Vegetation demographics in ACME: Capturing structural forest dynamics, plant co-existence, and plant functional shifts

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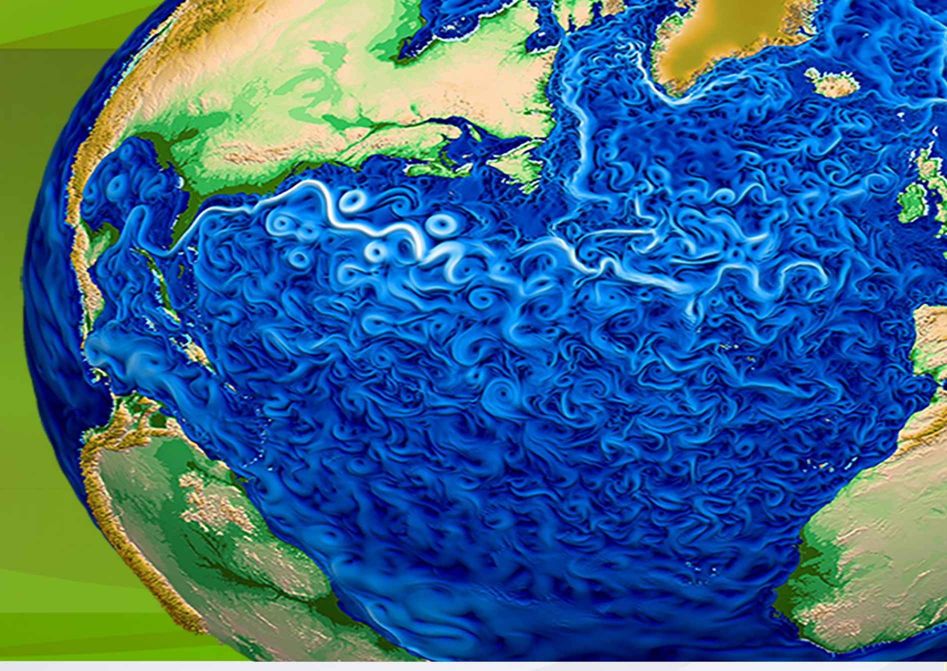
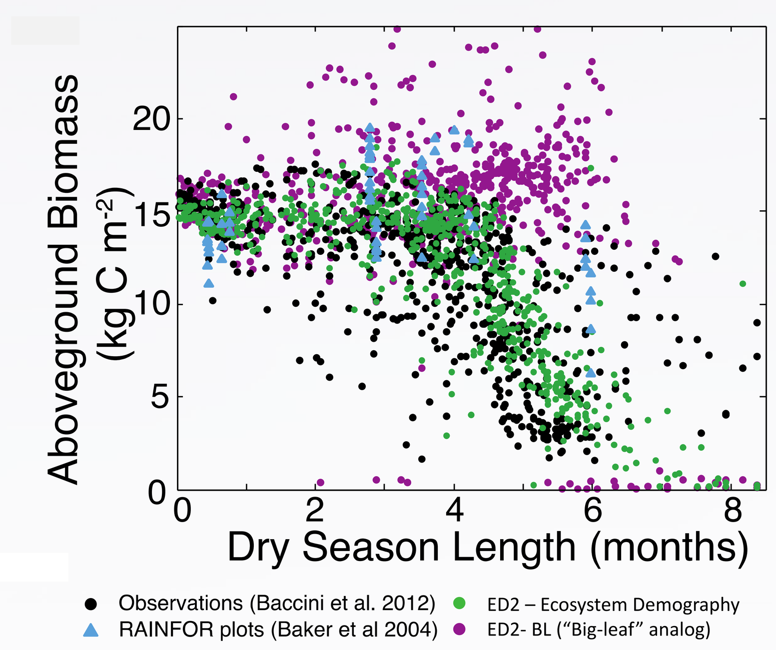


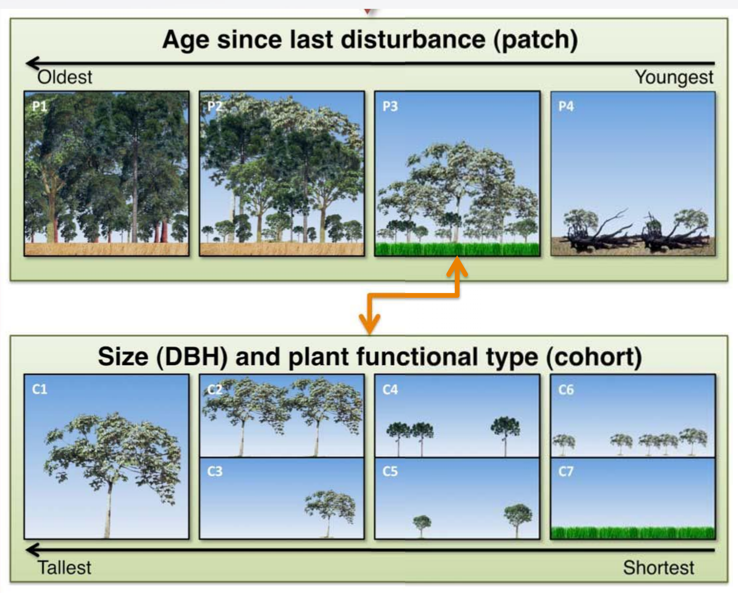
Issues concerning dynamic vegetation modeling

The inclusion of vegetation demography into Earth System Models (ESMs) will better represent plant ecology, and vegetation processes that govern fluxes of carbon, energy, water.

- However, incorporating dynamic vegetation demography poses huge challenges owing to their increased model complexity.
- **Current issue = global application of dynamic vegetation in ALM**

The role of ecosystem heterogeneity and diversity[1]: Aggregated **"big-leaf"** ecosystem vs. **demographic**; structured ecosystem means ability to capture differences in biomass with dry season length.





The Ecosystem Demography (ED) model vegetation structure, the basis for ALM-FATES. Tracks age and size of tree "cohorts", incorporates disturbance , and dynamic turnover. But these processes can lead to more model variability.

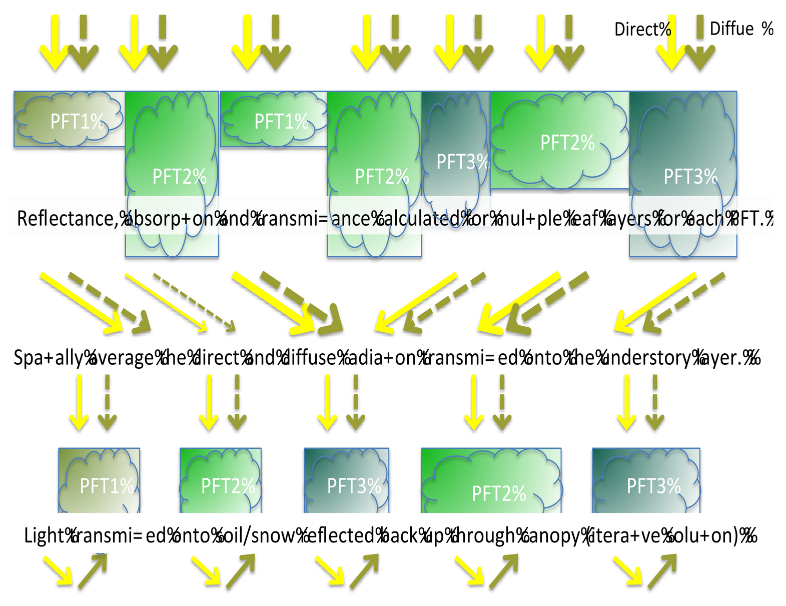
Solution Attempts

Examples of near-term development priorities for FATES and progress towards demographic ESMs:

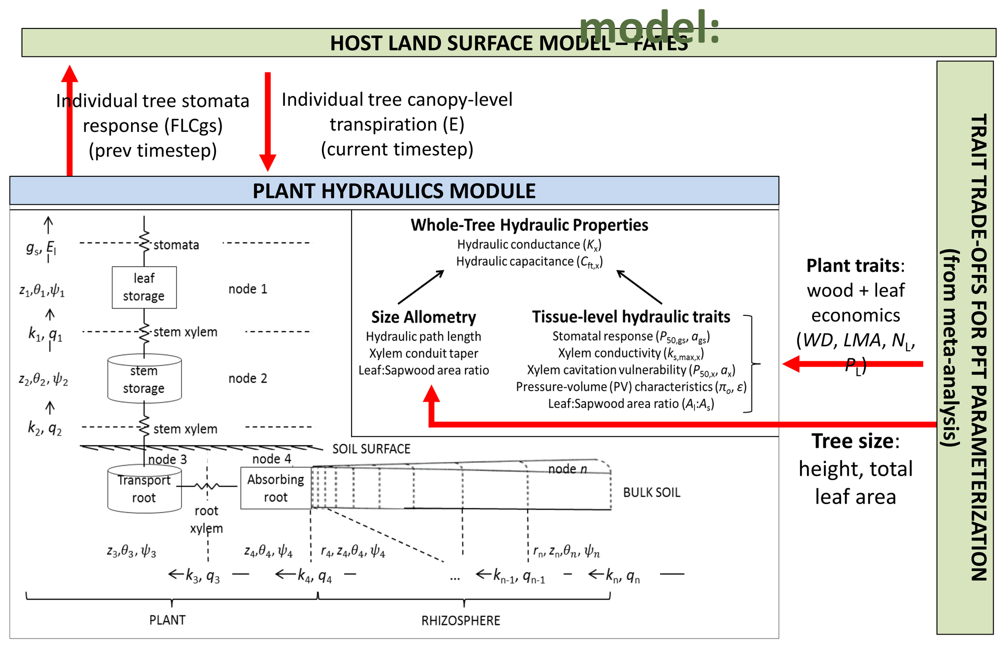
<u>**FATES model**</u> (Functionally-Assembled Terrestrial Ecosystem Simulator)[2]

- Carbon pools, fluxes, allocation; litter fluxes; phenology; regeneration, growth, mortality represented by ED (Ecosystem Demography Model).
- Canopy physics, soil BGC, land surface hydrology, photosynthesis, respiration represented by ALM.
- Incorporates discretized PPA for canopy structure.
- 'Some' current development foci:
  - Introduction of plant hydrodynamics and competitive plant water uptake
  - Librarification of ED code to allow multi-model compatibility (ACME/CESM/ARCOS)
  - Sensitivity analysis to input parameters
  - Multi-assumption photosynthesis module testing
  - Mechanistic mortality algorithms vs. static turnover

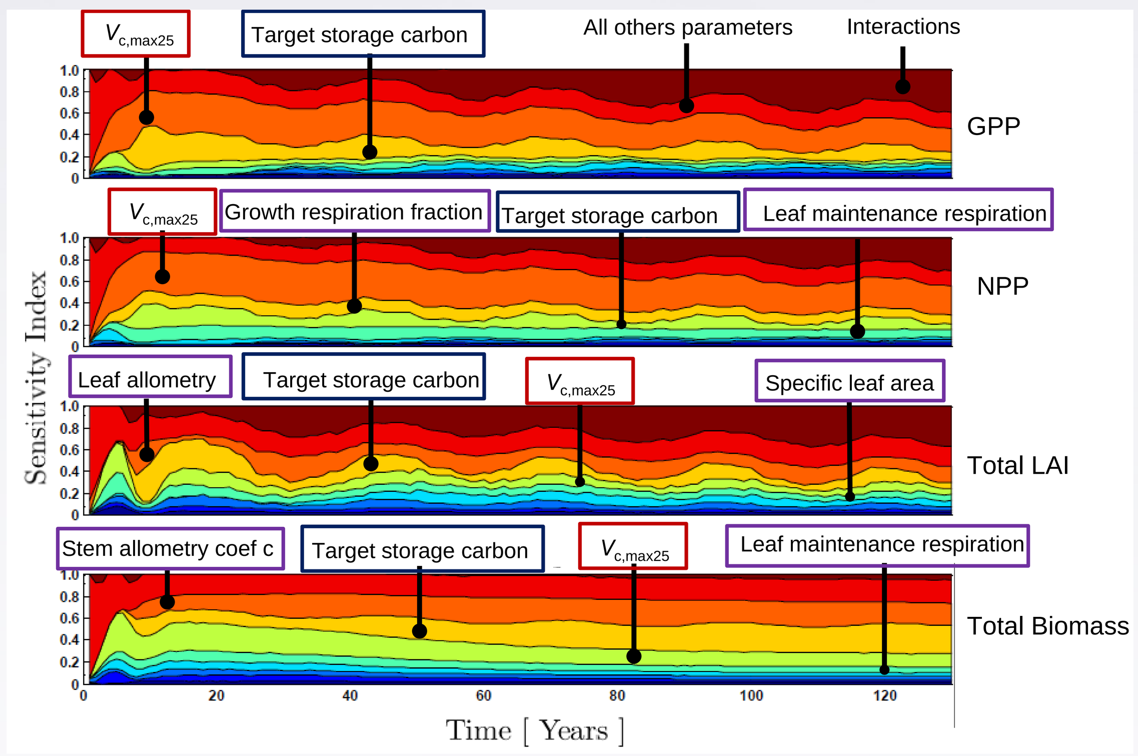
(1) Testing radiative transfer schemes: Discretized Perfect Plasticity Approximation (PPA)



(2) Testing competition for water/plant hydraulics and integration with trait based forest model:



Solution Attempts



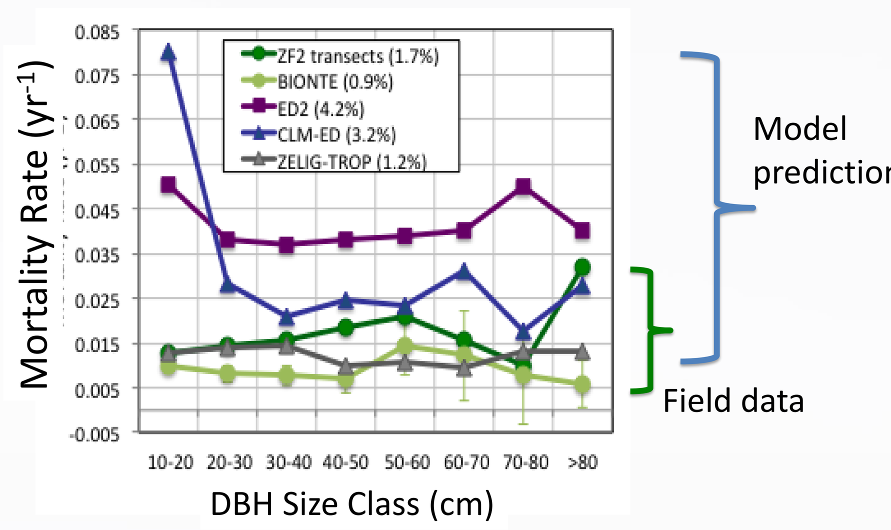
(3) Sensitivity analysis of 66 input parameters into FATES[3]

- FATES has >200 parameters
- Single site testing in Brazil
- Using Fourier Amplitude Sensitivity Testing (FAST) = variance based sensitivity analysis.
- Repeatedly found to be important for carbon dynamics = Vcmax,25; target storage carbon, stem allometry coef.

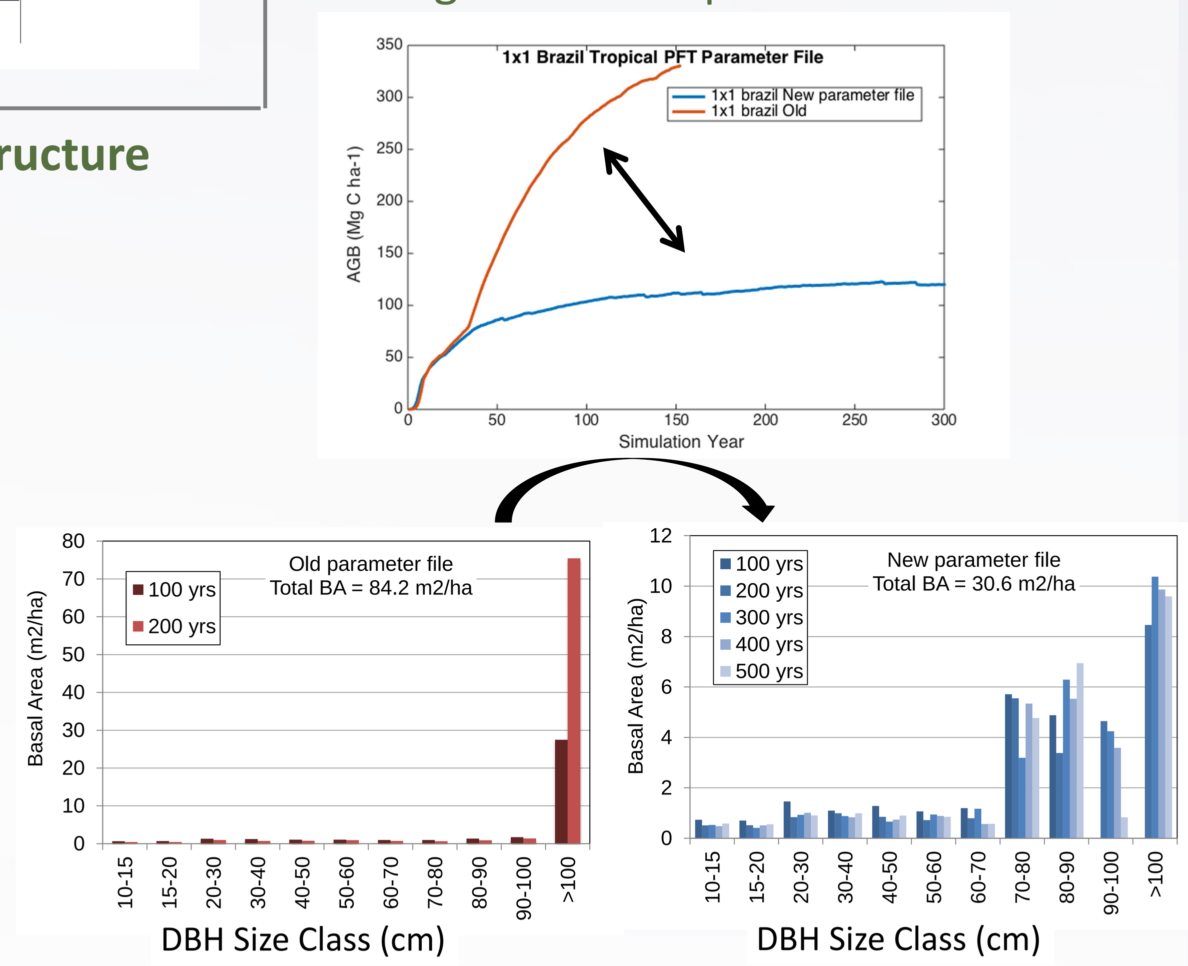
(4) Processes underlying demographic structure

Manaus Case Study – testing current plant mortality

- **ED2** = over-estimates mortality (4.2%)
- **FATES** = over-estimates mortality (3.2%)
- ZELIG-TROP = similar to observed (1.2%)



Changes to FATES parameter file

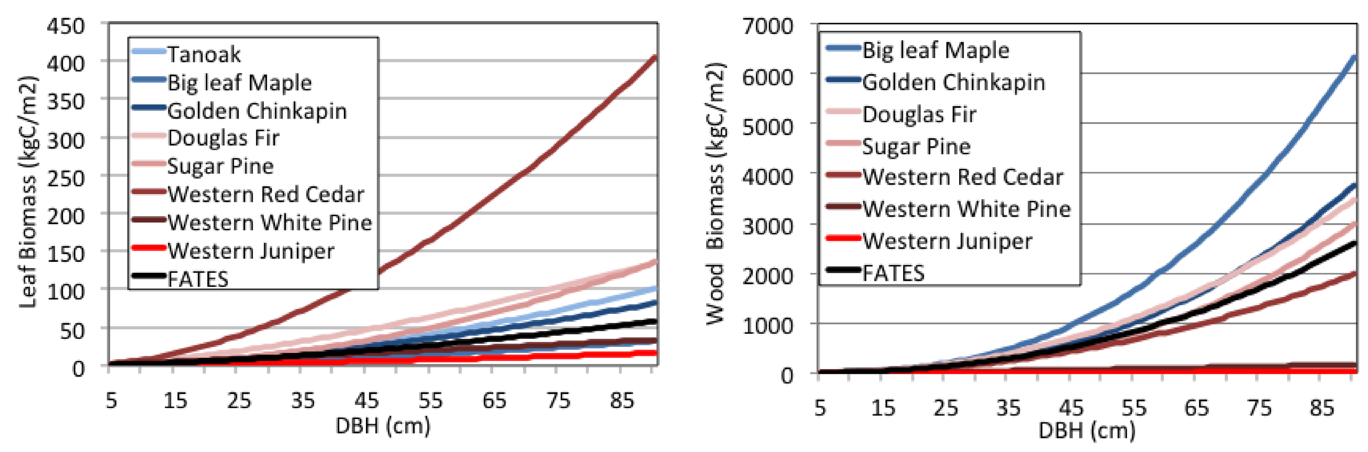


Ideas and future evaluation & testing

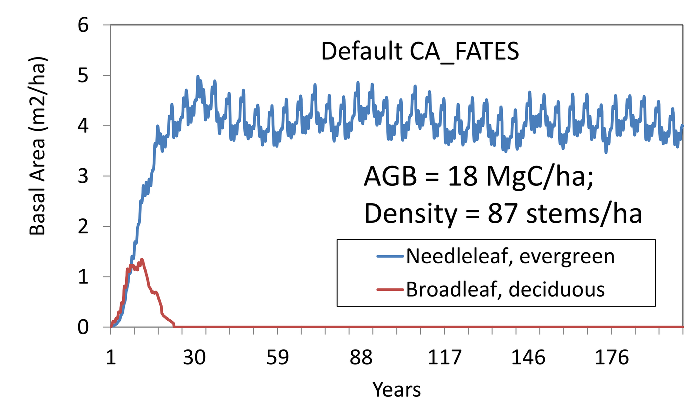
Global vegetation demography developments and science impacts:

- Investigate current and future outcomes of FATES as a result of various drought scenarios and climate change in California, over the 21st century.
- We hypothesize that under drought conditions in California the mortality of all trees will increase, but there will be higher mortality for large trees.
- Secondly, we hypothesize that changing climates in the 21st century will cause the climate of southern California to migrate to northern California.

Testing variations in allometry equations for Western US evergreen trees[4] (currently 1 global allometric equation for all PFTs)



Testing default FATES in Sierra Forest, CA, USA. (Single point)
Very low basal area, biomass, and stem density.
Competitive exclusion of needleleaf evergreen trees



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1. Levine NM, Zhang K, Longo M *et al.* (2016) Ecosystem heterogeneity determines the ecological resilience of the Amazon to climate change. Proceedings of the National Academy of Sciences, **113**, 793-797.
2. Fisher, R. A., et al. Taking off the training wheels: the properties of a dynamic vegetation model without climate envelopes, CLM4.5(ED), Geosci. Model Dev., 8, 3593-3619, 2015.
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ACME Accelerated Climate Modeling for Energy

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