Regional and Global Climate Modeling Program

Program Manager: Renu Joseph

Analysis of the Climate System
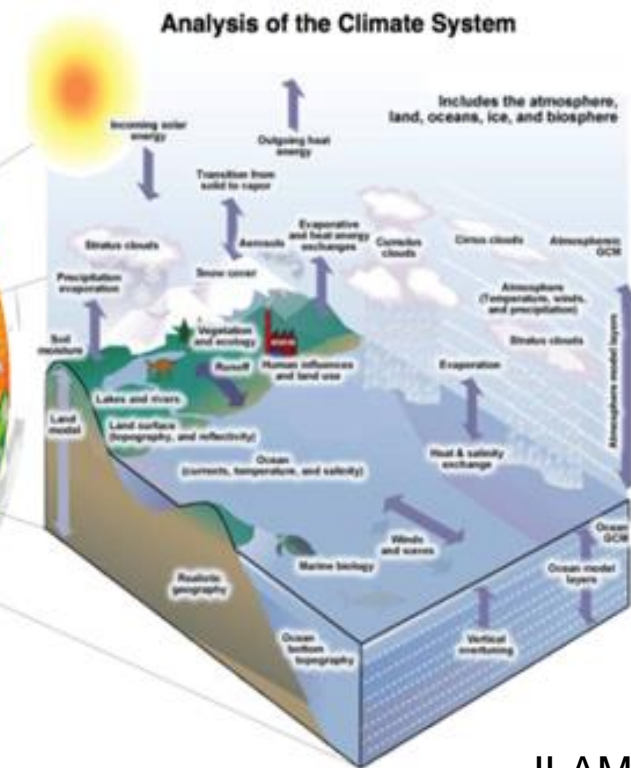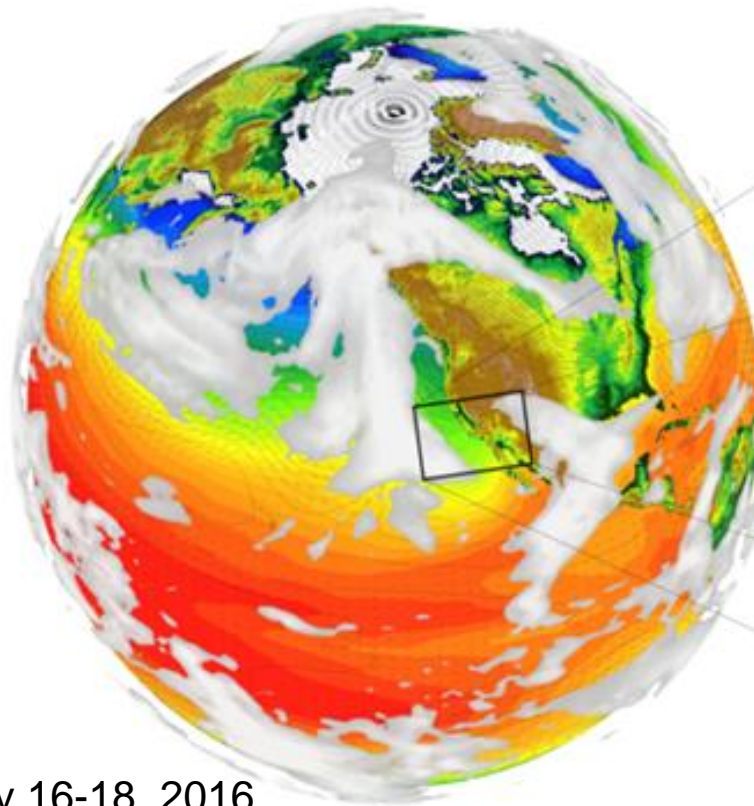
May 16-18, 2016

U.S. DEPARTMENT OF ENERGY

Office of Science

Office of Biological and Environmental Research

Climate and Environmental Sciences Division
(Gary Geernaert)

Earth System Modeling
(Dorothy Koch)

Atmospheric Radiation Measurement Climate Research Facility
(Sally McFarlane, Rick Petty)

Atmospheric System Research
(Ashley Williamson, Shaima Nasiri)

Regional & Global Climate Modeling
(Renu Joseph)

Integrated Assessment
(Bob Vallario)
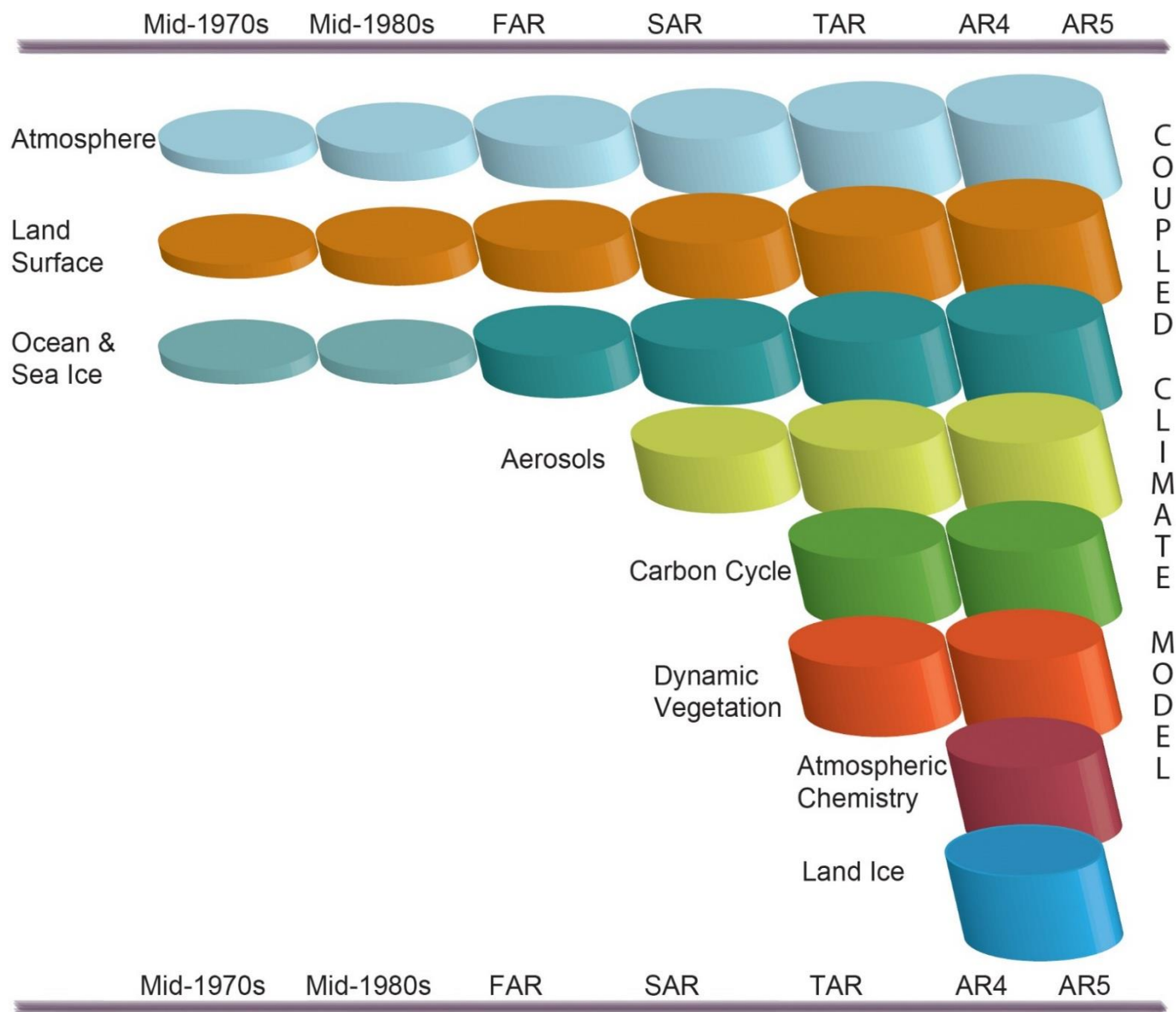
Data Informatics
(Justin Hnilo)

Terrestrial Ecosystem Science
(Dan Stover, Jared DeForest)

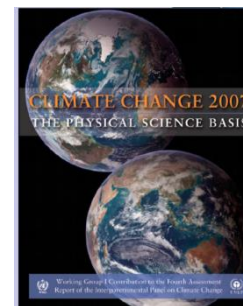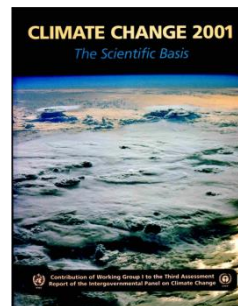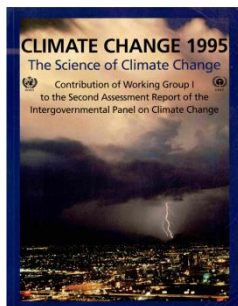**Subsurface Biogeochemical Research**
(David Lesmes)

Environmental Molecular Sciences Laboratory
(Paul Bayer)

Budget: $310M, divided roughly equally among the three groups

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Timeline of Climate Model Analysis
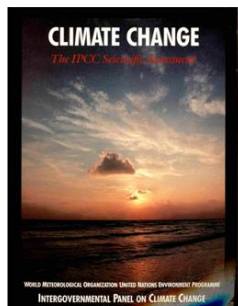
Pre-MIPs	IPCC AR1	IPCC AR2	IPCC AR3	IPCC AR4	IPCC AR5
<1989	1990	1995	2001	2007	2013
(Mostly) Qualitative analysis performed by modeling centers	FANGIO "MIP", AMIP1	CMIP 1	CMIP2	CMIP3	CMIP5
	30 models	21 models	18 models	23 models	~50 models
	10 countries	9 countries	8 countries	12 countries	13 countries
Difficult to share data.	10 analysis projects	15 analysis projects	22 analysis projects	>1000 papers	>1000 papers
No standard benchmark experiments	Data: GB	Data: ~MB	Data: ~GB	Data: 30 TB	Data: 2 PB
PCMDI was founded					

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

5 Science Focus Areas

Approx. Funding Distribution

Univ Effort, 40%
Lab Effort 60%

- Biogeo-chemical Cycle
- Clouds Climate Variability and Change
- Extremes
- High Latitude
- Water Cycle
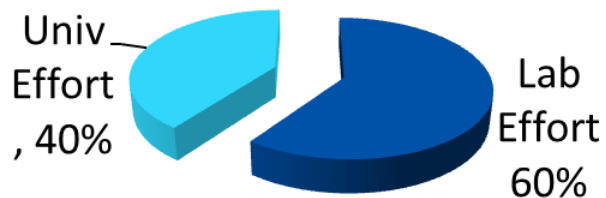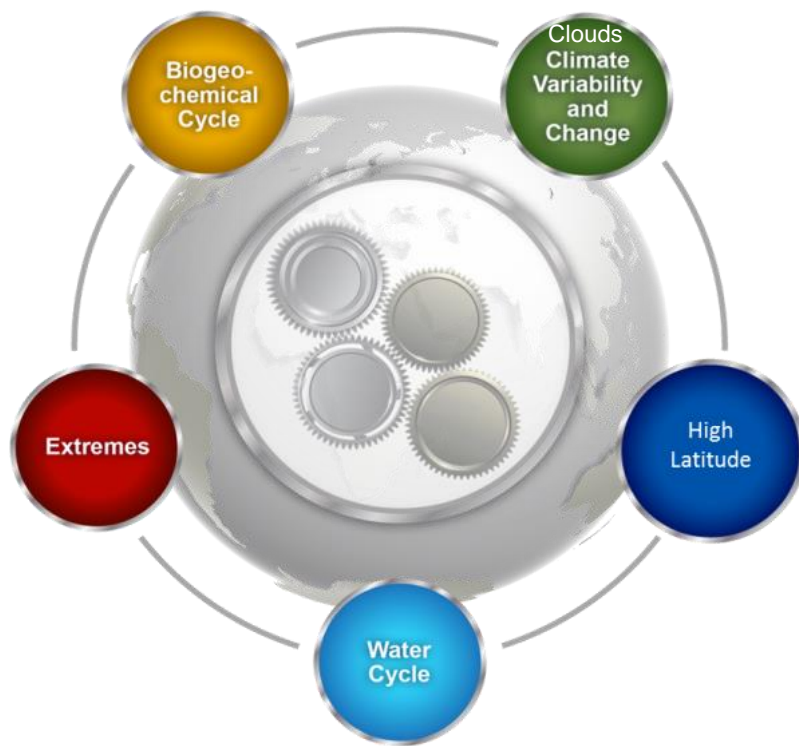
FY10	FY11	FY12	FY13	FY14	FY15	FY16
28M	31M	28M	29M	28M	26M	30M

WCRP
World Climate Research Programme

Research Challenges

CVC and Cloud Processes

High Latitude Feedbacks

Water Cycle

Extremes

Analysis of BGC feedbacks

Clouds, Circulation and Climate Sensitivity

Sea-level Rise and Regional Impacts

Cryosphere in a Changing Climate

Changes in Water Availability

Science Underpinning the Prediction and Attribution of Extreme Events

Regional Climate Information

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.

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

- **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.

- **Successful AGU Town Hall in Dec 2015**

- **Version 1 (in NCL)** was formally released at the AGU Town Hall Meeting in Dec '15.
  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.

- **DOIs** acquired for the ILAMB package
  - ILAMB.v001.00
    (To be cited as DOI:10.18139/ILAMB.v001.00/1251597)
  - ILAMB.v002.00
    (To be cited as DOI:10.18139/ILAMB.v002.00/1251621)
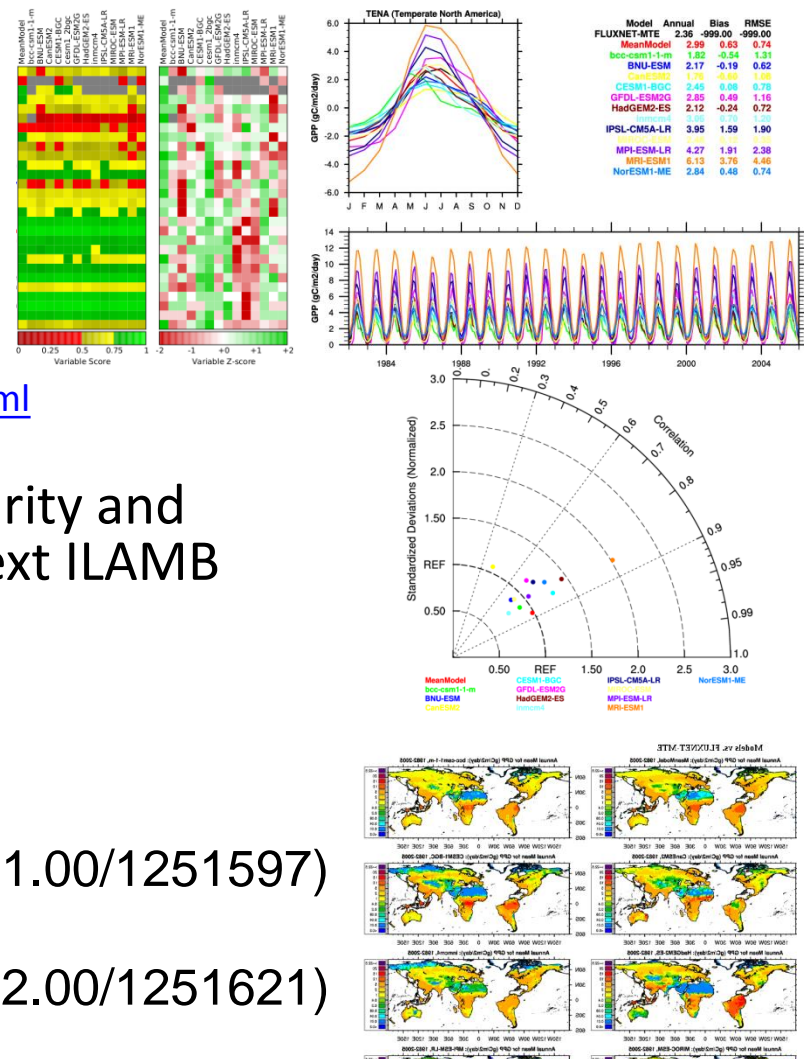
- Emphasized the importance of considering a suite of equally valid datasets and involving data providers in our activities

- the importance of uncertainty in the observations

- Inclusion of more metrics for model-data evaluation

- Community involvement in code and metrics development

- For future development - perturbation experiment metrics:
  - Ratios of related states and fluxes, e.g., NPP/precip;
  - Manipulative experiments (e.g., N, P fertilization, drought, FACE, warming);
  - Natural "experiments" or extremes (e.g., heat waves, floods, drought).

- a global synthesis evaluation of models from a variety of model intercomparison experiments.

- Permafrost Benchmarking System (PBS) from NASA might consider adopting the ILAMB framework

- Connections between Predictive Ecosystem Analyzer (PEcAn)

Jointly led by RGCM and ESM

- 60+ participants (national and international); 11 modeling centers; many research labs & universities.

- Agenda focuses 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 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 by crowdsourcing whitepapers and the final workshop report.

OFFICE OF BIOLOGICAL AND ENVIRONMENTAL RESEARCH
Climate and Earth System Modeling

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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 intercomparison

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, 14C 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 (ALMv1) annual mean biomass for years 1995 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 ALMv1). These biases are computed by subtracting the benchmark from the model annual mean biomass for years 1995 to 2005.

climatemodeling.science.energy.gov

BGC Feedbacks

Argonne NATIONAL LABORATORY | BERKELEY LAB | Los Alamos NATIONAL LABORATORY | NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH | OAK RIDGE National Laboratory | UCI | MICHIGAN

10 ILAMB Meeting   Department of Energy • Office of Science • Biological and Environmental Research

Goals of the Workshop:

- Facilitate **coordination, cooperation, and collaboration** as appropriate in the Community

  - Across various MIPS: C4MIP; LS3MIP; LUMIP, etc.

  - Across Model development activities

- Identify **new techniques for model evaluation** that can reduce uncertainties with respect to biosphere processes and biogeochemical feedbacks with the climate system;

- Increase awareness of **new data streams** that will be available for model verification and benchmarking from remote sensing, in situ measurements, and synthesis activities;

- To **prioritize the design new metrics** and evaluation approaches for integration into the next generation ILAMB system; and

- **Identify gaps** that need focused attention

- **Workshop Report** that captures discussion of

  - Scientific Challenges and Opportunities for Model Evaluation

  - New Metrics and Benchmarking Approaches

  - Observational Data Needs

  - Model Development and Output Requirements

  - Computational Needs and Requirements

Community Engagement & Next steps :

- Facilitate avenues for community involvement in code and metrics development

- Extensibility to other BGC components

- Inclusion and acknowledgement of all contributors to ILAMB

- Software engineering co-led by ORNL, UCI, LBNL, and the <u>CESM and ACME </u>Land Model Working Groups.

- Will be incorporated into <u>PCMDI Metrics Package </u>and included in the capabilities catalogue being prepared by WGNE/WGCM Climate Model Metrics and Diagnostics Panel

- Ensure availability to various model–data intercomparison studies and used for CMIP6 analysis

- ILAMB will be used by the C4MIP group for CMIP6, included it in standard diagnostics for all CMIP6 models at PCMDI

- **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

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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!]