



ILAMB & IOMB CMIP5 vs 6 Evaluation

- (a) International Land Model Benchmarking (ILAMB) and (b) International Ocean Model Benchmarking (IOMB) packages used to evaluate how land and ocean model performance has changed from CMIP5 to CMIP6

<https://www.ilamb.org/CMIP5v6/historical/dashboard.html>

- Model fidelity is assessed through comparison of historical simulations with a wide variety of contemporary observational datasets
- CMIP6 suite of land models (right) has improved over the CMIP5 suite of land models (left)
- ILAMB <https://www.ilamb.org/> and GitHub code repo <https://github.com/rubisco-sfa/ILAMB>
- GitHub ILAMB-Data Project Board and Issues <https://github.com/rubisco-sfa/ILAMB-Data>

(a) Land Benchmarking Results

Land Ecosystem & Carbon Cycle

	bcc-csm1-1	CanESM2	CESM1-BGC	GFDL-ESM2G	IPSL-CM5A-LR	MIROC-ESM	MPI-ESM-LR	NorESM1-ME	HadGEM2-ES	BCC-CSM2-MR	CanESM5	CESM2	GFDL-ESM4	IPSL-CM6A-LR	MIROC-ES2L	MPI-ESM1-2-LR	NorESM2-LM	UKESM1-0-LL	Mean CMIP5	Mean CMIP6
Biomass	0.20	-0.45	1.55	-1.51	-0.13	0.60	-0.43	-1.31	0.19	-0.43	0.66	0.48	-1.09	0.22	0.60	-0.07	1.00	0.49	1.63	-2.30
Burned Area		-0.87					0.10	-0.83			1.60									
Leaf Area Index	-0.20	-0.64	1.30	2.53	-0.01	0.30	0.01	1.85	-0.16	0.27	0.08	0.34	-0.70	1.19	0.82	0.46	0.37	0.69	1.04	1.81
Soil Carbon	0.27	1.26	1.46	0.07	0.75	0.47	-0.03	-1.14	0.07	0.23	1.35	-0.99	2.04	-1.55	0.90	-0.75	-0.17	0.24	1.01	1.48
Gross Primary Productivity	0.59	-1.23	0.01	1.81	-1.40	0.29	-0.53	-0.24	-1.04	0.77	0.04	0.59	-0.38	1.17	-1.02	-0.37	0.73	0.09	1.51	2.22
Net Ecosystem Exchange	-0.42	1.81	-0.21	-0.65	1.10	-0.24	0.80	0.02	-1.03	-1.02	-1.19	0.59	1.69	-0.42	0.63	-0.21	1.08	-1.43	1.28	1.43
Ecosystem Respiration	0.90	-0.56	-0.86	-0.24	1.35	0.99	-0.01	-0.94	1.54	0.81	0.59	0.51	-0.79	0.90	-0.21	-1.24	0.43	-0.94	1.34	2.21
Carbon Dioxide	-1.54	-0.36	2.92	-0.74	1.53	-0.00	0.37	0.85		0.42	0.26	0.39	0.59	1.10	-0.87	0.21	0.69	0.09	-0.07	
Global Net Carbon Balance	-1.64	-0.88	-1.13	0.17	-0.31	-0.38	-0.50	0.24		-0.23	1.34	-1.70	0.17	-0.74	1.45	1.56	0.26	0.92	1.40	

Land Hydrology Cycle

Evapotranspiration	-2.65	-0.42	0.44	-0.18	-0.49	-0.52	-0.57	0.17	0.70	0.15	-0.47	1.51	-1.24	0.58	-0.72	-0.83	0.97	0.87	1.00	1.70
Evaporative Fraction	-0.34	0.74	0.74	-0.14	-0.85	0.21	1.98	0.22	-0.34	0.10	1.11	1.25	-0.88	1.29	-1.65	-1.81	1.11	-0.06	0.98	1.29
...																				
Terrestrial Water Storage Anomaly	-2.79	-0.45	0.47	0.50	-0.38	0.34	0.35	0.43	0.58	0.15	-0.08	0.95	-2.91	0.43	0.37	0.15	0.39	0.51	0.49	0.50
Permafrost	-0.88	2.26	0.01	0.13	0.83	0.69	0.56	0.69	-0.56	-0.11	-3.02	0.83	0.74	-0.18	0.49	0.42	0.89	0.43	0.06	0.23

(b) Ocean Benchmarking Results

Ocean Ecosystems

Chlorophyll			2.18	0.20	-0.20		0.04		0.22		-0.37	0.83	-0.37	-0.26	-0.91	-0.67	1.93	0.27	0.30	0.67
Oxygen, surface	-1.50	2.11	0.44	1.02		0.49		0.56		-0.67	0.88	-0.21	0.10	-1.02	-0.41	2.19	0.18	0.13	0.34	0.04

Ocean Nutrients

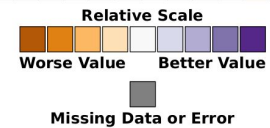
Nitrate, surface	0.73	-0.13	1.88			-0.53	-1.53	-0.29		0.73	0.34	-0.09	-0.41	0.35	-0.30	0.40	0.49	0.64	1.57	
Phosphate, surface		-0.84	-0.10	0.91			-0.80	-1.25			-0.02	1.00	1.88		-0.90	-1.14	-0.17	-0.16	1.60	
Silicate, surface	0.21	-1.63	0.67	1.22			-0.18	-1.70	0.82		1.21	-0.90	0.29	1.21	1.02	0.39	1.78	-0.56	0.47	0.18

Ocean Carbon

TALK, surface											1.24	-0.23	-0.62	-0.69	-1.08	-1.12	1.31			1.19
Salinity, 700m	-0.27	1.01	0.12	0.19			0.32	-2.31	-0.22		0.06	-0.36	0.85	-0.42	0.29	2.48	1.27	0.06	1.27	0.54

Ocean Relationships

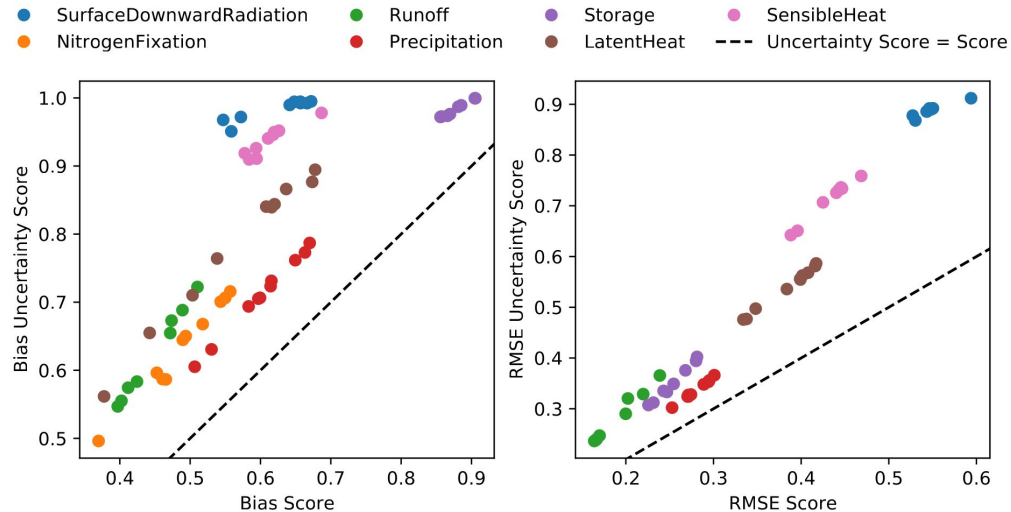
Oxygen, surface/WOA2018	0.44	-0.35	-1.06	-0.54	0.70	0.46	-0.46	-0.80	0.32	0.36	0.25	-1.16	-0.47	0.54	0.33	-0.39	-0.87	-0.54	1.58	1.64
Nitrate, surface/WOA2018			1.86	-0.36	-0.29		1.50	-0.43	0.68		-0.02	0.72	1.20	0.17	1.86	0.02		-1.12	0.39	1.25



From IPCC AR6 WG1, Chapter 5, Figure 5.22

Addressing Observational Uncertainty

- Few observational datasets provide complete uncertainties, but some are appearing
- ILAMB uses multiple datasets for most variables and allows users to weight them according to a rubric of uncertainty, scale mismatch, etc.
- ILAMB can also use:
 - Full spatial/temporal uncertainties provided with the data
 - Fixed, expert-derived uncertainty for a dataset
 - Uncertainties derived from combining multiple datasets
- Experiments with self-consistent CLASS data (Hobeichi et al. 2020) and Barnard's nitrogen fixation data demonstrate that while scores shift, including uncertainty rarely alters the rank ordering of models (figure)

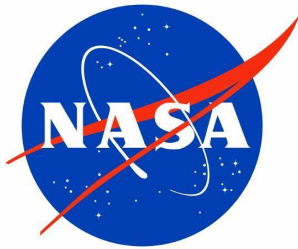


A Cross-Agency Solution to Diagnostics Interoperability



Coordinated Model Evaluation Capabilities (CMEC)

e.g. CESM WG Diagnostics



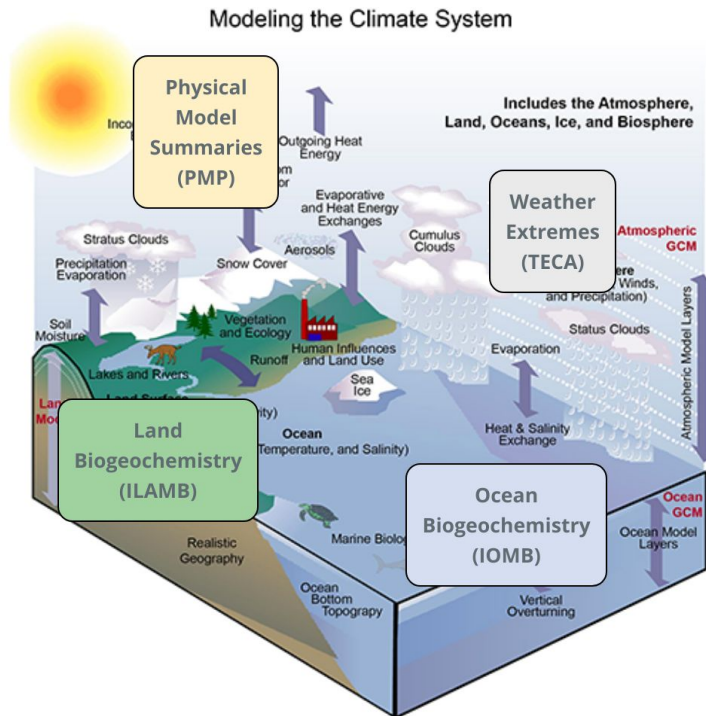
Model Diagnostics Task Force (MDTF)

e.g. Regional Climate Model Evaluation System (RCMES)



Coordinated Model Evaluation Capabilities

Coordinated Model Evaluation Capabilities (CMEC) is an effort to bring together a diverse set of analysis packages that have been developed to facilitate the systematic evaluation of Earth System Models (ESMs). Currently, CMEC includes three capabilities that are supported by the U.S. Department of Energy, Office of Biological and Environmental Research (BER), Regional and Global Climate Modeling Program (RGCM). As CMEC advances, additional analysis packages will be included from community-based expert teams as well as efforts directly supported by DOE and other US and international agencies.



Third-Party Contributors

A primary motivation for CMEC is to analyze model simulations that are contributed to the [Coupled Model Intercomparison Project \(CMIP\)](#). Virtually every institution worldwide involved in significant

LMT Dashboard: <https://lmt.ornl.gov/unified-dashboard/>

Colorblind colors

Hide Columns

Model

Metric

Global

Overall Score

SCALING

Row

Column

Not Normalized

ILAMB Color Mapping

EXAMPLES

Select Examples

LOGO

Select Logos

SWITCH

Tooltips

Cell Value

Bottom Title

Top Title

Screen Height

Row Expand/Collapse

Save to Html

Menu

Show/hide side menu containing multiple functions

Browse... file selected

Open local json files

Moveable columns

Different colors for model groups

Clickable cell linking to metric page

Show/Hide cell values

Scale/Normalize cell values along the row or column direction and color mappings

Multiple switches to toggle features

Collapse and expand Children rows

Save the dashboard to a plain html file

LMT Unified Dashboard

	bccr-csm1-1	CanESM2	CanESM1-BGC	CECISM2	GFDL-ESM2G	IPSL-CM5A-LR	MIROC-ESM	MPI-ESM-LR	MIROC-ESM2-ES	UK-HadGEM2-ES	BCR-CESM2-MR	CanESM2	CESM2	GFDL-ESM4	IPSL-CM6g-LR	MIROC-ES2L	MPI-ESM1-2-LR	NorESM1-LM	UKESM1-0-LL	MeanCMIP5	MeanCMIP6
Ecosystem and Carbon Cycle	-0.94	-1.26	-2.15	-0.20	0.50	-0.23	-0.99	0.10	0.55	0.47	-1.11	0.09	0.50	-0.14	0.86	0.38	1.48	2.11			
Biomass	0.20	-0.45	-1.52	-0.40	-1.26	-0.26	-1.07	1.77	0.92	1.39	0.74	-0.20	-0.54	0.16	0.93	-0.96	-0.01	1.04	1.23	1.82	
Tropical	0.35	-0.37	-2.31	0.22	-0.36	-0.95	0.18	2.75	0.54	0.79	0.28	0.05	-0.41	1.06	0.41	0.25	0.16	0.45	1.05	1.36	
GlobalCarbon	0.64	-0.59	-2.20	-0.17	-1.24	-0.26	0.18	2.54	0.34	1.22	0.00	-0.21	0.04	1.01	0.51	0.23	0.06	0.28	1.00	1.50	
NBCD2000	-0.99	0.83	0.86	-0.41	0.42	0.12	2.24	1.00	0.60	0.87	1.11	0.09	-1.35	-0.87	0.80	-2.22	0.19	0.75	0.09	0.35	
USForest	-1.05	0.65	0.48	-0.02	0.77	0.04	-2.29	0.80	0.51	0.71	1.40	0.28	-0.68	-1.03	1.23	-2.50	-0.18	0.74	-0.42	-0.03	
Thurner	0.93	1.30	0.04	-0.99	-2.76	0.71	-0.24	-0.05	0.78	0.53	-0.08	-0.88	0.45	-0.65	0.13	-0.09	-0.58	1.03	-1.76	1.65	
Leaf Area Index	-0.20	-0.64	-1.30	-2.33	-0.01	0.30	0.01	1.65	-0.16	0.27	0.08	0.34	-0.70	1.19	0.82	0.46	0.37	0.69	1.04	1.61	
Soil Carbon	0.27	1.26	-1.46	0.07	0.75	0.47	-0.03	-1.14	0.07	0.24	1.35	-0.99	-2.06	-1.55	0.90	-0.75	-0.17	0.24	1.01	1.48	
Gross Primary Productivity	0.59	-1.23	0.01	1.81	1.46	0.29	-0.53	-0.24	-1.04	0.77	0.04	0.59	-0.38	1.17	-1.02	-0.37	0.73	0.09	1.51	2.32	
Net Ecosystem Exchange	-0.39	-1.60	-0.34	-0.65	1.08	-0.17	0.95	0.11	-1.12	-0.93	-1.19	0.64	1.66	-0.76	0.66	-1.05	-1.04	1.26	1.41	1.61	
Ecosystem Respiration	0.89	-0.52	-0.93	-0.20	-1.33	0.98	-0.14	-0.99	-1.51	0.81	0.63	0.50	-0.76	0.88	-0.20	-1.21	0.40	-0.92	1.37	2.03	
Carbon Dioxide	-1.22	-0.24	1.34	-0.56	1.33	0.05	0.36	0.76	0.40	0.27	0.38	0.54	0.96	-0.66	0.23	0.62	0.43	0.50			
Global Net Ecosystem Carbon Balance	-1.42	-0.73	2.04	0.21	-0.22	-0.28	-0.39	0.28	-0.14	1.27	-1.47	0.22	-0.60	1.37	1.47	0.29	0.89	1.32			
Hydrology Cycle	-2.67	-0.63	0.42	-0.16	-0.39	-0.44	-0.50	0.23	0.63	0.13	-0.76	1.55	-1.12	0.55	-0.65	-0.77	1.04	0.89	0.98	1.68	
Evapotranspiration	-0.82	-0.99	-0.27	-1.02	0.64	-1.14	-0.62	-0.60	0.28	0.39	-1.08	1.09	0.65	0.43	-1.40	-1.01	0.82	1.05	1.41	2.00	
Evaporative Fraction	-0.34	0.74	0.74	-0.14	-0.85	0.21	1.38	0.22	-0.34	0.10	0.11	1.25	-0.88	-1.29	-1.65	-0.81	1.11	-0.06	0.96	1.29	
Runoff	-3.66	-0.35	0.47	0.05	-0.67	-0.57	1.12	0.44	1.33	-0.07	-0.23	0.96	-0.17	-0.19	0.02	-0.05	0.47	0.99	0.03	1.13	
Latent Heat	-0.02	0.39	-0.38	0.93	0.24	0.98	-0.73	-0.71	-0.21	0.66	-1.20	1.80	0.12	0.42	-1.52	-1.24	-1.40	0.40	1.45	1.95	
Sensible Heat	-0.85	-0.20	0.80	-0.28	-1.12	-1.23	-1.67	0.45	0.65	-1.04	0.37	1.02	-0.39	1.19	-0.54	-1.63	0.63	0.92	1.48	1.45	
Terrestrial Water Storage Anomaly	-2.76	-0.45	0.47	0.51	-0.38	0.34	0.35	0.43	0.58	0.15	-0.08	0.95	-2.01	0.43	0.37	0.15	0.39	0.51	0.49	0.50	

- **Tooltips:** show scores when mouse hovers the cells.
- **Column Hiding:** hide some models (columns) to focus into models of interest.
- **Column sorting:** sort the scores along the columns/models to see the best metric for the model.

Standards for Metrics/Diagnostics Interoperability

- **Compatibility with CMEC/MDTF effectively requires:**
 - A JSON file that provides metadata on the package being executed
 - A bash script that allows for “lowest common denominator” execution of the metrics module
 - Metrics output compatible with the package
- **“Lowest common denominator” (LCD) execution** – modules run over:
 - Path to the base directory of the metric module
 - Path to the observational data and model data
 - Path where output should be written
 - List of modules to be executed (and their configuration name)