Minutes of the
Biological and Environmental Research Advisory Committee Meeting
May 19-20, 2008
Hilton Hotel, Gaithersburg, Md.

BERAC members present:

Michelle S. Broido, Chair
S. James Adelstein
Eugene W. Bierly
Janet Braam
Robert E. Dickinson
James R. Ehleringer
Joanna S. Fowler
Raymond F. Gesteland
Andrzej Joachimiak
David T. Kingsbury
Joyce E. Penner
Gregory Petsko
David A. Randall
Karin Remington
Margaret A. Riley
Gary Sayler
Gary Stacey
Warren M. Washington
Raymond E. Wildung
John C. Wooley (Monday only)

BERAC members absent:

Steven M. Larson
Margaret S. Leinen
Stephen R. Padgette
James M. Tiedje
Mavrik Zavarin

Monday, May 19, 2008

Chairwoman **Michelle Broido** called the meeting to order at 8:00 a.m. She had all the members introduce themselves.

Michael Hochella reported on the Environmental Remediation Sciences Division's (ERSD's) Committee of Visitors (COV). He thanked the ERSD staff for their help and cooperation. ERSD's Environmental Remediation Sciences Program (ERSP) supports research that provides scientific knowledge and the Environmental Molecular Sciences Laboratory (EMSL) is a scientific user facility that provides experimental and computational resources. One panel reviewed the ERSP and another reviewed EMSL.

Their findings were that:

- The acting director of the Division did an outstanding job.
- ERSD's "rotating leadership" is working remarkably well.
- A permanent division director should be put in place.
- The technical staff should be increased with one added technical staff position.
- Travel funds for program managers should be increased.
- All solicitations have been clear and appropriate.
- The proposal review process is exemplary.
- Hundreds of pre-applications are handled fairly and thoroughly.
- Proposals get three or four high-quality reviews.

- Proposal with outlier scores should get additional reviews.
- The quality and quantity of proposals continues to increase.
- Some lower-scored proposals were selected over higher-scored ones for programmatic reasons; these decisions were justified by the agency's mission.
- Exploratory research is supported in the portfolio.
- The proceedings of ERSD annual meetings should be better documented.
- Shortcomings in the review process are moderate.
- The present leadership and management of EMSL are very satisfactory.
- Week-to-week (teleconference) oversight with EMSL can now be reduced.
- ERSD managers should complete the transition of the management of EMSL as a Scientific Focus Area (SFA) at PNNL.

Their recommendations were that:

- ERSD operational oversight of EMSL should be reduced.
- The ERSD management chain for EMSL should be more clearly defined.
- More integrated computational-experimental projects at EMSL should be encouraged.
- EMSL capital equipment purchases should be driven by a documented, clear process.
- ERSD interactions with other BER divisions and with Basic Energy Sciences (BES) should be better documented.

The Scientific Focus Area (SFA) is a new paradigm for funding research at the DOE laboratories that is being adopted by the entire BER office. The COV believes the ERSD staff to be cognizant of the issues related to transitioning to an SFA approach, that they recognize the challenges, and that they intend to keep the program fresh while maintaining the highest science quality possible. A primary goal of the SFA paradigm should be to allow the national laboratories to fully express the capabilities that they have that universities and industry do not. Similarly, this new paradigm for ERSD should encourage work that is best and most efficiently performed at national laboratories to be done there. This COV supports expanding the SFA program to allow the development of new SFAs at national laboratories that don't currently have ERSD SFAs if they are competitive.

To achieve SFA goals, ERSD should develop management and review procedures with documentation and metrics that cover monitoring and reviewing performance and funding, modify funding profiles based on performance, external collaboration, programmatic diversity and openness, cross fertilization, and programmatic integration of SFA efforts with field sites.

Thomassen noted that the tenure of an acting Senior Executive Service (SES) position is 120 days under DOE regulations, which leads to the "rotating leadership" of ERSD.

A written comment from Zavarin was read, commending the COV, the ERSD staff, and the EMSL leadership and pointing out the importance of the research supported by the Division.

Bayer thanked the COV for its work. The Division intends to responds to and follow up on the recommendations.

Bierly asked for additional information on declinations of proposals. Hochella said that, in some cases, the reasons for declination are not clear. More should be said; not just that the quality was not competitive or that funds were limited. Specifically, information on improving the proposal should be included.

Petsko asked if SFA reflects a less bottom-up than top-down approach. Hochella replied that the COV did not see it that way. It is really management looking carefully at strengths and directions.

Wildung asked what BER could learn from the Office of Basic Energy Science's experience. Hochella answered that the ERSD staff should get out and talk with their counterparts across the Office of Science (SC) .

Sayler asked if there was a quantitative measure of how well EMSL is being used as a user facility. Hochella did not have a specific numbers. Bayer said that there are about 750 users and that they reported annually. About half are academics. Not many are from the national laboratories as might be expected because the national laboratories tend to keep their equipment up to date so that EMSL's aging equipment doesn't always offer an advantage. There are a few industry users. Broido noted that many outreach activities have been initiated since the 2005 review.

Bierly asked how ERSD was going to involve young researchers. Hochella replied that they are covered by a small-grants program.

Broido asked for a vote on accepting the COV report. It was accepted unanimously.

James Adelstein described the BERAC review of the Low-Dose-Radiation Research Program (LDRRP).

The purpose of this program is to obtain a more robust estimate of health risks following radiation exposures of <100mSv with cellular, molecular and systems biological approaches. Most human exposures are in this dose range, including medical, industrial, and environmental ones. Beginning in 1998, 243 projects have been funded. In FY 07 the Program funded 19 projects at national laboratories for $7.7 million and 43 at universities for $9.4 million.

BERAC was charged to look at the scientific accomplishments, quality, and technical innovation of the research; determine if the Program is taking advantage of advances in biological research; determine whether the growing body of knowledge from the Program justifies reconsidering risk estimates at low doses; and determine whether additional biological issues or technical hurdles remain before regulatory policy might be appropriately re-examined in light of new scientific data.

The review found that the Program has played major role in a sea change of direction in radiobiologic research with new emphasis on gene expression, adaptive responses, genomic instability, bystander effect, use of tissue and 3-D models, employment of mutated vs. wild-type cell lines, as well as genetically modified animals. It is now known that DNA damage from ionizing radiation differs from endogenous reactive oxygen species, gene expression differs between high- and low-dose exposure, a large number of genes is responsible for the variation in sensitivity, cells grown in 2-D versus 3-D cell cultures differ in their responses to low doses, and the extracellular matrix is important in a system's biologic responses to ionizing radiation.

A four-grade ranking system was applied to the projects. 75% of 55 recent and current projects were rated good or excellent. Fair-to-poor ratings were due to deficiencies in progress reports or a lack of peer-reviewed papers.

It would be useful if there were more explicit expectations and monitoring of progress during and at the end of funded projects, if time-lines and milestones were required, if there were a more specific format for annual and final progress reports, and if proposals were carefully examined for relevance to program goals.

Principal investigators (PIs) appear to be familiar with current technologies and approaches, but greater use could be made of gene silencing and transgenic and knock-out animals.

This mission-oriented program requires a roadmap that directs radiobiologic research to making risk estimates.

Phenomenologic biological observations should lead to mechanistic studies with which will come health effects in experimental animals, leading to risk estimates in humans that will allow regulatory adjustments.

BER should establish a high-level advisory committee to develop a roadmap for research with a list of priorities for future work. Calls for proposals would be based on those priorities, and monitoring of program progress would include milestones. BER should encourage groups with differing expertise to work on the same systems. The Program should cooperate with the EU/Euratom low-dose initiative.

Sayler asked how the Subcommittee had made estimates of impact. Adelstein said that the Subcommittee was limited by what it could find in the written record.

Broido called for a vote on accepting the report. The vote was unanimous to accept the report.

A break was called at 10:28 a.m. The meeting was called back into session at 11:01 a.m.

Himadri Pakrasi presented a science talk on cyanobacterial membrane systems, an EMSL grand-challenge project. He described *Cyanothece*, a unique cellular nitrogen-fixing cyanobacterium. EMSL offers unique tools for studying large-scale biology. The team included collaborators from a half-dozen institutions.

Cyanobacteria (blue-green algae) are oxygenic photosynthetic prokaryotes, the progenitors of chloroplasts, the most abundant fossils in the precambrian rocks found in the most diverse ecological niches in the modern world, and the only known bacteria with circadian clocks. They have been around for 2 billion years, consuming hydrogen from water and producing oxygen as a by-product, setting the stage for the evolution of eukaryotes and transforming the Earth.

The system being looked at is *Cyanothece* sp. ATCC51142. It is a unicellular nitrogen-fixing cyanobacterium and a significant contributor to the marine nitrogen cycle. Photosynthesis produces oxygen, but nitrogenase is oxygen sensitive. So *Cyanothece* has a robust diurnal rhythm: it photosynthesizes at daytime and fixes nitrogen at night.

In the open ocean, all cyanobacteria experience diurnal oscillations, but little is know about the impact of such oscillations on the efficiency of the overall CO_2 utilization process. This systems-microbiology project is aimed at gaining fundamental insights into this process, with the ultimate goal of engineering oxygenic photosynthetic microbes with enhanced clean-energy production abilities.

An experimental scheme was set up: 12 hours of light and 12 hours of dark with bi-hourly sampling. Different inclusion bodies were found to be responsible for photosynthesis and nitrogen fixation, and they arrange themselves differently in day and night. The different granules change size with diurnal change.

Cells were grown under controlled conditions that could be replicated at different sites. The cellular ultrastructure was studied, and lipid bodies, a thylakoid membrane, a plasma membrane, and carboxysomes were found.

The genome was sequenced. The total genome size was 5.46 Mb in the circular chromosome along with four plasmids of 10 to 40 kb and a 0.43-Mb linear chromosome. The genome sequence allowed placing *Cyanothece* ATCC 51142 in the phylogenetic tree and provided information about the physiology of the species. Transcriptions were run for the entire diurnal cycle at two-hour intervals, showing transcriptional regulation. An analysis of the transcription process allowed the development of a model of the diurnal rhythm in the central metabolic pathways. These organisms are unlike other organisms that have been studied in that *Cyanothece* is metabolically active during both day and night.

The specificity of combined high-resolution separations and accurate mass measurements provides a basis for high-throughput microbial proteomics. The total includes more than 38,000 unique peptides corresponding to more than 3400 proteins, resulting in a >64% coverage of the predicted *Cyanothece* proteome. This effort

constitutes a unique opportunity to use proteomic identifications to assist in guiding genome curation/annotation efforts and has allowed identification of 53 additional *Cyanothece* proteins that would otherwise have been excluded in the final curation. Verification of the translation of specific protein open reading frames (ORFs) helped guide overall processing efforts. Out of 1930 hypothetical proteins, 457 (24%) were reclassified because of their observation in the AMT [accurate mass and time tag] library.

Nitrogenase-related genes cycle in both transcript and protein abundances, going up at night and down during the day, although the protein abundances change by multistep methods. There are clear examples of specific protein cycling characteristics across timepoints of the diurnal cycle. Proteome analysis performed at 2-hour intervals show six key timepoints. So far, 16 protein structures have been determined, the first structures of the *Cyanothece* ATCC 51142 proteins have been solved, and the structures of three ATP-binding cassette (ABC) transporter solute-binding proteins that are crucial for cyanobacterial physiology have been solved.

The proteins CmpA and NrtA are the soluble, substrate-binding components of ABC transport systems for bicarbonate and nitrate in cyanobacteria. They have about 450 amino acids with no other homologous structure available: 45% identical and 57% similar in amino acid sequence to each other. The structures were analyzed, and a loop was identified that is responsible for functionality. Future research will disclose even more detail. DOE Joint Genome Institute (JGI) data were used to identify what the same and different parts are in the different strains of cyanobacteria. All the culture collections in the world were searched, and six strains of *Cyanothece* were picked out for comparison of their characteristics and genomes. The hope is that the sequencing of these six strains will provide more information. All of them are capable of fixing nitrogen. *Cyanothece* ATCC 51142 is the only one that is also capable of photosynthesis.

In summary, genomics provided the first linear element in a photosynthetic bacterium and insights into the evolution of nitrogen fixation in cyanobacteria. Transcriptomics revealed 1450 genes (27%) cycle with at least a 1.3-fold change. The majority of genes within a given pathway share the same expression profile. Global transcript abundance and ribosomal protein transcripts are highest at D5. Genes expressed in anticipation of upcoming metabolic processes. And proteomics showed that nitrogen-fixation-related genes cycle strongly.

How has the Grand Challenge moved the science during this 3-year project? In the past decade, known genes have increased from six to 5500, proteins from 6 to 3500, and metabolites from two to many for this species.

Petsko noted that, in yeast, only the most expressed proteins show correlation between transcription and translation. Pakrasi replied that the team does not have a good picture of that, yet.

Stacey asked if cell division were occurring at night. Pakrasi replied that they divide 4 hours into light and divide for 4 or 5 hours.

Sayler asked if there were any evidence of horizontal gene transfer. Pakrasi replied that two papers have been published that suggest that independent events occurred. Evidence has not yet been seen of gene transfer in cyanobacteria.

Kingsbury asked if the master switch had been identified. Pakrasi said that it was already known: genes and proteins in Kai.

Washington asked, what if the diurnal cycle is not 12 hours? Pakrasi replied that the team was looking into that possibility. They are looking at 24 hours of light and are conducting experiments under different cycles, such as 16 hours of light and 8 hours of night, looking, for example, at glycogen use.

Stodolsky asked if the new genes identified could be broken down by function. Pakrasi replied that, of those annotated on the basis of proteomics, there are several unclassified proteins. Many have expression profiles similar to those of other, known proteins. This will guide the team in assigning functions.

The meeting broke for lunch at 11:53 a.m. The meeting reconvened at 1:30 p.m.

Jeff Amthor gave an update on the Program for Ecosystem Research (PER), that conducts basic research on terrestrial ecosystems to integrate knowledge across different levels of organization so that effects at the whole-ecosystem scale are understood. The focus is on understanding the mechanisms underlying potential ecological effects of climate change so that prediction is possible. The approach emphasizes manipulative experiments because the future cannot be predicted from the past.

Research funding began in FY93. In FY08, there are 25 active projects with 31 awards and 4 multi-institutional collaborations. Awards range from $200,000 to $1,108,180. High-risk research having the potential to rapidly advance the field is encouraged. The program's field and laboratory experiments study the effects of four factors on processes and states in several ecosystem types.

Research is conducted on small and large model ecosystems, mathematical models, and natural ecosystems and looks at enzymes, organs, organisms, populations, communities, and ecosystems.

Eight federal agencies, including DOE, contribute to the U.S. Climate Change Science Program's (CCSP's) ecosystems research element. BER cooperates and jointly plans with the other agencies, and they use each other's facilities. The BER program is the main U.S. sponsor of long-term, multi-investigator manipulative field experiments capable of quantifying cause-and-effect relationships between climate change and ecosystem-scale processes. This research can greatly facilitate mechanistic predictions of effects of climate change on ecosystems.

The program's Throughfall Displacement Experiment (TDE) was the pioneering field manipulation of precipitation at the ecosystem scale. There were 13 years (1993–2006) of ±33% of ambient forest rain throughfall. Ecosystem models used to predict the effects of reduced precipitation on deciduous forests often indicate large reductions in tree growth and altered ecosystem functioning. The TDE tested these predictions. Increased throughfall enhanced seedling (and sapling) survival; reduced throughfall reduced seedling (and sapling) survival. This effect on seedling and saplings has implications for longer-term ecosystem development (i.e., successional changes). Large trees (10+ cm in diameter) were quite resilient to the treatments, but effects were apparent only after 10 years. Large-tree growth was affected by the treatments, but this was not apparent in the short term. It is now known that many ecosystem models are sensitive to precipitation change.

Trees can acclimate to multi-year warming. Aspen, birch, oak, and sweetgum trees were grown for four years in field chambers, in the soil. Temperature was ambient, +2 °C, and +4 °C. The leaf photosynthesis–temperature response curve acclimated to warming, and so did leaf-level respiration rate. This type of response has been reported before, but this was the first study to use multi-year controlled-temperature treatments for field-like conditions. Growth increased up to 29% with warming for the "warm-climate" species, but was not affected for the cool-climate species.

Ozone affects forest CO_2 fertilization. The program's elevated CO_2 and O_3 field experiment in Wisconsin is the world's largest study of ecological effects of changes in atmospheric composition. Starting in 1998, summer O_3 and CO_2 concentrations were increased ~50% above ambient levels (singly and in combination); these levels are thought to be relevant to the year ca. 2050. Multiple agencies use this facility. As expected, CO_2 stimulated tree growth and O_3 slowed tree growth. A critical and novel finding was that the effects were not additive. In early 2006, the program began planning for a project wrap-up based on a 2006 BERAC recommendation that this occur by 2010. A large-scale destructive harvest of trees and soil will allow a full assessment of effects of 10+ years of treatment on the experimental ecosystems. A plan is in place to end the CO_2 and O_3 treatments in 2009, and to complete the harvest and analysis of trees and soil by 2011.

Warming may threaten dryland ecosystems. More than 33% of the United States is dryland. Dryland plants are already living "on the edge" and might be especially sensitive to climate change. One warming experiment is in a Utah dryland [joint with the U.S. Geological Survey (USGS)]. In plots warmed only 2°C with infrared lamps, about 40% of the dominant grass species perished in 2 years. The western United States is expected to be ~2°C warmer by 2050 and perhaps 5°C warmer by 2100. Loss of vegetation could lead to increased soil erosion and would affect the health and success of animal species throughout the food chain. This study is expanding to include warming up to 5°C, with plots on two soil types. Precipitation is also being manipulated. So far, changes in rain-event frequency have affected the biological communities living in the biological soil crust.

The program is not attempting to simulate a specific future climate, location, and ecosystem. Rather, basic research is conducted to understand mechanistic relationships between climate and ecological processes. This process understanding is needed to predict ecological effects of climate change across a wide range of ecosystems and geographies. Research on just a few specific climate-ecosystem combinations might be of limited ability to build a robust ecological forecasting capability. The program must focus on climatic variables of first-order importance: warming; increasing CO_2 concentration; changes in precipitation (amount and temporal distribution); and combinations of warming, increased CO_2, and precipitation change.

Recent mortality of pinyon pine (40–95%); juniper (2–25%); and ponderosa pine, Douglas-fir, and white fir (10–60%) in the Southwest was blamed on drought. Changes in summer Normalized Difference Vegetation Index [NDVI] indicated a loss of pinyon pine after the 2002 drought. A U.S. Department of Agriculture Forest Service aerial survey of mortality in pinyon-juniper woodlands corroborated the NDVI analysis. The Program's new pinyon-juniper experiment in New Mexico replicated the TDE approach with pumps and sprinklers, producing treatments of ambient, +50%, and –50% precipitation on 40- × 40-m plots to determine whether xylem cavitation, carbon starvation, insect attack, or a combination is the cause of mortality.

Fire is an important ecological factor in southern California. Climate change could affect its extent, timing, and severity. However, a Program-sponsored experiment to investigate such climate-change effects was damaged in the Santiago Fire in 2007 and is being rebuilt.

Warming could move a species' geographic range, but local adaptation might present a problem. A new research priority in FY07 is addressing the question of whether temperature increases projected by coupled atmosphere-ocean general circulation models for the coming 100 years have the potential to affect the abundance and/or geographic distribution of plant or animal species in the United States. Five new experimental warming projects address this question:

- Field experiments in the boreal–temperature forest ecotome,
- Field experiments in the eastern temperate forest,
- A field experiment at the alpine tree line,
- A field experiment directed at important ant species in the eastern temperate forest, and
- Laboratory experiments with a model ectotherm.

The program focuses on manipulative experiments because expected future climate-ecosystem combinations are well outside the envelope of climate-ecosystem combinations of the past and a mechanistic understanding is needed for. A critical need is improved methods for field manipulations of climatic variables.

Program progress has been excellent. Since the publication of the 2001 NRC report claimed that "insufficient progress has been made in analyzing…ecosystem responses to climate change…". Since that claim,

- the 13-year TDE was completed
- the Wisconsin FACE [Free Air CO_2 Enrichment] study collected six more years of one-of-a-kind data
- the New Mexico precipitation study was designed and implemented
- seven unique warming experiments were designed and implemented
- novel biochemical studies in an ecosystem context were conducted
- field studies of potential ecosystem "state changes" caused by climate change were initiated.

The DOE PER is a unique and critical part of the DOE climate change research program. It is also a key component of the Ecosystems element of the 13-agency CCSP. It is addressing one of the key "so what" question about climate change. It is providing the research community with unique experimental "facilities" needed to understand ecological effects of changes in climate and atmospheric composition caused by energy production. And it is pushing the research community to use new approaches to answer emerging scientific questions about climate change.

Remington asked how much coordination there was with the National Science Foundation (NSF). Amthor replied that future NSF programs like the National Ecological Observatory Network (NEON) have not yet been implemented. At the grassroots level, there is a very good connection between the staffs; at higher levels, there is not so much connection.

Stacey asked what was going on in the ability of the forest to restore itself. Amthor responded that work is being done with seedlings and sapling, so a good amount is known about regeneration except for the germination process.

Ehleringer asked how the program establishes species priorities. Amthor answered that the program can focus only on the biome or other large scales; it leaves it up to the researchers proposing research to define keystone or generalizable species.

In response to a BERAC recommendation from a BERAC report (October 16, 2006) on elevated CO_2 experiments, BER supported a community-based workshop to explore science needs for the next generation of climate and change and elevated CO_2 experiments in terrestrial ecosystems. Oak Ridge National Laboratory (ORNL) hosted such a workshop. **Paul Hanson** reviewed the status of that workshop. The workshop addressed the question: What existing or new methods are needed for conducting long-term ecosystem-scale warming, precipitation, elevated CO_2 or multiple-factor manipulation experiments in the field? There were 58 attendees.

Breakout groups were asked to identify the key science questions, terrestrial ecosystems demanding priority attention, and the technological and measurement requirements for a specific ecosystem focus area, including:

- Terrestrial ecosystem feedbacks affecting climate and atmosphere
- Ecosystem Response: Long-term
- Ecosystem Response: Thresholds and Nonlinearities

- Managed Ecosystem Responses as a Special Case

The workshop conclusions regarding climate change impacts research are that the accelerated rates of climatic change demand experimental manipulations to evaluate ecosystem responses to unprecedented future climates. There is a clear need to resolve uncertainties in the quantitative understanding of climate change impacts on the physiological, biogeochemical, and community mechanisms necessary to project responses to climate change. A mechanistic understanding is needed along with a characterization of long-term ecosystem responses. A clear limitation for projecting future ecosystem structure and composition is the limited mechanistic basis for projecting geographic range shifts by species. The most important drivers of long-term responses are temperature, water availability, and the composition of future atmospheres. Threshold and nonlinear effects of these key drivers are especially important and should be accorded a high priority for research. Important secondary impacts from primary climate change drivers that are insufficiently studied are inundation of coastal terrestrial ecosystems, increased disturbance from fire, and increased biotic perturbations. Uncertainty in the magnitude and, in some cases, the direction of key feedbacks between Earth's climate system and terrestrial ecosystems is one of the critical weaknesses in current projections of climate change futures.

The workshop conclusions regarding climate feedback research are that major uncertainties must be resolved in how ecosystems with large areal extent and leverage on the carbon cycle (e.g., boreal forest, wet tropical forest) will respond to warming and to warming in combination with increasing CO_2 and changing water availability. On the other hand, new and continuing experimentation is needed in temperate systems that also constitute a significant global carbon sink to determine how that sink capacity will change with accelerated climate change. Future terrestrial climate change research on feedbacks must include a portfolio of multifactor and multilevel global change experiments. Long-term experiments are needed to address the time scales over which biogeochemical limitations or vegetation compositional changes take place. Initial responses may not be indicative of what will happen 5 or 10 years hence.

The workshop conclusions regarding model-experiment interactions are that they need to become a formalized component of climate change research activities. The interactions need to include pre-experiment planning and hypothesis generation, data organization and synthesis during experiments, and post-experiment interpretation of results and looking for alternative models. New experiments should include projections of logical outcomes based on the proposed hypotheses and anticipated interrelationships, and there must be a model framework that identifies critical processes to be informed by experimental data. The inclusion of mechanisms responsible for species changes (seed production, establishment success, early growth) within mechanistic biogeochemical models of ecosystem function is essential for the projection of the fate of ecosystems and their organisms under climatic and atmospheric change.

In the context of selecting priority ecosystems for studying impacts, the conclusion was that the next generation of research should not arbitrarily exclude any ecosystems

because all ecosystems are fundamentally important to local inhabitants and their livelihoods. Any selected ecosystem would have to have inherent sensitivity to warming, CO_2, and precipitation change; a large enough extent for global feedback concerns; an ability to serve as a generic model-ecosystems; and/or vulnerability to total loss. In terms of feedbacks, key ecosystems include those for which net carbon exchange remains highly uncertain and those with large potential contributions to the global carbon cycle and energy balance.

The workshop conclusions regarding technical needs recognize that ecosystem research requires an integrated approach to design and execution. Next-generation experiments must emphasize quantitative responses to climate and CO_2 at treatment levels that include and exceed conditions expected by the end of this century. Key strategies for the development of new experiments include

- Experimental systems and designs capable of attributing cause-and-effect mechanisms for known environmental drivers,
- Studies of multi-level exposures in order to judge nonlinear responses,
- Incorporating trophic levels and island effects into plot-level experiments (or design new experiments),
- Incorporating the essence of disturbance regimes into experimental designs,
- Improving or establishing new methods for conducting environmental manipulations of in situ or model ecosystems,
- Understanding and acknowledging potential implications of step changes in experimental designs, and
- Better use of and the development of statistical and modeling tools for the interpretation of experimental results.

The workshop recommended a follow-on activity to identify and prioritize quantitative physiological and ecological measurement methods necessary to support model evaluation, improvement, and application to climate change effects. Understudied or intractable processes include

- Measures of biogeochemical cycling components for limiting elements and carbon
- Carbon allocation processes responsible for tissue growth
- Plant mortality
- Seed production/dispersal and seedling establishment

Genomic tools were discussed, but not emphasized, for characterization of a wide range of physiological and developmental processes. The application of remote-sensing data from satellite or aircraft platforms was viewed as a primary measurement interface between experiments and models. Without improvements in quantitative measurement methods for next generation experiments, attempts to improve ecological forecasts will be inhibited.

Conclusions of this workshop are consistent with other community evaluations, and they reinforce the DOE Grand Challenges framework for ecosystem research, that identified experimental approaches as a required component of ecosystem research.

The first draft of the workshop report has been distributed for comment. The final report is to be delivered to DOE by June 16, 2008. A reduced-form journal article will be submitted by mid-summer.

Sayler asked what crops were being considered. Hanson replied that that was wide open for the workshop and included agronomic systems and biofuel crops.

Wildung noted that complex interactions will need to be dealt with and asked if statistical approaches, models, etc. were considered. Hanson answered that multifactor experiments will be dealt with. As one receives feedback, one needs to capture that process in the model.

Susan Gregurick reviewed the policies governing the sharing of GTL data and information. In general, the GTL policy is that information and data from public research investment should be publicly available. Data and information sharing is essential for this highly focussed program. New technologies mean increasingly larger amounts of research data. Ownership of data generated through GTL-sponsored research lies with researchers and institutions but needs to be shared across the program. BER's role is to provide guidance and mechanisms to facilitate and support data and information sharing within the GTL program.

The workflow of policy development includes identifying science driver(s) necessitating a formal policy; creating a working group to bring the policy to fruition; polling GTL researchers with respect to data-policy needs and developments; researching current policies and data-sharing opinions/practices from the literature; drafting a straw-man document and defining key aspects of the policy; subjecting that straw-man draft policy to internal and external consultation; posting the final draft onto a public website and publicizing it. Support for the policy must be put in place (e.g., data centers, physical archives, institutions, award programs, education, and outreach). Then a compliance and enforcement policy must be monitored, the policy must be extended to cover subareas of science/data, and the policy must be revised as required.

The GTL Data and Information Sharing Policy states that: "The Office of Biological and Environmental Research (OBER) will require that all publishable information resulting from GTL-funded research must conform to community recognized standard formats when they exist, be clearly attributable, and be deposited within a community-recognized public database(s) appropriate for the research conducted. Furthermore, all experimental data obtained as a result of GTL-funded research must be kept in an archive maintained by the Principal Investigator (PI) for the duration of the funded project. Any publications resulting from the use of shared experimental data must accurately acknowledge the original source or provider of the attributable data. The publication of information resulting from GTL-funded research must be consistent with the Intellectual Property provisions of the contract under which the publishable information was produced."

Effective October 1, 2008, all investigators are expected to submit their publication-related information to a national or international public repository, when one exists, according to the repository's established standards for content and timeliness but no later than 3 months after publication. For cases where information-sharing standards or databases do not yet exist, the information-sharing and data-archiving plan provided by a project's PI must state these limitations. Data and information that are necessary elements of protected intellectual property are explicitly exempt from public access until completion of the patenting process. Accepted databases and ontologies include Genbank/EMBL, UniProtkb/Swiss-Prot Protein Knowledge database, and Protein Database (PDB).

The Microarray and Gene Expression Data (MGED) Society standards describe the Minimum Information About a Microarray Experiment (MIAME) needed to enable the interpretation of the results of the experiment unambiguously. A number of journals require MIAME-compliant data as a condition for publication. GTL data should be deposited in a MIAME-compliant format.

The Proteomics Standards Initiative (PSI), a working group of the Human Proteome Organization (HUPO) defines minimum information about a proteomics experiment (MIAPE) and minimum information required for reporting a molecular interaction experiment (MIMIx). A number of databases now accept PSI Molecular Interaction standards. GTL proteomics data will be deposited in MIAPE- and MIMIx-compliant formats.

In cases where there are no public repositories or community-driven standard ontologies, data and information should be made publicly available by the PI.

Computational software will follow the recommendations of the International Society for Computational Biology (ISCB) for open-source software at a "Level 0" availability. OBER will follow ISCB recommendations at a Level 0 availability.

Research projects involving more than one senior investigator will be required to implement a Laboratory Information Management Systems (LIMS) or a similar type of system for data and information archiving and retrieval across the entire project. The LIMS plan should balance the clear value of data availability and sharing within the project against the cost and effort of archive construction and maintenance.

A GTL Knowledgebase Workshop will be held in Washington, DC, May 28-30, 2008, to identify research needs and opportunities for a Systems Biology Knowledgebase to capitalize on GTL research investments, to provide an assessment of where the science and technology now stands and where barriers to progress might exist, and to describe the directions for fundamental research.

Washington asked what can be done when someone does not agree to the requirements. Gregurick responded that there is no current policy for noncompliance, but that shortcoming will be addressed this year.

Adelstein asked if there was a statute of limitations before a disclosure must be made when there is a delay caused by, say, a patent application. Gregurick replied that there was no such statute of limitations at the present time but that topic needs to be addressed.

Bierly asked what happened when the research ends and there is no publication. Gregurick responded that that is why the next workshop is being conducted, so there will be a place for that data to go. Wooley commented that there is some question about how much data can be affordably stored; it would be good to have the adopted language posted to the web.

Joachimiak asked how far back the data would go. Gregurick replied that that topic will have to be addressed at the workshop.

Petsko noted that protein structure information deposition is sometimes ambiguous. The Hughes method is the best way to specify such deposition. Also, sometimes people put a hold on deposited information; that should not be allowed.

A break was declared at 3:04 p.m. The meeting was reconvened at 3:20 p.m.

John Wooley and **Christine Chalk** presented an update on the joint Advanced Scientific Computing Advisory Committee (ASCAC) – BERAC evaluation of the GTL program performance measure.

Raymond Orbach had asked that a unified assessment of the Program Assessment Rating Tool (PART) goals for the GTL program be developed. The bottom line is being able to use knowledge bases and modeling and simulation to provide a framework for understanding all biology. The Joint ASCAC-BERAC Subcommittee answered all the questions posed in the charge. The intensity of the PART-goal statement was lowered, which allows putting milestones on the process. As currently written, the BER PART goal had a very high risk for failure. The Subcommittee found it essential that there be an effective interface between the computational and experimental components of the ASCR and BER programs.

The Joint Subcommittee recommended that DOE should work with the community to identify novel scientific opportunities for connecting modeling and simulation at the pathway and organism level to modeling and simulation at other space and temporal scales. It should also establish a mechanism to support the long-term curation and integration of genomics and related datasets (annotations, metabolic reconstructions, expression data, whole genome screens, phenotype data, etc.) to support biological research in general and the needs of modeling and simulation in particular in areas of energy and the environment that are not well supported by NSF and NIH. And it should establish an annual conference that focuses on highlighting the progress in predictive modeling in biological systems. The overall recommendation is that the two offices should work together in modeling and simulation coupled to theory and experiment.

Chalk expressed some concerns that were raised about the report and its language by ASCAC members:

- There is a growing divergence between ASCR and BER goals for GTL.
- The definition of goals ran a high risk of nonattainment.
- Some clarifying language was offered for inclusion in the report.
- There is a lack of clarity about program responsibilities.
- Most important was the lack of prioritization for resource-constrained scenarios.
- There was a lack of intermediate goals that would provide true indicators of success or lack thereof.
- ASCAC believed there is a need for a follow-up study to bring the two communities together.
- There were no comments on the science to be pursued.

Broido noted that PART is a government-wide evaluation process. Each agency has to set goals and demonstrate how they meet those goals. GTL is a joint program, so the setting of goals is a joint effort, also. The goals set, however, were not identical. Wooley stated that the problem is one of language, and ASCAC is asking for a simpler, cleaner statement of the goals.

Kingsbury said that there is a fundamental question about the report. The BERAC-ASCAC subcommittee meeting was very interesting and resulted in a striking recognition that there are brilliant biologists who are also talented computer scientists. The field is advancing very rapidly. None of these biologists is supported by DOE, although some have proposals in to DOE. One has to be careful how one puts the context around these goals. The field will be more robust if DOE plays a role. A lot of the problem is purely language. There are two parts to the problem: (1) hardware and (2) software and its underlying algorithms. There are new approaches and tools. One needs to make sure that everyone understands these systems and how they work. He recommended that the Subcommittee take another cut at this report.

Broido noted that the modeling activities are going on with multiple funding sources. However, these measures are DOE PART measures and have to reflect the DOE's effort.

Stacey stated that some of the questions raised by ASCAC are reasonable and should be seriously considered by the Subcommittee. Often, many of these data sets and software tools are developed in a vacuum. They all have to be integrated onto a platform. That integration would be a co-product of this effort. Wooley responded that this opportunity is not lost on the Subcommittee. The Subcommittee process should be sustained.

Petsko said that it is too easy to move the target in close. It seems the Subcommittee is asking that the target be put at a fit distance.

Wildung asked who the audience of this report was. Broido said that the ultimate reviewer is the Office of Management and Budget (OMB). Thomassen added that the evidence needs to be self-evident for any readers. Broido said that the Subcommittee

seems to have more work to do and suggested that it quickly produce the next draft to be sent to BERAC so BERAC can comment on it and send those comments to the next ASCAC meeting in August. Assuming that a draft report is approved by ASCAC in August, BERAC can then consider a final version at its fall meeting. Wooley agreed.

Anna Palmisano, the new Associate Director for Biological and Environmental Research, reviewed the current state of BER.

Her priorities for BER are rebuilding the leadership team after a number of retirements; increasing the visibility of BER's successes; building even stronger programs through strategic planning and scientific peer review processes; encouraging linkages among programs; delivering on investments through post-award management; and empowering program managers to develop and sustain national programs that provide world leadership.

The BER budget has been increasing, and it is hoped that the FY09 request of $568.5 million will be funded.

The BER portfolio continues to span a remarkable breadth of scientific fields important to DOE's mission and the Nation. In Life Sciences, three Bioenergy Research Centers continue to accelerate research in biofuels. Genomics:GTL research is enhanced, underpinning biotech solutions for DOE energy/environmental needs. Low-dose-radiation research activities are enhanced. Genome sequencing at the Joint Genome Institute supports BER goals. Radiochemistry and imaging research is enhanced in the current fiscal year to develop new imaging technologies and new applications for radiotracers in biology and the environment. In Medical Applications, support is provided for fundamental research and instrument development in imaging for an artificial retina that enables blind patients to see large objects. In Environmental Remediation Research, funding provides support for the scientific basis for understanding DOE's legacy environmental contamination issues. The Environmental Molecular Sciences Laboratory (EMSL) is initiating a multiyear program for the acquisition of new/improved instrumentation. In Climate Change Research, increases support the U.S. Climate Change Science Program to develop, test, and improve climate models that simulate the responses of climate to increased atmospheric greenhouse gases and aerosols. The Atmospheric Radiation Measurement (ARM) program adds a second mobile system to obtain observations of clouds and aerosols in poorly understood regions. Climate modeling increases to exploit leadership class computing.

During the next 12 months, federal agencies will be transitioning to a new administration, a process that always brings a degree of excitement and uncertainty. BER is planning for a possible FY09 Continuing Resolution for 6 months at the FY08 level.

There have been a number of retirements in BER. The leadership team is being rebuilt, optimizing existing structures to enhance communication.

The Scientific Focus Areas (SFA) for the national laboratories represent a new management approach for SC that takes advantage of the laboratories' ability to build team-oriented, collaborative research programs in support of SC missions. BER is developing SFA best-management practices. National laboratory program plans are initially peer-reviewed for scientific merit and relevance. Over time the programs will be required to report annually on their progress and will undergo tri-annual on-site reviews with external reviewers. This process will likely look and work very differently across the range of SFAs at different national laboratories.

The Life and Medical Sciences Division will have a Committee of Visitors (COV) review next month. The Division is partnering with DOE's Office of Energy Efficiency and Renewable Energy (EERE) to maximize the impact of GTL and Bioenergy Research Center (BRC) science. A sustainability workshop will be held in the fall 2008 seeking responsible bioenergy solutions. There will be a JGI science and operations review in the fall of 2008. JGI has also begun a strategic planning to map out their future. Aggressive management of the Bioenergy Research Centers (BRCs) will maximize their success. The future of BER's radiochemistry and imaging research will be balanced to meet BER, DOE, and broader research community needs.

All three BRCs are currently up and running. Each BRC has FY08 funding at $25 million plus $10 million in FY07 for start-up. Hundreds of PhDs, postdocs, and graduate students are now at work on fundamental science to develop a strategy to produce sustainable biofuels. A DOE Technical and Management Review was held in November 2007, and a BRC Science Coordination Meeting was held in February 2008 in conjunction with the annual Genomics:GTL science meeting. A DOE onsite review of BRCs with outside panels is being planned for the end of the current fiscal year.

The BioEnergy Science Center (BESC), led by ORNL, is bio-prospecting in Yellowstone hot pools for new, more-effective cellulases operating at high temperatures and creating a high-throughput pipeline to screen thousands of genetic variants of switchgrass and poplar for amenability to deconstruction.

The Great Lakes Bioenergy Research Center (GLBRC), led by the University of Wisconsin, is exploiting 454 sequencing capabilities at JGI to identify transcription factors in model-plant cell wall biosynthesis and is playing a leading role in the research and public-education effort on biofuels and sustainability.

The Joint BioEnergy Institute (JBEI), led by Lawrence Berkeley National Laboratory (LBNL), is experimenting with ionic liquids as an alternative pretreatment method that shortens enzymatic hydrolysis times by factor of 30 and is re-engineering *E. coli* to create hydrocarbons.

Concerns about the impact of corn ethanol on food supply and prices and life-cycle greenhouse gas emissions make development of cellulosic biofuels from non-food feedstocks more urgent. Understanding and ensuring sustainability of biofuels is essential for successful, next-generation cellulosic biofuels and to winning public acceptance. The

possibility of moving beyond ethanol and producing hydrocarbon fuels from plant lignocellulose is also being studied. Fundamental research is the nation's best chance of overcoming current cost barriers and has benefits beyond biofuels.

An ongoing challenge and concern is the restructuring of the Radiochemistry and Imaging Instrumentation Research. The reconfiguration will reflect BER's energy and environmental mission focus, areas distinct from the National Institutes of Health (NIH) focus on developing disease diagnostics and medical therapeutics. The program will support fundamental research to advance DOE's mission in biology and environmental sciences and new methods for real-time, high-resolution imaging of dynamic biological processes in environmentally responsive contexts. Research will be broadly useful and transferable to other agencies and industry, including nuclear medicine research at the NIH. The goal is to produce multiple uses and multiple benefits from new scientific discoveries. BER remains committed to helping develop a new generation of radiochemists.

BER will organize a workshop in the fall of 2008 to bring together scientists from nuclear medicine, biological, and environmental sciences fields. The workshop will foster discussion on knowledge gaps and opportunities to advance radiochemistry and imaging sciences for the reconfigured program, and how to best meet our mission goals. Intra- and interagency coordination with the DOE Office of Nuclear Physics and with NIH in isotope production, radiochemistry research, and education continues.

In the Climate Change Research Division, Jerry Elwood retired after a long and distinguished career at DOE. Several Synthesis and Assessment Products (SAPs) were released, the ARM Mobile Facility was deployed in China, a Next Generation Ecosystem Experiments Workshop was held, a Grand Challenges in Climate Change Research Workshop was held, a Carbon Cycling and Carbon Sequestration Workshop was held, and a number of solicitations are in play.

In the Environmental Research Science Division (ERSD), a COV reviewed ERSD Programs, and there are a number of solicitations coming out. In the Environmental Remediation Sciences Program (ERSP), a 2007 solicitation resulted in 17 multi-institutional awards, the 2008 solicitation got 105 proposals, the national-laboratory SFA program plans were submitted and reviewed, and the Integrated Field Challenge (IFC) project annual reports were submitted and reviewed. At EMSL, the 2008 User Opportunities solicitation was released, the ~160-Tflop High Performance Computer System 3 is on track, and a field emission–chemical transmission electron microscope will advance the science significantly.

NOTE: Effective June 23, 2008, BER will be reorganized from three divisions into two – the Biological Systems Science Division and the Climate and Environmental Sciences Division.

BERAC will be a vital contributor to BER through strategic thinking, program reviews, COVs, science leadership, forward-looking advice, and increased visibility. In the near-term, BERAC will likely be invited to review the JGI Strategic Plan and the Climate Change Strategic Plan.

Adelstein cautioned that, in reconfiguring the radioisotope and imaging program, one should beware of a gap between BER and the NIH. Palmisano agreed that that is critical and that she was encouraged by the two discussions that have been held so far.

Wildung asked if there were any ideas on cross-cutting themes. Palmisano replied that a BER blog has been set up to discuss just that possibility for the multiscale, materials, etc.

Bierly said that he had been shocked by the lack of understanding of what DOE does when he joined the staff of the American Geophysical Union (AGU). DOE needs to sell itself to the public and let the public know what it does in climate change and in other programs. Riley added that increasing the travel budget for program managers would be a good starting place. Palmisano agreed that the program managers need to have the resources to do the job right.

Bierly noted that, in the past few years, other parts of DOE have taken funding away from SC. Palmisano replied that Orbach has been a great champion for science.

Broido opened the floor for a discussion by Committee members. She noted that the BERAC meeting schedule is not aligned with the schedules of other advisory committees, which are driven by the federal budget cycle. BERAC, therefore, is trying to edge closer to the schedules of other advisory committees. There were no additional comments and no public comments. The meeting was adjourned for the day at 4:39 p.m.

Tuesday, May 20, 2008

The meeting was called to order at 9:00 a.m.

Sayler clarified the fact that the Mouse Genetics Facility at ORNL is still in operation even though it is no longer an official BER Scientific User Facility.

Joseph Graber summarized the recent Workshop on Carbon Cycling and Biosequestration. The rationale for the workshop is that a major mission of BER research programs focuses on increasing our understanding of carbon cycling. Of particular interest are the linkage of global biogeochemical processes to genome-based ecophysiology of plant and microbial communities and the potential to enhance carbon biosequestration in ecosystems. The workshop sought to identify research needs and opportunities for understanding biological carbon cycling and biosequestration, provide an assessment of where the science and technology now stand and where barriers to progress might exist, and describe potential directions for fundamental research that can

be pursued to meet these goals. It was a joint effort of the Life and Medical Sciences and Climate Change Research divisions.

The workshop had working groups on terrestrial plant productivity and biosequestration; biological cycling of carbon in terrestrial and ocean environments; effects of climate change on carbon cycling and biosequestration; and crosscutting science, technology, and infrastructure.

Basic research need plans (BRNPs), short write-ups of key topics, issues, or questions, were prepared by participants and given to all participants in advance of the workshop. The working groups met in two separate sessions of the workshop about two weeks apart. Currently, the output from all the working groups is being organized and integrated.

Each working group considered a series of broad themes:

1. Basic processes and molecular controls underlying gross primary productivity (GPP), net primary productivity (NPP), and carbon partitioning in plants; mechanistic studies that could lead to enhanced carbon biosequestration strategies; the molecular basis of resource acquisition and utilization and interactions between carbon and other resources that are determinative of rate, magnitude, or sustainability of biosequestration; the need for dynamic models of genetic regulatory networks; and the role of genetic variation of plant populations and communities in determining NPP, carbon biosequestration, and ecosystem responses to global climate change.

2. Linking metabolic processes of soil microbial communities to the global carbon cycle; identifying critical characteristics of microbial communities relevant to understanding environmental controls on biogeochemical processes; determining how microbial community composition defines or constrains function in regard to soil carbon cycling, influences interaction with overlying plant communities, and responds to changing environmental variables; assessing whether soil microbial processes are correctly represented in terrestrial biogeochemical models; and improving predictions of how climate change will influence soil carbon storage.

3. Linking metabolic processes of marine microbial communities to the global carbon cycle; the roles of genomic/metagenomic studies in characterizing photosynthetic and metabolic systems involved in carbon assimilation; managing, using, and integrating the massive amounts of data generated into modeling efforts; integrating research on microbial community function with large-scale oceanic biogeochemical datasets; and factors affecting the biological carbon pump.

4. The potential effects of climate change variables on carbon cycling and storage in terrestrial ecosystems; linking carbon, nitrogen, and water cycles in determining ecosystem productivity and carbon sequestration potential; identifying

fundamental science questions for evaluating effects of changing land use and disturbance regimes on stability of carbon stocks; determining the best model structures to reflect carbon processes in ecosystems; and the importance of considering multiple cycles.

5. Linking genome-based information to function; incorporating experimental data into ecosystem/climate models; scaling issues; applying genome-enabled methods to understanding complex environmental systems; new approaches for in situ monitoring of biological activities; new imaging technologies for monitoring properties and processes; diagnostic, prognostic, and integrated modeling approaches; necessary analytical tools and cyberinfrastructure; and improved data-assimilation techniques.

The workshop report and its executive summary are currently being developed. The target date for the report is August 2008.

Stacey liked the integration of the communities but noted that one has to get each group to appreciate the work and interests of the other groups. Graber said that there will be a major statement about the importance of and need for different research communities to appreciated each other's research and interests in the workshop report.

Ehleringer pointed out that this was also an opportunity to enhance the education of graduate students and postdocs.

Wildung called attention to the lack of mention of long-term datasets; most of what was discussed at the workshop was labile carbon, not long-term refractory pools of carbon. Graber responded that that topic was, indeed, addressed and will appear in the report.

Sayler asked where the human-intervention solutions will come from. Graber pointed out that this workshop was intended to inform those solutions. Other agencies and other offices in DOE would be responsible for those solutions. Palmisano added that the Office's mission is to look at fundamental science. One needs to ensure that regulators make science-based, informed decisions.

Robert Dickinson was asked to review the Workshop on Identifying Grand Challenges in Climate Change Research, that was held in response to a BERAC charge from Raymond Orbach. The workshop had about 60 participants, included plenary and breakout sessions, and was organized by the topics of the charge letter. The initial content of the report has been agreed to by the writing committee.

DOE recognizes the use of fossil fuels as a major constraint on the nation's future development and use of energy. The IPCC (Intergovernmental Panel on Climate Change) 2007 reported that climate change was already highly visible and was expected to continue, and subsequent studies have shown some changes happening even faster than anticipated. The scientific community has asked for more detailed local information on

what has and will change for their planning horizons. The National Oceanic and Atmospheric Administration (NOAA) has planned on providing a "Climate Service" to meet this need, but little research has been done for that Service to build upon.

The Workshop identified three grand challenges:

- Improve the characterization of Earth's climate and its evolution through the last century to its present state.
- Predict regional climate change for the next several decades.
- Simulate Earth-system change over centuries.

The second challenge is not being done at all. Natural variability needs to be accounted for.

The draft workshop report implies that much of DOE's current climate science program is needed, but that it should shift its emphasis to fit the current need for useful climate information. Obtaining and disseminating such information is a huge task with a large practical component that needs to be informed by a research program to which DOE can be a major contributor.

Global climate is a high-dimensional, dynamic system. Individual observations are snapshots of components at particular times and places and do not recognize interconnectedness. Numerical Weather Prediction (NWP) provides a prototype of what is needed. Through statistical modeling, it combines multiple streams of observations with model predictions to optimally describe a system. Re-analyses go back in time using a single consistent model. It provides global-system research data sets and initial conditions for future projections, and its performance improves with improvement of the model process descriptions.

To predict regional climate change for the next several decades, much more climate detail can be provided by the use of the latest high-performance computational tools and by limiting the time frame to a decade and processes to those that are important on that time frame. Additional information would be needed if the initial state were to be adequately constrained by observations (the first challenge).

To simulate Earth-system change over centuries on century time scales, many feedbacks that affect the climate system need to be understood but are not yet adequately modeled (e.g., biogeochemical cycling, dynamic vegetation, and atmospheric chemistry). Each of the research areas needed to address the grand challenges has three components:

- Characterizing the Earth's present climate,
- Predicting climate over the next several decades, and
- Simulating Earth-system change over centuries.

To characterize the impacts of radiatively active constituents, one needs to emphasize the analysis and assimilation of observations into models to show how forcing will change regionally in the next several decades.

In interactions between ecosystems and climate, the appropriate state variables for Earth-system models, the contributions of natural and managed ecosystems to atmospheric composition, spatial data sets, the regional climate-change and air-quality-change impacts on and contributions of ecosystems, and changes and feedbacks on a century timescale need to be identified and established.

Another research area identified consists of the interactions between climate change and management of hydrologic systems, including the regional climate impacts of land-use/land-cover change, the impacts of climate change on water management, the elimination of persistent biases in simulated regional predictions, quantitative measures of the ability to predict changes in extreme precipitation probabilities, changed frequencies of floods and droughts, and the effect of temperature change on soil moisture and land cover.

In Earth-system modeling, the issues are how to plan and develop next generation models; how to improve model complexity and parameterizations through advances in process understanding; how to develop, improve, and validate initialization procedures; how to resolve cloud processes; how to provide regional details to integrated assessment models; and how to use the next generation of emission scenarios to project the Earth system on a century scale.

The human-dimension issues are

- What are the most-promising near-term strategies for reduction of carbon emission?
- How will climate change and mitigation efforts impact national economies over the next several decades?
- What sectors of society are vulnerable?
- What adaptation strategies should be put in place?

The DOE Climate Change Research Program should better inform modeling activities through its climate observational programs and connect integrated-assessment modeling to climate modeling. This effort will require the training/education of many more scientists.

The directions highlighted by the draft report are that grand challenges include the integration and communication of many kinds of scientific information into the overall assessment of how climate is changing, how the physical processes operate, and the options for mitigation and adaptation. New research, computational, observational, and experimental directions are needed along with enhanced computing capabilities and a large, multiyear field program. Several workshops are needed to develop more details.

Broido noted that the structure of the report is confusing. Dickinson said that there will be an executive summary that will focus on the grand challenges. Broido added that she had reviewed the charge letter, which does not explicitly call for identifying those parts of the grand challenges which should be addressed as part of the BER portfolio. Nevertheless, she felt that some level of statement addressing BER's role should be

integrated into the report. Dickinson noted that there were statements in the presentation that are not in the report. Broido asked for more DOE-specific recommendations, noting that that is beyond the charge letter but would be helpful.

Randall asked how DOE carves out a mission in the practical issues, such as data management. Dickenson replied that he did not believe that NOAA will be able to step up to the plate and do it, so DOE could do it. Broido pointed out that DOE has been criticized for its involvement in nuclear medicine when the NIH did not do it. This strategy has led to a lot of controversy. One wants to be careful about how DOE enters the mission areas of other agencies.

Penner asked how the grand challenges were selected; she did not see the connections in the report. It should be stated in compelling terms why DOE should be involved in the analysis of clouds. Dickinson said that the writing team is divided about how much detail should be presented in the report.

Bierly viewed this report as a planning document to restructure the climate-research programs of the government. ARM and the aerosol program are examples where DOE reconstructed its programs to include important research that others were not performing. OMB's support is needed to get on with climate-change issues. In the 1970s, there was a Global Atmospheric Research Program that worked. The agencies should get together and figure out how to address these issues.

Washington said that the challenge here is to link DOE's strengths with the general goals of this program. When the new administration comes in, this report will be helpful to identify the scientific problems and to articulate the existing strengths of the DOE climate program.

Petsko said that he was uncertain of a recommendation that calls for predicting climate change over centuries that cannot be validated or evaluated. There should be some discussion about validation in the report. Dickinson said that it is impossible to validate a prospective model. The only technique is to do a retrospective run. Petsko pointed out that, with a retrospective run, one knows the answer that one is to get. Dickenson replied that, if the climate does not change as much as expected, no harm is done. If it changes more than expected, it is too late. Reducing this uncertainty is important.

Broido said that she did not know how to deal with long-term prediction. In the report, the restraints should be highlighted. This report calls for more-detailed workshops. It might also call for multi-agency meetings and coordination. A graphic may help. There are some options for approving this report at a later date.

A break was declared at 10:40 a.m. The meeting was called back into session at 11:01 a.m.

Michael Kuperberg gave an overview of the Climate Change Research Division. The Division has four main foci: climate change forcing, climate change modeling, climate change response, and climate change mitigation.

In forcing, the Division operates ARM to conduct continuous field measurements and data products that promote the improvement of cloud science in climate models at three fixed facilities and one mobile facility. ARM has successfully completed the Indirect and Semi-Direct Aerosol Campaign (ISDAC) to study properties of arctic aerosols during April and compare with those measured during the Mixed-Phase Arctic Cloud Experiment in October 2004. The ARM Science Program is looking at the indirect effect of arctic aerosols in the infrared. It found increased anthropogenic aerosols during arctic spring in low-level stratiform clouds, leading to about a 4-W/m^2 increase in downwelling longwave radiation. The Community Climate System Model (CCSM) predicted double rainfall bands from a spurious second intertropical convergence zone (ITCZ), and the ARM cloud parameterization was improved to avoid this spurious additional precipitation band across the Pacific Ocean. The Atmospheric Science Program found dramatically higher levels of secondary aerosols in China than in Pittsburgh. The Terrestrial Carbon Program is trying to identify the roles of the terrestrial ecosystem, vegetation, and soil in climate change.

In modeling, the Program's goals are to bring software capabilities up to better use today's computer capabilities. It has conducted pioneering simulations of carbon, ozone, sulfur, ammonia, and the development of interactive aerosol effects for an Earth System Model.

In climate-change response, the goal is to understand mechanisms well enough to make predictions. Integrated-assessment research seeks to develop tools that policy makers can use.

In mitigation, the Program seeks to produce scientific and technological advances that will significantly impact the development of improved strategies for the enhancing carbon sequestration in terrestrial ecosystems.

In addition, the Program's science education effort operates the Summer Undergraduate Research Experience and the Graduate Research Environmental Fellowships.

Wildung asked if there was an overall strategic plan for the Division. Kuperberg replied, no. One is under development and awaiting guidance from the BERAC workshops. It is a high priority.

Sayler asked where in China the station would be located. Ferrell replied that it will be taking measurements at three locations at once. There is an ancillary facility out in the desert, measuring dust. In July, it will move to Beijing.

Ehleringer instituted a discussion on the vision of the Division. The penultimate graphic of Graber's presentation captured such a vision. However, no next-generation climate-change research was expressed. Such research would require vision, genetics, models, and engineering. For example, links between modelers and climate-change researchers are not evident. BERAC recommended such links and integration four years ago. He was anxious about the diffuseness of the PER program. The key areas are not obvious. The DOE missions should be addressed, and other activities need to be justified. Amthor pointed out that, at the prior BERAC meeting, a report pointed out that a team was set up to standardize soil sampling, and a workshop was held on this topic. Significant resources have been invested in soil genetics. More time is needed to straighten out where the systems are and where they are going. Ehleringer said that, in other areas, multiple communities are integrated; such connectivity in climate change and PER would be good. Amthor said that the communities were connected at the hip and will be focusing on common topics and on where changes will be happening most rapidly.

Paul Bayer provided an overview of the Environmental Remediation Sciences Division (ERSD). ERSD has two programs, the Environmental Remediation Sciences Program (ESRP) with funding of about $47 million and the Environmental Molecular Sciences Laboratory (EMSL) with funding of about $43 million. ESRP studies processes that control contaminant mobility and focusses on DOE-relevant metals and radionuclides. EMSL is a scientific user facility that provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation.

A COV reviewed ERSD in January 2008. They made comments and recommendations that need to be addressed but raised no major issues.

ERSP conducts research across scales from the field to the pore scale to the microscopic scale to the nanoscale. Its FY07 research solicitation garnered more than 117 proposals and was complicated by the FY08 budget delay. In all, 17 awards were made, most to multi investigator research teams. The success rate was about 15%. This year's solicitation has similar themes, is open to university leads only (because of the SFA process), encourages collaborations, requires that only the lead PI submit. It garnered 105 proposals. Reviews are in August, and awards will be made in FY09.

ERSP has SFA programs at seven national laboratories. ERSD requested program plans for each SFA by January 31, 2008. The plans were reviewed by six to eight external reviewers. The reviews and the ERSP staff responses were transmitted to each national laboratory. Responses to the reviewer comments are due by June 13, 2008, and revised Program Plans by July 10, 2008. The SFAs will be initiated October 1, 2008.

ERSP has three Integrated Field Challenges (IFCs) at the Oak Ridge Y-12 Plant in Tennessee, the Old Rifle, Colorado UMTRA [Uranium Mill Tailings Remedial Action] site, and the Hanford 300 Area in Richland, Washington. The IFCs are field-based, 5-year, multi-institutional, multi-investigator research projects funded at $3 million/year.

They are intended to enable testing of hypotheses at well-characterized field sites with different hydrogeologic settings, enable laboratory research with natural media, and provide a mechanism to enhance the transfer of research results to DOE Sites. The IFCs submitted annual progress reports in January 2008 that were reviewed by the Field Research Executive Committee. The reviews detailed progress toward stated research goals, likely impact of the science, and overall scientific assessment. All three projects are on track.

ERSP has produced 41 peer-reviewed publications since January 2008, among which was the *ES&T* most cited article for 2006. It has also received a Nano 50 Award.

EMSL has $36 million in operations funding, and $6.5 million capital equipment funding in FY08. Four EMSL science themes enable EMSL to focus staff expertise, align future equipment upgrades and purchases with the science theme directions, and align with SC programs:

- Atmospheric aerosol chemistry
- Biological interactions and dynamics
- Geochemistry/biogeochemistry and subsurface science
- Science of interfacial phenomena

BER works with Pacific Northwest National Laboratory management to oversee EMSL's scientific direction and with the Pacific Northwest Site Office to oversee EMSL's operational management. Capital Equipment Refresh is a multiyear initiative to upgrade EMSL's capabilities.

The Division has been working with EMSL to develop a 2008 Strategic Plan. Strategic planning includes key environmental molecular science challenges for the next decade and leading-edge capabilities (equipment) to enable users to meet the challenges. *The Goldbook* will capture science drivers and investment areas.

Major new EMSL capabilities include the Chinook, EMSL's third-generation high-performance computing system at 162 teraflops; a focused ion beam scanning electron microscope, a time-of-flight secondary-ion mass spectrometer, and a field emission–chemical transmission electron microscope. In the future, it will also have a Tesla Fourier transform ion cyclotron resonance mass spectrometer.

EMSL has produced 11 journal covers from 183 user publications, 57% of which were in top-10 journals.

Coming up for the Division are the review and funding of the FY09 proposals, working with national laboratories to implement the new SFA approach, project management oversight to ensure delivery and availability of the Chinook, oversight of the EMSL Equipment Refresh, and a science and operations review of EMSL in September 2008.

Wildung asked how the SFAs and IFCs interact. Bayer said that the IFCs came first and allow investigators to use the field site. The SFA process came after the announcement for the IFCs was issued. SFAs have some connection to the extant IFCs. It is not a strong connection yet in Oak Ridge, but it is strong at Hanford 300. Where there is not an IFC, SFAs are stand-alone projects.

Sayler asked how successful the RFPs have been in bringing in young investigators. Bayer said that he did not have those figures. The FY06 RFP funded six proposals specifically for new approaches. That number was doubled in the next year.

Wildung noted that the exploratory research program can be separate from a young-investigator program, and it might be helpful to have both such programs.

Broido pointed out that the NIH is now flagging proposals from new investigators for whom the requirements for preliminary results are relaxed.

David Thomassen reviewed the activities of the Life and Medical Sciences Division, which operates the Genomics:GTL program, Joint Genome Institute, Low-Dose Radiation Research, Structural Biology, radiopharmaceutical, imaging, and artificial retina programs. It is also responsible for the protection of Human Subjects in all DOE research and at all DOE facilities. The Division is having a COV on June 8-11, 2008. There will also be a scientific and operational review of the JGI later this year.

The Division has solicitations out on low-dose fundamental mechanisms (with the National Aeronautics and Space Administration), low-dose integrated program projects, plant-feedstock genomics (with the U.S. Department of Agriculture), radiochemistry and imaging instrumentation, and genomics for biohydrogen.

The Bioenergy Research Centers are multi-institutional partnerships that are organized as institutes, research centers, or science centers:

- The BioEnergy Science Center at ORNL has a strong central strategic focus on overcoming "recalcitrance," a longer-term goal of consolidated bioprocessing, and a capability for working directly on energy crops.
- The Joint BioEnergy Institute has a strong basic science-oriented approach, a focus on model crops of *Arabidopsis* and rice (and on switchgrass), and is especially creative on the microbial side in its use of synthetic biology.
- The Great Lakes Bioenergy Research Center addresses agronomic issues, focusing on a wide range of plants, and includes a major "thrust area" on sustainability of biofuels production.

ASCR and BER are engaged in joint efforts to accelerate progress toward GTL goals. In the past, new molecular dynamics codes were written for very large biological systems, network analysis was conducted for hydrogen metabolism, and computer programs like BACTER were aimed at bridging the computational/experimental microbiology gap. Currently, proposals are being solicited for joint activities to interface computational and mathematical efforts with biological mission-relevant research

directions. At the end of May, the two Offices will conduct a GTL Systems Biology Knowledgebase Workshop.

Foundational GTL research is addressing deficiencies in genomic annotation through more robust annotation, confirmation of annotation, and innovative experimental approaches. It also seeks to understand lignocellulose degradation with a focus on understanding degradation through imaging.

At the JGI, several sequencing successes have recently been made.

In radiation protection, radiation epidemiology information is translated to national standards, and low-dose radiation biology contributes fundamental science to understand these processes. A workshop is planned to discuss future epidemiology needs. The widely distributed dose-range charts have now been translated into Spanish, Russian, Georgian, Chinese, and Latvian.

The Structural Biology Program is small but of high impact. Some of its investments are made jointly with the NIH. The National Synchrotron Light Source (NSLS) protein crystallography program was reviewed jointly with NIH in March 2008. The Los Alamos Neutron Science Center (LANSCE) protein crystallography station program was renewed in 2005. Some pending issues in the program are:

- How will life-sciences access be developed and what new techniques will be enabled by the facility when the National Synchrotron Light Source is replaced?
- How important are neutron techniques, and how much should BER invest in user stations for them?
- What is the potential impact on life sciences in general and on BER research programs of other new national user facilities [such as the Linac Coherent Light Source (LCLS)] and major facility upgrades?

The Radiochemistry and Imaging Program got $6.05 million in FY07 to support radiotracer and advanced imaging instrumentation for medical research and technology development. In the FY08 Omnibus Bill, Congress provided an additional $17.5 million for nuclear-medicine research.

The Artificial Retina Project will end in FY 2010. It has developed a 16-microelectrode device that has been implanted in six blind patients with no device failures to date. The implant is still operating after more than 6 years of daily use. The next generation is a 60-microelectrode device with radio frequency power and data transmission in a smaller implant. It will undergo worldwide testing. Ten patients have been implanted in the United States.

BER has responsibility for the protection of human research subjects in all DOE-funded research and at all DOE laboratories. It has a new program manager; has conducted site visits at LBNL, Lawrence Livermore National Laboratory (LLNL), and Fermilab; coordinates with the National Nuclear Security Administration (NNSA); provides resources to investigators and laboratories; coordinates with Health and Human

Services Office for Human Research Protections; and has/is supported lab accreditations at PNNL and Brookhaven National Laboratory (BNL).

Broido noted that, at the time of the new neutron facilities review in 2005, the LANSCE crystallography facility was being built and there was a question as to whether or not the completed facility would be used at a level sufficient to warrant its construction. Hirsch said that the facility is fully subscribed, and a full complement of users has been in existence since 2005.

Joachimiak asked how the GTL and bioenergy centers are connected. Thomassen replied that the bioenergy centers will cut across many disciplines but lack some capabilities that the GTL can provide.

Broido open the floor to the Committee for new business. There were no additional comments and was no public comment. The meeting was adjourned at 12:23 p.m.

Respectfully submitted,
Frederick O'Hara Jr.
Recording Secretary
June 9, 2008