Minutes
Biological and Environmental Research Advisory Committee
March 9-10, 2011
Omni Shoreham Hotel
Washington, D.C.

BERAC Members Present

Gary Stacey, Chair
Robert Dickinson
James Ehleringer (Wednesday only)
Joanna Fowler
Susan Hubbard
Andrzej Joachimiak
Gerald Mace
Joyce Penner
David Randall
Karin Remington (Thursday only)
G. Philip Robertson
Gary Sayler
Herman Shugart
Judy Wall
Warren Washington (Wednesday only)
Raymond Wildung
Mavrik Zavarin
Minghua Zhang

BERAC Members Absent

Janet Braam
Paul Gilna
Gregory Petsko
L. Ruby Leung
James Tiedje
Stephen Padgette
Margaret Riley

About 50 others were in attendance during the course of the two-day meeting.

Wednesday, March 9
Morning Session

The meeting was called to order at 9:00 a.m. by Chairman **Gary Stacey**. He asked the Committee members to introduce themselves.

William Brinkman introduced **Warren Washington** [Senior Scientist, National Center for Atmospheric Research] to speak on the past and future of climate modeling.

In 1978, Fred Koomanoff and Michael Riches of BER suggested a collaboration between the National Center for Atmospheric Research (NCAR) and DOE on modeling climate change. The climate change program managers have been Ari Patrinos, Jerry Elwood, David Bader, Anjuli Bamzai, Renu Joseph, and Dorothy Koch.

Holding climate change to a 2° temperature change from 1850 to the beginning of the 21st century will be very difficult. Emissions have been going up and are not slowing down even though the rate of land-use change has declined. Fossil fuels are the largest source of emissions. The globally averaged surface temperature continues to rise no matter how it is measured. 2010 was a year of record warmth. In addition, the changes in extremes show more record highs than record lows, another indicator of a warming trend.

Carbon dioxide atmospheric concentrations have also been rising. There is now a satellite-produced global map of these carbon dioxide concentrations in the atmosphere. All major indicators are pointing to warming: land-surface temperature, ocean surface temperature, marine air temperature, sea level, Northern Hemisphere thaw depth, Northern Hemisphere snow cover, tropospheric temperature, upper-ocean heat content, humidity, stratospheric temperature, Arctic sea ice extent, and glacier mass balance.

The second atmospheric model was produced at NCAR in 1978. Most storms and the biggest variety of storms were seen to occur in the Northern Hemisphere. Very-high-resolution models can now be run because of advances in computer science.

There has been no change in solar irradiation over the 11-year solar cycle during the past four decades.

Climate and earth-system models are becoming more complete. An example is Robert Dickinson's Community Land Model, which now even includes changes in plant communities as climate varies. In the early days, computer model resolutions were very coarse. Superfast computers have increased that resolution tremendously and allowed a lot of features (e.g., ice sheets, aerosols, and interactive vegetation) to be included. The Fujiwara Effect (the merging of two cyclones) is often seen in the Pacific Ocean. That phenomenon has now been captured in the models. Very-high-resolution ocean models are needed to capture the effects of the ubiquitous eddies.

2010 was a record year for melting of the Greenland ice sheet. The scientific community is working on modeling ice sheets and is now at a 5-km resolution.

The components of a hybrid model now have to be more tightly coupled and integrated.

The convergence of the longitudinal lines at the poles has made modeling based on a longitude–latitude grid difficult. Different techniques are being tried to overcome this problem (e.g., David Randall's icosahedral grid). Again, large computers have been key to approaching this problem.

The results of today's mobile sea surface temperature (SST) models are *very* close to observations of regional climate features [e.g., of El Niños and of the Madden-Julian Oscillation (MJO) in the Indian Ocean].

Aerosols are very important and not well understood contributors to cloud dynamics. Joyce Penner and others are developing a better understanding of cloud physics and the contribution of aerosols to those physics.

The extent of Arctic sea ice has been declining, and a decent job is now being done of modeling and understanding this sea-ice cycle. It has been suggested that the Earth is entering the Anthropocene, the period when human actions have affected the climate.

Our society has not solved the policy issues of limiting greenhouse-gas emissions. China has surpassed the United States as the leading emitter. India's emissions have grown significantly, also.

In the Mount Pinatubo eruption, the emissions went directly to the stratosphere; in the Mount St. Helens eruption, the ejecta stayed in the troposphere and were quickly rained out. Natural variations (e.g., solar and volcanic forcing) do not explain the observed climate change. If the world does not get on a stabilizing pathway, the carbon dioxide concentration will approach 2100 ppm in a future century with large accompanying global temperature increases, sea level rise, health problems, and food production shortfalls (inter alia). It is hard for policymakers and the public to understand climate change because the topic involves different infrared effects on different gases, feedback mechanisms, and the scientific method itself. The feedbacks are water vapor, lapse rate, clouds, and albedo.

New developments include the Climate Science for Sustainable Energy Futures program of DOE, cloud-resolving climate models, and community Earth-system models. Setbacks include the loss of two major National Aeronautics and Space Administration (NASA) satellite instruments. The path forward should include an integrated program among federal agencies. We owe it to our children and grandchildren to develop excellent scientific information on climate change.

DISCUSSION

Randall noted that, in 1965, climate change was an academic exercise and asked when it changed to being a public policy issue. Washington replied that a call from Presidential Science Adviser Bromley in 1989 to install a climate model in the White House for the Chief of Staff to run was when it became evident that climate change had become a pressing issue.

Brinkman noted that the Gravity Recovery and Climate Experiment (GRACE) is supposed to fall out of the sky in a couple of years and asked if there were any plans to replace it. Washington

answered that the Space Studies Board is interested in having a glacier-melt observing satellite as a high priority. Space observations are essential to improving climate models.

Robertson asked about climate engineering. Washington responded that models of many climate engineering schemes have been carried out. These schemes do not deal with the acidification of the ocean. Marine life's skeletons will not be able to survive in the acidified upper oceans. One can stop global warming with climate engineering but not regional changes. Virtually all scientists put halting emission increases as the highest priority. Policymakers are still not willing to make decisions on the big questions. We have not gotten to the critical stage (with people dying) to motivate political action.

William Brinkman [Director, Office of Science, USDOE] was asked to discuss the FY12 budget request of the Office of Science (SC).

The week of this meeting had seen a proposal to cut the budget of SC by $100 million, which can be done.

SC has done well in science, supporting more than 100 Nobel Prize winners (22 in the past decade); 45% of federal support of basic research in the physical sciences; and 27,000 Ph.D.s as well as graduate students, undergraduates, and high school students and a wealth of facilities serving more than 26,000 users a year.

President Obama noted that the United States faces greater competition now than ever before and that competition will be focused on clean energy and new energy technologies. SC is in a good position to respond to that national need. It has six research directorates. It supports major user facilities, national laboratories, and researchers. The FY12 budget will make a three-fold attack on energy problems by addressing materials by design (for nuclear power and photovoltaics), biosystems by design (for environmental remediation and bioenergy), and modeling and simulation (of climate, biofuels, and reactor design). There is a huge amount of data coming out of these programs and need to learn how to manage these data efficiently and effectively. We have 40,000 proteins in a structural database. The Cray XT5 at Oak Ridge National Laboratory (ORNL) and the Blue Gene/P at Argonne National Laboratory (ANL) are important in this process.

SC is asking for a 14.8% increase in its budget: 21.0% in the Office of Advanced Scientific Computing Research (ASCR), 0.6% in High Energy Physics (HEP), 19.9% in Nuclear Physics (NP), and 22% in Biological and Environmental Research (BER). The budget request fully funds the Fuels from Sunlight Energy Innovation Hub was begun in FY10 and serves as an integrating focal point for the solar-fuel R&D community with collaborations with 20 Energy Frontier Research Centers. There are two other hubs: nuclear reactor modeling in SC and better buildings in Energy Efficiency and Renewable Energy (EERE). This year, SC is proposing the establishment of a Batteries and Energy Storage Energy Innovation Hub to push energy storage closer to the theoretical energy density. Batteries are needed that can store hundreds of megawatt hours of power.

ASCR is delivering world-leading computational and networking capabilities to the energy R&D community. It is proposing investments for exascale computing to leverage new chip technologies; to develop libraries, tools, and software for these new technologies; and to create public–private partnerships to develop platforms and codes. Uncertainty quantification is a major issue at the exascale. Long-haul trucks get an average 6.7 miles per gallon at 70 mph. There are 1.3 million trucks on the road with 300,000 being added each year. Computer modeling and simulation have shown that a simple redesign can increase their mileage by 6.9%.

In Basic Energy Sciences (BES), DOE is proposing science for clean energy, computational materials and chemistry, and enhancements at user facilities. The integration of the different scientific disciplines is still not optimal. The free-electronic laser at SLAC can hit a liquid jet that has nanocrystals of a protein with a 50-nsec X-ray pulse and produce a diffraction pattern for the protein, revealing its structure. SC R&D on cathode materials has produced high-energy lithium batteries, increasing the energy density of the batteries by a factor of 2.

The Office of Biological and Environmental Research (BER) is working on climate and bioenergy through (1) clean-energy biodesign on plant and microbial systems, (2) a comprehensive Arctic-environmental-system model, and (3) support for the Bioenergy Research Centers (which have filed 66 patent applications in 2 years) and other facilities. BER is also tackling major climate uncertainties. The community is looking forward to systems that will not produce biofuels that need blending or conversion (like ethanol) but can be used directly (like butanol).

Fusion Energy Science is working on the International Thermonuclear Experimental Reactor (ITER), which would produce 10 times as much power as goes into heating the plasma. The United States is providing management and is establishing cost and schedule baselines. Precision manipulation of the magnetic field of a tokomak can prevent dangerous heat-flux transients that cause plasma instabilities.

In NP, the 12-GeV upgrade of the Continuous Electron Beam Accelerator Facility (CEBAF) is being continued, the Facility for Rare Isotope Beams (FRIB) is being designed, and the Holifield Radioactive Ion Beam Facility (HRIBF) in Oak Ridge is being closed. A new form of antimatter has been discovered at the Relativistic Heavy Ion Collider (RHIC). Work at the High-Flux Isotope Reactor at ORNL contributed to the discovery of a new element (number 117), hinting at a valley of stability in the chart of the nuclides. The Isotope Development and Production Program is making hundreds of isotopes available, 20% to scientific research, 20% to industry, and 60% to the medical community. An important action is integrating the activities and output of the current, widespread, and diverse domestic sources of isotopes. The nuclear community has two major projects to support and is unlikely to get large increases. That situation prompted the decision to close the HRIBF. The decision had to be made quickly with no time to consult with the scientific community.

HEP has had successes with the Fermi Gamma-Ray Space Telescope. The Tevatron at Fermilab has been running extremely well as has the Large Hadron Collider (LHC). An extended Tevatron run was considered, but a doubling of the integrated luminosity would take several years, so the President's budget request does not call for running the Tevatron beyond 2011. The Long Baseline Neutrino Experiment at Fermilab and the Deep Underground Scientific and Engineering Laboratory (DUSEL) is a high-priority experiment and is being reconsidered in light of the refusal of the National Science Board (NSB) to endorse the DUSEL. New accelerator technologies have far-reaching benefits and are reducing the size of accelerators by factors of 0.1 to 0.01. These accelerators are showing up in hospitals and other workplaces.

The Office of Workforce Development for Teachers and Scientists is supporting the Science Bowl, research experiences at national laboratories for teachers and students, and graduate fellowships.

The America Competes Reauthorization Act of 2010 establishes a working group under the National Science and Technology Council to coordinate federal research and policies related to the dissemination and long-term stewardship of research data. The different disciplines have different approaches. A snapshot of what each community is doing is being sought. BERAC is being asked to report current policies, practices, dissemination models, and opportunities for enhancing public-access policies and practices. Laura Bivens has taken the lead in writing the charge.

DISCUSSION

Washington asked if there were anything that the Committee members could do to influence what happens in Washington. Brinkman replied that there are a lot of new faces in Congress that need to know what this program does.

Sayler asked about the current use of the Bioenergy Research Centers. Brinkman answered that they will be protected.

Patricia Dehmer [Deputy Director for Science Programs, Office of Science, USDOE] was asked to describe the new charge on data management being made to all of the advisory

committees. A snapshot of what each community is doing about storing, assuring access to, and disseminating data is being sought. The Nuclear Science Advisory Committee (NSAC) is being asked to report current policies, practices, dissemination models, and opportunities for enhancing public-access policies and practices. There were six directives, the first of which was to establish the National Science and Technology Council (NSTC) working group mentioned by Brinkman.

Stacey said that a questionnaire about data-management and -access practices has been put together and will be circulated to all Committee members. The information from questionnaire will be collated and forwarded to the working group.

A break was declared at 10:50 a.m., and the meeting was called back into session at 11:21 a.m.

Sharlene Weatherwax [Acting Associate Director of Science, Office of Biological and Environmental Research, Office of Science, USDOE] was asked to report on the state of the Office of Biological and Environmental Research (BER).

This is a challenging period. There are strategic increases in the FY12 budget request, but there is no budget for FY11 yet.

In the Biological Systems Science Division (BSSD), Genomic Science has $241.5 million in the request, Radiological Sciences has $34.3 million, and Biological Systems Facilities and Infrastructure has $90.2 million. Ethical, Legal, and Societal Issues and Medical Applications have been zeroed out. Of the $376.3 million requested, $286 million is for research, and $90.2 million is for facilities and infrastructure.

In the Climate and Environmental Sciences Division (CESD), $26.4 million has been requested for Atmospheric System Research, $101.2 million for Environmental Systems Science, $77.3 million for Climate and Earth System Modeling, $128.2 million for Climate and Environmental Facilities and Infrastructure, and $8.6 million for the Small Business Innovative Research/ Small Business Technology Transfer (SBIR/STTR) Program. Of the $341.6 billion requested, $214.1 million is for research, and $128.2 million is for facilities and infrastructure.

New opportunities that have been proposed in the FY12 request for BSSD include developing new synthetic molecular toolkits for understanding natural systems combined with computer-aided design testbeds; further developing fundamental components, articulating principles and modeling the systems, and placing great emphasis on the knowledge base; and developing life-science experimental stations and instrumentation.

New opportunities that have been proposed in the FY12 request for CESD include prototyping of the experimental structure needed to initiate the next-generation ecosystem–climate-change experiment with a focus on Arctic tundra; performing research on carbon-cycle multi-scale dynamics to describe presently observed system noise; enhancing research to develop numerical methods and model testing and validating a comprehensive, coupled, high-resolution Earth-system model; and introducing new remote sensing and in situ measurements of clouds and aerosols, including a new fixed Atmospheric Radiation Measurement (ARM) site in the Azores for remotely sensed measurements of marine clouds and aerosols. Acquisition of new instrumentation for the Environmental Molecular Sciences Laboratory (EMSL) is also requested.

Some difficult changes had to be made in BSSD. Funding is reduced for studies on bystander effects and adaptive immune function, and research on genome instability and DNA damage in single cells in response to low-dose radiation exposure was ended. Ethical, Legal, and Societal Issues research was completed as a stand-alone activity. Funding for the Artificial Retina effort was completed with integration and pre-clinical testing of a 240-electrode retinal device as a basis for the fabrication of a 1000-electrode device.

In CESD, a series of research projects focused on the cycling of carbon sequestration associated with long-studied field sites was completed, and the graduate-education program was ended.

Anna Palmisano retired in November, Kiran Alapaty moved to the Environmental Protection Agency (EPA), and Marvin Stodolsky retired after 20 years in federal service. New staff include

Dan Stover, ecologist; Pablo Rabinowicz, on loan from the University of Maryland School of Medicine; and Dorothy Koch, team leader for climate modeling. Patrick Horan will arrive in April as a science assistant. A new Associate Director is being sought; the announcement closed January 31. An atmospheric scientist is also being sought, but this position has been stalled because of the continuing resolution.

There were two 2010 Presidential Early Career Awards to scientists and engineers in BER: Jacob Hooker at Brookhaven National Laboratory and Trent Northen at Lawrence Berkeley National Laboratory. Seven BER awards are anticipated in FY11.

Because of the late resolution of the FY11 budget, no solicitation for the SC Graduate Student Research Fellowships was released. It was postponed until FY12, potentially in the fall of 2011.

DOE is cooperating with the National Science Foundation (NSF) and the U.S. Department of Agriculture (USDA) on regional climate modeling. NSF contributed $30 million, DOE $10 million, and USDA $9 million to an FY10 solicitation. Decisions are pending on the availability of FY11 funds.

BER performs transdisciplinary science and systems-based, data-intensive, and diverse research, a lot of which is collected through world-class, high-impact use of facilities. Much scientific partnering is performed to meet DOE emission needs.

DISCUSSION

Robertson asked Weatherwax to elaborate on the "completion" of the BER education program and asked if this cessation indicated less interest in graduate education. Weatherwax answered that the BER fellowship program was seen as redundant to the SC Graduate Research Fellowship Program, which provides broader support.

Joachimiak asked how one communicates the value of science to the new Congress. Weatherwax encouraged all of the Committee members to communicate the importance of basic science and to stress the importance of user facilities that serve hundreds of thousands of users from around the world.

Zavarin asked how the funds for new instruments are to be distributed to EMSL and ARM. Weatherwax responded that Geernaert will present a lot of detail about that subject in his talk. Stacey noted that Allison Campbell would speak on that topic at the next BERAC meeting.

Stacey asked if these new opportunities were to come out in 2012. Weatherwax answered that workshops (e.g., on clean energy) and partnerships with other agencies were anticipated in FY12. The Office wants to be more proactive in these activities through funding opportunity announcements and in partnering with facilities.

Wildung asked about radiation biology. Weatherwax responded that epidemiological data will make a lot of new transitions from single cells to organisms.

Sayler asked where carbon cycling and sequestration research will be recaptured. Geernaert replied that the Carbon Sequestration in Terrestrial Ecosystems (CSITE) program has been an important one; the Office will try to wrap up all of the information in the next year. It will continue carbon-cycling work, which will be a multi-geography effort. It is hoped to have a tropic experiment as well as others. It will be a third-generation carbon-sequestration effort.

Paul Bryan [Manager, Biomass Program, Office of Energy Efficiency and Renewable Energy, USDOE] was asked to describe the activities in DOE/EERE's Biomass Program.

The focus of the Biomass Program is bringing ideas to commercial reality. There have been great advances in manipulating biological systems. The Office of Biomass looks at the whole value chain: feedstocks, conversion technologies, integrated biorefineries, infrastructure, biopower, and advanced systems.

The Biomass Program's budget has been increasing, with new components being added (e.g., a reverse auction for subsidies to biofuel manufacturers, biopower, algae, and thermochemical and biochemical conversion).

The program has been working toward developing the resources needed to reach the Renewable Fuel Standard (RFS). It published the billion-ton report and its update. Its data will be available through the Knowledge Discovery Framework (KFD) at ORNL. The Program has been unlocking baseline productivity, moving to improve that productivity, measuring sustainability, and supplying a uniform, high-density, stable feedstock. It is looking to shift the emphasis on feedstock productivity to the USDA, implement the Uniform Format Feedstock Supply Design, and fully implement the Biomass Crop Assistance Program (BCAP).

Where in the United States today could one put cellulosic biomass facilities? Because of the cost of transport, they could only be put where corn is intensively cultivated because one can use half of the corn stover. One can move corn by truck to grain elevators and then to trains or barges and then to market. The same type of transportation system needs to be developed for biomass feedstocks. The biomass (e.g., corn stover) would have to be stabilized. Such a multimodal transport system would hugely increase the areas that could be exploited for biofuel feedstocks.

In conversion, the program is focusing on energy crops, algae, and urban waste through three platforms:

- cellulosic sugar
- pyrolysis oil
- lipids (oils)

Several of these platforms require upgrading the primary product.

Ethanol only replaces gasoline; it does not replace the "drop-ins," such as diesel oil, petrochemicals, and jet fuel. One has to replace all the products of a barrel of crude oil. The foreseeable capacity is 100% ethanol. The conventional renewable fuel will be corn ethanol; the first major commonplace renewable fuel will be Brazilian sugar ethanol. There is no single hydrocarbon that is a panacea. The chemical nature of a renewable fuel would require huge retrofit costs and problems for users in its deployment. In addition, combustion behavior is very complex.

Advanced biofuel refineries will largely produce ethanol. To make a gallon per year of biofuel requires $10. The technology needs to be made more effective so elements of scale can kick in.

Algae collect about 10 times the solar energy that leafy plants (e.g., corn) do. Algae production uses flat wastelands; it uses carbon dioxide and wastewater as feedstocks; it can also produce co-products (e.g., animal feed). Capital costs are high; Algae is inefficiently harvested and dried; siting can be a problem.

SC looks at discovery and basic research; the technology offices look at applied research and technology maturation and deployment.

DISCUSSION

Penner asked how much contact the biomass program has with BER, which is predicting water availability. Bryan replied that the program is looking at crops that would require no irrigation. It is looking at how the billion-ton study changes with climate.

Hubbard asked if an accounting-based approach or other approach were used. Bryan answered that an accounting-based approach [e.g., ANL's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET)] was used. The Program is expanding into water usage and soil health. Hubbard noted that that would provide a good interface with BER.

Shugart asked whether soil nutrients and soil degradation would be a problem. Bryan replied that that has been discussed at length with the USDA's, and the optimal level of stover removal was seen to be half. The Program would look at returning the minerals to the fields through animal feeds and manure fertilization and through gasification energy extraction.

Wildung asked what the relationship was between EERE and BER. Bryan responded that the two organizations have had several relationships. They are all based on ethanol and include partnering with the Joint Genome Institute (JGI). BER can improve and manipulate biological

systems to improve the productivity of crops (including converting tough sugars to hydrocarbon fuels, especially diesel fuel) and expand the range of crops (e.g., through salt tolerance).

Wall asked if there were a solution to piping ethanol. Bryan answered, yes. The Brazilians have done it. It would cost billions of dollars and require the acquisition of rights of way.

Zhang asked if any algal fuels were available. Bryan responded that algal fuels are only available at test quantities. The proof of concept is there; the economics of production are yet to be established. Algae that produce sugars will have to be competitive with corn ethanol shortly.

Robertson asked if the subsidy program's auction will be solely on a monetary basis or if it would include sustainability components. Bryan said that a fuel must produce a 60% reduction in the net carbon dioxide production. One also has to consider the carbon dioxide release resulting from the cultivation of virgin fields.

Joachimiak noted that the field is rapidly changing and asked how BER can make a significant impact. Bryan said that it could make an impact in fundamental sustainable crop production (through genomics) and by developing a platform for producing economic products from sugars.

Stacey asked about the food-versus-fuel controversy and the displacement of land uses in biomass production. Bryan said that biomass production should not negatively impact the human food supply. Corn stover would not compete with food. Work on bioenergy crops could positively impact food production; salt-tolerant fuel crops would expand the production of food crops. Linking the cost of vegetable oil to that of diesel oil was a disaster. There has to be a limit on the amount of food crops converted to energy production.

A break for lunch was declared at 12:50 p.m.

Wednesday, March 9, Afternoon Session

The meeting was called back into session at 12:18 p.m.

Gary Geernaert [Director, Climate and Environmental Sciences Division, Office of Biological and Environmental Research, Office of Science, USDOE] was asked to give an update on the Climate and Environmental Sciences Division.

There have been three new hires in the Division: Dorothy Koch in climate modeling, Renu Joseph in climate modeling, and Dan Stover in terrestrial ecology.

Priorities have been set (1) to build on historical strengths and use of facilities, high-performance computing, and fieldwork and to develop new campaigns that incorporate more disciplines; (2) to address Arctic ecosystems; (3) to model natural variability; (4) to develop revolutionary experimental methodologies with other agencies; (5) to manage massive data sets efficiently; and (6) to address uncertainty quantification (UQ).

Workshops have been held on Arctic permafrost in climate science to identify what investments will provide the largest scientific return, on UQ to look at how to develop methodologies, and on climate prediction to develop capabilities on Earth system projections. In addition, there have been (1) a review of the ARM Program and (2) various programmatic interactions with other offices and agencies.

$125 million was received for Recovery Act projects. The EMSL received $60 million for new equipment, all of which is in place and either accepted or in the acceptance phase. The ARM Climate Research Facilities received $60 million for revolutionary capabilities that will benefit the international community, all of which are now in place.

All of the ARM Climate Research Facilities have been upgraded to provide 3-D, high-resolution cloud data. The two mobile and three fixed sites are all operational. One mobile facility just completed an Azores campaign; the results indicate the need for a permanent facility. That mobile facility will begin a Ganges Valley, India aerosol experiment in late spring. A third campaign will investigate the Madden-Julian Oscillation on the Island of Gan in October. The *Quarterly Journal of the Royal Meteorological Society* will present 22 articles in its March issue

on the advances in the understanding of convective processes and precipitation over low-mountain regions, which papers resulted from the deployment of an ARM mobile facility in the Black Forest area of Germany in 2007. Another mobile facility continues to operate in Colorado to measure cloud and aerosol properties, looking for the role of aerosol nucleation in the event formation. Observations from this facility are available in real time.

Atmospheric system research has produced an article on ice nucleation, a difficult process to measure and model. It re-analyzed older data and put a parameterization and theory framework in place. The study of human influences on extreme precipitation ended up on the cover of *Nature*. It provided the first scientific evidence that human-induced increases in greenhouse gases have contributed to the observed intensification of heavy precipitation events. There are large spatial variabilities of sea-level rise produced by El Niño and other processes. Global warming is causing the atmosphere over the Indian Ocean to warm in ways that are different from the way the ocean is warming, changing the spatial variability of sea-level rise. The more frequent El Niño events observed under greenhouse-forcing scenarios are consistent with a more energetic late 20th century North Pacific Gyre Oscillation (NPGO) and imply that the NPGO may play an increasingly important role in shaping Pacific climate and marine ecosystems in the 21st century. The more frequent appearance of this anomalous temperature change in the mid-Pacific is expected to affect rain all over China and North America.

Early work of the Division focused on the North Atlantic and the potential of the slowing down of the North Atlantic conveyor belt. The early work was based on coarse grid models. Now, all ocean basins are being focused on, and higher-resolution models are being used. They give different answers and impacts. If one were to have greenhouse-gas-reduction strategies in place, the effects could be reversible. In other research, the dynamics of methane-clathrate emissions were analyzed and characterized, and the predictive understanding of the structure and functions of Arctic terrestrial ecosystems in response to climate change is being studied. An article in the *Proceedings of the National Academy of Sciences* showed that carbon "fertilization" is limited by nitrogen availability. Americaflux results have shown that evapotranspiration analyses have to consider surface hydrology. Statistical techniques have been used to increase substantially the accuracy of seasonal hurricane count forecasts. An integrated assessment was conducted on the impact of climate change on the U.S. wind energy resource. In a surprise result, dissolved organic matter was found to both increase *and* decrease methyl mercury in streams; ORNL found that the effect was concentration-driven.

The Environmental Molecular Sciences Laboratory (EMSL) is holding a users meeting in May of 2011. Two research campaigns have been selected with experimental and competition research focused on data integration. EMSL serves a broad base of users from within and without DOE and is progressing to a new class of user facility. EMSL's cryogenic nuclear magnetic resonance (NMR) capabilities and theory helped prove the validity of a photosynthesis model. EMSL also recently showed that charging makes nano-sized electrodes swell, elongate, and spiral, suggesting how rechargeable batteries give out and offering insights for building better batteries.

DISCUSSION

Shugart asked if the Arctic system includes boreal areas and whether DOE was able to work with the Russians. Geernaert replied that boreal systems broadly are not the Arctic; however, the Office is doing a separate study of boreal systems. As the permafrost warms, it will be very much like a boreal system in hydrology and in other characteristics. And yes, the Office will have a workshop this summer to which the Russians are invited.

Wildung asked Geernaert what he meant by a business model. Geernaert responded that the scientific return on investment is being quantified and that a UQ framework was being established to distribute the uncertainty so areas with the greatest potential return as an investment could be identified. The Office wants to advance discovery through teams of inquiry. Wildung asked if there were a potential for integration of the program. Geernaert answered that

they had not gotten that far but were looking for ways to address uncertainty in a class of problems.

Stacey asked if they had thought about how new equipment drives up the costs of maintenance and operations. Geernaert replied affirmatively. Those increased costs are addressed by increases in future budgets, and budget constraints can make that process difficult. In FY18 or FY20, maintenance costs will increase, and difficult choices will have to be made.

Sharlene Weatherwax [Acting Associate Director of Science, Office of Biological and Environmental Research, Office of Science, USDOE] was asked to present an update on the Biological Systems Science Division.

Three solicitations are in process. One on genomic science and technology for energy and environment just closed; reviews and selection have been made; funding authorization is being awaited. One on plant feedstock genomics for bioenergy will depend on funding. And one on systems-biology knowledgebase architecture is awaiting proposals.

A DOE Switchgrass Workshop was held to coordinate efforts across agencies and researchers, looking for gaps in knowledge and the types of genomes needed. Priority needs were identified. Requirements that were noted included the ability to screen for natural variation in desired traits, the availability of protocols and factors for high-efficiency genetic transformation, and the development of specific genome-based sequence markers. The workshop participants formed a Switchgrass Executive Committee to define the group's scope, develop processes for information sharing, and continue follow-on discussions.

The DOE Human Subjects Protection Order has been updated to include requirements set forth in the December 2009 Secretarial Policy Memo on "Military and Intelligence-Related Research." This research seeks to understand the motivations and behavior patterns of the people among whom the U.S. armed forces are operating. Modifications prohibit DOE laboratories from sending researchers to these countries to do the data collection but allow them to contribute their computational and modeling capabilities and to analyze de-identified data. In addition, reviews of DOE-site human subjects protection programs will be conducted in 2011, and regular meetings of the central DOE Internal Review Board (IRB) will be held.

A study of cyanobacterial hydrogen production under aerobic conditions came out of a BER program. In light, this organism produces hydrogen; in dark, it fixes nitrogen and generates hydrogen. Transcript analysis shows that hydrogen production is driven by nitrogenase rather than hydrogenase.

A study to understand structure–function relationships for bioprocessing enzymes through visualization produced new information about how enzymes bind, recognize, and process carbohydrate substrates and about how variations in enzyme structure impact enzyme function. This work helps explain key steps in carbohydrate metabolism.

A new process for semantic indexing of patent literature maps techniques or technologies against microbes and indicates the number of patents for each pair, identifying promising lines of research.

A study of computational approaches to simulate microbial ecosystems takes flux-balance algorithms and looks for growth media that force microbe pairs to cross-feed. It thus identifies types of microbial interactions, nutrient exchange, and media requirements that promote community growth.

The Great Lakes Bioenergy Research Center looked at how the gram-negative bacterium *Cellvibio japonicus* secretes its diverse complement of extracellular cellulases and found that wild-type *C. japonicus* effectively solubilized and consumed biomass but mutants lacking the outer membrane secretin of the type II secretion system could not. This finding provides new targets for metabolic engineering of *C. japonicus* to make biofuels.

The Joint Bioenergy Institute (JBEI) developed a microfluidic technology for the rapid (one minute per sample) and large-scale screening of cellulases. It developed a mathematical model based on molecular weight and separation parameters to rationally select the system characteristics for optimized separation.

The Bioenergy Science Center (BESC) altered a gene to increase the biomass in dicots. It found that loss of function in a single gene leads to a significant increase in stem biomass, suggesting a strategy to enhance biomass without adversely affecting the health and fitness of the plant.

Rice genetic variation in bioenergy traits was analyzed to detect significant variation among all lines. The variation was explained largely by variety and breeding history rather than by varietal group, suggesting the existence of multiple targets for biomass improvement.

New tools were developed to measure elemental distributions in archived tissues and to highlight applications of new molecular-biology techniques to tissues from historic mega radiobiology studies. Open access to these extensive archival materials provides a resource that can avoid or reduce the scope of new animal experiments while achieving a better understanding of radiation qualities, doses, and dose rates.

New quantitative methods were developed for using positron emission tomography (PET) to determine radiotracer concentration in plants. This work enables study of dynamic physiological processes in plants with PET to understand plant responses in active ecosystems.

The Joint Genome Institute (JGI) studied the genomics of *Daphnia pulex* to understand the environmental response of complex biological systems. Many tandem gene clusters were observed, with varying expression patterns under differing environments seen.

In the future, BSSD will have principle-investigator (PI) meetings in radiochemistry and instrumentation research, genomic sciences, and low dose. It will also hold workshops in structural biology and synthetic biology.

DISCUSSION

Sayler noted that the first announcement had said that the daphnia study showed 77,000 genes rather than 30,000. Weatherwax responded that the final paper was more conservative in its method of estimation.

A break was declared at 3:53 p.m., and the meeting was called back into session at 4:15 p.m.

Todd Anderson [Program Manager, Climate and Environmental Sciences Division, Office of Biological and Environmental Research, Office of Science, USDOE] was asked to present the response of the Climate and Environmental Sciences Division (CESD) to the Committee of Visitors (COV) report on the Division.

In regard to the general CESD issues:

- *The COV recommended that more support staff and program managers be made available.* BER is actively recruiting and hiring new program staff.
- *The COV recommended that more-informative statements be included in declination letters.* BER agrees and recently adopted an Office-wide measure to provide a short summary of program decisions in declination letters.
- *The COV recommended that the productivity of program managers and support staff be enhanced by a well-designed and -maintained electronic grants information system.* Program staff are in discussions with the Office of the Deputy Director for Science Programs about implementing the portfolio analysis and management system (PAMS) in CESD.
- *The COV urged that accountability of all scientists associated with a Scientific Focus Area (SFA) be carefully monitored and recommended that a plan for re-competing SFAs be put in place.* BER agrees. Re-competition of national laboratory programs is not the main intent of the SFA process. Rather, BER is challenging the national laboratories to stand-up and maintain long-term, team-oriented mission-focused science within these programs that is distinct from financial assistance awarded to academic and/or private research institutions. SFA programs are reviewed every 3 years in prospective and retrospective reviews, and the review results are consequential.

- *The COV encouraged more effort to showcase the contributions of DOE to the public.* BER agrees. An internal communications team has been assembled within BER to develop new methods of communication products to showcase a BER science. Highlights are collected weekly. BER visibility at national meetings is increased by hosting symposia, co-locating booths, etc.; and BER is taking leadership roles in interagency activities.

In regard to the Atmospheric Systems Research (ASR) issues:

- *The COV recommended that quantitative metrics of the output publications be considered.* The ASR website does provide a list of all publications with options to search on particular topics to track program performance. A set of metrics would potentially be useful in identifying new science areas, but broad input by the scientific community in the form of workshops is also important.
- *The COV recommended that the inclusion of accomplishments from prior support from the program be required as part of the proposal process.* All renewal applicants are now requested to include results obtained from prior support, and renewal applications will continue to be required to provide a summary of past research progress.
- *The COV recommended that the programmatic issues used in funding decisions should be fully documented and suitably articulated.* BER will more fully document the funding decision-making process.
- *The COV strongly encouraged increasing attention to PI diversity and balance across career development.* Diversity is an objective of the ASR. Career development is a strong focus in ASR funding activities. ASR has four postdoctoral fellows at national and international modeling centers and a fifth under consideration. ASR also participates in the Early Career Researcher Program.
- *The COV recommended that the definitions of conflict of interest should be more formally defined.* DOE policies and rules on conflict of interest are set at the Office of Science level. ASR will continue to articulate and implement those rules.

In regard to the Terrestrial Ecosystems Science (TES)/Terrestrial Carbon Sequestration Research issues:

- *The COV recommended that the program manager reduce the number of non-review renewals so that awards would be guided by competitive processes that are transparent, rigorous, and well-documented.* Project renewals are not made without peer review. The COV may be referring to the 1-year extensions, which have been used in the past when an additional year of funding is judged by the program manager to be justified. This is not a routine funding mechanism.
- *The COV recommended that the TES program consider bringing the state-of-the-art ecosystem models and climate modelers together to determine how ecosystem models can be better interface with climate models.* BER agrees and will develop plans to conduct such a meeting.
- *The COV recommended that the program rapidly transition to a system of solicitations for non-national laboratory science that includes (1) an annual solicitation, (2) fewer renewal proposals and more longer-term awards for proposals that clearly have a term longer than 3 years, and (3) funding for synthesis activities.* BER agrees. TES will follow the general BER practice of soliciting 3-year projects from the academic community, explore the use of longer-term projects, and promote science-synthesis activities.
- *The COV recommended that the program consider a solicitation to fund collaborative work with the Spruce and Peatland Responses Project and the Next-Generation Ecosystem Experiment.* BER agrees. Both projects are intended to support external collaborators in addition to the core experiment. TES solicitations will provide funding opportunities to participate on these projects.
- *The COV recommended considering an emphasis on model needs or deficiencies as a selection criterion for proposals.* BER agrees. This consideration was highlighted in the

program's most recent solicitation and was an important criterion for making funding decisions.

- *The COV recommended considering soliciting short, lower-cost proposals for high-risk–high-reward ideas for proof of concept.* BER agrees. Shorter-term exploratory proposals were a component of the program's most recent solicitation.
- *The COV recommended keeping the program informed on publications.* BER recognizes this challenge and agrees with the COV's recommendation. With the additional staff, TES should be able to allocate more time to tracking the progress, publications, and other accomplishments of programs.
- *The COV recommended as a high priority the development of web pages that document the program and continue to update impact.* BER agrees. Web-based information about the TES program will be a priority.
- *The COV recommended continuing the transition from projects that are renewed with little review to funding based on periodic solicitations for proposals and rigorous transparent reviews that are carefully organized to minimize bias and conflicts.* BER agrees and intends that renewals will be an exception in the future.
- *The COV recommended continuing to solicit research on important topics that cannot be accomplished outside the program.* BER agrees. BER works closely with other federal agencies through the global change research program to ensure that its programs are appropriately integrated with and distinct from those of other agencies.
- *The COV recommended recruiting more highly qualified reviewers.* BER will continue to strive to recruit reviewers of the highest caliber regardless of national origin. Recruiting qualified, unconflicted reviewers is an ongoing and recognized challenge. BER seeks to achieve balance in its panels (in gender, age, institution, etc.). Program managers will be encouraged to seek international representation as a form of review-panel diversity.

In regard to the Subsurface Biogeochemistry Research (SBR) issues:

- *The COV recommended that the language dealing with the linkage between existing DOE field sites and DOE collaborators be strengthened to emphasize the importance of this connection in the decision process.* BER points out that all projects must provide an explanation of the environmental relevance of the proposed research. The language will be clarified in future solicitations.
- *The COV recommended a more consistent format and content of the annual SBR SFA progress reports and the use of videoconferencing for progress reporting, where possible.* BER agrees. Guidance on report production is provided in the SFA management documents, but a review of the report format and utility is appropriate and will inform future submissions. BER will consider the videoconferencing of progress reports.
- *The COV recommended broadening the scope of the portfolio and the establishment of links to the climate change and climate-cycling efforts in CESD.* BER appreciates the finding. Broadening the scope of the program is intended to allow for more effective integration within CESD, enabling BER to develop new initiatives across programs. This is a part of the new strategic planning process within CESD.
- *The COV recommended developing a comprehensive data management plan for all Integrated Field Research Centers (IFRCs).* BER agrees. Preliminary workshop plans are being developed. A mini workshop will be conducted on this topic immediately following the SBR PI meeting in April 2001. This topic extends well beyond SBR.
- *The COV recommended developing plans for re-competing the IFRCs soon.* BER agrees. After successful mid-term reviews, the IFRC projects have been extended a year to complete ongoing projects. The program will request proposals for new research in FY12 for FY13 funding.

In regard to the Climate Modeling Program issues:

- *The COV recommended a program of mentoring for new program managers.* BER agrees. Mentoring a relatively new program management staff for the program is ongoing. Similar mentoring efforts will be made with future new hires.
- *The COV recommended installing a more systematic method for the allocation of high-performance computer resources, coupled to the funding of the project.* BER agrees and is working with ASCR to explore ways to more closely align the allocation of resources from these two SC programs.
- *The COV recommends two or three additional program managers for climate modeling.* BER appreciates the comments. It recently hired two full-time program managers and continuously evaluates its staffing needs and shares those needs with SC.
- *The COV recommended long-term support for vital high-profile committees for the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and computing for the Intergovernmental Panel on Climate Change and the Coupled Model Intercomparison Project.* BER agrees and is working with ASCR to identify mechanisms to maintain the Earth System Grid (ESG) without negatively impacting CESD modeling programs. BER will work with other federal and international agencies to ensure that effective planning for future modeling needs is in place.

In regard to the Atmospheric Radiation Measurement Climate Research Facility issues:

- *The COV noted that the Atmospheric Radiation Measurement Climate Research Facility is managed separately from the science that uses data produced by the facility and recommended that a reliable mechanism for frequent communication exchanges with the modeling scientists be established.* BER disagrees with the premise that the relationship between the Atmospheric Radiation Measurement Climate Research Facility and the supporting research programs has changed. ARM program managers attend ASR Working Group and Science and Infrastructure Steering Committee meetings with ASR program managers. Mechanisms are in place to routinely solicit scientific input from ASR scientists, the ASR working groups, and the Science and Infrastructure Steering Committee (SISC). These mechanisms are long-standing, time-tested, and proven to be effective.
- *The COV recommended convening a face-to-face meeting or teleconference for the technical merit review panel to discuss disparate proposal evaluations.* BER agrees. This program is implementing face-to-face meetings for its merit-review panels.
- *The COV recommended that "best-estimate" data-set-development activities should be continued and broadened to include measurements/data from other areas of Earth science research.* BER agrees. Input will be solicited from the community to identify candidate sets and to establish priorities for their development.
- *The COV recommended assessing whether the Atmospheric Radiation Measurement Climate Research Facility measurement suites deliver sufficient chemical and biogeochemical data to support the basic development of climate model components.* BER agrees. This will be accomplished through a workshop and developed jointly with ARM, ASR, and Climate Modeling Program managers.
- *The COV recommended that ARM implement an agreement on the data registration webpage to include a standard one-sentence acknowledgement statement in all publications or presentations that make use of ARM/Atmospheric Radiation Measurement Climate Research Facility data.* BER agrees, and the recommendation will be implemented as soon as possible.

In regard to the Environmental Molecular Sciences Laboratory (EMSL) issues:

- *The COV recommended users write short proposals to obtain access to the sophisticated instrumentation and expert guidance of EMSL personnel and that the proposal guidelines be firmly enforced to prevent the perception of, or actual, inequitable treatment. Furthermore, the program should enforce the proposal requirements.* BER agrees, and guidance has been transmitted to EMSL management to enforce the proposal guidelines.

- *The COV recommended that the definition of distinguished users should clearly indicate recognition of the highest level of scholarship and research accomplishment.* BER agrees and will work with EMSL to evaluate a way to clearly distinguish scientific from organizational recognition.
- *The COV recommended attracting more industrial uses.* BER agrees and has asked EMSL to propose outreach mechanisms and/or incentives that would increase the potential for industrial users.
- *The COV recommended support to continue acquisition of state-of-the-art equipment.* BER agrees and will continue to develop capitalization plans for EMSL and maintain support for state-of-the-art equipment.
- *The COV recommended including in the FY11 science and operational review of EMSL a comprehensive assessment of ES&H [environment, safety, and health]*. BER agrees and will include such a component.
- *The COV recommended that the travel budget for the program manager be increased.* BER recognizes the potential travel needs of program managers with responsibilities for facilities. Each division within BER holds a reserve for travel needs beyond a standard allocation. Facility program managers are given higher priority in travel allocation from this reserve. Today, BER has been able to accommodate all necessary travel through this mechanism.

DISCUSSION

Dickinson called attention to the fact that a statement had been left out: The COV was impressed with the Division's operations.

Shugart noted that *Science Citation Index* was being used as an index of scientific quality, but it does not cover books. He suggested asking people who have used *Science Citation Index* in this manner.

Wildung noted that the COV had said that there is little evaluation of the Atmospheric System Research portfolio by the program and that that is in stark contrast with what the COV said about quantitative evaluation. Anderson responded that a more consistent format for reviews is being introduced across the Office.

Wall said that, prior to the SFAs, proposals came in from universities and national laboratories together; now there are parallel systems. She asked whether that doubled the Division's work. Anderson answered that it certainly has not decreased the workload. Weatherwax added that, although there are now parallel tracks, for the national laboratories, the Office is not soliciting new SFA areas; therefore, that workload has decreased.

Robertson noted that there was a recommendation for *requiring* the mentioning of results from prior research but that the actions said that the Division now *requests* such information. Ashley Williamson [Program Manager, Atmospheric System Research, Office of Biological and Environmental Research, Office of Science, USDOE] responded that such information *is* required.

Sayler asked whether, in attracting more industrial users, there were any considerations of cost recovery. Anderson replied that industrial users are treated differently; they are charged for the use of the facility. Paul Bayer [Program Manager, Environmental Molecular Sciences Laboratory, Office of Biological and Environmental Research, Office of Science, USDOE] added that, if industrial users publish their results in the open literature, they use the facility for free.

Sayler asked whether, in recompeting the Atmospheric Radiation Measurement Climate Research Facility s, there should be more emphasis on fundamental hypothesis-driven research. Anderson responded that there could be.

Zavarin asked if the balance in funding by the Division between the national laboratories and universities had changed since the inception of the SFAs. Anderson answered that what has been seen is national laboratories being used as co-principal investigators (co-PIs) by universities. The scope of national laboratory co-PIs has been limited monetarily. He did not have at hand the hard numbers about the total amount of money going to the national laboratories and the universities.

The floor was opened to new business. There was none. The floor was opened to public comment.

Min Park [Bioscience Division, Los Alamos National Laboratory] said that research initiatives used to be able to be presented to BER. Because funding is now coming to the SFAs, BER does not have a mechanism to respond to such small funding needs. Weatherwax pointed out that the SFAs are for long-term funding, exploiting the strengths of the national laboratories. FOAs are open to universities. At the same time, there are mechanisms for funding small, innovative projects. Park noted that the number of new solicitations targeted to national laboratories is not as great as it was prior to the implementation of SFAs. Hubbard said that, within SFAs, there can be consideration of small, innovative projects. That is part of the flexibility of SFAs. Joachimiak added that it is good to be open-minded about the need for flexibility in the conduct of SFAs. Hubbard pointed out that SFAs are each committed to a 5-year program, but they should be open to innovative ideas. Park asserted that the Congressional language on Laboratory-Directed Research and Development (LDRD) funding does not allow funding of such projects.

There being no other public comments, the meeting was adjourned for the day at 5:10 p.m.

Thursday, March 10, 2011
Morning Session

The meeting was called back into session at 9:00 a.m., and **Sharlene Weatherwax** [Acting Associate Director of Science, Office of Biological and Environmental Research, Office of Science, USDOE] was invited to respond to the Committee's report on the Long-Term Vision for Grand Challenges in BER.

The cross-cutting themes of the report are

- Complex systems science across scales
- Multidisciplinary research
- Computation and mathematics
- Broad view of human impacts and feedbacks
- Uncertainty quantification and data management

Some of the key recommendations of the report are that systems biology provides the approaches needed to address biological complexity, while synthetic biology tests this understanding through application; that biology is becoming a data-intensive, informational science that requires new paradigms to deal with data management and complexity; that issues of climate change and sustainability require that the development of a better understanding of Earth system processes; and that an essential component of energy sustainability is fundamental knowledge of relevant natural and physical processes, their interactions, and their human influences, which cuts across a number of the themes.

The budget narrative for the FY12 request is posted on the Office's website. That request is largely driven by the vision offered by the Committee. In clean energy by biodesign, the request calls for identifying fundamental biological design principles, developing synthetic molecular and genetic toolkits, and developing computer-aided biodesign testbeds. Planning for a workshop is under way. In scaling from genome to climate, the request points to the need for modular add-ons; improved data assimilation and uncertainty quantification (UQ); the extension of models to more-rapid climate change requiring more-accurate prediction of terrestrial domains; and next-generation ecosystem experiments, which will involve a series of workshops. And in multidimensional climate data and knowledge management, the request points to the need for adaptable model physics and parameterizations as scales change (i.e., the rolling up of information so it is not so cumbersome); the integration of atmospheric models with surface

hydrology, ecology, and soil biogeochemistry, showing interdependencies, impacts, and feedbacks; and knowledgebases for all the science BER does and the pursuit of UQ.

DISCUSSION

Stacey said that he did not see sustainability mentioned. Weatherwax said that the Office does not have a concrete plan on how to address sustainability. It is something that will have to be done in concert with other agencies, and the Office is awaiting indications of what those other agencies are going to do.

Geernaert noted that the Office was trying to bridge its activities and is seeking community involvement. One thrust is natural variability. Others are extremes, tipping points (setting the stage for the permafrost initiative), scale interactions (one of the most poorly pursued scientific problems), integrating all the systems (soil, ocean, atmosphere, ice sheets, etc.) and models, sustainability (leading to an ability to assess the long-term effects of bioenergy strategies), and benchmarking/UQ/data management.

Gaps and the DOE niche need to be identified, leveraging other agencies' investments to advance DOE's goals. Federal program managers have a responsibility to be aware of what their neighbors are doing and to fuse their activities with the neighbors' activities. The report is an extraordinary document.

Weatherwax stated that there are pieces of sustainability in all the activities of the Office. That issue will continue to be embedded in other programs. The Integrated Assessment program touches everything, also, producing cross-talk.

Geernaert said that sustainability is why climate science is important to the nation. Climate change is increasingly becoming a driver of other national challenges and priorities (e.g., national security).

Mace asked what the next concrete steps are. Geernaert replied that the Office had held a leadership retreat, and the knowledgebase, UQ, and data management were seen as tasks that have to be accomplished in the next 4 to 5 years. Weatherwax added that the Office needs to identify the major people and have them write documents and hammer out a framework for a climate knowledgebase (ultimately, the knowledgebase will have to serve those researchers) and then BER must use that climate knowledgebase as a template for a systems biology knowledgebase. A budget is needed to do that.

Sayler asked if that plan extends to plants and whole ecosystems. Weatherwax replied, yes; that is how the report seems to read. It will draw on all the facilities' capabilities. This is a big, scary step forward.

Stacey said that it was clear that not all the needed expertise was present at the meeting. There should have been some sociologists. Weatherwax agreed and said that the structure of future workshops will allow for that. Such expertise does not exist in BER. Stacey urged thinking big and grabbing a leadership role in synthetic biology, computational biology, etc. Weatherwax agreed and said that DOE accepted the challenge.

Wildung pointed out that it is important that DOE actually does what it is proposing to do. It is easy to have scope creep that incorporates and embeds a lot of targeted topics. He urged DOE to focus on basic science.

Fowler pointed out that it is important to engage the public and Congress about how important this research is. Geernaert agreed. The climate community has to define important issues like a tipping point occurring by 2050. It has not been successful with the public because climate community has not stepped back and provided concrete concepts. Discussions are being held about having town meetings with the American Geophysical Union (AGU) and reaching out to the scientific community. Weatherwax pointed out that BER had a presence at the American Association for the Advancement of Science (AAAS) meeting and hosted discussions on family day. Committee members should look for opportunities like this, and when they have found them, the Office will support those efforts.

Robertson pointed out that it is important to recognize the underlying role of sustainability. He suggested drawing up a map of how sustainability concerns are addressed by the different activities of BER.

Sayler said that little has been said about manipulative research. The role of manipulative experiments and how they illuminate "natural systems" need to be explained. Weatherwax said that the Office might have a testbed that re-creates an ecosystem. Geernaert stated that the Arctic experiment does manipulate the subsurface to see how it will react in future climates. It is an important component of the Arctic experiment. Geo-engineering is another type of manipulation, and we often do not know enough about ecosystem responses to be able to have confidence in its projected results. Joachimiak said that there may be a bioengineering revolution that will produce super biofuel crops. The plan is an excellent one, but it needs to be adjusted as priorities change and discoveries are made.

Stacey asked if this document were being used outside BER. Weatherwax replied that it is on the Office's website and it is referenced in the budget request. It is brought to meetings with other agencies. Geernaert said that the Office needs to use the report to guide how it frames its approach to sustainability. Weatherwax noted that the report had been shared with Paul Bryan of EERE. The major partners of the Office are aware of the report.

Zavarin said that there have been several statements during this meeting about diffusing information out into the public. The program should recognize the importance of that process. Weatherwax replied that outreach and communication are performed. Any advice from the committee is welcome. A lot of the policies on outreach are currently under development.

Mace said that, if one wants to change the perception of climate change, one needs to approach junior high school, high school, and undergraduate students. Weatherwax stated that the Office gets a lot of requests for educational materials and is happy to help anyone involved in curriculum development.

Stacey expressed appreciation of the Office's concern with and response to the report.

Eddy Rubin [Director, Joint Genome Institute] was asked to present an update on the Joint Genome Institute (JGI), a scientific user facility.

The JGI has scientific programs on plants, microbes, metagenomes, and fungi; user programs; and specific capabilities. In 2008, it had 101 publications, in 2009 it had 126, and in 2010 it had 153.

The plant program is a major activity of the JGI that has provided to the community a large number of flagship genomes. It has added functional data, transcription data, and data the community has added for *Populus tricocarpa*, foxtail millet, and *Chiamydomones reinhadtii*. It has also added five new public genomes for peach, columbine, eucalyptus, microbes and algae, and others. It provides more genomes than any other institution in the world, and it is now scaling up its high-throughput capability. The work being done is of critical importance to DOE's programs, providing sequencing and analysis from many DOE researchers

The JGI processed 20 new draft and 12 improved fungal genomes in FY10. It also has a new program in low-dose radiation. Overall, 600 projects were completed in FY10. It provided whole reference genomes for the Bioenergy Research Centers; this work is waning, but there are new activities, such as resequencing and the meta-genomics program. The JGI user community includes 1171 users from 52 countries, and it is very interested in educating the next generation of users. 88 faculty members and more than 2100 students use JGI tools to annotate sequences. The 2011 JGI user meeting is in two weeks; diverse topics link energy and the environment

The JGI has completed a technological transition from Sanger sequencers to next-generation sequencers and next-next-generation sequencers. The cost per million base pairs has decreased dramatically: the Sanger cost was $400, the Roche 454 was $15, the PacBio was $2.50, and the Illumina HiSeq is ten cents. This is a revolutionary change in sequencing. As cost per unit decreases, the number of units generated increases and one looks at shorter segments; they are not equivalent products. The computational part is expanding, also.

The JGI will have 12 Illumina HiSeq machines by summer. The output is expected to go up to terabases. They are very accurate, but miss some parts of the genome. They just came out 8 months ago and are expected to get much better in 3 to 4 years. Most of the applications of the PacBio machines are to the human genome. A real-time molecular analysis is produced. The DNA is pulled through in a 4-hour run time with long reads (up to 7000 base pairs; 5% of the reads are more than 4000 base pairs). It picks up those pieces of the genome that were missed by the earlier technology. It has a 15% error rate that can be dealt with statistically and that will be improved.

Challenges include the masses of data and the possibility that DNA sequences will become a commodity product. For the next 5 years, data production will be way off Moore's law. Data can be produced cheaply, but it is expensive to store and process. One needs to leverage resources at supercomputer centers and to apply new computational approaches (algorithms). The National Energy Research Scientific Computing Center (NERSC) assumed responsibility for JGI's information technology (IT) in April 2010 to assist JGI in devising scalable approaches to genome and meta- genome sequence data analysis. It is looking at new ways to look at the data.

A huge increase in sequencing was anticipated, so a 5- to 10-year roadmap of what the JGI needed to accomplish was written. The plan called for relevance, novelty, and credibility. JGI needs to know where BER research is going in the next 5 years. The JGI Scientific Advisory Committee was polled, a user meeting was held, and a strategic planning retreat will be conducted to determine what capabilities the facility will need to have.

The Genomic Foundry will be a user facility that will pioneer the application of functional genomics technologies in addition to DNA sequencing to solve the most relevant energy and environmental problems. The Institute has been told that "we are facing an impending crisis in the nation's DNA sequencing events ... . Amidst this rush to get as much DNA sequence as we can, we are falling woefully behind in our understanding of the biological function of those sequences." It needs to be understood how JGI can contribute to shrinking this gap. Transitioning to a "foundry" type user facility is envisioned to do edgy science and help users do that science. People are needed to analyze the data being produced. JGI should provide for the user genes/genome synthesis, single-cell genomics/transcriptomics, high-throughput culturing under hundreds of conditions, high-throughput/custom sample preparation, large-scale functional annotation of genes (a real challenge), and analysis expertise linked to high-performance computational infrastructure. JGI will continue to be an extreme sequence generator.

Some stretch goals that the Institute would like to achieve in the next 5 to 10 years include: routinely assigning a function to more than 90% of the genes in microbial and plant genomes; discovering new branches of life in the dark matter of uncultured organisms; and designing and building large segments of DNA to address scientific hypotheses.

JGI is piloting several grand challenges on the prairie soil genome, rhizosphere, and cow rumen. A cow-rumen project was just completed that led to a massive discovery of biomass-degrading genes and genomes. The cellulases used in biofuel production are predominantly from one fungal species; more cellulases of greater diversity are needed. Biomass (switchgrass) was put in nylon sacks, inserted into a cow's rumen, and removed 72 hours later. The microbes present were looked at, and the microbes' DNA was sequenced, producing a half terabyte of rumen sequence data.

The enzyme discovery pipeline uses assembly of 100-base reads, gene prediction, and software which searches a database for hidden Markov models, leading to the discovery of new glycosyl hydrolase enzymes, doubling the number of known such enzymes.

Are there more genes to be discovered? Yes! We are nowhere near the bottom of the well of genes. From the deep-sequenced rumen metagenome, many full-length cellulase genes were predicted. Hundreds are far away from anything else seen before, and they have functions that were unknown before. More than half of them were active, testing for cellulolytic activity on six substrates. Through this work, JGI has dramatically added to the total number of known cellulases from the deep sequencing of switchgrass-adherent microbiome. More than half of the tested enzymes had cellulolytic activity, including many novel enzymes. Trawling deep

metagenomics data is a successful strategy to add to the diversity of enzymes with desired activities. The whole picture is the genomes. Genes are chunks of that picture. There are lots of pieces of the picture, but they are not connected, yet. JGI is trying to convert scaffolds into draft genomes binned by tetranucleotide frequency and sequence coverage.

Several-thousand-base-pair-long PacBio reads facilitate correct genome assembly by joining contigs, resolving repeats, and resolving mis-assemblies. 15 graphic genomes were assembled from the cow rumen microbiome, none of which have ever been previously reported. JGI performed single-cell genome sequencing, taking a rumen community and separating single cells and multiple-displacement amplifying them to produce single amplified genomes, and then produced shotgun sequencing and genome assembly of DNA from the isolated single cell. The binned metagenomics scaffolds were developed, and single-cell genome reads map to every metagenomics scaffold. The vast majority of single-cell genome reads map to this single draft genome, suggesting that the draft genome is fairly complete. Ultradeep metagenomics sequencing, even with short reads, is likely to increasingly become a method of choice to identify genes and to characterize the genomes of uncultured organisms.

The genomic capabilities required to enable energy and environmental advances in the future will include single-cell genomics, analysis expertise linked to high-performance computer infrastructure, sequence generation, large-scale functional annotation of genes, and gene/chromosomal synthesis.

Most importantly, the great capability of the JGI is not the machines but the people.

DISCUSSION

Sayler asked if the JGI were processing total extractive nucleic acids. Rubin replied, yes. Sayler pointed out that that has crappy efficiency. Rubin agreed that there is a problem. Sayler asked how close they were to linking a transcriptome to a genome. Rubin replied that it is doable. There is a lot of venture capital involved in developing sequencing technology.

Remington asked how the transition from data generator to analyst will scale. Rubin replied that it is about the people and JGI's relationship with NERSC. The objective is to make the process a pushbutton. Remington offered that informatics tools will help navigate the data and scientists' intuition on where to look in the data. Rubin replied that, in the future, postdocs will work at JGI.

Joachimiak observed that sequencing is a growth industry. Some places have 50 machines. The challenge is the data, and its analysis should be the focus of research and development. One must prove unique properties of genes. Rubin agreed. One can leapfrog if one uses intelligent machines to look for patterns. JGI's future will be a step away from function. The community will provide that information.

Wall asked if one can reduce the percentage of hypothetical genes. Rubin stated that that is a grand challenge, to annotate 100% of an organism.

Wildung noted that the initial focus of the JGI was on sequencing. Now it is increasing its capabilities. Where does it stop? Rubin replied that JGI's mission is to develop capabilities that users can benefit from. It is not invading people's laboratories; it is scaling up laboratories' capabilities. Wildung suggested that JGI's outreach is a good model for extending BER's research into colleges and high schools. Rubin agreed and said that Paul Alivisatos came up with the foundry concept: collect instruments and staff that can use them well and have researchers come and use the instruments. JGI is targeting a different use than the universities' sequencing centers are.

Minghua Zhang [Director, Institute for Terrestrial and Planetary Atmospheres, School of Marine and Atmospheric Sciences, Stony Brook University] was asked to discuss the BERAC report on the Atmospheric Radiation Measurement Climate Research Facility.

The Atmospheric Radiation Measurement Climate Research Facility has three fixed sites, two mobile facilities, an aerial facility, data-processing and data-archive facilities, and engineering and operational infrastructure. The fixed sites are located in the southern Great Plains, the tropical

western Pacific, and on the North Slope of Alaska. The Atmospheric Radiation Measurement Climate Research Facility collects and develops datasets of radiation, aerosols, and clouds with dynamics and thermodynamics at the locations of various climate regimes. It supplements the continuous data sets with laboratory studies and shorter-duration field campaigns. Thus, it enables researchers to understand and parameterize cloud and radiation processes and enables research to improve climate models.

The review looked at the Atmospheric Radiation Measurement Climate Research Facility's science impact and support, management, and resources and made recommendations. It conducted a site visit and review meeting at Ponca City, Okla., on February 16-18, 2011.

In terms of science, impact, and support, the review panel found that the Atmospheric Radiation Measurement Climate Research Facility has improved radiative-transfer codes in general circulation models (GCMs), including the Community Atmospheric Model (CAM); improved parameterizations of clouds and convection in GCMs; incorporated the improved aerosol indirect effects on climate in GCMs; developed a multi-scale modeling framework; and improved weather-prediction models. It has produced 1000 peer-reviewed publications. The review panel believes that the Atmospheric Radiation Measurement Climate Research Facility has made a significant contribution, providing the Atmospheric System Research (ASR) science team and the larger science community with a suite of observations that allow the study of radiation, clouds, aerosols, precipitation, and their interactions; the capability to propose new instruments, new measurements, and field campaigns; and high-level processed data products. The review panel concluded that the dataset the Atmospheric Radiation Measurement Climate Research Facility has collected has significantly impacted climate science. The Atmospheric Radiation Measurement Climate Research Facility has supported the science objectives of the DOE ASR program and the general science user community. And it is appropriate and important for DOE BER to operate Atmospheric Radiation Measurement Climate Research Facility because of the critical needs of Atmospheric Radiation Measurement Climate Research Facility data in climate research, the complexities of the facilities, the scale of measurement operations, and the technical and science expertise required.

In terms of management, the review panel concluded that the Atmospheric Radiation Measurement Climate Research Facility actively solicits, and decisively acts upon, inputs from the science community in setting its priorities. Effective mechanisms are in place to track progress and resolve problems at all levels. The coordination among the national laboratories is seamless; management carries out its responsibilities effectively. The Atmospheric Radiation Measurement Climate Research Facility assesses its operation and progress continually for improvements, but no self-assessment protocol is formally documented.

In terms of resources, the review panel found that one can access the Atmospheric Radiation Measurement Climate Research Facility data archive to download data directly, that field campaigns are proposed through a peer-review process of proposals, and that adding instruments or measurements to a field campaign can be proposed. All data from the field campaigns are available in a timely manner to the general user community. The allocation of resources is balanced, and the management is well carried out. The review panel concluded that the Atmospheric Radiation Measurement Climate Research Facility user model suits its missions and is compatible with resource allocations, which are appropriate. The Atmospheric Radiation Measurement Climate Research Facility has been functioning well under the present budget challenges with the newly acquired instruments. The current level of funding must be maintained and needs to be implemented in future years to include operation, maintenance, and production of data products from the full instrument suite.

The review panel recommended that:

- A quality-control protocol be established for the Data Quality Control Office, instrument mentors, and the ASR site scientists to interact and operate in a well-defined process.

- The Atmospheric Radiation Measurement Climate Research Facility conduct user tutorial workshops regularly to target undergraduate and graduate students as well as young scientists.
- A value-added-product mentor program should be established for critical high-level data products.
- The Atmospheric Radiation Measurement Climate Research Facility should expand its showcase product with an oversight board to design and implement the critically needed data and processing.

In summary, the Atmospheric Radiation Measurement Climate Research Facility has enabled research on critical questions in climate science. The Atmospheric Radiation Measurement Climate Research Facility management is effective and rigorous. Current resources are adequate but need to be maintained. The Atmospheric Radiation Measurement Climate Research Facility will benefit from more emphasis on data quality, user workshops, and high-level products. BER and the scientific community can be proud of how the Atmospheric Radiation Measurement Climate Research Facility is being operated and of its outcome.

DISCUSSION

Penner noted that a previous review committee found that the delivery of data needed improvement in the reporting of uncertainty. Zhang replied that the team recommended data-quality flags. Mace said that the recommendation is rather strong on improving the ease of access to data. It was implied that the value-added product (VAP) needs error bars. Penner said that that should be brought out more. Mace said that it would be easy to include more specific language.

Randall asked if the oversight board would include representation from the customer community. Zhang replied that it would; at least one member of the user community would be involved.

Stacey asked if those VAPs would require additional staff. Mace said that the information has to be derived (with accompanying algorithms, uncertainty, etc.). Significant effort could go into producing them. A new approach is suggested: a mentor program outside the Atmospheric Radiation Measurement Climate Research Facility to produce these VAPs. As a result, no new staff would be required.

Stacey called for a vote on accepting the report with the addition of language suggested by Penner plus editorial changes. Hubbard moved to accept the report; Randall seconded the motion. The vote was unanimously positive.

The floor was opened for new business. There was none. Stacey announced that the questionnaire on data management had been e-mailed to all Committee members. He reminded them that this action is in response to an official charge, and the report is due July 1. A teleconference may be held for the committee to discuss and vote on the compilation of responses.

Stacey noted that the topic of the next project that BERAC could undertake is open to suggestions from the Committee.

The floor was opened to public comment. Douglas Ray [Associate Laboratory Director, Fundamental and Computational Sciences Directorate, Pacific Northwest National Laboratory] announced that the NSTC has included the word “sustainability” in one of its subcommittees’ names. Its role is to move policy into practice.

Min Park [Bioscience Division, Los Alamos National Laboratory] thanked the Committee for posting the planning document to the Web. The user community welcomes the transition of JGI to analysis and functional annotation. That capability has significant influence on biofuel and biocrop research, increasing the productivity of biocrops. It leads to a framework for eukaryotic sequencing.

There being no other public comments, the meeting was adjourned at 11:47 a.m.