Prospectus for Synthesis and Assessment Product 3.1

Climate Models and Their Uses and Limitations: Climate Sensitivity, Feedbacks, and Uncertainties

Lead Agency: DOE
Supporting Agencies: NASA, NOAA, NSF

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

Computer simulation models of the coupled atmosphere–land surface–ocean–sea ice system are essential scientific tools for understanding and predicting natural and human-caused changes in the Earth's climate. Coupled climate system models (called "climate models" herein) provide scientists a way to integrate their knowledge about elements of the climate system in a mathematical framework so that they can conduct computer simulations of the system.

The topic addressed by this CCSP product is the strengths and limitations of climate models at different spatial and temporal scales. Its purpose is to provide guidance for the appropriate use of climate model outputs. (*CCSP Strategic Plan*, page 19). This CCSP product will focus on natural and human-caused factors influencing climate variability and change during the period 1870-2000, and will characterize sources of uncertainties in climate models. Discussion of specific future projections of climate will be limited in this product, because Synthesis and Assessment Product 3.2 will deal with climate projections. This product will focus on the models and their sensitivity, feedbacks, and uncertainties, rather than future projections using these climate models.

The intended audiences of this CCSP product are decisionmakers and researchers who use climate model output as input to studies or analyses in their respective, non-climatic disciplines (e.g., ecosystem science, hydrology and water resources, economics, human health, and agriculture/forestry). In order to facilitate application and decisionmaking using information generated by climate models, an evaluation and assessment of limitations of state-of-the-science climate models is essential. This product is directed towards this goal. Users often need climate information at regional scales and Question 5 (see below) addresses issues related to dynamical downscaling of climate projections.

The intended use of this CCSP product is to provide information to those who use climate model outputs about the uncertainty and limitations associated with using models to project the potential effects of human activities on climate and sea-level rise. A discussion of appropriate and inappropriate uses of model output 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.

Specific questions to be addressed by this CCSP product are:

1) *What are the major components and processes of the climate system that are included in present state-of-the-science climate models, and how do climate models represent these aspects of the climate system?* This section will include descriptions of crucial processes such as tropical convection and major feedbacks in the climate system (e.g., clouds, atmospheric water vapor, surface albedo, and soil moisture). It will also include brief discussion of crucial processes that are likely to play an important role in climate that not yet incorporated in the models.
2) *How are changes in the Earth's energy balance incorporated into climate models? How sensitive is the Earth's (modeled) climate to changes in the factors that affect the energy balance?* This section will explain current approaches for incorporating changes in radiative forcing from both natural and human factors since the pre-industrial era. These include changes resulting from greenhouse gas and trace constituent emissions into the atmosphere, volcanic eruptions, and variations in the sun's intensity. This section will present a brief overview of the response of the global climate system, as derived from climate model results, for the various forcings (e.g., solar, volcanic, aerosols, anthropogenically derived greenhouse gases). (Note: Synthesis and Assessment Product 2.3 will focus on aerosols and their relationships to climate change, so aerosols will be treated only briefly in this product.)
3) *How uncertain are climate model results? In what ways has uncertainty in model-based simulation and prediction both increased and decreased over time with increased knowledge about the climate system?* This section will provide a discussion of the major sources of uncertainty in climate model results including the identification of the major sources of uncertainty in model assumptions and the characterization of radiative forcing. A description (or acknowledgement) of how increased knowledge can lead to greater uncertainty by increasing the number and complexity of processes included in climate models will be included.
4) *How well do climate models simulate natural variability and how does variability change over time?* The ability of climate models to simulate the climatology and interannual variability is crucial for their use by the impacts and applications community. This section will describe efforts to evaluate these aspects of model performance. This section will also discuss the ability of climate models to simulate known patterns of natural variability, such as the Madden-Julian Oscillation, the El Niño Southern Oscillation, the North Atlantic Oscillation, and the Pacific Decadal Oscillation. Included will be a section on how these modes of variability have changed over time.
5) *How well do climate models simulate regional climate variability and change?* This section will discuss how changes in certain regions (e.g., the North Atlantic or Tropical Pacific) can influence global climate change. It will also discuss limitations of "downscaling" methodologies, including regional climate modeling, used to obtain regional information from global simulations.
6) *What are the tradeoffs to be made in further climate model development (e.g., between increasing spatial/temporal resolution and representing additional physical/biological processes)?* This section will consider the opportunities and constraints on future model development (e.g., additional computational cycles and lack of process knowledge). It will outline prospects for improvements potentially important to policymaking and decisionmaking.

Answers to each of these questions will include descriptions of the spatial and temporal aspects of climate models as they relate to each of the questions—for example, how uncertainty at the mean annual global scale (e.g., mean annual global surface temperature) is related to uncertainty at a continental or sub-continental scale. Three variables—surface temperature, precipitation, and sea level—will be emphasized in this CCSP product because they are often considered by decisionmakers and non-climate scientists concerned with climate variability and change.

This CCSP product will be an "interpreted product" as that term is used in the information quality guidelines issued by the Department of Commerce and NOAA. Namely, an interpreted product is one that has "… been developed through interpretation of original data and synthesized products. In many cases, this information incorporates additional contextual and/or normative data, standards, or information that puts original data and synthesized products into larger spatial, temporal, or issue contexts. This information is subject to scientific interpretation, evaluation, and judgment. Examples of interpreted products include journal articles, scientific papers, technical reports, and production of and contributions to integrated assessments."

2. Contact Information: E-Mail and Telephone for Responsible Individuals at the Lead and Supporting Agencies

Department of Energy (DOE), lead agency

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National Aeronautics and Space Administration (NASA), supporting agency

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National Oceanic and Atmospheric Administration (NOAA), supporting agency

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National Science Foundation (NSF), supporting agency

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

The list of lead authors is expected to include:

- Dr. David Bader/PCMDI LLNL (coordinating lead author)
- Dr. Curtis Covey/PCMDI LLNL
- Dr. Isaac Held/NOAA GFDL
- Dr. Jeffrey Kiehl/NCAR
- Dr. David Rind/NASA GISS

Brief bios for each of the above are provided in Appendix A. Additional lead and contributing authors will be finalized by the lead agency in consultation with the supporting agencies.

4. Stakeholder Interactions

The intended audiences of this CCSP product are decisionmakers and researchers who use climate model output as input to studies or analyses in their respective, non-climatic disciplines (e.g., ecosystem science, hydrology and water resources, economics, human health, and agriculture and forestry). In order to facilitate application and decisionmaking using climate model information, an evaluation and assessment of the state of science of climate models is essential. This product is directed towards this goal. Users often need climate information at regional scales and Question 5 of the prospectus addresses issues related to dynamical downscaling of climate projections. The intended use of this CCSP product is to provide information to those who use climate model outputs about the current scientific uncertainty and limitations associated with using models to project the potential effects of human activities on climate and sea-level rise. The product will address scientific issues on a comprehensive, objective, open, and transparent basis. While based on the peer-reviewed literature, it will be written to be accessible and useful to the well-informed general reader and decisionmaker.

In preparing this draft prospectus, careful consideration has been given to the feedback received from stakeholders at the December 2002 Climate Change Science Program Planning Workshop for Scientists and Stakeholders. In addition, other recent developments have been reflected. For example, results from a workshop focusing on tropical biases that degrade projections have also guided the selection of topics to be covered in the product. The authors also intend to further shape the product with the input provided by scientists, decisionmakers, and general readers during the prospectus public comment period.

5. Drafting Process (Including Materials to be Used in Preparing the Product)

The lead authors—organized by the coordinating lead author—will meet in person, through e-mail exchanges, and via teleconferences (as they see fit) to draft answers to the six key questions addressed in the product. They will also prepare an introductory section to describe the topic, the audience, and the intended use of this product. The coordinating lead author may assign primary

responsibility for drafting the text associated with each question to a specific author. The lead authors will incorporate material from any contributing authors in the draft product as they see fit.

After the product is drafted, the lead authors (or coordinating lead author and the authors responsible for each of the six questions) will write a non-technical summary.

Lead and contributing authors will base all their writing on published, peer-reviewed scientific literature. Lead authors will consider the full range of relevant peer-reviewed information. The product and its non-technical summary will identify disparate views, where appropriate.

6. Review

The lead and supporting agencies will identify a pool of technical reviewers to review the draft product. The review will be equivalent to a journal peer review with each reviewer preparing an independent review. At least 10 reviews will be conducted by scientific experts. Nominations for reviewers should be made to the responsible individual listed in this prospectus at the lead agency at any time prior to the expert review of the draft product, including during the public comment period on the prospectus.

At least three independent reviews will be obtained from non-climate scientists, selected by the lead and supporting agencies, to comment on how understandable and useful the draft product is to non-specialists.

The lead and supporting agencies will generate a charge statement for reviewers which will be distributed with the draft product.

Following expert review, the lead authors will revise the draft product by incorporating comments and suggestions from the reviewers, as the lead authors deem appropriate.

Following this expert review process, the draft product will be released for public comment following the CCSP guidelines. The public comment period will be 45 days and will take place from approximately 1 November to 15 December 2005. The expert reviewers will review the revised draft to ensure that their views were adequately considered. The lead authors will prepare a third draft of the product, taking into consideration the comments submitted during the public comment period. The scientific judgment of the lead authors will determine responses to the comments.

If the CCSP Interagency Committee review determines that no further action is needed and that the product has been prepared in conformance with these guidelines and the Data Quality Act (including ensuring objectivity, utility, and integrity as defined in 67 FR 8452), they will submit the product to the National Science and Technology Council (NSTC) for clearance. If the CCSP Interagency Committee determines that further revision is necessary, their comments will be sent to the lead agency for consideration and resolution by lead authors. If needed, the National Research Council (NRC) will be asked to provide additional scientific analysis to bound

scientific uncertainty associated with specific issues. Once the CCSP Interagency Committee has determined that the synthesis and assessment report has been prepared in conformance with these guidelines and the Data Quality Act, the Committee will submit it to NSTC for final review and clearance. Clearance will require the concurrence of all members of the Committee on Environment and Natural Resources. Comments generated during the NSTC review will be addressed by the CCSP Interagency Committee in consultation with the lead and supporting agencies and the lead authors. The lead agency will produce the final product and it will be released in coordination with the Climate Change Science Program Office (CCSPO).

7. Related Activities, Including Other National and International Assessment Processes

This CCSP product will build on previous Intergovernmental Panel on Climate Change (IPCC) assessments (e.g., First, Second, and Third Assessment Reports) and other reports (e.g., *Climate Change Science: An Analysis of Some Key Questions*). It is expected that this CCSP product will provide input to future NRC reports on climate models. This product is likely to draw from results emerging from the interagency Climate Model Evaluation Project (CMEP). CMEP activity is primarily to evaluate the IPCC model runs for the historical period 1870-2000.

8. Communications: Proposed Method of Publication and Dissemination of the Product

Once NSTC clearance has been obtained the lead agency will coordinate production and release of the product with CCSPO 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 CCSPO web site.

9. Proposed Timeline

2005

Feb	Approved prospectus posted on CCSP web site, and lead and contributing authors selected by lead agency
Feb - Aug 2005	Draft product written by lead authors, with input from contributors
Aug	Peer reviewers selected by lead and supporting agencies
Aug - Sep	Draft product reviewed by specialist and non-specialist peer reviewers
Oct	Lead authors revise draft product based on peer reviews
1 Nov – 15 Dec	Draft product made available for public comment (45 days)
Dec-Jan	Draft product revised based on public comments

2006

Feb	CCSP Principals review product
Mar	NSTC clearance
Apr	Lead agency produces final product according to format provided by CCSPO
May	Product released, lead agency coordinates release with CCSPO

APPENDIX A—Bios for Potential Lead Authors

DAVID BADER

David C. Bader received his Ph.D. (Atmospheric Science) in 1985 from Colorado State University. Since June 2003, he has been Director, Program for Climate Model Diagnosis and Intercomparison, which coordinates major international climate model evaluation and intercomparison activities for the World Climate Research Programme. He is also Chief Scientist for the U.S. Department of Energy's Climate Change Prediction Program. From 1990 to 2002, he developed and managed climate modeling and computational research programs for DOE's Office of Science, and was the agency's principal representative for climate research and climate modeling to interagency working groups and committees. He was a lead author of the interagency *U.S. Climate Change Science Program Strategic Plan* Chapter 10 on Modeling Strategy, and in 2001 was chair of the interagency Climate Change Research Initiative (CCRI) Working Group on Climate Modeling. He was the U.S. Government review coordinator of the climate model evaluation chapters in the Working Group I contributions to the IPCC Second Assessment Report and Third Assessment Report.

CURT COVEY

Curt Covey is a physicist at the Lawrence Livermore National Laboratory (LLNL). He received a Ph.D. in Geophysics and Space Physics from the University of California, Los Angeles, in 1982. He joined LLNL in 1987, after a postdoctoral fellowship at the National Center for Atmospheric Research and an assistant professorship at the University of Miami. He has spent most of his time at LLNL working for the Program for Climate Model Diagnosis and Intercomparison, where he maintains the database for the Coupled Model Intercomparison Project (CMIP). He has written or co-authored about 80 papers on climate modeling, climate change, and extraterrestrial atmospheres. He has served as an editor for the journal *Global and Planetary Change*, as a Lead Author for the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, and as a member of the World Climate Research Programme Working Group on Coupled Modeling Climate Simulation, which is providing data for the IPCC's forthcoming Fourth Assessment Report.

ISAAC HELD

Isaac Held is a Senior Research Scientist at NOAA's Geophysical Fluid Dynamics Laboratory, where he conducts research on climate dynamics and climate modeling, and is head of the Weather and Atmospheric Dynamics Group. After receiving his Ph.D. at Princeton University, and after a short stint at Harvard University, he joined GFDL in 1978 and has remained there ever since. He is also a lecturer with rank of Professor at Princeton University, in its Atmospheric and Oceanic Sciences Program, where he has supervised over a dozen Ph.D. theses. He also serves as an Associate Faculty member in Princeton's Applied and Computational Mathematics Program and in the Princeton Environmental Institute, and has taught at Woods Hole Oceanographic Institution. Dr. Held is a Fellow of the American Meteorological Society (1991) and the American Geophysical Union (1995), and a member of the National Academy of Sciences (2003). He has received the Meisinger Award of the AMS (1987) for "outstanding contributions to the study of climate dynamics…," the Bernhard Haurwitz Memorial Lectureship of the AMS (1999), the Rosenstiel Award from the University of Miami (1994) "for breadth and incisiveness is attacking fundamental problems of geophysical fluid dynamics, the general

circulation of the atmosphere, and climate dynamics," and the Department of Commerce Gold Medal (1999) "for world leadership in studies of climate dynamics."

JEFFREY KIEHL

Dr. Jeffrey T. Kiehl is a senior scientist at the National Center for Atmospheric Research's Climate Change Research Section. This section applies the Community Climate System Model (CCSM) to past, present, and future climate change. Dr. Kiehl has carried out research on the effects of ozone depletion on Earth's climate, the role of clouds in the climate system, and the role of aerosol particles in the climate system. For the past 2 years Dr. Kiehl was chairman of the Scientific Steering Committee for the CCSM and led the development of the CCSM modeling effort. He also led a CCSM effort to simulate the climate of the 20th century, including the effects of greenhouse gases. He was a contributing author to the chapters on aerosols and radiative forcings in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report. He has served on the Climate Research Committee of the National Research Council, as Editor for the *Journal of Geophysical Research*, and was a member of the Board of Reviewing Editors for *Science Magazine*. He has also served on the Science Steering Committee for the U.S. Climate Variability (CLIVAR) and the National Research Council (NRC) Committee on Global Change Research. He currently serves on the NRC Committee on Radiative Forcing Effects on Climate. Dr. Kiehl has taught graduate courses in atmospheric science at the University of Colorado and at Scripps Institution of Oceanography, and has been a Visiting Fellow at Cambridge University. Dr. Kiehl was also co-director of the NSF Science and Technology Center for Clouds, Chemistry, and Climate. Jeffrey Kiehl holds a B.S. and M.S. in Theoretical Physics and a Ph.D. in Atmospheric Sciences from the State University of New York, Albany.

DAVID RIND

Dr. David Rind is a climate modeler at the NASA Goddard Institute for Space Studies, and an adjunct professor in the Department of Earth and Environmental Sciences of Columbia University. He received his Ph.D. from Columbia University in 1976, and has been working with NASA since 1978. He has published more than 200 papers in the fields of climate modeling, paleoclimate studies, and atmospheric dynamics. He's received NASA awards for Special and Superior Achievement, been on various NRC and AMS panels, and was an AGU Charney Lecturer. His particular emphasis has been on the potential for climate change associated with increasing atmospheric greenhouse gases and its associated impacts. He has also been working on evaluating the importance of other forcing factors, such as varying solar radiation.