Experimental Design for CTSM6 Latin hypercube PPE

Linnia Hawkins, Daniel Kennedy, Katie Dagon, Dave Lawrence
+ CTSM-PPE community

Quick links:

- *Table of parameters and ranges (Table 4)*
- *Google drive folder*
- *Github repository*
- *CTSM6 OAAT documentation*

1. Objectives

Our primary objectives for this ensemble are to (1) tune CTSM6 and (2) assess parametric uncertainty in land carbon cycling. We will employ the history matching methodology which balances these two objectives.

For the tuning objective, we will run ensembles designed to train cost-efficient ML-based emulator(s) with which we can perform calibration of a suite of metrics. To assess parametric uncertainty, we will cautiously rule out parameter combinations that lead to implausible model simulations then evaluate uncertainty within the remaining parameter space.

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2. Model configuration

Codebase: BNF_v2.n01_ctsm5.3.012 released Nov. 20th, 2024 (link)
Resolution: 2-degree, 30-minute
Sparsegrid: Kennedy et al., (2024)

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3. Simulation protocol

Spin up

- Initial state:
  - 2degree fullgrid 280AD+280SASU+160pSASU (hand tuned parameters)
  - Sparse grid 280AD+280SASU+160pSASU (default parameters)
  - Sparse grid 280AD+280SASU+160pSASU (default +corrected FUN_fracfixers)
- Accelerated Decomposition (AD: 40 years)
- Matrix (SASU: 120 years)
- Normal (postSASU: 40 years)

Transient simulations

- 1850-1901 recycling 1901-1920 meteorological forcing
- 1901-2023 CRUJRA, recycling 2014 aerosol forcings (as in TRENDY 2024)
- 2014-2023 recycling 2014 aerosols

Variables saved (Table 1)

- Monthly gridcell and PFT level data (1850-2023)
- Daily gridcell and PFT level data (1985-2023)

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4. Parameters & ranges

Parameter selection process involved leveraging the CLM5-OAAT (Kennedy et al., 2024; JAMES) to identify parameters influential on processes at the global, biome, and PFT level under control, high CO2, and future climate scenarios. Additionally, we solicited input from the community on which variables and metrics they would consider using the ensemble to tune/evaluate/assess uncertainty. Metrics from the community were collected in (Table 2), we coded up many of these metrics and identified influential parameters again using the CLM5-OAAT.

We opted not to use a quantitative methodology for identifying parameters (i.e., set a sensitivity threshold and include all parameters above the threshold), we used a more subjective method that involved expert judgment and several iterations. This process allows us to integrate decades of collective modeler expertise, and attempt to be parsimonious when possible. We converged on 56 parameters (Table 3).

Next, we ran a one-at-a-time ensemble with the 56 parameters (CTSM6-OAAT documentation). We performed transient simulations (1850-2023) using the same protocol as described in Section 3. We then evaluated the parameter sensitivity and again iterated with the CLM-PPE community. One notable decision was that we opted to group sets of parameters and modify them as one parameter (see CTSM6-OAAT documentation) including parameters related to nitrogen usage, photosynthetic acclimation to temperature, decomposition pools. See github discussion and slide deck for additional information on all decisions.

For the majority of parameters we are using the same ranges as in Kennedy et al., (2024), however some parameter ranges were modified to ensure survivability (specifically for broadleaf evergreen boreal tree and C4 grass). We settled on 56 parameters to be included in the CTSM6 Latin hypercube ensemble (Table 4).

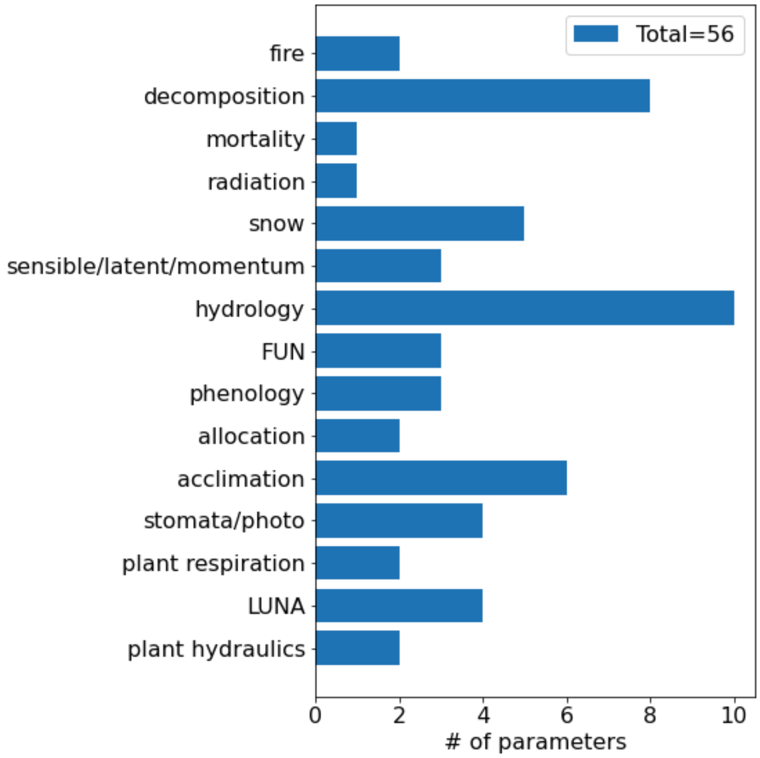

Figure 1. Parameters included in the CTSM6 LHC PPE grouped by process (total=56).

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4. Costs & storage

We ran a 1500 member ensemble with a Latin hypercube sampling scheme. The ensemble size was chosen in part due to computational availability, but also because we think this is a wide, poorly constrained parameter space (more so than the CLM5-LHC ensemble, i.e., decomp_depth_efolding) which requires more than the 10x number of parameters rule of thumb. Additionally, 56 parameters is many more than we have used in a PPE before and anticipate challenges emulating in such high dimensions.

Compute:

- 1 simulation: Spinup = ~1200 core-hours
- transient simulation = ~1200 core-hours
- Ensemble: 1500*2400 = 3.6M core-hours

Storage:

- /glade/campaign/cgd/tss/projects/PPE/ctsm6_lhc/
- Total: 14TB

A1. Spin up evaluation

Disequilibrium in postSASU spin up stage.

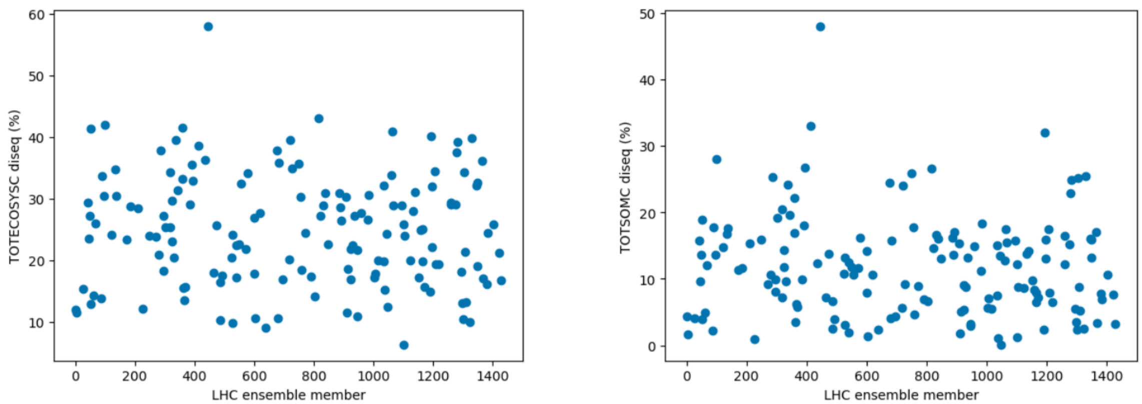

Figure A1. Spin up disequilibrium shown for a random subsample of the LHC simulations. Disequilibrium is calculated as the percentage of land area with a change in TOTECOSYSC (left) and TOTSOMC (right) greater than 1 gC/m2/yr.