R: ACME-FATES: dynamic vegetation and demography to estimate forest carbon cycling and competition

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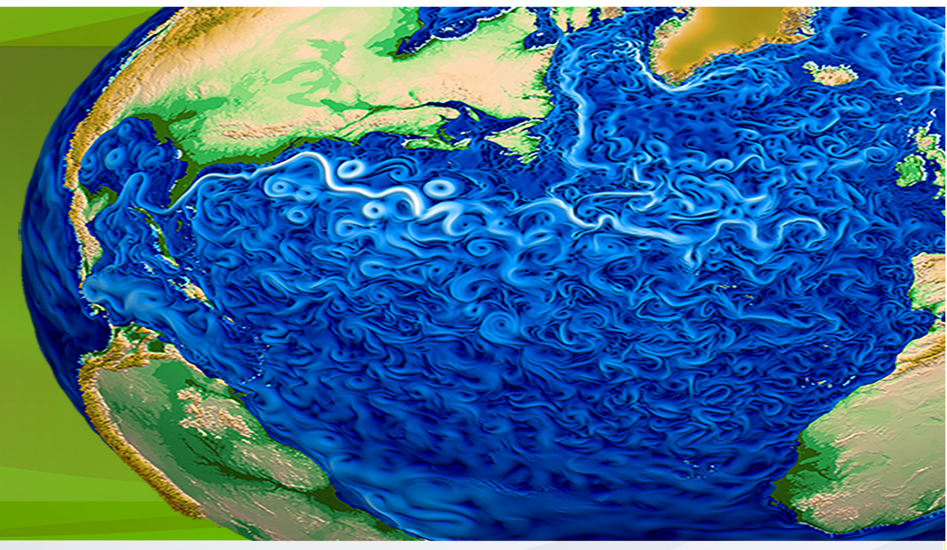


Objective and Background

Objective = global application of plant demography and trait-based dynamic vegetation (via FATES) within ACME.

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 the increased model complexity, and demands for model testing.

Integrated model development with experimental science (Model-Experiment, MODEX) via NGEE-Tropics, NGEE-Arctic.

Vegetation in ALM-FATES

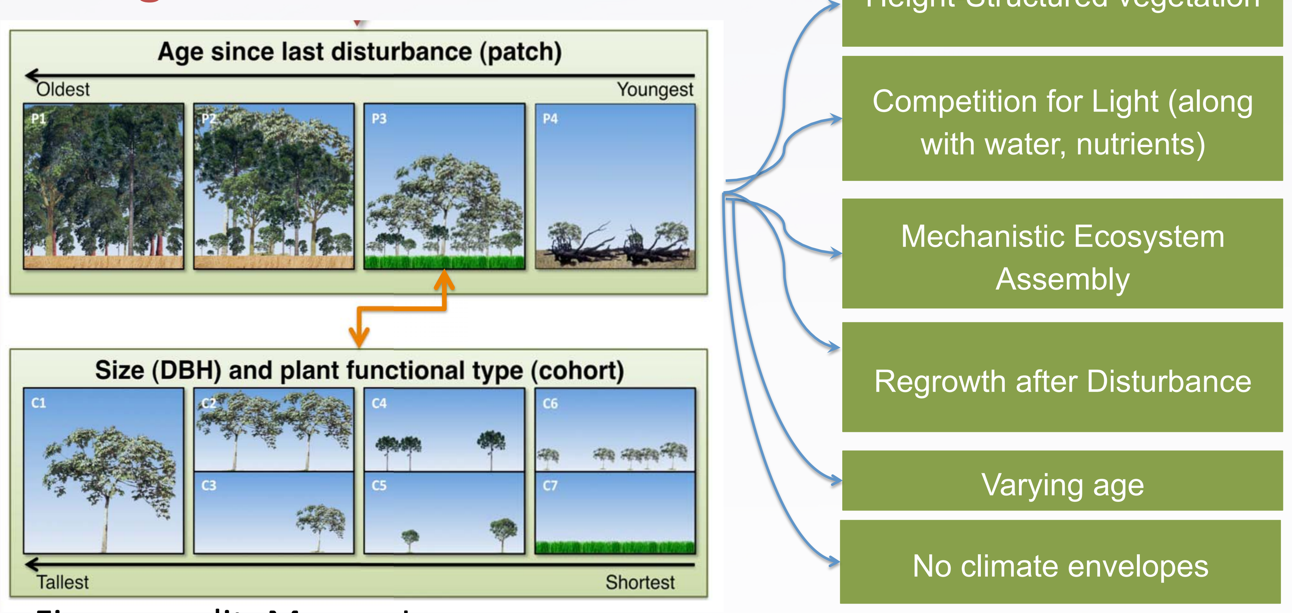


Figure credit: Marcos Longo

Approach: ALM-FATES

FATES model (Functionally-Assembled Terrestrial Ecosystem Simulator)

- Carbon pools, fluxes, allocation; litter fluxes; phenology; regeneration, growth, mortality, photosynthesis, respiration represented by **FATES**, which is derived from the Ecosystem Demography Model **(ED)**.
  - Incorporates discretized Perfect Plasticity Approximation (PPA) for canopy structure and testing radiative transfer schemes.
- Canopy physics, soil BGC, land surface hydrology, represented by ACME Land Model **(ALM)**.

Methods:

1) Site level ALM-FATES testing in Brazil
- Lowland, old-growth tropical forest, with 10 years of observed data.
- Compare model results using dynamic, structured vegetation against "big-leaf" models.
- What is the response of the tropical forest carbon sink with rising CO2, out to 2100?

2) ALM-FATES Global Simulations
- Global evaluation of NPP, LAI

	ED2	ALM-FATES	CLM4.5-BGC	ALMv1-ECA-CNP
Time step	1 day	1 day	1 hour	1 hour
Resolution	1 ha	1 ha	100 km2	100 km2
Dynamic vegetation	Yes	Yes	No	No
Number of PFTs used here	5	1	2	2
Biomass pools	L, WS, WH, R, ST, S	L, WS, WH, CR (L and D), FR, ST, S	L, WS, WH, CR (L and D), FR, ST	L, WS, WH, CR (L and D), FR, ST
Litter C pools	1	4 (adds CWD)	3	3
Soil C pools	3	4	4	4
C partitioning	Pipe model and resource capture	Pipe model and resource capture	Fixed fractions	Flexible
Mortality	Prognosed; 5 forms	Prognosed; 5 forms	Fixed annual mortality	Fixed annual mortality
LAI	Prognosed allometrically	Prognosed allometrically	Prognostic based on C,N pools	Prognostic based on C,N pools
Photosynthesis	Collatz	Farquhar	Farquhar	Farquhar
Vcmax (µmol m-2 s-1)	Prognosed	45	55	55
N cycle	Leaf N, N mass balance	No	Yes	Yes
P cycle	No	No	No	Yes

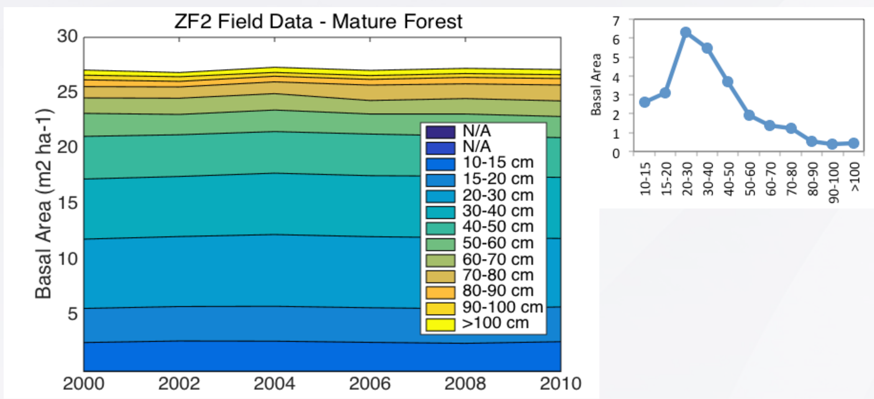
L = leaf; WS = sapwood, WH = heartwood, R = roots; CR = coarse roots; FR = fine roots; ST = storage; S = seeds; L = live; D = dead; CWD = coarse woody debris

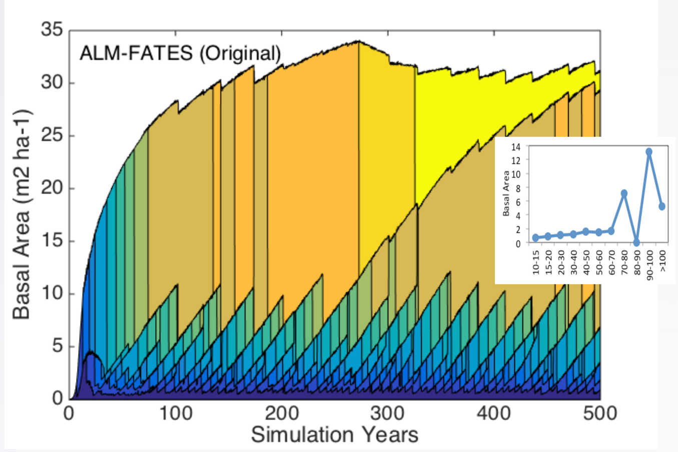
* Adopting terminology and abbreviations from Walker et al. 2014

Tropical Single Site Testing of ALM-FATES (compared to observed data)

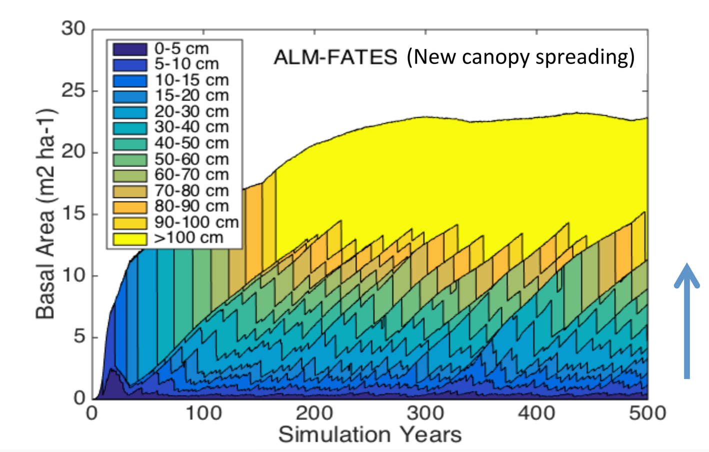
The quest to capture mature tropical forest **SIZE STRUCTURE**, and hence biomass and stem density in ALM-FATES.

Why is varying age and size structure important?
- Biomass and carbon representation
- Canopy radiation and light competition
- Trait variations in PFTs
- Growth dynamics of understory and canopy trees

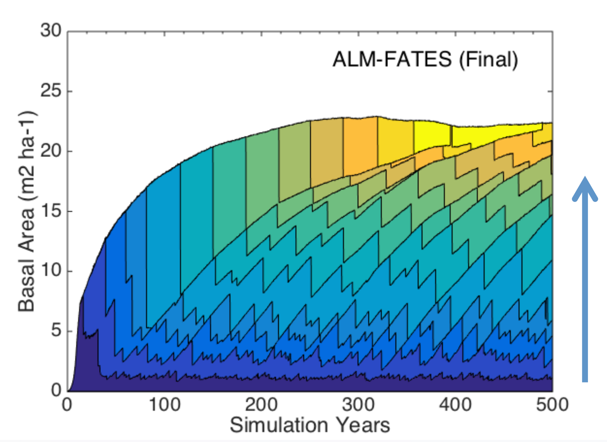




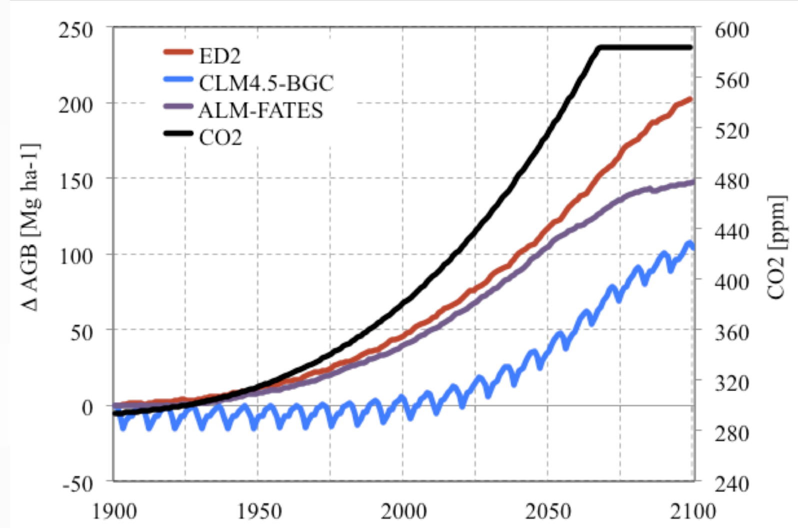
TEST #1: Original version, plus updates to parameter file indexing

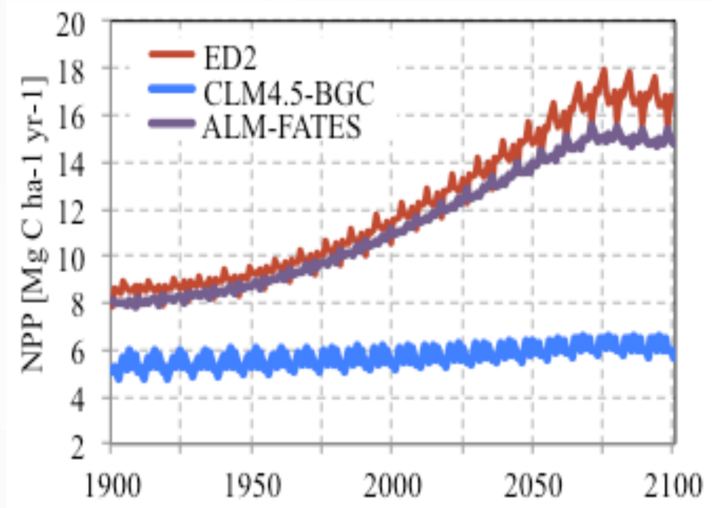


TEST #2: Updates termination mortality and canopy spreading



TEST #3: Same in #2, and lower stress mortality, more seed allocation, lower Vcmax, higher leaf storage priority





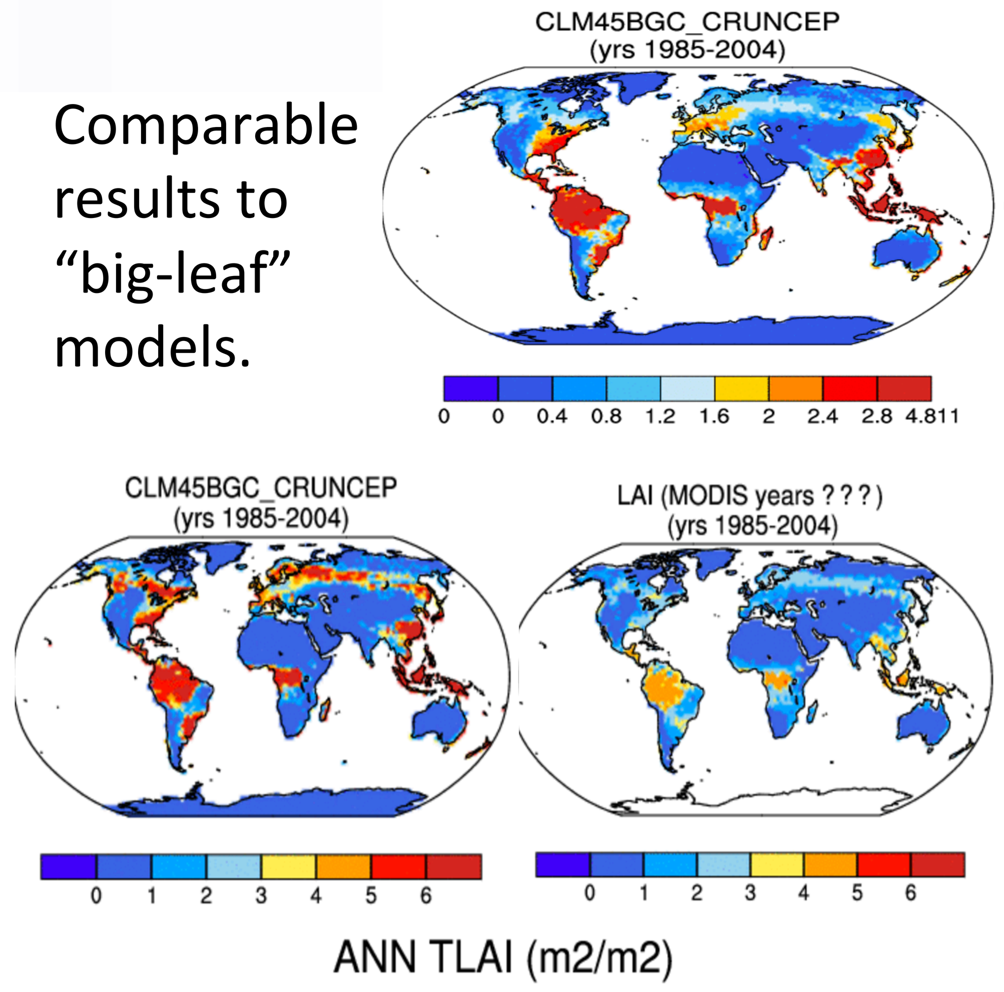
Long-term biomass response to rising CO_2 (out to 2100). ALM-FATES vs. ED2 vs. CLM

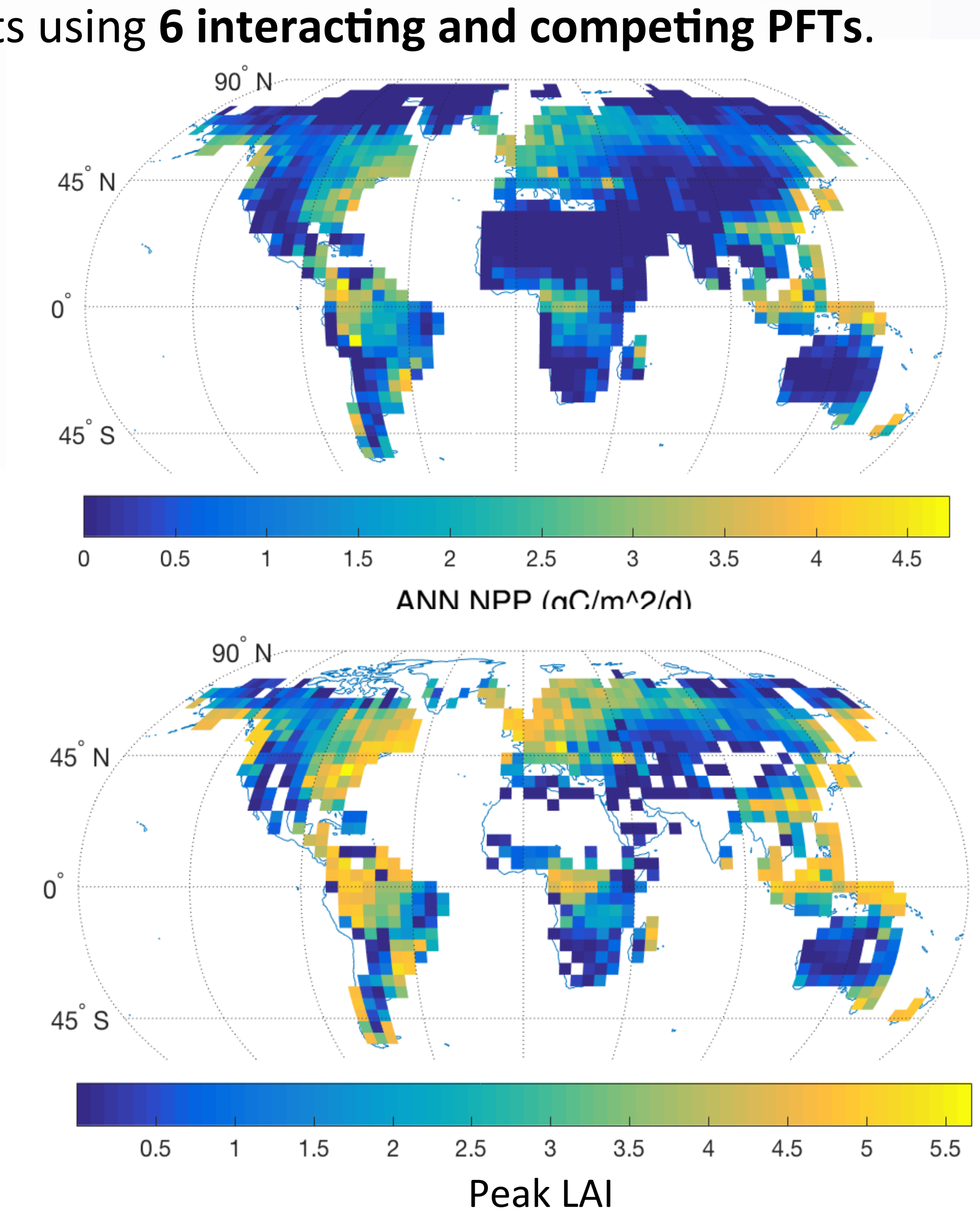
Impact: ALM-FATES Global Runs

Initial ALM-FATES NPP and LAI results using **6 interacting and competing PFTs.**

NET: Needleleaf, temperate
NEB: Needleleaf, boreal
BDT: Deciduous, temperate
BETrop: Evergreen, tropical
BETemp: Evergreen, temperate
BES: Evergreen, shrub

Comparable results to "big-leaf" models.





ACME Accelerated Climate Modeling for Energy

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