Functionally Assembled Terrestrial Ecosystem Simulator (FATES)

Next-generation modeling with vegetation demography

Charlie Koven, Rosie Fisher, Ryan Knox, Jacquelyn Shuman, Adrianna Foster, and FATES team

Jacquelyn Shuman,
Climate and Global Dynamics, Project Scientist

CESM LMWG
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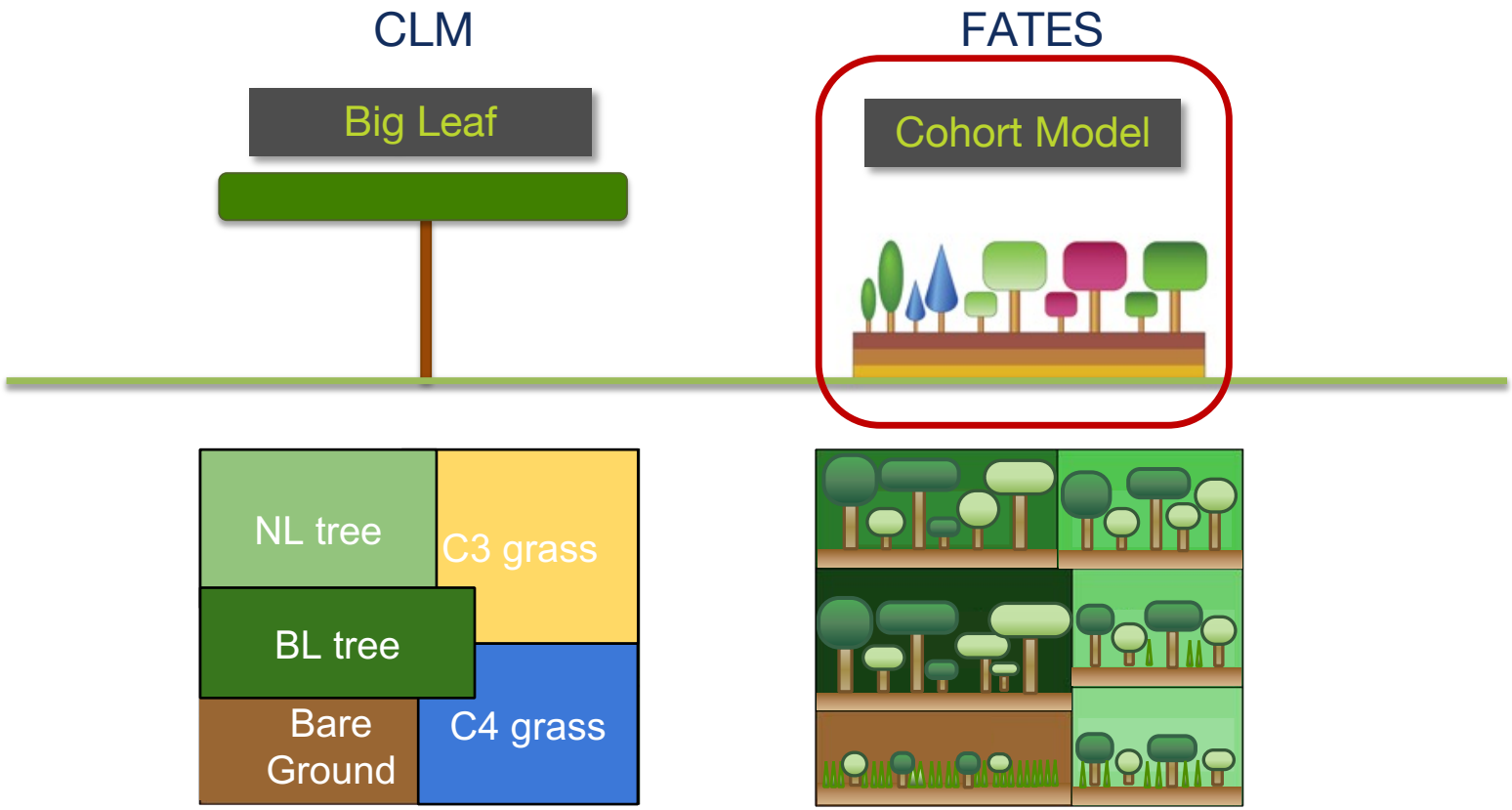
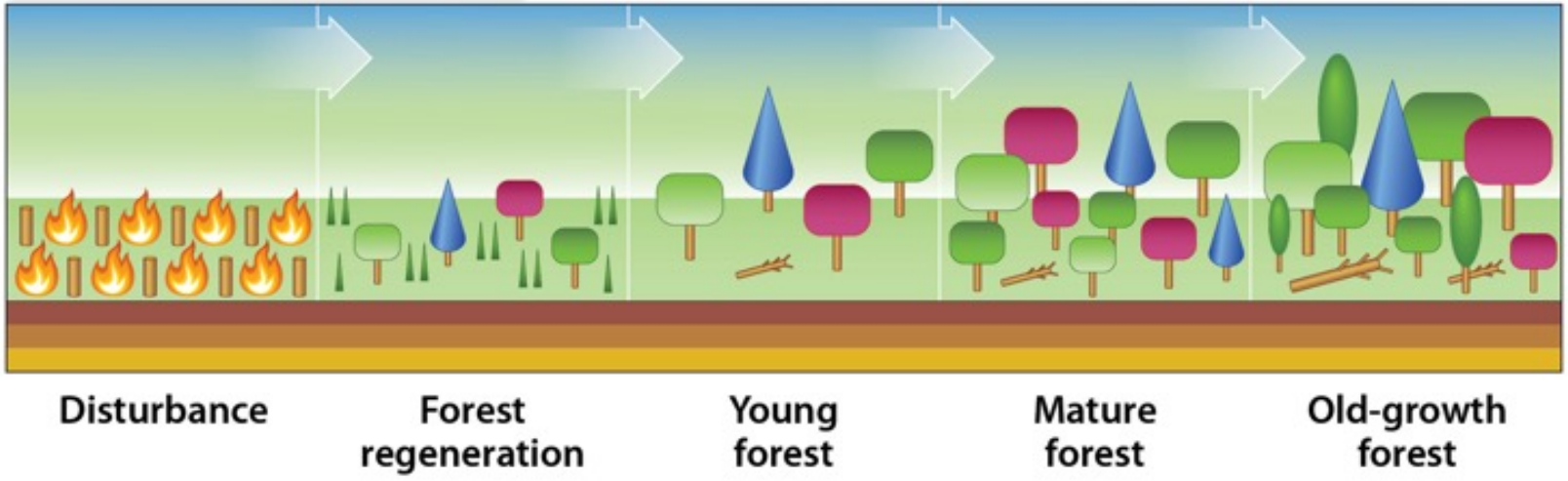
Ecological processes in land surface models

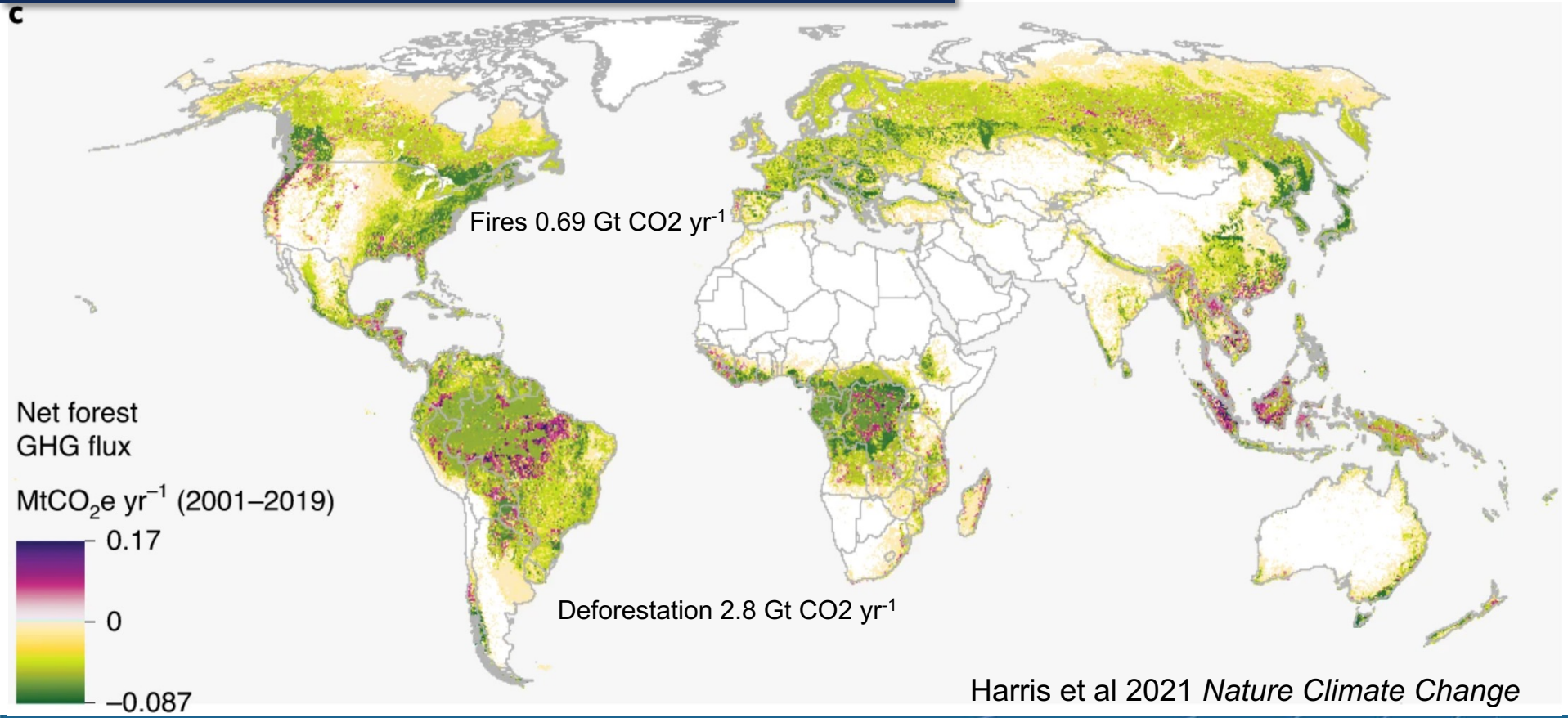


FATES has variability

Time since disturbance

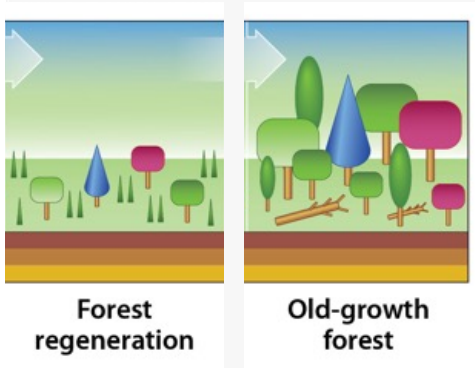


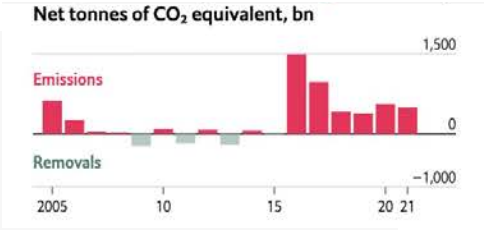
Forest degradation drives emissions

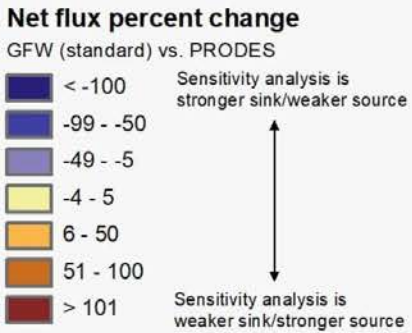


Harris et al 2021 *Nature Climate Change*

Forest degradation drives emissions



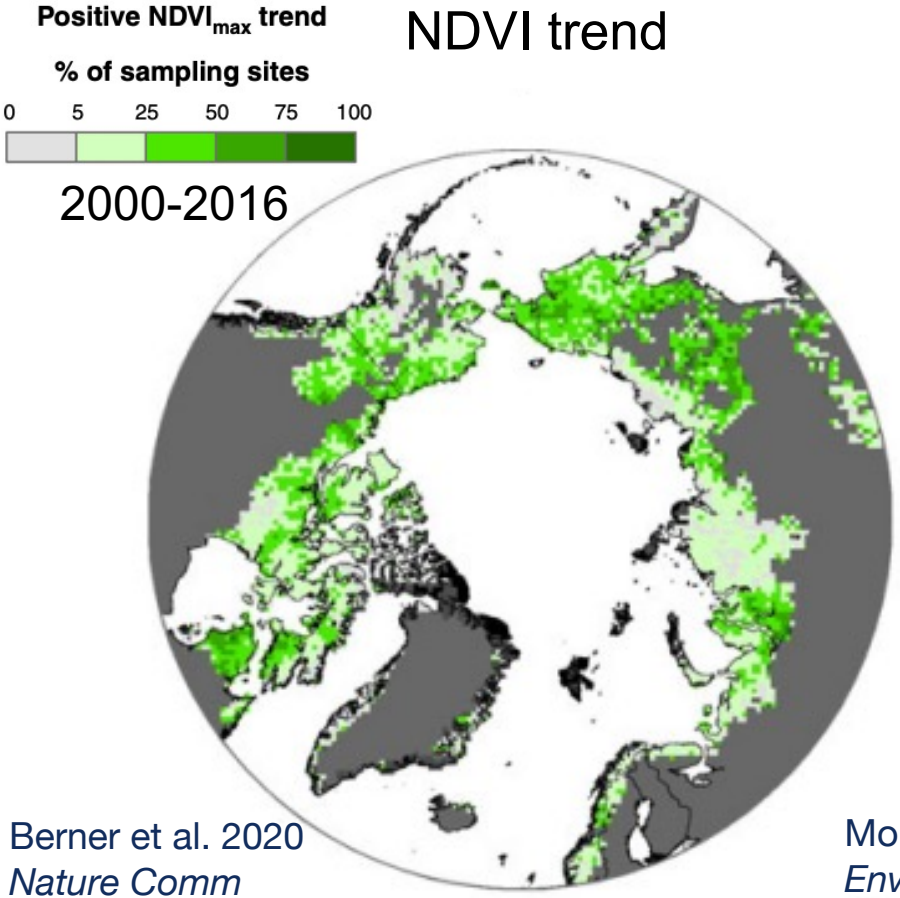




Map: Harris et al 2021 *Nature Climate Change* ; *graph*: Economist 21 May 2022
https://www.economist.com/interactive/graphic-detail/2022/05/21/the-brazilian-amazon-has-been-a-net-carbon-emitter-since-2016

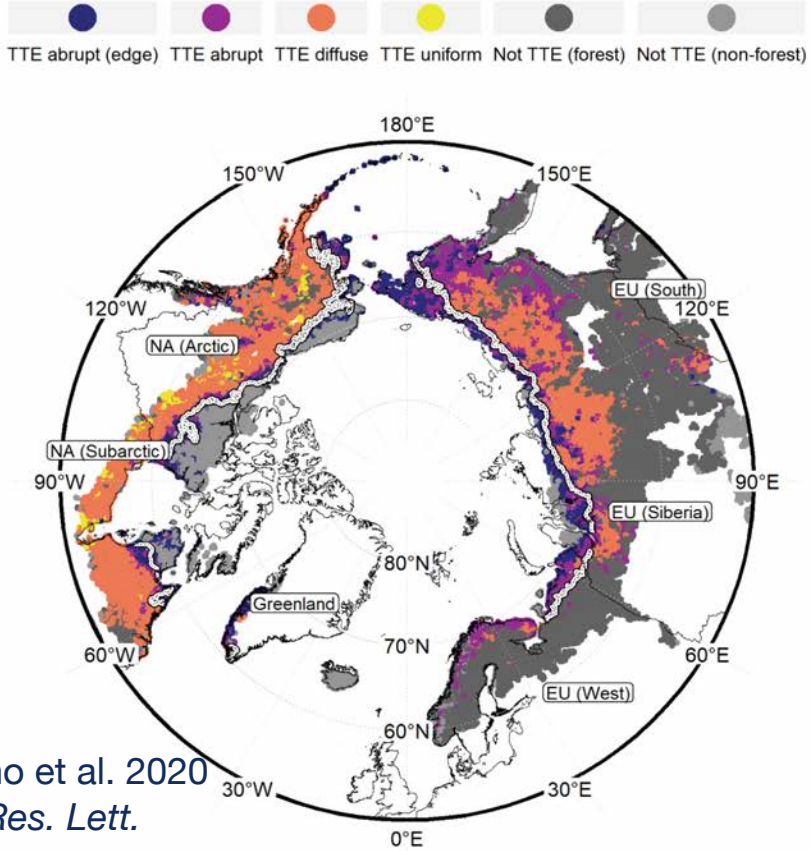
Increased productivity and altered structure

NDVI trend



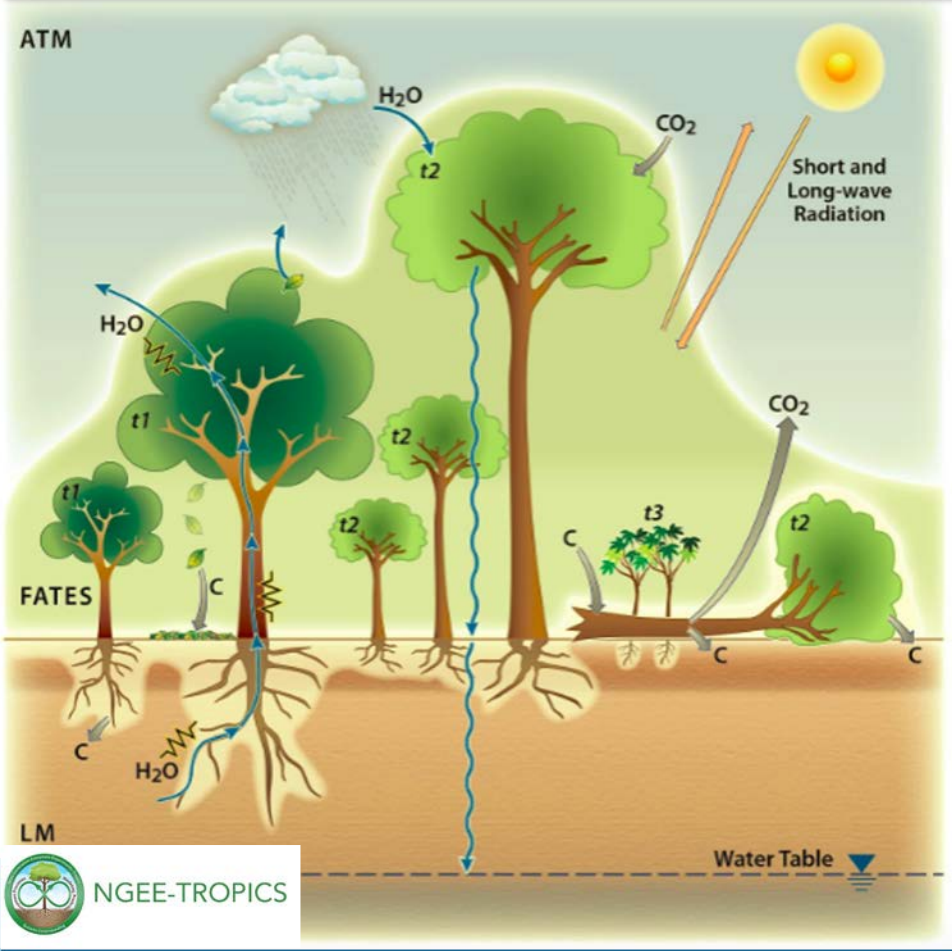
Berner et al. 2020
Nature Comm

Tundra Taiga Ecotone (TTE)



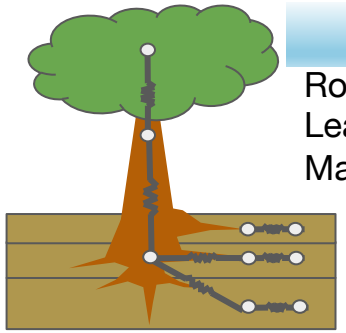
Montesano et al. 2020
Environ. Res. Lett.

Instances where structure is essential



- Hydrodynamics (FATES-Hydro)
  - Need path length, rooting depth, with size
  - Need canopy position to determine atmospheric demand
- Nutrients (PARTEH)
  - N fixation only makes energetic sense early in succession
  - Allometric growth necessary for nutrient budgets
- Fire (SPITFIRE module)
  - Fire impacts on canopy structure, which affects fire behavior
  - Tree-grass coexistence in fire regions is along successional or vertical gradients
- Snow
  - Snow covers short vegetation but not taller vegetation

FATES



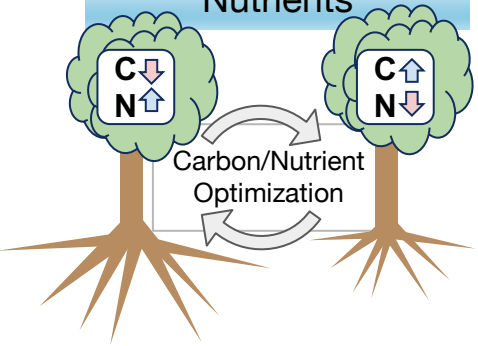
Plant Hydraulics

Root layers and plant-size root depth
Leaf humidity, stomata set transpiration
Mass balance at root nodes

Fire

Live fuel moisture
Crown fire

Nutrients

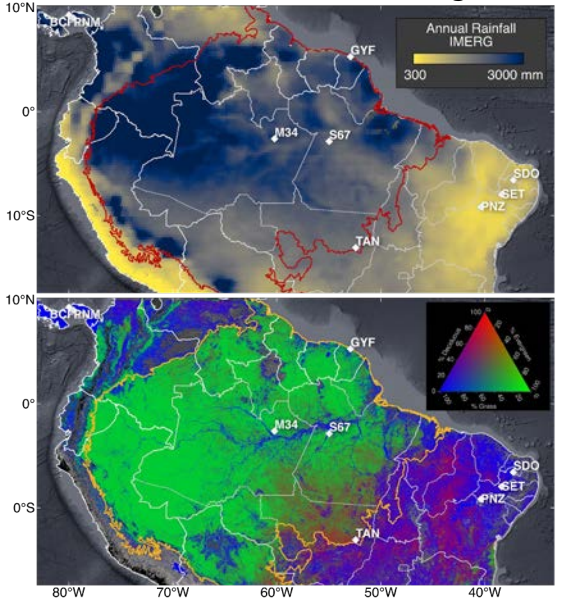


User Interface

Tutorial in jupyter
User's guide
Technical document

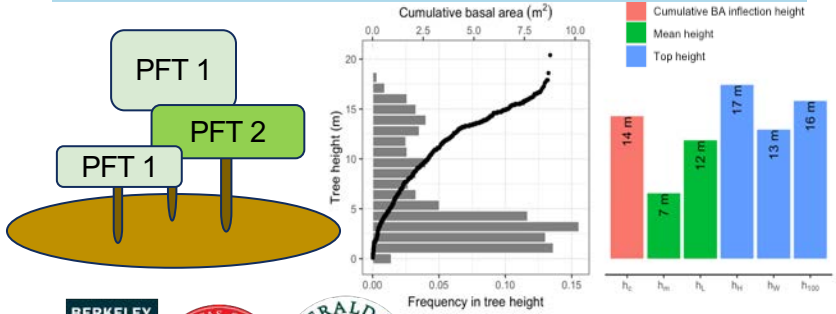
Deciduous Phenology

Forest resilience to drought



Moss

Canopy turbulence for mixed vegetation



Data from DeFries et al. (2000) *GCB*
Figure credit Marcos Longo, LBNL

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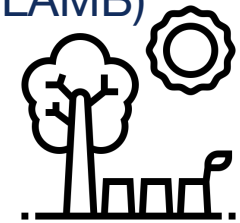
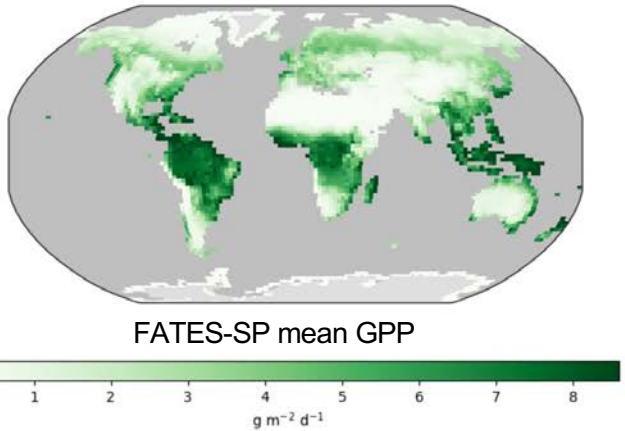
FATES

Global

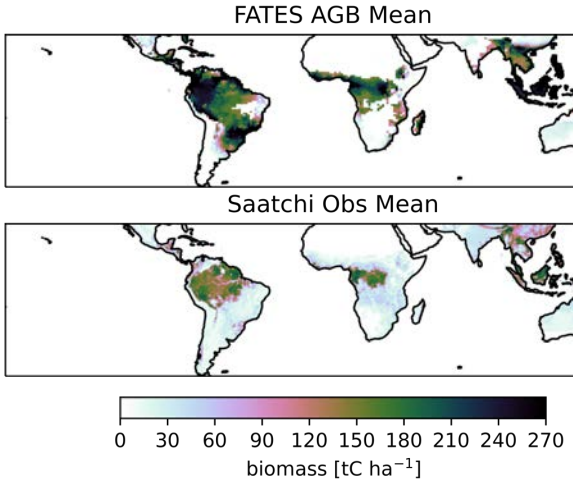
- Reduced Complexity modes
- Diagnostic testing (ILAMB)
- Land use harvest

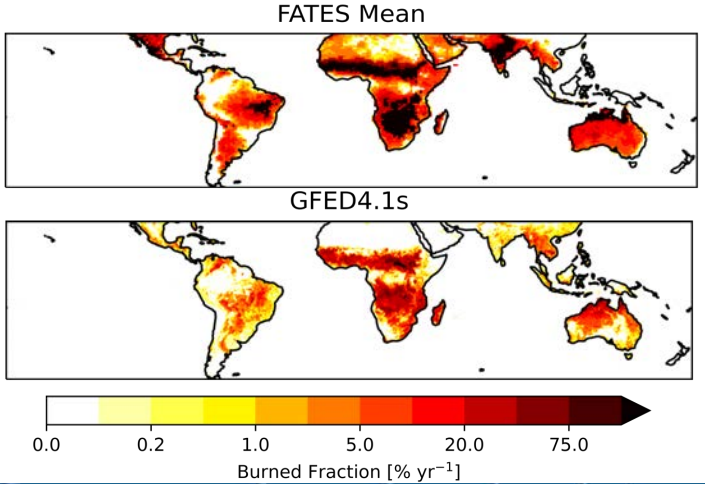




Regional

- FATES captures dynamic biogeography and biomass
- Fire feedbacks determine plant survival
- Critical for tropics simulation
- Testing in California (LBNL)





Model Development Updates: Nutrient Dynamics

Ryan Knox

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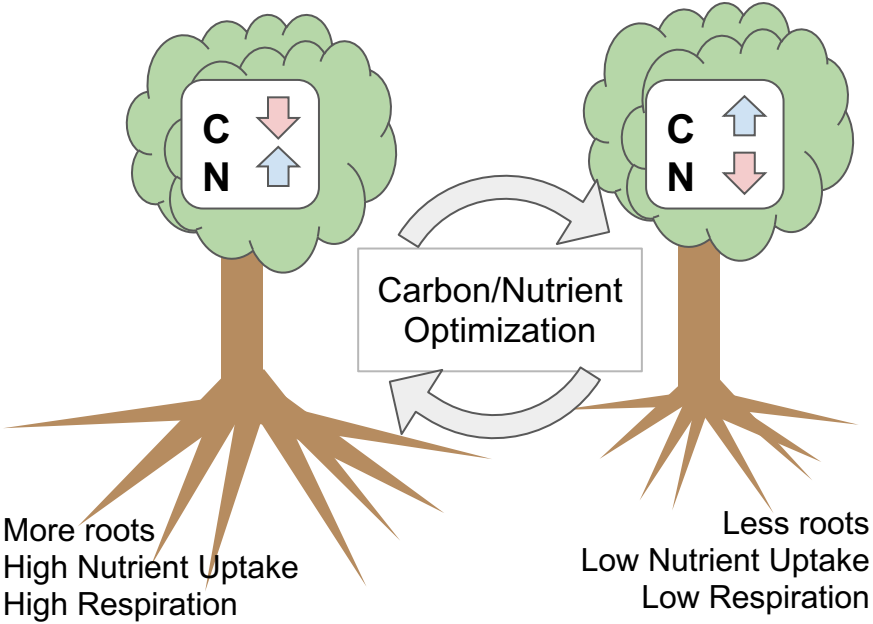
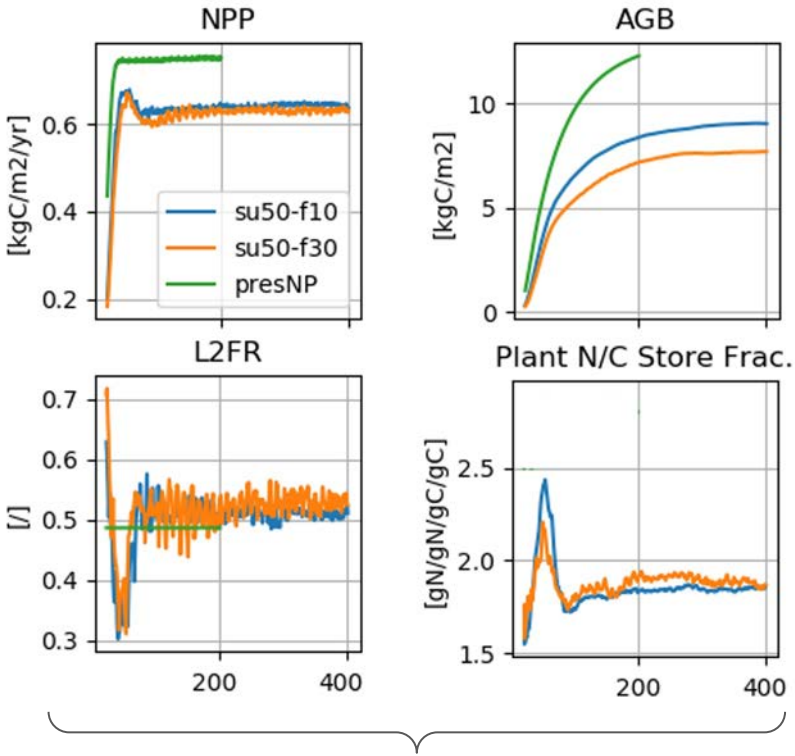
Core V2 Concept:

Introducing “costs” to nutrient uptake via dynamic fine-root optimization





Sensitivity experiment at **Barro-Colorado Island Panama**

Model Development Updates: Plant Hydraulics

Yilin Fang, Junyan Ding

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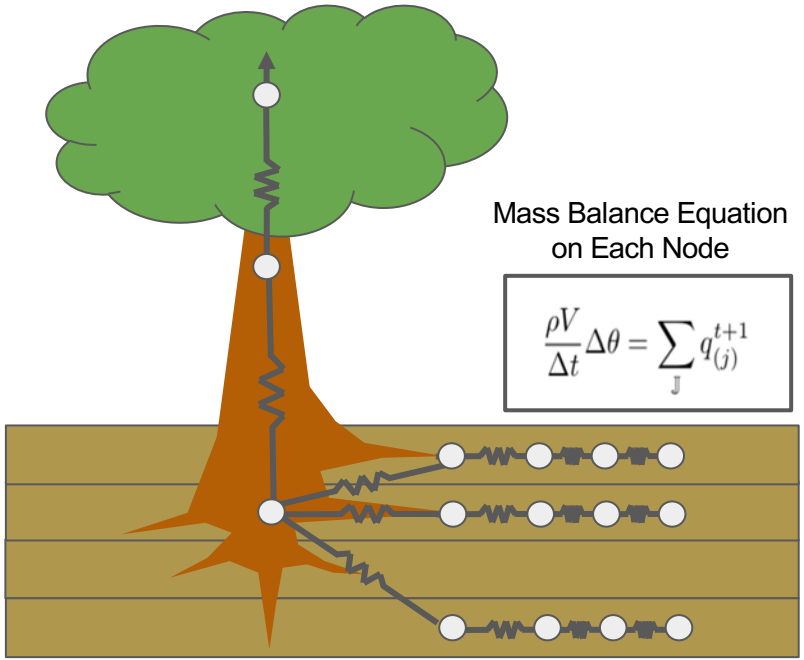
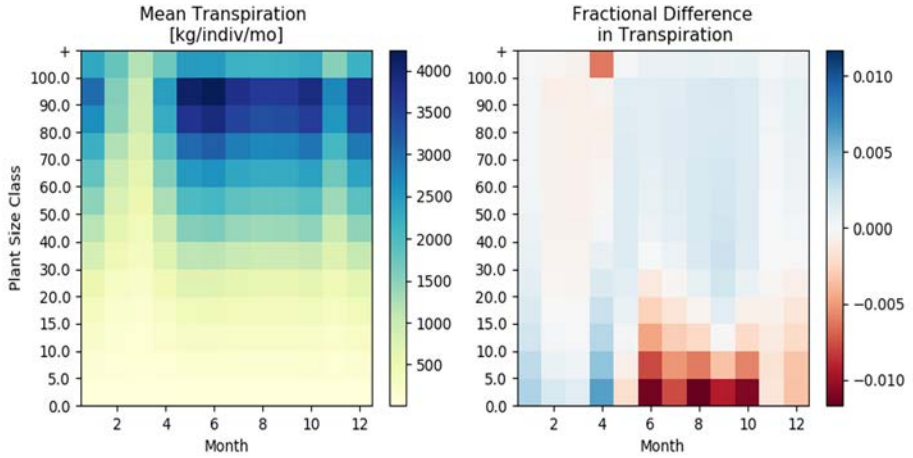
Comparing the default “1D” sequential solver versus a “2D” Newton Solver



Mass Balance Equation on Each Node

$$\frac{\rho V}{\Delta t}\Delta\theta = \sum_{\mathbb{J}} q_{(j)}^{t+1}$$



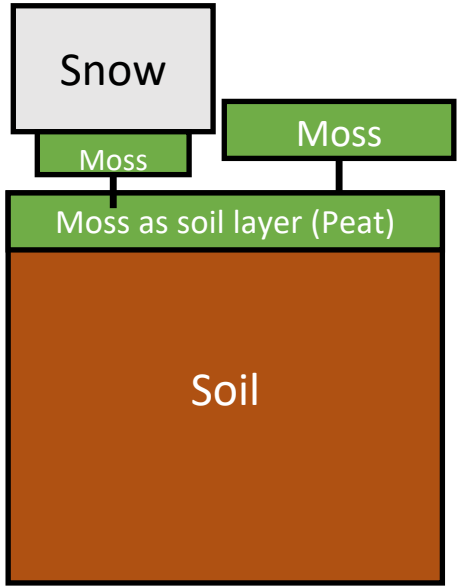
1D Result

(2D-1D)/abs(1D) Result

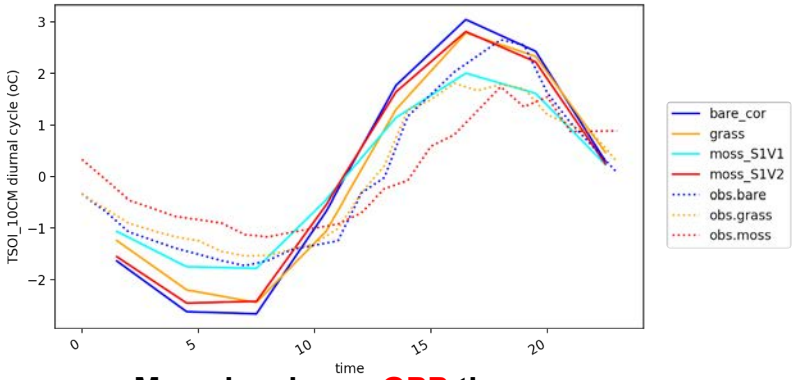
Up to ~1000 cohorts per grid-cell!

- Variable resolution fine-root layering
- Updated pressure-volume & pressure-conductance
- Plant size-specific rooting depth
- Leaf stomatal humidity controls on transpiration

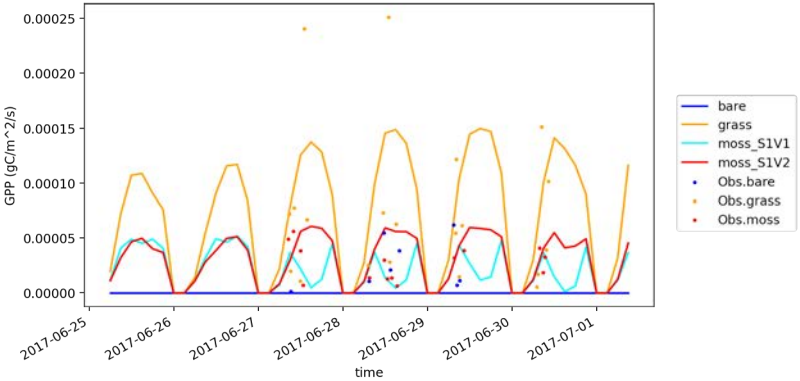
Representing moss as a mixture of soil and vegetation in CTSM-FATES *Hui Tang, Kjetil Aas, Sonya Geange et al.*

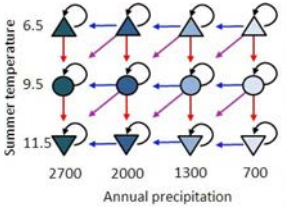


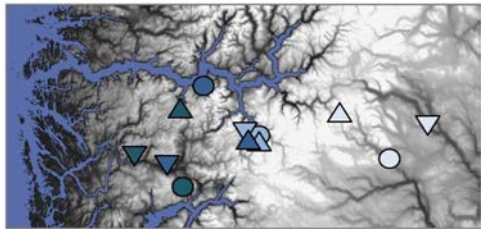
Moss reduces diurnal cycle of soil temperature

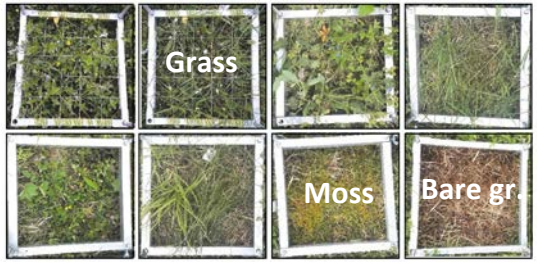


Moss has lower GPP than grass





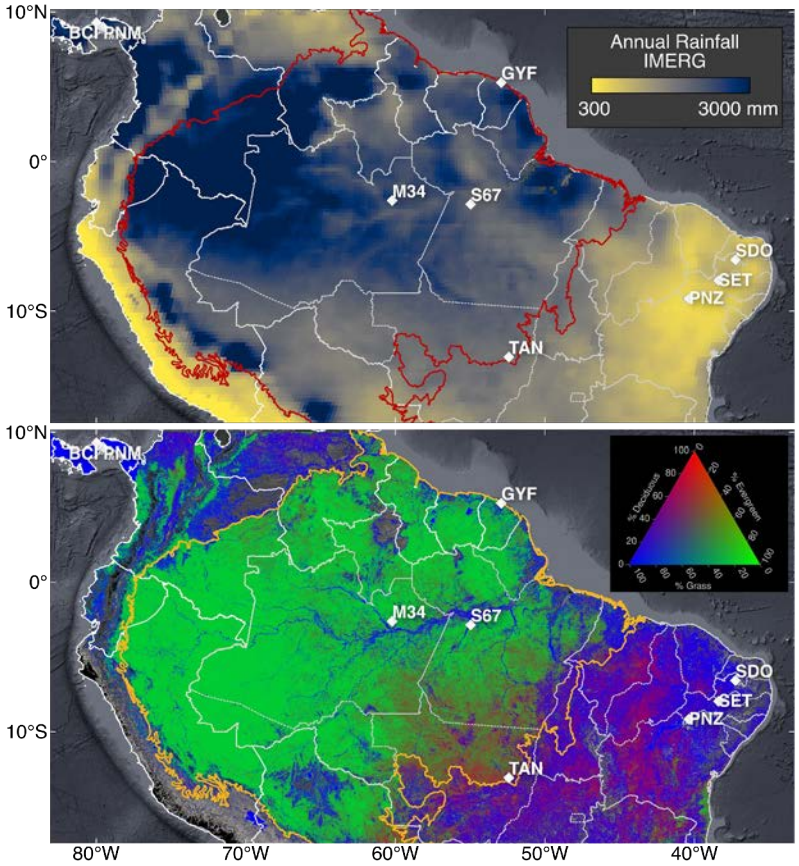




Observation data from Vandvik et al., Sci. Data. 2022 (in revision)

Drought-deciduous phenology in FATES

Marcos Longo



Goals

- Represent dominance/coexistence of evergreen and deciduous trees across rainfall gradients in the tropics
- Investigate how deciduousness may increase forest resilience to hotter droughts.

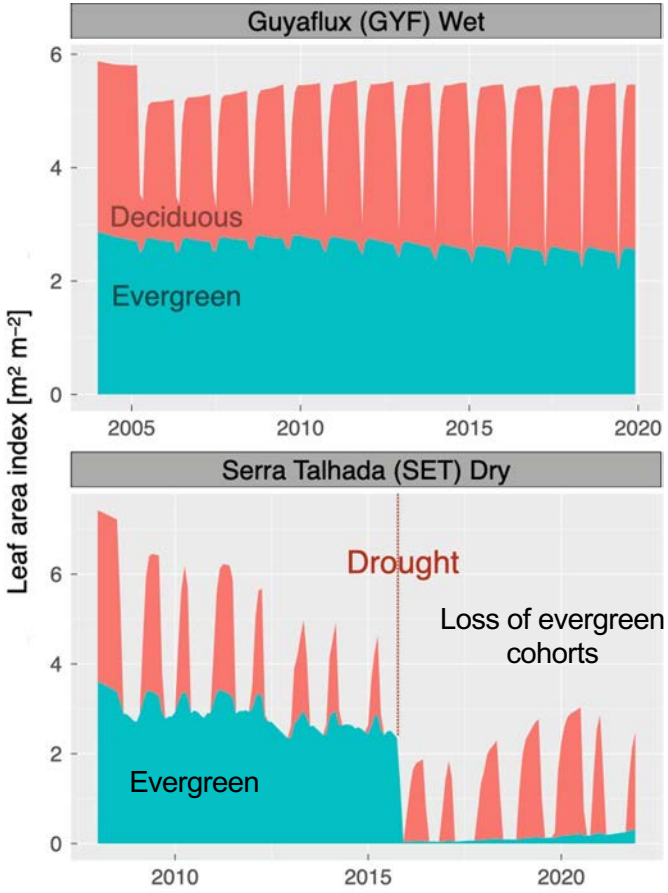
Model developments

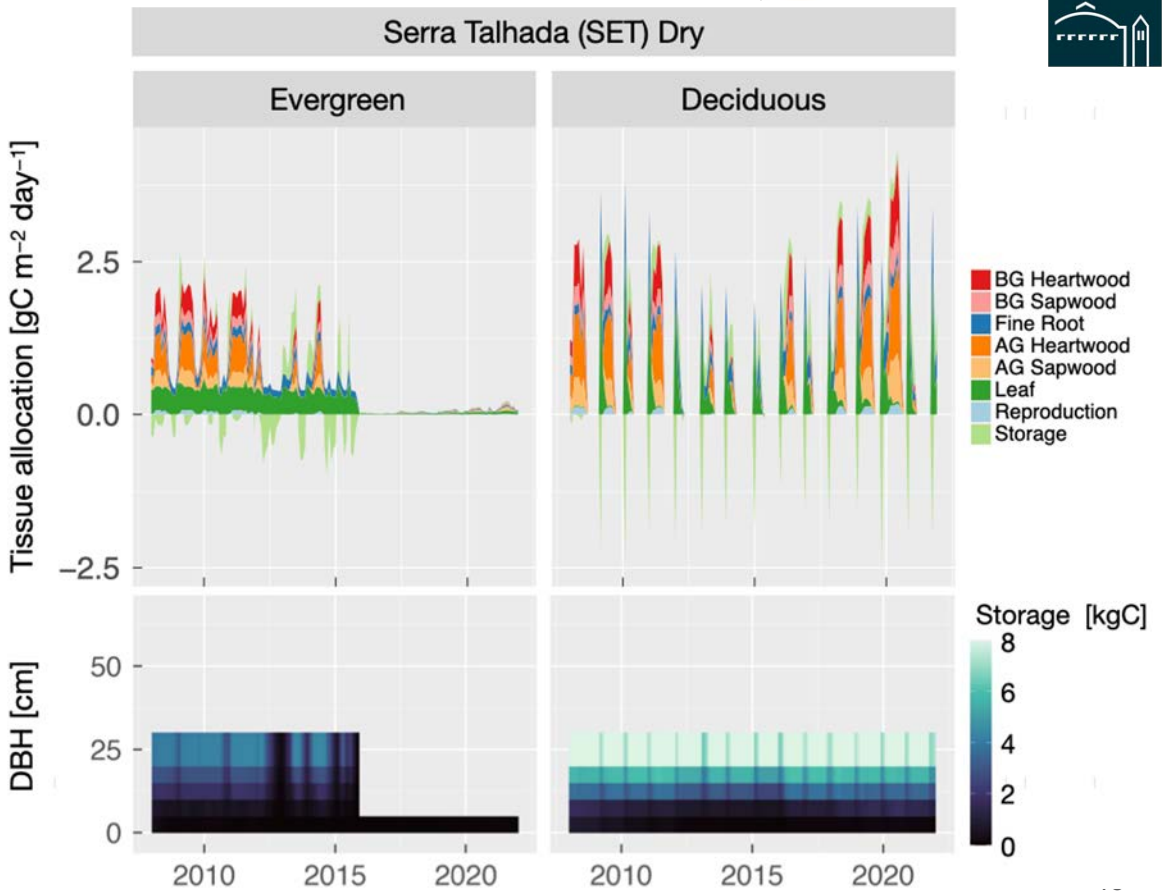
- PFT-specific flushing and abscission
- Water stress: Matric potential Rooting zone
- Optional semi-deciduous phenology
- Leaves off = No growth or maintenance
- Optional active fine-root abscission

Data from DeFries et al. (2000) *GCB* 10.1046/j.1365-2486.2000.00296.x

Deciduous allocation strategy increase survivorship in dry forests

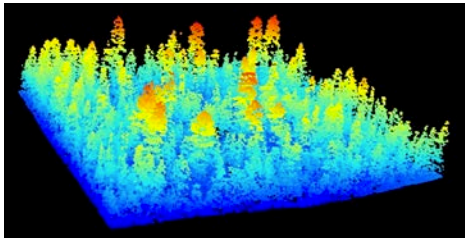
Marcos Longo

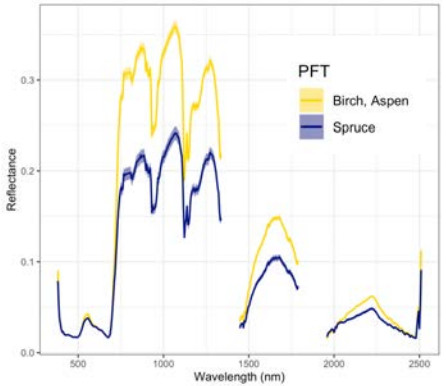




FATES single-point simulations at NEON sites

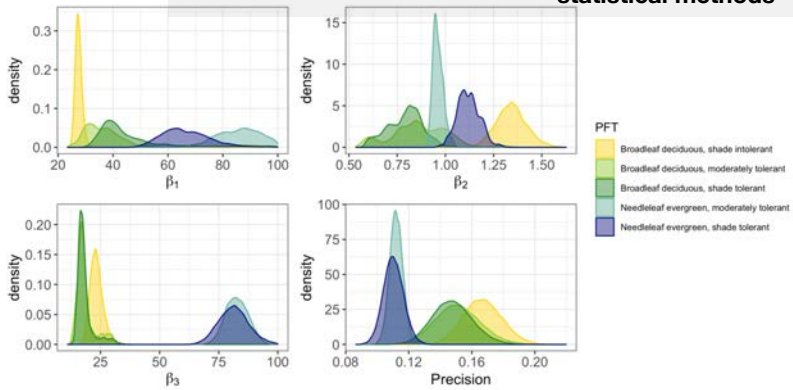
Adrianna Foster

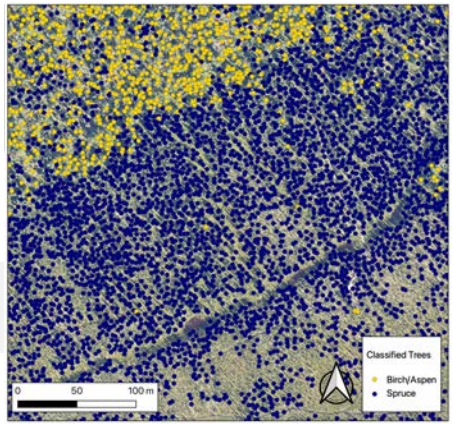




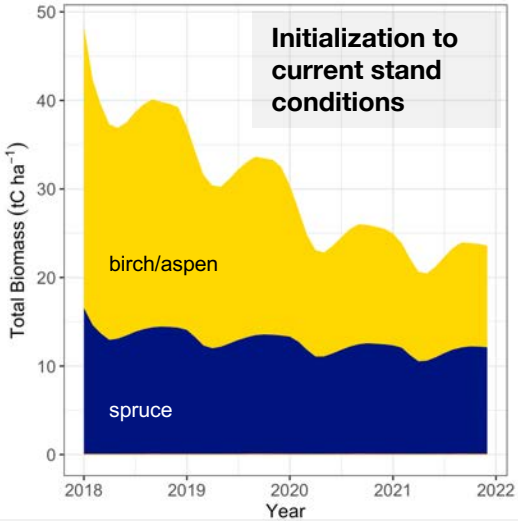
Leveraging NEON aerial LiDAR and hyperspectral imagery

Parameter calibration & uncertainty using Bayesian statistical methods

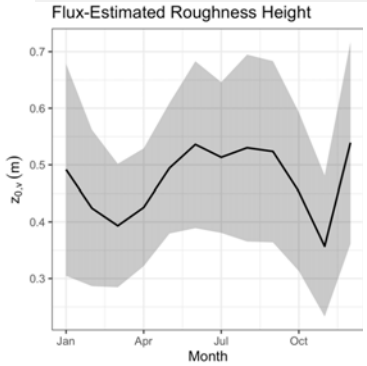


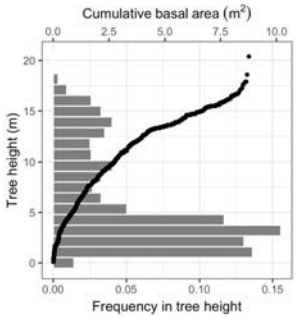


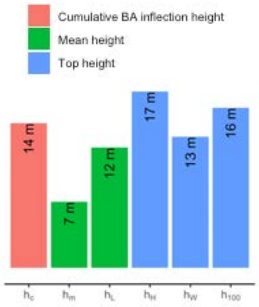
Bonanza Creek, Alaska



Investigating roughness and canopy height parameterizations

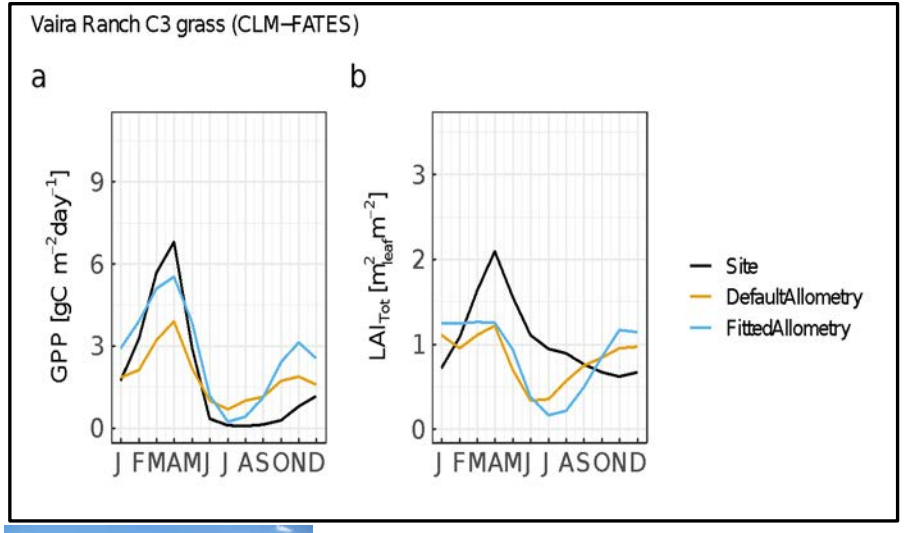


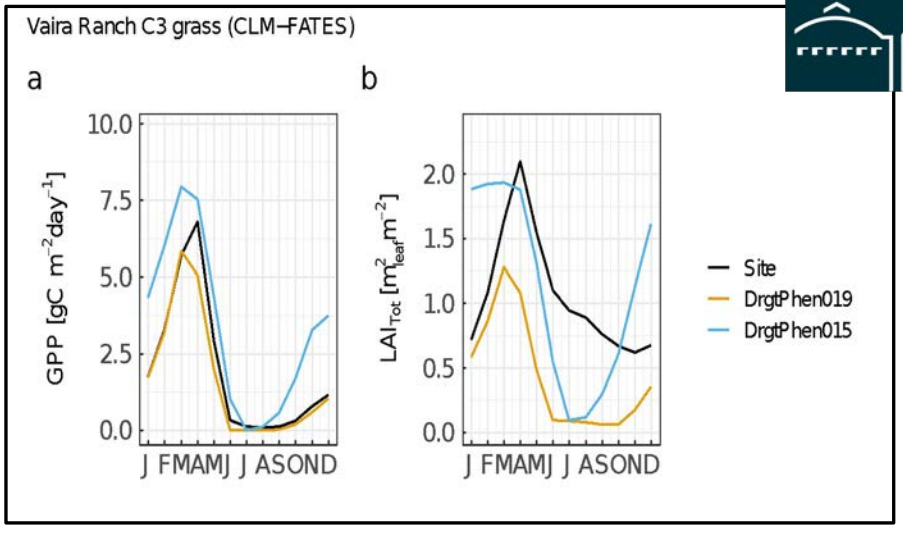




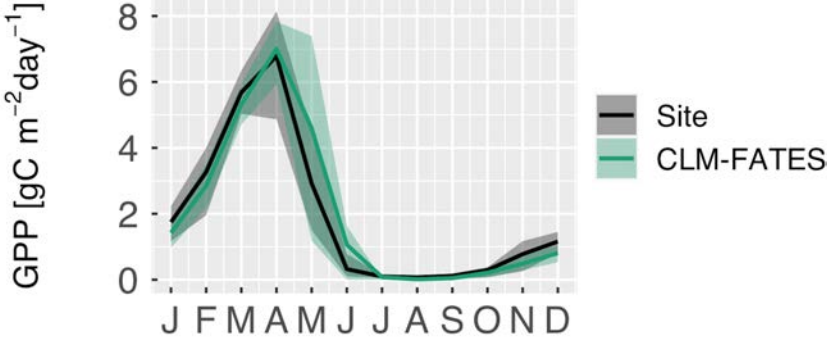
Allometry and phenology important for grassland productivity and structure

Xiulin Gao, Charlie Koven, Lara Kueppers





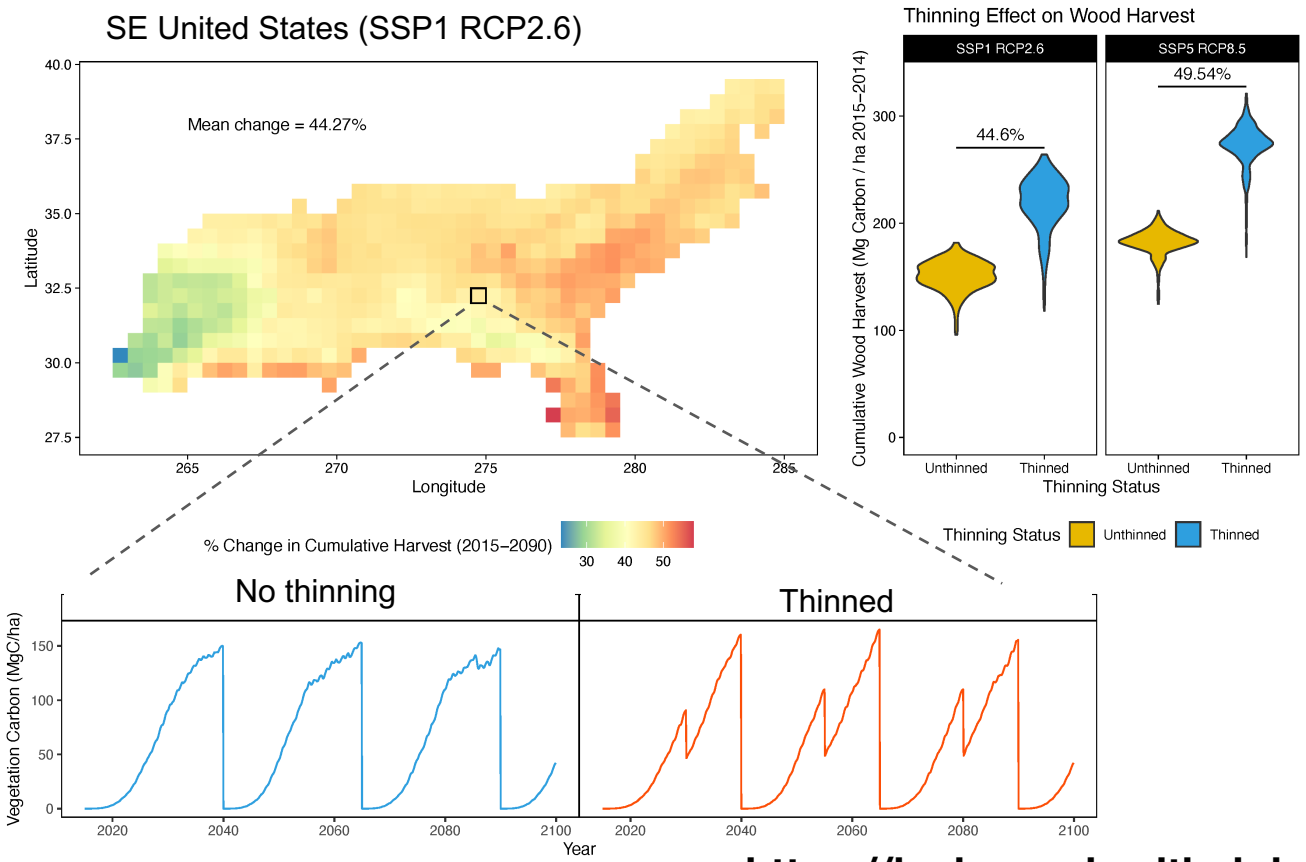
Grass allometry experiment



Forest Management Practices under Future Climate with CLM-FATES

Joshua M. Rady ***jmrady@vt.edu***

VIRGINIA TECH™



https://joshuarady.github.io/VegetationManagement/

Forest Management Practices under Future Climate with CLM-FATES

Joshua M. Rady *jmrady@vt.edu*

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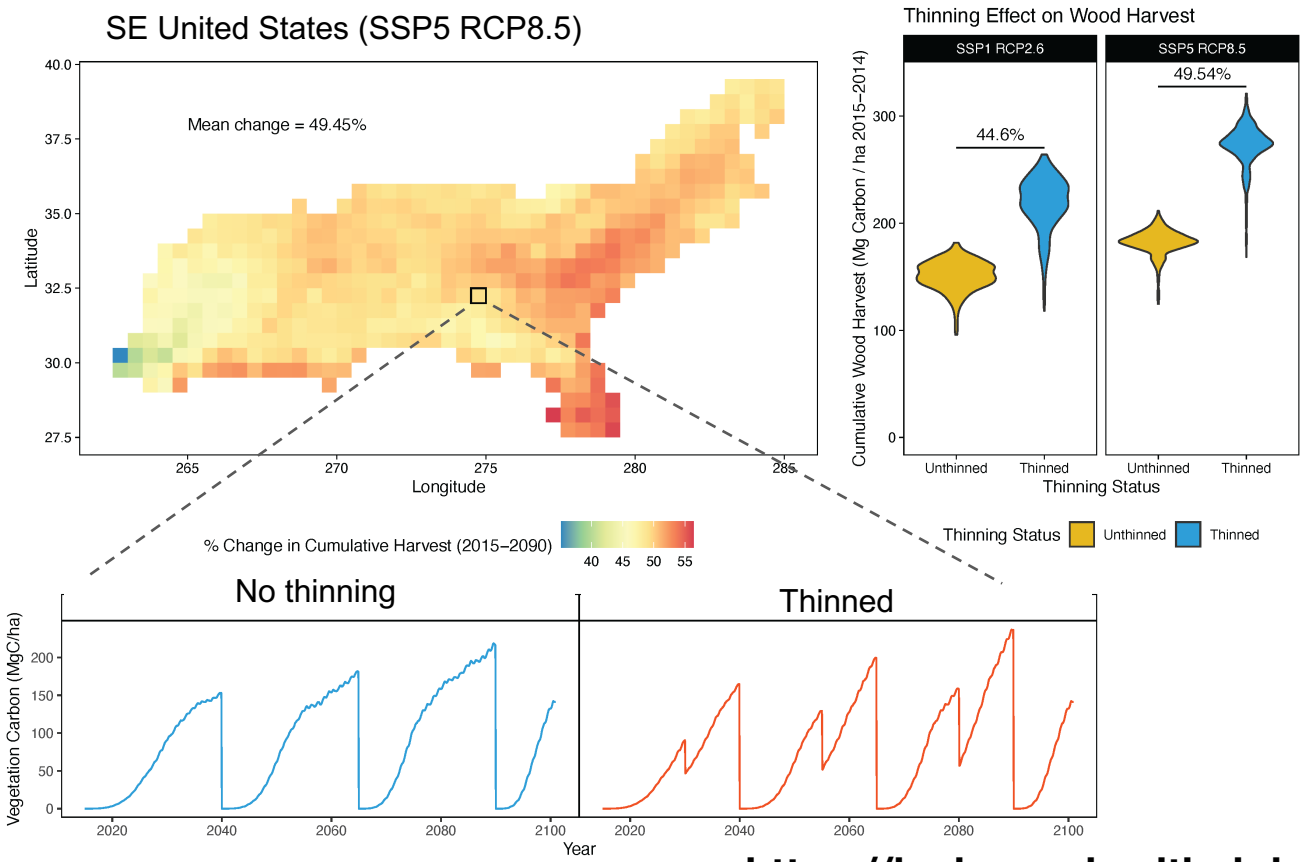


https://joshuarady.github.io/VegetationManagement/

Simulating environmentally sensitive tree recruitment in vegetation demographic models

Adam Hanbury-Brown, Tom Powell, Joe Wright, Helene Muller-Landau, Lara Kueppers

The Tree Recruitment Scheme (TRS) represents:

– size-dependent reproductive allocation
– moisture- and light-sensitive seedling emergence, mortality, and transition to the sapling size classes
– is compatible with existing VDM model infrastructure

Result: TRS improves the magnitude and rank order of PFT-specific recruitment at BCI compared to existing VDMs (Fig 1)

Takeaway: TRS is well-positioned to improve predictions of future forest functional composition and distribution

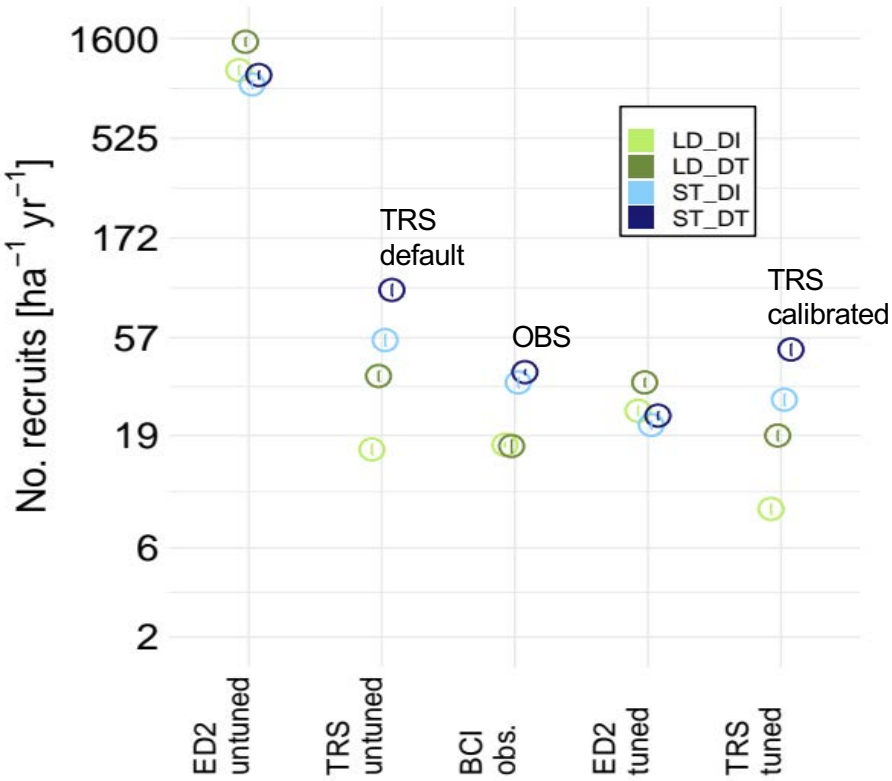


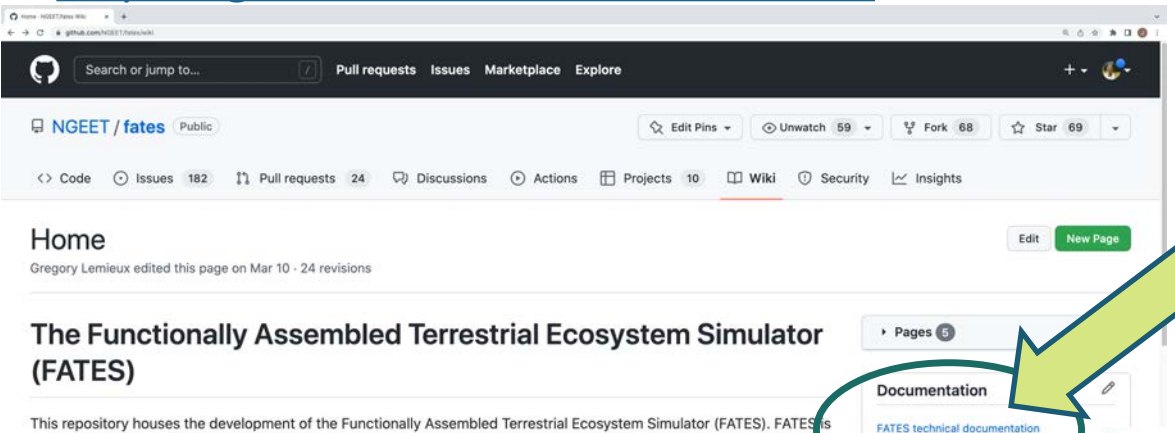
Fig 1. Recruitment (at 1-cm dbh) for 4 PFTs at BCI (center) compared with model predictions under 20 yr of observed meteorology (2008–2014 recycled).

Hanbury-Brown et al 2022 *New Phytologist*

U.S. DEPARTMENT OF ENERGY | Office of Science | NGEE-Tropics Next-Generation Ecosystem Experiments | Berkeley UNIVERSITY OF CALIFORNIA

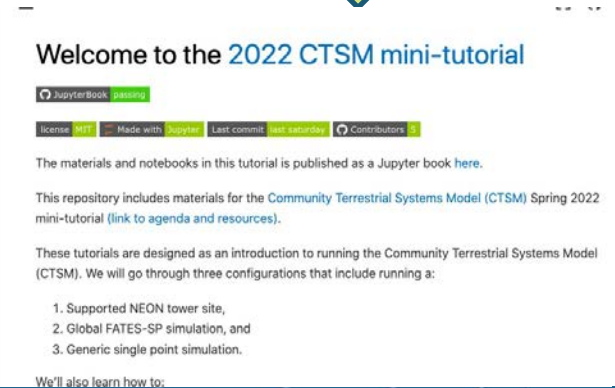
FATES code and information

https://github.com/NGEET/fates/wiki



Technical Documentation
&
User's Guide

Tutorial materials



https://ncar.github.io/CTSM-Tutorial-2022/README.html

Acknowledgment

A portion of this research was supported as part of the Next Generation Ecosystem Experiments-Tropics, funded by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research.

Thank You! Questions?

Contact details:
Jacquelyn Shuman jkshuman@ucar.edu

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NEXT-GENERATION ECOSYSTEM EXPERIMENTS–TROPICS