Biological and Environmental Research Advisory Committee
Gaithersburg Marriott Washingtonian Center
Gaithersburg, Md.
June 27-28, 2013

BERAC Members Present

Gary Stacey, Chair
Dennis Baldocchi
Janet Braam
Susan Hubbard
Andrzej Joachimiak
David Randall
Karin Remington
William Schlesinger
Martha Schlicher
Gus Shaver
Herman Shugart
David Stahl
Judy Wall
Warren Washington
Minghua Zhang

BERAC Members Absent

Judith Curry
James Ehleringer
L. Ruby Leung
Gerald Mace
Sabeeha Merchant
Joyce Penner
James Randerson
G. Philip Robertson
Jacqueline Shanks
Huimin Zhao

About 65 others were in attendance during the course of the two-day meeting.

Thursday, June 27, 2013
Morning Session

The meeting was called to order by the Chair, **Gary Stacey**, at 9:00 a.m. He had the Committee members introduce themselves and review their own scientific interests and research. He stated that the discussion on the following morning would consider ideas that the group thinks are important for the Committee to consider on research direction, program reviews, and other issues so the Committee can provide guidance to the Office of Biological and Environmental Research (BER) during these tight budget times.

Sharlene Weatherwax, Associate Director of Science for Biological and Environmental Research (BER), was introduced to review the activities of BER.

The budget request has been rolled out since the previous meeting. The House and Senate marks are very different in funding levels and focus. The enacted appropriation for BER for FY12 was $610 million. Because no budget was passed for FY13, the Office is now operating under a budget produced by a continuing resolution and sequestration totaling $613 million. The President's request for FY14 for BER is $625 million. During the development of the President's request, the Office of Management and Budget (OMB) provides each department with a target number to base a budget on; the request then goes to Congress.

The FY14 budget priorities of SC are clean energy, full funding for the hubs, funding for the Bioenergy Research Centers, operation of facilities at optimal levels (computing centers and light sources), engagement of the research community with facilities, and construction. SC's mission is broad, and the mechanisms that BER uses are broad, so the Office needs to build bridges and partnerships with other program offices (e.g., Basic Energy Sciences and Advanced Scientific Computing Research). The different offices can learn from each other through useful point-counterpoint. BER has no large construction projects or major items of equipment. Overall, the budget provides a balance among research, facility operations, and construction.

The Department has a new Secretary of Energy, Ernest Monize. He has a deep appreciation of basic research and has been talking with researchers across the country about research directions and needs. William Brinkman has stepped down; Patricia Dehmer is the Acting Director of the Office of Science.

The mission statement of BER is to understand complex biological, climatic, and environmental systems across vast spatial and temporal scales. In the FY14 budget request, the three DOE Bioenergy Research Centers are fully funded. Core research in biological systems science supports new opportunities to (1) develop biosystems design tools for plant and microbial systems and (2) scale processes from the molecular to subcellular levels. Some tough choices had to be made. Radiological Sciences decreases. Atmospheric and Terrestrial Ecosystem Research's focus on the Arctic and the tropics is a big priority, all tied in to observations and climate modeling during a minimum term of 10 years. Scientific user facilities are funded at optimal operations.

In FY14, BER will build on existing test beds and genetic toolkits, soliciting for new platform organisms, capabilities, and demonstrations of bioengineering techniques. Mesoscale to Molecules is a new area; one needs to investigate at all levels of biological activity from atoms to organisms. One needs to learn about mesoscale biological units.

Funding is also being sought for the Next-Generation Ecosystem Experiments (NGEE), coupling terrestrial field experiments and modeling to improve the representation of terrestrial processes in Earth-system models. In climatologically sensitive areas, plans for infrastructure are needed. Arctic-permafrost research is ongoing, and tropics activities will be initiated. A workshop has been held on tropical and terrestrial/atmospheric processes.

In personnel, Kent Peters was welcomed as the new Bioenergy Research Center (BRC) program manager, and Susan Gregurick, the former KBase program manager, has moved to the National Institutes of Health (NIH). Several personnel actions are pending. The flexibility of the staff is appreciated.

Significant awards have been made to BER researchers: Janet Braam (BERAC) won the 2012 Cozzarelli Prize in Applied Biological, Agricultural, and Environmental Sciences; Gary Stacy (BERAC) received the 2013 Mumford Outstanding Faculty Award; Phil Rasch won the Community Earth-System Model Distinguished Achievement Award; and Jay Keasling won the Biotechnology Industry Organization 2013 George Washington Carver Award and the 2013 Promega Biotechnology Research Award from the American Society for Microbiology.

BER wants to encourage the next generation of researchers to get to this level of professional achievement. The Early Career Awards (ECAs) are made SC-wide with each office making some awards. In 2013, BER made awards in systems biology and biosystems design, environmental systems science, and uncertainty characterization for integrated Earth-system modeling. The hope is that Early Career Awards will continue to contribute to BER growth areas. In BER, it was found that the years-from-doctorate to receipt of an ECA are broadly distributed among awardees from 2 to 10 years. The call for applications will be coming out in July. The first two years, BER's call was for general topics; now specific topics are used to cultivate leadership in areas of science of particular interest to BER and in need of Early Career scientists. This past year, BER had seven awardees, three from national laboratories and four from universities.

Questions and Comments: Remington appreciated how much extra effort is required when operating under these budget constraints.

Stacey asked if there were any feedback on the facilities report that was requested by SC Director William Brinkman. Weatherwax replied that all offices in SC met the March deadline. Brinkman organized the material so that the next director will be able to act on it. The OMB requirement for facility planning and input has therefore been met. The BER OMB examiner is also stepping down. The information will be used in future planning (e.g., for the FY15 budget).

Schlesinger asked how competitive the ECA application process was in BER. **David Thomassen** of the Office of Biological and Environmental Research replied that the success rate was less than 10%. The number of awards made is based on budget levels within BER. These are 5-year awards.

Zhang noted that there was a 10% reduction in workforce development in the FY14 budget request. Weatherwax explained that all workforce-development activities were combined and DOE was given strict guidelines by OMB on what can be done outside the National Science Foundation (NSF) in training and education.

Stacey noted that the NSF, the Smithsonian Institution, and the Department of Education are also reorganizing science, technology, engineering, and mathematics (STEM) education. He asked what effect this will have on DOE and BER. Weatherwax replied that internships have been absorbed into the "Pathways" program. **Julie Carruthers** of SC's Office of the Deputy Director for Science Programs noted that the budget terminates 75 programs across the federal government: NSF, the Department of Education, and the Smithsonian have been given lead responsibilities in various areas. SC's Graduate Research Fellowship Program has been zeroed out, although funding has been continuing for that program under the continuing resolution. There will be a Graduate Research Program for thesis research opportunities at national laboratories. This will be rolled out in the fall.

Stacey said that, under the continuing resolution, the budget for BER is under the control of the House leadership. He asked what the House markup has been. Weatherwax replied that the House and Senate subcommittees marked up the President's request. Funding levels and guidances have to be reconciled between the House and Senate versions. There has not been a conference between the House and Senate committees for several budget cycles. The House has its own priorities, and the Senate has its own. The marks have been quite different in funding and flavor. If there is not a conference between the House and Senate, there will be another continuing resolution with a lot of odd, unintended consequences. The varying terms of continuing resolutions make planning difficult. For BER, the House and Senate marks were very different last year. As a result, managers have to plan at the lower markup level. This year's House mark for BER is very low at $494 million (compared to the request of $625 million).

Remington commented that going into a budget year without knowing what one has is extremely difficult. It is a strange way to run a business. Weatherwax said that there are very large error bars in planned budgets. The Office is trying to protect the workforce and facilities with its budget goals. At some point, it will have to cut things off and innovate. Remington added that it is not so much that the budget is *constrained*, it is that one does not know *what the constraints will be*.

Schlicher noted that $494 million is a bigger reduction if it does not come at the beginning of the year. She asked if the Office needed to rank priorities. Weatherwax replied that the Office has to figure out what is possible in the long run. It would like BERAC to give it the scientific ammunition to bolster its budget requests. The community needs to think about the science part of the endeavor.

A break was declared at 10:34 a.m. The meeting was called back into session at 10:59 a.m.

Gary Geernaert was asked to review the activities of BER's Climate and Environmental Sciences Division (CESD).

A data-informatics agenda is being developed for the Division to help execute plans. For FY13, a funding opportunity announcement (FOA) was issued for the Terrestrial Ecosystem (TES) program; 121 proposals were submitted, and 16 were selected. For FY14, three FOAs have been issued, one for the Atmospheric Systems Research (ASR) program, one for TES [via the National Aeronautic and Space Administration's Research Opportunities in Space and Earth Sciences (ROSES) program], and one for the Green Ocean Amazon (GOAmazon) field campaign. For the ASR FOA, 111 proposals have been received and will be reviewed in late July. For the other two FOAs, proposals are still being received. The GOAmazon FOA was released simultaneously with FOAs from two Brazilian agencies; it is a joint project with Brazilian investigators that can rapidly advance the Atmospheric Radiation Measurement (ARM) program's contribution to modeling.

Scientific Focus Area (SFA) reviews have recently been held for SFAs at Lawrence Berkeley National Laboratory (LBNL) on Subsurface Biogeochemical Research and on Regional and Global Climate Modeling and at Argonne National Laboratory (ANL) on Terrestrial Ecosystem Science. The outcomes are very positive. These SFA reviews are used for considering renewal of funding.

Principal-investigator (PI) meetings were held this past spring for the ASR Science Team and the joint TES and Subsurface Biogeochemical Research programs. The modeling PI meeting was been postponed until fall or winter 2013. Workshops were held on (1) the new DOE Earth-system model to see how to rapidly advance modeling with BER data, (2) North American Carbon Project (NACP), (4) climate–finance (which focused on the effects on infrastructure of century-long events like sea-level rise) and (5) an Environmental Molecular Science Laboratory (EMSL) workshop on aerosol chemistry. An EMSL Science Roadmap Workshop in response to BER needs is upcoming to consider science directions. The Office is preparing for a BERAC committee of visitors meeting on July 8–10, 2013.

In FY12, the Office released its strategic plan to advance a robust predictive understanding of Earth's climate. Its goals are

- Process knowledge and innovative computational methods advancing next-generation, integrated models of the human-Earth system
- Process-level understanding of atmospheric systems and terrestrial ecosystems, extending from bedrock to the top of the vegetative canopy
- Coupled biogeochemical processes in complex subsurface environments to enable systems-level environmental prediction and decision support

- To enhance the unique capabilities and impacts of the ARM (Atmospheric Radiation Measurment) and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science
- To address science gaps that lead to solutions for DOE's most pressing energy and environmental challenges

The plan attempts to integrate community models, observational infrastructure, and community data infrastructure.

The BER Earth-system model is a spin-off of the Community Earth System Model (CESM). All CESD programs will be able to plug into it, and it is a partnership with DOE's Office of Advanced Scientific Computing Research (ASCR). Governance is led by the national laboratories. It will support scientific research and provide data useful to DOE and other federal stakeholders. The CESD strategy focuses on predictability, requiring integration of climate, environment, computation, and uncertainty-quantification research, and is moving much faster with the ASCR partnership. DOE's investments require a modeling platform and a governance structure that are compatible with DOE needs. Major international competition (specifically from Germany and Britain) has integrated science and computation, and CESM may lose its "research edge" if aggressive action is not taken to advance computational efficiencies and to forge partnerships with other agencies. A new planning cycle is being begun for the next rounds of the Intergovernmental Panel on Climate Change (IPCC) and Sixth Coupled Model Intercomparison Project (CMIP6). Ensemble runs will be able to be made that would otherwise not be possible. The science framework and objectives of the model cover specific areas of interest to DOE. The programmatic home will draw on BER-wide input; a proposal and roadmap will be drafted before FY14 and reviewed. All data needed to validate the modeling will be unified to address BER's big research needs and those of other agencies, and microbial-community inventories will have leveraging opportunities.

New sites of the ARM Climate Research Facility are rapidly progressing. The first set of instruments has been delivered to Oliktok Point, Alaska, the third mobile facility, and to the Azores site. Instruments will be operational at both sites in September. The cloud radars will be delivered in October.

EMSL is facing budgetary constraints, as is all of BER. EMSL has held planning workshops on atmospheric aerosol chemistry, belowground carbon cycling, and molecules for biofuels and renewable chemicals. Its FY13 science-theme call elicited 192 proposals. Its success rate in FY12 was 25%; a similar rate is expected in FY13. A joint call from EMSL and the Joint Genome Institute (JGI) in FY13 to make crosstalk vigorous is very exciting; 27 full proposals have been submitted and are undergoing peer review.

Division science highlights include:

- An investigation of how phytoplankton communities respond to climate change found that phytoplankton that are efficient in vertically transporting carbon are less efficient at higher ocean temperatures.
- A 22-year investigation at the Harvard Forest on the effects of climate change on soil organic matter decay and the release of soil carbon found shifts in the microbial respiration rate, suggesting interactions across microbial communities in warmer plots that increase taxa or pathways adapted to recalcitrant carbon decomposition, leading to a depletion of the recalcitrant soil carbon stocks and an unforeseen, self-reinforcing feedback to the climate system.

- An investigation of small-scale processes in the atmosphere showed that organic aerosol forms are enhanced when biological and anthropogenic emissions are mixed in the atmosphere. It determined that NO_x concentrations play a role in enhancing soil organic amendment (SOA) formation in these conditions and that these mechanisms need to be represented in climate models. In a major follow-up experiment in Brazil in FY14, it is hoped to be able to see comparative effects of polluted and pristine atmospheres on cloud condensation nuclei (CCN).
- A new model for uranium bioremediation was developed to understand uranium, iron, and sulfur redox transition pathways in aquifers at molecular-to-pore scales. It showed that a newly discovered biotic-abiotic reaction pathway helps explain uranium behavior under widely varying conditions in biostimulated aquifers and ore deposits.
- A study looking at the relationship among bacteria, fungi, and leaf-cutter ants in lignocellulose degradation revealed that fungus appears to be the primary driver of leaf degradation. These results provide insight toward the development of large-scale plant-biomass-conversion processes.
- The question was posed whether a future grand solar minimum like the Maunder Minimum could stop global warming. A study showed that, if solar irradiance were reduced by 0.25% for 50 years, it would not produce a Little Ice Age; it could slow down, but not stop, global warming.
- The climate impacts of large-scale expansion of biofuel production constitute a basic topic for DOE. A Massachusetts Institute of Technology (MIT) study investigated how land-use policies and economic factors influence (1) where and how biofuel crops are planted, (2) the ramifications for land-use change and greenhouse-gas emissions, and (3) how these changes in land-use change influence climate. It found that there was little to no impact on global climate change, but there could be dramatic regional change. With patchwork bioenergy production, regional warming was decreased.

Questions and Comments: Randall asked if the new model was a community model. Geernaert replied that it depends on how one defines "community." It is an analysis platform that is community based. It is national-laboratory led and serves the U.S. Government scientific community with software development managed by the national laboratories. A governance structure is in place that has national-laboratory upper management and University Corporation for Atmospheric Research (UCAR) leadership.

Stahl asked if there was an explicit effort to link different modeling scales. Geernaert replied that, in the ocean portion, not as much; in the terrestrial portion, the effort is in that direction.

Shugart noted that the total system model will be difficult to test. The Maunder Minimum study and surface-climate effects are glimmers in that direction. He asked how this problem of testing was viewed. Geernaert said that one has to start somewhere, so one starts with a rudimentary model and builds upon it. Climate models rapidly advance with finer resolution. It is anticipated that this model will run 5- to 10-km-resolution ensembles and specific models down to 1-km resolution. The scientific analysis of what is going on in the subgrids has to be increased.

Baldocchi asked to what degree BER was developing gridded databases at different scale layers. Geernaert replied that the recommendations of the BERAC report are right on. One has to develop a data infrastructure as recommended by that report.

Zhang said that, in regard to the new model, one must articulate how it is different from the normal community model. Geernaert answered that it is based on interagency partnerships, it involves the community modelers, and it has many different branches (features). It is a branch of the Community Model. This model has been talked about a lot for 6 months. It needs to be announced. It will employ software engineering and an uncertainty-quantification approach that will provide unique DOE capabilities. This new branch of modeling holds the promise of rapidly accelerating the modeling process; it is being co-organized by BER with ASCR actively engaged.

Schlesinger called attention to the large number of acronyms employed in the presentations and suggested that plainer language be used.

Hubbard asked how far along the partnership with ASCR was. Geernaert replied that ASCR staff have attended and been engaged in every workshop that BER has held.

Randall noted that, in the next few weeks, there will probably be a news article about the new model in *Nature* or *Science* and asked whether BER had a process to influence that article. Geernaert said that it did not.

Stacey asked whether Geernaert could be clearer about where the controversy lies. Geernaert said that it was an opportunity, not a controversy. BER is trying to preserve its relationship with NSF and trying to accelerate its mission-directed efforts through partnerships with other parts of SC. BER has been talking about this for more than a year. NSF appreciates what BER is doing because they benefit from modeling results.

Shugart said that Chunglin Kwa of the University of Amsterdam in The Netherlands makes the point from a science-historian point of view that modelers have traditionally viewed climate processes as homogeneous. Now terrestrial science sees those processes as being very heterogeneous, leading to a scientific revolution. These are difficult questions and difficult to explain and address; it is not cookbook stuff working without a map.

Randall said that there is nervousness from change, but nervousness is not opposition.

Stacey pointed out that these discussions are not held just at the scientific level. There are political ramifications and others. One should work out how and why these changes are being made before and not after a public announcement.

Shaver said that Earth is a patchwork of systems, the states of which are constantly changing. Changes happen at different scales. The integration of photosynthesis, respiration, etc. is not well understood. Currently, efforts to integrate them are scenario based, not predictive models. Changes in the physical system (e.g., tree species migrating northward) are not reflected in the models as is biogeochemistry.

Todd Anderson was asked to present an update on BER's Biological System Science Division (BSSD).

Programmatic activities completed by the Division since the previous BERAC meeting include the FY13 annual reviews of national laboratory programs in Genomic Science: Biofuels Research [at Pacific Northwest National Laboratory (PNNL)] and in Radiochemistry and Imaging [at LBNL and Oak Ridge National Laboratory (ORNL)]. Upcoming reviews are the SFA competition and the annual Bioenergy Research Center (BRC) reviews of the BioEnergy Science Center (BESC) in Oak Ridge, Tenn.; the Great Lakes Bioenergy Center (GLBRC) in Madison, Wisconsin; and the Joint Bioenergy Institute (JBEI) in Emeryville, Calif.

Two FOAs have been issued: Plant Feedstocks Genomics for Bioenergy (issued jointly with the USDA), for which 54 proposals were reviewed with awards expected later this summer, and Systems Biology Enabled Research on the Role of Microbial Communities in Carbon Cycling, for which 67 proposals were reviewed and selections are in progress. Several proposals in each FOA have linkages to KBase.

The Division has 16 SFAs, three BRCs, the Joint Genome Institute user facility, and 20 beamlines at DOE synchrotron light and neutron sources. It also has some research projects that are jointly sponsored with the National Institutes of Health (NIH). It has about 100 academic lead PIs. Its programmatic areas are

- Genomic Science: Foundational
- Genomic Science: Biofuels
- Genomic Science: Systems Biology Knowledgebase
- Radiobiology : Low-Dose Radiation Research
- Radiochemistry and Imaging

The challenge is how to coordinate research efforts toward DOE mission areas. The core philosophy is to advance the systems-biology research agenda. The Division has great researchers, ecological capabilities, and computational systems. The job is to integrate genome sequencing, experimentation, and modeling to make them converge on DOE mission needs. The JGI is used to focus the efforts, KBase to manage and analyze the data, and EMSL to conduct scientific analyses to help the researchers collaborate, an iterative process and format that converges on answers. This core approach is applicable across observational scales. One output is the development of models to translate the state-of-the-art biological information to larger scales and to translate science between divisions in BER.

The new Emerging Technologies Opportunity Program at the JGI is designed to bring added value to the DNA sequences produced. The JGI has awarded six new projects to this program:

- Single-cell Raman spectroscopy
- Microfluidics for single cells
- New metagenome assembly approaches
- Advanced DNA synthesis strategies
- Specialized plant genomic libraries
- High-throughput fungal DNA preparation and phenotyping

The KBase launch continued with the establishment of new biological capabilities (increased metabolic, regulatory, and functional associations); new capabilities to understand protein interactions; and added functional-abundance data. Outreach now includes a KBase YouTube channel with webinars and tutorials, a help desk, and ongoing boot camps and tutorials. It is also deploying redundant infrastructure at all sites and launching a monitoring system with visualization of computing system operations across all four sites.

There has been a joint call for exploratory collaborations between EMSL and JGI focused on plant, fungal, soil and microbial interactions, and physiology related to biofuel production and carbon cycling; 27 proposals have been submitted; successful awardees will start October 1, 2013.

Division science highlights include:

- A thermophilic treatment process employing *Caldicellulosiruptor bescii* for converting non-pretreated biomass has been shown to solubilize switchgrass carbohydrates and lignin at similar rates
- A solution of small-angle X-ray scattering and small-angle neutron-scattering protein experimental data on the degradation of recalcitrant plant polymers by leaf-cutter ant fungus has been developed to rapidly obtain shapes of proteins in solution under a wide

range of experimental conditions and, therefore, the shape and molecular weight of the protein

- A new structural-systems-biology method has produced a more predictive understanding of genomic processes, specifically heat tolerance in *Escherichia coli*
- Research on how arbuscular mycorrhizal fungi (AMF) influence soil microbial communities during nutrient uptake has shown significant uptake of microbially released nitrogen, but not carbon, by the AMF, which may possibly modify community structures and decomposition processes through nitrogen export
- A project looking at genetically engineering plants to decrease ferulic acid and increase saccharification has identified a mutant of rice that has decreased ferulic acid and, therefore, is a plant that is more easily converted to biobuel
- A new thrust for the Division is using metabolic information to discern metabolic pathways to probe how organisms will adapt to temperature increase
- Positron emission tomography (PET) has been successfully used to investigate sucrose movement in living plants
- A human-skin model is being used to examine and predict risks from heavy-ion radiation by studying effects on molecular-, cellular-, and tissue-level processes in relevant experimental systems; an integrated approach provides a framework to understand the responses of multicellular systems and can be adapted to other epithelial tissues and radiation-exposure scenarios
- From JGI, a number of new genomes have emerged, such as that for *Emiliania huxlei*, a single-cell, widespread, marine alga
- A metagenomic approach is being taken to study microbial "dark matter" by analyzing genomes; two recovered genomes exhibit evidence of recoding, suggesting that the canonical genetic code may not be all that is out there in the wild

Since the previous BERAC meeting, JGI has published 60 papers in a wide variety of journals.

Questions and Comments: Stacey said that this joint EMSL–JGI call should just be the beginning. There are other "marriages" that could be arranged. Anderson replied that the Office will engage other user facilities.

Joachimiak noted that these efforts are important for the Knowledge Base (KBase) in that they bring together different data sets. In some cases, though, one cannot recover the data because of the data format used. Also, some organisms cannot be cultured, so single-cell genomics must be employed.

Schlicher asked how BER got economic feedback and by what feedback mechanisms. Anderson replied that they are aware of economic models. The Office takes a long view of energy needs. Weatherwax added that each BRC has an industrial advisory panel to give it feedback.

Stahl asked what was meant by synthetic biology. Anderson answered that it does not refer to new amino acids; rather, it employs molecular engineering. Components are being borrowed from other organisms and are being employed in new, beneficial organisms. Things that are already out there are being used. Microbial communities are not yet being manipulated.

A break for lunch was announced at 12:47 p.m.

Thursday, June 27, 2013
Afternoon Session

The meeting was called back into session at 2:30 p.m.

William Schlesinger (BERAC) of the Cary Institute of Ecosystem Studies was asked to review the research on the global nitrogen cycle.

We have entered the anthropocene. The biogeochemistry of the planet is undergoing a period of rapid change, with humanity being the dominant player. One of the mechanisms of anthropogenic global change is the deposition of 100 million tons of nitrogen per year on the surface of the Earth to feed the human population. What is the human impact on the circulation of elements in the environment? The big players are carbon, sulfur, and calcium. The best estimates of releases of these elements to the environment are

- For volcanic emanations: 30 million tons of carbon, 0.1 million tons of nitrogen, 10 million tons of sulfur, and 120 million tons of calcium
- For chemical weathering of the crust of the Earth: 210 million tons of carbon, 20 million tons of nitrogen, 70 million tons of sulfur, and 500 million tons of calcium
- For the amounts entering the environment today: 107 billion tons of carbon, 9.2 billion tons of nitrogen, 450 million tons of sulfur, and 2.3 billion tons of calcium
- For the concentration of elements in the biosphere: 446,000,000 tons of carbon, 458 million tons of nitrogen, 5.6 million tons of sulfur, and 3.7 million tons of calcium
- For human extraction of elements (e.g., by mining): 8.7 billion tons of carbon, 221 million tons of nitrogen, 130 million tons of sulfur, and 65 million tons of calcium.

The resulting enhancement factors of releases caused by human activities are 36.3 for carbon, 11.0 for nitrogen, 1.6 for sulfur, and 0.1 for calcium.

Under the preindustrial steady-state conditions of the nitrogen cycle, nitrogen was delivered by biological fixation and lightning fixation. About 20% of that nitrogen was taken to the oceans by rivers, and the rest went to the atmosphere. Industrial production of nitrogen took off after World War II, doubling or tripling the amount of nitrogen delivered to the Earth's surface. This is a widespread industrial process.

The human population could never have grown so explosively without nitrogen fertilizers. However, nitrogen growth is faster than population growth.

There are other advertant and inadvertent nitrogen fixations, such as industrial combustion, internal combustion engines (largely automobiles), and vegetation uptake and respiration. Where does all this nitrogen go? It goes to denitrification, groundwater, the terrestrial biosphere, and rivers. Nitrogen is not applied to the land surface evenly. Corn gets a lot of fertilizer, but only about one-third of that nitrogen fertilizer is incorporated into the plant, about one-third goes to the soil, and about one-third goes to the atmosphere or into runoff (much of which is unaccounted for).

A 2006 study of atmospheric ammonium-ion concentration showed the major source to be the corn belt from Northern Illinois to the Dakotas and it showed high concentrations from southern Texas to northern Maine as the ammonium ion rains out over eastern states. Ammonium ion deposition is seen to occur most heavily in the Western states, in a band from Nebraska to northern Maine, and along the coastal plain from Florida to South Carolina.

Nitrogen-enriched rain inadvertently fertilizes forests. Across sites in Europe, wet nitrogen deposition is seen to be strongly correlated with net ecosystem productivity, producing an increase in the forest growth rate. Other experiments show that 25 to 30% of the nitrogen from the sky ends up in plants' biomass. A large fraction runs off to the sea and causes hypoxia, but the amount is not known. Riverflow nitrogen has more than doubled. Van Breeman et al. estimated the amount of nitrogen exported from watersheds to be about 23% of the deposited nitrogen. How much goes into the groundwater is a big unknown. A study on the nitrate concentration in well water across the United States assumed that the preindustrial concentration was zero and that all the nitrate found now represents human perturbation. Running the numbers gives an estimate of about 18 Tg of nitrogen per year going to groundwater globally. The United States applies only 20% of the world's fertilizer.

The calculation of the rate of denitrification is traditionally based on the chemical reaction for the oxidation of carbohydrates. Measurements of denitrification of land-based sources give a range of 65 to 175 Tg of nitrogen per year globally. However, other chemical species are also produced in denitrification, such as nitrous oxide. This byproduct is well monitored, largely because of the concern about its being a greenhouse gas. Denitrification occurs non-homogeneously around the world, and wetlands are major players in providing this ecosystem service. Nonetheless, bubbles of nitrous oxide in ice-core samples show a significant rise after 1500 or 1600, the advent of modern agriculture.

An exhaustive literature review has shown that about 80 studies have done a good job of comparing the production of nitrous oxide with the total production (at the soil surface) of nitrogen plus nitrous oxide. These studies indicate that the nitrous oxide fraction is about 0.374 in agricultural soils, 0.4924 in soils under natural or recovering vegetation, and 0.0824 in freshwater wetlands and flooded soils. The calculation of change in denitrification from nitrous oxide is about 17 Tg of nitrogen per year globally going to groundwater.

The situation today in terms of the mass balance of nitrogen at the Earth's land surface is that the natural, preindustrial biological nitrogen fixation of 60 Tg of nitrogen per year globally is being matched by another 60 Tg from anthropogenic sources. Lightning is contributing its usual 5 Tg each year, rock weathering is contributing 20 Tg, industrial nitrogen fixation is producing 136 Tg, and fossil-fuel combustion is contributing 25 Tg a year. As a result, the industrial age has tripled the nitrogen input to the Earth's surface to 306 Tg of nitrogen per year globally. Along with the normal contributions of 27 Tg of nitrogen per year globally to riverflow, 27 to denitrification, and 25 to pyrodenitrification, the industrial age is contributing an additional 9 Tg per year to the biosphere increment, 48 to soil accumulation, 31 to river flow, 18 to groundwater, 17 to denitrification, 12 to pyrodenitrification, and 48 to atmospheric land-sea transport for a total of 268 Tg of nitrogen per year globally.

The total inputs (306 Tg of nitrogen per year globally) and fates (268 Tg) do not balance; some sinks are missing (most likely in groundwater denitrification). However, these numbers give an estimate of what these values may be; but until these budgets are better balanced, it will be difficult to make a scientific case for the need to investigate nitrogen pollution. There are ecological studies to conduct and policy options to consider for reducing nitrogen oxides in the environment (e.g., the development of more efficient crops, better agricultural management, and the preservation and establishment of wetlands).

Questions and Comments: Shaver asked what the implications on carbon balance were of nitrogen stimulation of plant productivity. Schlesinger replied that the CO_2 stimulation of plant productivity has been possible only because nitrogen inputs have increased, as well. It is not a big sink, but does take a globally significant portion of the carbon out of the atmosphere. The results of the FACE experiments at Duke University showed that the plots that did the best were those that had high CO_2 plus nitrogen fertilization. But this is not the missing CO_2 sink. The CO_2-induced stimulation of the biosphere will not continue without that newly available nitrogen. It would be pretty small, a few tenths of a petagram; a 10% reduction of the residual sink in the atmospheric budget might result from nitrogen stimulation.

Baldocchi asked why studies show both flat results and large upticks in denitrification. Schlesinger answered that the data are of different qualities; more frequent sampling would be very helpful. With 50 or 60 data sources, one-off studies could be eliminated, improving the quality. A joint response has been found in studies of nitrogen and phosphorus. The global distribution of CO_2 is recognized, but the global distribution of nitrogen is not studied. The regrowth of eastern U.S. forests is a major sink.

Shugart asked whether the excess nitrogen produced by people during the increase in CO_2 could be an inadvertent experiment that could be used to test vegetation models in system models. Schlesinger responded that a paper in the literature in the past year showed a joint response for nitrogen and phosphorus effects that might give an answer to that question. Also, scientists consider CO_2 to be highly mixed and have used simple discounting with nitrogen. Now, however, it is believed that most nitrogen deposition is occurring in the eastern United States.

Wall asked if the anammox process used by waste-treatment plants were reflected here. Schlesinger said, no; he could not think how to include it. It would be evident in the digesters and in freshwater runoff.

Stahl pointed out that the wetlands perform an environmental service in removing nitrogen oxides but are also a source of atmospheric nitrogen. Schlesinger agreed that his data showed that duality: the outputs were 0.37 for natural systems and 0.45 from agricultural systems. The conditions in the agricultural systems seem to be more conducive to the microbes' taking the reactions to completion.

Schlicher asked if there were good examples of multiyear system experiments on understanding optimized agronomic practices to minimize nitrogen loss. Schlesinger replied that there were very few, but having a good ecosystem budget under different management for nitrogen input and output would be useful.

A break was declared at 3:26 p.m. The meeting was called back into session at 3:58 p.m.

Sharlene Weatherwax introduced **Edmund Synakowski**, Associate Director of SC for Fusion Energy Science (FES), to explain how fusion is a transformational science.

Fusion energy holds potential opportunities but also challenges. The United States is currently engaged in a critical international experiment during a challenging budget period. The goal is to develop plants with 1-GW power, no carbon emissions, and a lifetime of tens of years. The ambition is to power the planet with a carbon-free energy source. If successful, fusion energy will be a game changer.

In fusion, deuterium and tritium are combined to produce a neutron and helium along with a huge amount of energy. Deuterium is plentiful, and tritium can be produced from lithium, which is also plentiful. The radioactive by-products have short lifetimes. If nature is kind, a mid-century deployment is possible.

For any version of fusion energy, plasma physics will be central. Other topics besides fusion physics are also funded, such as magnetospherics. There are three ways to hold the plasma to gather: gravitational confinement (as is employed by the sun), magnetic confinement (as is done with the tokamak, the National Ignition Facility's hohlraum, and auroras), and inertial confinement [in which a current is induced in a primary transformer circuit to induce a current in a secondary (outer) circuit in the plasma].

The plasmas are excellent conductors; and the hotter the plasma, the better the conduction. The dynamics of this fusion system when it heats itself are unknown. Fusion-energy science is conducted at many sites across the United States, with major facilities at the University of Wisconsin, MIT, Princeton University, ORNL, and San Diego General Atomics.

With massive costs and shrinking budgets, the United States has to engage internationally to use machines to answer the major fusion-energy questions of the next 10 years. As a result, nearly half of the president's request for FY14 fusion-energy funding is for the nation's participation in the ITER ["The Way"] project, the latest experimental machine for fusion research. The first such machine was a stellarator at Princeton University in 1951. Since then, the Russians saw that the plasma can do some of the work of confinement with magnetic fields in a tokamak, many of which have since been built in different countries.

The research objective is to increase the fusion triple product: fuel density × temperature × confinement time. There has been an increase in the triple product by a factor of 10,000 during the past 30 years; another factor of 6 is needed for a power plant. The hot fusion fuel must be decoupled from the wall. Measurements of turbulence are demanded, challenging the computer codes. Currently, the intellectual challenge is to gather simulation data to limit the engineering risk.

The United States has been a significant leader in spite of its low funding for facilities. ITER is the essential next step in the development of fusion energy. Today's machines produced 10 MW for 1 sec with a gain of less than 1; ITER is designed to produce 500 MW for more than 400 sec with a gain of more than 10. The seven international partners in ITER represent 50% of the world's population. It is being built on a 100-acre site in France and needs to conform to nuclear regulations.

The contributions of the United States are in-kind and on a limited budget. Deliverables include diagnostics, a central magnet, and the cooling-water system. This machine is an engineering and logistics challenge of enormous proportions. It is a major project, it is international, and it is on a limited budget. The machines at General Atomics and Princeton University pursue dimensionless parameters that form a strong basis for ITER physics and solutions and provide a test bed for evaluating mission space for a future fusion nuclear science program.

The facility at General Atomics is a highly collaborative program with 440 researchers, 320 of which are from outside General Atomics (from 21 U.S. and 10 foreign universities, 22 overseas research groups, 4 national laboratories, and 4 private industries). The Princeton facility has a unique field-line geometry and serves as a test bed for assessing the potential of this configuration for a compact neutron source. Its smaller device lowers costs, and the issue of compactness leads into the next fusion-visibility decision. It also is a highly collaborative program with 217 researchers, 150 of which are from 21 U.S. universities, 5 national laboratories, and 5 private industry groups.

The International Program in fusion science will give U.S. researchers access to experience with the world's leading challenges, leveraging U.S. expertise and existing facility capabilities. The International Program includes stellarators in Germany and Japan (which avoid the instabilities of plasma currents), a tokamak in China, and the Korea Superconducting Tokamak Advanced Research (KSTAR) in South Korea. All have superconducting-magnet capabilities, which lower refrigeration costs. A variety of designs is being looked at because tokamaks can become unstable quickly, producing huge amounts of power to be dissipated and leading to structural damage.

University programs have been historically quite important in fusion research. It is important to reduce costs and risks through the use of massively parallel computing. Theory and Scientific Discovery Through Advanced Computing (SciDAC) work together to advance the fundamental science of magnetic confinement. This strategy takes fusion research where the aircraft industry has already gone, but it deals with a more complex problem than aerodynamics. Computer codes must be validated. As a result, FES has engaged ASCR and its SciDAC program.

The general plasma science program conducts laboratory experiments in a joint effort between DOE and NSF. The Burning Plasma report of the National Academy of Sciences and the 2010 Plasma Science decadal study are driving fusion energy science today. We know what we have to do for fusion to succeed. The next great step in fusion is the exploring of self-heated plasmas, the burning plasma state: this is what ITER will enable. The big gap is in materials science: the heat flux at the boundary must be managed. The United States can make a huge contribution here. In addition, there is a neutron flux to deal with. The world agrees that a parallel development effort is needed.

If all of these efforts succeed by 2050 and fusion energy production grows even at less than 0.9% per year, fusion can deliver at least 30% of the world's energy production by 2100. Fusion can also contribute to fuel-switching strategies (e.g., off-peak hydrogen production). The future of fusion lies in answering scientific questions so the next steps toward development can be taken. The well-being of everyone is intimately linked to this technological transformation that is not resource-limited. Fusion represents a transformational science that can be part of long-term energy and climate solutions and can be critical in enhancing political stability.

Questions and Comments: Washington noted that there are a lot of similar approaches represented in this research and asked whether fresh ideas were received from the proposals and whether there is a process to keep fresh ideas coming into the system. Synakowski replied that the tokamak is the only game in town for getting alpha burning, but it has many risks. Those risks may not be able to be managed. Its major challenge is long-term steady-state operation. Therefore, there is a budget for alternative confinement schemes. For example, the United States is investing in the stellarator in Germany. All of the work is done at universities.

Baldocchi said that the world's economy needs to be de-carbonized. 2050 is too late. He asked if this research can be accelerated. Synakowski answered that, if there were more resources, the goal would be reached sooner. Several burning-plasma experiments are needed, not just the ITER. A Manhattan Project-sized effort is needed. The U.S. risk-aversion sentiment is very high. Scientific risks need to be taken. However, the budget is constrained. So it comes back to our choices as a society, said Baldocchi. Synakowski said that it is a value judgment that is made.

Stacey pointed out that the different advisory committees have different cultures across SC and asked how Synakowski interacted with the Fusion Energy Science Advisory Committee (FESAC). Synakowski replied that FESAC conducts gap analyses and has come up with many good ideas. They suggest priorities under various budgets. He was happy to engage the fusion community to get their points of view. The advisory committee would like to have a stronger say in the budgeting process, but that is too conflicting. They also consider the next questions to ask; they have come up with a mixed bag. The Office's budget negotiations are embargoed, and the advisory committee, wishing more foresight, feels frustrated by that.

Stacey opened the floor to new business. There being none, he opened the floor to public comment. There being none, the meeting was adjourned for the day at 5:14 p.m.

Friday, June 28, 2013
Morning Session

The meeting was called back into session at 8:28 a.m. Stacey initiated a discussion of a longer view of BER activities and BERAC responsibilities. Both should be looking ahead 5 years and noting gaps in the program.

Joachimiak pointed out that the budget for FY14 is devastating. He said that somebody is not thinking. This situation is not acceptable. He asked what could be done. Stacey said that the Committee members can act as individuals but not as an advisory committee in commenting on budgetary matters to those outside the Department. He refocussed the discussion on what BERAC should be doing in the future.

Wall pointed out that the Bioenergy Research Centers are now in their second 5-year term. There is anticipation that they will be closed down after these 5 years and that there is no future for the researchers there. She asked if a message could be sent or a plan developed for what the programs will look like to give the researchers there a sense that they can have a career in the biological and environmental sciences.

Baldocchi commented that the science tends to change in steps as technology improves. Technological development should be kept in mind along with the grid's changing powers. Land-use change is an important component of ecosystem science that should be addressed.

Randall stated that it should be articulated why DOE should be involved in climate-change research (as opposed to or in cooperation with NSF and NOAA).

Zhang stated that BERAC could promote a more organized approach to DOE's program. BERAC should articulate its support.

Shaver pointed out that DOE is different from NSF and NOAA in that it can pick specific scientific topics to address in a comprehensive way. It should pick some large subjects.

Shugart commented that, in tight-budget times, one distills off good people. DOE should develop a program that, by promoting creativity, will not drive off its strong horses by funding exceptional molecular-biology programs and taking on global issues. There is lots of good stuff going on in BER. There is a creative approach to modeling the Earth. In the next 10 years, BER needs to bridge the two unifying challenges for this program: (1) the science that looks at well-mixed systems and (2) modeling that deals with an unmixed, chunky Earth system.

Stahl said that DOE is impressive in dealing with complex biological processes and communities. JGI is getting large gene inventories, but there is a huge disconnect between genome sequences and lists of genes. This gap needs to be bridged to get from gene sequences to physiology. Plus, no microbe is an island. Communities are how they operate. Community interaction, structure, rules of assembly, and resilience need to be looked at to understand how these communities operate.

Washington remembered that BER used to look at health effects. It needs to look at how climate change affects health (e.g., via heat, climate, and drought); those two issues are combined with the biology. This is another way to stress what BER does. As models go to higher resolutions, data becomes more and more important. Petabytes of data are being used in the IPCC assessment. How the data are saved (e.g., with new algorithms) can be altered to bring down archiving costs. At a recent CESM workshop, there was a push to cut back costs in data saving. DOE and the Earth System Grid make the data available to anyone who wants to work with it. That is a great accomplishment for DOE. It affects thousands of researchers worldwide. DOE deserves a lot of credit for establishing and maintaining that data service.

Remington stated that what is important is being able to use data once they are stored. Accessibility to the broad community (not just those with sophisticated computer support) is paramount. Metadata should also be available with all stored data. A bigger deal should be made of the BERAC report on this subject and of what DOE has accomplished along these lines.

Joachimiak pointed out that a system of transferring and storing large amounts of data is being studied and developed at the University of Chicago. NIH is looking at microbes that affect human health. The question is whether one can predict looming crises as the energy balance of the Earth is changed by humans. DOE has unique resources that could be provided to researchers to address that question.

Stacey said that, in the 1970s, there was an energy crisis. In the 1990s, there was cheap energy. Now, costs are up again, and the budget for alternative energy is up. The United States might become energy independent because of natural gas. There may also be a need to go to a less-carbon-intensive economy. The three legs of bioenergy research are energy costs, geopolitical issues (energy coming from unfriendly countries), and climate change. The 5-year horizon for alternative energy research is good. He asked what the 15- to 20-year outlook was.

Baldocchi pointed out that solar works 365 days a year at 20% efficiency. Corn works 100 days per year at 2% efficiency; it also competes with food and fiber needs. An integrated research portfolio in alternative fuels is needed.

Joachimiak asked whether there would be suitable land available for growing such plants in an era of drought and floods.

Stacey noted that heavy-metal remediation cannot be carried out because of the lack of an understanding of microbial communities. This is a pressing part of the DOE research portfolio. If this topic were looked at by BERAC, a report could be issued.

Zhang stated that the marine ecosystem side of biogeochemistry is important and could be investigated by DOE. Weatherwax commented that NSF and NOAA have large research programs in marine science. DOE's climate modeling incorporates their marine data collection. DOE's participation in such research is limited. It comes down to costs. One needs oceanographic vessels to do such research, and they are expensive. DOE does conduct research on related coastal ecosystems.

Stahl said that sustainability is an important topic, although broad.

Stacey summarized the discussion: one needs to be concerned about big data, but that topic is being investigated by others. Remington commented that the White House initiative on big data depends on everyone's pitching in to help. It is a cooperative effort, not someone else's problem. BER should be engaged so that the DOE science effort will be represented and protected.

Stacey noted that another issue is articulating the unique DOE climate-change mission. Randall added that it would be good for BER to send a letter to the Director of the Office of Science to clarify this mission.

Stacey noted that another issue is the future of bioenergy research, a forward-looking report on this science (not the centers) would be helpful. Remington added that there have been many programs that have promoted research directions and then cut off funding. That is demoralizing to the research community. People need to realize that they will be working together on a topic for a long time. In addition, it leads to competing efforts rather than cooperation. Weatherwax pointed out that there is a robust portfolio in bioenergy that transcends the BRCs.

Stacey added that there are two other ideas: (1) integration across scales, from the microbial to Earth-system scales, and (2) the anthropocene is upon us, as man-made effects on the ecosystem start to dominate the global climate and environment. Baldocchi called attention to the broad range of scales reflected in BER's research. What is needed is to bridge these scales so it is understood how communities interact and depend upon each other.

Stacey said that he would write a summary of this discussion, circulate it to Committee members for feedback, and schedule further discussion at the next BERAC meeting.

Thomas Armstrong, Director of National Coordination for the U.S. Global Change Research Program (USGCRP), was introduced to describe the Program.

A need for a more coordinated approach to climate change and global change was seen, so the Global Change Research Act of 1990 was enacted. It called for a comprehensive and integrated United States research program to assist the nation and the world in understanding, assessing, predicting, and responding to the human-induced and natural processes of global change. There has been a lot of productive work on predicting the climate system. People want to know what is going to happen to their backyards. The gap between research organizations and individuals needs to be bridged. There has been a paradigm shift from portfolio development to a sustainable service of information provision to the people of this country and the world.

The 13 agencies of the USGCRP and the President signed off on this Plan. The program emphasizes the human aspects of global change with a desire to make that information relevant to decision makers. All this led to an OMB–Office of Science and Technology Policy (OSTP) guidance to the agencies for FY14 that calls for emphasis on research that advances understanding of vulnerabilities in human and natural systems and their relationships to climate extremes, thresholds, and tipping points. This guidance was authorized across the 13 agencies; it focuses on sound, fundamental research tied to communication with funders and communities. A multidisciplinary integrated approach is needed, especially across social science and physical science. This guidance goes to the agencies for their funding plans. The value added is that the research effort is more than the sum of its parts.

The USGCRP has a Board of Directors that has DOE representation and many subcommittees and working groups that provide information that guides the strategic thinking of the Global Change Research Program. It is a subcommittee of the Committee on Environment, Natural Resources, and Sustainability, which in turn is a committee of the National Science and Technology Council.

The first goal of the USGCRP is to advance science through Earth-system understanding, science for adaptation and mitigation, integrated observations, integrated modeling, and information management and sharing. Its second goal is to provide the scientific basis to inform and enable timely decisions. Its third goal is to conduct sustained assessments every 4 years; it is on its third one now and is focused on stakeholder needs; these assessments must be scientifically sound and relative to stakeholder needs and must provide a baseline of information for predictive efforts. There are also sector- and region-based assessments and evaluations of smaller, focused projects relevant to smaller communities. Consideration is being given to how to conduct sustained assessments. The fourth goal is to broaden public understanding of global change and to develop the scientific workforce of the future. The USGCRP has not done this for the past 20 years; it is a rate-limiting effect; an objective, educational program is needed; there are not adequate resources to do this at this time; there is no dedicated program for educating people on climate change.

The USGCRP Strategic Plan calls for providing knowledge on scales appropriate for decision making, incorporating social and biological sciences, and enabling responses to global change via iterative risk management. Its priority activities are to enhance information management and sharing; to enable new capabilities for integrated observations and modeling; to increase proactive engagement and partnerships with the World Climate Research Project, the Arctic Council, the United Nations Climate Change Conference, etc., in which the White House envisions strong U.S. leadership; and to find ways to develop the scientific workforce for the future (responsibility to do this has been notched up, but the resources are declining).

The guidance to the agencies calls for them to use interagency working groups to make observations to detect trends in extremes and to integrate observations into models (this is a leadership role for DOE); to attribute change to human or natural causes; to integrate research on human and natural systems; to understand and predict spatial and temporal scales conducive to decision making; and to adapt responses to changing frequency and intensity of extreme events. The gap between scales for weather prediction and climate prediction needs to be bridged to understand climate variability; a long-term-trend baseline needs to be established to understand the context. All agencies are tasked to come up with 50- to 100-year plans on such topics as migration of invasive species. Foundational science is being done that supports both adaptation and mitigation. One is not being given up for the other. Issues of preparedness are being addressed.

The Climate Action Plan is on the web and should be read by all climate-change researchers. The science research community’s input was used to inform and produce this Plan that was developed with White House leadership. It contains very specific information, it points out that risk modeling framework is more than short-term modeling, and it includes both adaptive management and communication.

This subject is being taken very seriously at the White House and at OMB, and they will be looking for responses to the Plan in budget requests from the agencies. They will be looking at how such requests can be coordinated to achieve the goals of the Plan. This is the biggest opportunity in 10 years in this area.

Big data include big Earth data, which will be incorporated into this initiative. One of the nodes in the architecture of the data-storage system will be climate. This system will be portal-based. The objective would be to leave the data where it originated, to standardize the metadata, and to make it all available in a uniform manner to the public as well as to the research community. A lot of work is still needed, and data sharing should be a focus of DOE.

Questions and Comments: Washington said that international discussions look to Future Earth to get information out in a coordinated way. Armstrong responded that the USGCRP has an international desk and it has put $1.4 million into programs associated with Future Earth. Future Earth is still in its early stages and is seen as a cost-effective manner to develop and share global-change information. An effort must be made to reach out to the international global-change community for its input.

A break was declared at 10:14 a.m. The meeting was called back into session at 10:27 a.m.

James Mather, Technical Director for the DOE ARM Climate Research Facility, was asked to present an update on the ARM Climate Research Facility.

The ARM Climate Research Facility is a ground-based, distributed, observational facility that is managed by nine national laboratories. The phenomena observed are distributed around the world. Other countries are adopting ARM-like strategies. Observations are used in model development. ARM is still unique in its ability to go where the measurements are.

The BER mission statement includes the advancement of a robust predictive understanding of Earth's climate and environmental systems and the development of sustainable solutions to the nation's energy and environmental challenges.

Two goals of CESD are (1) to develop, test, and simulate a process-level understanding of atmospheric systems and terrestrial ecosystems, extending from bedrock to the top of the vegetative canopy and (2) to enhance the unique capabilities and impacts of the ARM and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science.

The world needs to understand what is forcing climate change. It needs to understand the sources and cycling of greenhouse gases; the sources and cycling of aerosols and their radiative and microphysical properties; the characteristics of current cloud properties and radiative feedback caused by changes in cloud populations, particularly marine stratus, tropical convection systems, mixed-phase Arctic clouds, and Southern Ocean storm track systems (which present problems in modeling); and interactions of clouds and aerosols with the Earth's surface. All of these issues underpin the observational goals.

The ARM Climate Research Facility incorporates research sites (permanent, mobile, and aerial); instruments and measurements; field campaigns with ground-based, ship-based, airborne, and mobile stations; and data processing, data quality, and data archiving. The ARM mission and vision statements have been updated to include (1) understanding and representing clouds, aerosols, and their interactions and coupling with the Earth's surface in climate and earth-system models and (2) providing a detailed and accurate description of the Earth's atmosphere in diverse climate regimes.

The research sites are located at the Southern Great Plains, North Slope of Alaska, Tropical Western Pacific, deployed mobile facilities, and Eastern North Atlantic. The site at Nauru is to be phased out this year. The measurements taken and instruments used include millimeter radar and lidar to get at cloud profiles, radiosondes targeted at temperatures/relative humidity/wind profiles, microwave radiometers, solar spectroradiometers, in situ aerosol optical and cloud-nucleation properties, solar and terrestrial IR radiometers, and surface meteorology.

Most instrument data are processed to a standard NetCDF format before being delivered to the Archive. When necessary, higher-order value-added products are developed, such as liquid-water content rather than just radar reflectivity.

Individuals become ARM science users through several processes, including successful field-campaign proposals, successful proposals to use ARMs computing facilities, or peer-reviewed science proposals requiring access to archived data. Science users interact with the Facility through data access, field campaigns and facility deployments, and data-product requests, providing feedback for new capabilities. Data-flow statistics through the data archive include the number of files and volumes stored and the number of files and volume accessed. There has not been a drastic increase in the number of files stored but a slow, upward trend. There was a dramatic increase in the data volume stored about 3 years ago because of new instruments put online that collect up to 1 TB per day. The number of files requested has gone up by a factor of 4 during the past 10 years, approaching 10 TB per month.

The tools for data discovery and analysis include the Archived Data Discovery Browser, which provides faceted data search, auto-fill quick search, and graphical data-quality information. It has a new user interface that facilitates use, it better describes the quality of data, and it allows filtering out of data of questionable quality. Other advances are the addition of digital object identifiers at ORNL, a development area for large data sets, and machine-readable data-quality reports.

The annual field campaign call for pre-proposals is issued in January, preproposals close in February, notifications are sent for full proposals in mid-February, full proposals are due in May, infrastructure costs and logistics analyses are due in June, field-campaign proposals and costs go to the Science Board in June, the Science Board reviews these proposals in July and August, and the awards for ARM fixed sites and campaigns are made in September. A science plan is developed, and the field campaign is executed. Experimental results and all collaborative data must be submitted to the ARM Archive within 6 months of the end of a campaign.

The AMF1 [the first ARM Mobile Facility] transportable and land-based deployments have been in California, Niger, Germany, China, Azores, India, Cape Cod, and Brazil. The AMF2 for ship and complex-terrain use has been deployed in Colorado, Maldives, Eastern Pacific, and Finland. ARM has always had an aircraft component, originally for aerosol processes; that aerial facility has been deployed in Oklahoma, Alaska, California, Cape Cod, Washington, and Tennessee.

Value-added products are algorithms that translate measurements of geophysical parameters into data products that enable scientific analysis. Such products are prepared in four stages: initiation, development, evaluation, and release. This is important in how ARM interacts with the modeling community. These are the products most used by modelers. Synthesis of data used for model evaluation includes ARM Best-Estimate Products (parameters on a 1-hr grid, specifically intended for model evaluation); variational analysis based on model-forcing data sets; and Radiatively Important Parameters Best-Estimate Products (inputs for a radiative-transfer model on 1-min and 30-min grids).

ARM solicits user feedback at science team and working group meetings, Science and Infrastructure Steering Committee meetings and interactions, user workshops, user surveys, and general science meetings.

Some science highlights are noteworthy:

- Measurement techniques have been developed, evaluated, and improved, such as broadband radiation measurement techniques and improvements in water-vapor measurements using radiosondes.
- Cloud macrophysical and microphysical properties were derived with millimeter radar and lidar.
- Merged data products were used to explore the factors associated with the transition from shallow to deep convection over the Southern Great Plains.
- In the characterization of the Sahel, analyses were performed of the column radiation budget, relationships among thermodynamic and radiative parameters, cloud microphysical properties, aerosol properties, and convective anvil properties.
- There has been an emphasis on measurements of aerosol optical properties, such as the sensitivity of radiative forcing to aerosol optical properties and the effects of scale and the representativeness of aerosol radiative forcing derived from surface measurements vs. airborne measurements; the distribution of aerosol profiles has come to be seen as an important issue.

- The 2010 Carbonaceous Aerosols and Radiative Effects study included measurements of aerosol composition and structure from the ground and from the G1 aircraft downwind of Sacramento, California, showing a high fraction (88%) of particles measured containing internal mixtures of multiple chemical species with key aerosol components including soot, organic carbon, sulfate, and nitrate; the aerosol composition varies significantly with location as well as with time.
- Observational data provide a grounding for a physical understanding that leads to the improvement of general circulation model processes.
- Significant advances have been made in the ability to measure mixed-phase cloud properties by using airborne measurements from two campaigns and combinations of ground-based sensors.
- Modeling studies have advanced understanding of mixed clouds and have improved their representation in general circulation models, although the models still have a long way to go.
- The 2006 Tropical Warm Pool International Cloud Experiment has led to more than 60 publications, ranging from analyses of cloud observations to model studies and including ice-cloud properties from ground-based remote sensors and aircraft, vertical structure of heating in deep convection, sensitivity of convection in GCMs to mid-troposphere humidity, sensitivity of convection in GCMs to model resolution, and observations of vertical motion in convective cores; these data are used to constrain the models.
- The Community Atmosphere Model has been modified substantially with a range of enhancements and improvements in the representation of physical processes; ARM contributions to the model include a rapid radiative-transfer method for GCMs, a three-mode modal aerosol scheme, a two-mode cloud-microphysics scheme, and a planetary boundary layer/shallow convection scheme.
- Optical properties (scattering and absorption) and CCN concentration have been measured by the aerosol observing system.

The 2007 workshop provided feedback regarding setting priorities, data infrastructure needs, aircraft measurement needs, and design priorities for a second mobile facility. The 2008 workshop provided feedback on instrument/measurement needs.

In 2009, ARM received $60 million in Recovery Act funding from SC for investments in instrumentation and research infrastructure to support instrumentation and the associated increase in data volume and complexity. New measurements resulting from this funding include 3-D measurements of cloud properties; enhanced measurements of atmospheric aerosol absorption, scattering, composition, and chemistry; improved measurements of humidity and vertical motion; and expanded capabilities for airborne measurements. The list of needs was user driven.

The Climate Research Facility has a number of important instruments. The Aerosol Observing System provides measurements of optical properties and CCN concentration. The Mobile Aerosol Observing System provides a suite of instruments to address science questions posed by aerosol and aerosol-cloud interaction field campaigns. High spectral resolution lidar (HSRL) provides aerosol extinction and liquid/ice discrimination in thin clouds. Doppler/Raman lidar provides means to study details of convection, water-vapor profiles, and fluxes. Raman lidar also provides improved sensitivity to optically thin tropical cirrus. Cloud-detecting millimeter-wavelength radars scan geometries for sample cloud properties and 3-D structures with various modes. ARM operates the most sophisticated and broadly distributed radars in the world.

These capabilities are managed by a Radar Science and Operations Team. It is now emphasizing radar calibration, using the Sun to calibrate the absolute position of the pedestal and as a noise source that can be observed with the radar.

Upcoming activities include maturation of applications for new instruments, focus groups, upcoming AMF deployments, collaborative activities with the European Union, and the establishment of new sites.

Vertical velocity has emerged as a major issue. It is central to many atmospheric-science issues and particularly the cloud lifecycle. New measurements of capabilities put in reach the ability to characterize vertical motion like never before. An array of data products is coming online to capitalize on these measurements. There will be a special session at this year's American Geophysical Union Winter Meeting to explore measurement techniques and applications of these measurements.

A lot of work is going on in addressing uncertainties and cloud retrievals and other parameters. Instrument-level uncertainties are being collected from all instrument mentors. Documentation is ongoing. Machine-Readable Data Quality Reports are being applied.

GOAmazon is a collaborative research project in a tropical rainforest. It will begin in January 2014 and run for 2 years. AMF1, the G1 aircraft, and the Mobile Aerosol Observing System will be deployed to Brazil. There will be additional partnerships with CESD Modeling and Terrestrial Ecosystems, EMSL, researchers in Brazil, and other agencies and nationalities.

A second mobile facility will be established to study biogenic aerosols' effects on clouds and climate in Finland. A recent study suggests negative climate feedbacks from biological processes; ARM data will help test this hypothesis. Areas of emphasis that were identified were cloud retrievals, radar calibrations, microwave radiometry, model-forcing data sets, a common data portal, large-eddy simulations (LES), and field campaigns. This activity is an indicator of how ARM plugs into European studies. In 2012, DOE hosted a workshop with colleagues from the European Union.

Two new ARM sites will be established in 2013: in the Azores, a region characterized by marine strata cumulus that have a strong influence on climate, and at Oliktok Point, which offers an opportunity to link coastal conditions from the standard ARM measurement suite with near-coast conditions with the use of an unmanned aerial system. The sites are scheduled to come online by September 2013.

Questions and Comments: Remington appreciated the attention paid to tools for discovery and data analysis. She asked if ARM has a profile of data users. Mather replied, yes. People come from all but two or three states and from 15 to 20 countries. They register, and their usage is tracked. It is a variety of types of users: academics, researchers, and dot-coms.

Laura Biven of SC's Office of the Deputy Director for Science Programs was asked to provide an update on the SC Digital Data Policy.

The America COMPETES Reauthorization Act of 2010 set up the Interagency Public Access Committee. The Office of Science established the SC Working Group on Digital Data and requested reports from Federal Advisory Committee Act (FACA) committees, which were incredibly useful. The OSTP requested information from the public. SC user facility input was provided to OSTP in 2013, and OSTP issued the memo, "Increasing Access to the Results of

Federally Funded Scientific Research," for agencies. A Draft Office of Science Statement on Digital Data Management has now been published.

It was desired to (1) have a policy that was specific to SC's needs and mission, providing a clear statement of goals and expectations from SC; (2) give programs within SC maximum flexibility in tailoring their implementation of the policy; (3) be consistent with administration guidance and take into account input from community and public; and (4) not overburden our research communities with a policy that is inconsistent with policies of other research funding agencies. Specifically, the Statement is consistent with the recent OSTP guidance on "Increasing Access to the Results of Federally Funded Research"; requirements will apply to all proposals for research funding regardless of institution but not to Small Business Innovative Research/Small Business Technology Transfer awards and not to applications for time on user facilities; and requirements will apply to proposals submitted in response to SC research solicitations and invitations for new, renewal, and some supplemental funding issued on or after October 1, 2013.

Data management reflects all stages of the data lifecycle for capture to preservation. The stated requirements are intended for PIs and research institutions, but reviewers and program staff will have new responsibilities, too.

Research data are defined as the recorded factual material commonly accepted in the scientific community as necessary to validate research findings, but not preliminary analyses, drafts of scientific papers, plans for future research, peer reviews, or communications with colleagues. Recorded material also excludes physical objects (e.g., laboratory samples).

The statement's development was guided by three principles:

1. Effective data management has the potential to increase the pace of scientific discovery and promote more efficient and effective use of government funding and resources. Data-management planning should be an integral part of research planning.
2. Sharing and preserving data are central to protecting the integrity of science by facilitating replication of results and to advancing science by broadening the value of research data to disciplines other than the originating one and to society at large.
3. Not all data need to be shared or preserved. The costs and benefits of doing so should be considered in data-management planning.

The SC Statement on Digital Data Management places three requirements on the research community:

1. All proposals submitted to SC for research funding must include a Data Management Plan (DMP) that describes how data generated through the course of the proposed research will be shared and preserved or explains why data sharing and/or preservation are not possible or scientifically appropriate. At a minimum, DMPs must describe how data sharing and preservation will enable validation of results, or how results could be validated if data are not shared or preserved.
2. DMPs must provide a plan for making all research data displayed in publications resulting from the proposed research digitally accessible at the time of publication. This requirement includes data that are displayed in charts, figures, images, etc. This requirement could be met by including the data as supplementary information to the published article or through other means. The published article should indicate how these data can be accessed.
3. In determining the resources needed for data management, researchers who plan to work at an SC user facility as part of the proposed research should consult the published data

policy of that facility and reference it in the DMP. DMPs that explicitly or implicitly commit data-management resources at a facility beyond what is conventionally made available to approved users should be accompanied by written approval from that facility.

Questions and Comments: Stacey noted that the NSF has had this requirement for a while and asked if this is to become standardized across agencies. Biven replied, yes; it is mandated by OSTP.

Remington commented that putting a data management plan and structure into an FOA makes one think about why one has it and how the data management plan should be evaluated. Biven answered that it will be part of the submission software. It will not detract from the page numbers required for a proposal.

Joachimiak asked who will pay for storing data and set the format for accessibility. Biven replied that it would be paid for by programs or institutions.

Randall asked if storage costs would be direct-chargeable. Biven replied, yes.

Remington asked if there were any progress in getting publishers to help in archiving data. Biven said that she had not heard of any big pushback from publishers. Remington asked if there were some way to make this a win-win situation for publishers. Biven hoped that that would develop, but she did not know of any activities in that direction.

Thomassen said that, if one looks back through FOAs on the genomic side, there is already a requirement for substantial KBase data archiving and, on the environmental and climate side, there are several paragraphs on BER expectations that are more stringent requirements than the SC Statement calls for.

Remington pointed out that other data products not cited in publications are not mentioned in these requirements. Those other data can be helpful to the scientific community. Weatherwax pointed out that those guidelines are minimum ones; one can always exceed them.

The floor was opened for new business. There being none, the floor was opened for public comment.

Mary Maxon of Lawrence Berkeley National Laboratory stated that a BERAC report for the future might address recommendations for high-impact research priorities on the biological response to environmental change: microorganisms, human health, etc.

There being no further business or comments, the meeting was adjourned at 11:46 a.m.