

INTERNATIONAL LAND MODEL BENCHMARKING (ILAMB) AND INTERNATIONAL OCEAN MODEL BENCHMARKING (IOMB) PACKAGES

To advance understanding of biogeochemical processes and their interactions with hydrology and the earth system under changing environmental conditions, new methods are being developed that use observations to constrain model predictions, inform model development, and identify needed measurements and field experiments. The International Land Model Benchmarking (ILAMB) and the International Ocean Model Benchmarking (IOMB) packages embody those methods to provide quick and easy model-data comparison capabilities for multiple earth system models (ESMs).

SCIENCE OBJECTIVES

Building upon past model evaluation studies, the goals of the ILAMB and the IOMB projects are to:

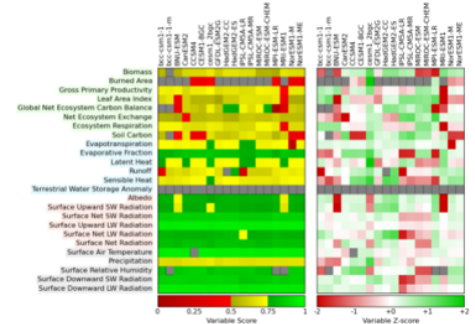
1. Develop internationally accepted benchmarks for land and ocean model performance by drawing upon international expertise and collaboration.
2. Promote the use of these benchmarks by the international community for model evaluation and model-data intercomparison.
3. Strengthen linkages among experimental, remote-sensing, and earth system modeling communities in the design of new model tests and new measurement programs.

4. Support the design, development, and distribution of open-source benchmarking tools.

The U.S. Department of Energy's (DOE's) Office of Biological and Environmental Research has supported research and development activities to begin realizing the goals of ILAMB and IOMB. Leveraging observational research activities from DOE's Next-Generation Ecosystem Experiments (NGEE) project for the Arctic and Tropics, and integrating with DOE's Energy-Exascale Earth System Model (E3SM), a team of researchers in the Reducing Uncertainty in Biogeochemical Interactions through Synthesis and Computation (RUBISCO) project have developed benchmarking software packages. The ILAMB Package, version 2.2, is now available for use and the IOMB Package, currently in beta testing, will be available soon.

RESEARCH FOCUS

The ILAMBv2.2 Package assesses model fidelity on 25 variables in four categories from about 50 data sets; produces graphical global-, regional- and site-level diagnostics; and provides a hierarchical scoring system based on model performance for the annual mean, bias, relative bias, root-mean-square error (RMSE), seasonal cycle phase, spatial distribution, interannual variability, and variable-to-variable comparisons (functional benchmarks). The IOMB Package



ILAMB provides graphical views of high-level scores for model performance for a variety of land model variables.

leverages the ILAMB code base and evaluates ocean biogeochemistry results compared with global, regional, and ship-track observations. IOMB also scores models based on performance for the annual mean, bias, relative bias, RMSE, seasonal cycle phase, spatial distribution, and interannual variability.

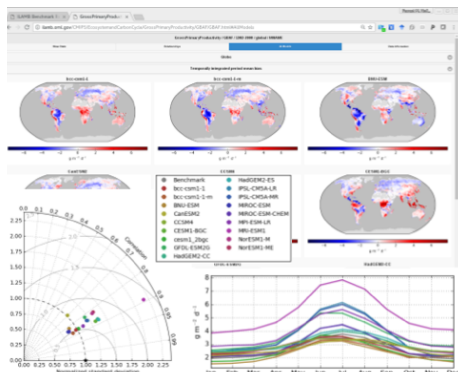
ILAMB and IOMB are designed for use by individual modelers or model developers for verification and rapid model development cycles, by modeling centers to track the evolution of model performance, and by model intercomparison projects for multi-model analysis. ILAMB and IOMB are being integrated into the workflow systems at multiple major modeling centers and are being extended for use in high-latitude and hydrology studies. The packages are also expected to provide a platform for engaging experimentalists in identifying model weaknesses and

needed measurements and field experiments. Both packages have been adopted by the E3SM and the Community Earth System Model (CESM).

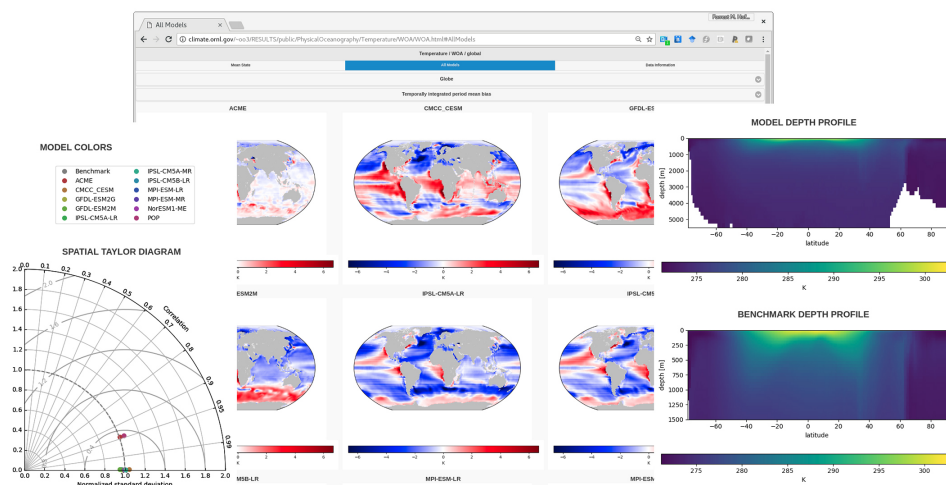
MODEL INTERCOMPARISON PROJECTS (MIPs)

MIPs are important activities for assessing the coherence and reliability of ESMs. Ongoing and future MIPs focused on modeling terrestrial water, energy, and carbon cycles and on modeling ocean biogeochemistry and circulation are particularly relevant to ILAMB and IOMB. The upcoming sixth phase of the Coupled Model Intercomparison Project provides a valuable opportunity to apply ILAMB and IOMB capability to evaluate model results for the Historical and Diagnostic, Evaluation, and Characterization of Klima experiments. In addition, ILAMB will be used to benchmark models for the Coupled Climate-Carbon Cycle MIP (C4MIP); the Land Surface, Snow and Soil Moisture MIP; and the Land Use MIP. IOMB will benchmark models for the C4MIP and Ocean MIP (OMIP).

The ILAMB and IOMB Packages expand DOE's role in coordinating CMIP activities and improves DOE's capabilities to assess the fidelity of



Example diagnostics produced by the International Land Model Benchmarking (ILAMBv2.2) package.



Example diagnostics produced by the IOMB package.

model development in the E3SM and CESM projects by supporting comprehensive terrestrial and marine model evaluation and benchmarking. Moreover, these capabilities create new opportunities for improving understanding of biosphere earth system interactions and highlight important challenges with respect to effectively harvesting information to reduce uncertainties and improve understanding of fundamental earth system processes.

2016 ILAMB WORKSHOP

The 2016 ILAMB Workshop brought together the international community to identify scientific challenges and priorities for future research. Convened on May 16 to 18, 2016, in Washington, D.C., USA, and sponsored by the U.S. Department of Energy's (DOE's) Office of Biological and Environmental Research, the workshop addressed (1) design of new biogeochemical and hydrological metrics, (2) improvement of model development and workflow practices, (3) CMIP evaluation needs and strategies, and (4) new observational data sets and new measurement campaigns relevant to model evaluation. Presentations focused on model benchmarking,

emergent constraints, evaluation metrics, uncertainty quantification, and field experiment and measurement networks. Tutorials on using and extending the ILAMB software package were conducted at the workshop.

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Websites

ILAMB: <https://www.ilamb.org/>

2016 ILAMB Workshop Report:
<https://doi.org/10.2172/1330803>

ILAMB and IOMB packages are available for download:

<https://www.bgc-feedbacks.org/software/>