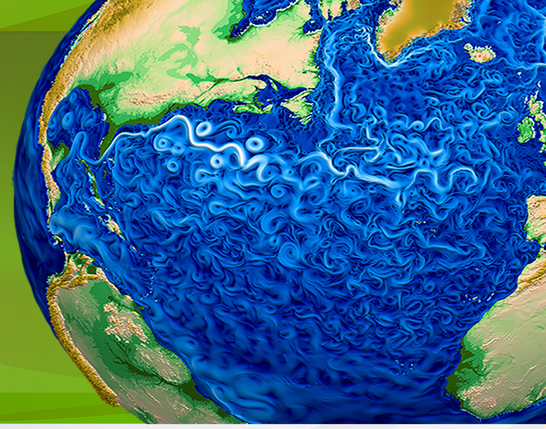
Traits and trait filtering from the soil to the canopy

Jennifer A. Holm, Ryan G. Knox. William J. Riley, Charles D. Koven,
Jinyun Tang, Qing Zhu, Bardan Ghimire, Jeff Q. Chambers, and Rosie Fisher*
Lawrence Berkeley National Laboratory, *NCAR



Hypothesis

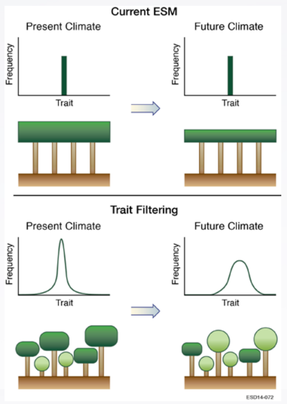
Why have trait filtering in models?:

- Current Earth System Models (ESMs) prescribe plants and microbial traits that are static in both time and space, thus unrealistically limiting the range of ecosystem responses to environmental change **(Fig. 1)**.
- Interactions among plants, free-living microbes, and symbiotic microbes helps to shape a plant's response to a changing climate.

- **Hypothesis: ecosystem responses to a changing climate will be governed by changes in these traits and the costs associated with them**.

Research questions: **(1)** How can the representation of plant and microbial traits and trade-offs help address ACME mission goals?
(2) What are the most theoretically sound and numerically robust approaches to represent these traits?

(Figure 1)



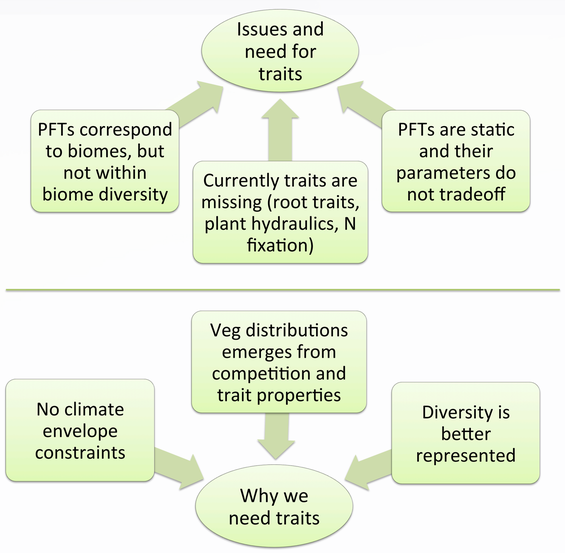
Implementation in ALM-ED and ALM:

- The Ecosystem Demography (ED) model can be a "starting point" due to inclusion of varying size structure and age classes, competition and coexistence between plants, and the capacity to **predict distributions of plants directly from their given physiological traits**.

Developments Required

Potential Development in ALM-ED:

- New approaches to represent **life-history strategies**.
- Include different successional statuses (i.e. pioneers, late successional, etc.).
- Trait filtering to represent carbon trade-off between seed generation, reproduction, or defense in large, established trees.
- Include: wood density and leaf economic trait trade-offs .
- Goal: Include traits and mechanisms for trait filtering that control the distribution of plants as a function of resistance to drought, fire, pests, cold, and other disturbances.



Potential Development in ALM:

- Representation of symbiotic microbes (e.g., mycorrhizal fungi) → Linkages to belowground nutrient availability (i.e. resource acquisition).
- Representation of free-living microbes (e.g., heterotrophic decomposer) → Competition with plants for nutrient acquisition.
- Represent plant-microbes interactions → Ex.1. Existence of mycorrhizal fungi to help harvest mineral phosphorus for tropical tree (mutualistic interaction).
  Ex.2. Existence of decomposing microbes outcompete plant roots and suppress plant growth (parasitic interaction).

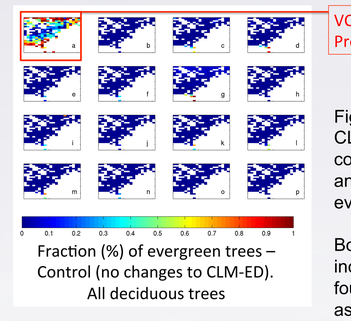
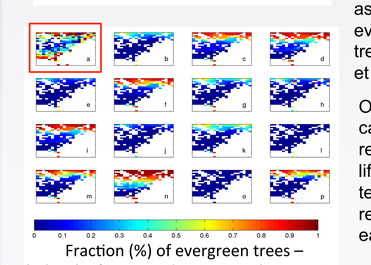


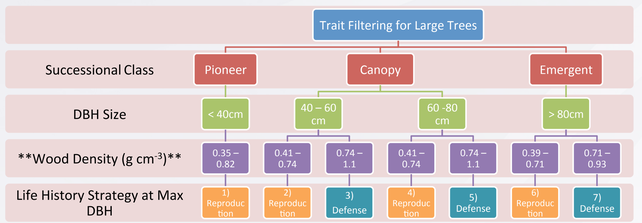
Fig. 2. Under control CLM(ED) conditions competitive exclusion and no representation of evergreen trees.

Bottom panel = Impact of including leaf traits and four carbon economy assumptions of evergreen and deciduous trees in CLM(ED) (Fisher et al. 2015).



Once including changes to leaf carbon allocation, base rate of respiration, leaf lifespan and root lifespan as a function of temperature there is a stronger representation of evergreen trees in eastern North America.

Fig. 3. Proposed model development to correct the large tree bias and also introduce trait filtering in ALM-ED is to introduce (1) successional classes which are delineated by, (2) DBH size and then, (3) wood density ranges which correspond to seven reproduction or defense carbon economic trade-offs.



Trade-off Scenarios (% from Central Amazon):
1) Reproductive Pioneer (11%)
2) Reproductive, Low WD, Small Canopy (32%)
3) Defensive, High WD, Small Canopy (23%)
4) Reproductive, Low WD, Large Canopy (11%)
5) Defensive, High WD, Large Canopy (9%)
6) Reproductive, Low WD, Emergent (4%)
7) Defensive, High WD, Emergent (10%)

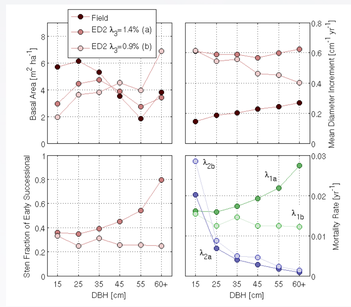


Fig. 4. Changes in exogenous mortality rate leads to **active trait filtering, evidence by wood density shift in lower left panel**.

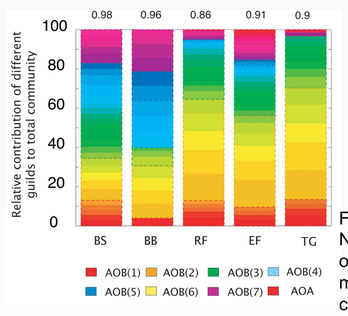


Fig 5a. Results from a microbial trait based model (MicroTrait-N) (Bouskill et al. 2012). Uses traits related to enzyme kinetics and physiological traits to represent contributions of ammonia-oxidizing bacteria (AOB) and ammonia-oxidizing archaea (AOA) across different plant types. (BS = black spruce, BB = bog birch, RF = rich fen, EF = emergent fen, TG = tussock grassland).

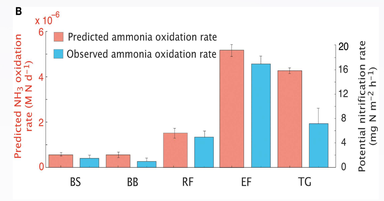


Fig 5b. Microbial trait based model (MicroTrait-N) ammonia (NH_3) oxidation rates compared to observations in Alaska. A small number of traits may be sufficient to characterize nitrifying community structure.

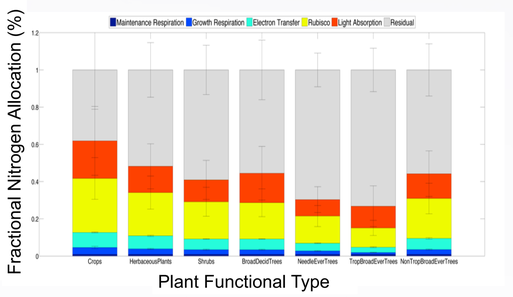


Fig. 6. Fractional leaf nitrogen allocation for six plant processes separated by PFT, as analyzed from the TRY database.

Expected Impact

Ecosystem Demography and Traits:

- Represent successional status by including range of **maximum DBH** and **wood density traits** to determine carbon economy preference and allocating carbon to reproduction or defense.
  - Wood density is related to a number of plant functional traits
  - Direct relationship between wood density, tree growth, and drought tolerance
- **Impact**: Assess the capacity of ALM-ED to predict trait distributions and improve modeling carbon assimilation and respiration.

Leaf Traits and Photosynthesis/Respiration:

- **Impact**: Based on our analysis, crops partition the largest fraction of nitrogen to photosynthesis (~57%) and respiration (~5%) followed by herbaceous plants (~44% and 4%). Tropical broadleaf evergreen trees partition the least to photosynthesis (~25%) and respiration (~2%) followed by needleleaf evergreen trees (~28% and 3%).

Microbial Traits and Trait Filtering:

- **Impact**: Microbial trait based model (MicroTrait-N) was used to successfully predict nitrified diversity, ammonia (NH_3) oxidation rates, and nitrous oxide (N_2O) production across pH, temperature, and substrate gradients.

ACME Accelerated Climate Modeling for Energy

For additional information, contact:
Jennifer A. Holm
Postdoctoral Fellow
Climate Sciences, LBNL

LBNL
(510) 495-8083
jaholm@lbl.gov

References:
Bouskill et al. 2012. Frontiers in Microbiology. 364
Fisher et al. 2015. Geo. Model Dev. Discuss. 8: 3293-3357.

climatemodeling.science.energy.gov/acme

U.S. DEPARTMENT OF ENERGY