, thus changing the temperature of the atmosphere.
[5] Aerosols are very small airborne solid or liquid particles that reside in the atmosphere for at least several hour with the smallest remaining airborne for days.

Short-lived greenhouse gases and particles have received less attention than long-lived greenhouse gases in previous international assessments and were not explicitly treated in Synthesis and Assessment Product 2.1, but, as this report describes, they may affect the future climate in a substantial manner. Although sources of these pollutants tend to be localized, their impact is felt globally. This is of direct relevance to policy decisions regarding pollution, air quality and climate change.

Readers Guide to Synthesis and Assessment Product 3.2

The report includes an Executive Summary and four Chapters.

Executive Summary presents the key results and findings and recommends four critical areas of future research. It is written in non-technical language and is intended to be accessible to all audiences.

Chapter 1 provides an Introduction to this study and is intended to provide all audiences with a general overview. It is written in non-technical language, which should be accessible to all readers with an interest in climate change. It includes background material, discusses the scope of and motivation for this study, addresses its goals and objectives, and identifies the issues that are not addressed. It also contains two Boxes, one providing non-technical definitions of important terms and the other containing a clear concise description of the computer models employed in this study.

Chapter 2 focuses on the long-lived greenhouse gases and a set of emission scenarios provided by Synthesis and Assessment Product 2.1.The Statement of Findings and the Introductory section 2.1 are written in non-technical language and intended for the general reader. The remainder of the Chapter 2 provides detailed technical information about specific computer models, the resulting climate simulations and a detailed interpretation of the results. It is intended primarily for the scientific community.

A simplified global climate model, MAGICC[6], is used to simulate globally-averaged surface temperature increases for the stabilization scenarios and the results are assessed in the context of the most recent Intergovernmental Panel on Climate Change (IPCC) report (4th Assessment Report, Working Group 1). These comparisons are used to answer the first four questions posed in our Prospectus:

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 carbon dioxide emission scenarios?
3. What would be the changes to the climate system under the scenarios being put forward by SAP 2.1a?

[6] MAGICC is a two component numerical model consisting of a highly simplified representation of a climate model coupled to an equally simplified representation of the atmospheric composition of radiatively active species. This model is adjusted, based on the results of more complex climate models, to make representative predictions of global mean surface temperature and sea-level rise.

4. For the next 50 to 100 years can the climate projections using the emissions from SAP 2.1a be distinguished from one another or from the scenarios recently studied by the IPCC?

Chapter 3 attempts to assess the direction, magnitude and duration of future climate impacts due to changing levels of short-lived radiative active species of human-caused origin. This is an area of research that is still at the initial stages of exploration and which 4th Assessment Report, as well as previous IPCC reports, investigated only superficially.

First the stabilization emission scenarios and models used to generate them are discussed. Next the chemical composition models[7] used to produce the global distributions of short-lived species that help to drive the climate models are introduced. 21st century climate is then simulated with three state-of-the-art comprehensive climate models[8], and the results are then used to address the four questions raised in the second section of our Prospectus:

1. What are the impacts of the radiatively active short-lived species not explicitly the subject of SAP 2.1a?
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?

[7] Chemical composition models are state-of-the-art numerical models that use the emission of gases and particles as inputs and simulate their chemical interactions, global transport by the winds, and removal by rain, snow and deposition to the earth's surface. The resulting outputs are global three-dimensional distributions of the initial gases and particles and their products.
[8] Comprehensive climate models are a numerical representation of the climate based on the physical properties of its components, their interactions and feedback processes. Coupled atmosphere/ocean/sea-ice General Circulation Models (AOGCMs) represent our current state-of-the-art.

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?

The Statement of Findings and the Introductory section 3.1 are written in non-technical language and intended for the general reader. The remainder of the chapter provides detailed technical information about the models, the resulting climate simulations and our interpretation of the results. It is intended primarily for the scientific community.

Chapter 4 provides a summary of the major findings, identifies a number of scientific issues and questions that arise from our study, and identifies new opportunities for future research. The four most critical areas identified by this study are:

1. The projection of future human-caused emissions for the short-lived species;
2. The of indirect and direct effects of particulates and mixing between particulate types;
3. Transport, deposition, and chemistry of the short lived species.
4. Regional climate forcing vs. regional climate response.

We have written Chapter 4, as much as is possible, in non-technical language and it is intended for all audiences.