Regional and Global Climate Modeling Program

Program Manager: Renu Joseph

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ESS PI Meeting
Regional and Global Climate Modeling

Advance a **predictive and process level understanding** of climate variability and change over a variety of scales, and diagnose and analyze state-of-the-science for climate and Earth system models

- **Science:**
  - Extremes, thresholds and tipping points
  - Feedbacks within the climate system
  - Detection and attribution of climate change
  - Decadal predictability and sea-level rise
  - Cross-cutting topics like the water and biogeochemical cycles

- **Tools include:**
  - Advanced (multivariate) model metrics
  - Observation-based diagnostics
  - Uncertainty quantification methods to guide model development, gauge model improvement, and establish confidence in model projections
  - Tools to facilitate analysis of model results
Regional and Global Climate Modeling
($26M – 2015)
Divided between Lab, University, and large Cooperative Agreements

5 SFA Topics

1. Climate Variability and Change – LLNL, UCAR

2. High Latitude Feedbacks – LANL/PNNL, RASM

3. Water Cycle and Climate Extremes Modeling – PNNL

4. CAlibrated and Systematic Characterization, Attribution, and Detection of Extremes – LBNL

5. Feedbacks and uncertainties of biogeochemical cycles – ORNL/LBNL
**Biogeochemistry–Climate Feedbacks Scientific Focus Area**

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

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**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. Create an **Open Source benchmarking software** system that leverages lab, field, and remote sensing data sets.
4. **Evaluate** the performance of biogeochemical processes and feedbacks in Coupled Model Intercomparison Project (CMIP) ESMs, CESM, and ACME models.

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http://www.bgc-feedbacks.org/
Biogeochemistry–Climate Feedbacks Scientific Focus Area

Measurements & Experiments Community for Understanding Fundamental Processes

- AmeriFlux
- Measurement campaigns
- Manipulation experiments
- Remote sensing

Benchmarking Package

Biogeochemistry (BGC) Feedbacks SFA

- Model Testbeds
- Modeling groups
- Model comparisons
- Sensitivity experiments

Earth System Grid Federation

Earth System Modeling Community for Predicting Impacts of Environmental Change

New model improvements

New measurement campaigns
Why do we need Benchmarks?

- Human capital costs of making rigorous model–data comparisons is considerable and constrains the scope of individual MIPs.
- Many MIPs spend resources “reinventing the wheel” in terms of variable naming conventions, model simulation protocols, and analysis software.

**An ideal benchmarking tool should:**

- **Provide each new MIP access to the model-data comparison modules from past MIPs (e.g., MIPs use one common modular software system).**
- **Standardized international naming conventions also increase MIP efficiency.**
- **An Open Source Benchmarking Software System**
Adopting ILAMB as the benchmarking software

Built from the C-LAMP prototype (Randerson et al., 2009; Luo et al., 2012)

- Initial prototype with efforts within DOE, community involvement, NASA, NSF, and data from other agencies.

Now the core support for ILAMB comes from DOE funding.
ILAMB Package

- 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.

- Software engineering is co-led by ORNL and LBNL, in collaboration with UCI and the CESM and ACME Land Model Working Groups.

- New version will be in python to improve extensibility and maximize use in DOE software tools being developed.

- Will be incorporated into PCMDI Metrics Package and the WGNE/WGCM Climate Model Metrics Panel.

Luo et al. (2012)
**Community Engagement**

- **ILAMB will be used by the C⁴MIP group for CMIP6**, and we are working to include it in standard diagnostics for all CMIP6 models at PCMDI.

- 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]

- Will be **convening community workshops** to offer training sessions on using the benchmarking system.
Current Participants:

Forrest Hoffman, Bill Riley, Jim Randerson, David Lawrence, Charlie Koven, Gretchen Keppel-Aleks, Sean Swenson, Mingquan Mu, Nate Collier, Gautam Bisht, Keith Moore, Umakant Mishra, Erik Kluzek, Scott Elliott, Jitendra Kumar (and others)

Friends of ILAMB:
(your name)
Metrics

• Large-scale state and flux estimates
  – LH, SH, total water storage, albedo, river discharge, SCF, LAI, soil and veg C stocks, GPP, NEE, ER, burnt area, permafrost distribution, $T_{2m}$, P, …
  – RMSE, spatial pattern corr, interannual variance, annual cycle phase, trends

• Functional relationships and emergent properties
  – soil moisture – ET, soil moisture – runoff, precip – GPP, stomatal response to VPD, precip – burnt area, transient carbon storage trajectory, runoff ratio, spring albedo transition

• Experimental manipulation (testing model functional responses)
  – Nitrogen additions, FACE, artificial warming, rainfall exclusion
## Example Carbon Cycle Metrics

### Global Variables

<table>
<thead>
<tr>
<th></th>
<th>MeanModel</th>
<th>CLM40cn</th>
<th>CLM45bgc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aboveground Live Biomass</strong></td>
<td>0.72</td>
<td>0.65</td>
<td>0.76</td>
</tr>
<tr>
<td><strong>Burned Area</strong></td>
<td>0.45</td>
<td>0.33</td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Gross Primary Production</strong></td>
<td>0.58</td>
<td>0.54</td>
<td>0.57</td>
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<tr>
<td><strong>Leaf Area Index</strong></td>
<td>0.44</td>
<td>0.41</td>
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<tr>
<td><strong>Net Ecosystem Exchange</strong></td>
<td>0.37</td>
<td>0.36</td>
<td>0.37</td>
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<tr>
<td><strong>Global Net Land Flux</strong></td>
<td>0.80</td>
<td>0.27</td>
<td>0.39</td>
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<tr>
<td><strong>Ecosystem Respiration</strong></td>
<td>0.52</td>
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<td>0.52</td>
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<tr>
<td><strong>Soil Carbon</strong></td>
<td>0.67</td>
<td>0.37</td>
<td>0.61</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td>0.57</td>
<td>0.43</td>
<td>0.53</td>
</tr>
</tbody>
</table>
What is a Benchmark?

- A Benchmark is a quantitative test of model function achieved through comparison of model results with observational data.

- Acceptable performance on benchmarks is a necessary but not sufficient condition for a fully functioning model.

- Functional benchmarks offer tests of model responses to forcing and yield insights into ecosystem processes.

- Effective benchmarks must draw upon a broad set of independent observations to evaluate model performance on multiple temporal and spatial scales.

Models often fail to capture the amplitude of the seasonal cycle of atmospheric CO₂.

Models may reproduce correct responses over only a limited range of forcing variables.
Why Benchmark?

- to demonstrate to the science community and public that the representation of coupled climate and biogeochemical cycles in Earth system models (ESMs) is improving;

- to quantitatively diagnose impacts of model development in related fields on carbon cycle processes;

- to guide synthesis efforts, such as the CMIP efforts, in the review of mechanisms of global change in models that are broadly consistent with available contemporary observations;

- to increase scrutiny of key datasets used for model evaluation;

- to identify gaps in existing observations needed for model validation;

- to accelerate incorporation of new measurements for rapid and widespread use in model assessment;

- to provide a quantitative, application-specific set of minimum criteria for participation in model intercomparison projects (MIPs);