International Land Model Benchmarking (ILAMB) Update

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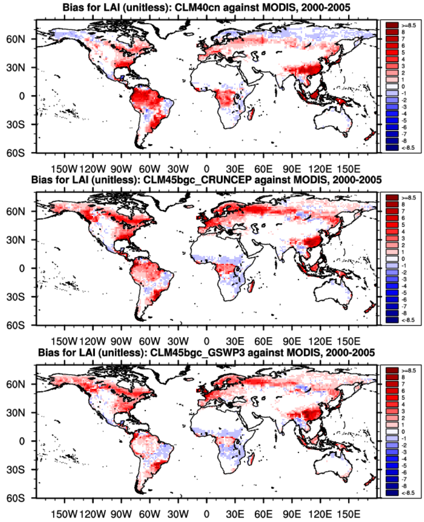
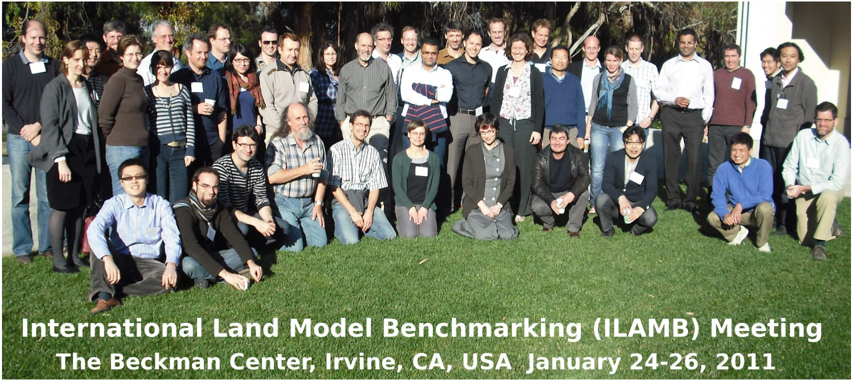
What is ILAMB?

- The **International Land Model Benchmarking (ILAMB)** project seeks to develop internationally accepted standards for land model evaluation.
- Model **benchmarking** can diagnose impacts of model development and guide synthesis efforts like IPCC.
- **Effective benchmarks** must draw upon a broad set of independent observations to evaluate model performance on multiple temporal and spatial scales.
- A free, **open source analysis and diagnostics software package** for community use will enhance model intercomparison projects.



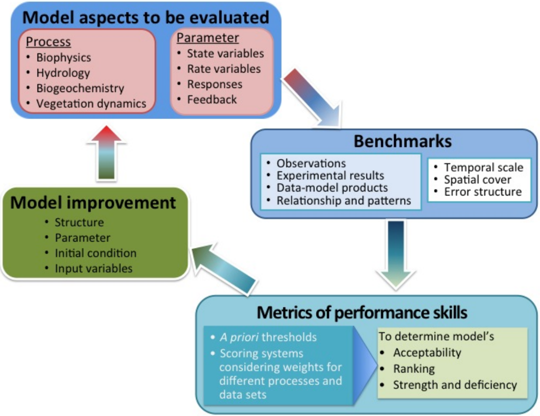
Bias in mean annual leaf area index from comparison of three versions of CLM with MODIS.



- We co-organized inaugural meeting and ∼45 researchers participated from the United States, Canada, the United Kingdom, the Netherlands, France, Germany, Switzerland, China, Japan, and Australia.
- **ILAMB Goals:** Develop an internationally accepted set of benchmarks for model performance; advocate for design of open source software system; and strengthen linkages between experimental, monitoring, remote sensing, and climate modeling communities.
- Methodology for model–data comparison and baseline standard for performance of land model process representations (Luo et al., 2012).

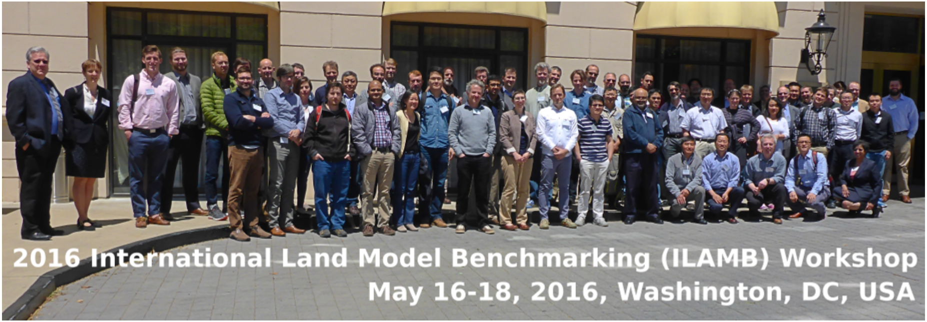
Benchmarking Methodology (Luo et al., 2012)

- Based on this methodology and prior work on C-LAMP (Randerson et al., 2009), we developed a new model benchmarking package for ILAMB.
- First prototype in NCL was released at 2015 AGU Fall Meeting and a new version using python was released in May 2016.



(Luo et al., 2012)

2016 ILAMB Workshop, Washington, DC, USA



- 60+ researchers from Australia, Japan, China, Germany, Netherlands, Sweden, UK, and the U.S., representing 10 modeling centers, participated in DOE-sponsored ILAMB Workshop (plus 20–30 online attendees).
- Held poster session and breakout sessions on model metrics, MIP evaluation needs, and observational data needs and opportunities.
- Workshop white papers developed by crowdsourcing for the final report.
- ILAMBv2 (doi:10.18139/ILAMB.v002.00/1251621) released at two tutorials.

ILAMB Packages

- Assess 24 variables in 4 categories from ∼45 datasets
  - aboveground live biomass, burned area, carbon dioxide, gross primary production, leaf area index, global net ecosystem carbon balance, net ecosystem exchange, ecosystem respiration, soil carbon
  - evapotranspiration, latent heat, terrestrial water storage anomaly
  - albedo, surface upward SW radiation, surface net SW radiation, surface upward LW radiation, surface net LW radiation, surface net radiation, sensible heat
  - surface air temperature, precipitation, surface relative humidity, surface downward SW radiation, surface downward LW radiation
- Graphics and scoring system
  - annual mean, bias, RMSE, seasonal cycle, spatial distribution, interannual coefficient of variation, spatial distribution, long-term trend

ILAMBv1 Prototype: Global Variables for 12 Models

Global Variables (Info for Weightings)

	MeanModel	bcc-csm1-1-m	BNU-ESM	CanESM2	CESM1-BGC	GFDL-ESM2G	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	MIROC-ESM	MPI-ESM-LR	MRI-ESM1	NorESM1-ME
Aboveground Live Biomass	0.68	0.52	0.50	0.61	0.65	0.58	0.67	0.54	0.68	0.52	0.51	0.67	0.65
Burned Area	0.38	-	-	-	0.37	-	-	-	-	-	0.38	-	0.38
Carbon Dioxide	0.85	-	0.65	0.65	0.78	0.65	-	-	-	0.79	0.68	0.68	0.75
Gross Primary Productivity	0.77	0.72	0.73	0.64	0.70	0.67	0.68	0.70	0.67	0.69	0.69	0.53	0.70
Leaf Area Index	0.66	0.66	0.41	0.60	0.53	0.49	0.59	0.68	0.66	0.62	0.68	0.43	0.50
Global Net Ecosystem Carbon Balance	0.58	-	0.38	0.27	0.38	0.18	-	0.46	0.25	0.38	0.42	0.27	0.40
Net Ecosystem Exchange	0.49	0.47	0.47	0.39	0.48	0.49	0.46	0.44	0.53	0.48	0.50	0.48	0.48
Ecosystem Respiration	0.75	0.72	0.72	0.65	0.67	0.71	0.66	0.70	0.67	0.68	0.68	0.47	0.66
Soil Carbon	0.55	0.50	0.42	0.56	0.38	0.51	0.51	0.53	0.57	0.53	0.41	0.53	0.39
Summary	0.64	0.59	0.54	0.54	0.55	0.53	0.59	0.57	0.57	0.58	0.54	0.51	0.55
Evapotranspiration	0.75	0.73	0.72	0.72	0.73	0.70	0.74	0.69	0.75	0.70	0.73	0.73	0.72
Latent Heat	0.80	0.76	0.77	0.77	0.78	0.74	0.77	0.72	0.77	0.75	0.76	0.78	0.76
Terrestrial Water Storage Anomaly	0.53	0.45	0.35	0.54	0.48	0.43	-	0.52	0.45	0.52	0.55	0.47	0.45
Summary	0.69	0.65	0.61	0.68	0.66	0.62	0.75	0.64	0.65	0.66	0.68	0.66	0.64
Albedo	0.72	0.71	0.61	0.71	0.73	0.69	0.74	0.67	0.71	0.67	0.73	0.64	0.72
Surface Upward SW Radiation	0.78	0.73	0.67	0.74	0.78	0.74	0.77	0.74	0.74	0.72	0.78	0.67	0.76
Surface Net SW Radiation	0.84	0.86	0.84	0.85	0.85	0.86	0.85	0.84	0.82	0.83	0.87	0.85	0.85
Surface Upward LW Radiation	0.90	0.91	0.91	0.91	0.92	0.91	0.92	0.89	0.90	0.91	0.92	0.92	0.92
Surface Net LW Radiation	0.81	0.82	0.81	0.79	0.82	0.81	0.83	0.79	0.78	0.78	0.81	0.82	0.81
Surface Net Radiation	0.78	0.79	0.76	0.80	0.80	0.80	0.79	0.74	0.77	0.76	0.80	0.78	0.80
Sensible Heat	0.76	0.69	0.70	0.71	0.75	0.69	0.75	0.66	0.69	0.69	0.69	0.72	0.72
Summary	0.79	0.78	0.75	0.78	0.80	0.78	0.80	0.75	0.76	0.76	0.79	0.77	0.79
Surface Air Temperature	0.87	0.87	0.85	0.85	0.88	0.85	0.87	0.85	0.87	0.85	0.88	0.88	0.87
Precipitation	0.70	0.67	0.66	0.67	0.70	0.68	0.72	0.68	0.68	0.68	0.70	0.69	0.69
Surface Relative Humidity	0.81	-	0.80	0.76	0.82	-	-	0.79	0.82	-	-	0.83	0.81
Surface Downward SW Radiation	0.86	0.88	0.87	0.87	0.88	0.87	0.87	0.87	0.83	0.86	0.88	0.86	0.88
Surface Downward LW Radiation	0.90	0.92	0.91	0.91	0.92	0.92	0.92	0.90	0.89	0.91	0.93	0.91	0.91
Summary	0.82	0.82	0.81	0.80	0.83	0.82	0.84	0.81	0.81	0.81	0.84	0.83	0.82
Overall	0.69	0.51	0.59	0.60	0.64	0.56	0.49	0.57	0.57	0.59	0.61	0.59	0.63

ILAMBv1 Prototype: Global Variables for 12 Models

Global Variables (Info for Weightings)

	MeanModel	bcc-csm1-1-m	BNU-ESM	CanESM2	CESM1-BGC	GFDL-ESM2G	HadGE
Aboveground Live Biomass	0.68	0.52	0.50	0.61	0.65	0.58	0.6
Burned Area	0.38	-	-	-	0.37	-	-
Carbon Dioxide	0.85	-	0.65	0.65	0.78	0.65	-
Gross Primary Productivity	0.77	0.72	0.73	0.64	0.70	0.67	0.6
Leaf Area Index	0.66	0.66	0.41	0.60	0.53	0.49	0.5
Global Net Ecosystem Carbon Balance	0.58	-	0.38	0.27	0.38	0.18	-
Net Ecosystem Exchange	0.49	0.47	0.47	0.39	0.48	0.49	0.4
Ecosystem Respiration	0.75	0.72	0.72	0.65	0.67	0.71	0.6
Soil Carbon	0.55	0.50	0.42	0.56	0.38	0.51	0.5
Summary	0.64	0.59	0.54	0.54	0.55	0.53	0.5
Evapotranspiration	0.75	0.73	0.72	0.72	0.73	0.70	0.7
Latent Heat	0.80	0.76	0.77	0.77	0.78	0.74	0.7
Terrestrial Water Storage Anomaly	0.53	0.45	0.35	0.54	0.48	0.43	-
Summary	0.69	0.65	0.61	0.68	0.66	0.62	0.7
Albedo	0.72	0.71	0.61	0.71	0.73	0.69	0.7
Surface Upward SW Radiation	0.78	0.73	0.67	0.74	0.78	0.74	0.7
Surface Net SW	0.84	0.86	0.84	0.85	0.85	0.86	0.8

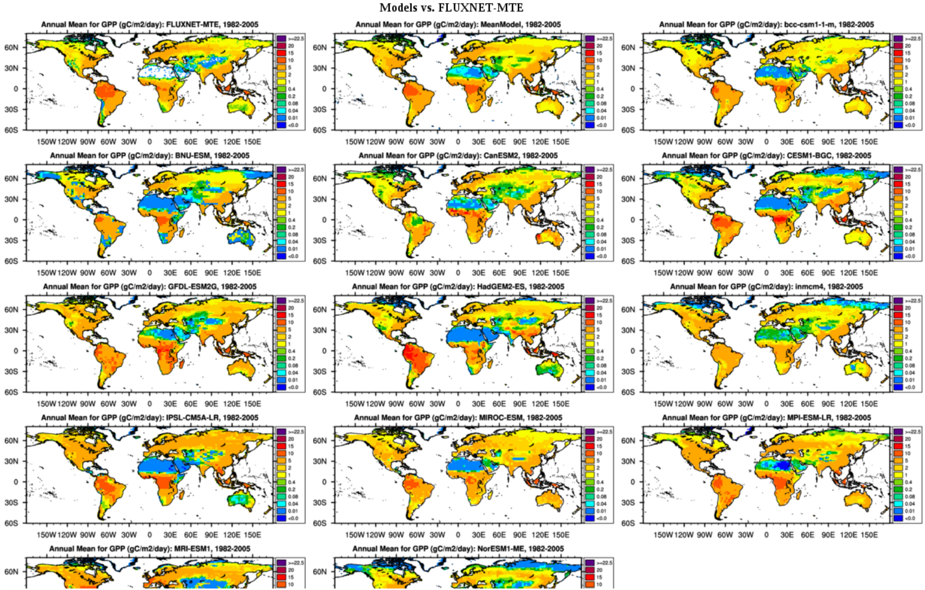
Scoring for Global GPP from Fluxnet-MTE

Diagnostic Summary for Gross Primary Productivity: Model vs. FLUXNET-MTE

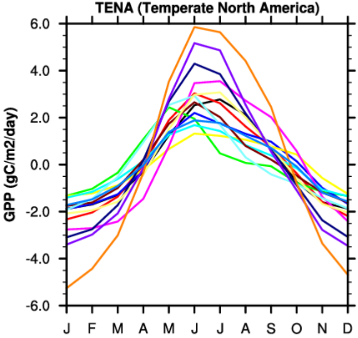
	Global Patterns				Regional and Seasonal Patterns	Scoring (Info)				
	Annual Mean (PgC/yr)	Bias (PgC/yr)	RMSE (PgC/mon)	Phase Difference (months)	Regional Means	Global Bias	RMSE	Seasonal Cycle	Spatial Distribution	Overall
Benchmark [Jung et al. (2009)]	118.4	-	-	0.0	access to plots	-	-	-	-	-
MeanModel	145.3	26.9	4.7	0.6	access to plots	0.77	0.73	0.78	0.94	0.79
bcc-csm1-1-m	114.4	-4.0	6.0	-0.2	access to plots	0.72	0.64	0.80	0.89	0.74
BNU-ESM	102.0	-16.4	6.2	0.1	access to plots	0.69	0.66	0.78	0.84	0.73
CanESM2	129.2	10.8	7.3	0.8	access to plots	0.64	0.60	0.68	0.70	0.64
CESM1-BGC	130.3	11.9	5.8	0.5	access to plots	0.69	0.65	0.76	0.87	0.72
GFDL-ESM2G	175.1	56.7	9.8	0.5	access to plots	0.66	0.54	0.73	0.83	0.66
HadGEM2-ES	145.9	27.5	7.4	0.3	access to plots	0.65	0.58	0.78	0.79	0.68
inmcm4	111.4	-7.0	5.6	0.3	access to plots	0.71	0.66	0.78	0.83	0.73
IPSL-CM5A-LR	166.6	48.2	8.8	0.4	access to plots	0.63	0.56	0.77	0.84	0.67
MIROC-ESM	131.7	13.3	6.2	0.2	access to plots	0.72	0.66	0.74	0.86	0.73
MPI-ESM-LR	169.9	51.5	7.4	0.3	access to plots	0.67	0.62	0.70	0.89	0.70
MRI-ESM1	236.1	117.7	12.5	0.2	access to plots	0.45	0.43	0.79	0.59	0.54
NorESM1-ME	130.4	12.0	6.5	0.5	access to plots	0.66	0.62	0.76	0.84	0.70

Notes: In calculating overall score, rmse score contributes double in comparison with all other scores.

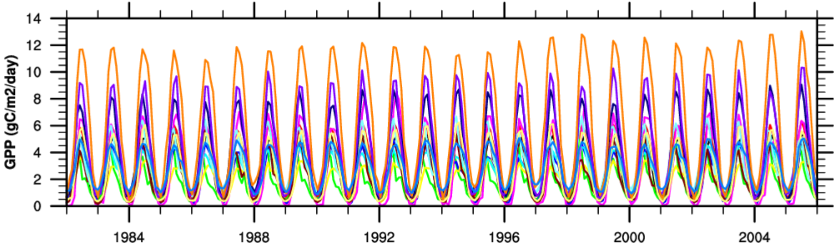
Annual Mean Global GPP



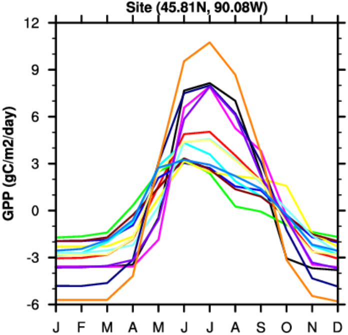
Seasonal Cycle of Regional GPP



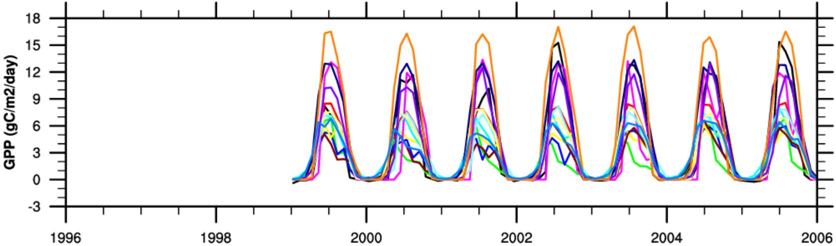
Model	Annual	Bias	RMSE
FLUXNET-MTE	2.36	-999.00	-999.00
MeanModel	2.99	0.63	0.74
bcc-csm1-1-m	1.82	-0.54	1.31
BNU-ESM	2.17	-0.19	0.62
CanESM2	1.76	-0.60	1.08
CESM1-BGC	2.45	0.08	0.78
GFDL-ESM2G	2.85	0.49	1.16
HadGEM2-ES	2.12	-0.24	0.72
inmcm4	3.06	0.70	1.20
IPSL-CM5A-LR	3.95	1.59	1.90
MIROC-ESM	2.48	0.12	0.35
MPI-ESM-LR	4.27	1.91	2.38
MRI-ESM1	6.13	3.76	4.46
NorESM1-ME	2.84	0.48	0.74



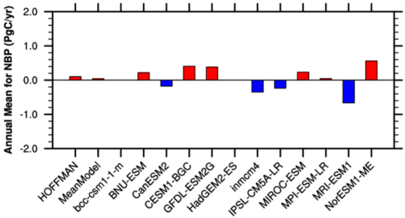
Seasonal Cycle of Site GPP



Model	Annual	Bias	RMSE
FLUXNET	3.62	-999.00	-999.00
MeanModel	3.11	-0.51	2.49
bcc-csm1-1-m	1.79	-1.83	4.42
BNU-ESM	2.00	-1.62	3.81
CanESM2	2.32	-1.30	3.69
CESM1-BGC	3.04	-0.58	3.19
GFDL-ESM2G	3.59	-0.03	2.87
HadGEM2-ES	2.06	-1.56	3.77
inmcm4	2.79	-0.83	2.75
IPSL-CM5A-LR	4.85	1.23	2.37
MIROC-ESM	2.81	-0.81	2.85
MPI-ESM-LR	3.68	0.06	1.72
MRI-ESM1	5.76	2.14	3.45
NorESM1-ME	2.69	-0.93	3.45

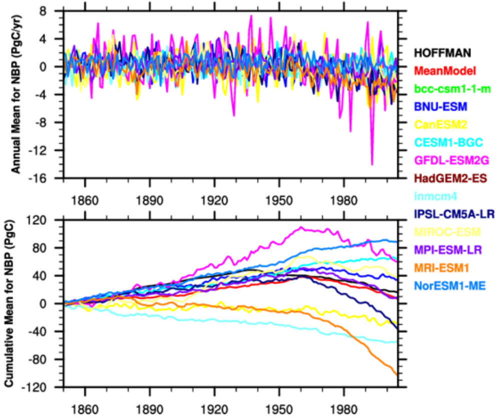


Global Net Ecosystem Carbon

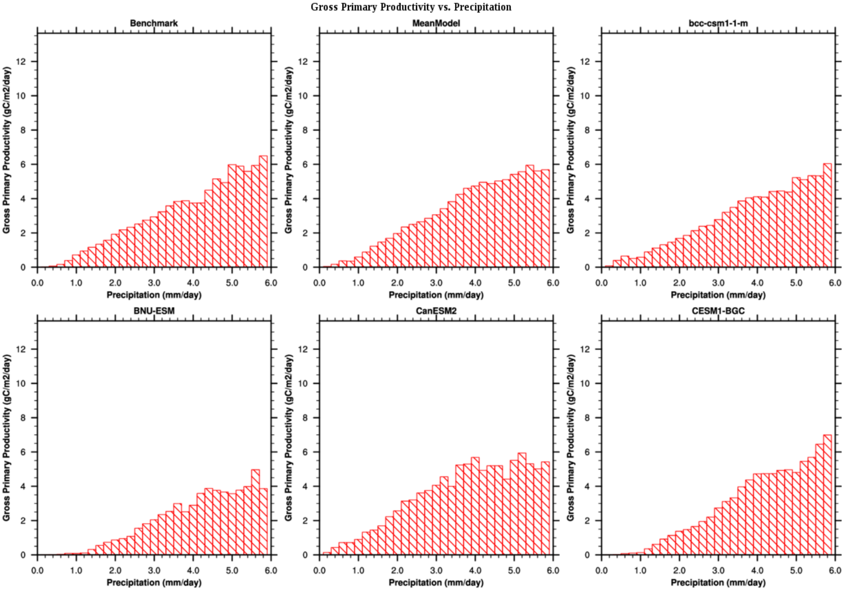


Global Net Ecosystem Carbon Balance

Long term carbon storage



Functional Relationships: GPP vs. Precipitation



ILAMB Metrics Document

B. Root Mean Square Error Metric

For different variables, we use 2 different methods to calculate their global mean RMSE scores. For above ground biomass (biomass), burned area (burntarea), evapotranspiration (et), gross primary production (gpp), lead area index (lai), latent heat (le), net ecosystem exchange (nee), precipitation (pr), ecosystem respiration (reco), sensible heat (sh) and soil carbon (soilc), we use mass weighting (B3.1). For other variables, we use area weighting (B3.2).

$$M_i = 1 - \frac{RMSE_i}{\Phi_{obs,i}} \tag{B1}$$

$$M_i' = e^{M_i} / e \tag{B2}$$

Mass weighting to calculate global mean RMSE score:

$$M = \frac{\sum_{i=1}^{ncells} M_i' \times A_i \times |AM_{obs,i}|}{\sum_{i=1}^{ncells} A_i \times |AM_{obs,i}|} \tag{B3.1}$$

Area weighting to calculate global mean RMSE score:

$$M = \frac{\sum_{i=1}^{ncells} M_i' \times A_i}{\sum_{i=1}^{ncells} A_i} \tag{B3.2}$$

We use Eqs. B1-2 and Eq. B3.1 or B3.2 to calculate root mean square error metric score M_i at grid cell or site *i* and its global mean *M*, respectively. Where $\Phi_{obs,i}$ is the root mean square for monthly mean annual cycle of the observation at grid cell *i* (for grid data) or site *i* (for site observation), and $RMSE_i$ is the root mean square error between model and observation. $AM_{obs,i}$ is annual mean of the observation at grid cell or site *i*. $|AM_{obs,i}|$ is to calculate its absolute value. A_i is the area for grid cell or site *i*. *ncells* is the number if all land grid cells or sites where observation data is available. If the observation is site data, we set A_i equal to 1 (*Ref: David Lawrence's personal Communication*). This metric is used to compare magnitude and phase difference of the monthly mean annual cycle between the model and the observation.

C. Spatial Distribution Metric

$$M = \frac{4(1+R)}{(\sigma_f + 1/\sigma_f)^2(1+R_0)} \tag{C}$$

We use Eq. C to calculate spatial distribution metric score *M*. *R* is the spatial correlation coefficient of the annual mean between model and observation. R_o is their ideal maximum correlation. Here, we set R_o equal to 1 for all models. σ_f is ratio for standard deviation of model to that of observation (*Ref: Taylor, J. Geophys. Res., 106, 2001*). This metric is used to compare magnitude and spatial pattern of annual mean of model with observation.

D. Seasonal Cycle Phase Metric

For different variables, we use 2 different methods to calculate their global mean phase scores. For above ground biomass (biomass), burned area (burntarea), evapotranspiration (et), gross primary production (gpp), lead area index (lai), latent heat (le), net ecosystem exchange (nee), precipitation (pr), ecosystem respiration (reco), sensible heat (sh) and soil carbon (soilc), we use mass weighting (D2.1). For other variables, we use area weighting (D2.2).

$$M_i = (1 + \cos\vartheta_i)/2 \tag{D1}$$

Mass weighting to calculate global mean phase score:

$$M = \frac{\sum_{i=1}^{ncells} M_i' \times A_i \times |AM_{obs,i}|}{\sum_{i=1}^{ncells} A_i \times |AM_{obs,i}|} \tag{D2.1}$$

Area weighting to calculate global mean phase score:

$$M = \frac{\sum_{i=1}^{ncells} M_i' \times A_i}{\sum_{i=1}^{ncells} A_i} \tag{D2.2}$$

We use Eqs. D1 and D2.1 or D2.2 to calculate seasonal cycle phase metric score M_i at grid cell or site *i* and its global mean *M*, respectively. ϑ_i is the difference of the angle between the month of the maximum value for the model and that for the observation at grid cell *i* (for the grid data) or site *i* (for the site data). $AM_{obs,i}$ is annual mean of the observation at grid cell or site *i*. $|AM_{obs,i}|$ is to calculate its absolute value. A_i is the area for grid cell or site *i*. *ncells* is the number of all land grid cells or sites where observation data is available. If the observation is site data, we set A_i equal to 1 (*Ref: Prentice, et al., GBC, 25, 2011*). This metric is used to compare phase difference of the monthly mean annual cycle between the model and the observation.

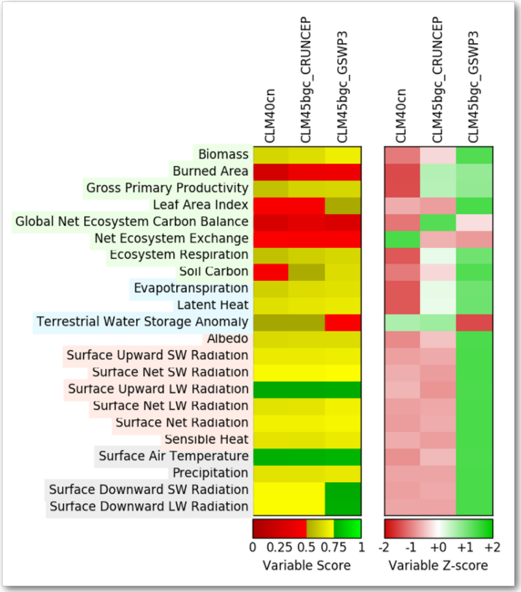
E. Interannual Variability Metric

ILAMB Scoring Rules

Rules for scoring system

Score	Certainty of data	Scale appropriateness and coverage	Overall importance of constraint or process
1	Uncertainty estimates not available; significant methodological issues may influence data quality	Site level observations with limited regional coverage and/or short temporal duration	Observations that have limited influence on carbon cycle processes; includes some driver datasets and land surface measurements (e.g., Lin)
2	Uncertainty estimates not available; some methodological issues may influence data quality	Partial regional coverage; data sets providing up to 1 year of coverage	Driver observations or land surface measurements that have direct influence on carbon cycle processes (e.g., PPT, Tair, and Sin)
3	Uncertainty estimates not available; some peer-review evaluation of quality; minor methodological issues may remain	Regional coverage for at least 1 year; mismatches may exist between site-level and model grid cells	Biosphere process that contributes to carbon dynamics; data are a useful constraint for thi specific process
4	Qualitative uncertainty information available from peer-review evaluations; methodology is well accepted	Important regional coverage; at least 1 year or more of observations	Important biosphere process regulating carbon cycle dynamics; data are moderately well-suited for constraining this process
5	Well defined and traceable uncertainty estimates; relatively low uncertainty estimates relative to range of model estimates; uncertainties less than ± 20% at regional scales	Global scale in coverage; time series spanning multiple years; data products appropriate in scale for comparing directly with model grid cells	Critical process or constraint regulating climate-carbon or carbon-concentration feedbacks; data are well suited for discriminating among different model estimates

ILAMBv2 Model Scoring by Variable



ILAMBv2 Layout

ILAMB Benchmark R… ×

www.climatemodeling.org/~nate/ILAMB/index.html

Forrest M.

ILAMB Benchmark Results

Overview | **Results Table** | Model Comparisons

Columns...

	CLM40cn	CLM45bgc_CRUNCEP	CLM45bgc_GSWP3
Biomass	0.40	0.40	0.41
Burned Area	0.62	0.66	0.65
Gross Primary Productivity	0.70	0.72	0.73
Fluxnet (36.0%)	0.69	0.72	0.73
Fluxnet-MTE (60.0%)	0.71	0.72	0.73
Leaf Area Index	0.62	0.60	0.63
Global Net Ecosystem Carbon Balance	0.17	0.23	0.20
Net Ecosystem Exchange	0.55	0.55	0.55
Ecosystem Respiration	0.67	0.70	0.72
Soil Carbon	0.55	0.58	0.65
Evapotranspiration	0.73	0.75	0.75
Latent Heat	0.73	0.75	0.75
Terrestrial Water Storage Anomaly	0.30	0.31	0.31
Albedo	0.72	0.72	0.72
Surface Upward SW Radiation	0.77	0.77	0.78
Surface Net SW Radiation	0.80	0.80	0.81
Surface Upward LW Radiation	0.81	0.81	0.82
Surface Net LW Radiation	0.73	0.73	0.77
Surface Net Radiation	0.77	0.77	0.78
Sensible Heat	0.72	0.72	0.74
Surface Air Temperature	0.83	0.83	0.84
Precipitation	0.76	0.76	0.78

ILAMBv2 Layout

www.climatemodeling.org/~nate/ILAMB/EcosystemandCarbonCycle/GrossPrimaryProductivity/Fluxnet-MTE//Fluxnet-MTE.html

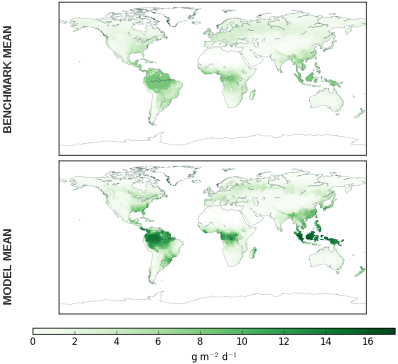
GrossPrimaryProductivity / Fluxnet-MTE / global / CLM40cn

Single Model | All Models

global

Model	Data	Period Mean [Pg yr-1]	Bias [Pg yr-1]	RMSE [Pg yr-1]	Phase Shift [d]	Bias Score [1]	RMSE Score [1]	Phase Score [1]	Interannual Variability Score [1]	Spatial Distribution Score [-]
Benchmark	[-]	115.711								
CLM40cn	[-]	130.054	17.551	77.741	-1.497	0.761	0.576	0.828	0.728	0.77
CLM45bgc_CRUNCEP	[-]	117.757	5.466	70.723	-2.595	0.784	0.557	0.832	0.711	0.899
CLM45bgc_GSWP3	[-]	107.227	-5.213	66.767	-1.556	0.794	0.556	0.82	0.731	0.922

Temporally integrated period mean



ILAMBv2 Documentation

The ILAMB Benchmarking System — ILAMB 2.0 documentation – Mozilla Firefox

climate.ornl.gov/~ncf/ILAMB/docs/

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The ILAMB Benchmarking System

The International Land Model Benchmarking (ILAMB) project is a model-data intercomparison and integration project designed to improve the performance of land models and, in parallel, improve the design of new measurement campaigns to reduce uncertainties associated with key land surface processes. Building upon past model evaluation studies, the goals of ILAMB are to:

- develop internationally accepted benchmarks for land model performance,
- promote the use of these benchmarks by the international community for model intercomparison,
- strengthen linkages between experimental, remote sensing, and climate modeling communities in the design of new model tests and new measurement programs, and
- support the design and development of a new, open source, benchmarking software system for use by the international community.

It is the last of these goals to which this page is concerned. We have developed a python-based generic benchmarking system, for which the source code may be found on bitbucket. The development is open and patches are welcome. The main output of our package comes in the form of a HTML site which can be navigated to explore and understand the results.

Documentation

- Tutorials
  - Beginner Level
  - Developer Level
- Package Contents
  - Variable
  - ModelResults
  - Confrontations
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Future ILAMB Development and Application

- ILAMBv1 Prototype and now ILAMBv2 applied to:
  - Model development of the Community Land Model (CLM)
  - CMIP5 Historical and esmHistorical simulations
  - ACME Land Model evaluation
- Within U.S. Department of Energy projects:
  - NGEE Arctic, NGEE Tropics, and SPRUCE are adopting the framework for evaluating process parameterizations & integrating field observations
  - ACME is developing metrics for evaluation of new land model features
  - BGC Feedbacks is developing the framework and benchmarking MIPs
- Future (and past) projects where we hope to apply ILAMB:
  - CMIP6, including C^4MIP, LS3MIP, and LUMIP
  - TRENDY, MsTMIP, PLUME-MIP
  - NASA Permafrost Benchmark System (PBS) (Schaefer et al.)
- Plans are to integrate ILAMBv2 into standard CESM2 workflow.

ILAMBv2 Tutorial: Today at 5:00–7:00 p.m. in the Tarn Room at The Village at Breckenridge.

2016 AGU Fall Meeting Biogeosciences Session

Consider submitting your abstract to this session by August 3:

B056. New Mechanisms, Feedbacks, and Approaches for Improving Predictions of Global Biogeochemical Cycles in Earth System Models

Predictions of future atmospheric CO_2 levels are influenced by global carbon and nutrient cycles, climate interactions, and feedbacks. Relevant processes operate at different spatial and temporal scales and vary across terrestrial, coastal, and marine ecosystems. Uncertain biogeochemical feedbacks may be altered by anthropogenic disturbance agents, including tropospheric O_3, acceleration of the N and H_2O cycles, eutrophication, and land cover/use change. This session focuses on integrated understanding of feedback mechanisms, methods for evaluating and benchmarking process representations in Earth system models, and approaches for constraining future climate projections (e.g., emergent constraints).

Co-Organized with:
Biogeosciences, Atmospheric Sciences, Global Environmental Change, Hydrology, Ocean Sciences

Conveners:
Forrest M. Hoffman, Oak Ridge National Laboratory
James T. Randerson, University of California Irvine
Atul Jain, University of Illinois Urbana-Champaign
J. Keith Moore, University of California Irvine

Acknowledgments

U.S. DEPARTMENT OF ENERGY

Office of Science

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Extra Slides

Biogeochemistry–Climate Feedbacks Goals & Objectives

BGC Feedbacks SFA Goals

The overarching goals of the BGC Feedbacks SFA are to identify and quantify the feedbacks between biogeochemical cycles and the climate system, and to quantify and reduce the uncertainties in Earth system models (ESMs) associated with those feedbacks.

In particular, we are

- developing new hypothesis-driven approaches for evaluating ESM process representations at site, regional and global scales;
- investigating the degree to which contemporary observations can be used to reduce uncertainties in future scenarios (e.g., emergent constraints);
- developing open source benchmarking software tools that leverage laboratory, field, and remote sensing data sets for systematic evaluation of ESM biogeochemical processes; and
- evaluating performance of biogeochemical processes and feedbacks in different ESMs using benchmarking tools.

Biogeochemistry–Climate Feedbacks SFA Diagram