ACME BGC Experiments

- The purpose of this BGC experimental protocol is to identify nitrogen (N) and phosphorus (P) effects on C-Climate and C-concentration feedbacks (beta and gamma) in the presence of Land Use and N and P deposition trajectories. The experiment will also be used to assess structural uncertainty in the way nutrient constraints affect current and transient climate
- Hypotheses:
  - Climate and CO_2 driven changes to nutrient dynamics over the coming decades will have transient effects on C-Climate feedbacks. Nitrogen and Phosphorus limitations to C cycle processes will vary in space and time over the simulation. Process representation and parameterization choices will lead to qualitatively and quantitatively different responses in C, energy, and hydrological responses in the coupled simulations

Strategy I

- To accomplish this analysis we will produce coupled simulations with the ACME V1 land model (ALM1), branched from CLM4.5, and including coupled subsurface carbon-nitrogen-phosphorus dynamics (based on Yang et al., 2014), CTC-based SOM decomposition, and two parameterizations for the representation of plant-microbe competition for nutrients:
  - Relative Demand (RD) with plant N and leaf C storage pools
  - Equilibrium Chemistry Approximation (ECA), plant N pools, and trait plasticity in roots and leaves
- Additional CTC-based development and testing required by August 1:
  - Addition of longer-lived SOM pools
  - Testing against datasets of:
    - Litter decomposition
    - Global SOM
    - Site-level radiocarbon
- These parameterizations differ in several important aspects that are expected to affect the coupled model response:
  - How nutrient competition is represented
  - How nutrients control photosynthesis
  - How C, N, and P storage pools are represented

Strategy II

- To separate the nutrient effects on C-Climate feedbacks, we will follow the C4MIP protocol, with C-only, CN, and CNP simulations, for each competition parameterization:
  - C4MIP protocol: Control, BGC coupled, radiatively coupled, and fully coupled
- We therefore have six fully coupled model configurations ((RD & ECA) × (CN & CNP)) + 2 controls (C, C_r) to perform each of the four C4MIP simulations:
  - Controls: *C1*: (no down-regulation), *C2* (fixed pft-specific vcmax down-regulation to match pft-integrated Pre-Industrial NPP as mean of *C3* and *C5*)
  - *C3*: RD-CN; *C4*: RD-CNP
  - *C5*: ECA-CN; *C6*: ECA-CNP
- We will systematically explore the sensitivity of predictions to process parameterization in ALM1 by isolating the effects on global carbon dynamics of
  - Structural differences in process representations
  - Climate versus CO_2 concentration
  - Spatial gradients of the roles of N&P limitations
  - N&P limitations on biophysical feedbacks (e.g., LH & SH exchanges)

ACME V1 Model Configurations

- Spatial resolutions:
  - Land: f09_g16 resolution (f09_g16 resolution, ~1 degree)
  - Atmosphere: ACME-CAM starting tag (CAM5 SE, 1 degree)
  - Ocean/sea ice: ACME-POP ~1 degree (gx1v6)
  - Land ice: ~1 degree (gx1v6)
- Simulations will be based on existing CESM compsets: B1850, B20TR, and BRCP85

Proposed Simulations I

- For each *C*, we will perform four historical-plus-RCP8.5 C4MIP protocol simulations (control, BGC coupled, radiatively coupled, and fully coupled) covering the period 1850 to 2100

Proposed Simulations II

- **Equilibrium coupled 1850** simulation
  - Offline spinup to 1850 with 1850 atmosphere
    - Use repeating 20 year cycle of MOAR output from CAM5 for 1850 climate (3 hourly forcing)
    - Develop CLM4.5 surface datasets for f09_g16 for 1850
    - CO_2 held constant at 1850 conditions
    - Perform an offline spinup with new ACME acceleration approach until equilibrated (~100 years accelerated + 50 years post-acceleration)
    - Land use held constant at 1850 conditions
    - The reduced-productivity control *C2* will be initialized by:
      1. Running the offline CN versions (*C3* and *C5*) globally for 1850 conditions from CAM5 forcing files as described above
      2. Calculating the PFT-integrated preindustrial control NPP for both *C3* and *C5*, and then taking the mean of these two values for each PFT (requires outputting PFT-level NPP variables; i.e., hist_dov2xy = .false.)
      3. Running the C–only model (suplnitro = 'ALL') several times with FNITR values ranging between 0 and 1 (e.g., with FNITR = 0.2, 0.4, 0.6, 0.8, 1.0) (also requires outputting PFT-level NPP variables)
      4. Calculating the pft-specific FNITR values from these C-only runs that give the same PFT-integrated NPP values as in step 2 by interpolating the FNITR-NPP relationships for each PFT diagnosed in step 3
      5. Using those pft-specific FNITR values in the reduced-productivity coupled C-only simulation *C2*
  - Coupled spinup to 1850
    - Based on ACME version of B1850 compset
    - Start with offline spinup for land, ocean, land ice, and sea ice
    - Prescribe ocean BGC fluxes
    - Iterate (tune) until the land biogeochemistry is stable with the rest of the system
      - Run until the global and per-grid NEE absolute values are close to zero (specified threshold)

Proposed Simulations II

- **1850 to 2005 CO_2 concentration forced** (historical CO_2, N&P deposition, LULC) transient coupled simulation
  - ACME version of B20TR compset
  - Use transient land surface datasets from 1850 to 2005 (including transient LULC)
  - Consider ensembles once computational costs are assessed
- Evaluate the historical simulations with ACME-ILAMB
- **2005 - 2100** coupled simulation (**RCP8.5** CO_2, N&P deposition, LULC)
  - ACME version of BRCP85 compset

Practicalities

- This combination of simulations leads to a total simulation time of: (6 configurations) * (4 C4MIP scenarios) * 250 years = 6,000 years + time required for spinup
- We will evaluate the offline and historical simulations with the ILAMB benchmarking framework
- Preliminary Tasks Required
  - Development of ALM1 surface datasets
    - for 1850, 1850-2005, and 2005-2100
  - Development of mapping files for different model components
- Given sufficient resources and time, we could also perform
  - Ensembles
  - Different LULC and N & P deposition trajectories