Multidisciplinary Team Science from the Office of Biological and Environmental Research

September 23, 2014

Sharlene Weatherwax, Ph.D.
Associate Director of Science
Biological and Environmental Research

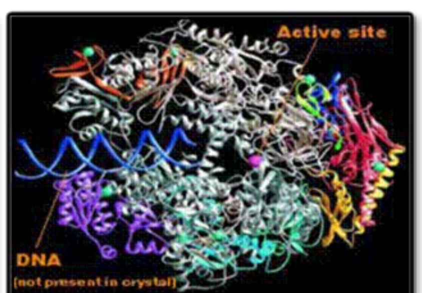
(http://science.energy.gov/ber/)

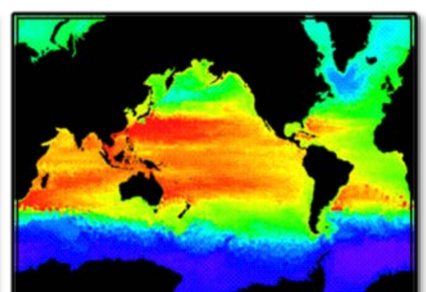
Biological and Environmental Research

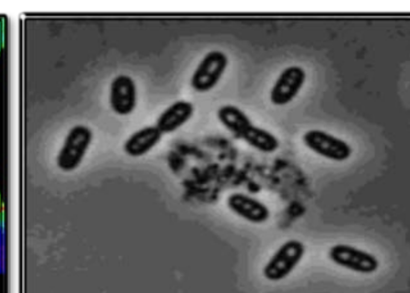
Understanding complex biological, climatic, and environmental systems across vast spatial and temporal scales

The Scientific Challenges**:**

- Understand how genomic information is translated with confidence to redesign microbes, plants or ecosystems for improved carbon storage, contaminant remediation and sustainable biofuel production
- Understand the roles of Earth's biogeochemical systems (atmosphere, land, oceans, sea ice, subsurface) in determining climate so we can predict climate decades or centuries into the future, information needed to plan for future energy and resource needs.





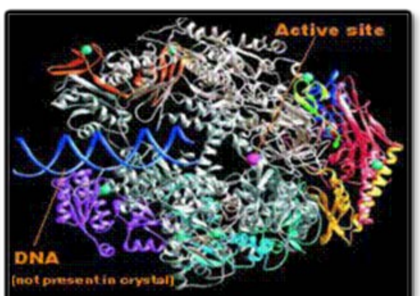


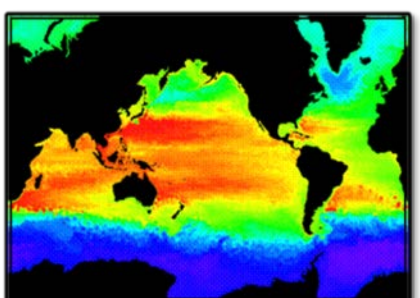
Biological and Environmental Research

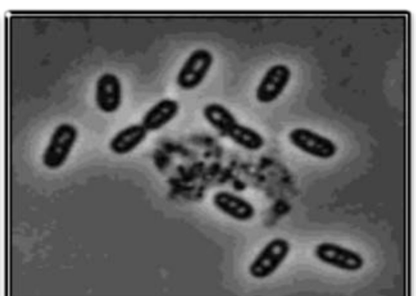
Understanding complex biological, climatic, and environmental systems across vast spatial and temporal scales

Addressing this challenge requires:

- Research across
  - spatial scales from microns to kilometers to the entire Earth
  - temporal scales from seconds to years to centuries
- Coordinated teams of scientists with diverse expertise from multiple institutions that raise unique management challenges







Office of Biological & Environmental Research

BER research and user facilities are managed within and across two Divisions.

Biological Systems Science

- Genomic Science
  - Bioenergy Research Centers
- Mesoscale to Molecules
- Radiological Sciences
- Facilities & Infrastructure
  - Joint Genome Institute
  - Structural Biology

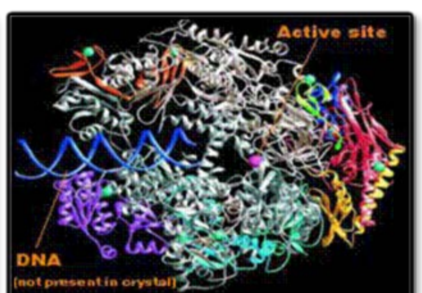
Climate & Environmental Sciences

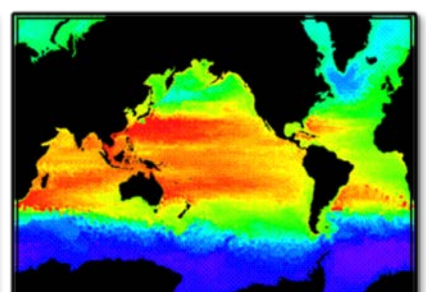
- Atmospheric System Research
- Environmental System Science
- Climate & Earth System Modeling
- Facilities & Infrastructure
  - Environmental Molec. Sciences Lab
  - ARM Climate Research Facility
  - Climate & Environmental Science Data Analysis, Simulation & Visualization

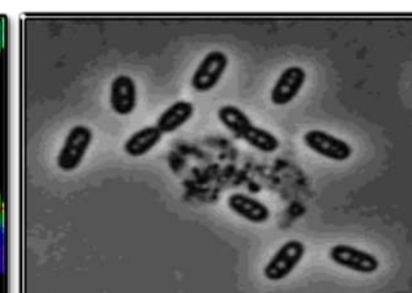
Biological and Environmental Research

Examples of multidisciplinary team science:

- Bioenergy Research Centers
- Multi-lab Climate Modeling
- Climate change research meets microbial genomics – a new opportunity
- Joint Genome Institute and Environmental Molecular Sciences Laboratory joint call
- Scientific Focus Areas - SFAs







Biological and Environmental Research (BER)

Foundational Science - integrating observations and experimental capabilities with modeling for predictive understanding

jbei Joint BioEnergy Institute

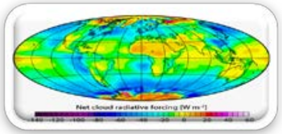
BESC BioEnergy Science Center

GREAT LAKES BIOENERGY RESEARCH CENTER

KBase PREDICTIVE BIOLOGY

DOE Systems Biology Knowledgebase





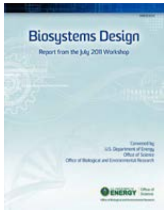
Explore frontiers of genome-enabled biology

- **Sustainable bioenergy resources**
- Function & organization of plant and microbial systems
- **Mechanisms and regulation of carbon storage in plant biomass and microbial communities**
- Biosystems design
- Systems biology via data integration and analysis within a systems biology knowledgebase

Understand the effects of greenhouse gas emissions on Earth's climate and biosphere

- **World-leading capabilities in climate modeling**
- Representation of clouds in climate models
- Direct/indirect effects of aerosols on climate
- **Interactions of carbon cycle and climate**
- **Predictive understanding of terrestrial ecosystems, focus on sensitive systems, e.g., Arctic and tropics**








Biological and Environmental Research (BER)

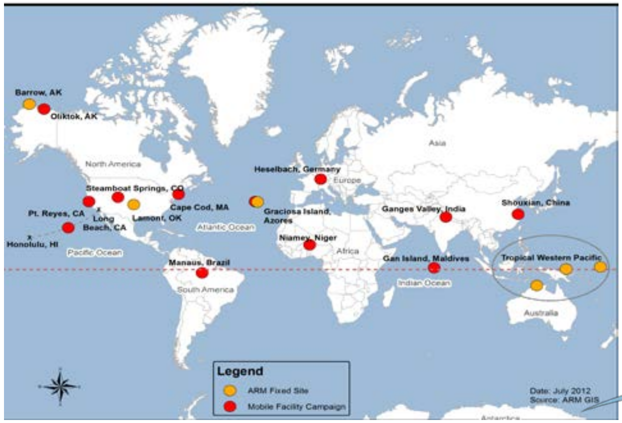
Scientific User Facilities

Joint Genome Institute (JGI) - meeting the DNA sequencing needs of the bioenergy, carbon cycle, and biogeochemical science communities

Fungal ligninase

Poplar

Eucalyptus

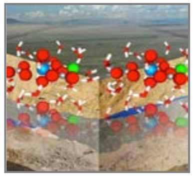


ARM CLIMATE RESEARCH FACILITY

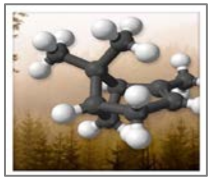
Atmospheric Radiation Measurement (ARM) Climate Research Facility - providing continuous field measurements and data products to improve cloud and aerosol science in climate models

EMSL

Nanosized battery



Modeling contaminants

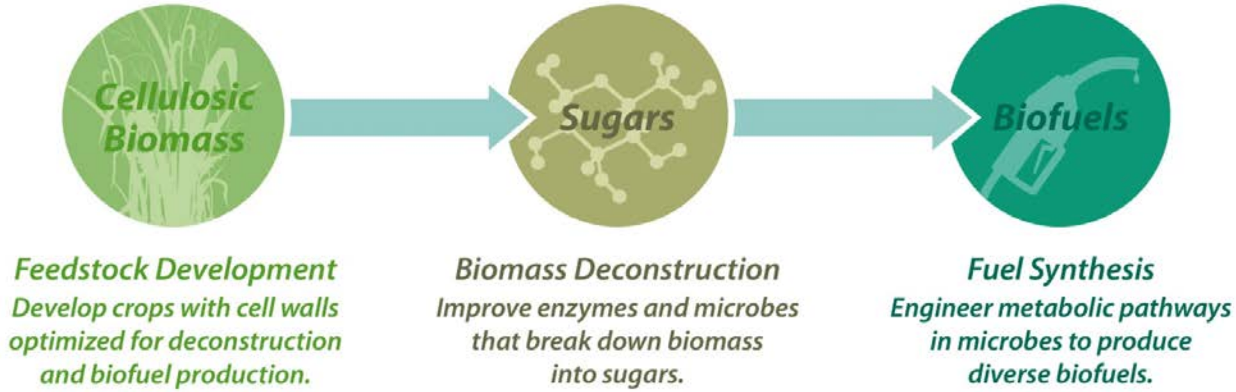


Atmospheric aerosols

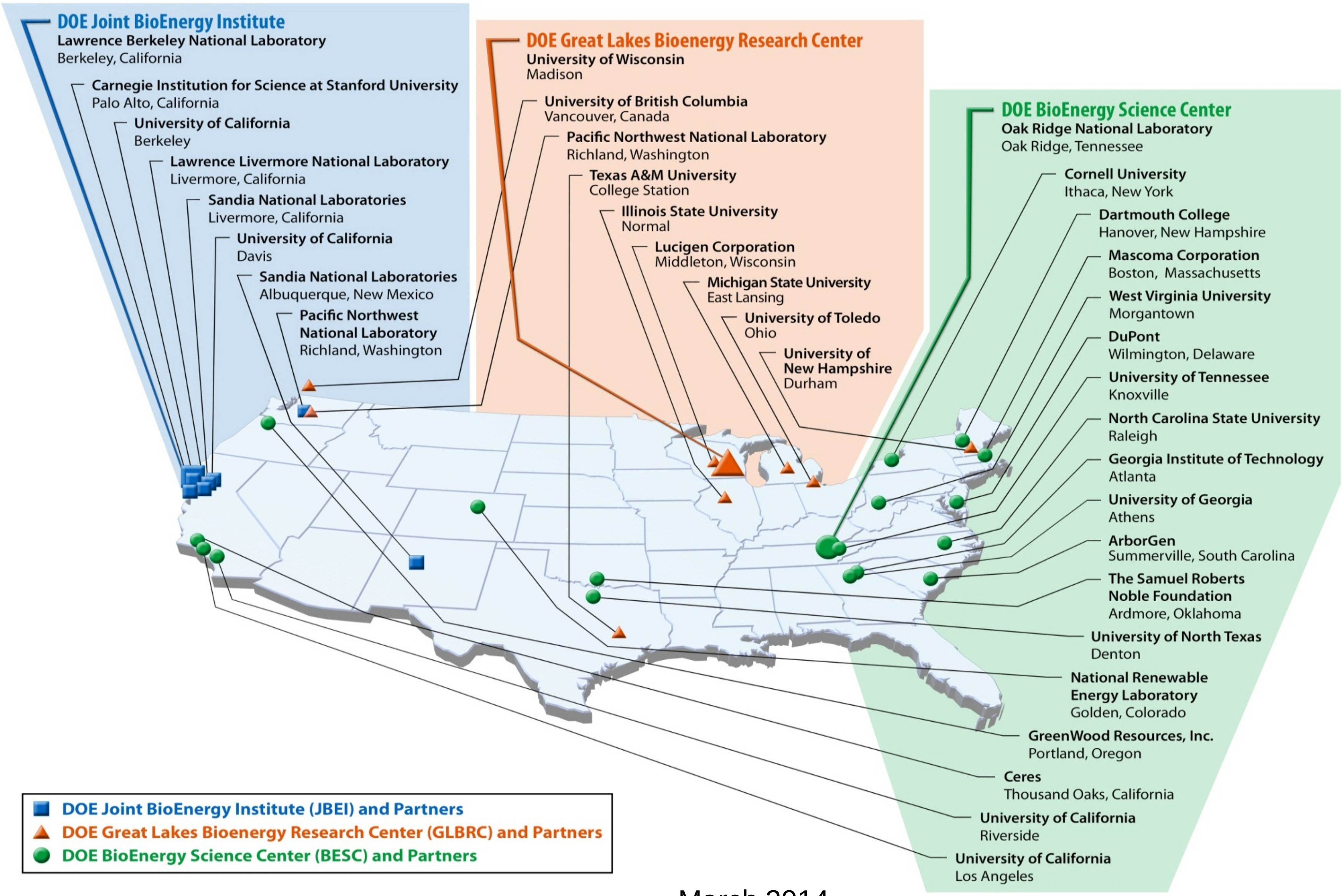
Environmental Molecular Sciences Laboratory (EMSL) - providing integrated experimental & computational resources for discovery and technological innovation

The DOE Bioenergy Research Centers

- Research paradigm—single focus, multi-disciplinary, team-based transformational science
- Rigorous DOE management and progress review against milestones
  - Early management review
  - Annual scientific and management peer review
  - Renewal review after initial 5 years of funding (renewed for 5 years)
- Each center has the authority and responsibility to reallocate resources and personnel to meet their milestones and address new scientific opportunities
- In 7 years of operations:
  - 602 invention disclosures and/or patent applications
  - 19 patents awarded
  - 108 licensing agreements
  - 1661 peer-reviewed publications



Bioenergy Research Center Partner Institutions



March 2014

Industry Benefits from the Bioenergy Research Centers' Discoveries and Technologies

- All three BRCs have industry partners, collaborators, advisors, intellectual property and technology licensees, and spin-offs.
- BRCs have reached out to the bioenergy industry creating links for future commercialization.

Cargill
ceres
DOW
ROESLEIN
tesela gen
POET biorefining
Weyerhaeuser
MONSANTO
Borregaard LignoTech
AMYRIS
SCION forests·products·innovation
novozymes Rethink Tomorrow
firstgreen PARTNERS
Lignol
IOGEN CORPORATION
GREENWOOD RESOURCES
evolva
Pacific Ethanol, Inc.
DSM BRIGHT SCIENCE. BRIGHTER LIVING.
BOEING
virdia
MillerCoors
GlucanBio
GE
allopartis
GINKGOBIOWORKS
PlantProbes
FuturaGene Yielding the Future™
genomatica
ZeaChem
LYGOS
Nextval
LS9, INC.
FDC Enterprises Grasslands Services
bp
Mendel BIOTECHNOLOGY
opxbio good chemistry.
ADM
syngenta
ABENGOA
NIDUS
MASCOMA
ARBORGEN
ExxonMobil
GM
Oakbio Clean Technology, Clean Products
Statoil
Elanco
SuGanit
BASF The Chemical Company
TOTAL
Hyrax ENERGY
Caliper a PerkinElmer company
Afingen
DUPONT
Show Me Energy Cooperative empowering the next generation... through a flexible model that allows plant matter to be turned into fuel and power

June 2014

Climate and Energy

Greenhouse gases (GHG) are emitted during energy production…
and climate change impacts energy production and the environment.

BER programs seek to:

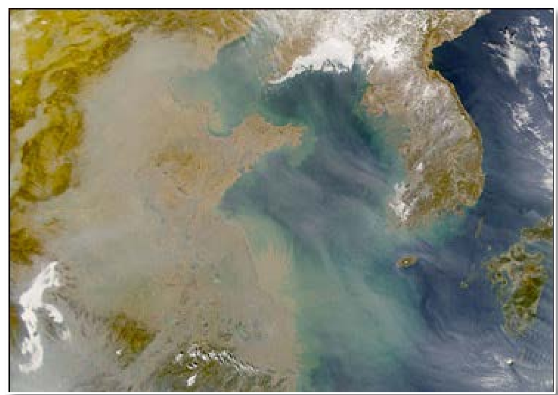
- Understand the effects of GHG emissions on Earth's climate and the biosphere through:
  - World-leading capabilities in climate modeling
  - Unique capabilities in cloud and aerosol observations and process research
  - Ecosystem level research on climate change impacts and the carbon cycle.
- Advance foundational science to support effective energy and environmental decision making

BER is tackling the major knowledge gaps in climate models

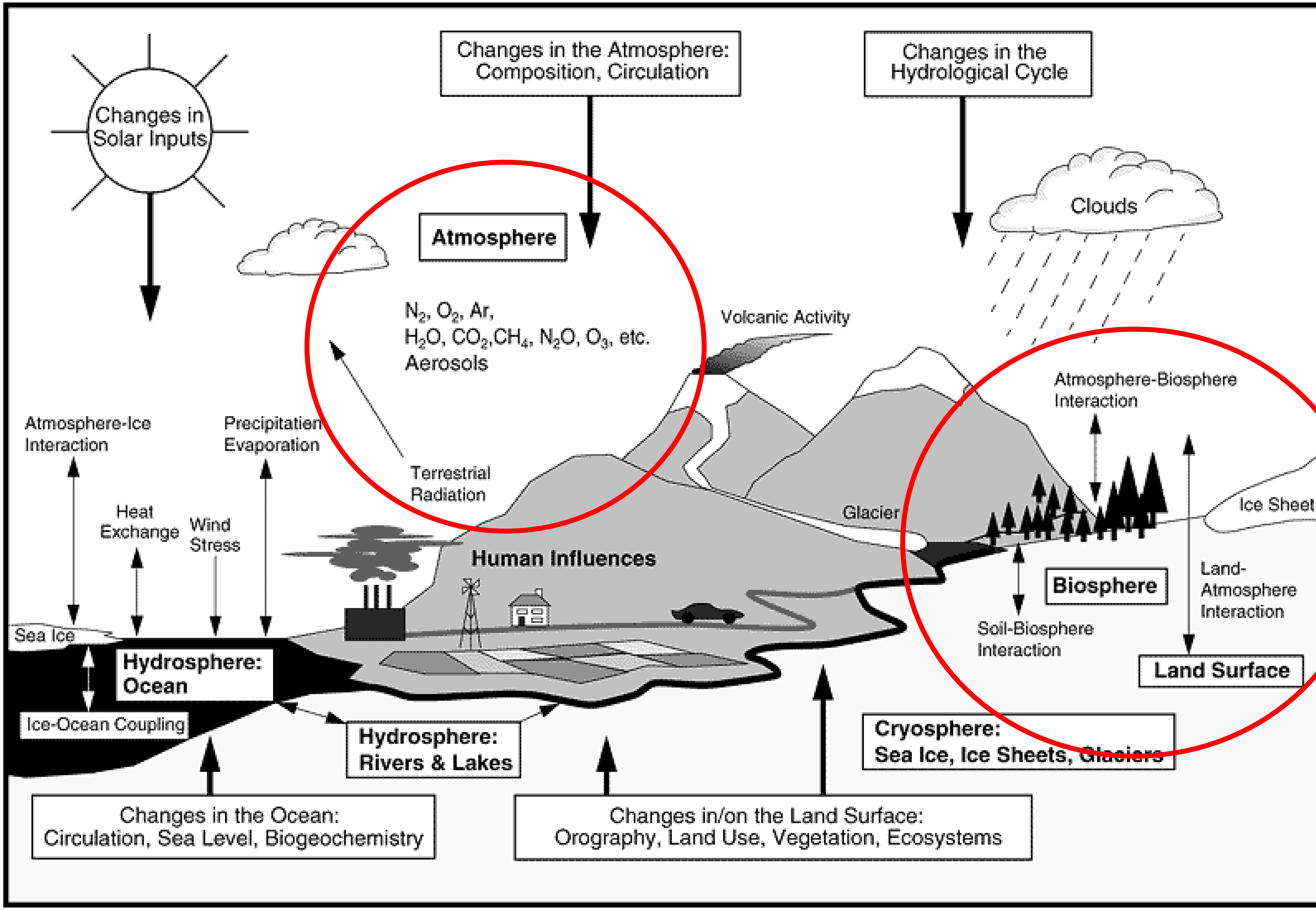
Representation of **clouds** in climate models

Direct and indirect effects of **aerosols** on climate

Interactions of the **carbon cycle** and climate



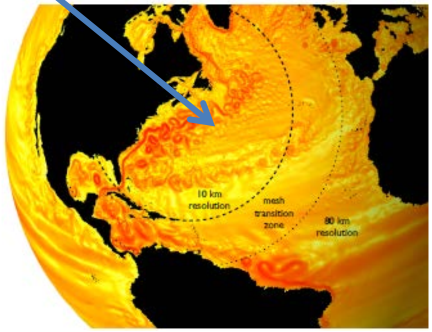
Climate system components



Accelerated Climate Model for Energy

ACME is a new multi-laboratory project to develop a climate prediction model, in support of the Department of Energy's science mission.

- **Fully coupled at 15-25 km resolution, yet have advanced adaptive-mesh to resolve important regions on resolutions well below 10 km.**
- **Able to utilize next-generation DOE computers.**



Science focus areas support energy and societal planning:

a) Improving projections of water availability
b) Projecting changes to ice sheets and sea-level
c) Estimating land-atmosphere exchange of carbon

ACME was formed from 7 multi-Lab projects, and spans 8 Labs and 6 non-Laboratory institutions. It is managed by a Council of 8 Lab scientists.

Pacific Northwest National Laboratory · Oak Ridge National Laboratory · Argonne National Laboratory · Sandia National Laboratories · Los Alamos National Laboratory · Berkeley Lab · Brookhaven National Laboratory

Next-generation Ecosystem Experiments (NGEE)

NGEE—coordinated projects coupling terrestrial field experiments and process modeling to more rapidly improve the representation of terrestrial ecosystem processes in Earth system models thereby improving the quality of climate model projections.

- Target regions chosen are globally important, climatically sensitive, and understudied/underrepresented in predictive models.
- NGEE projects combine field and laboratory studies, observations, and multi-scale model simulation, coordinating with ARM mobile campaigns.
- Major campaigns: Arctic (FY2012-2022); Tropics (FY2014-2023)
  - **Arctic** permafrost (ongoing): Warming of permafrost soils will release vast amounts of CO_2 and/or CH_4 to the atmosphere—a strong positive feedback to warming
  - **Tropics** (FY 2014): Rainfall stress on tropical ecosystems and release of biogenic aerosols impact cloud condensation nuclei.

Discovery of a Novel Methanogen in Thawing Permafrost

Objective:

Characterize microbial community structure and functional processes at a permafrost-to-wetland transitional ecosystem in northern Sweden.

Approach:

Deep metagenomic sequencing, metaproteomics, and methane flux measurements were used to characterize the microbial community and correlate members with *in situ* carbon cycle processes.

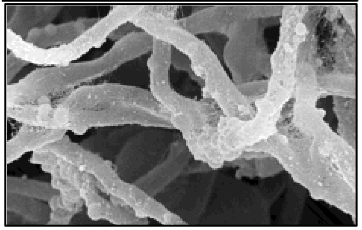
Results/Impact:

- Assembly of nearly complete genome of Candidatus *Methanoflorens stordalenmirensis,* the dominant methanogen in thawing bog sites, from metagenomic libraries
- Coupled CH_4 flux measurement quantitative metaproteomic detection of *M. stordalenmirensis* methanogenesis proteins suggest that this organism dominates CH_4 production at bog sites.
- Methanogens closely related to *M. stordalenmirensis* are prevalent in metagenomic libraries for other thawing permafrost sites, suggesting global distribution in these ecosystems.

Mondav et al. 2014 **Nature Communications** DOI: 10.1038/ncomms4212

Joint Genome Institute (JGI):
A DOE USER FACILITY

JOINT GENOME INSTITUTE
DEPARTMENT OF ENERGY

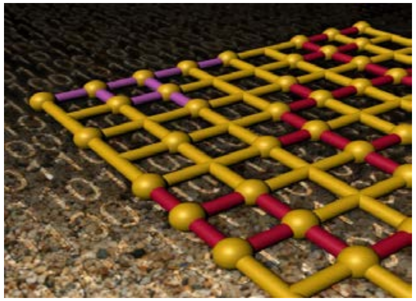


- The mission of the JGI is to provide genome sequencing, genome data acquisition, and genome analysis in support of the DOE mission needs in bioenergy, carbon cycling and biosequestration, and environmental remediation and biogeochemical processes.
- Genome and metagenome expression and sequencing of microbes, plants, and other complex systems, such as microbial communities or the rhizosphere.
- Genome annotation, functional analysis and verification of genome-scale biological system models. Systems-level integration and validation of genomic data from multiple sequencing and functional analyses.
- Sequencing more than 70 Terabases of DNA per year.
- Data analysis and storage enhanced via a partnership with the National Energy Research Scientific Computing center (NERSC) at Lawrence Berkeley National Laboratory.

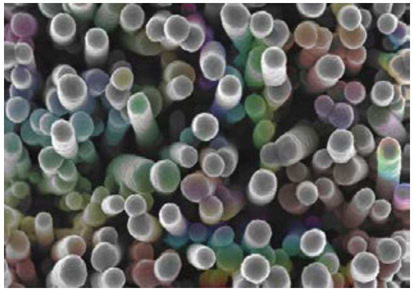
NERSC

Environmental Molecular Sciences Laboratory – A DOE User Facility

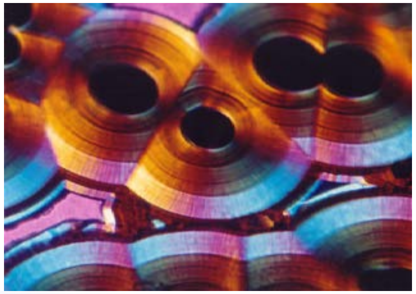
EMSL's suite of over 75+ premier experimental capabilities enables molecular-scale experimental and theoretical research on aerosol chemistry, biological systems, geochemistry/ biogeochemistry, and interfacial and surface science.



Biosystem Dynamics and Design – Understanding and optimizing the response of organisms and biological communities to their environment.



Atmospheric Aerosol Systems - Molecular-scale understanding of key chemical and physical properties of aerosols to improve the prediction of climate models.



Terrestrial and Subsurface Ecosystems - The dynamics of nutrients, metabolites, and contaminants at biogeochemical interfaces in heterogeneous environments across scales.

Energy Materials and Processes – Understanding the physical and chemical properties of interfaces to design new materials and systems for sustainable energy applications.

EMSL

DOE JGI, EMSL Announce 2015 Collaborative Science Projects

The U.S. Department of Energy Joint Genome Institute (DOE JGI) and the Environmental Molecular Sciences Laboratory (EMSL) have accepted 12 projects submitted during the 2014 call for Collaborative Science Initiative proposals.

The collaborative call represents a unique opportunity for researchers to combine the power of genomics and molecular characterization in one research project to help advance the missions of the Department of Energy's Office of Biological and Environmental Research (BER). The selected researchers will have access to the capabilities of both user facilities. They will also be able to generate datasets unique to these two facilities – beyond what could be generated by either facility by itself.

The interaction between aspens, ectomycorrhizal fungi and plant growth promoting bacteria is the focus of a selected proposal from Jonathan Cumming of West Virginia University.

Researchers submitted a total of 31 proposals during the call. The 12 approved projects will kick off in fiscal year 2015 and run for up to 18 months. These projects fall within the second collaborative call by EMSL and the DOE JGI since the first in winter 2013.

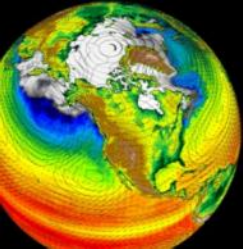
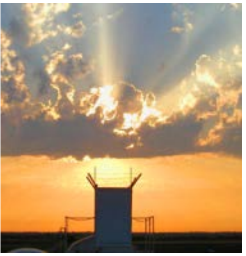
Scientific Focus Areas (SFAs) – a new research management tool

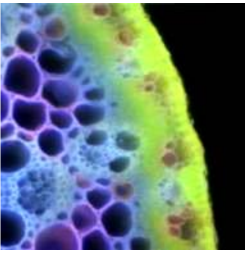
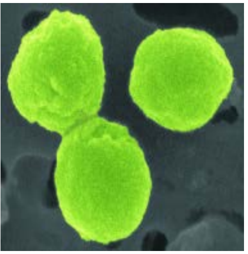
- Traditionally BER funded research at the National Labs as single PI projects that were "recompeted" every three years.
- Ineffective use of Lab capabilities and resources.
- Beginning in 2007, BER created SFAs to integrate groups of previously individual projects into a single, focused effort. Not everything is an SFA.
- SFAs -
  - Have a single point of contact at the Lab and in BER
  - Are required to have a management plan and to NOT simply be a collection of individual projects lumped together (see next slide)
  - Are the responsibility of the lab to allocate personnel and resources
  - Provide annual progress reports.
  - Are merit reviewed every 3 years and receive guidance of accept, accept with revisions, partially accept, reject – We have done all four.
  - Are still a work in progress
    - ❖ Challenge of starting new work
    - ❖ Unequal distribution of funds across labs
    - ❖ Challenge of multi-lab projects

Management of SFAs is key – one of 7 review elements

To what extent does the proposed Science plan demonstrate a team-oriented, collaborative effort that takes advantage of the unique analytical and administrative capabilities of the National Laboratory?

- The Labs have been challenged to develop integrative research programs that are greater than the sum of their parts. Please assess the extent to which the proposed new Science plan demonstrates a fully integrative, team-oriented program rather than simply a collection of individual projects by considering the following:
  - Is it evident that scientific staff within the SFA communicate and coordinate research results among each other? Does SFA management facilitate this communication and coordination?
  - Does the scientific output of the program appear to be directed towards attaining results that are greater than the sum of individual research contributions?
  - Does SFA management proactively manage overall program direction towards an integrated scientific goal?
  - Does SFA management proactively manage the SFA budget by directing funds where they are needed in a timely manner?
  - Do individual PIs within the program take the initiative to contribute to a larger integrated scientific goal?

BER encourages its research community to seek scientific partnerships and new collaborations to accomplish mission goals.

Thank you!

http://science.energy.gov/ber/