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

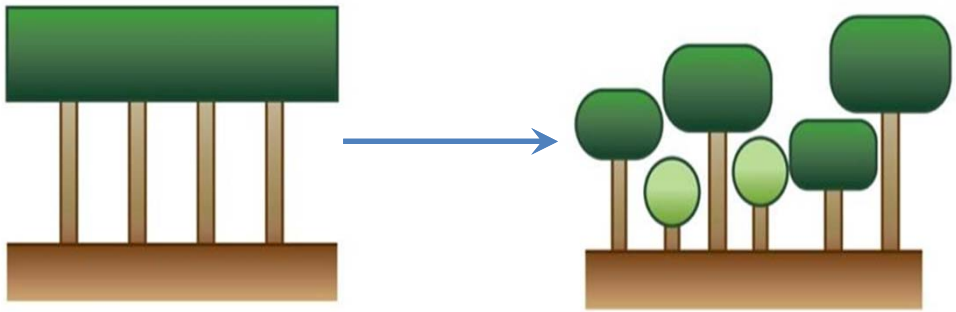
C. Koven, R. Fisher, R. Knox, B. Andre, J. Shuman, J. Holm, C. Xu, B. Christoffersen, E. Massoud, Y. Xu, D. Lawrence, M. Dietze, L. Kueppers, J. Chambers

NGEE–TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS

U.S. DEPARTMENT OF ENERGY | Office of Science

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

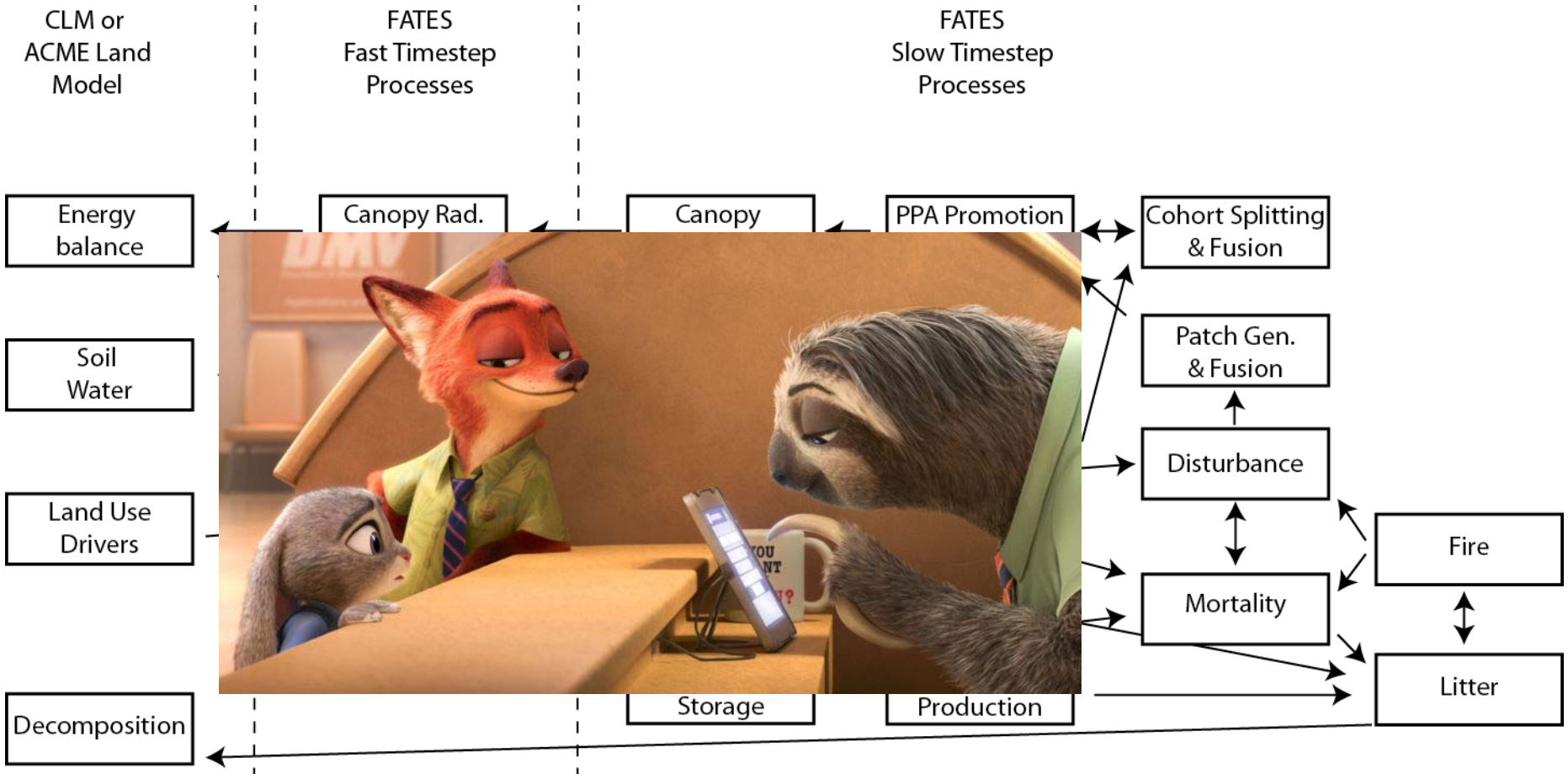
Software updates & FATES v1 code release

- 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    - Driver (slightly out-of-date clone of CLM5): https://github.com/NGEET/fates-clm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

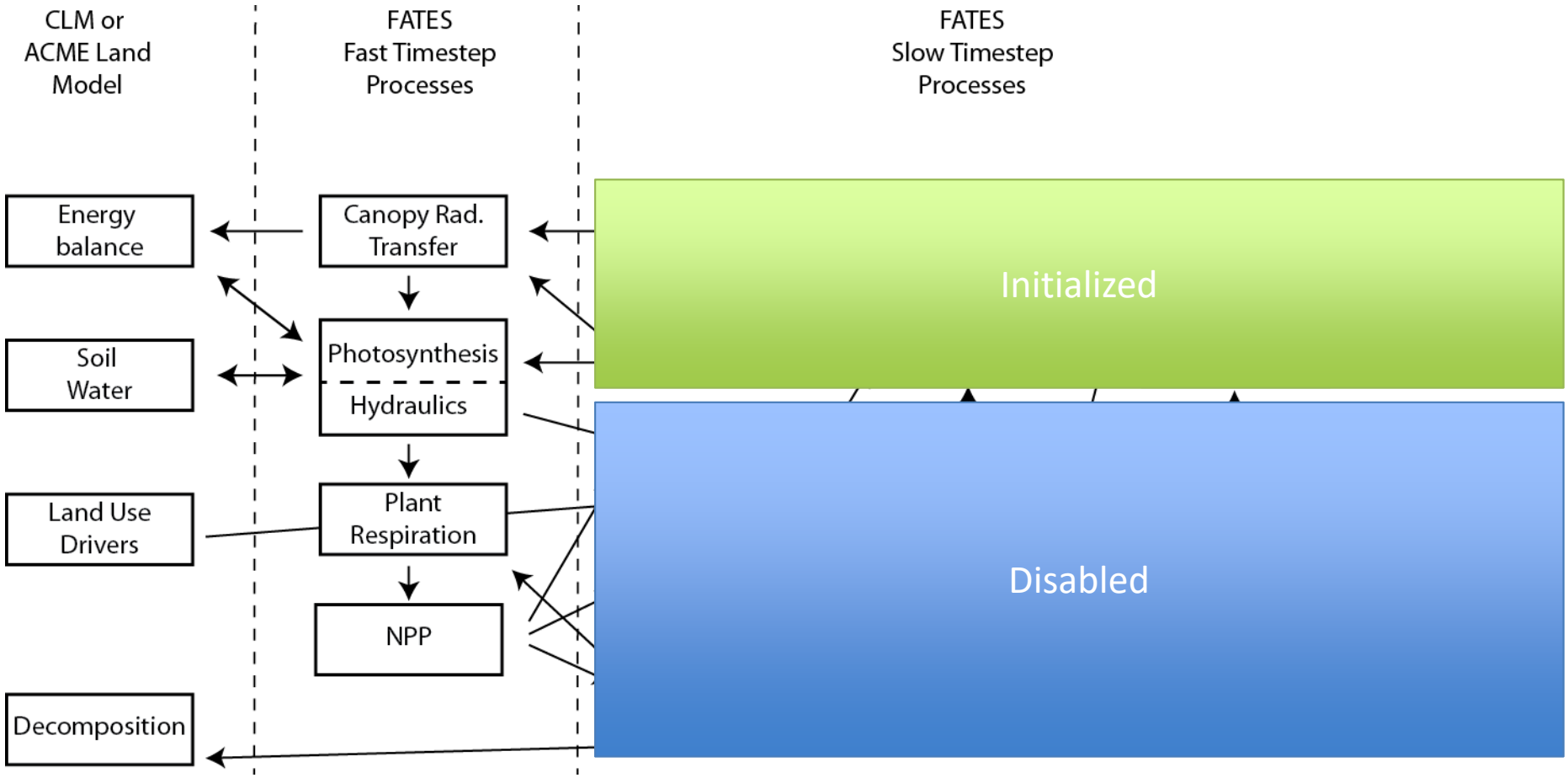
- A complex model like CLM benefits greatly from being able to scale along a complexity hierarchy: SP <-> BGC
- Need to develop similar capabilities in FATES
  - Controlled experiments
  - Isolating cause and effect
  - Comparison against simpler models

FATES schematic



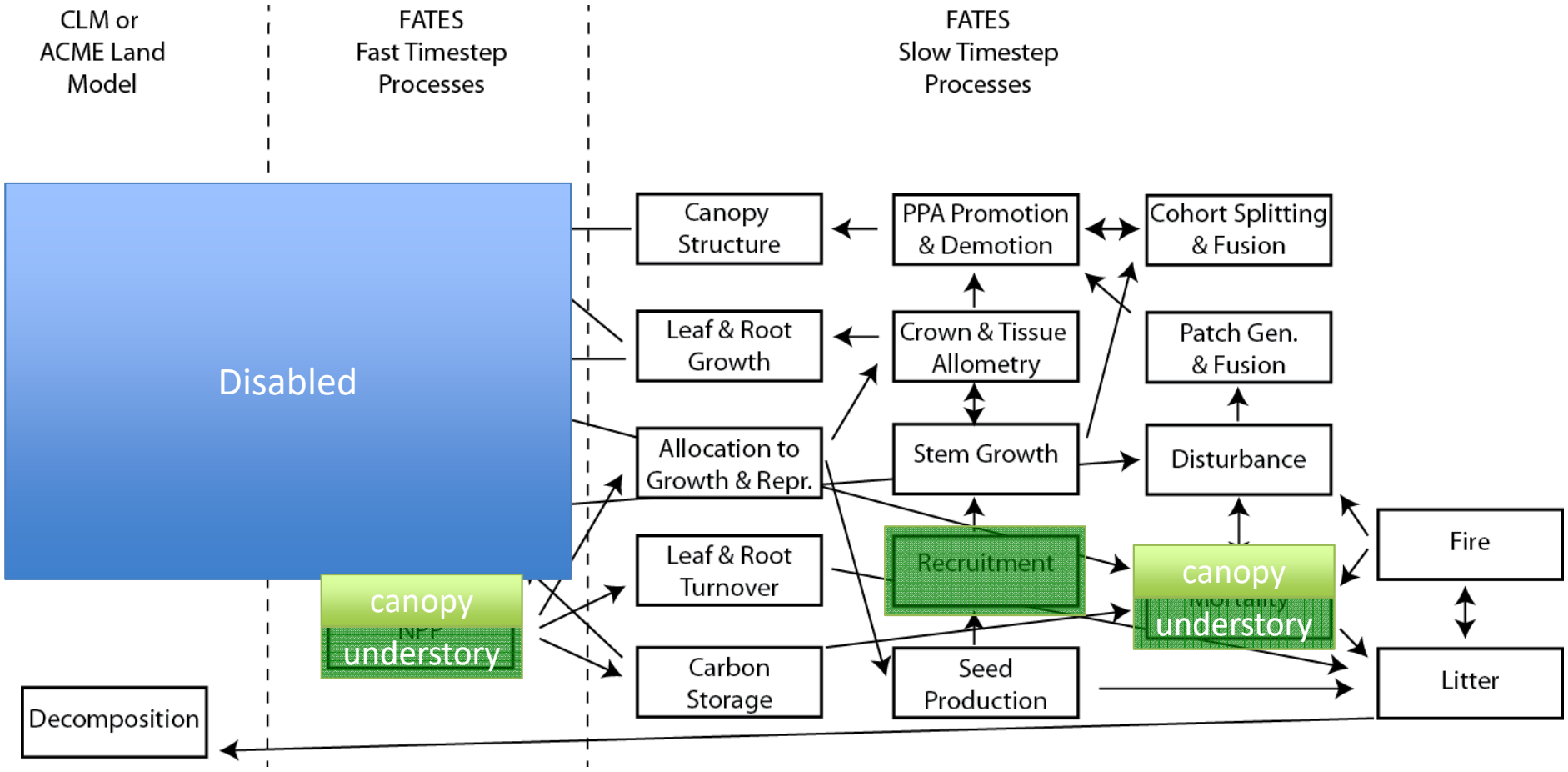
To begin taming FATES, separate the problem into 2 parts: fast and slow dynamics.

Static Stand Structure Mode (phase 1, static phenology too)



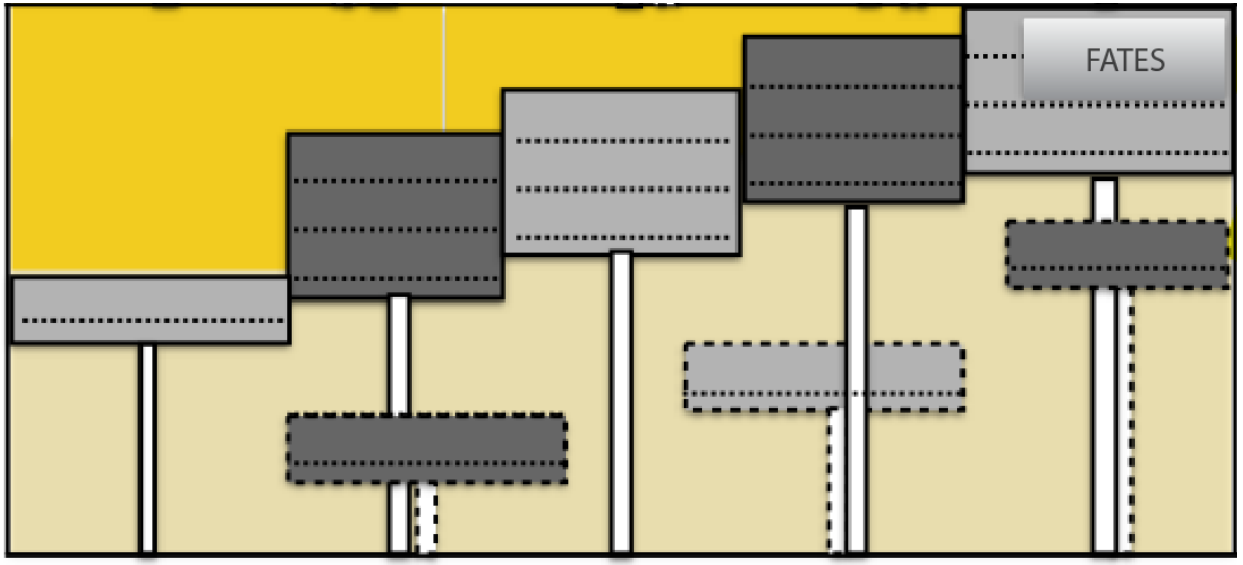
"fast" dynamics only: slow dynamics held constant

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*

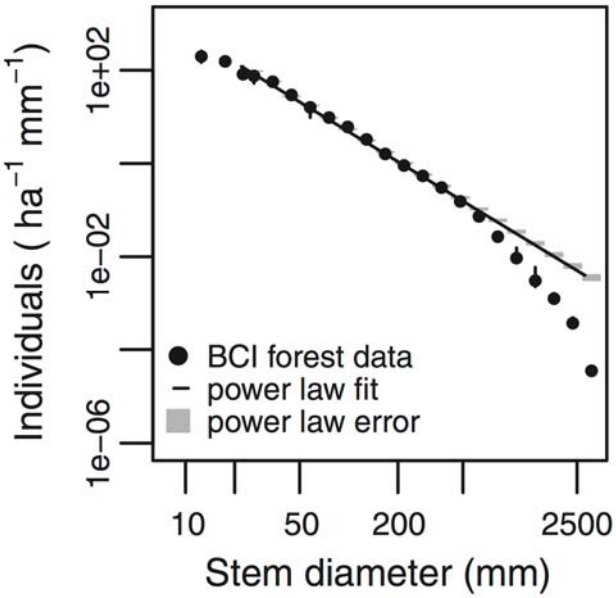
ED + PPA models can predict size distributions of tropical trees, in both numerical and analytical models

FOREST ECOLOGY

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

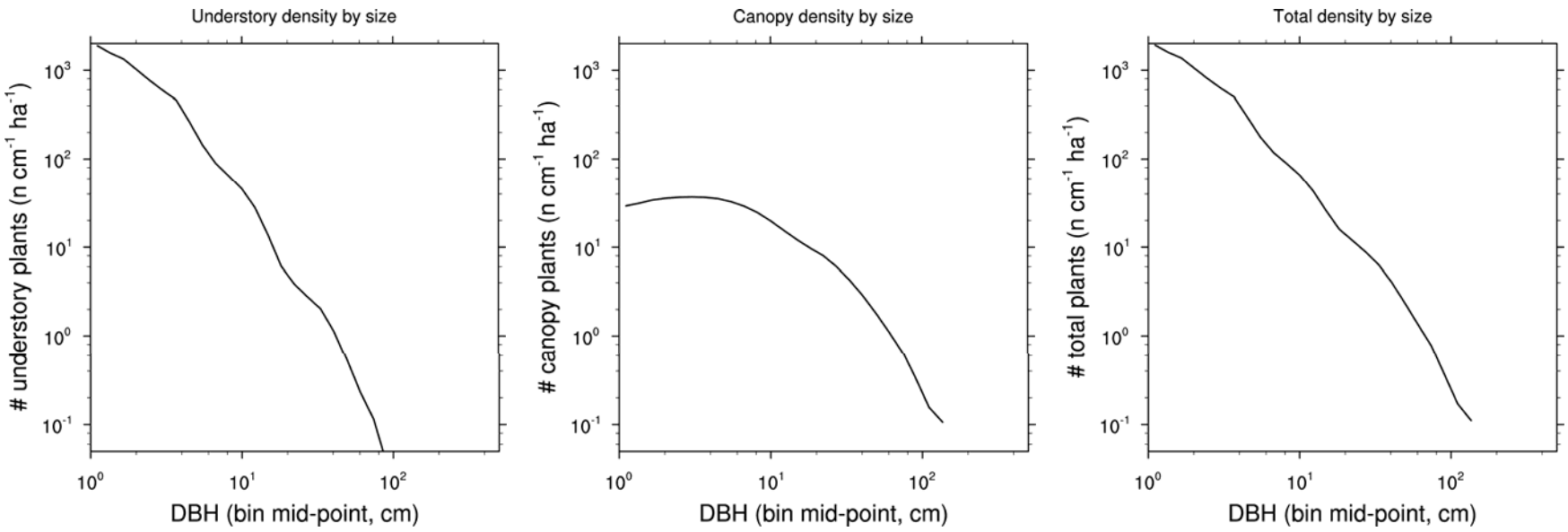
C. E. Farrior,[1,2]* S. A. Bohlman,[3,4] S. Hubbell,[4,5] S. W. Pacala[6]

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.



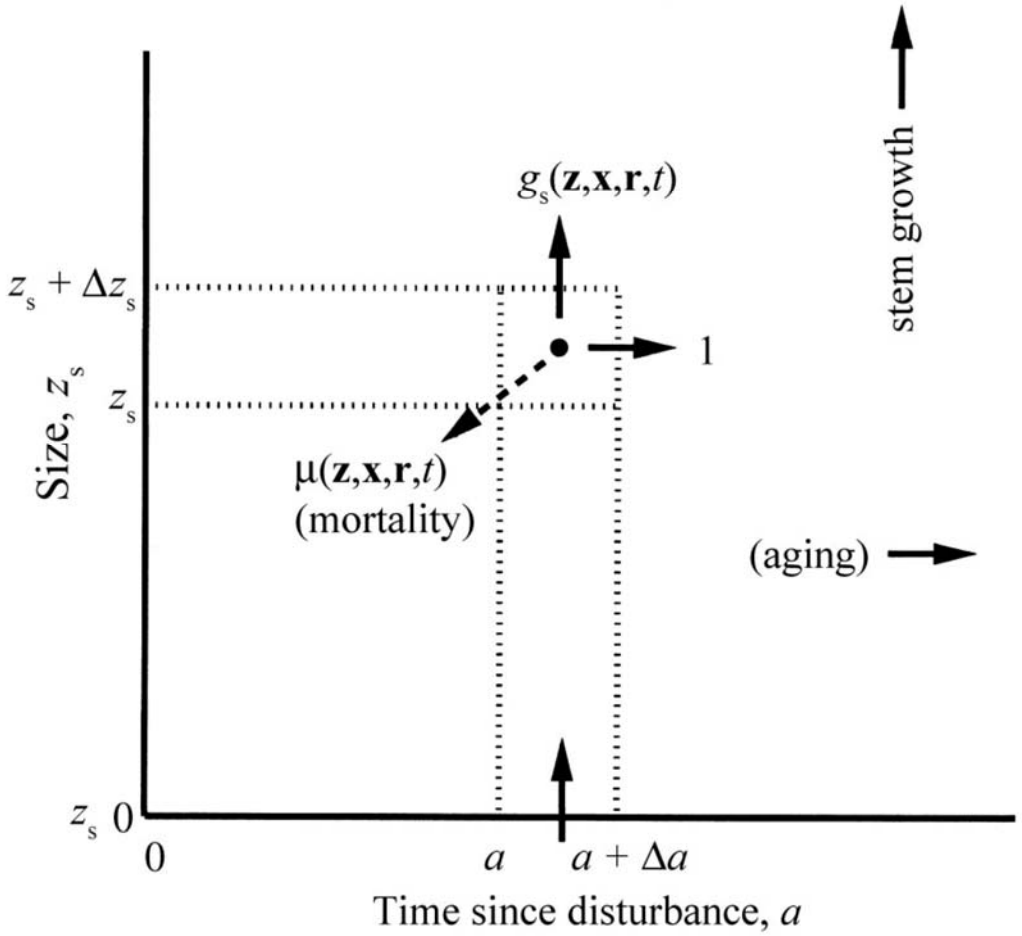
- FATES “Prescribed Physiology Mode” follows same logic, though implementation differs.
- E.g., Farrior et al. (2016) prescribe canopy and understory DBH increment; while in FATES we prescribe NPP / tree crown area for canopy and understory trees, which *can* give (roughly) constant DBH growth trajectories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

Exploring tropical forest size distributions in FATES – Prescribed Physiology Mode



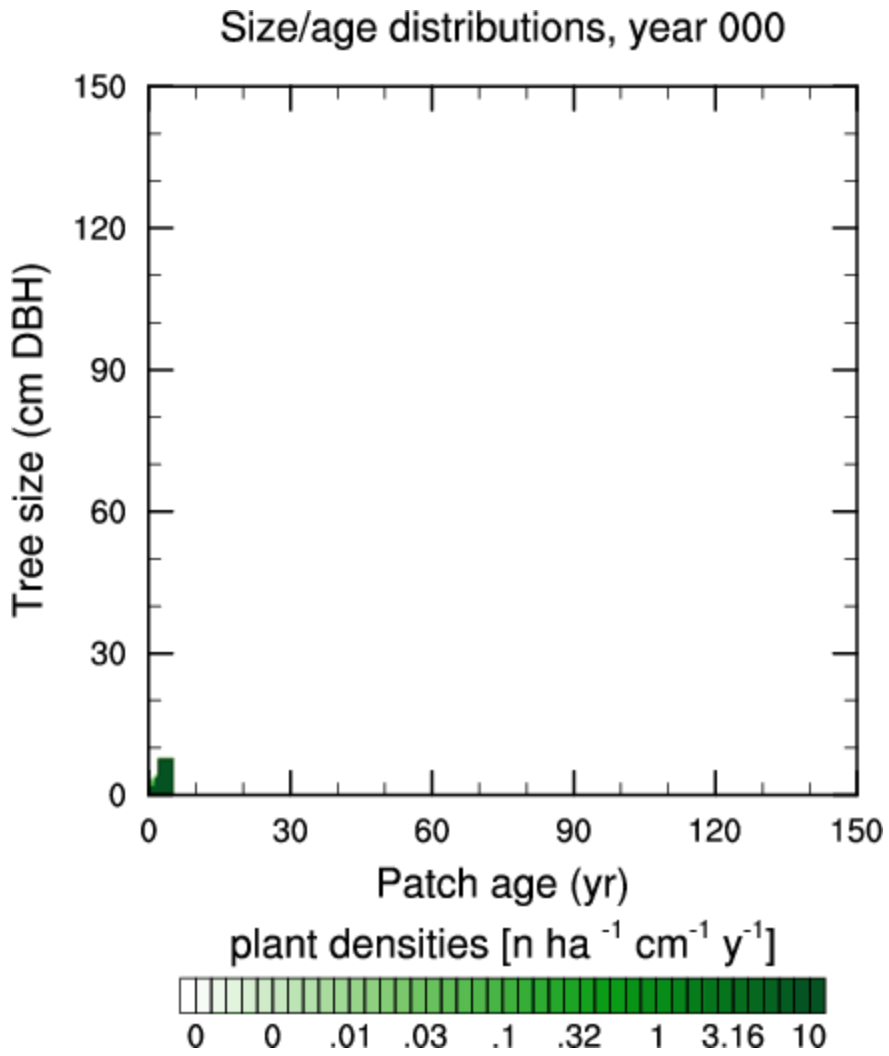
FATES qualitatively reproduces results of Farrior et al., 2016—
"sanity check" that vegetation dynamics component agrees with expectations

Transient dynamics in ED size x age space

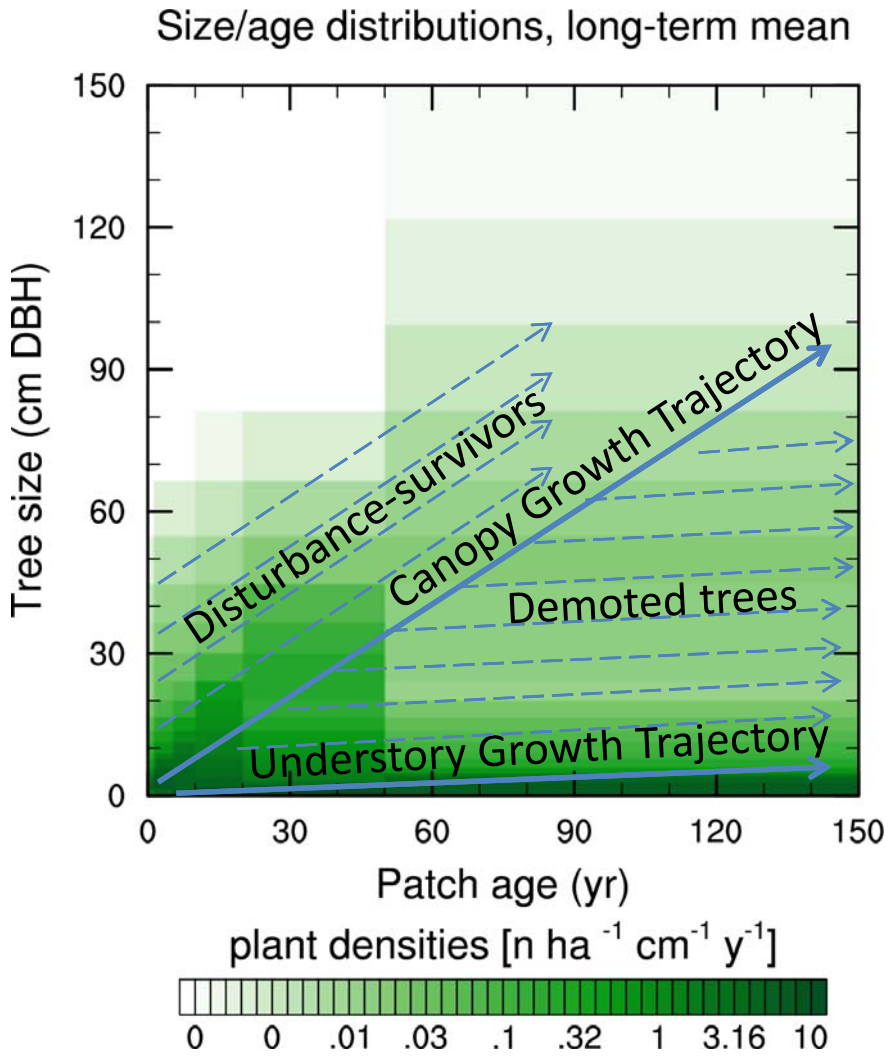


Moorcroft et al., 2001

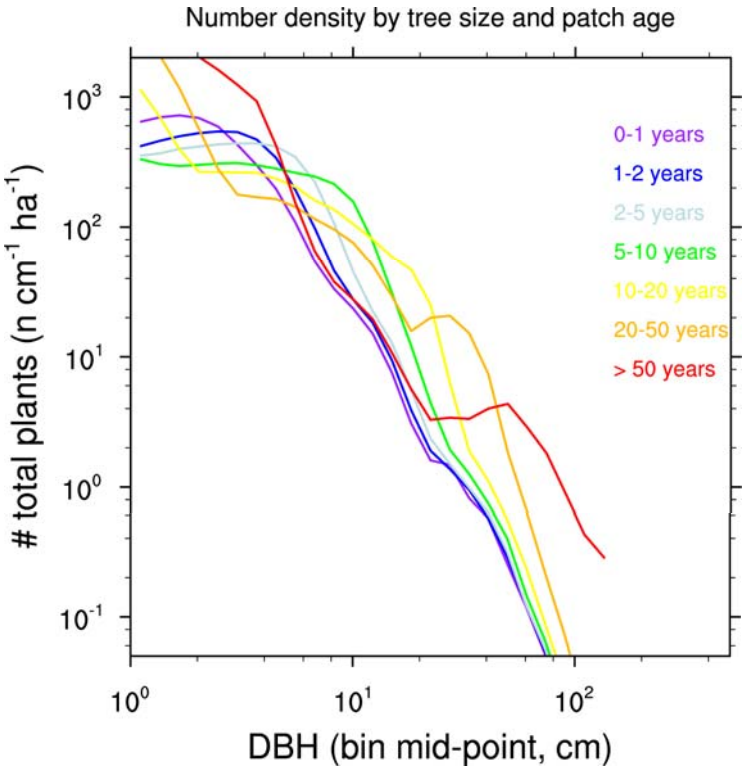
Transient dynamics in ED size x age space

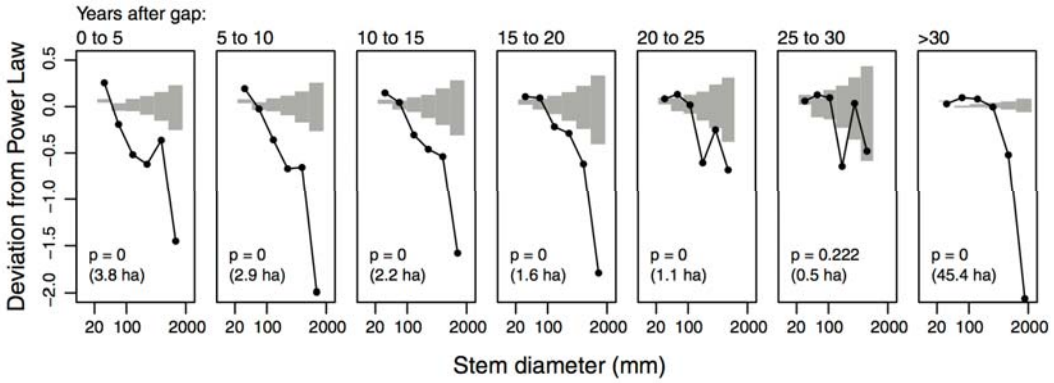


Long term steady-state in ED size x age space



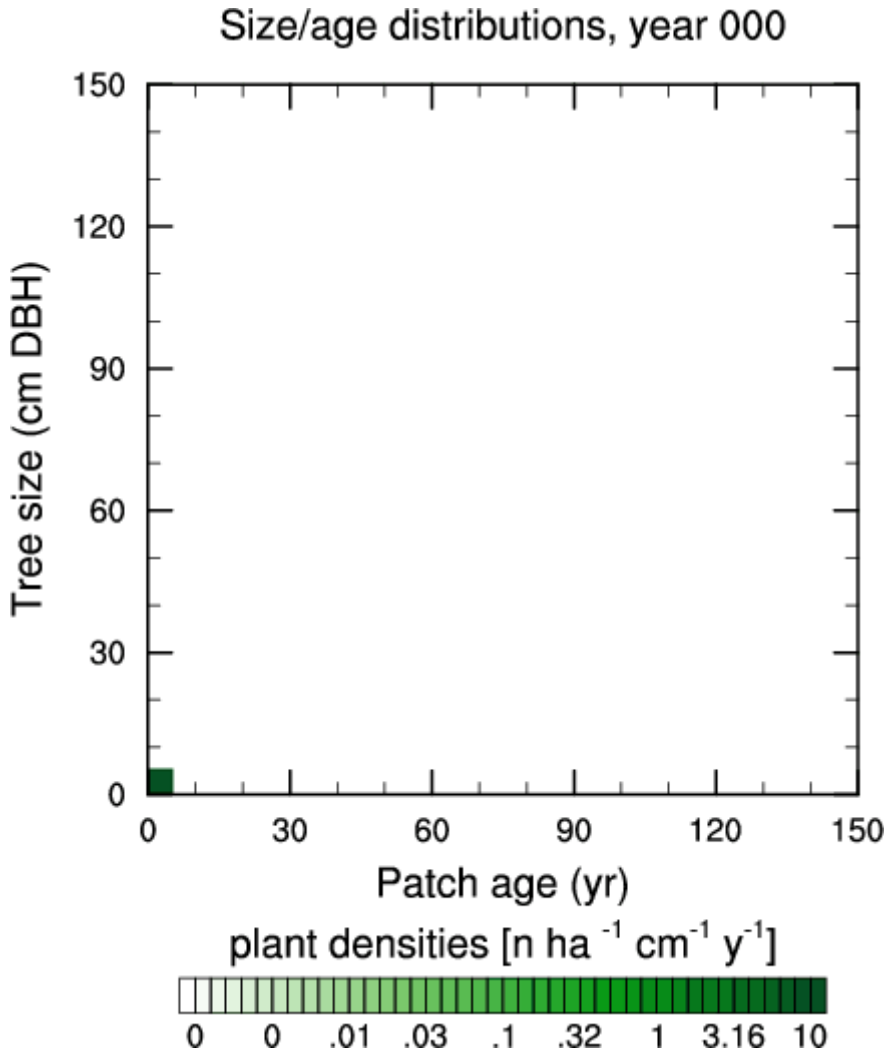
Steady-state disturbance & recovery mosaic in FATES (prescribed physiology mode)



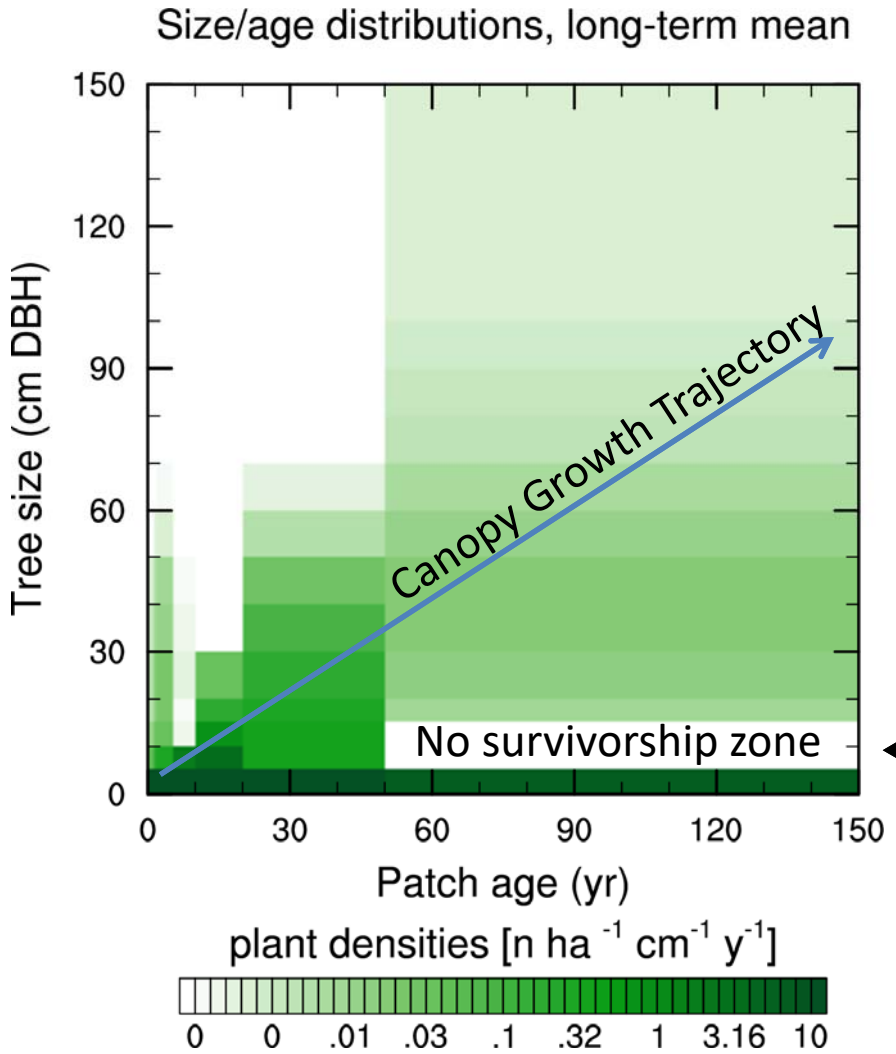


Farrior et al., 2016

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