Development of a Tropical Ecological Forecasting Strategy for ENSO Based on the ACME Modeling Framework

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Rationale

- To study responses and feedbacks of tropical droughts induced by 1997–1998 and 2014–2016 El Niño events in the ACME land model (baseline model)
- To study model responses of the 2005 and 2010 Amazon droughts, which were a consequence of Atlantic Ocean conditions
- To construct a set of meteorological forcing data, including strong tropical land–atmosphere interactions, from CAM5-SE for use in process model development and testing
- To test the utility of the ACME framework for tropical carbon cycle forecasting

Model Configuration

- **Accelerated Climate Modeling for Energy (ACME) model** v0.3
- **1-degree (ne30np4) AMIP-style (F-compset) configuration**: Active atmosphere (CAM5-SE) and land (ALM) with data ocean (DOCN) and thermodynamic sea ice (CICE)
  - Data ocean reads NOAA Optimum Interpolation (OI) version 2 daily sea surface temperature (SST) (September 1981–present)
  - Ice fractions are also provided in the OISSTv2 data set
  - Future SST projections come from 9-month seasonal forecasts of the NOAA Climate Forecasting System (CFSv2)
  - Beyond 9 months from present, SSTs and ice fractions are drawn from historical OISSTv2 data to complete 5-y simulations
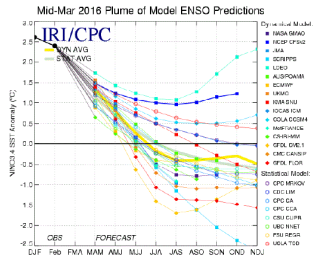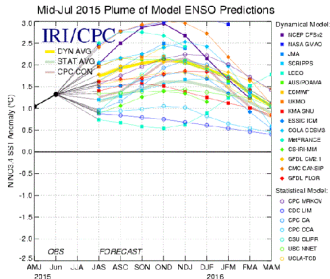
Simulation Protocol

▶ Spin up strategy: Start with CESM/CLM4.5-BGC year 2000 initial state and cycle 1982–1994 OISSTv2 data

▶ Simulate entire 1997–2018 period, saving 3-h coupler history for atmosphere fields needed for subsequent offline land model forcing

▶ Non-ENSO control simulation from (a) 5-y window between 1997 and 2014 ENSOs or (b) climatology of selected weak El Niño/La Niña years
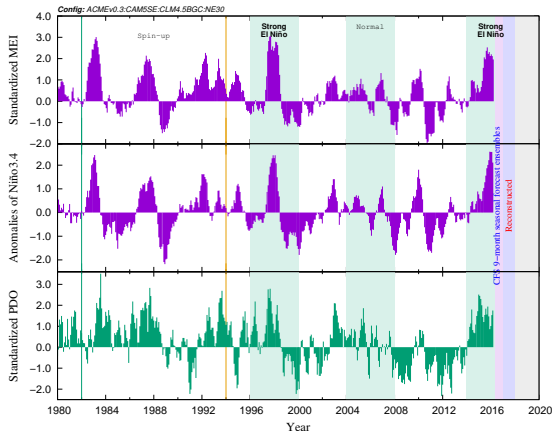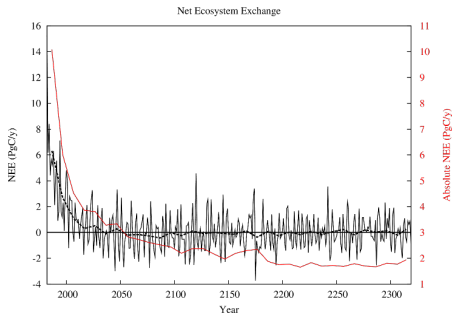

Spin up and simulation experiments are shown with respect to the standardized Multivariate ENSO Index (MEI), temperature anomalies of the Niño3.4 region, and the standardized Pacific Decadal Oscillation index.

Modeling Status

- ▶ ACME v0.3 model was built and tested on Titan (OLCF), Cori and Edison (NERSC).
- ▶ F-compset configuration was tested and performance optimized at both ne30 ($\sim 1^\circ$) and ne120 ($\sim \frac{1}{4}^\circ$) resolutions. Given queue wait times for moderately sized jobs and limited performance, we decided ne120 was computationally prohibitive.
- ▶ OISSTv2 data were remapped to the target ne30 grid to reduce the computational cost of remapping by the data ocean model at run time.
- ▶ The spin up simulation cycled 13 times (169 years) before initial transient simulation, and it continues for additional ensemble members.
- ▶ Two 25 year transient simulations through 2020 were performed.
- ▶ Land model results were evaluated using the International Land Model Benchmarking (ILAMB) package.

Carbon Cycle Equilibrium

Net Ecosystem Exchange

(a) First 56 yrs — total, abs = 1.959, 4.898PgC/y

(f) Sixth 56 yrs — total, abs = 0.032, 0.831PgC/y

The plot (above) shows the net ecosystem exchange (NEE) (solid black), the 5-y running mean of NEE (dashed black), and the absolute value of NGEE (solid red) globally from cycling the 1982–1994 OISSTv2 forcing. The years shown on the x-axis are simply accumulated during the cycling. The maps (right) show the first and last 56-y mean NEE distributions from the spin up simulation.
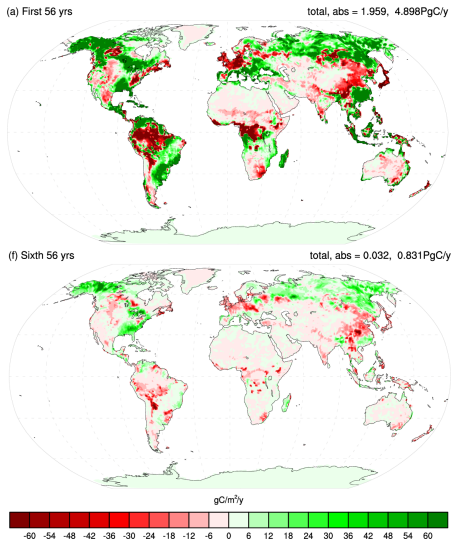
Regional 2 m air temperature anomalies
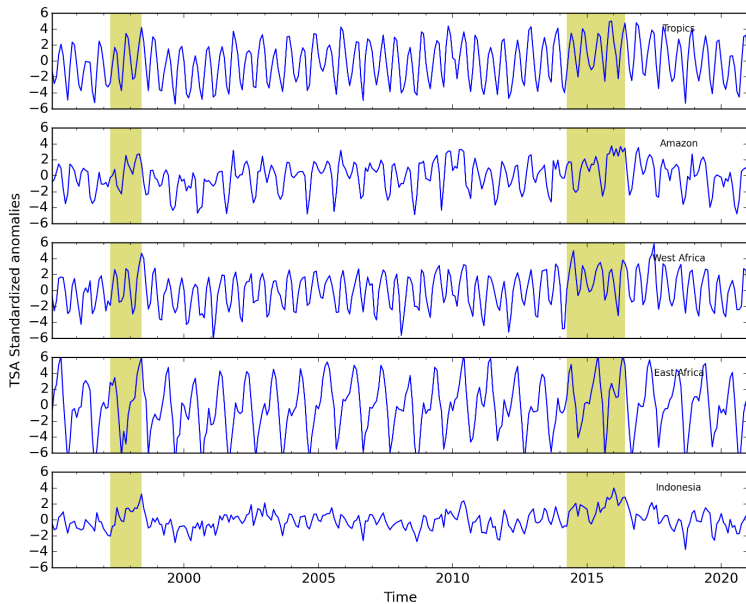
Regional PFT-level gross primary production anomalies
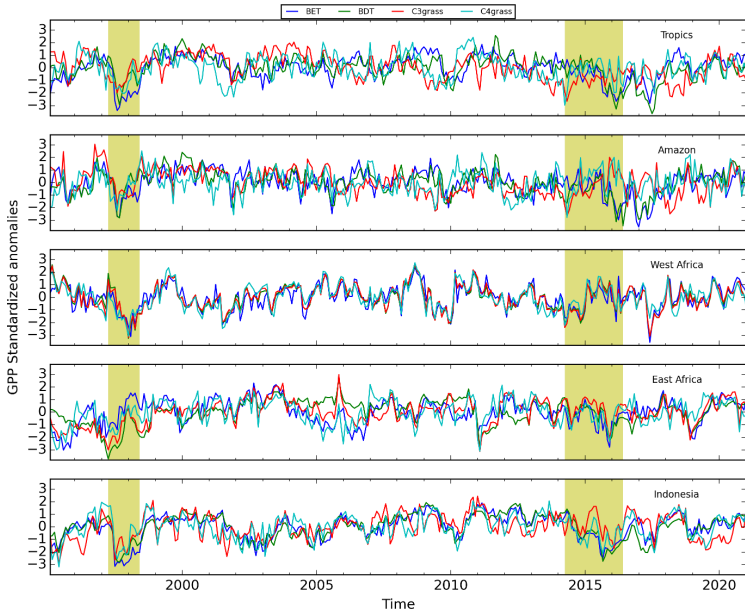
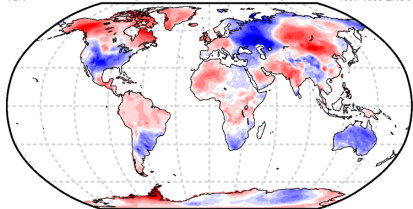# Regional PFT-level stomatal resistance anomalies
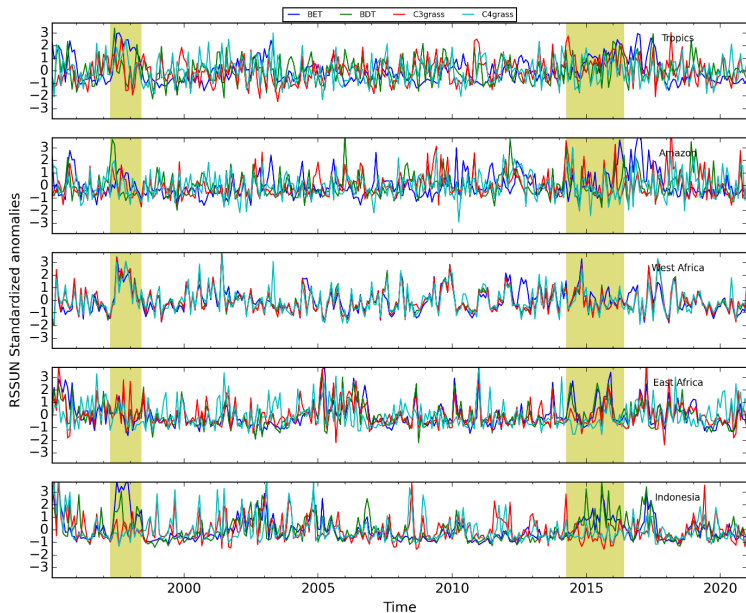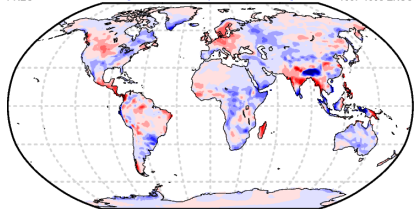
Regional PFT-level leaf area index
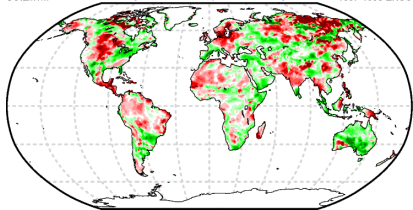
Model Patterns for the 1997–1998 El Niño Event
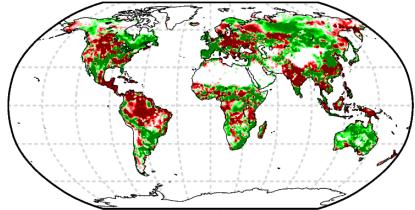
Anomaly maps for the 1997–1998 ENSO for the 2-m air temperature (TSA), precipitation (PREC), soil moisture to 1 m (SOILM1m), and gross primary production (GPP) are calculated by subtracting the 1982–2015 mean (climatology) variable from the 1997–1998 mean variable. While the model exhibited global increases in soil moisture and GPP, in the tropics it projected a mean decrease in soil moisture of 0.11 mm and a mean reduction in GPP of 0.68 Pg C y^{-1}.

Model Patterns for the 2010 Amazon Drought
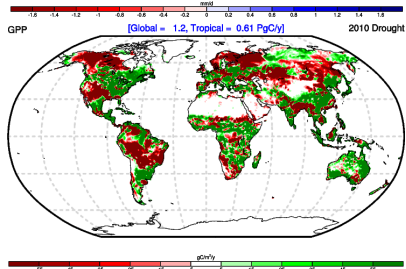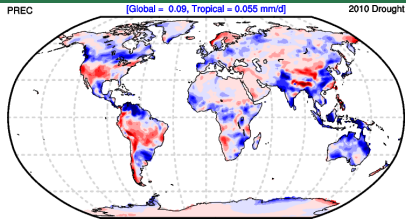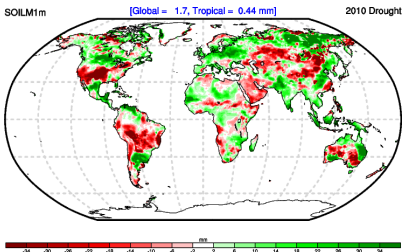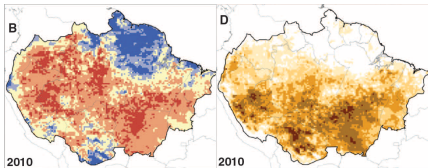
The model appears to capture the overall pattern of drought in the Amazon during 2010. The upper left figures are (B) the satellite-derived standardized anomalies for dry-season rainfall and (D) the difference in the 12-month (October to September) maximum climatological water deficit (MCWD) from the decadal mean (excluding 2005 and 2010) for the Amazon basin from Lewis et al. (2011). The soil moisture anomaly from the model correlates well with (B) and the GPP anomaly correlates well with (D).

ILAMB Assessment
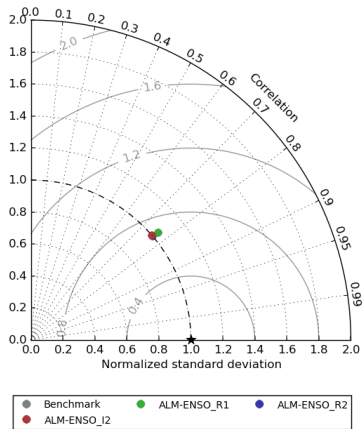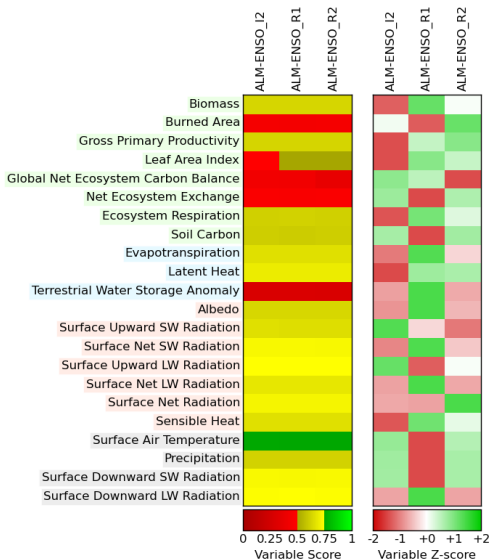
Global spatial variance of GPP
(1995–2009)

The mean state of the two AMIP-style ensemble members is equivalent, as is the offline ALM simulation performed using the coupler forcing from the second ensemble member.

Summary and Next Steps

- Analysis of spin up simulation indicated that land carbon pools approached equilibrium when driven by OISSTv2.
- ILAMB climate evaluation of the spin up run showed a $+0.5$ K bias in mean surface air temperature over land and a positive bias in mean precipitation at high elevations.
- The first transient simulation showed expected anomalies in outgoing longwave radiation and precipitation, with expected ecosystem responses in leaf area index, stomatal conductance, and GPP.
- Daily mean quantities were saved from simulations, including PFT-level output for many of the variables for detailed analysis.
- In the second transient simulation, we saved 3-hourly coupler history and tested it with an offline (I-compset) simulation. It may be used for offline model development and testing.
- Analysis of the spatial patterns of soil moisture and GPP for ENSO events will be compared with observations. Those for the 2005 and 2010 Amazon droughts are consistent with data reported by Lewis et al. (2011).

For more details about the PFT-level analysis, see:

B51E-0465: Modeling Biogeochemical Responses of Vegetation to ENSO: Comparison and Analysis on Subgrid PFT Patches

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Friday, 16 December 2016   08:00–12:20
Moscone South - Poster Hall
MS 0456

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Office of Science

References

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Amazon drought. *Science*, 331(6017):554, Feb. 2011.