Report of the
Biological and Environmental Research Advisory Committee
(BERAC)

Review of the Climate Change PART Measure:
(Performance Assessment and Rating Tool)

October 16, 2006

TABLE OF ACRONYMS

AOGCM	Atmosphere-Ocean General Circulation Models
ARM	Atmospheric Radiation Measurement
ASP	Atmospheric Science Program
BER	Biological and Environmental Research
BERAC	Biological and Environmental Research Advisory Committee
CCPP	Climate Change Prediction Program
CCRP	Climate Change Research Program
DOE	Department of Energy
FACE	Free-Air CO_2 Enrichment
IAGCRP	Integrated Assessment of Global Change Research Program
IPCC	Intergovernmental Panel on Climate Change
LTM	Long Term Measure
MAX-MEX	Megacity Aerosol Experiment in Mexico City
PART	Program Assessment and Rating Tool
PER	Program for Ecosystem Research
SciDAC	Scientific Discovery through Advanced Computing
SOA	Secondary Organic Aerosol
TCP	Terrestrial Carbon Processes

Introduction

The Biological and Environmental Research Advisory Committee (BERAC) Climate Change Research Subcommittee met on August 29-30, 2006, to review the Biological and Environmental Research (BER) programs in Climate Change and to evaluate progress towards meeting the long term measure (LTM) established under the Federal Program Assessment and Rating Tool (PART). Specifically, the subcommittee was asked to:

- Understand the BER Climate Change Research Program (CCRP)/portfolio
- Understand the LTMs and annual measures, as established under PART, for the Climate Change Program and assess whether
  - These measures are reasonable and representative of the research programs recognizing that the intent of the PART LTM is not to capture all activity within the comprehensive program.
  - If the LTM is not reasonable, what new measure should be used?
  - If progress towards the measure is not adequate, why not? Were insufficient funds provided? Did the science (results and tools) change in unanticipated directions?
- Write a report that:
  - Evaluates progress toward achieving the long term PART measure in the CCRP. This includes both actual progress and progress that can be inferred from the areas supported by the BER program.
  - Use short- and intermediate-term milestones as a guide in assessing progress.
  - Specify ratings of excellent, good, fair, or poor, and provide a basis or rationale for each of the ratings.

The three core areas of BER's Climate Change Research that are focused on the long term goal are climate forcing, climate change modeling, and climate change response. Climate forcing includes the Atmospheric Radiation Measurement (ARM) Science Program, the ARM Infrastructure Program, the Atmospheric Science Program (ASP), the Terrestrial Carbon Processes Program, as well as Information and Data Management. Climate change modeling has two components: the Climate Change Prediction Program (CCPP) and the climate modeling component of the Scientific Discovery through Advanced Computing (SciDAC) program. Climate change response includes the Program for Ecosystem Research (PER), the Free-Air CO_2 Enrichment (FACE) facilities, and Integrated Assessment Research.

During the meeting, program managers for each area presented the goals and metrics for their individual programs and gave a brief overview of science highlights. In addition, the Chief Scientist (or a representative) from each program was present to answer any specific questions. In the following, we comment on each program, discussing both positive aspects and suggestions for improvement. Then we discuss the annual and long term performance measures. The conclusions give our overall assessment.

Atmospheric Radiation Measurements (ARM) Program

The ARM Program has been one of the most successful atmospheric science programs ever created. It has created an elaborate and geographically far-flung observational apparatus that is constantly updated and enhanced. It has organized a very talented and productive Science Team, supported by a well managed infrastructure group.

A major innovation of the ARM Program has been to collect data suitable for testing models not just for a few weeks in a "campaign" mode, but continuously over years. As a result, the ARM data archives document a large and extremely valuable record of diverse atmospheric phenomena that can be used to challenge and improve models. This is a new way of doing atmospheric science.

The ARM data collection sites include the U.S. Great Plains, the north slope of Alaska, the tropical Western Pacific, and the north shore of Australia. A mobile facility has been deployed on the west coast of North America and in Africa. Other agencies are imitating ARM's data collection strategies and even its instrument facilities.

ARM has worked hard to forge strong use of its data by the global atmospheric modeling groups around the U.S. and the world. To its credit, ARM recognized and explicitly acknowledged early on both the importance and the difficulty of this task. The effort has had some important successes, perhaps most notably in the very fruitful collaboration between ARM and the European Centre for Medium Range Weather Forecasts, one of the most renowned atmospheric modeling centers in the world. ARM continues to work hard to create strong working relationships with other modeling centers. The current ARM Chief Scientist has been particularly proactive in this area.

ARM should be encouraged to work more closely with the CCPP. In this way it can influence more strongly the development of new modeling techniques.

Atmospheric Science Program (ASP)

The ASP has the goal of developing a comprehensive understanding of the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter, especially in the context of climate change. Over the years it has evolved from a focus on acid rain to tropospheric ozone and now tropospheric aerosols. In response to BERAC recommendations, the program was reconfigured in 2004 to focus on aerosol radiative forcing of climate, which is one of the most uncertain aspects of the climate system.

The program seems well configured to accomplish the goal of quantifying the radiative forcing by aerosols: of 32 science projects, approximately one-third are laboratory-based, one-third have modeling components, and one-third include instrument development and application. Since its inception, two major field campaigns have been conducted, one joint with ARM in July 2005, and one multi-agency campaign in March 2006. A third campaign is planned for 2007 and will again be joint with ARM. Several of the modeling activities within the program help with logistical support for these campaigns. The committee appreciated the joint field programs with ARM (as well as with other agencies). This shows good use of funds and expertise towards understanding processes and fulfilling mutual goals.

The scientific highlights provided to the committee showed that the program is exploring some of the most important uncertainties in aerosol science. Secondary organic aerosol (SOA) formation is poorly understood. The MAX-MEX (Megacity Aerosol Experiment in Mexico City) field program focused on quantitative monitoring of anthropogenic SOA and will likely be a test bed for understanding SOA formation in the future. New mechanisms for SOA formation have been quantified and are adding new insights. The optical properties of carbonaceous aerosols are being explored, and aerosol properties, forcing, and interactions with clouds are being both measured and modeled.

To continue on a path towards successfully meeting the long term performance measure, we suggest that the program set the goal of integrating the results from the program into global climate models. While this might occur by any number of mechanisms, one such mechanism would be to determine historical forcing by aerosols for use in the next Intergovernmental Panel on Climate Change (IPCC) assessment.

Terrestrial Carbon Processes (TCP) Program

The key goals of the TCP Program are to understand the influence of terrestrial ecosystems and ecosystem processes on today's carbon cycle and on how ecosystems are anticipated to respond to future elevated atmospheric carbon dioxide levels. Photosynthetic processes currently reduce the rate of increase in atmospheric carbon dioxide by fixing approximately half of the fossil fuel combusted today. While year-to-year variations in climate and other factors can affect the interannual carbon sink strength, the locations of, and controls over ecosystem carbon cycle dynamics are not so clear. Thus, this program appears essential for providing a mechanistic and quantitative understanding of the terrestrial carbon cycle.

There is a strong, diverse, and balanced experimental-observation measurement and modeling program in TCP (FACE, AmeriFlux, soil carbon) that spans the dominant natural ecosystems of North America; their observations and models address important aspects of carbon-sink strength and will be critical for policy makers in making determinations of the safe levels of greenhouse gases. The TCP Program is a key program at the Department of Energy (DOE), providing the critical data and modeling related to terrestrial carbon sink and source issues. Its progress is excellent and is on track to help meet the 2015 long term objective. The time series observations in TCP (AmeriFlux and soil carbon) are providing new and important insights into the magnitudes of carbon, water, and energy balances of the dominant natural ecosystems and into the factors influencing the interannual variations in carbon-sink strength and carbon-stock accumulations. The recent incorporation of human-dominated landscapes (*e.g.*, disturbance driven) into AmeriFlux and TCP is applauded, as land-use change will continue to be one of the most dominant features influencing uncertainty in predicting greenhouse gas levels.

Several actions could further strengthen the TCP Program. Both AmeriFlux and soil carbon components of TCP could expand further into disturbance-driven and urbanizing landscapes in order to provide additional quantitative data to modelers and policy makers relative to meeting the overall 2015 long term objective. While the TCP Program has a justifiable and strong focus on understanding the current carbon cycle, understanding interactions between climate and the carbon cycle and synthesis modeling are perhaps underdeveloped. As the TCP program moves towards meeting its future fiscal year objectives and the 2015 program goal objectives, additional cross-site and synthesis efforts would enhance development of the final products.

The FACE component of the TCP will be reviewed shortly by a separate BERAC subcommittee and is not commented on further in this report.

Climate Change Prediction Program (CCPP) and SciDAC

One of the key questions for climate research is whether the DOE program is producing improved climate models and whether the DOE is supporting a diverse set of approaches to climate modeling. The answer is clearly "yes." Each successive generation of climate model is better than the previous model. We can expect the Annual Performance Results and Targets and LTMs, *'to deliver improved climate data and models for policy makers to determine safe levels of greenhouse gases in the Earth's atmosphere and to reduce differences between observed and model simulated temperatures at sub-continental scales, based on the use of several decades of recent data,'* will be met. As noted in some of our suggestions to other programs, we do have some concerns about whether the other parts of the DOE program such as the carbon, ARM, ASP, and ecology program are effectively providing data to improve the models supported by the CCPP. We know that is difficult for scientists in one program to interact closely with scientists in other programs. In our view, the climate modelers supported by the DOE can benefit from data and interactions with other parts of the DOE program. This will improve the models. We do not fault the program managers for any lack of fostering interactions because we know they have been searching for ways to promote interactions. The committee feels that efforts to promote interactions could be further sought through the use of additional incentives. We believe that new research announcements could be more explicit about the need for interactions with other parts of the overall climate change program.

We are very pleased to see that CCPP and the SciDAC supported programs complement each other and that both are aimed at climate model improvement and efficient use of the DOE supercomputing capabilities.

We do have concerns about the straightforward coupling of carbon cycle, ecological, and ice sheet components to present day climate models. These additional components are very sensitive to both temperature and precipitation biases that exist in present day climate models. We suggest that, for the next IPCC, we continue to improve the climate models without these components to see if the current biases can be substantially reduced. At the same time, we think testing these components in climate models should go forward while being mindful of the limitations.

Eventually, as there is more understanding of the causes of the biases and we obtain observed data that is critical for determining the fluxes between various components, over time we should be able to move from climate models to comprehensive Earth system models.

Program for Ecosystem Research (PER)

The PER is an extremely innovative program designed to understand climate change impacts on ecosystems beyond the FACE elevated carbon dioxide studies. PER research examines a broader range of issues than the Terrestrial Carbon Processes Program. The DOE commitment to understand climate change impacts on ecosystems is to be commended. Here the DOE shines as the lead Federal agency directing the effort to better understanding the impacts of climate changes on ecosystems and ecosystem processes. These research results will be of immense importance to policy makers, particularly as results are integrated through modeling. Ecosystems provide goods and services that may be altered under a changing environment. Because these goods and services are diverse (primary production, biodiversity, succession, clean water and hydrology, etc.), the program is looking at a very broad range of issues. Consequences of seasonality shifts on ecosystems and single species, altered thermal regimes on nutrient cycles and species distributions, and their impacts on a wide variety of ecosystem processes and species-level issues are extremely relevant high priority issues that provide additional quantitative data to modelers and policy makers relative to meeting the 2015 objectives. The links between PER with its national perspective and the National Institute for Climatic Change Research with its regional perspective are complementary and appear to be working well.

The PER has experiments across the country addressing climate change issues. One example is the focus in how coupled changes (such as changes in precipitation and CO_2 or changes in CO_2 and O_3) affect ecosystems. The program is also concerned with how species might migrate or adapt when climate conditions change. There are a number of important scientific findings that have been made within the program. However, it is not clear how and whether these results are being integrated into models. Moreover, the very broad nature of the program makes it difficult to know how to integrate many of the findings into models.

The diversity of topics funded by the PER is indeed broad. Yet the PER appears to be among the smallest of the DOE Programs in this review; it could really benefit from sizeable increases in budget. The diversity of PER projects is both a strength and a weakness. Until incremental increases in PER funding levels can be achieved, there may be an advantage to accomplishing PER objectives by reducing the diversity of research projects.

The committee recommends that the program focus more on one or two key issues in order to guarantee better progress towards the long term goal of improving models. Perhaps a more thorough review of the program, with the aim of developing this focus, would improve the capability of the program to contribute more effectively to the long term goal. In this context, the PER could benefit from more extensive research facilities to address system-scale climate change issues.

Integrated Assessment of Global Change Research Program (IAGCRP)

The BER IAGCRP of DOE addresses issues that are central to DOE's CCRP objective of generating policy relevant information for use by the Federal government to decide on directions of global environmental policy. Furthermore, it is of high quality and appears to have been reasonably effective in providing the kind of guidance most needed. Indeed, it is at the forefront internationally in establishing the connections between the results from DOE's Global Change modeling and the economic theory related to policy options. Its extensive progress in advancing a probabilistic formulation of the issues is especially commendable.

We suggest that the most crucial elements of this activity are the connections between the components that include human dimensions and economic theory and the components that include models of natural processes. Although there are good reasons for the IAGCRP to allocate some effort to modeling the physical and biological aspects of the system, such modeling is not likely to be supported at a level to make it competitive with the more advanced modeling supported in other parts of DOE's CCRP. It is essential, therefore, for the IAGCRP scientists involved to have adequate experience with the content of the physical and biological or ecological models. However, the physical modeling aspects of this program might be better considered a means to interface the results gained from all of DOE's climate change simulations with the human dimensions issues, rather than as a stand alone activity. While this cannot be formulated as simply as a big input-output linear matrix, many of the coupling considerations are linear or effectively so within the large uncertainties involved. Perhaps a focus on a 'human dimensions' coupler would help clarify the issues involved.

The IAGCRP will be reviewed shortly by a separate BERAC Subcommittee and is not commented on further in this report.

Annual and Long Term Performance Measures

The committee felt that the long term performance measure that sets a goal *'to deliver improved climate data and models for policy makers to determine safe levels of greenhouse gases in the Earth's atmosphere and to reduce differences between observed and model simulated temperatures at sub-continental scales, based on the use of several decades of recent data,'* is reasonable. However, the language used for this LTM needs to be clarified. Fully-coupled Earth System models have not yet been developed. Because of the inherent difficulties in developing coupled models, it is possible that when the components of the system are coupled initially, the prediction of precipitation and temperature may be significantly degraded until the individual components have sufficient fidelity to allow an accurate prediction of these components in the fully coupled system. Moreover, both this metric and the annual performance metrics do not adequately reflect the breadth of the BER climate change program. In some cases, the annual metrics seem far too specific while in other cases (*e.g.*, providing improvements on regional and large watershed scales) they are actually more stringent than the long term goal. One way to address the need to better reflect the breadth of the program is to write a more general long term goal. We recommend adopting the following long term goal:

'*to deliver improved scientific data and models about potential effects of increased atmospheric greenhouse gas levels on Earth's biosphere and climate for policy makers to determine safe levels of greenhouse gases in the atmosphere*'.

We would also encourage the DOE to then think about how each of the annual goals determines a road map to this final goal. Such analysis may well lead to a revision of the annual goals, which would make the connections between the annual goal and the long term goal more apparent. Interactions between the different research components of the overall CCRP need to begin early enough to ensure that the 2015 goal is met, and it is not clear that these interactions are adequately captured in current planning. It may be possible to write annual goals that encourage this cross fertilization.

We would also recommend changing the evaluation measures for success to continue to focus on improvements in temperatures and precipitation for Atmosphere-Ocean General Circulation Models (AOGCMs) while at the same time working to develop an accurate fully coupled Earth System model together with models for biosphere response. We suggest the following:

- Definition of "Excellent" **-** Global and sub-continental temperatures and precipitation are successfully modeled using AOGCMs to reduce discrepancies between predictions made with DOE-supported models and observed data (1975-2010) by at least half relative to the state of modeling that supported the 2001 IPCC assessment, and DOE-supported fully-coupled Earth System models have discrepancies that are no larger than the AOGCMs of the 2001 assessment. The fully-coupled Earth System models include models of biosphere response that predict the overall timing and magnitude of changes in the functioning and structure of selected terrestrial ecosystems subjected to experimental modifications of temperature and precipitation.

- Definition of "Good" **-** Global and sub-continental temperatures are successfully modeled using DOE-supported AOGCMs to reduce discrepancies between predictions made with models and observed data (1975-2010) by at least half relative to the state of modeling that supported the 2001 IPCC assessment and DOE-supported fully-coupled Earth System models have discrepancies that are reduced relative to the Earth System models available in 2011. The models of biosphere response are not fully-coupled to the Earth System models, but predict the overall timing and magnitude of changes in the functioning and structure of selected terrestrial ecosystems subjected to experimental modifications of temperature and precipitation.
- Definition of "Fair" - Global and sub-continental temperatures are successfully modeled using DOE-supported AOGCMs to reduce discrepancies between predictions made with models and observed data (1975-2010) by at least a quarter relative to the state of modeling that supported the 2001 IPCC assessment and discrepancies in DOE-supported fully coupled Earth System models are not improving. The models of selected biosphere response are developed, but not fully tested.
- Definition of "Poor" - Global and sub-continental temperatures are successfully modeled using DOE-supported AOGCMs to reduce discrepancies between predictions made with models and observed data (1975-2010) by at least a quarter relative to the state of modeling that supported the 2001 IPCC assessment and discrepancies in DOE-supported fully coupled Earth System models are not improving. The models of selected terrestrial ecosystem biosphere response are not yet developed.

Conclusions and Overall Assessment

The committee felt the materials, presentations, and interactions with the program management for BER were excellent. We also felt that the quality and quantity of research supported by BER is excellent. The supported research is both improving our understanding of the climate system and is unique within the Federal Climate Change Science Program.

As an overall assessment, based on our review of the programs and based on the science being pursued, we feel that the progress towards the long term goal is excellent. Nevertheless, we felt that the breadth of the program, which is needed to meet the goal, could be better represented by a revised wording of the long term goal. In addition, to assure continued progress, the programs need to continue to work towards better integration. We realize that in many science-based programs, there can be a disconnect between modeling and the use of information from observations. Nevertheless, the excellent data that is being collected by the DOE Programs needs to be incorporated and used by the global modelers to reach the goal set in the LTM. One possibility to ensure that this happens, which is mentioned above, is to make this integration part of the requests for proposals to ensure that the scientists within the different programs are focused on this need.

Appendix A -- BERAC Climate Change Research Subcommittee Members

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Appendix B -- BERAC Climate Change Research Subcommittee Meeting Agenda

Tuesday, August 29, 2006

8:30 – 9:00 Joyce Penner, Discussion of charge

9:00 – 9:30 Jerry Elwood, Overview

9:30 – 10:15 Kiran Alapaty/Wanda Ferrell - ARM science program & ARM Infrastructure (Mark Miller available to comment on ARM accomplishments)

10:15 – 10:30 BREAK

10:30 – 11:15 Ashley Williamson – Atmospheric Science Program (Steve Schwartz available to comment on ASP accomplishments)

11:15 – 12:00 Roger Dahlman – Terrestrial Carbon Cycle Program (Bev Law available to comment on TCP accomplishments)

12:00 – 1:00 Lunch

1:00 – 1:45 Anjuli Bamzai - Climate Modeling Program (Dave Bader available to comment on CCPP accomplishments)

1:45 – 2:30 Jeff Amthor – Ecosystem Research Program (Paul Hanson available to comment on PER accomplishments)

2:30 – 2:45 BREAK

2:45 – 3:30 John Houghton – Integrated Assessment Program (Jae Edmonds available to comment on IA accomplishments)

3:30 – 5:00 Committee discussion of the LTM and progress toward LTM

5:00 – 5:15 Wrap up, assignments

Wednesday, August 30

8:30 – 10:00 Further discussion of PART goal and performance, as needed

10:00 – 10:30 Committee brief of report

10:30 – 11:45 Writing assignments and time to write report

11:45 – 12:00 Final wrap-up