Ecosystem Dynamics and Fire

Next-generation modeling with vegetation demography using the Functionally Assembled Ecosystem Simulator (FATES)

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NGEE–TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS–TROPICS

CESM Tutorial
August 10, 2022

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Active fire counts

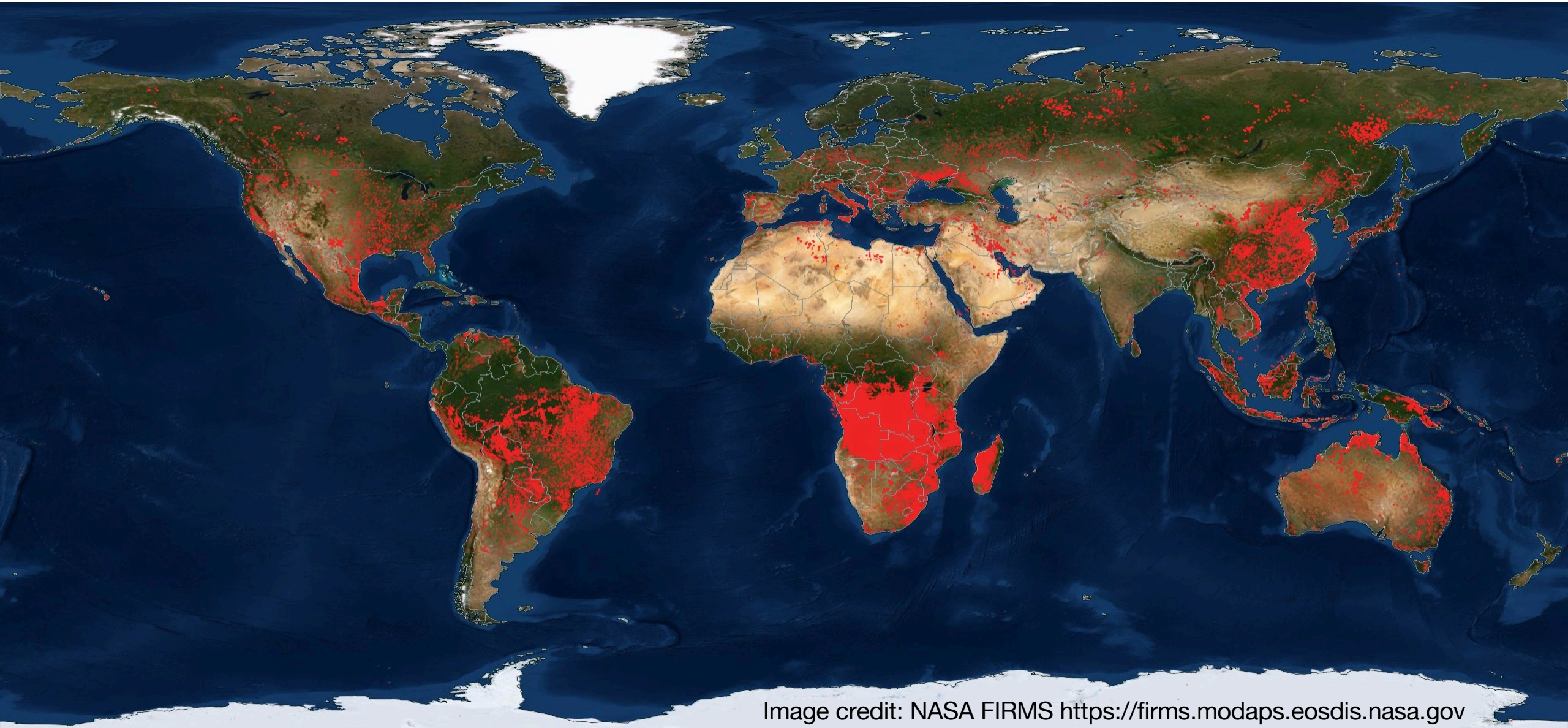
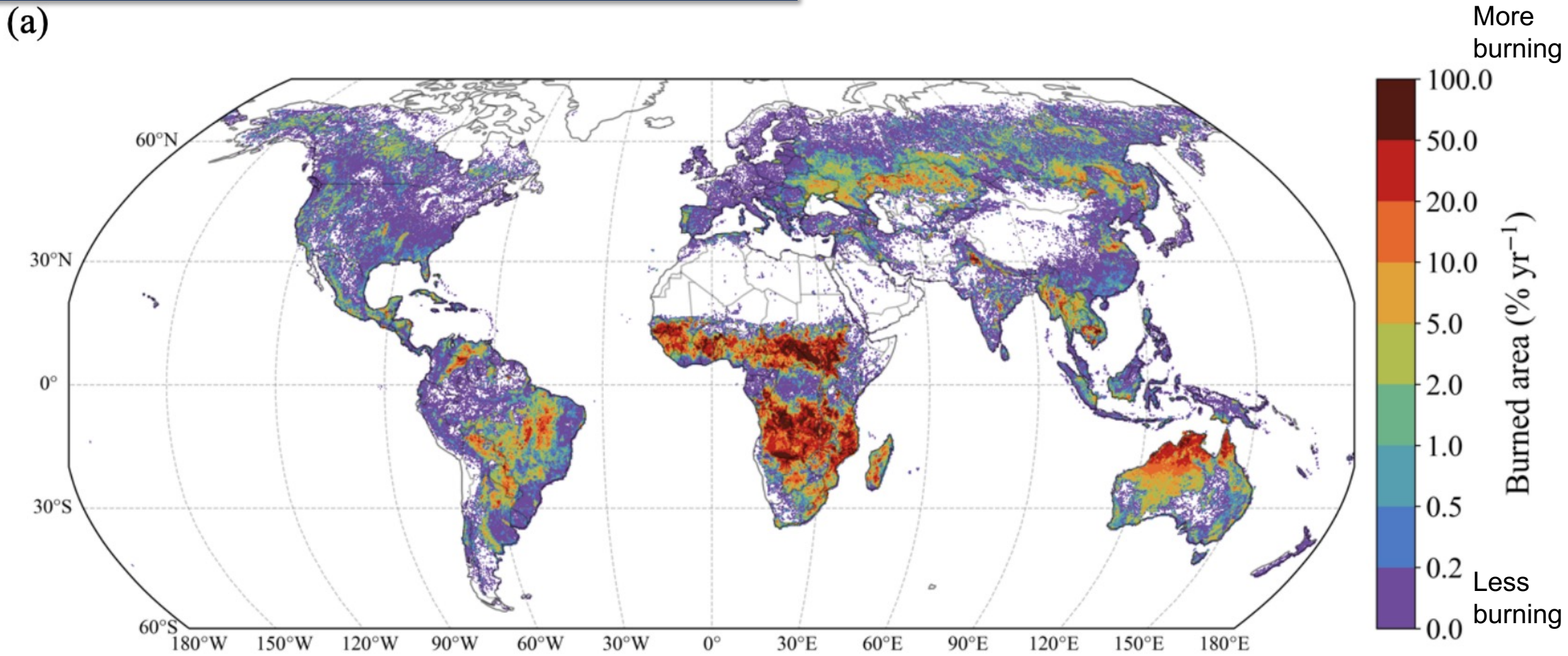


Image credit: NASA FIRMS https://firms.modaps.eosdis.nasa.gov

Global burned area (2002-2019)

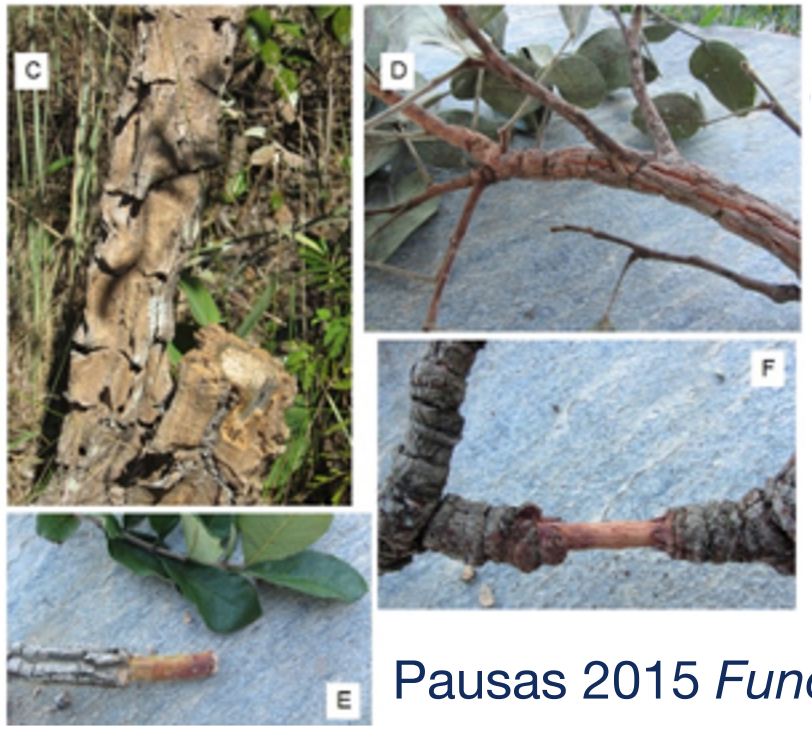


van Wees *et al.* preprint *Geoscientific Model Development*

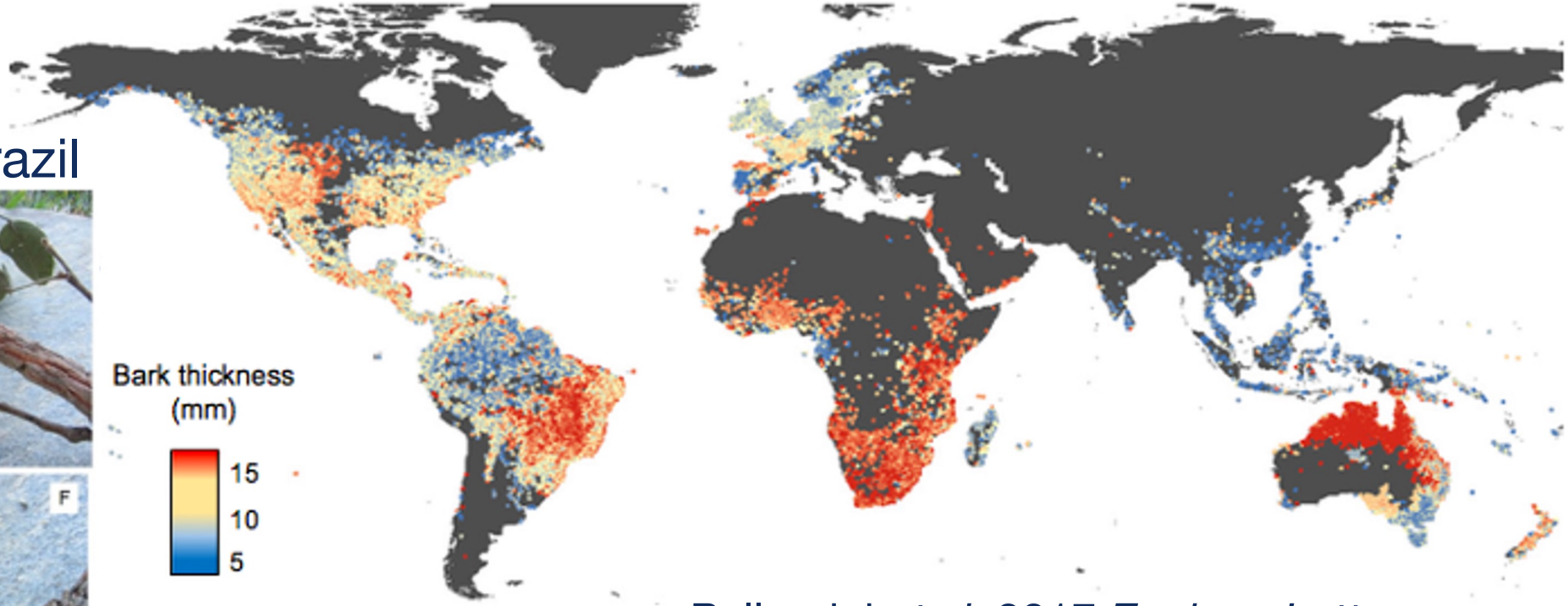
Biogeography shaped by vegetation traits and fire

Thick-barked trees dominate in high fire areas

Thick-barked trees of Brazil

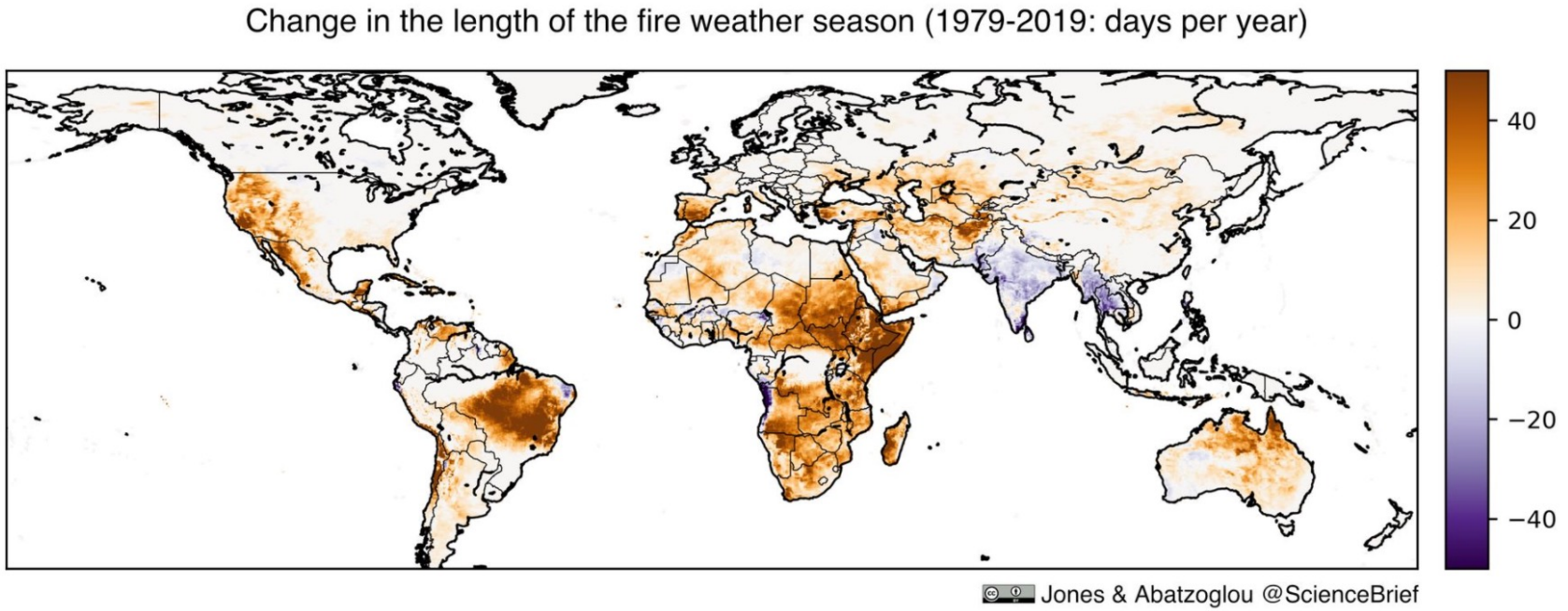


Pausas 2015 *Functional Ecology* FigS2

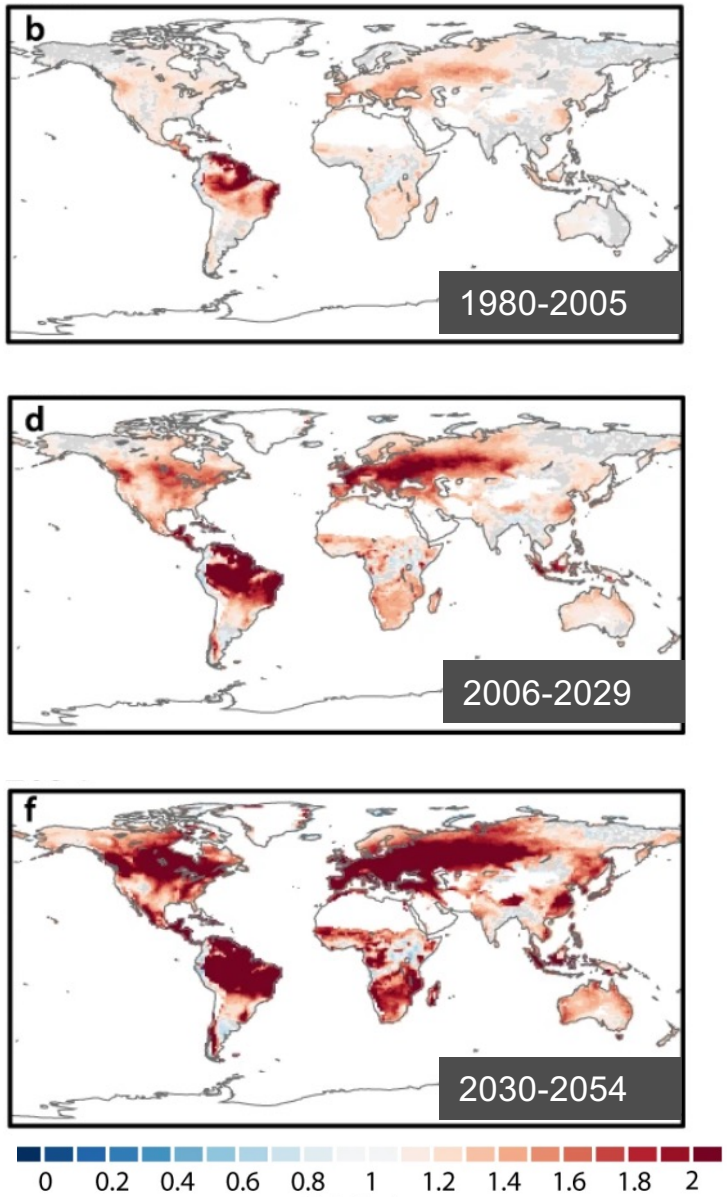


Pellegrini *et al.* 2017 *Ecology Letters*

Increasing Fire danger



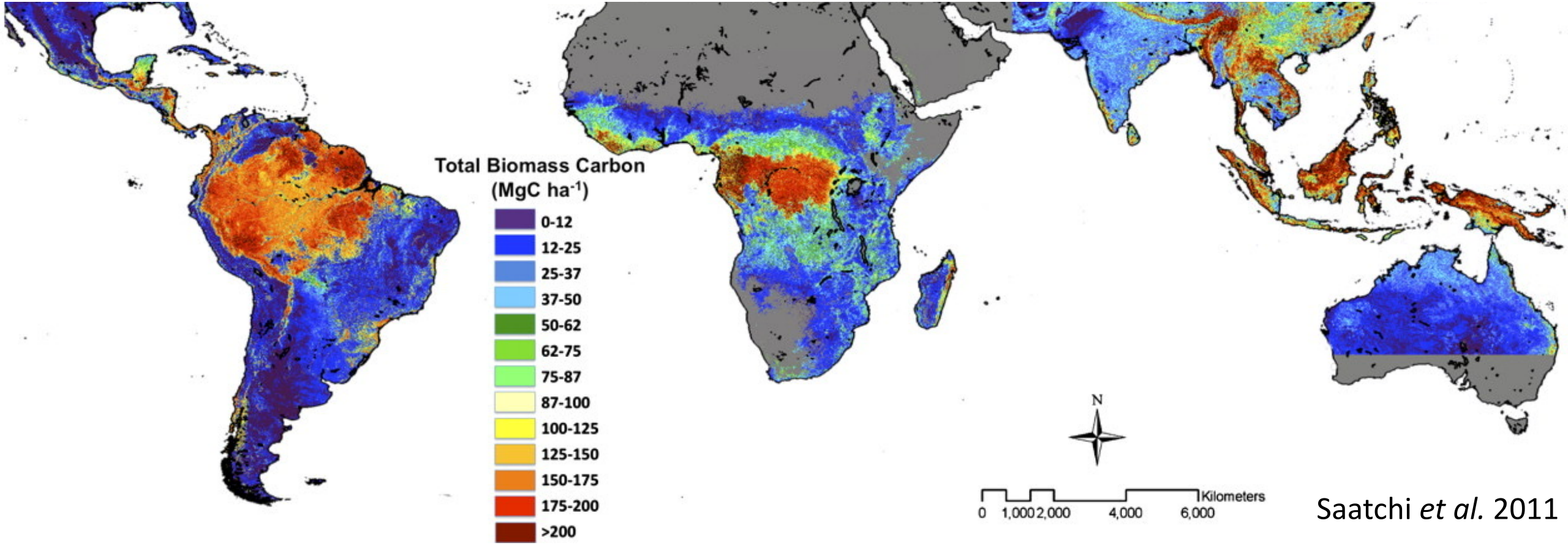
Change in the length of the fire weather season between 1979–2019 as seen in meteorological data (figure produced by M. Jones and J. Abatzoglou following Jolly et al. (2015); data from Vitolo et al., 2020, using the ERA5 dataset)



Touma et al. 2021 *Nature Communications*

Critical high biomass regions

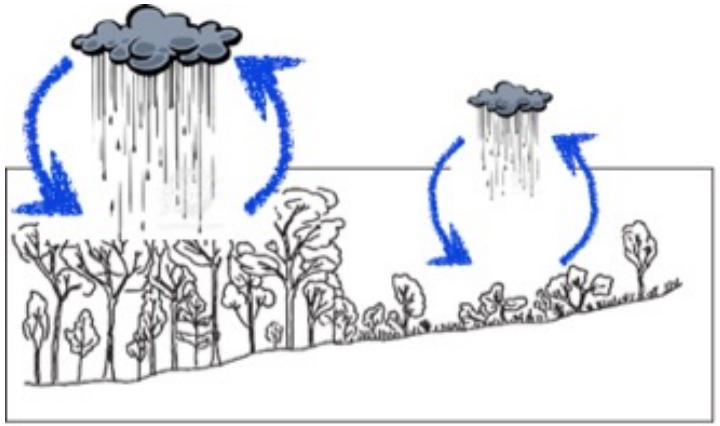
- Shift in fire regime may alter vegetation and C stores



Saatchi *et al.* 2011

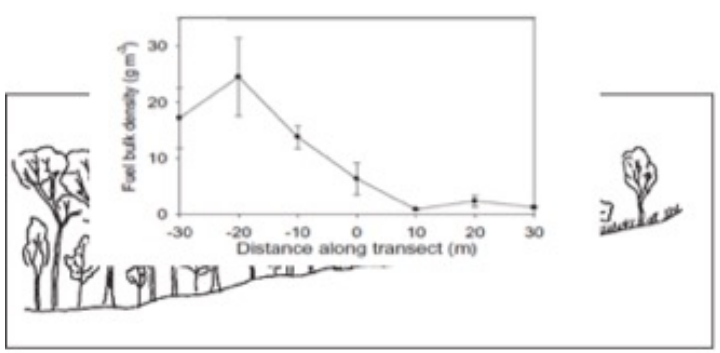
Tropical forests hold 193 Gt carbon aboveground

Fire is interactive in CLM, CLM-FATES

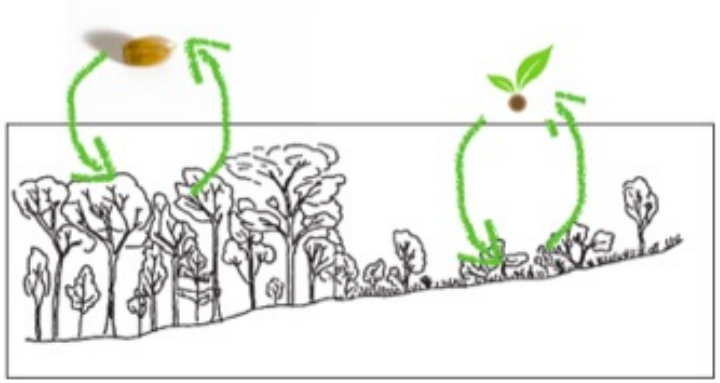


Land-atmosphere feedback

Wind speed feedback



Flammability feedback



Demographic feedback

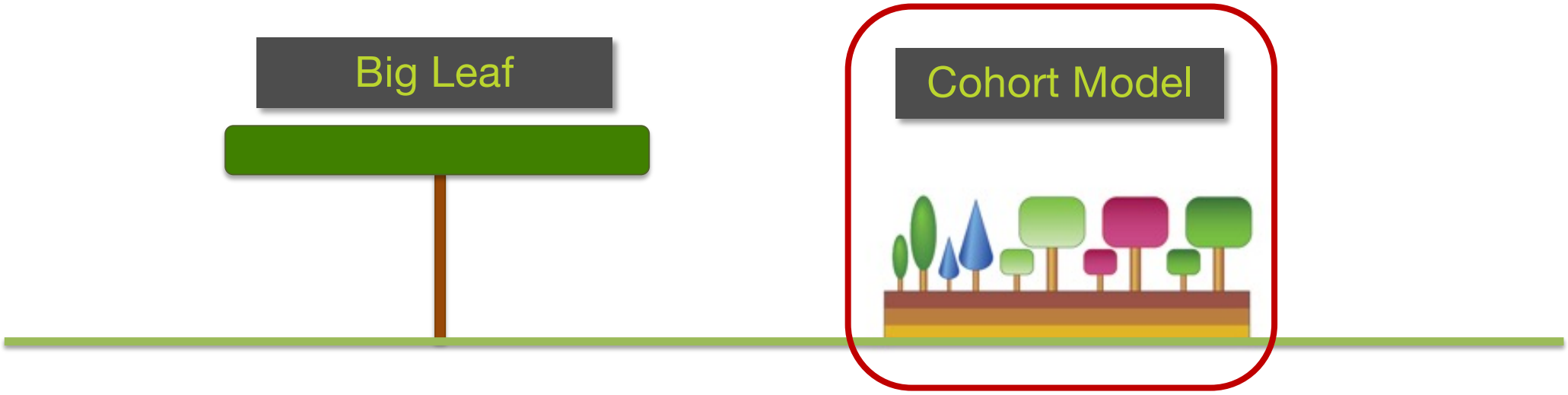
- Adaptation of SPITFIRE (Thonicke et al 2010) into FATES (Fisher et al 2018)

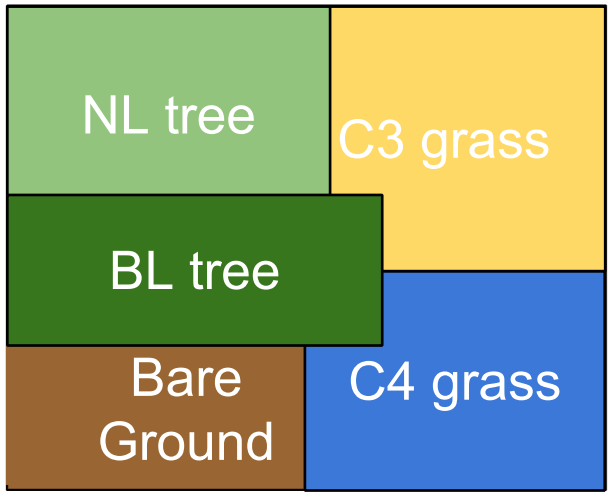
Adapted from Hoffman et al 2011

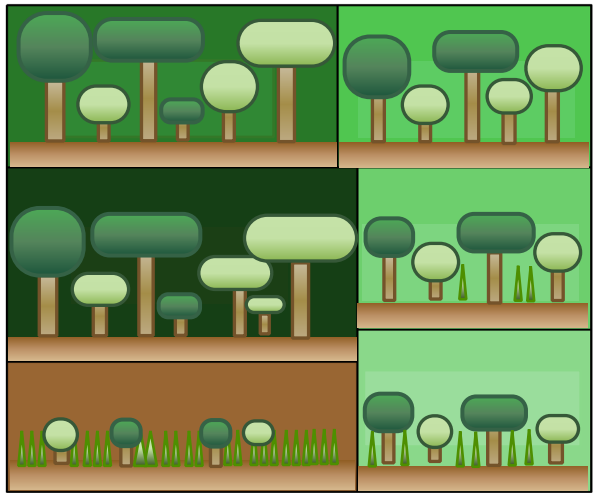
Ecological processes in land surface models

CLM

FATES

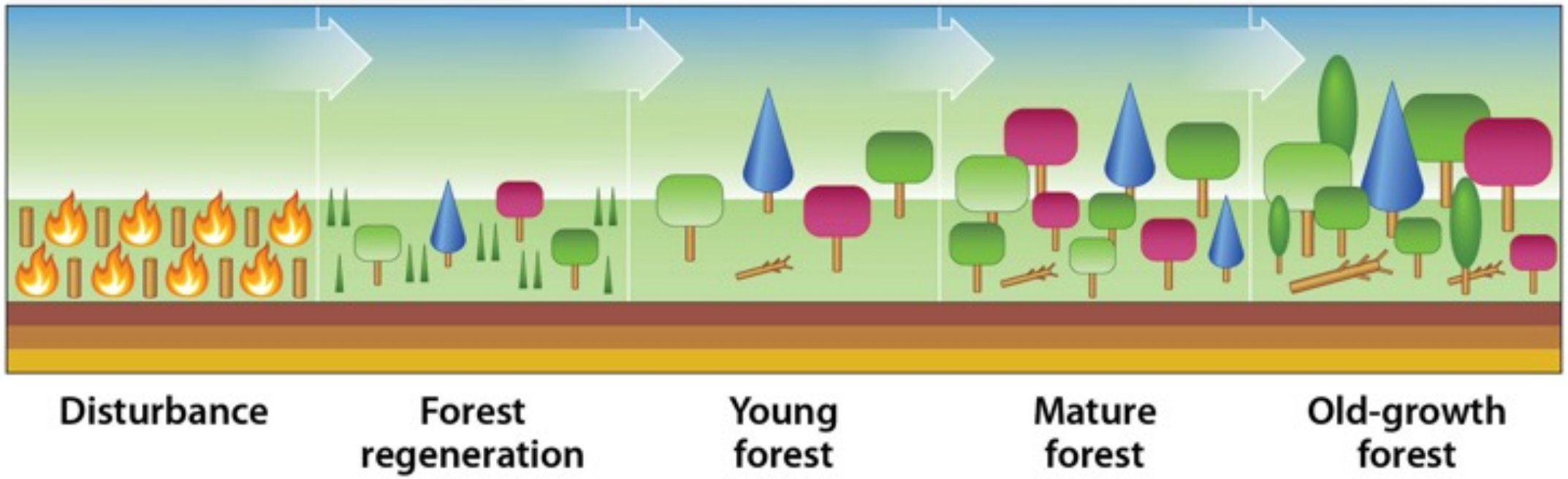


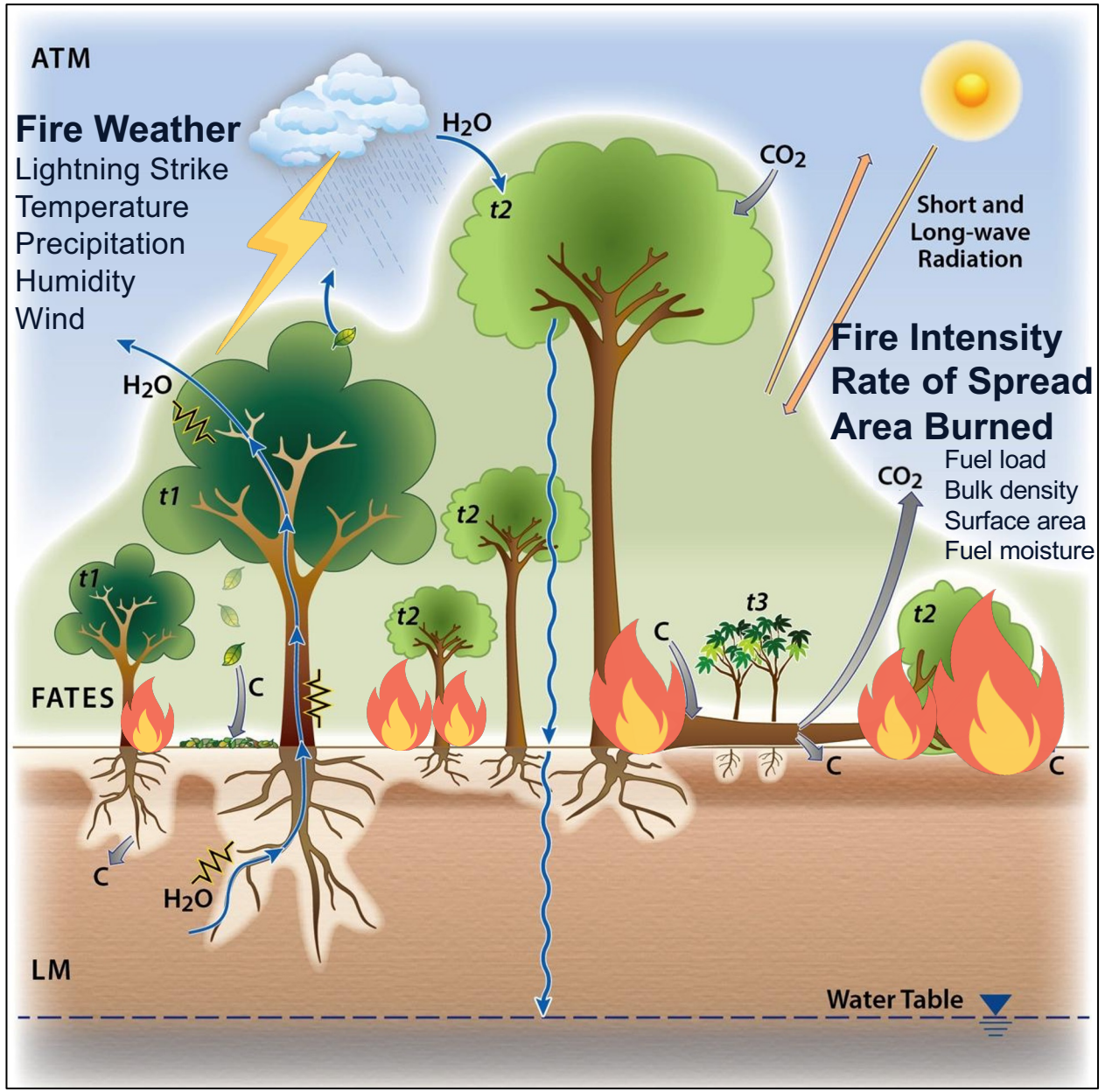




FATES has variability

Time since disturbance





CLM-FATES

- Simulates plant cohort growth, death, and regeneration at sub-daily to daily time steps

SPITFIRE

- daily process-based fire behavior and effects
- six litter & fuel classes
- flame scorch height, crown damage, bark damage
- size-based tree mortality

Thonicke et al 2010; Fisher et al. 2015; Fisher et al. 2018

FATES-SPITFIRE: vegetation traits and structure

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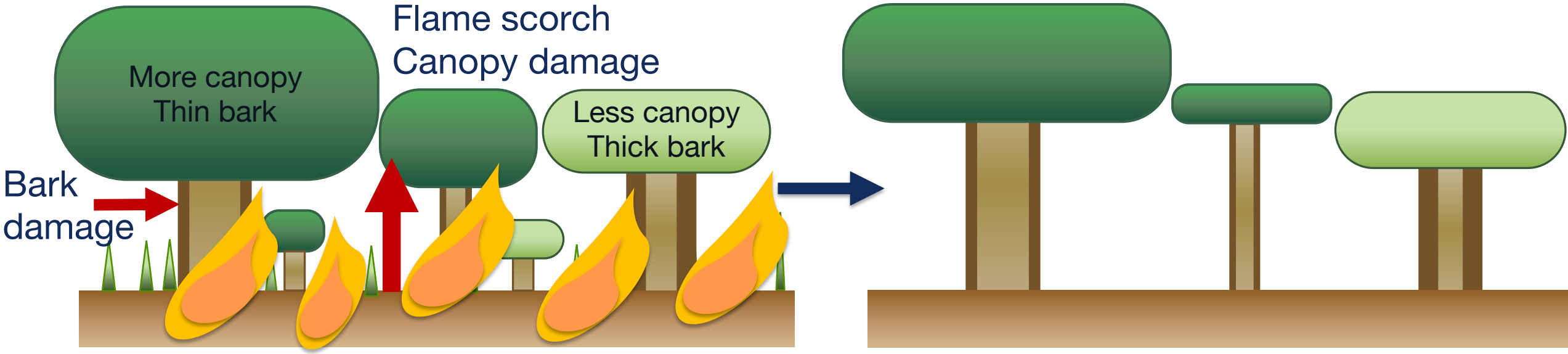
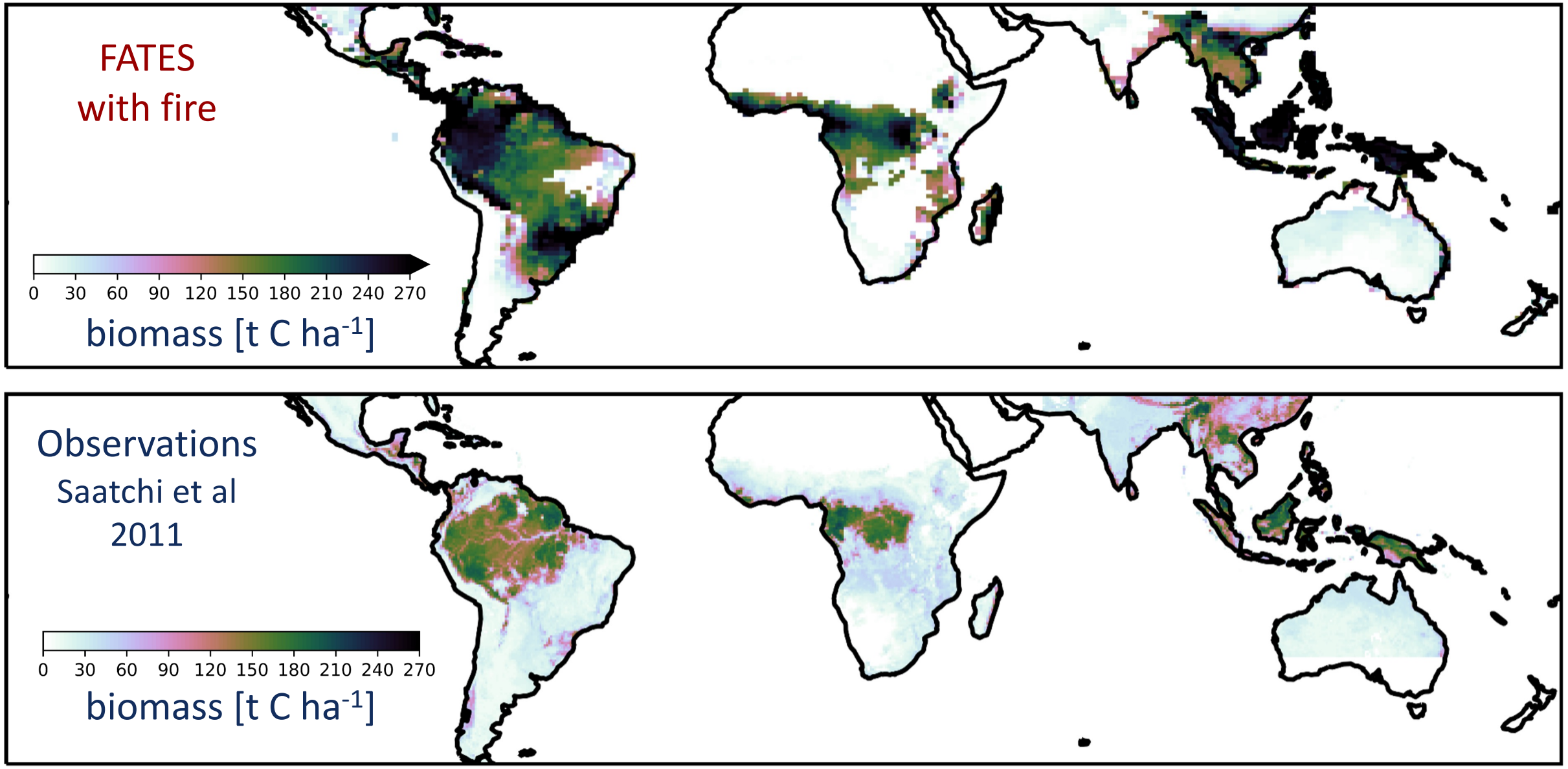


Trees: Trait- and height-level protection from fire

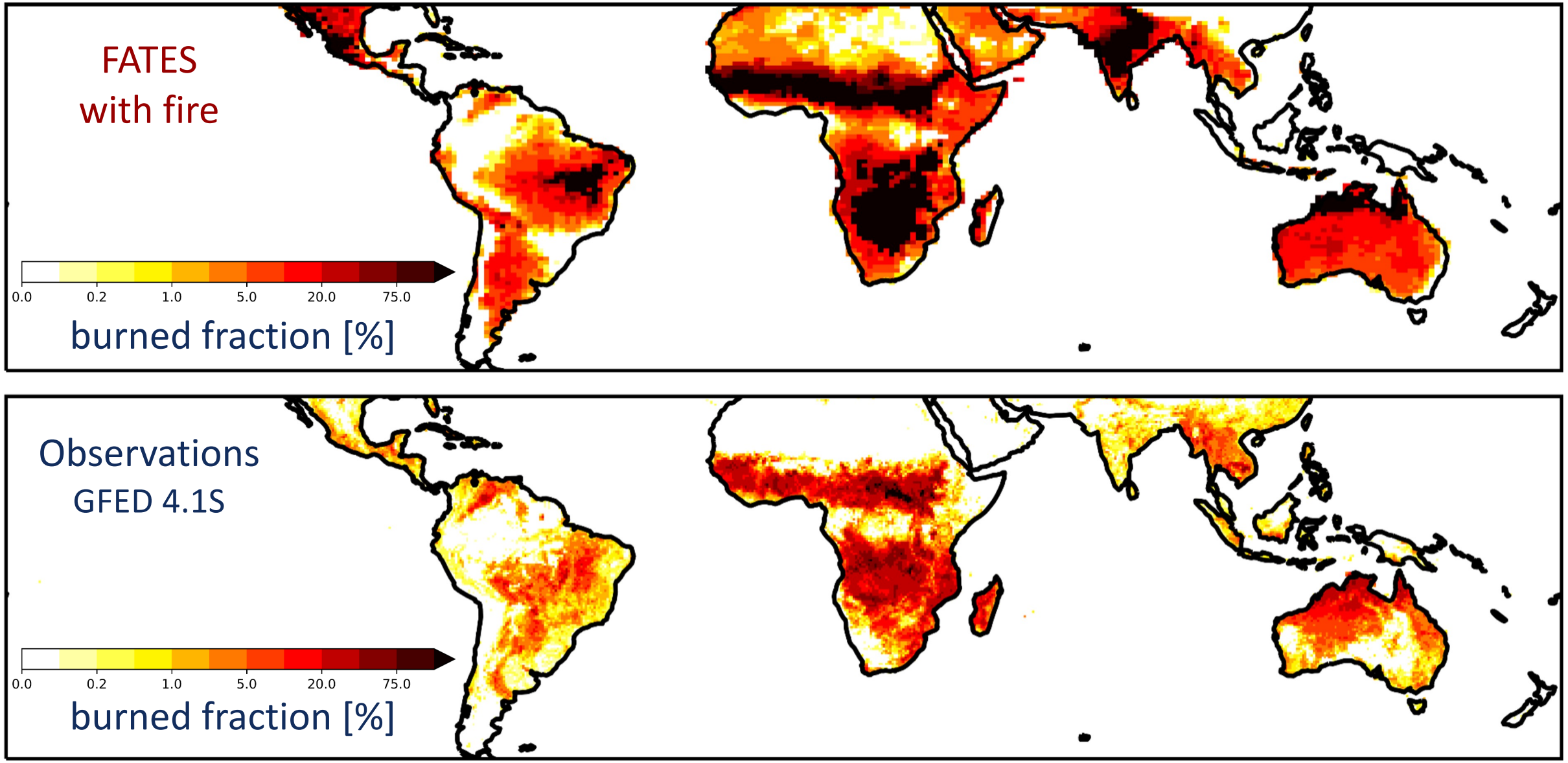
Grasses: no protection and burn with all fires.

FATES captures biomass accumulation



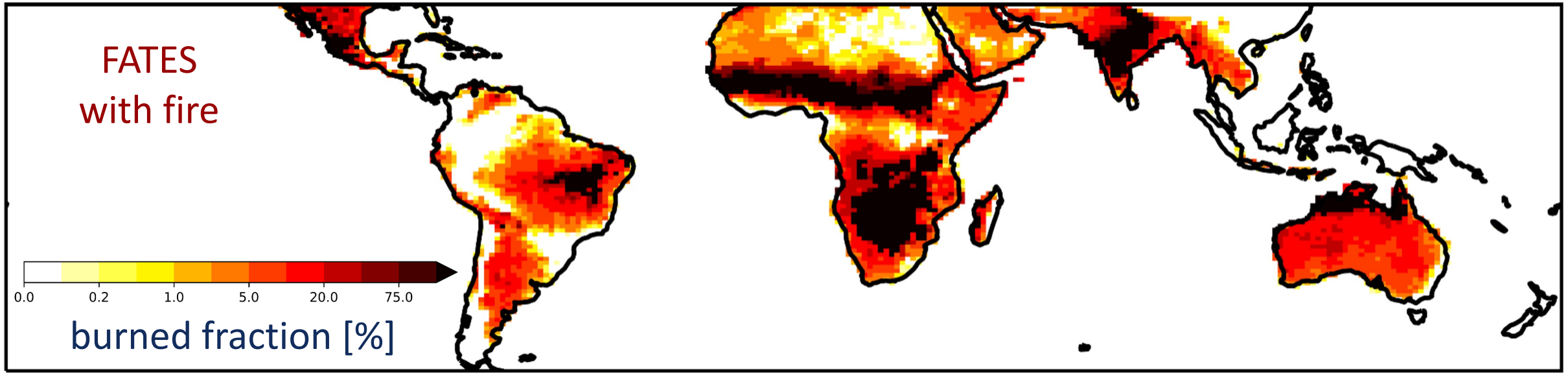
Shuman et al (in prep)

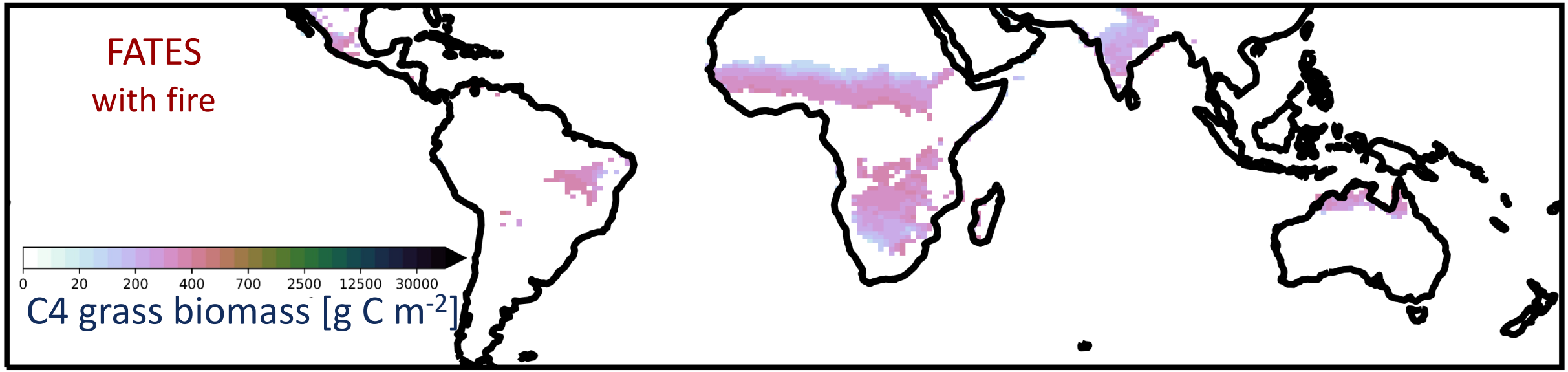
FATES captures broad spatial burn pattern



Shuman et al (in prep)

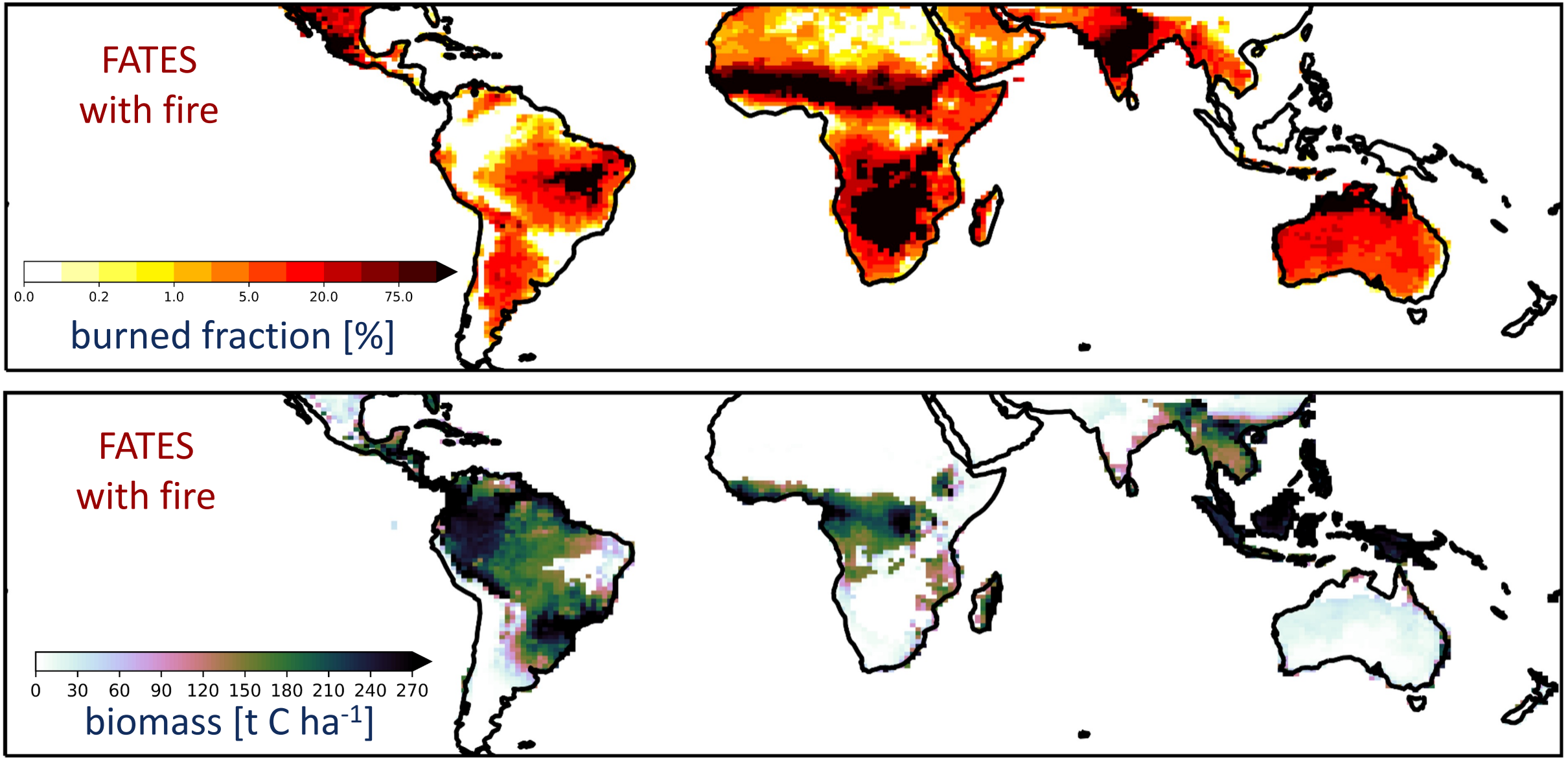
Grasses drive high burned area





Shuman et al (in prep)

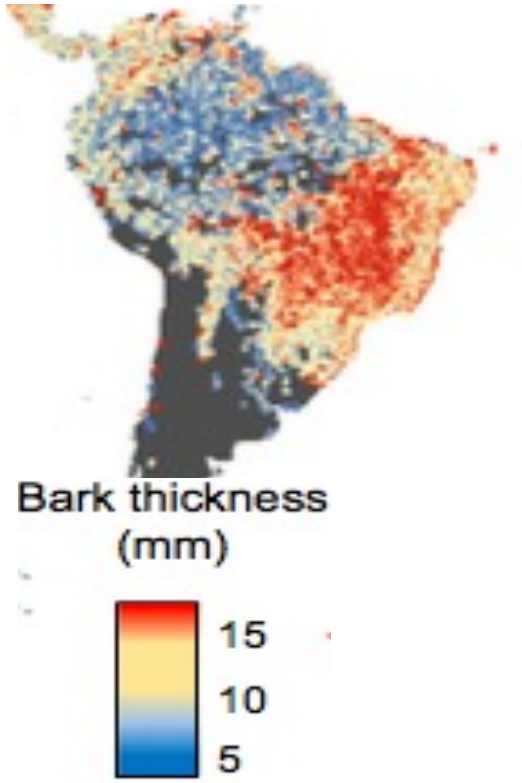
High biomass in areas of low disturbance



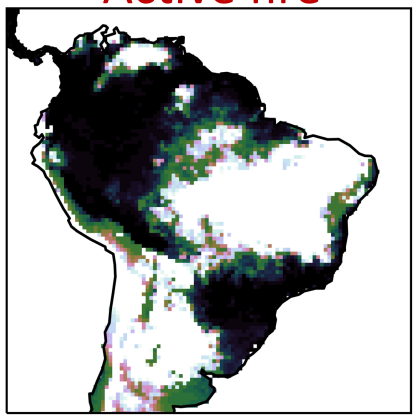
Shuman et al (in prep)

Fire is essential to plant distribution

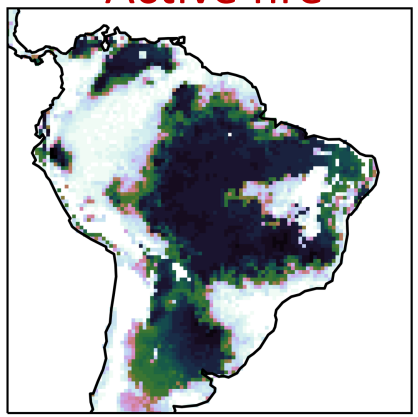
Observations
Pellegrini et al 2017



Thin bark tree
Active fire

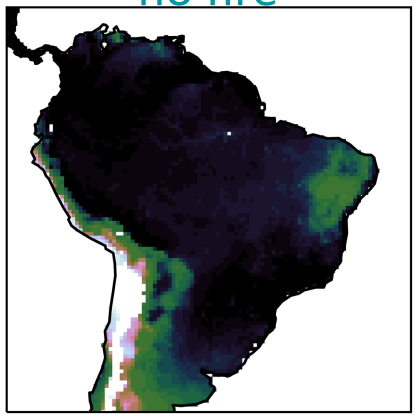


Thick bark tree
Active fire

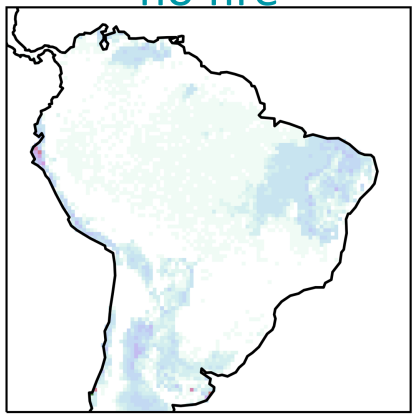


C4 grass
Active fire

Thin bark tree
no fire

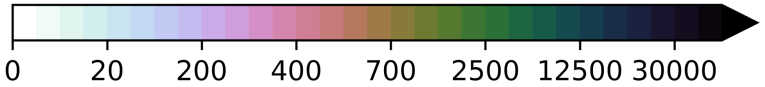


Thick bark tree
no fire

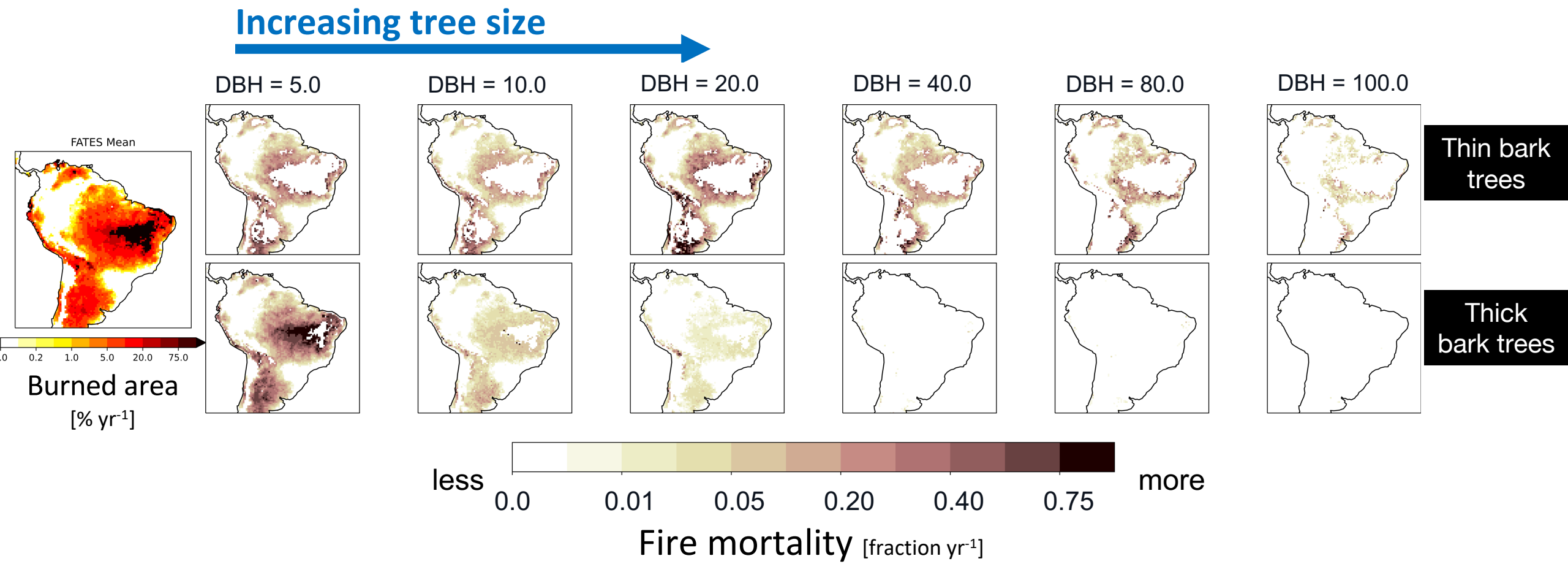


C4 grass
no fire

Biomass [g C m^{-2}]



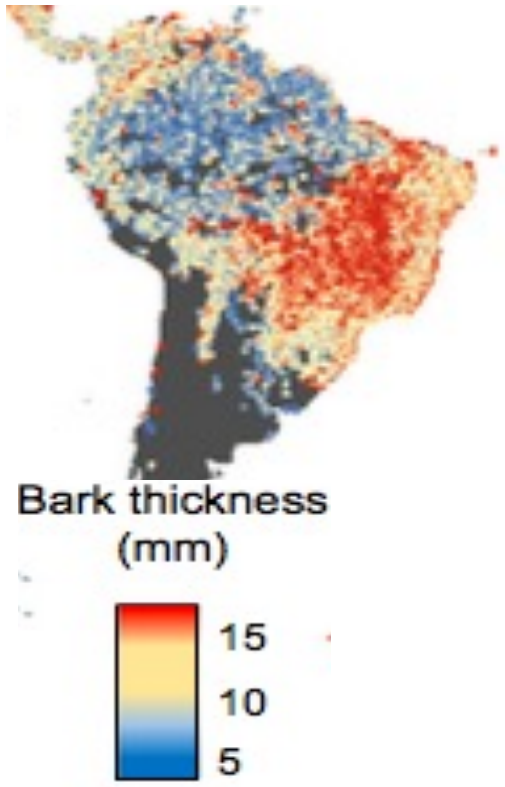
Size- and trait-based mortality impacts survival



Vulnerability/resistance is a function of feedbacks between traits and fire regime

Shift in fire regime shifts biogeography

Observations
Pellegrini et al 2017

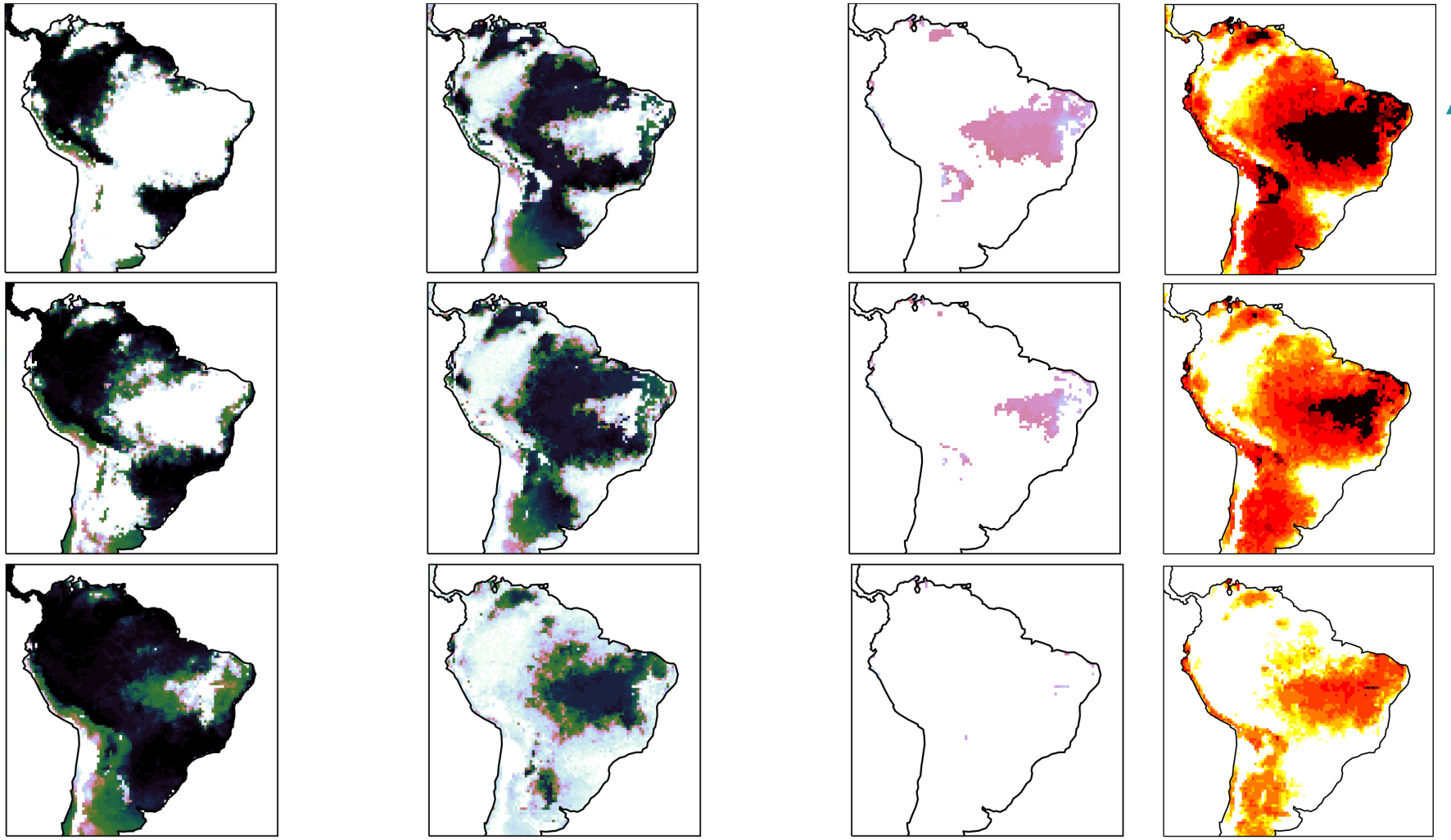


FATES
Thin bark tree

FATES
Thick bark tree

FATES
C4 grass

FATES
Burned fraction

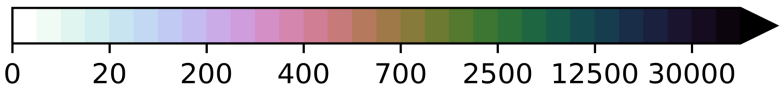


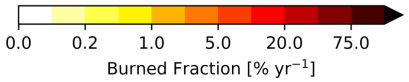
more dry fuels

Increase drying

less dry fuels

Biomass [g C m^{-2}]

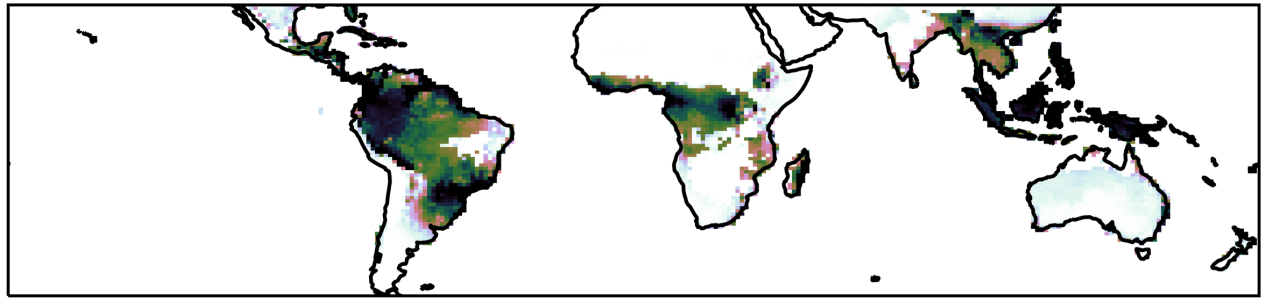




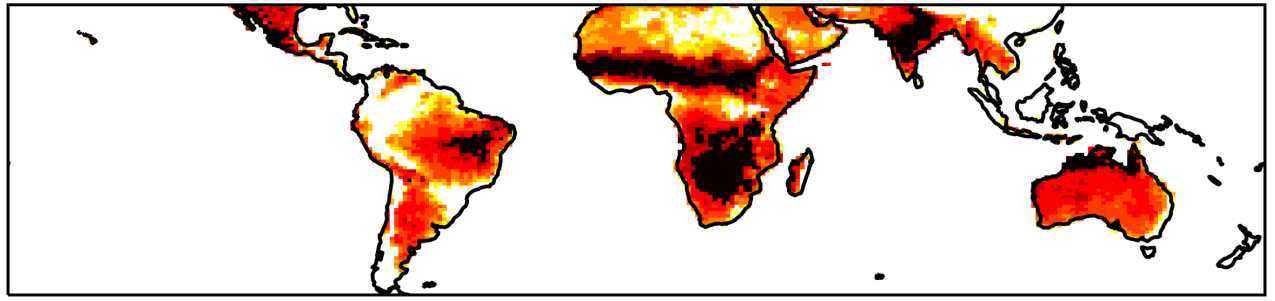
Conclusions

- FATES captures dynamic biogeography and biomass
- Fire feedbacks determine plant survival
- Critical for tropical simulation

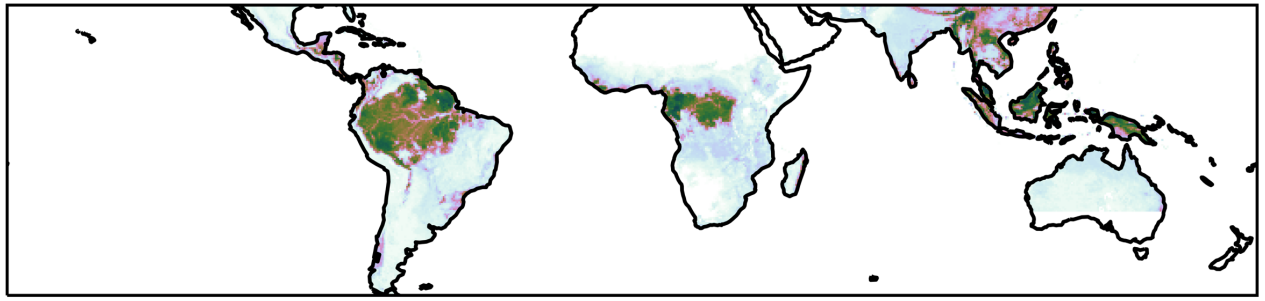
FATES Active fire



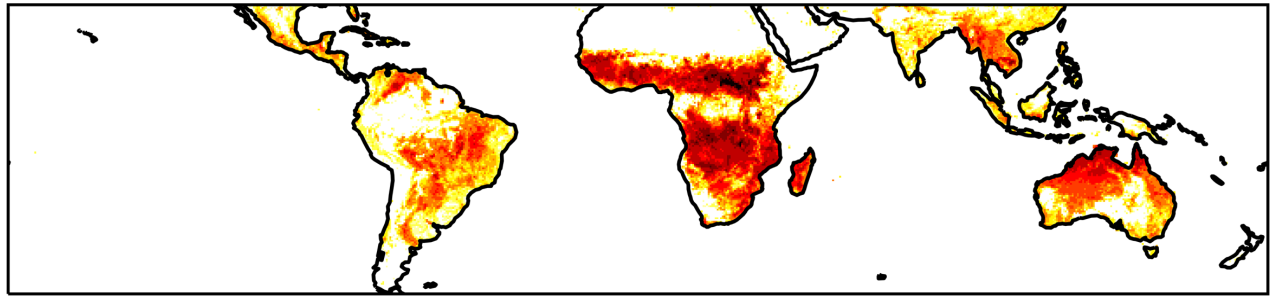
FATES Active fire

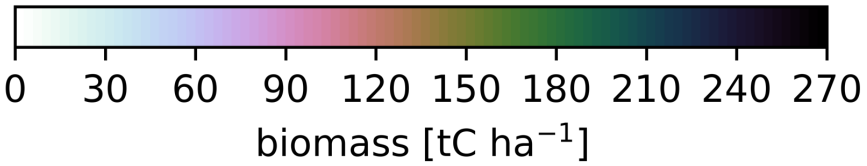


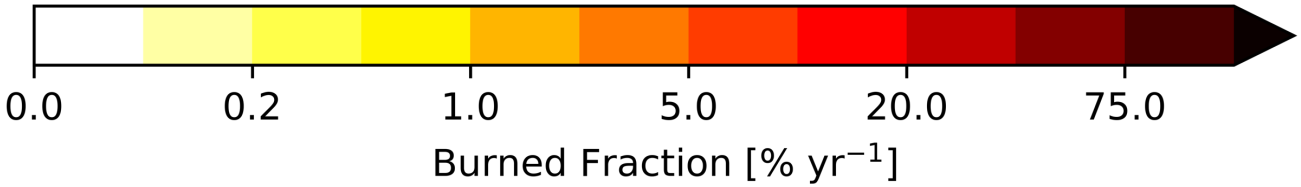
Observations Saatchi et al 2011



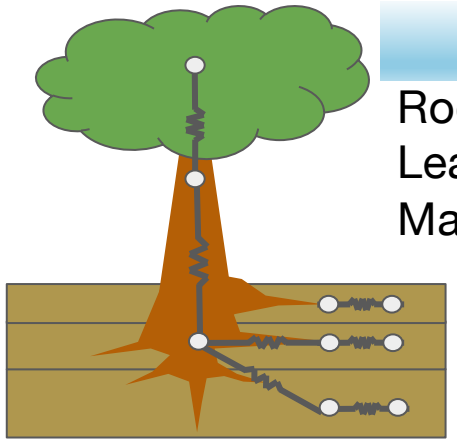
Observations GFED4.1s







FATES



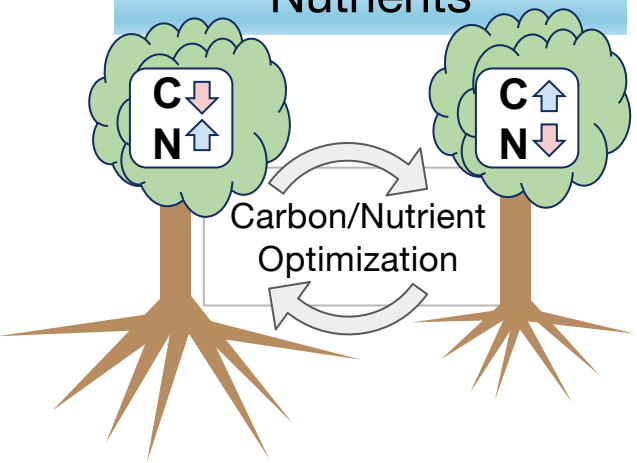
Plant Hydraulics

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

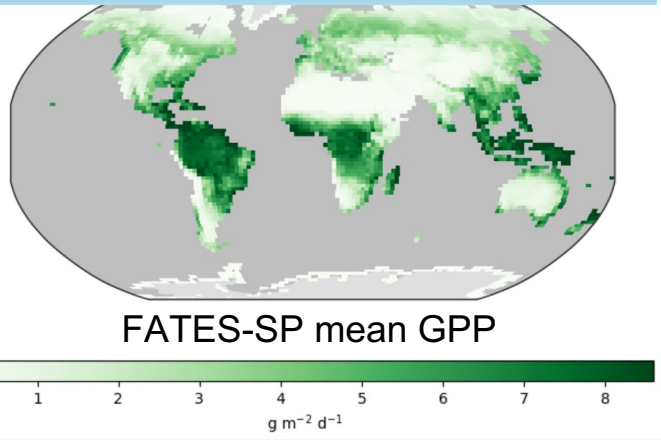
Fire

Live fuel moisture
Crown fire

Nutrients

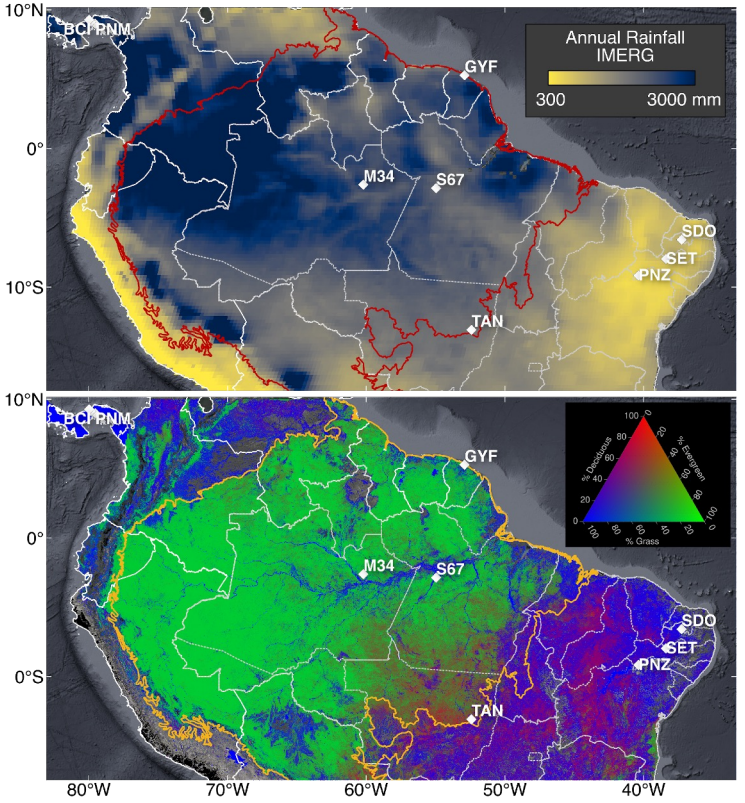


Reduced Complexity modes



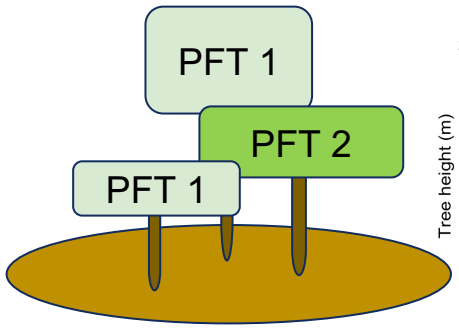
Deciduous Phenology

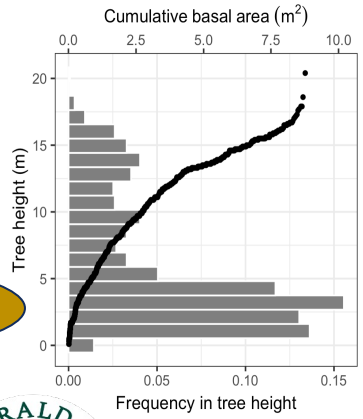
Forest resilience to drought

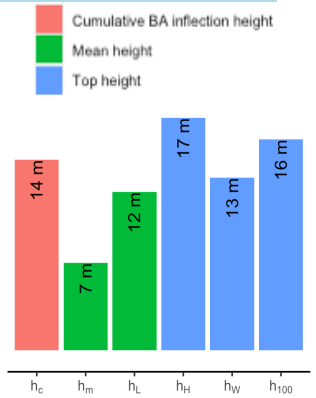


Moss

Canopy turbulence for mixed vegetation







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

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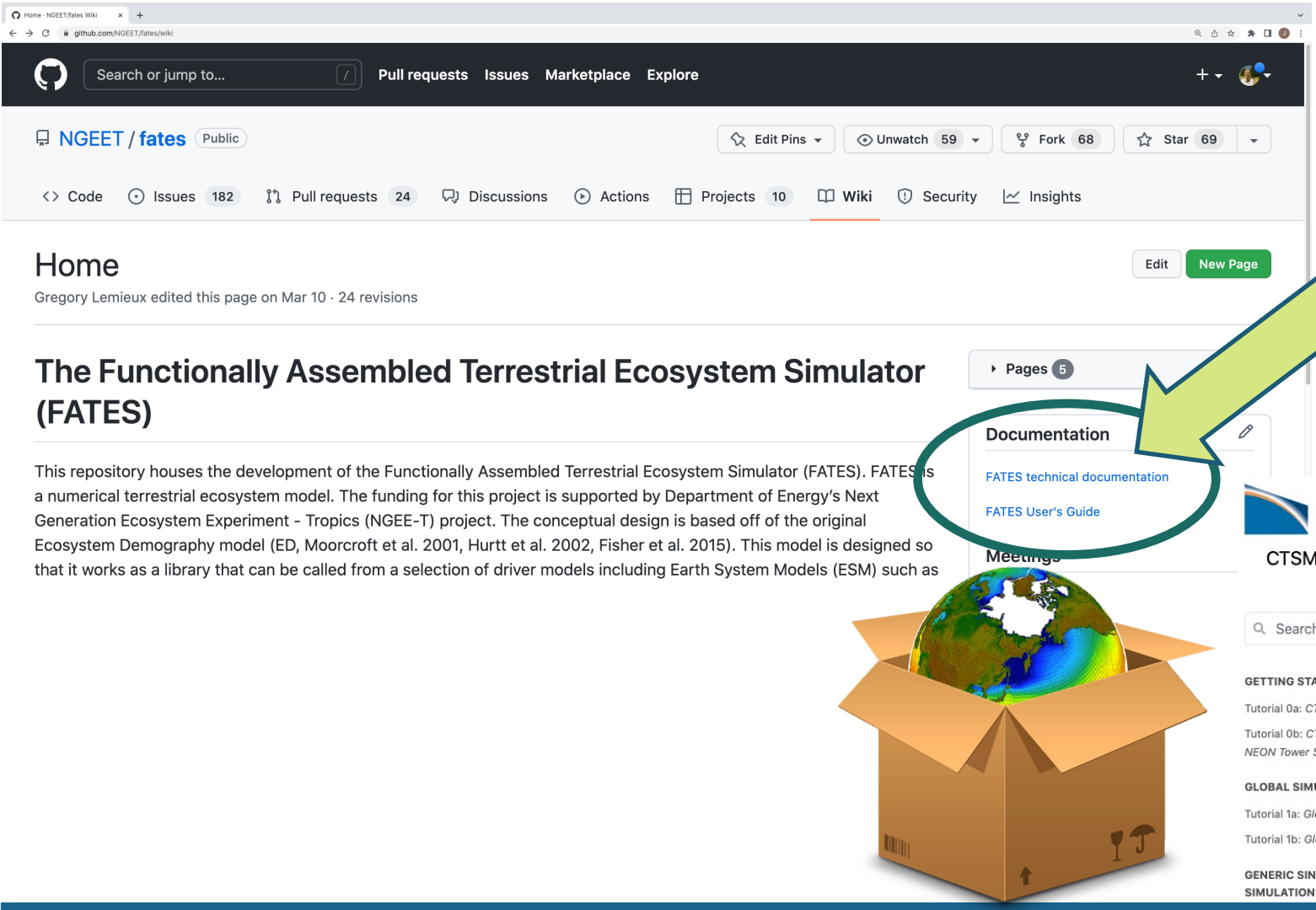
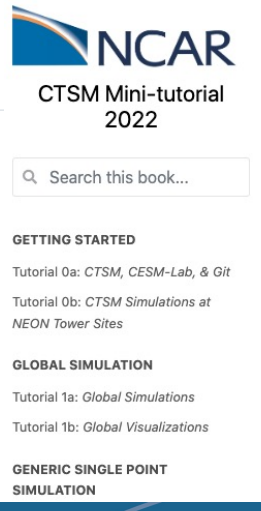
FATES code and information

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?

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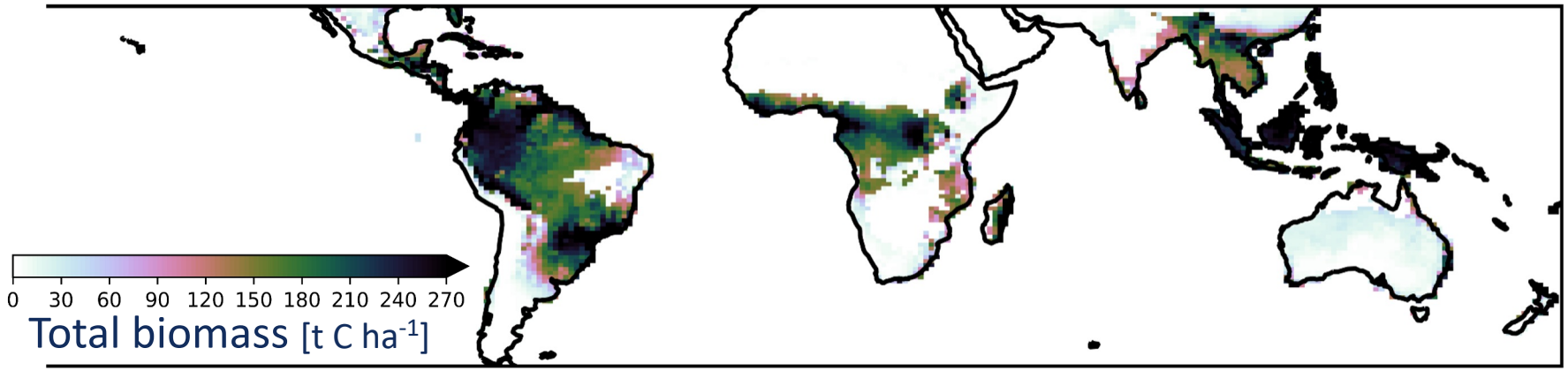
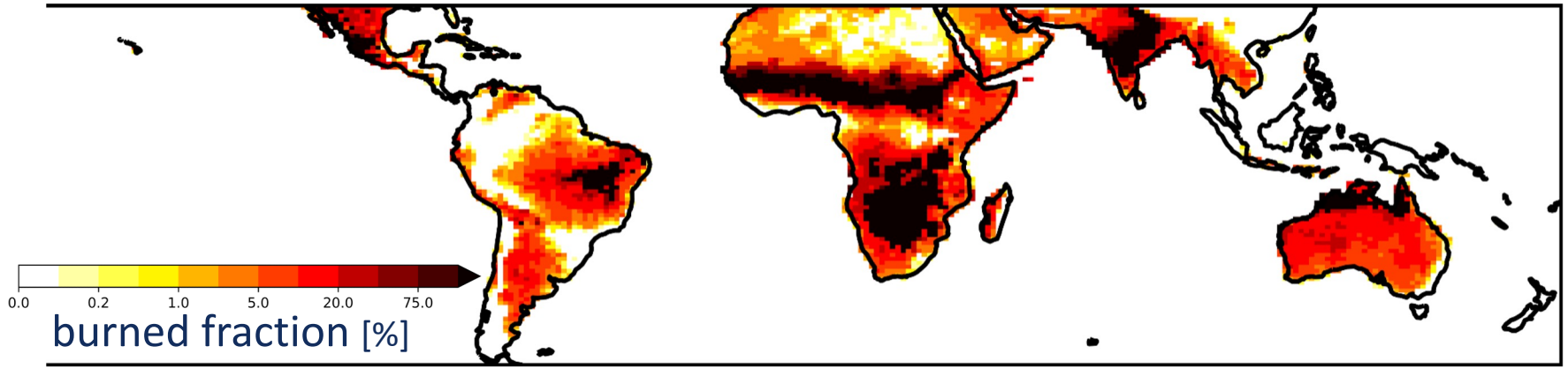
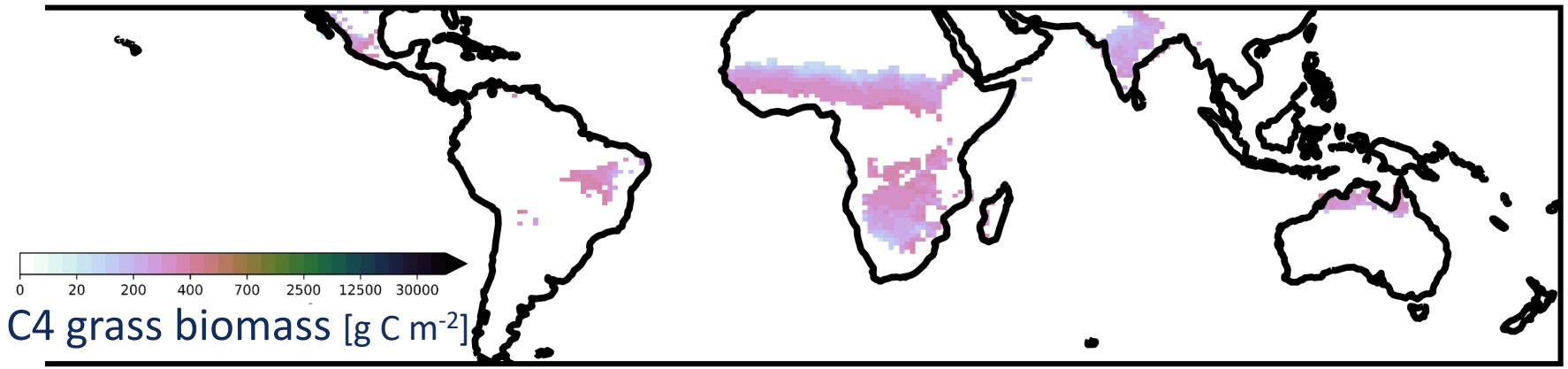
Conclusions







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