The Functionally Assembled Terrestrial Ecosystem Simulator (FATES): updates and progress on taming the complexity

What is FATES?

- Vegetation model, which replaces the unstructured bulk canopy representation in CLM with the size- and age-structured ED approximation of individual plant dynamics.
- Modularized from CLM(ED) in order to: plug into multiple land models (CLM, ACME); and to more cleanly separate demographic from other code.

“Big-Leaf” vegetation

Demographic Vegetation
Software updates &
FATES v1 code release

• FATES code available:
  – public repo: https://github.com/NGEET/fates-release
  – NCAR mirror (auto-pulled when compiling CESM2):
    https://github.com/NCAR/fates-release
  – ACME mirror (linked to via git submodule):
    https://github.com/ACME-Climate/fates
  – Developer repos:
    • FATES: https://github.com/NGEET/fates
    • Driver (slightly out-of-date clone of CLM5):
      https://github.com/NGEET/fates-clm
A next step: taming the complexity

• A complex model like CLM benefits greatly from being able to scale along a complexity hierarchy: SP <-> BGC

• Need to develop similar capabilities in FATES
  – Controlled experiments
  – Isolating cause and effect
  – Comparison against simpler models
To begin taming FATES, separate the problem into 2 parts: fast and slow dynamics.
Static Stand Structure Mode (phase 1, static phenology too)

“fast” dynamics only: slow dynamics held constant
Prescribed Physiology Mode
Blue: disabled; Green: Prescribed

“slow” dynamics only: fast dynamics specified as 5 parameters
Canopy construction and vertical light environment: “PPA” approach simplifies the light environment into two regimes: canopy and undestory

Fisher et al., *in review*
ED + PPA models can predict size distributions of tropical trees, in both numerical and analytical models.

**FOREST ECOLOGY**

**Dominance of the suppressed:**
**Power-law size structure in tropical forests**

C. E. Farrior, S. A. Bohlman, S. Hubbell, S. W. Pacala

Tropical tree size distributions are remarkably consistent despite differences in the environments that support them. With data analysis and theory, we found a simple and biologically intuitive hypothesis to explain this property, which is the foundation of forest dynamics modeling and carbon storage estimates. After a disturbance, new individuals in the forest gap grow quickly in full sun until they begin to overtop one another. The two-dimensional space-filling of the growing crowns of the tallest individuals relegates a group of losing, slow-growing individuals to the understory. Those left in the understory follow a power-law size distribution, the scaling of which depends on only the crown area-to-diameter allometry exponent: a well-conserved value across tropical forests.

- FATES “Prescribed Physiology Mode” follows same logic, though implementation differs.
- E.g., Farrior et al. (2016) prescribe canopy and understory DBH increment; while in FATES we prescribe NPP / tree crown area for canopy and understory trees, which *can* give (roughly) constant DBH growth trajectories across size classes.
Exploring tropical forest size distributions in FATES – Prescribed Physiology Mode

FATES qualitatively reproduces results of Farrior et al., 2016—“sanity check” that vegetation dynamics component agrees with expectations
Transient dynamics in ED size x age space

Moorcroft et al., 2001
Transient dynamics in ED size x age space

Size/age distributions, year 000

Tree size (cm DBH)

Patch age (yr)

plant densities [n ha⁻¹ cm⁻¹ yr⁻¹]

0 0 .01 .03 .1 .32 1 3.16 10
Long term steady-state in ED size x age space
Steady-state disturbance & recovery mosaic in FATES (prescribed physiology mode)

Farriort et al., 2016
Transient Dynamics of full FATES model in ED size x age space
Long-term steady-state of full model in ED size x age space

To be solved; indicative of too-strong control of mortality by light-limited carbon starvation
Summary

• FATES development continuing; code released and available for research by the community
• A current focus is to develop simplified modes in FATES
• One result of comparison to full FATES with prescribed physiology is the overly strong role that light-limited carbon starvation plays in determining mortality in default configurations