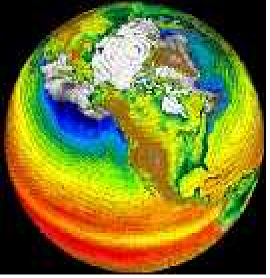
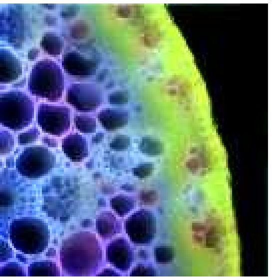
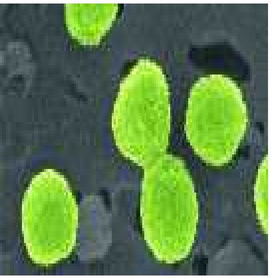


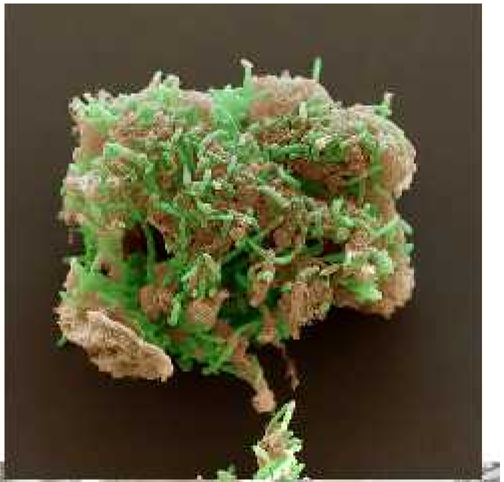
Bioenergy and Climate Research in DOE's Office of Science

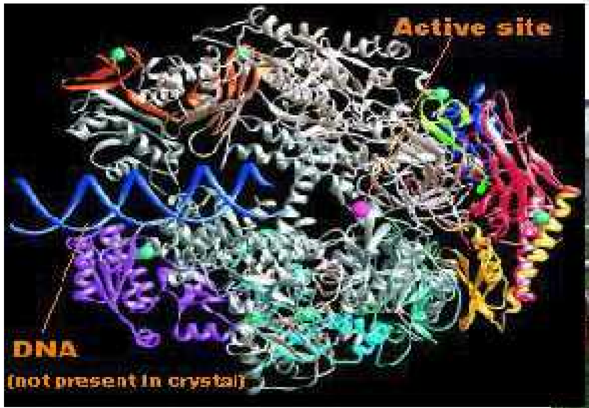
Click to edit Master subtitle style

Anna Palmisano, Ph.D.
Associate Director of Science
Biological and Environmental Research

Biological and Environmental Research

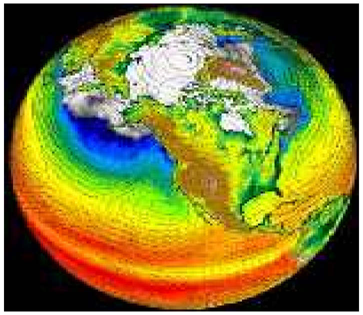
Complex systems science to meet DOE mission needs in bioenergy, climate and the environment.

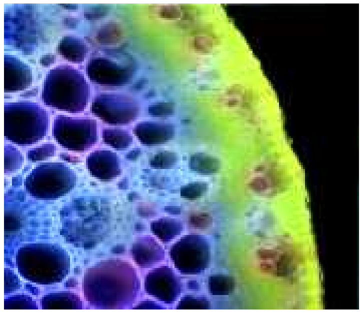
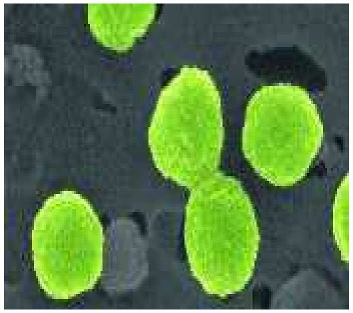


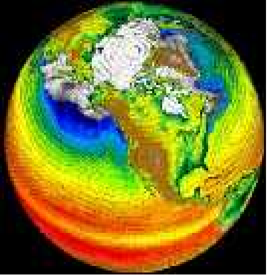


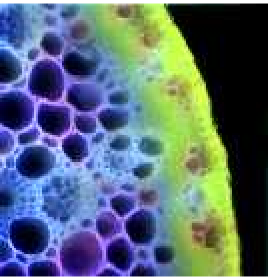
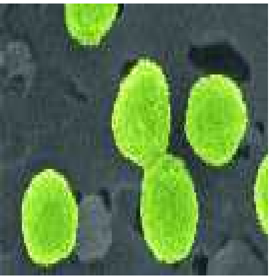
Biological and Environmental Research Mission

- To understand complex biological, climatic, and environmental systems across spatial and temporal scales.
- BER provides the foundational science to:
  - Support the development of biofuels as major, secure, and sustainable national energy resources
  - Understand potential effects of greenhouse gas emissions on Earth's climate and biosphere and the implications of these emissions for our energy future
  - Predict the fate and transport of contaminants in the subsurface environment at DOE sites
  - Develop new tools to explore the interface of biological & physical sciences





Bioenergy Research

Click to edit Master subtitle style

Properties of optimal bioenergy feedstocks

- High yield (>15 tons/acre/year)
- High water use efficiency
- Low input (e.g., fertilizer, tillage, pesticides)
- High conversion efficiency
- Sustainable
- Stable quality and quantity from year to year

Crop residues will play a part, but the need for large-scale production favors dedicated energy crops

DOE Bioenergy Research Centers

Multi-institutional partnerships

DOE Bioenergy Research Centers

DOE Joint BioEnergy Institute (JBEI)

- Lawrence Berkeley National Laboratory, Berkeley, California
- Carnegie Institution for Science at Stanford University, Palo Alto, California
- University of California, Berkeley
- Lawrence Livermore National Laboratory, Livermore, California
- Sandia National Laboratories, Livermore, California
- University of California, Davis
- Sandia National Laboratories, Albuquerque, New Mexico

DOE Great Lakes BioEnergy Research Center (GLBRC)

- University of Wisconsin, Madison
- Pacific Northwest National Laboratory, Richland, Washington
- Iowa State University, Ames
- Illinois State University, Normal
- Lucigen Corporation, Middleton, Wisconsin
- Oak Ridge National Laboratory, Oak Ridge, Tennessee, GLBRC Partner
- Michigan State University, East Lansing

DOE BioEnergy Science Center (BESC)

- Oak Ridge National Laboratory, Oak Ridge, Tennessee
- Cornell University, Ithaca, New York
- Dartmouth College, Hanover, New Hampshire
- Verenium Corporation, Cambridge, Massachusetts
- Mascoma Corporation, Boston, Massachusetts
- Brookhaven National Laboratory, Upton, New York
- Virginia Polytechnic Institute and State University, Blacksburg
- University of Tennessee, Knoxville
- North Carolina State University, Raleigh
- University of Georgia, Athens
- Georgia Institute of Technology, Atlanta
- ArborGen, Summerville, South Carolina
- University of Minnesota, St. Paul
- The Samuel Roberts Noble Foundation, Ardmore, Oklahoma
- National Renewable Energy Laboratory, Golden, Colorado
- Washington State University, Pullman
- University of California, Riverside
- Ceres, Thousand Oaks, California

- ■ DOE Joint BioEnergy Institute (JBEI) and Partners
- ▲ DOE Great Lakes Bioenergy Research Center (GLBRC) and Partners
- ● DOE BioEnergy Science Center (BESC) and Partners

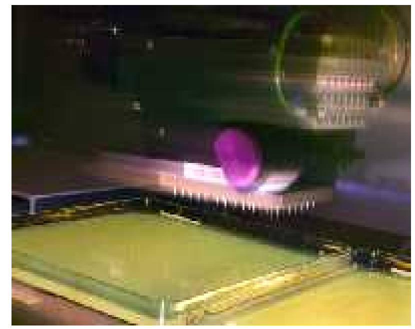
BioEnergy Science Center

BESC
BioEnergy Science Center

- **Focus**: **Overcoming "recalcitrance"** (resistance of plant fiber, or lignocellulose, to break down into sugars)
  - Gene discovery for **recalcitrance** in switchgrass and poplar
  - Use of synthetic biology to re-engineer the **cellulosome**
  - Long-term **"consolidated bioprocessing"** goal: one microbe or microbial community for processing plants into fuel
  - Opportunity to test discoveries in a **demonstration biorefinery** being constructed by the state of Tennessee

Joint BioEnergy Institute

- Focus: Model crops (*Arabidopsis* and rice) for rapid advances that can be transferred to bioenergy crops
  - **Modifying lignin** to change its monomer composition for easier degradation and access to cellulose
  - Using ionic liquids for room-temperature biomass **pretreatments**
  - Using **synthetic biology** to look beyond ethanol to green gasoline, diesel, and jet fuels
  - Connecting with the **Bay Area Biotech Community** (a hub of bioenergy technology and venture investment)



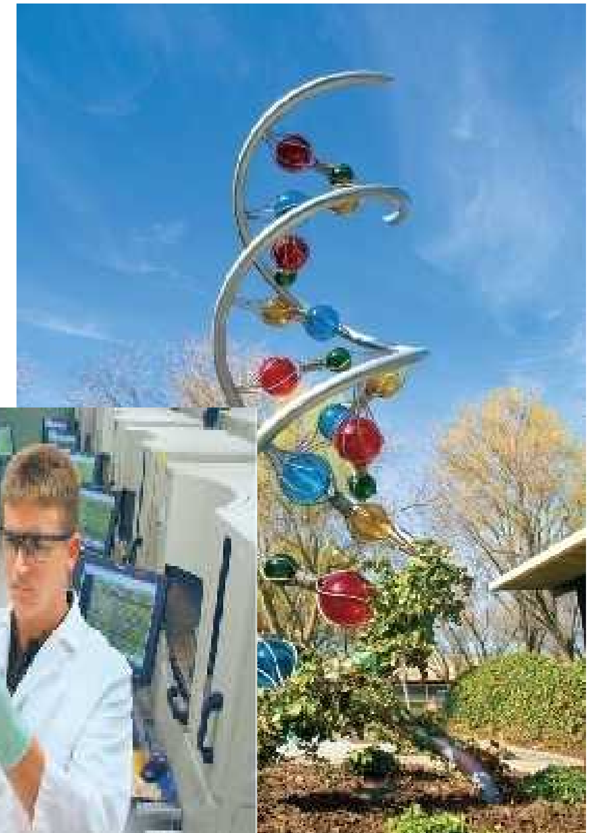
Great Lakes Bioenergy Research Center

GLBRC
Great Lakes Bioenergy Research Center

- Focus: Wide range of plants, including models and potential bioenergy crops (approach leverages the agronomic orientation of the two universities)
  - Engineering plants to incorporate **lignin "zippers"** and to produce more starches and oils for biodiesel
  - **Developing alternative approaches** to fuels: Microbial biorefineries that use sunlight and biomass to generate hydrogen, electricity, or high-energy chemicals
  - **Investigating the sustainability** of biofuel production by studying the environmental and socioeconomic dimensions of a biofuels economy

DOE Scientific User Facility
DOE Joint Genome Institute

- Focus: Genomes and metagenomes of microbes, microbial communities, and plants vital to DOE missions
  - Provide state-of-the-science capabilities for sequencing and analysis
  - Maintain expert staff in a range of computing and biological research disciplines
  - Host workshops and annotation jamborees



High-throughp
sequencing facility
at DOE JGI in Walnut Creek, California

Sequencing more than 1 tera base pairs of DNA per year or 333 human genome equivalents!

Joint Genome Institute and Bioenergy

Cellulosic Feedstock development

- Poplar
- Maize and corn stover
- Switchgrass
- *Brachypodium*
- Sorghum

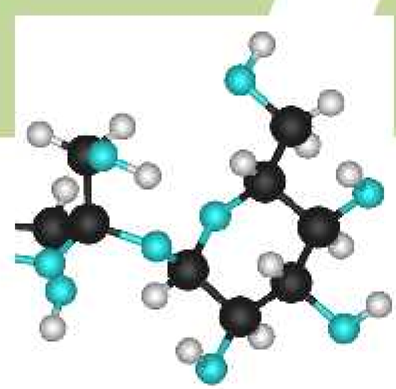
Cellulose and lignin degradation

- Termite hindgut microbiota
- White rot fungus
- *Clostridium thermocellum*
- *Saccharophagus degradans*
- *Acidothermus cellulolyticus*

Fermentation with ethanol-producing organisms

- *Saccharomyces cerevisiae*
- *Zymomonas mobilis*
- *Thermoanaerobacter ethanolicus*
- *Pichia stipitis*

Cellulosic materials

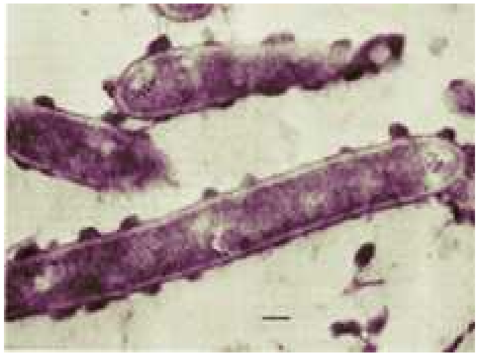


Sugars

Bioethanol

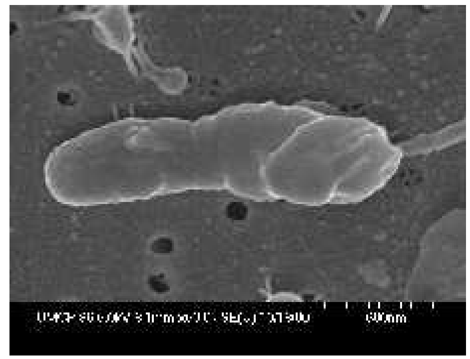
Harnessing the catalytic power of microbes and microbial communities

Clostridium thermocellum



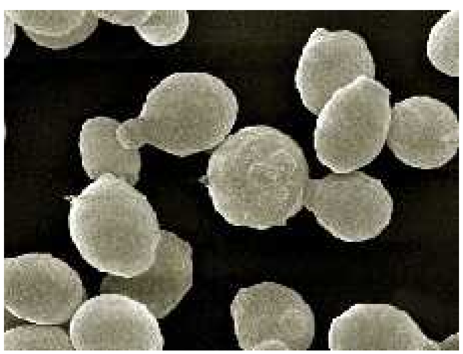
Conversion of cellulose to ethanol

Saccharophagus degradans 2-40



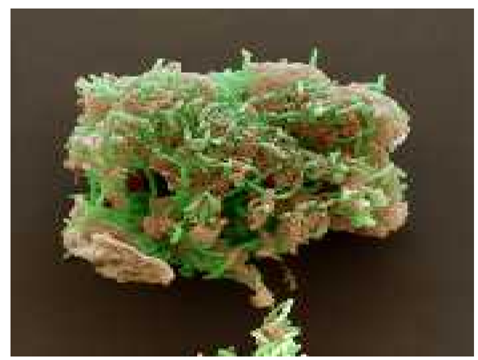
Cellulose degradation

Pichia stipitis



Conversion of xylose to ethanol

Geobacteraceae

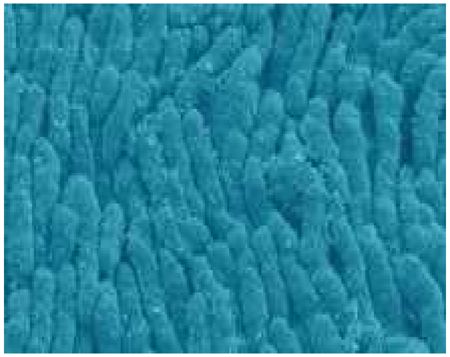


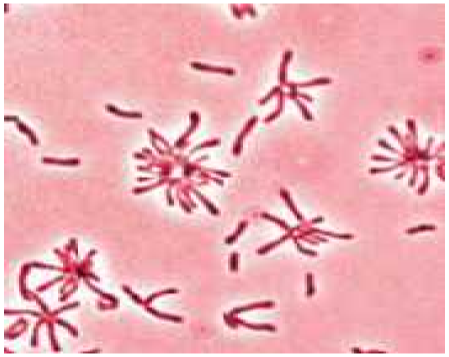
Cells growing on Fe(III) oxide

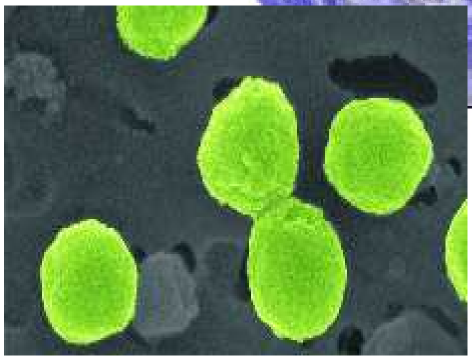
Ecogenomics: A new scientific frontier

Global biogeochemical processes are mediated by microbes, but relatively few have been cultured

- Ecogenomics: Applying the tools of genomics, proteomics, and systems biology to ecological questions
- Metagenome-scale sequences may reveal:
  - Structure and function of microbial communities
  - Microbe-host and microbe-microbe interactions
  - Metabolic capabilities that drive global-scale processes



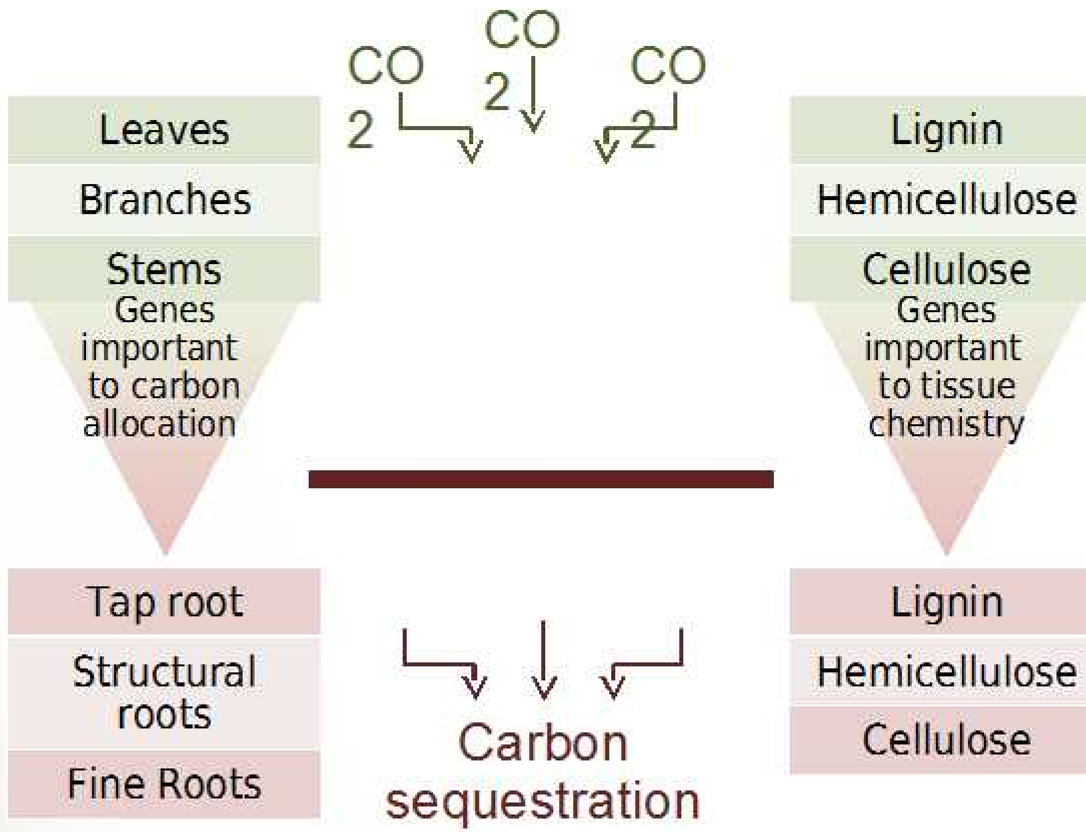




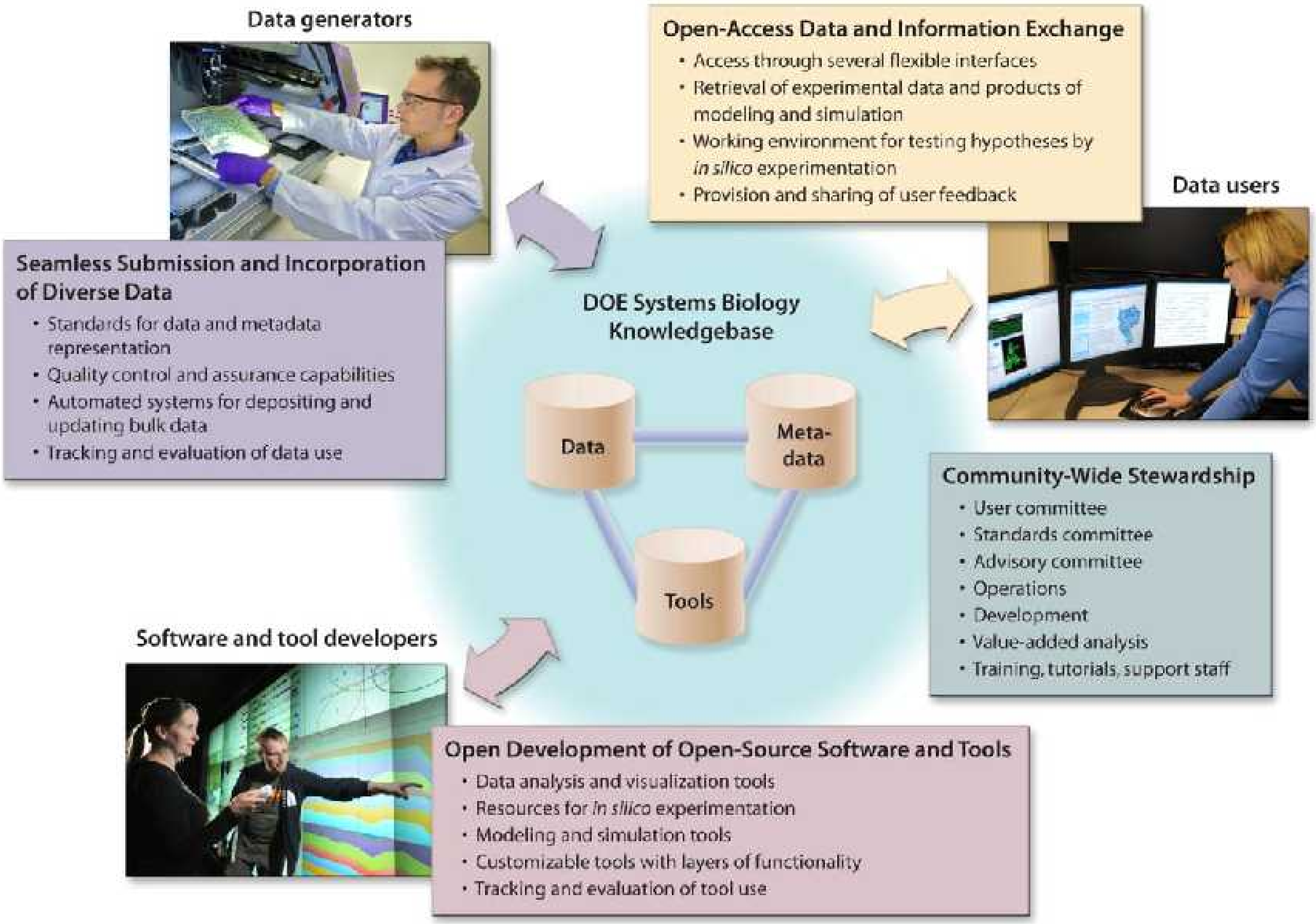
Plant genomics for bioenergy and carbon sequestration

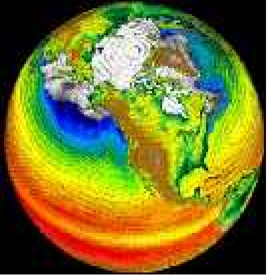
Greenhouse testing of poplar trees

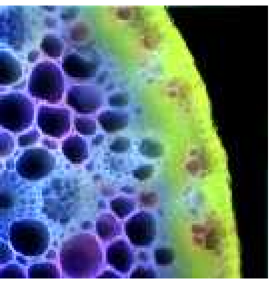
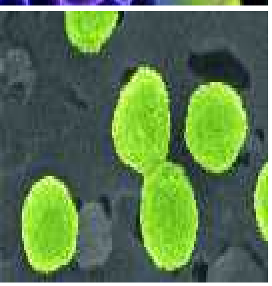
Genome-enabled discovery of carbon sequestration genes in *Populus*



DOE Systems Biology Knowledgebase
Establishing a systems biology modeling framework





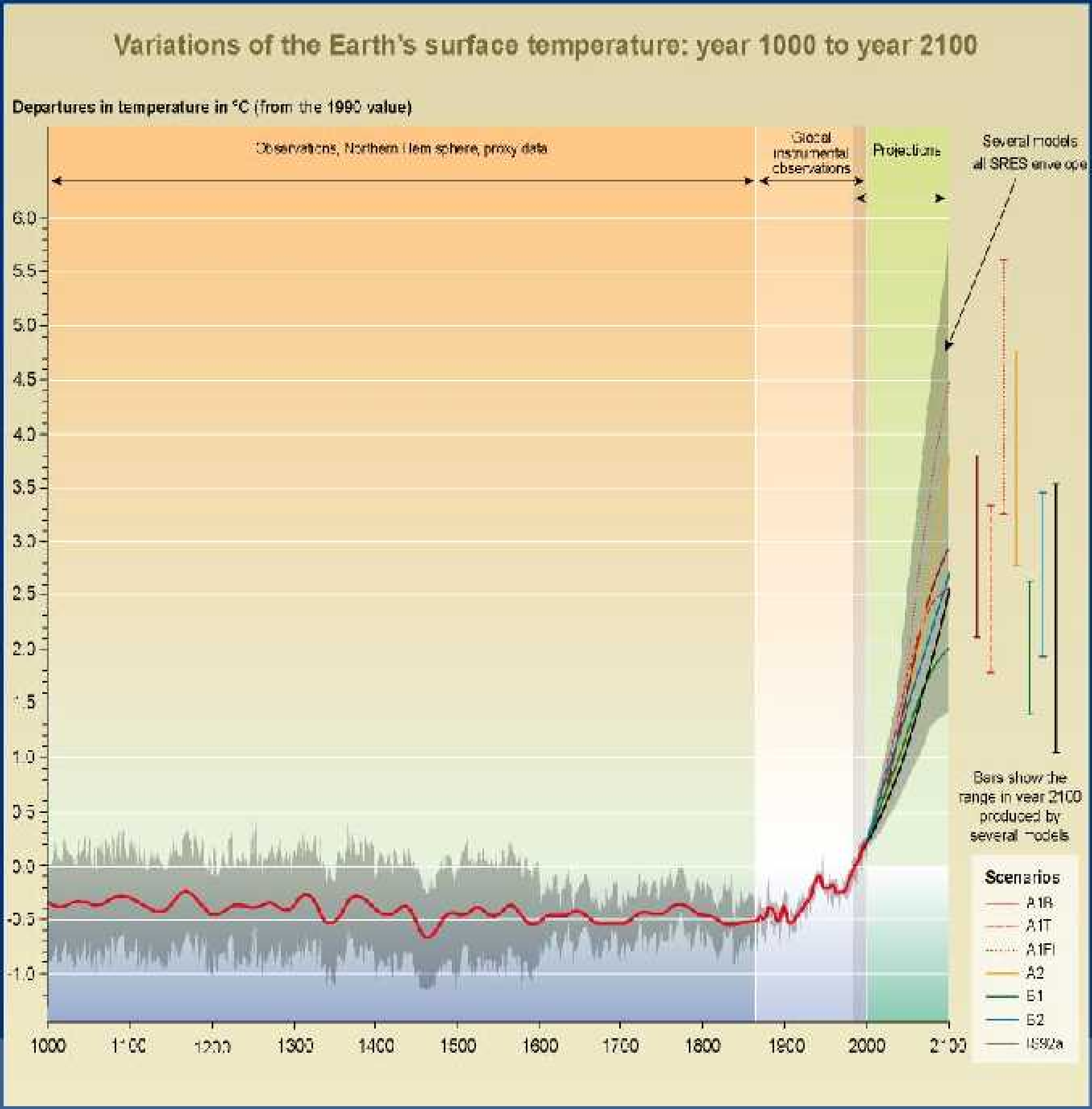
Climate Research

Click to edit Master
subtitle style

U.S. DEPARTMENT OF ENERGY

Office
of Science

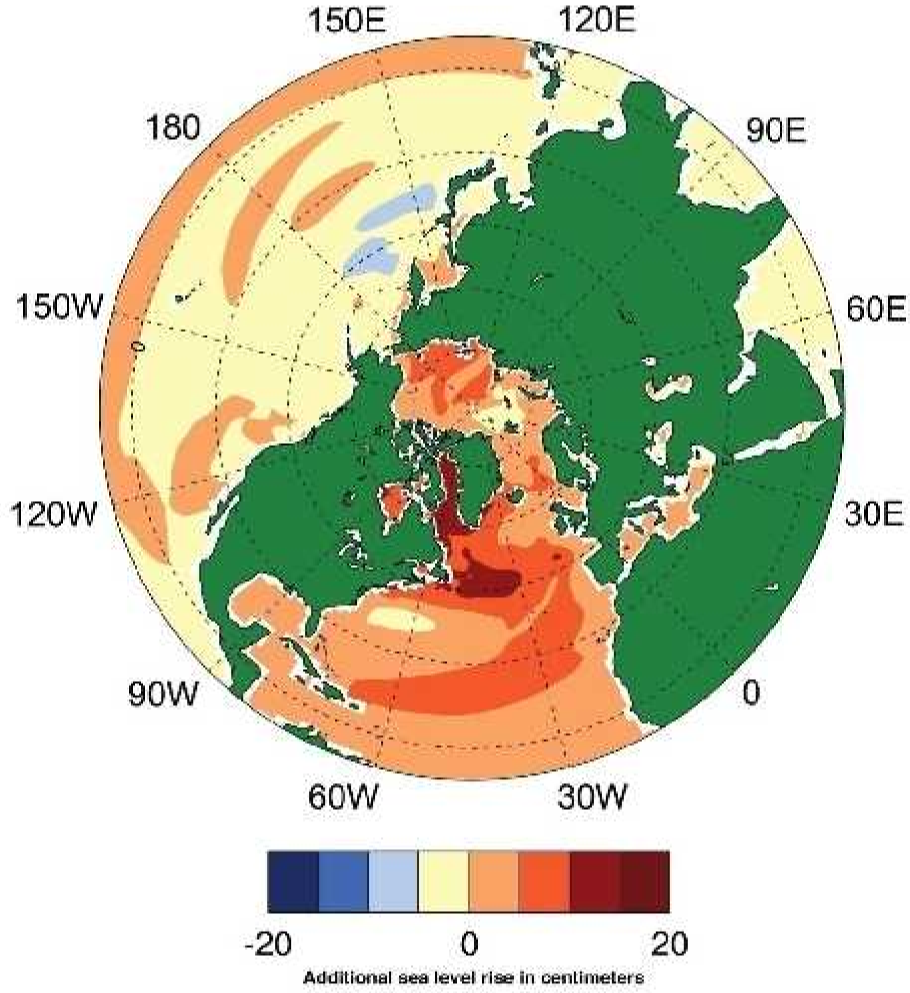
Office of Biological
and Environmental Research



SYR - FIGURE 9-1b

BER climate change research
The energy-climate connection

"Advance climate change research to provide knowledge of effects of greenhouse gas emissions on Earth's climate and biosphere—supporting effective energy and environmental decision making"



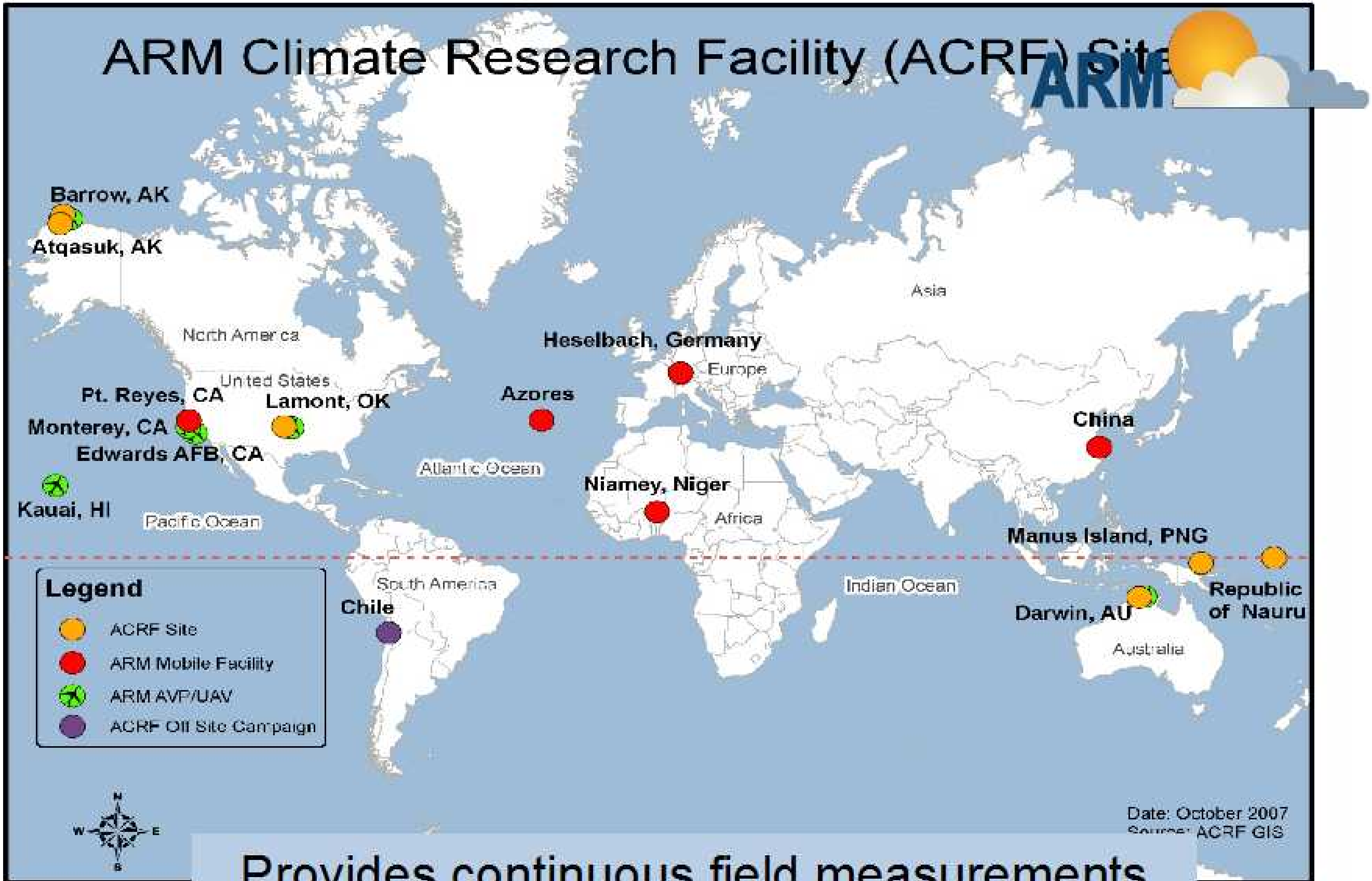
Modeling the impacts of climate change
Sea level rise modeled with the
Community Climate System Model

What are the Major Uncertainties In Climate Change?

- Representation of clouds in climate models;
- Direct and indirect effects of aerosols on climate;
- Interactions of the carbon cycle and climate

Radar Wind Profiler and radio acoustic sounding system (RASS), Barrow, Alaska

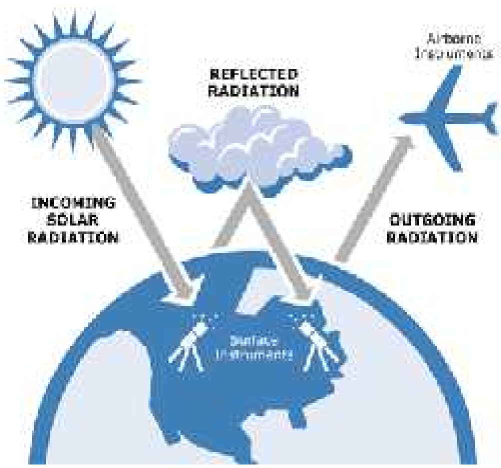
DOE Scientific User Facility
AF

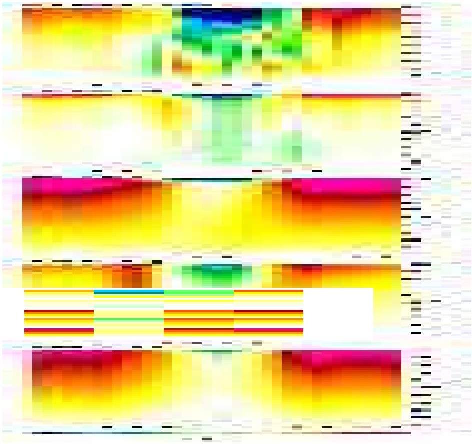


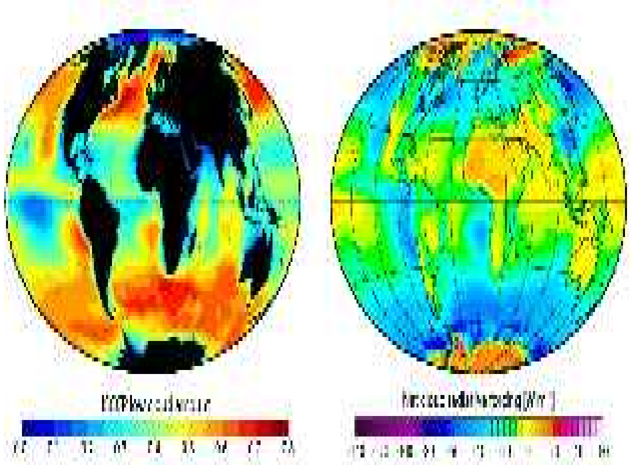
Provides continuous field measurements and data products that improve cloud science in climate models

From Measurements to Models

- Use of ACRF short- and long-term climate measurements
- Analysis, theory, process modeling, and retrospective climate simulations and evaluations
- Improved cloud and radiation formulations used to improve decadal climate predictions







The vital role of aerosols

- Objective:
  Improve scientific understanding of the atmospheric processes that drive aerosol radiative forcing of climate
- Includes:
  - Laboratory and field experiments
  - Modeling
  - Instrumentation

Multiagency MILAGRO campaign
(Megacity Initiative: Local and
Global Research Observations)
Mexico City, 2006

Terrestrial Carbon Cycle and Ecosystem research

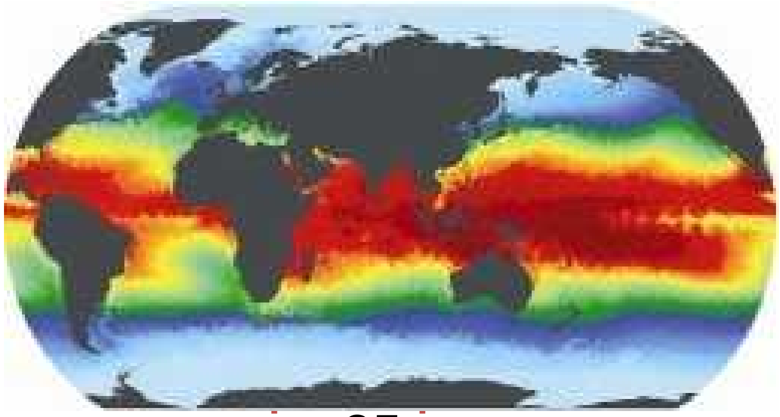
- Experimental and field-oriented programs to:
  - Understand processes and mechanisms controlling the exchange of CO2 between the atmosphere and terrestrial ecosystems
  - Develop process-based models
  - Improve reliability of global carbon models
  - Understand and predict the potential effects of climatic change on terrestrial ecosystems

Long-term, ecosystem-scale experiments

- Hallmark of DOE science -
  long-term, ecosystem-scale experiments manipulating temperature, precipitation, and CO2 levels
- Free-Air CO2 Enrichment (FACE) experiments experimentally enrich the atmosphere of a terrestrial ecosystem with controlled amounts of CO2 without using enclosures.
- Four current experiments
  (up to 20 years of data)
- Plans for a next generation ecosystem experiment in an ecosystem that is:
  - globally important
  - sensitive to climate change.
  - relatively understudied.
  - feasible

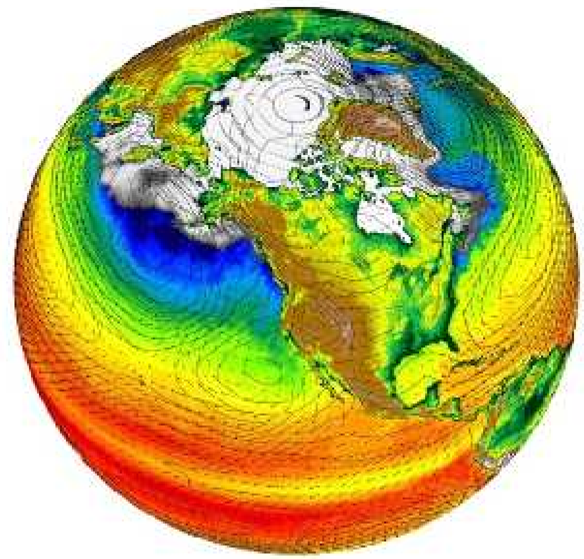
Why are climate models important?

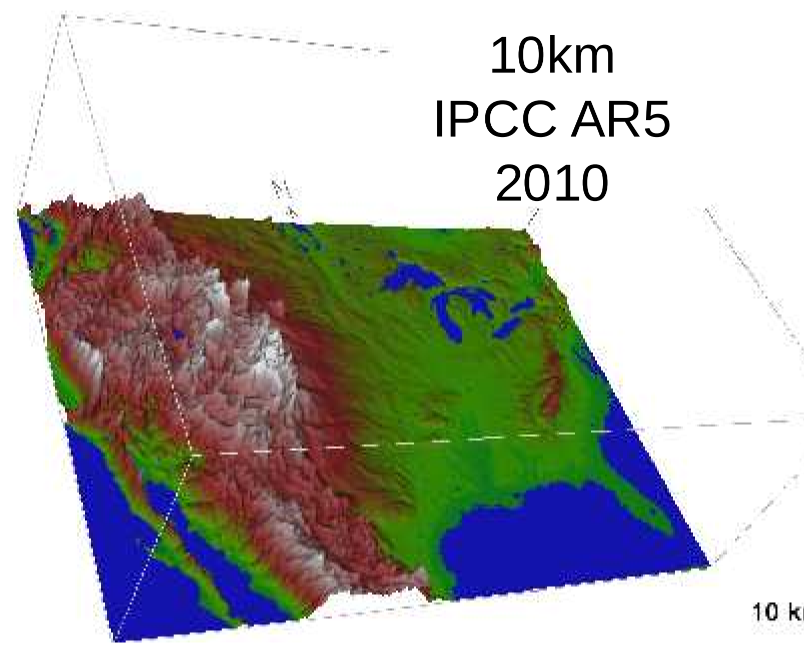
- Synthesis of climate theory & data
- Tool for predicting the future
- Tool for understanding the past
- Numerical “parallel Earth”
- Inform energy policy



Types of Climate Models

- <u>Earth System Models</u>:
  Couple individual process models (e.g.atmosphere, land, ocean, sea ice, carbon and sulfur cycles) _
- <u>Global and Regional Models:</u>
  Based on general circulation models (GCMs), downscaled to regional levels
- <u>Integrated Assessment Models</u>:
  Understand and model the complex interactions of human and natural systems





Partnerships with Advanced Scientific Computing Research

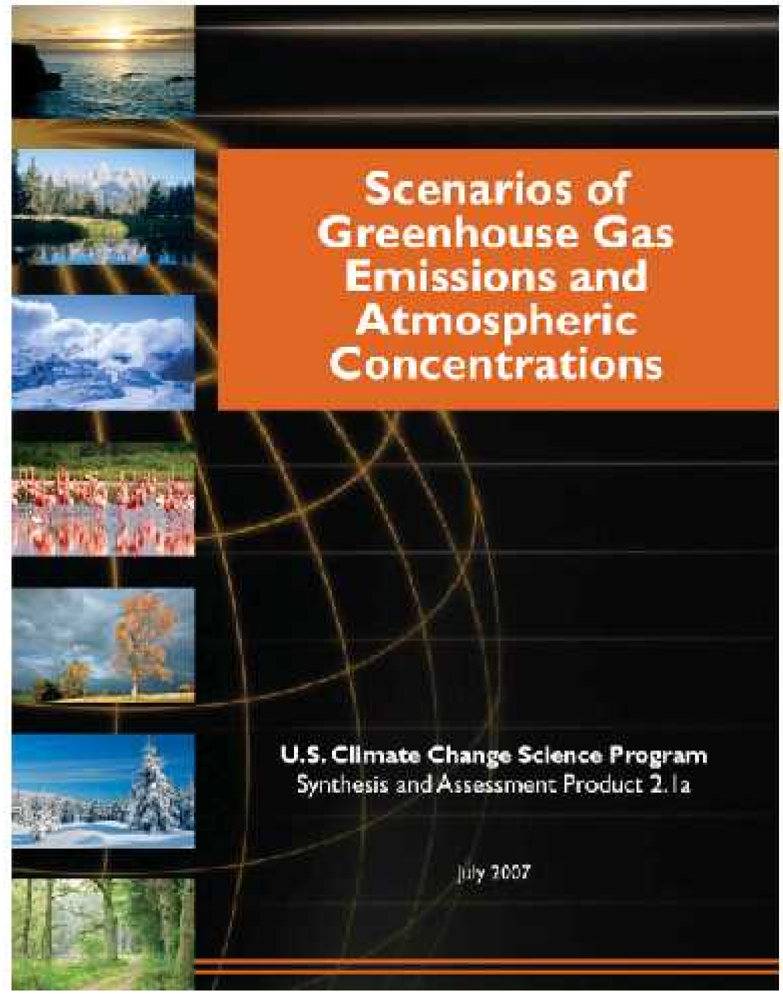
- The Scientific Discovery through Advanced Computing (SciDAC) program applies computational science expertise to critical aspects of climate change science
- The Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program provides computational time to BER projects in climate modeling that need very large allocations
- The National Energy Research Scientific Computing (NERSC) facility provides a significant amount of smaller allocations for climate change research
- The Energy Sciences network (ESnet) provides scientific network capability for climate scientists to share data via the Earth Syste



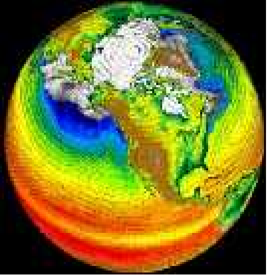


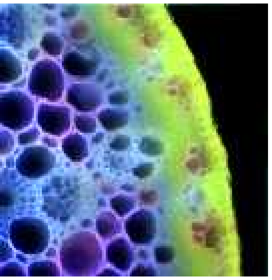
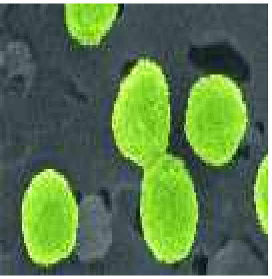
Coordinating U.S. Climate Change Research

- All DOE climate change research is coordinated with the interagency U.S. Global Change Research Program (USGCRP)
- USGCRP integrates federal research on climate and global change among 13 federal agencies



US Global Change Research Program
www.usgcrp.gov



Click to edit Master subtitle style

Thank you!

Anna Palmisano
Anna.Palmisano@science.doe.gov
http://science.doe.gov/ober