Evaluating the ACME Land Model (ALM) with ILAMBv2

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Abstract

Assessment of overall model fidelity requires a comprehensive comparison of model results with a wide variety of observational data spanning multiple space and time scales. The International Land Model Benchmarking (ILAMB) activity has developed an open source benchmarking software system that employs a growing collection of laboratory, field, and remote sensing data sets for systematic evaluation of terrestrial biogeochemical and biogeophysical processes. The ACME Project is leveraging the ILAMB metrics and diagnostics system, developed by the Biogeochemistry–Climate Feedbacks Scientific Focus Area (SFA), and extending the system to assess the overall performance of the ACME Land Model (ALM), both coupled and uncoupled, as it evolves over time. Here we show how the performance of the latest version of ALM, run offline forced with CRU-NCEP reanalysis and run fully coupled, compares with the performance of the Community Land Model (CLM) versions CLM4.0-CN (forced with CRU-NCEP), CLM4.5-BGC (forced with CRU-NCEP), and CLM4.5-BGC (forced with GSWP3) on a sample of the metrics currently contained in the new ILAMB version 2 system.

Model Description and Experimental Design

The ACME Land Model (ALM) started as a branch of the Community Land Model version 4.5 (CLM4.5-BGC), employing vertically resolved soil carbon and nitrification/denitrification. Unlike the default configuration of CLM4.5-BGC, the initial version of ALM is utilizing the Convergent Trophic Cascade (CTC) (Thornton et al., 2005) instead of the CENTURY soil organic matter submodel (Parton et al., 1987). The new phosphorus limitation mechanism on vegetation growth in ALM was not enabled.

To test the fidelity of ALM in different configurations, we performed offline simulations at $1^\circ \times 1^\circ$ resolution for the past 50 years (1970–2010) in CTC and satellite phenology (SP) modes, using CRU-NCEP reanalysis as forcing. Land use change was disabled in these test simulations. The results of these simulations, as well as the output from an alpha version of an ACME fully coupled simulation for year 2000, were benchmarked with the ILAMB Prototype diagnostics package and compared with similar simulation results from CLM4.0-CN and CLM4.5-BGC forced with CRU-NCEP and CLM4.5-BGC forced with the Global Soil Wetness Project version 3 (GSWP3) reanalysis. The model configurations of ALM and CLM used in the comparisons below are described in Table 1.

Table 1: *Model designations and configurations.*

Model Name	Coupling	BGC Mode	Climate Forcing
ALM_CN	Offline	CTC	CRU-NCEP
ALM_SP	Offline	SP†	CRU-NCEP
ALM_WCYCL (α6.01)‡	Fully Coupled	SP†	CAM-SE
CLM40cn	Offline	CTC	CRU-NCEP
CLM45bgc_CRUNCEP	Offline	CENTURY	CRU-NCEP
CLM45bgc_GSWP3	Offline	CENTURY	GSWP3

†Satellite Phenology (SP) mode disables prognostic biogeochemistry.
‡Model output on the ne30 grid was remapped to the $0.9^\circ \times 1.25^\circ$ grid.

Summary of ALM Performance and Comparison with CLM

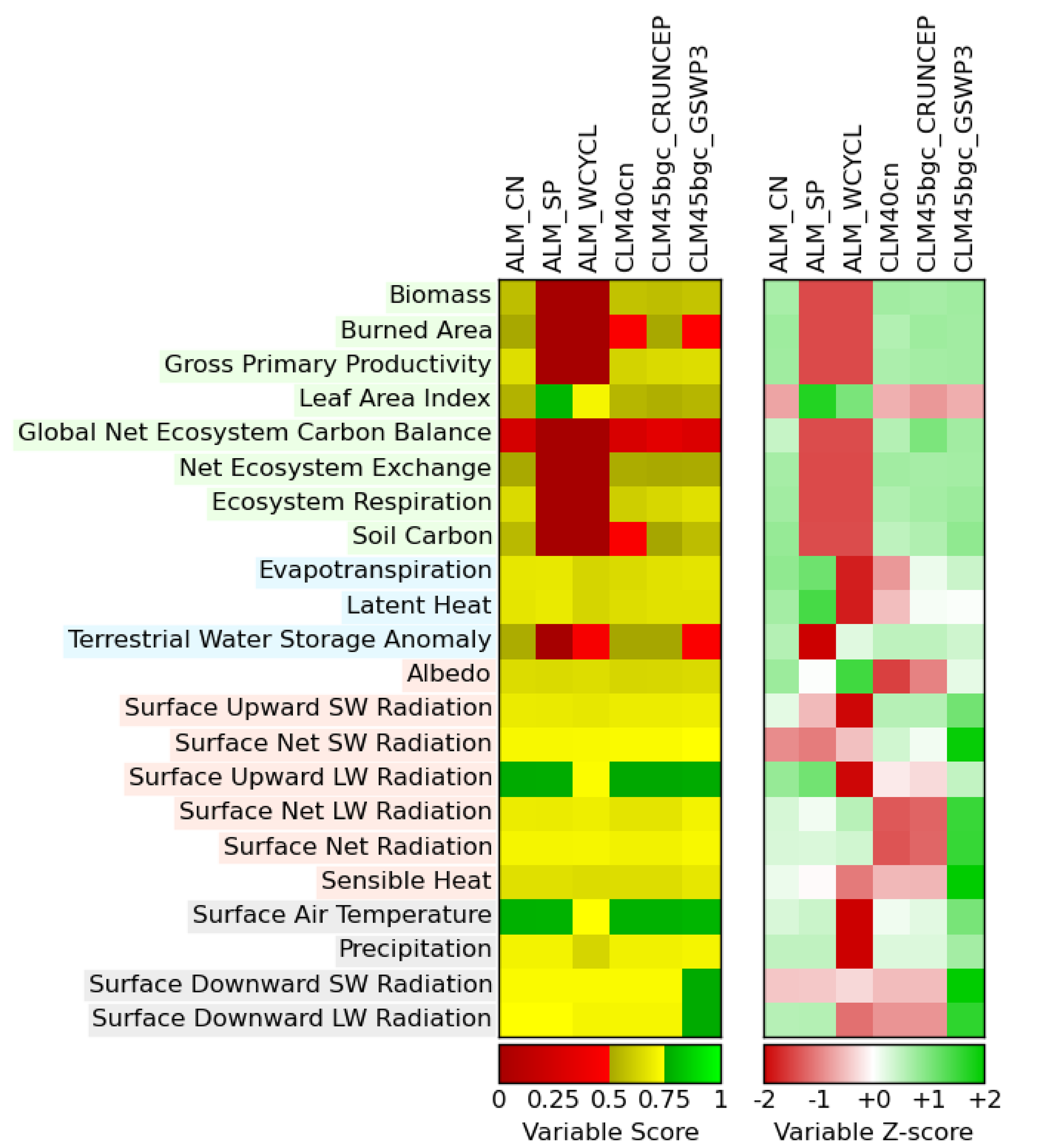

Figure 1: *This summary graphic depicts model performance across 22 variables, showing absolute performance (left) and relative performance (right) in comparison to best-available observational datasets. The ALM_SP and ALM_WCYCL configurations appear to exhibit poor performance on biogeochemical variables only because these variables are not prognostically computed in SP mode simulations, while leaf area index is read from an external forcing file.*

Ecosystem and Carbon Cycle Performance

Details for example variables in the Ecosystem and Carbon Cycle category are presented here to demonstrate the utility of the evaluation metrics and show how ALM compares with prior versions of CLM.

Aboveground Live Biomass

Four different biomass datasets are currently available in ILAMB:

- Global above- and below-ground biomass [GEOCARBON] (Saatchi et al., in prep.),
- Pan-tropical forest biomass [GLOBAL.CARBON] (Saatchi et al., 2011),
- Contiguous U.S. (Kellendorfer et al., 2000), and
- Contiguous U.S. and Alaska (Blackard et al., 2008).

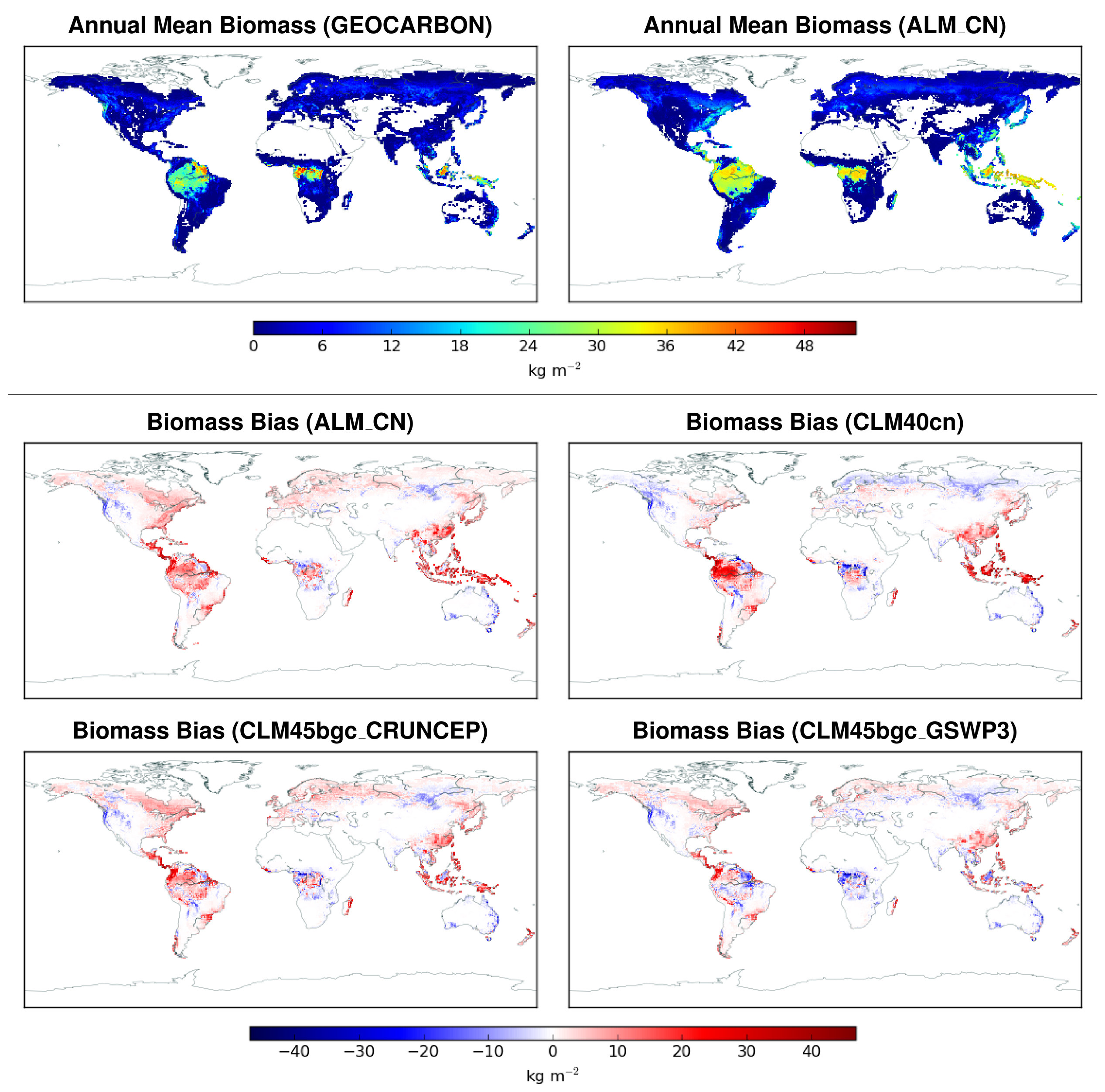

Figure 2: *Shown here are the year 2000 global above- and below-ground live biomass benchmark data (Saatchi et al., in prep.) (top row left) and the ALM_CN annual mean biomass for years 1996–2005 (top row right). Below the horizontal line are maps of the bias from all four prognostic biogeochemistry models computed by subtracting the benchmark from the model annual mean biomass for years 1996–2005.*

Table 2: *Diagnostic Summary for above- and below-ground live biomass: Models versus the GEOCARBON benchmark.*

Model	Annual Mean [Pg]	Bias [Pg]	RMSE [Pg]	Bias Score	RMSE Score	Spatial Dist. Score	Overall Score
Benchmark	431.5						
ALM_CN	666.0	218.0	333.0	0.369	0.561	0.888	0.595
CLM40cn	568.8	122.7	303.4	0.407	0.582	0.821	0.598
CLM45bgc_CRUNCEP	584.3	136.6	285.6	0.396	0.551	0.875	0.593
CLM45bgc_GSWP3	472.6	31.4	241.4	0.425	0.555	0.891	0.607

Radiation and Energy Performance

Surface All-Sky Albedo

Three different surface all-sky albedo datasets are currently available in ILAMB:

- Cloud and Earth Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Ed2.7 (Kato et al., 2013),
- NASA Global Energy and Water Exchanges (GEWEX) Surface Radiation Budget (SRB) Release 3.0 (Stackhouse et al., 2011), and
- MODerate-resolution Imaging Spectroradiometer (MODIS) Albedo product, MODIS MCD43C3 16-day 0.05 degree CMG L3, version 5 (Schaaf et al., 2011).

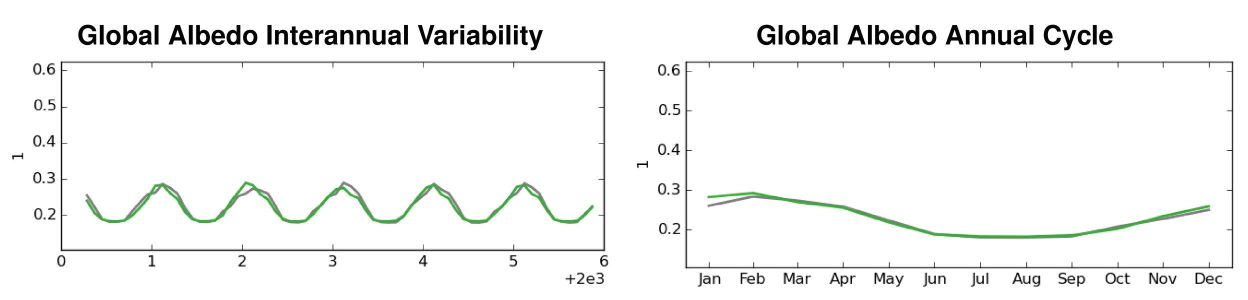

Figure 3: *Shown here are global interannual variability (left) and annual cycle (right) of the surface all-sky albedo for years 2000–2005. The gray line represents the CERES-EBAF observationally constrained data and the green line represents the CLM_WCYCL coupled model result.*

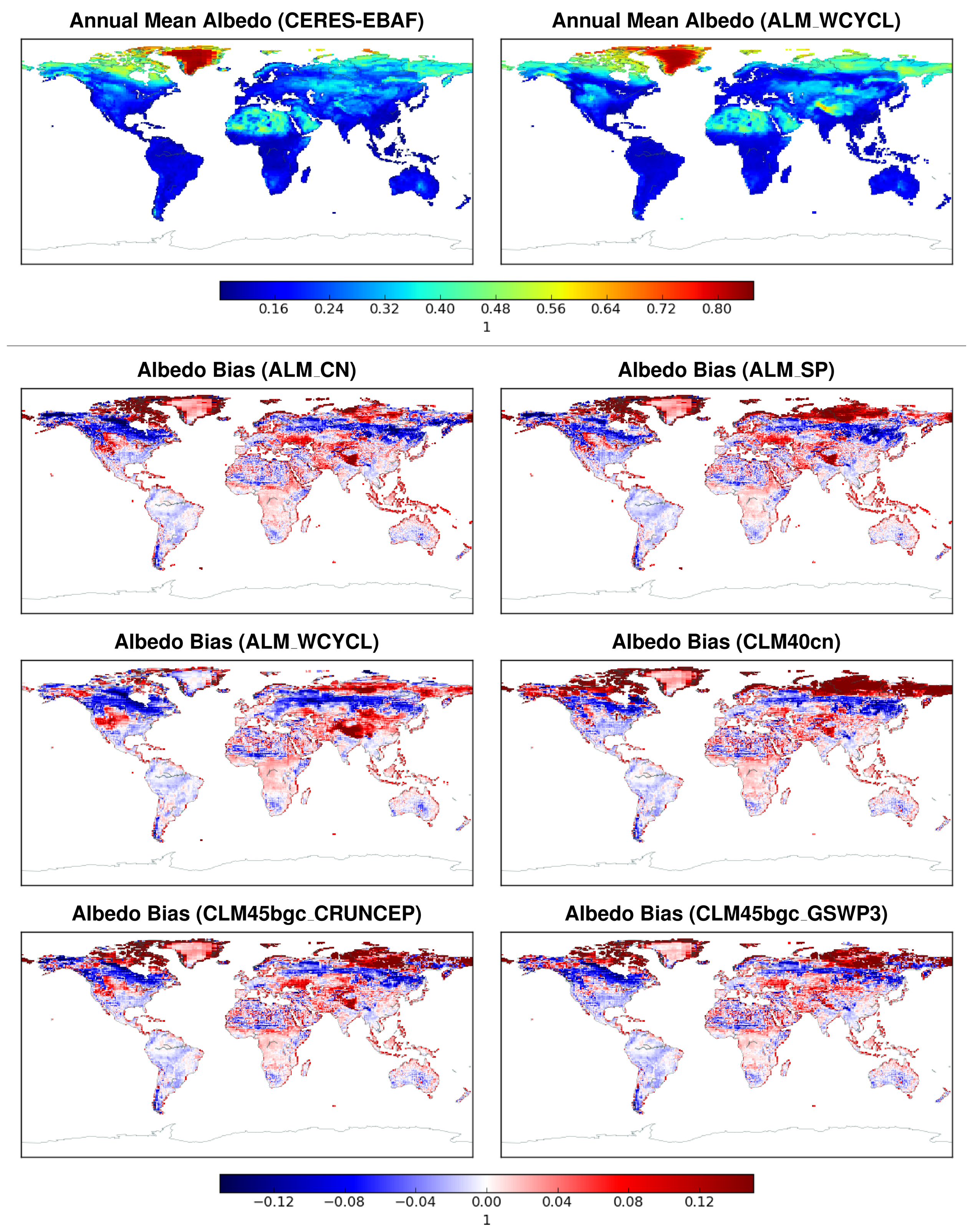

Figure 4: *Shown here are the 2000–2005 annual mean surface all-sky albedo benchmark data (Kato et al., 2013) (top row left) and the ALM_WCYCL annual mean surface all-sky albedo for the same years (top row right). Below the horizontal line are maps of the bias from all six models computed by subtracting the benchmark from the model annual mean albedo for years 2000–2005.*

Table 3: *Diagnostic Summary for surface all-sky albedo: Models versus the CERES-EBAF benchmark.*

Model	Annual Mean [1]	Bias [1]	RMSE [1]	Phase Shift [d]	Bias Score	RMSE Score	Seasonal Cycle Score	Spatial Distribution Score	Interannual Variability Score	Overall Score
Benchmark	0.230									
ALM_CN	0.233	0.005	0.062	−12.5	0.836	0.480	0.626	0.966	0.639	0.671
ALM_SP	0.235	0.007	0.061	−12.3	0.839	0.487	0.624	0.960	0.634	0.672
ALM_WCYCL	0.227	0.003	0.065	−11.7	0.844	0.480	0.657	0.960	0.651	0.679
CLM40cn	0.244	0.012	0.064	−17.9	0.840	0.495	0.611	0.893	0.644	0.663
CLM45bgc_CRUNCEP	0.241	0.009	0.063	−13.4	0.844	0.487	0.625	0.906	0.641	0.665
CLM45bgc_GSWP3	0.237	0.005	0.059	−13.3	0.850	0.481	0.627	0.925	0.672	0.673

Summary of ALM Performance and Conclusions

- Figure 1 indicates that ALM_CN performed similarly to CLM45bgc_CRUNCEP for variables in all categories.
- The recent addition of the GEOCARBON global live biomass dataset (Saatchi et al., in prep.) suggests that ALM_CN overestimated live biomass by >50%.
- CLM45bgc_GSWP3 has a much lower bias in biomass, likely due primarily to reductions in tropical shortwave radiation forcing in the GSWP3 reanalysis.
- Recent interest in top-of-atmosphere (TOA) energy biases have led to a more detailed analysis of the surface albedo over land. Figures 3 and 4 indicate that the coupled ALM exhibited rather small biases globally in surface all-sky albedo compared with CERES-EBAF estimates, with the largest global biases appearing in northern hemisphere winter. More analysis is needed to understand the sources of TOA imbalances.
- Next steps are to evaluate ALMv1 with phosphorus limited enabled and forced with GSWP3. This simulation will likely have a lower tropical biomass bias.
- Since it can easily highlight changes in model performance, the ILAMBv2 package will be integrated into the standard workflow process for ACME model development.

Acknowledgments

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