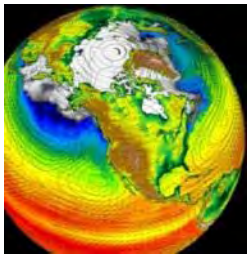
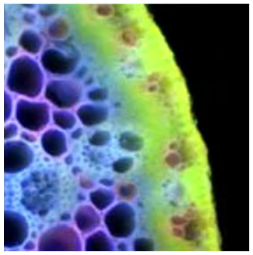
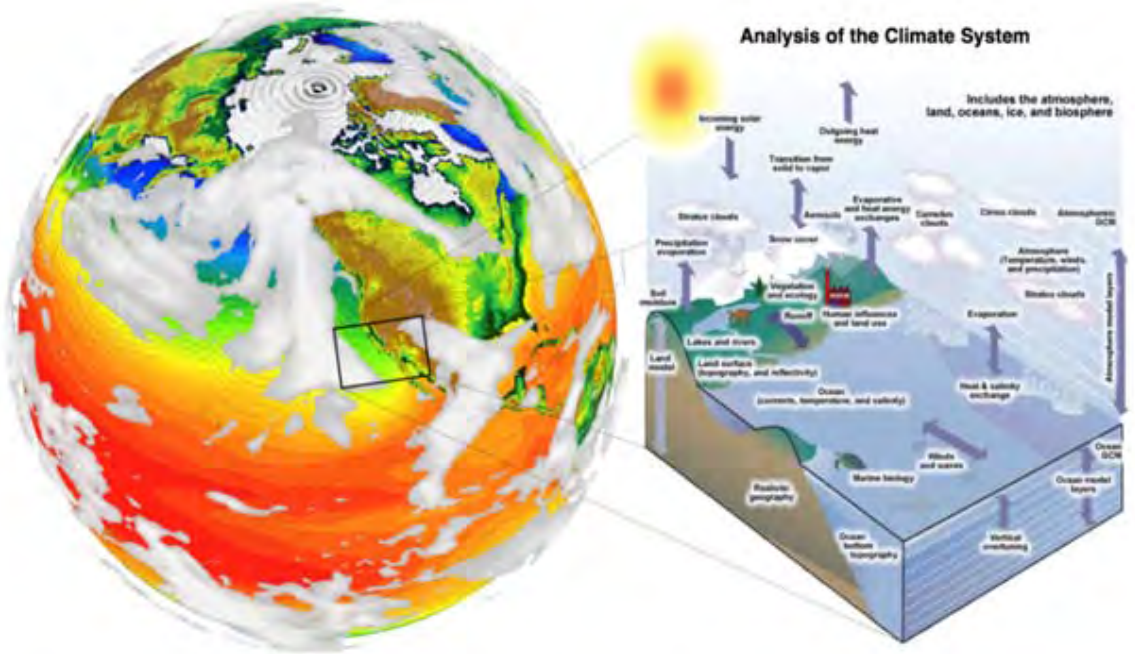



Regional and Global Climate Modeling Program

Program Manager: Renu Joseph



April 26, 2016

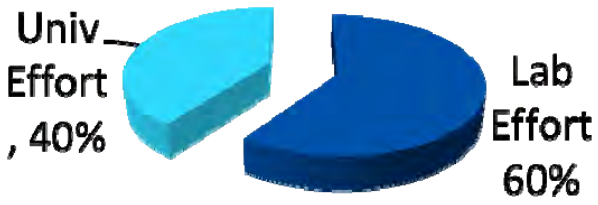
ESS PI Meeting

Regional and Global Climate Modeling

Strategic Goal

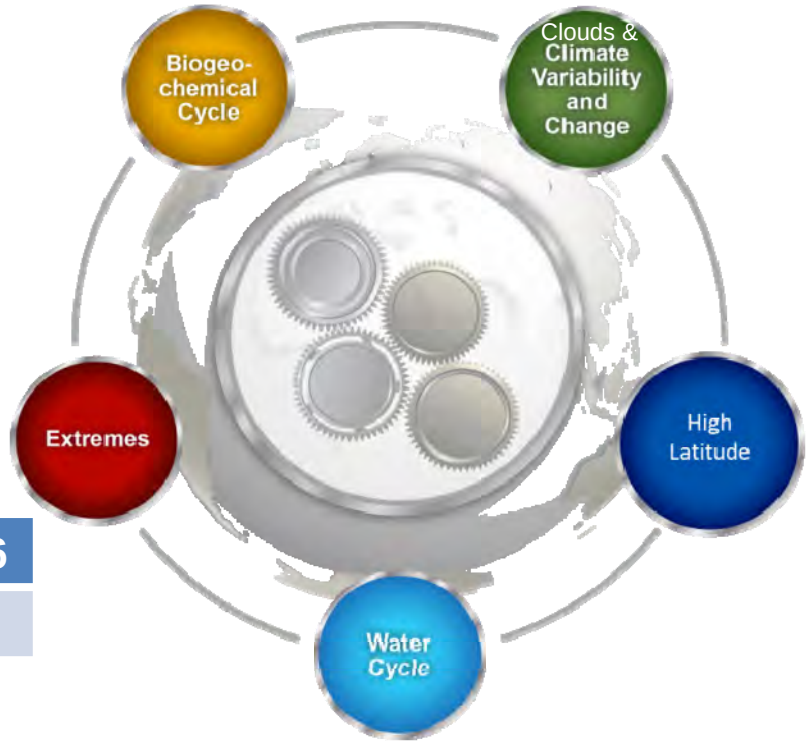
To enhance a predictive understanding of climate variability and change by analyzing global and regional models in conjunction with observations

Approx. Funding Distribution

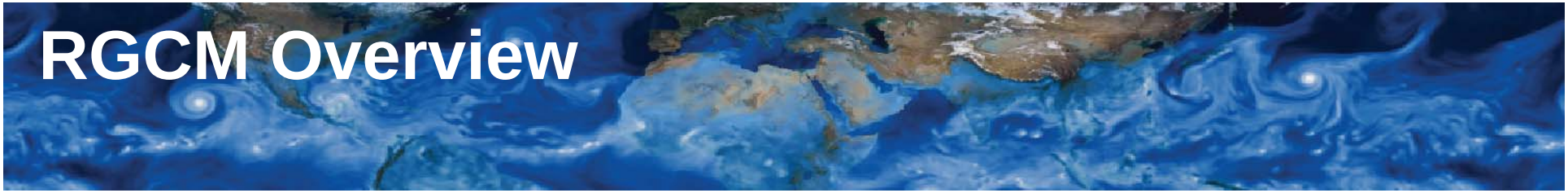


FY10	FY11	FY12	FY13	FY14	FY15	FY16
28M	31M	28M	29M	28M	26M	30M

5 Science Focus Areas



RGCM Overview



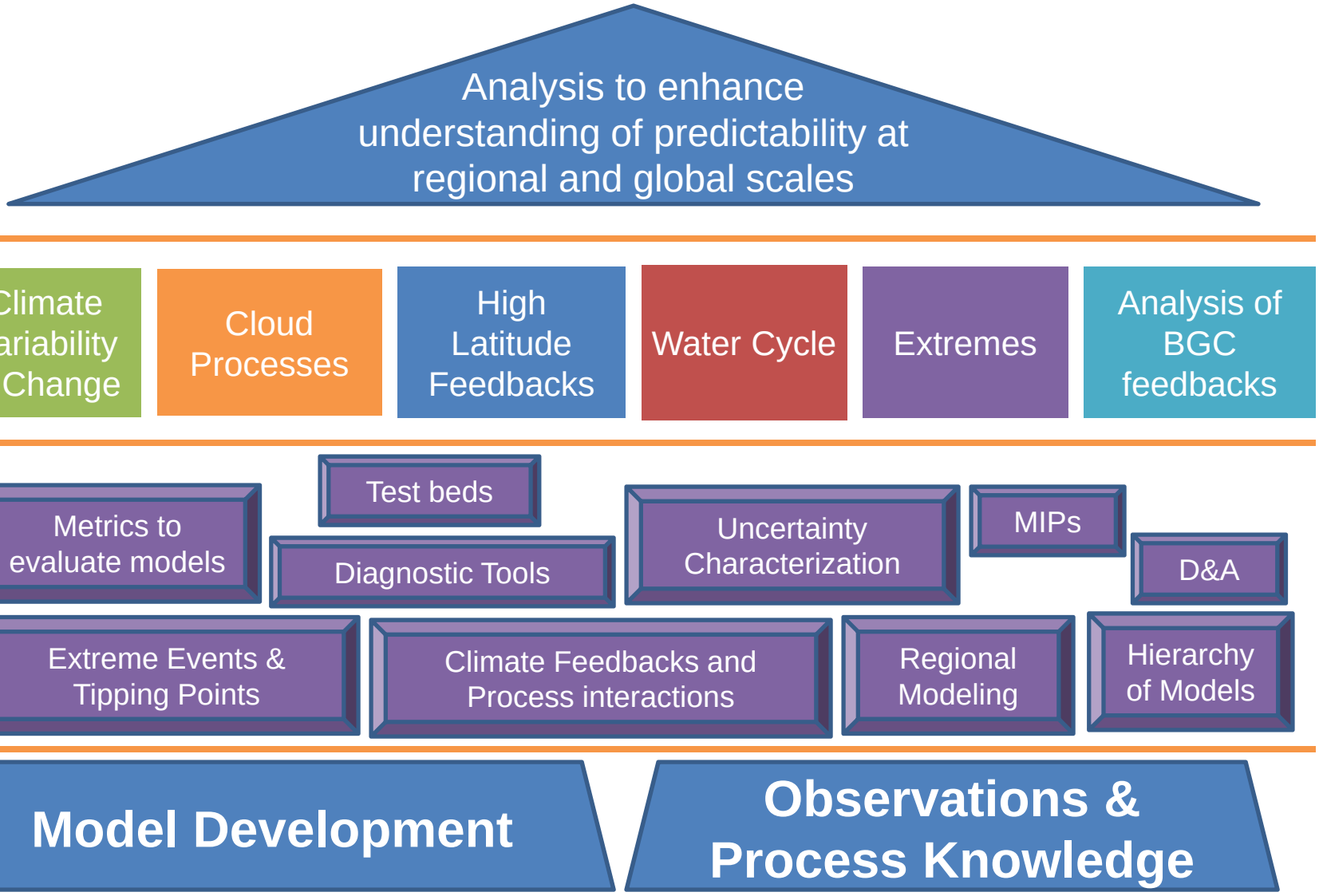
Analysis to enhance understanding of predictability at regional and global scales

Climate Variability & Change	Cloud Processes	High Latitude Feedbacks	Water Cycle	Extremes	Analysis of BGC feedbacks

Cross-cutting Foundational and Enabling Capabilities

Foundational Capabilities

Regional and Global Climate Modeling



Biogeochemistry: Climate Feedbacks Scientific Focus Area

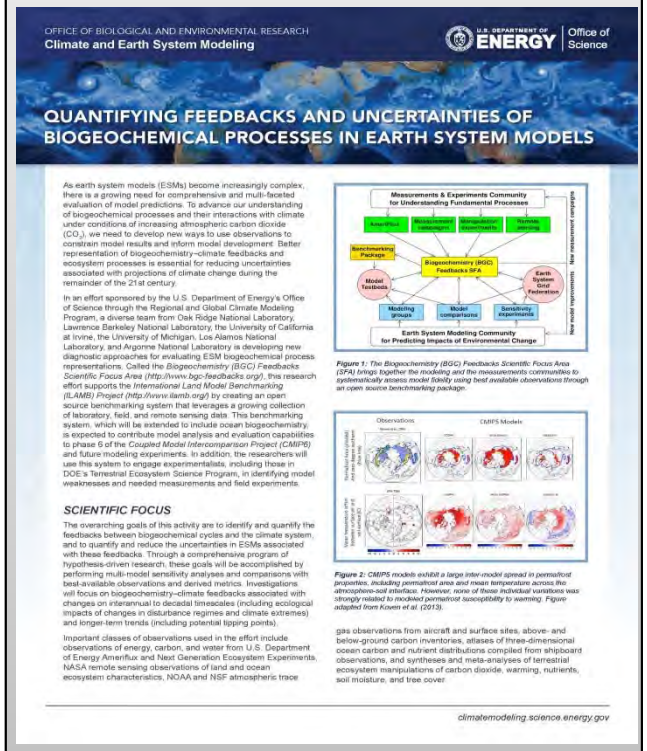
Forrest M. Hoffman (Lab Research Manger, ORNL), William J. Riley (Senior Science Co-Lead, LBNL) and James T. Randerson (Chief Scientist, University of California–Irvine)

Research Goals:

- Identify and quantify **feedbacks** between biogeochemical cycles and the climate system.
- Quantify and **reduce the uncertainties** in ESMs associated with these feedbacks.

Research Objectives:

1. Develop new **hypothesis–driven approaches for evaluating ESM processes** using **observations and models** at site, regional, and global scales.
2. Investigate the degree to which contemporary **observations can reduce uncertainties**, using an "emergent constraint" approach.
3. **Evaluate** the performance of biogeochemical **processes and feedbacks** in Coupled Model Intercomparison Project (CMIP) ESMs, CESM, and ACME models.
4. Create an **Open Source benchmarking software** system that leverages lab, field, and remote sensing data sets.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QUANTIFYING FEEDBACKS AND UNCERTAINTIES OF BIOGEOCHEMICAL PROCESSES IN EARTH SYSTEM MODELS

As earth system models (ESMs) become increasingly complex, there is a growing need for comprehensive and multi-faceted evaluation of model predictions. To advance our understanding of biogeochemical processes and their interactions with climate under conditions of increasing atmospheric carbon dioxide (CO_2), we need to develop new ways to use observations to constrain model results and inform model development. Better representation of biogeochemistry–climate feedbacks and ecosystem processes is essential for reducing uncertainties associated with projections of climate change during the remainder of the 21st century.

In an effort sponsored by the U.S. Department of Energy's Office of Science through the Regional and Global Climate Modeling Program, a diverse team from Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, the University of California at Irvine, the University of Michigan, Los Alamos National Laboratory, and Argonne National Laboratory is developing new diagnostic approaches for evaluating ESM biogeochemical process representations. Called the *Biogeochemistry (BGC) Feedbacks Scientific Focus Area (http://www.bgc-feedbacks.org/)*, this research effort supports the *International Land Model Benchmarking (ILAMB) Project (http://www.ilamb.org/)* by creating an open source benchmarking system that leverages a growing collection of laboratory, field, and remote sensing data. This benchmarking system, which will be extended to include ocean biogeochemistry, is expected to contribute model analysis and evaluation capabilities to phase 6 of the *Coupled Model Intercomparison Project (CMIP6)* and future modeling experiments. In addition, the researchers will use this system to engage experimentalists, including those in DOE's Terrestrial Ecosystem Science Program, in identifying model weaknesses and needed measurements and field experiments.

Measurements & Experiments Community for Understanding Fundamental Processes

Benchmarking Package | Biogeochemistry (BGC) Feedbacks SFA | Model Testbeds | Earth System Grid Federation | Modeling groups | Model comparisons | Sensitivity experiments

Earth System Modeling Community for Predicting Impacts of Environmental Change

Figure 1: The Biogeochemistry (BGC) Feedbacks Scientific Focus Area (SFA) brings together the modeling and the measurements communities to systematically assess model fidelity using best available observations through an open source benchmarking package.

Observations | CMIP5 Models

Figure 2: CMIP5 models exhibit a large inter-model spread in permafrost properties, including permafrost area and mean temperature across the atmosphere-soil interface. However, none of these individual variations was strongly related to modeled permafrost susceptibility to warming. Figure adapted from Koven et al. (2013).

SCIENTIFIC FOCUS

The overarching goals of this activity are to identify and quantify the feedbacks between biogeochemical cycles and the climate system, and to quantify and reduce the uncertainties in ESMs associated with these feedbacks. Through a comprehensive program of hypothesis-driven research, these goals will be accomplished by performing multi-model sensitivity analyses and comparisons with best-available observations and derived metrics. Investigations will focus on biogeochemistry–climate feedbacks associated with changes on interannual to decadal timescales (including ecological impacts of changes in disturbance regimes and climate extremes) and longer-term trends (including potential tipping points).

Important classes of observations used in the effort include observations of energy, carbon, and water from U.S. Department of Energy Ameriflux and Next Generation Ecosystem Experiments, NASA remote sensing observations of land and ocean ecosystem characteristics, NOAA and NSF atmospheric trace gas observations from aircraft and surface sites, above- and below-ground carbon inventories, atlases of three-dimensional ocean carbon and nutrient distributions compiled from shipboard observations, and syntheses and meta-analyses of terrestrial ecosystem manipulations of carbon dioxide, warming, nutrients, soil moisture, and tree cover.

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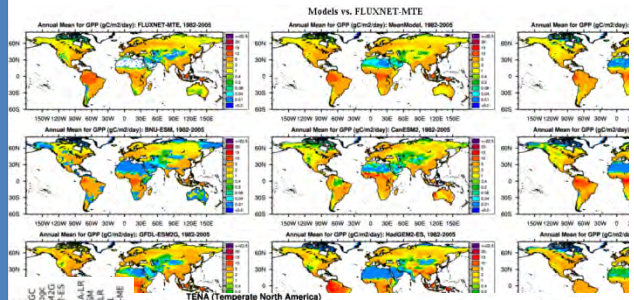
http://www.bgc-feedbacks.org/

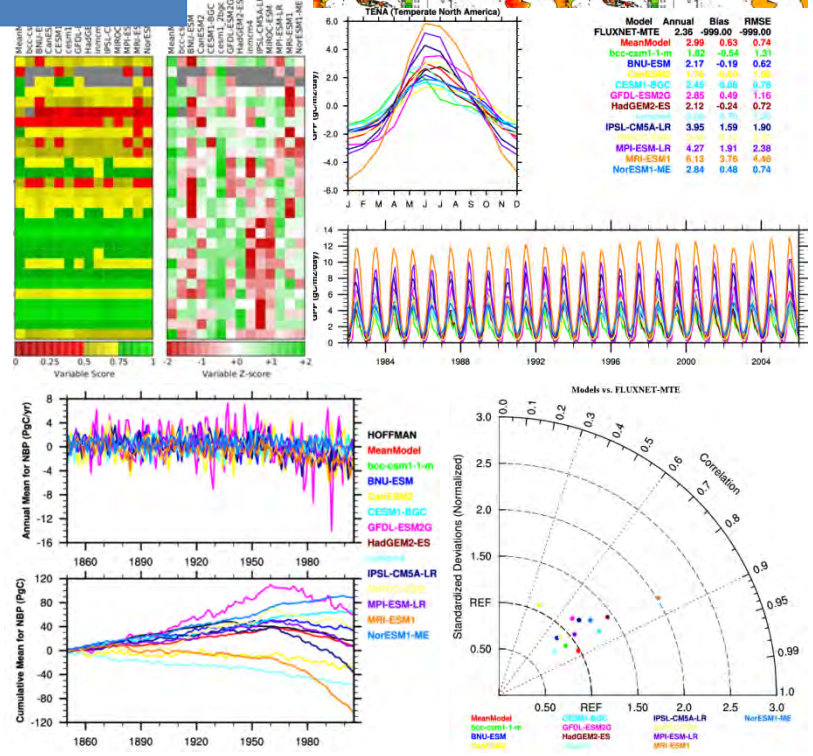
International Land Model Benchmarking (ILAMB)

ILAMB Goals: Develop internationally accepted Benchmarks for model performance, advocate design of open-source software system, and strengthen linkages between experimental, monitoring, remote sensing, and climate modeling communities



- **DOE's Biogeochemistry–Climate Feedbacks Scientific Focus Area (SFA)** has developed a free, open source analysis and diagnostics package that assesses **24 variables from ~45 datasets** using a wide variety of metrics.
- **Version 1 (in NCL)** was formally released at the AGU Town Hall Meeting in December 2015.

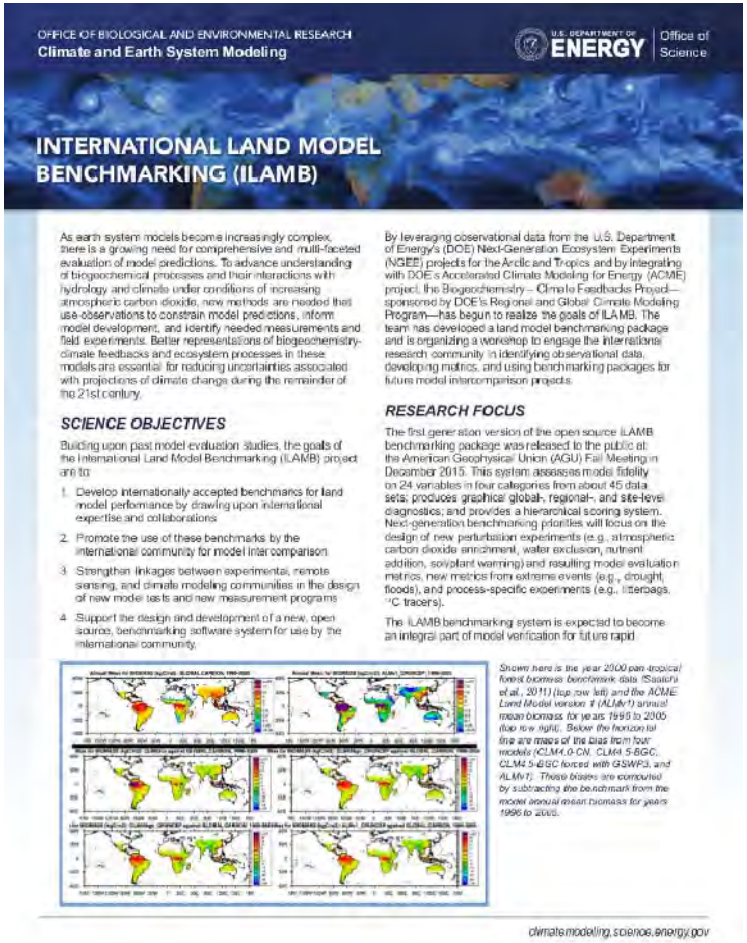
  See http://redwood.ess.uci.edu/mingquan/www/ILAMB/index.html
- **Version 2 (in python)** will improve modularity and extensibility, and will be released at the next ILAMB Workshop in May 2016.



ILAMB 2016 Workshop in Washington (May 16–18, 2016)

Jointly led by ESM and RGCM

- 60+ participants – including international -11 modeling centers represented -many research labs & universities.
- Agenda will focus on benchmarking tools, new model evaluation metrics, and next generation modeling/benchmarking challenges & priorities.
- Extensive tutorial sessions for the ILAMB package over two days with hands-on training.
- Breakout groups on MIPs, process-specific experiments, extreme event metrics, design of perturbation experiments, high latitude and tropical systems, and remote sensing.
- Participants asked to identify observational data needs and gaps in data availability.
- Special plenary session on uncertainty quantification (UQ) methods and tools.
- Engaging the community in the workshop report.



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INTERNATIONAL LAND MODEL BENCHMARKING (ILAMB)

As earth system models become increasingly complex, there is a growing need for comprehensive and multi-faceted evaluation of model predictions. To advance understanding of biogeochemical processes and their interactions with hydrology and climate under conditions of increasing atmospheric carbon dioxide, new methods are needed that use observations to constrain model predictions, inform model development, and identify needed measurements and field experiments. Better representations of biogeochemistry-climate feedbacks and ecosystem processes in these models are essential for reducing uncertainties associated with projections of climate change during the remainder of the 21st century.

By leveraging observational data from the U.S. Department of Energy's (DOE) Next-Generation Ecosystem Experiments (NGEE) projects for the Arctic and Tropics and by integrating with DOE's Accelerated Climate Modeling for Energy (ACME) project, the Biogeochemistry–Climate Feedbacks Project—sponsored by DOE's Regional and Global Climate Modeling Program—has begun to realize the goals of ILAMB. The team has developed a land model benchmarking package and is organizing a workshop to engage the international research community in identifying observational data, developing metrics, and using benchmarking packages for future model intercomparison projects.

SCIENCE OBJECTIVES

Building upon past model evaluation studies, the goals of the International Land Model Benchmarking (ILAMB) project are to:

1. Develop internationally accepted benchmarks for land model performance by drawing upon international expertise and collaborations
2. Promote the use of these benchmarks by the international community for model inter comparison
3. Strengthen linkages between experimental, remote sensing, and climate modeling communities in the design of new model tests and new measurement programs
4. Support the design and development of a new, open source, benchmarking software system for use by the international community.

RESEARCH FOCUS

The first generation version of the open source ILAMB benchmarking package was released to the public at the American Geophysical Union (AGU) Fall Meeting in December 2015. This system assesses model fidelity on 24 variables in four categories from about 45 data sets; produces graphical global-, regional-, and site-level diagnostics; and provides a hierarchical scoring system. Next-generation benchmarking priorities will focus on the design of new perturbation experiments (e.g., atmospheric carbon dioxide enrichment, water exclusion, nutrient addition, soil/plant warming) and resulting model evaluation metrics, new metrics from extreme events (e.g., drought, floods), and process-specific experiments (e.g., litterbags, ^{14}C tracers).

The ILAMB benchmarking system is expected to become an integral part of model verification for future rapid

Shown here is the year 2000 pan-tropical forest biomass benchmark data (Saatchi et al., 2011) (top row left) and the ACME Land Model version 1 (ALM-1) annual mean biomass for years 1996 to 2005 (top row right). Below the horizontal line are maps of the bias from four models (CLM4.0-CN, CLM4.5-BGC, CLM4.5-BGC forced with GSWP3, and ALM-1). These biases are computed by subtracting the benchmark from the model annual mean biomass for years 1996 to 2005.

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Biogeochemistry–Climate Feedbacks Scientific Focus Area

Future Directions for the BGC Feedbacks SFA

- Ocean biogeochemistry benchmarking
- Data assimilation for determining the contemporary carbon state and improving model process representation
- Small but frequent workshops focused on mechanisms/processes, phenomena, and perturbation experiments
- New studies on deforestation, drought, mortality, and CO_2 enrichment
- New metrics for coastal/estuarine processes, riverine nutrients, bi-directional canopy and marine ecosystem fluxes
- Open Model Benchmarking Architecture (OpenMBA) software infrastructure
- Integration with uncertainty quantification (UQ) packages and offline transport models
- Design simulation protocol for future MIPs in CMIP7, conduct model experiments, and evaluate ecosystem responses and feedbacks to Earth's climate system

Community Engagement for ILAMB

- Software engineering is co-led by ORNL, UCI, and LBNL, and the **CESM and ACME** Land Model Working Groups.
- Will be incorporated into **PCMDI Metrics Package** and the **WGNE/WGCM Climate Model Metrics Panel.**
- Expect it will be adopted by various model–data intercomparison studies and used for CMIP6 analysis including C4MIP

- Connections with modeling centers, measurement activities, and MIPs, including GEWEX, iLEAPs, MAREMIP, MsTMIP, TRENDY/RECCAP/GCP, GSWP3, and future FACE-MIP and LBA-DMIP.
- **Looking for community participation in the regular telecons** and in the development phase of the activity. [Contact: Forrest Hoffman, Bill Riley, Jim Randerson]
- Will be **convening community workshops** to offer training sessions on using the benchmarking system, starting in May 2016.

Current Participants:

Forrest Hoffman, Bill Riley, Jim Randerson, Gretchen Keppel-Aleks, David Lawrence, Charlie Koven, Jiafu Mao, Sean Swenson, Mingquan Mu, Nate Collier, Keith Moore, Umakant Mishra, Scott Elliott, Jinyun Tang, Xiaojuan Yang (and others)

Friends of ILAMB:

[Your Name Here!]