

Fire behavior and effects: importance of feedbacks between vegetation structure and fire risk

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Active fire counts

 FIRMS
Fire Information for Resource Management System

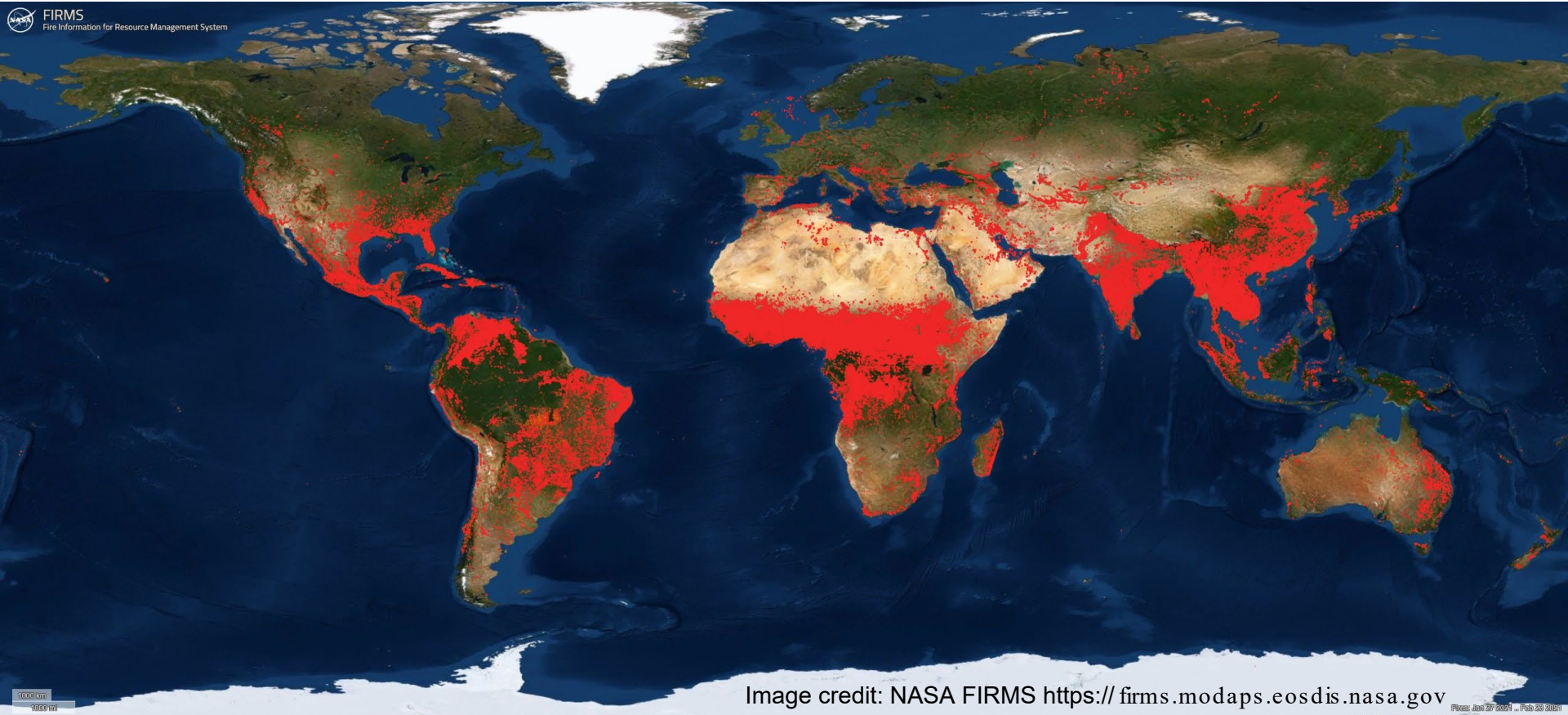
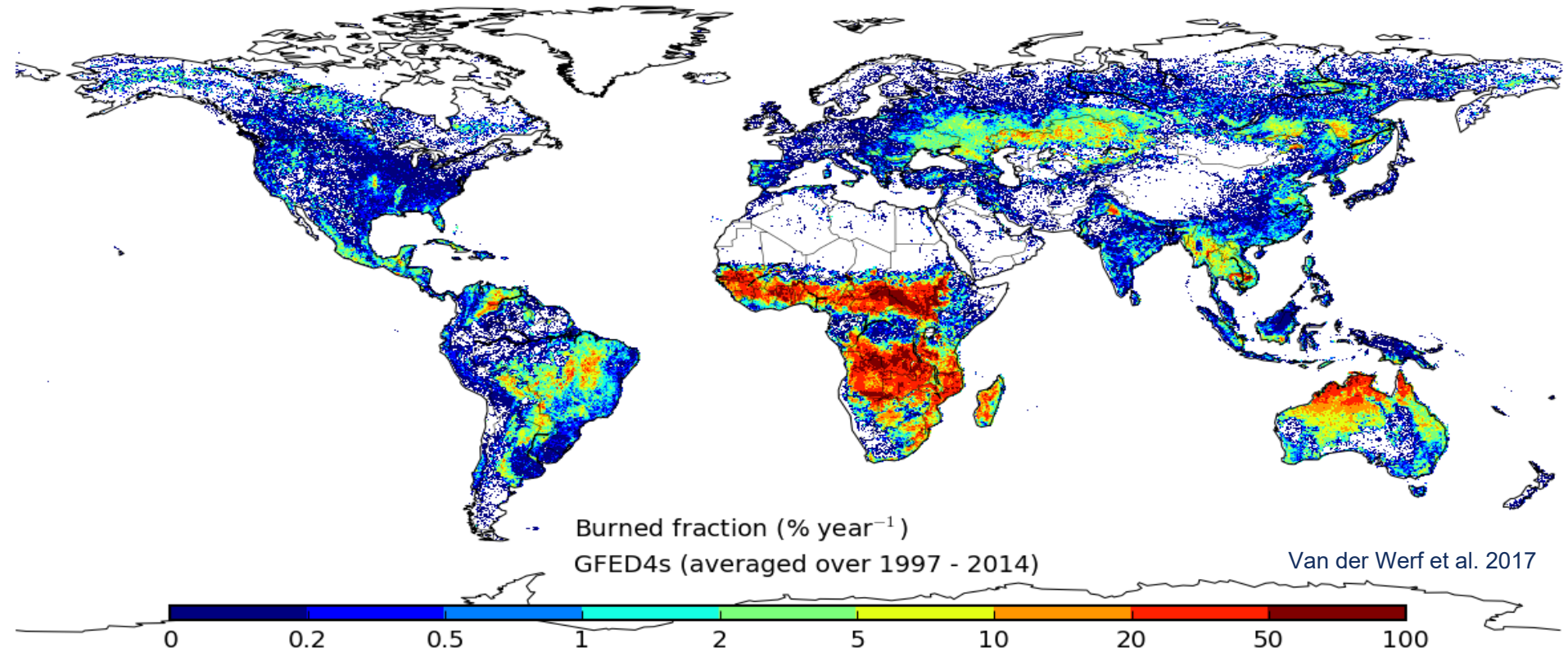


Image credit: NASA FIRMS <https://firms.modaps.eosdis.nasa.gov>

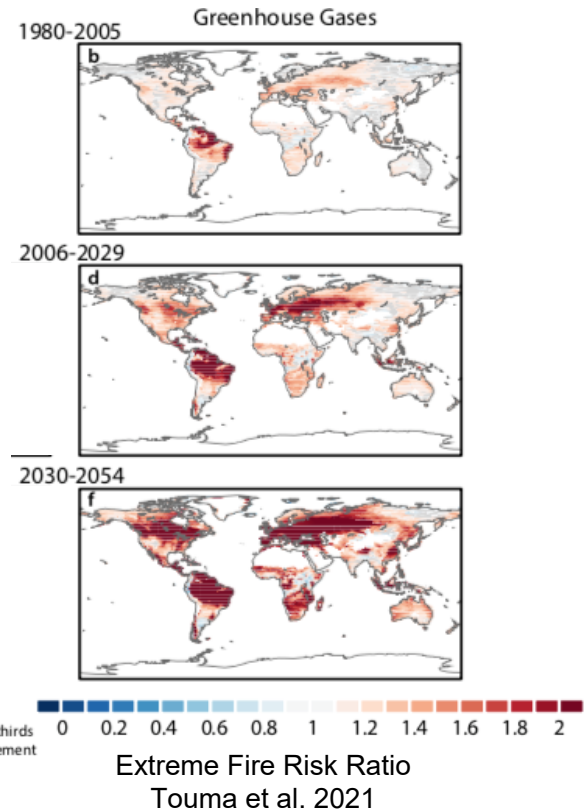
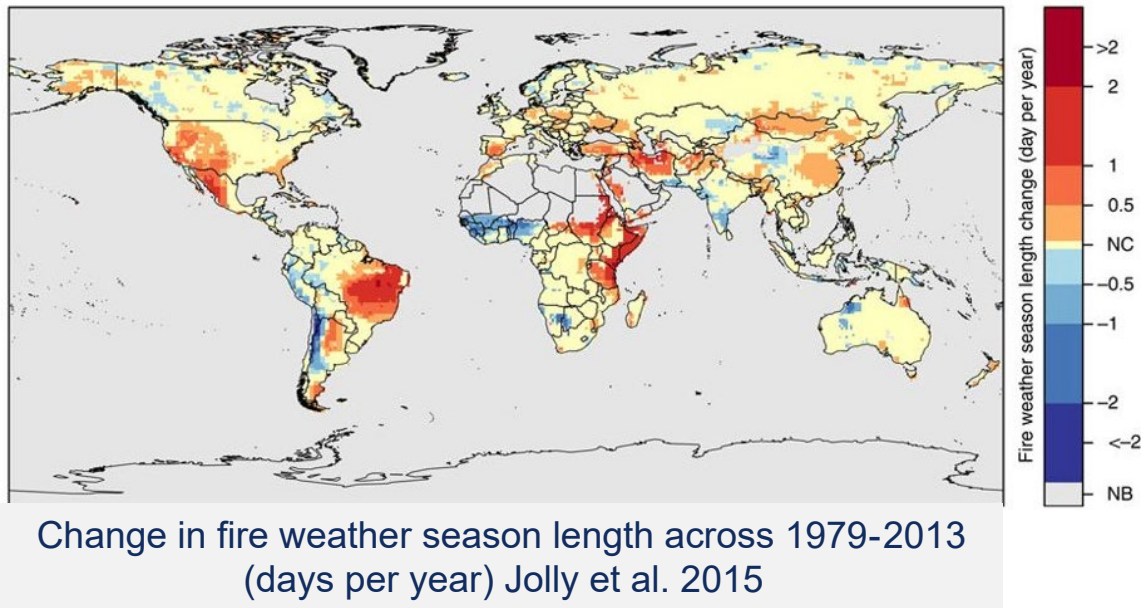
Processed: Jan 27 2024 ... Feb 23 2024
The Feb 23 2024 16:11:44 GMT-0700 (Mountain Standard Time)

Global Burned fraction



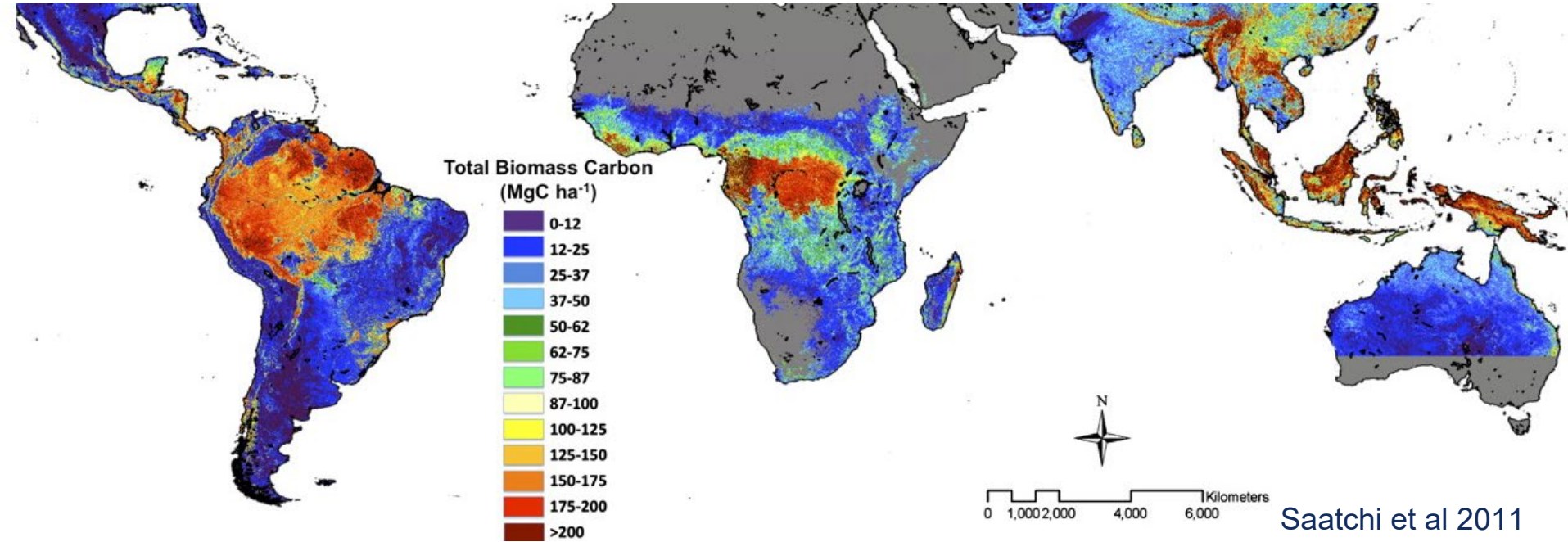
- Fire regime is interaction of climate, vegetation and ignitions over decades to centuries

Increasing Fire danger



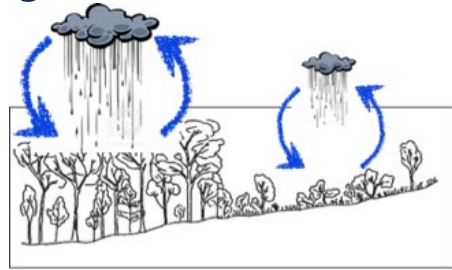
- Anthropogenic change (heating, longer dry seasons, increasing land use) increases risk of more frequent and severe fires

Vulnerable carbon stores



- Tropical forests hold 247 Gt C, with 193 Gt C aboveground

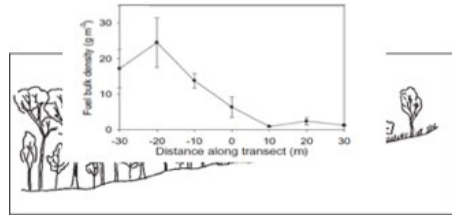
Model projections must capture feedbacks



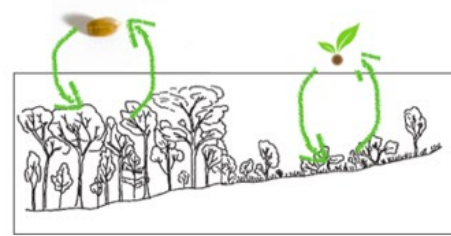
Land-atmosphere feedback



Wind speed feedback



Flammability feedback

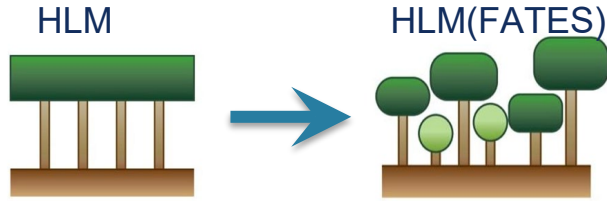


Demographic feedback

Adapted from Hoffman et al 2011

- Complex & dynamic feedback between vegetation structure and fire risk
- Adaptation of SPITFIRE (Thonicke et al 2010) into FATES (Fisher et al 2018)

FATES: The Functionally Assembled Terrestrial Ecosystem Simulator

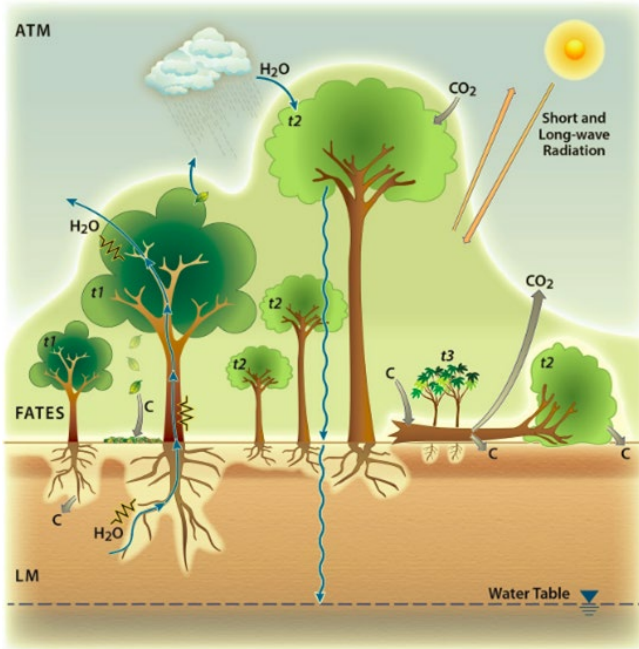


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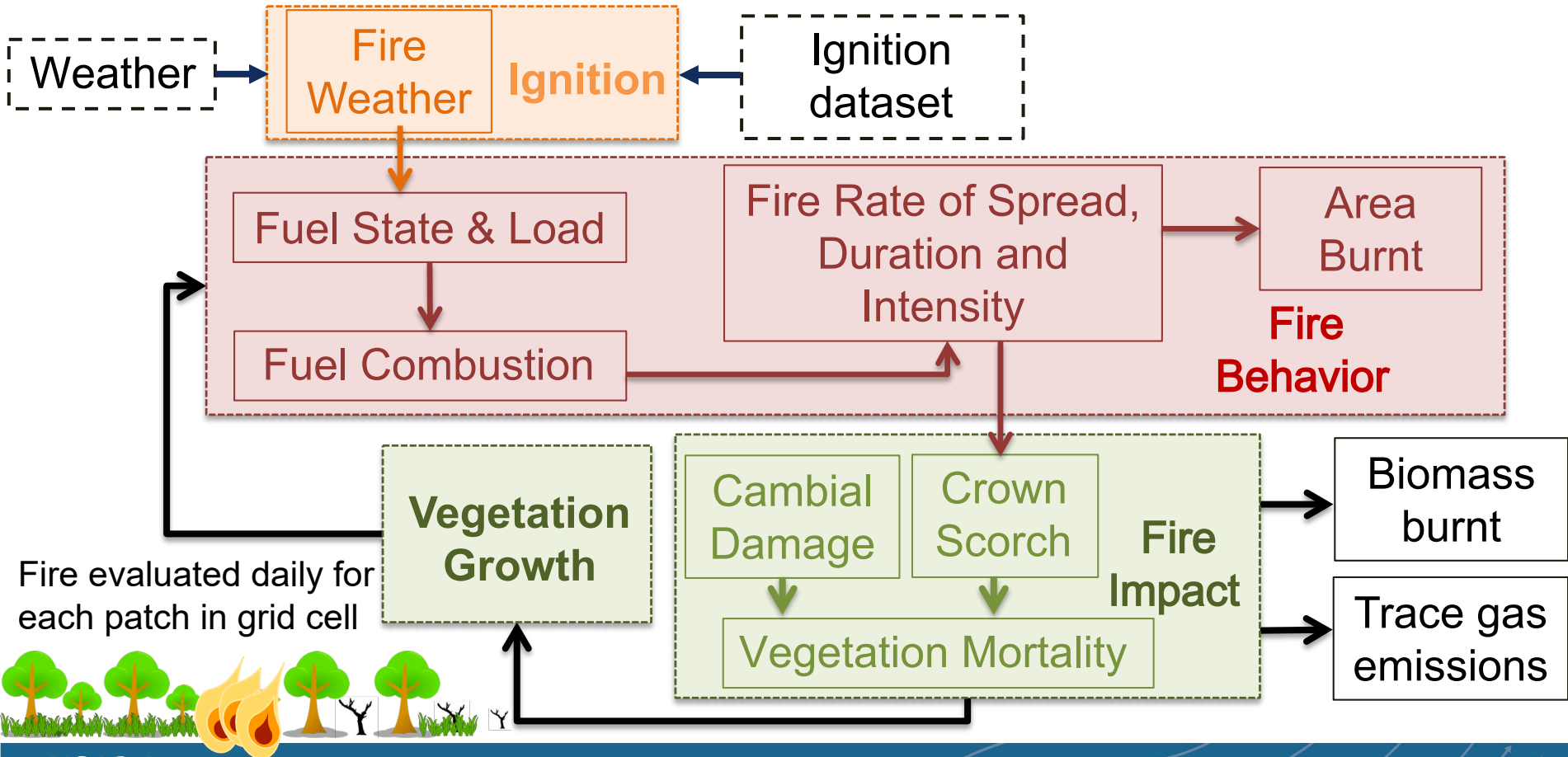
NGEE-TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS



FATES
is a module,
runs within a Host Land Model,
replaces traditional process with
more realistic vegetation
that simulates:
plant physiology,
competition processes,
ecosystem assembly
vegetation distribution
(cutting edge for these models)

Fisher et al. 2015; Fisher et al. 2018

FATES-SPITFIRE



FATES-SPITFIRE vegetation mortality

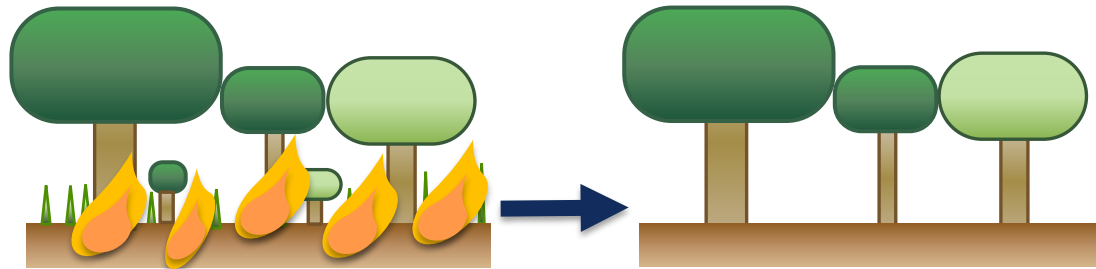
Tree mortality :

Fire intensity and duration

Scorch height (relative to canopy height)

Bark damage varies with bark thickness (varies by PFT & size)

Grasses are not protected, and burn with all fires.



FATES retains the fire-affected canopy structure
thus affecting future fire behavior

Notable Fire updates

- EQ for fuel drying and fire intensity; decoupled seed decay and fire behavior
- Updated fire ellipse shape to be dynamic based on dominance of trees vs grasses
- Fixed typo for ellipse shape for grass fuels present in all SPITFIRE variants

Pages 44 and 58: Equation 80 should read,

$$LB = 1.1 \times WSV^{0.464}, WSV \geq 1.0 \quad (80)$$

Updates and Revisions to the 1992 Canadian Forest Fire Behavior Prediction System.
Wotton et al. 2009

The length-to-breadth relationship for grass fuel types (O-1) is as follows (see also Fig. 22):

$$LB = 1.1 + WSV^{0.464} \quad WSV \geq 1.0 \quad (80)$$

CFFBS. Ont. Int. Rep ST-X-3, 1992

correction

Typo persists

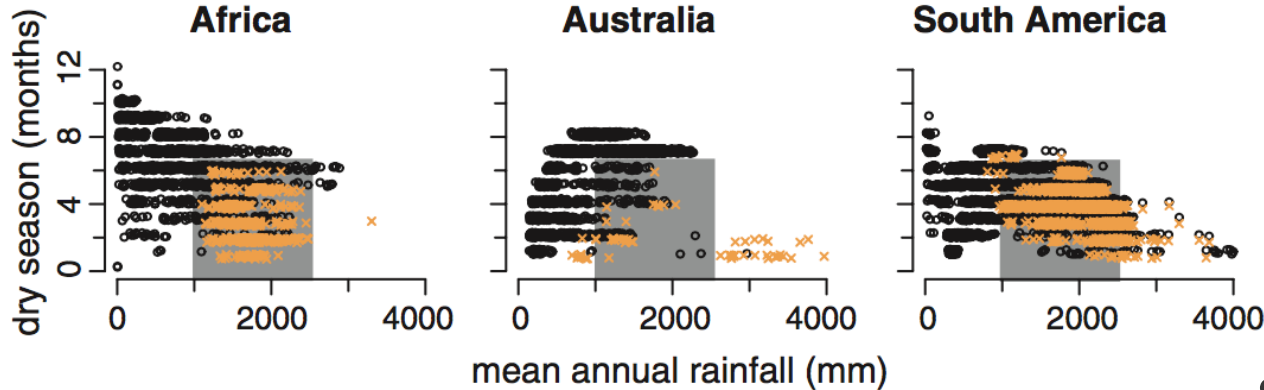
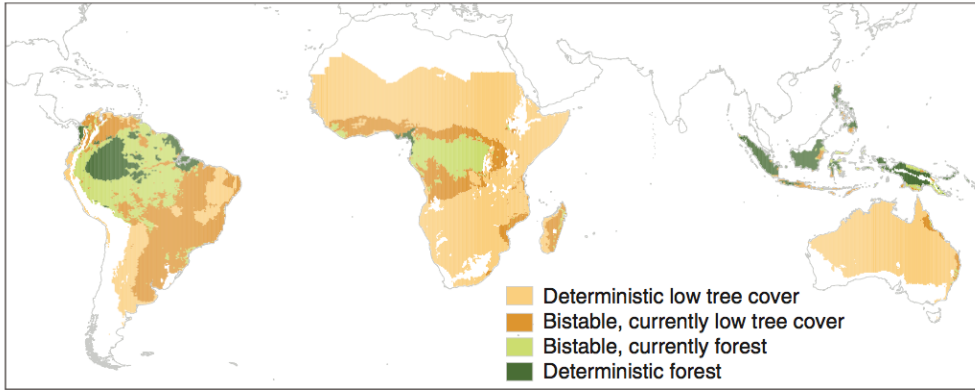
$$L_{B, \text{grass}} = 1.1 + U_{\text{forward}}^{0.464} \quad (13)$$

Thonicke et al. 2010 (and all SPITFIRE variants, incl FATES)

Forest/Savanna bi - stability

Important Factors:

- Climate
- Seasonality (# dry months)
- Fire
- Vegetation Traits and state

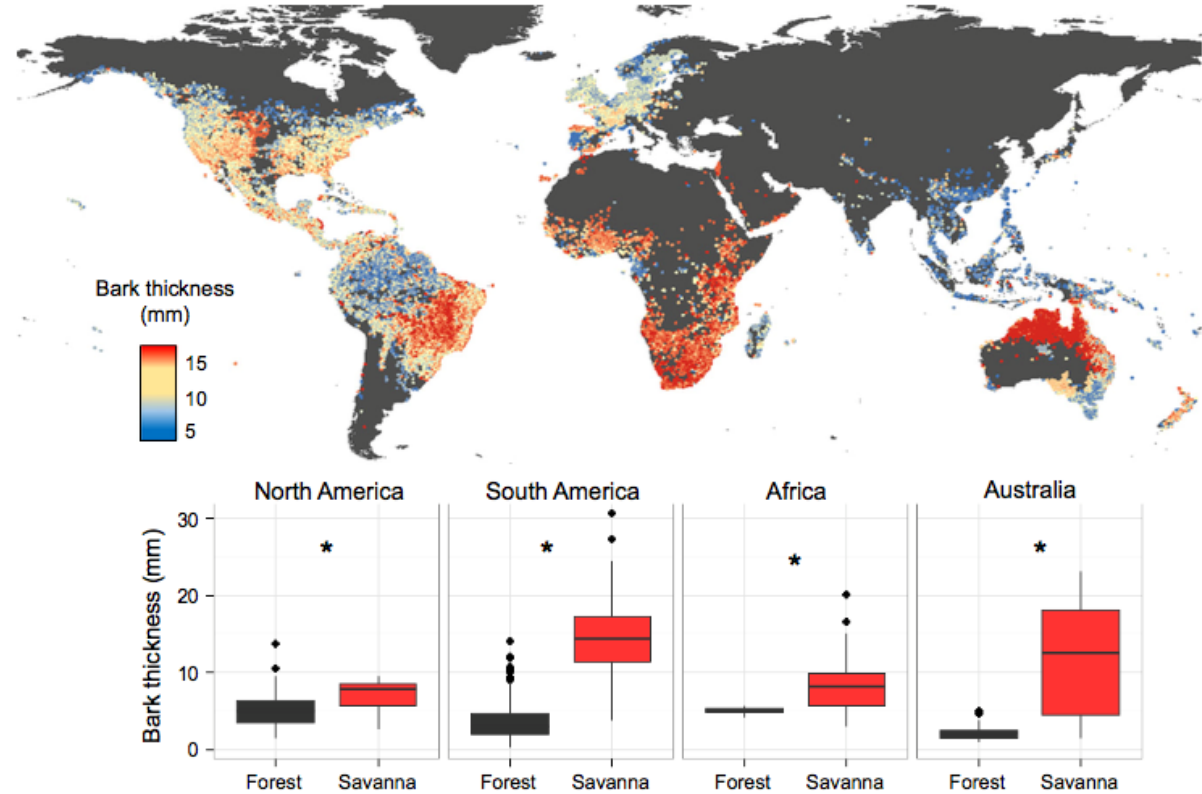


x = forest (> 55% trees)
o = savanna

Staver *et al.* 2011 *Science*

Bark thickness as vulnerability indicator

- Annual burned area explained 20% global variation in bark thickness
- Tropics: bark 3 times thicker in savanna than forests
- Infrequently burned areas have thin bark – vulnerability for future



Pellegrini *et al.* 2017 *Ecology Letters*

How do vegetation traits impact ecosystem assembly and fire behavior?

Trees & Grass

75 years



Trees & Grass+ Fire 75 years



0.9 x 1.25 km runs

GSWP3 climate data (1995-2013)

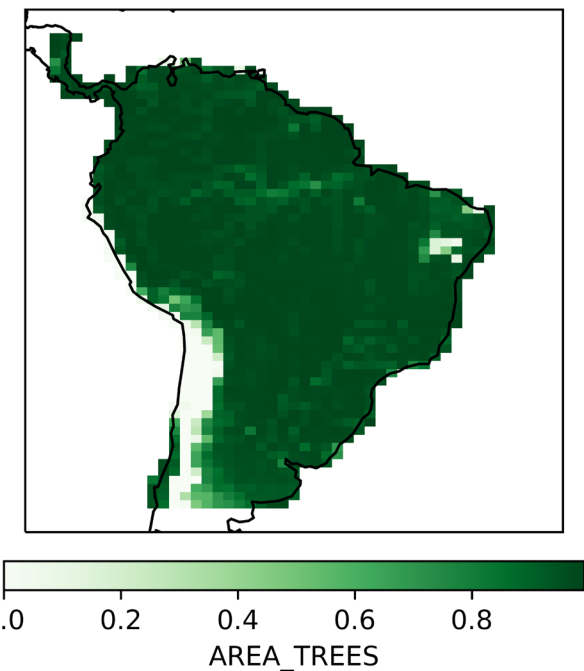
Lightning strikes (NASA LIS/OTD)

Average across final 10 years

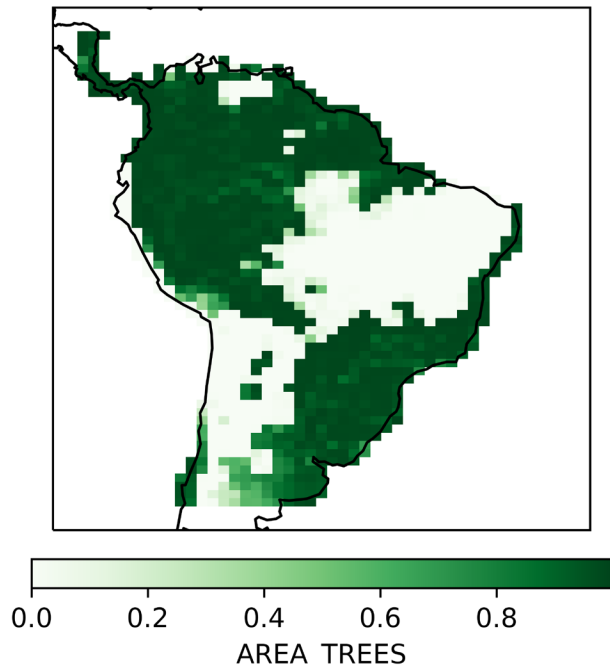
	Crown and Leaves	Leaf lifespan	Fire resistance
Moist Tropical Tree	Large crown, vulnerable foliage	Long (~1 yr)	vulnerable thin bark
Dry Tropical Tree	Thin crown, tolerant foliage	Long (~1 yr)	fire-adapted thick bark
C4 Grass	n/a	Short (~4 months)	None

Fire acts to limit tree extent

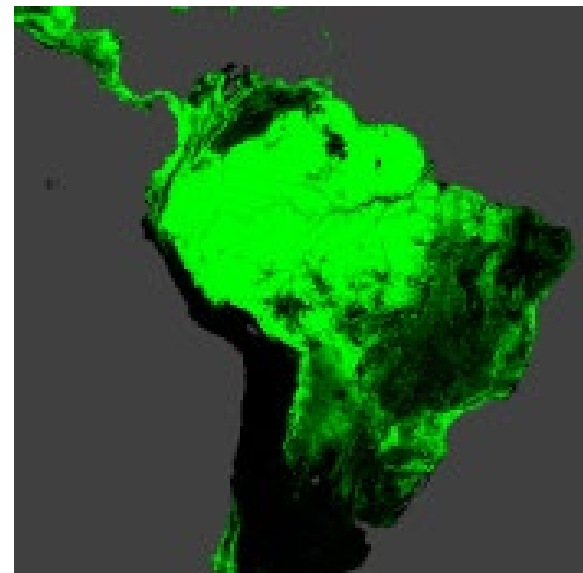
Moist & Dry Trees, Grass
No Fire



Moist & Dry Trees, Grass
Fire from bare ground



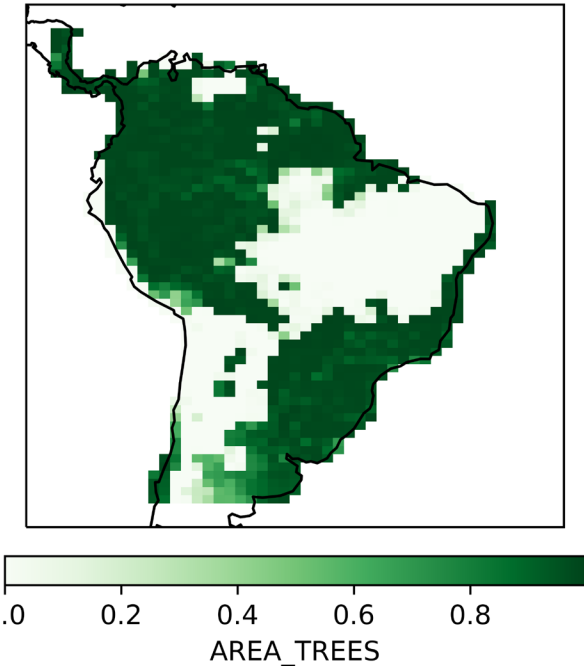
Observations Landsat



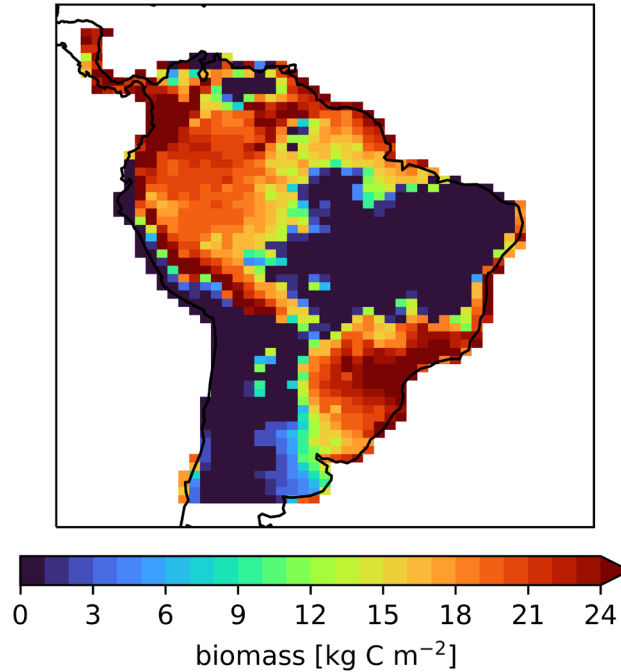
Hansen, M. C., et al.
(2013) *Science*

Biomass of forest

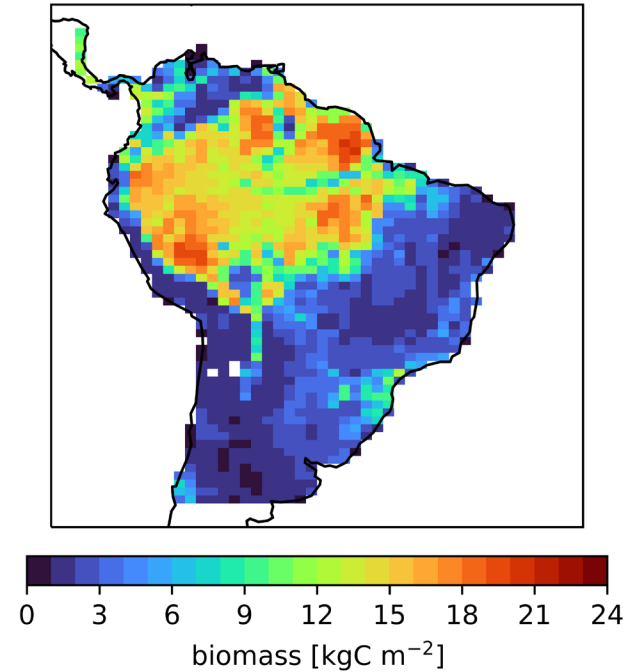
Moist & Dry Trees, Grass
Fire from bare ground



Moist & Dry Trees, Grass
Fire from bare ground



Observations
Saatchi et al 2011

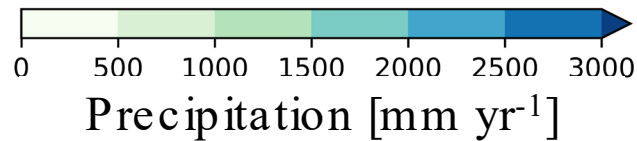
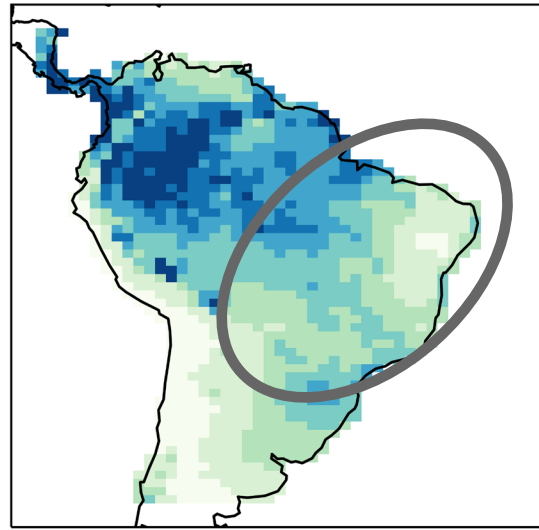
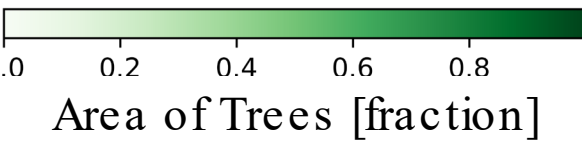
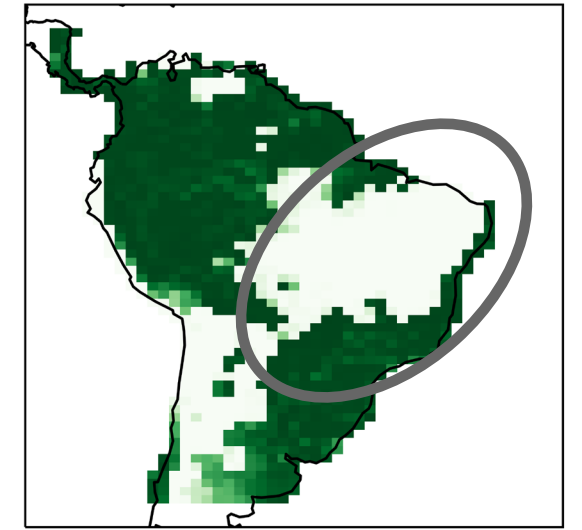


Precipitation as determinant of forest

Moist & Dry Trees, Grass
Fire from bare ground

Climate Reanalysis
GSWP3

Staver et al 2011

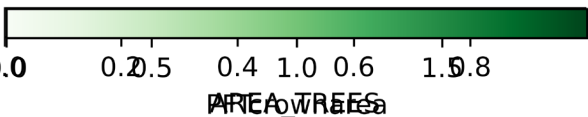
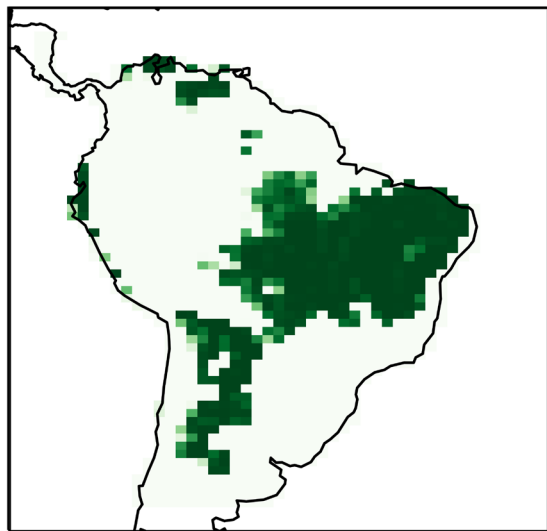


- Deterministic low tree cover
- Bistable, currently low tree cover
- Bistable, currently forest
- Deterministic forest

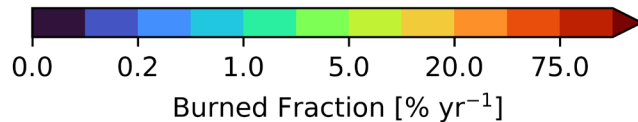
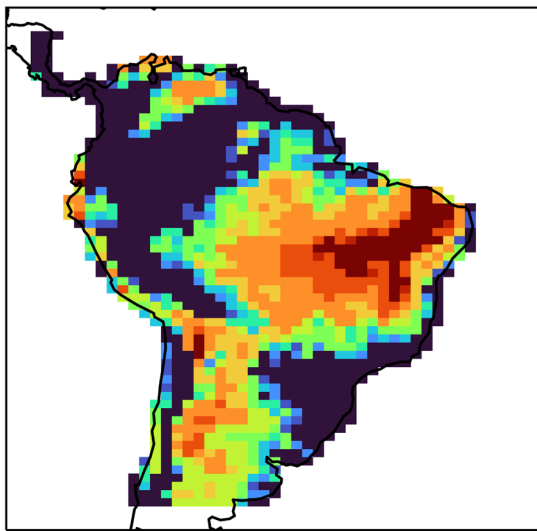
Fire as a limit on forest

Observations

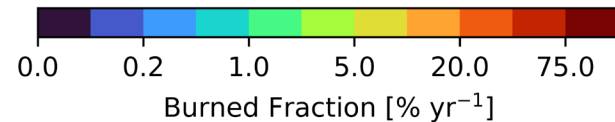
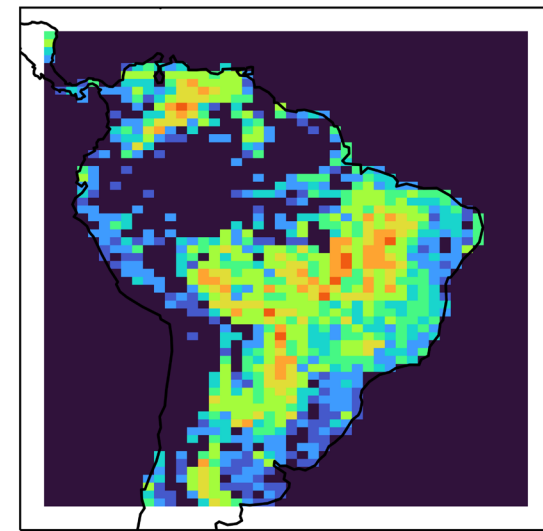
FATES Trees



FATES Mean



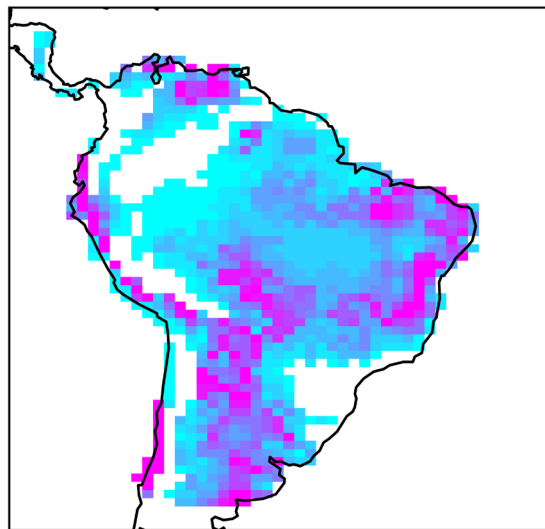
GFED4s



Fire as determinant of forest

Observations

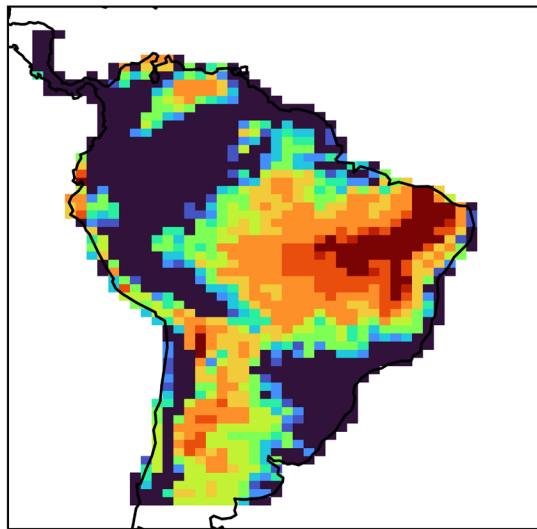
FATES Mean



1000 2000 3000 4000 5000

Fire Intensity [kW m^{-1}]

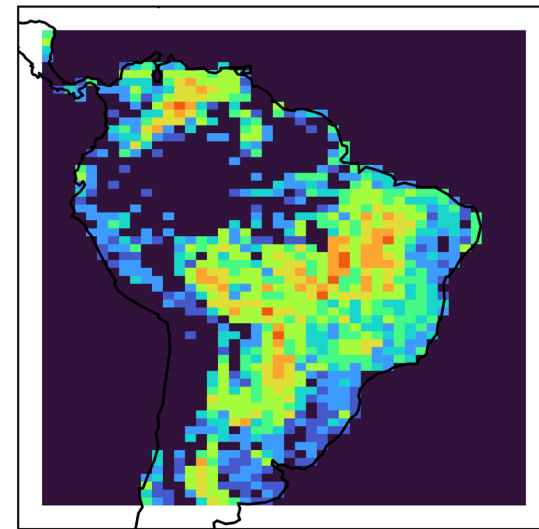
FATES Mean



0.0 0.2 1.0 5.0 20.0 75.0

Burned Fraction [$\% \text{ yr}^{-1}$]

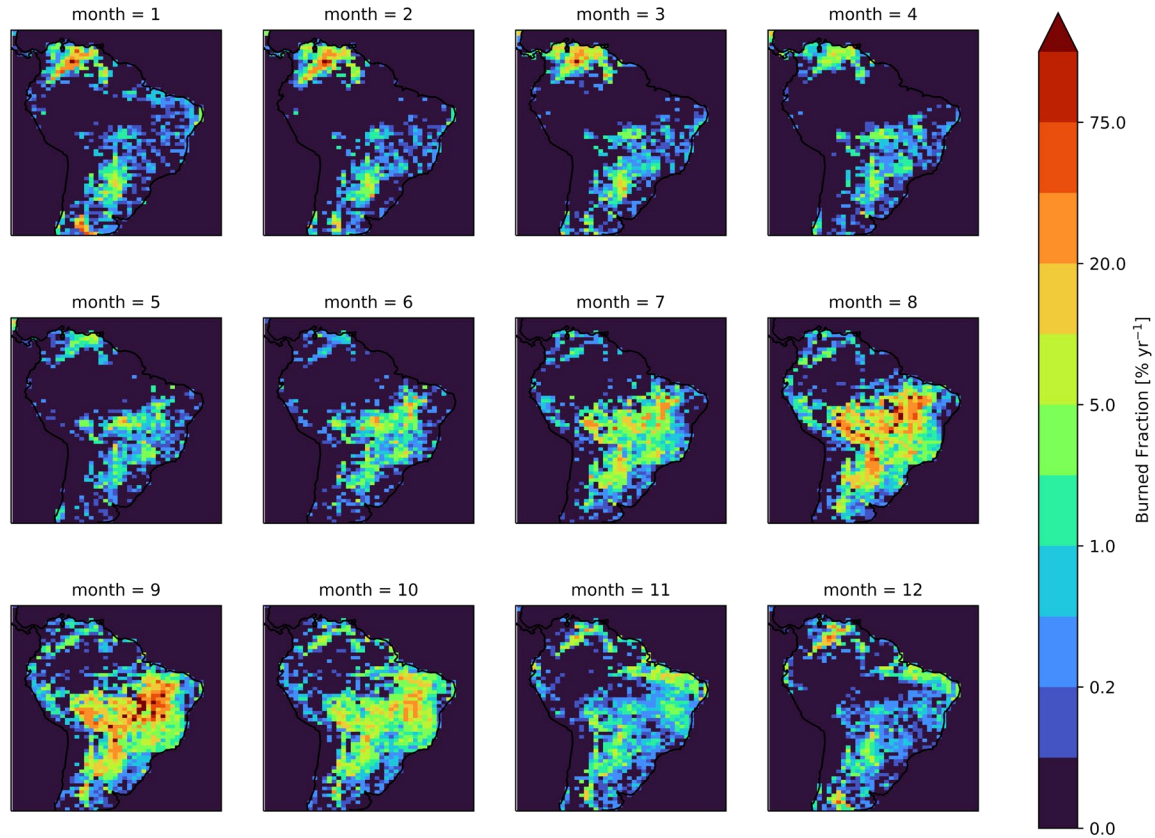
GFED4s



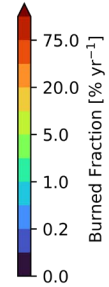
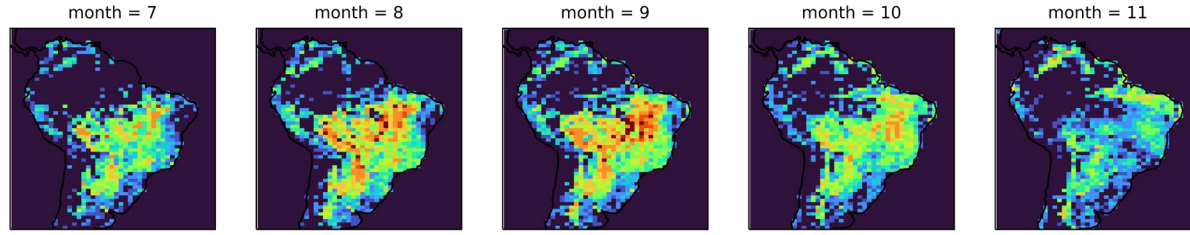
0.0 0.2 1.0 5.0 20.0 75.0

Burned Fraction [$\% \text{ yr}^{-1}$]

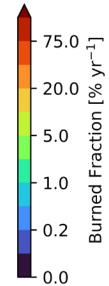
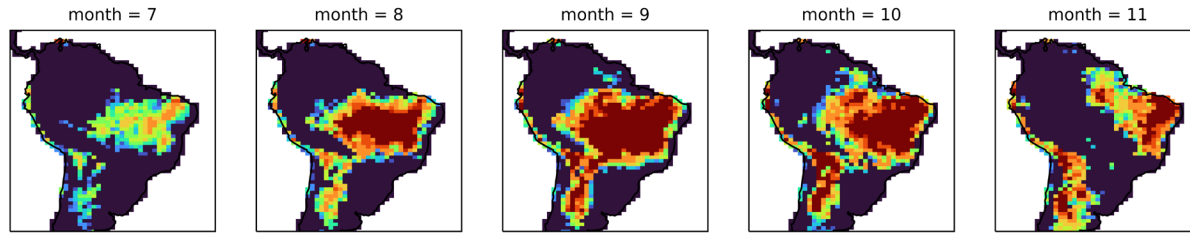
Fire Season: Observations GFED4s



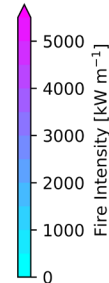
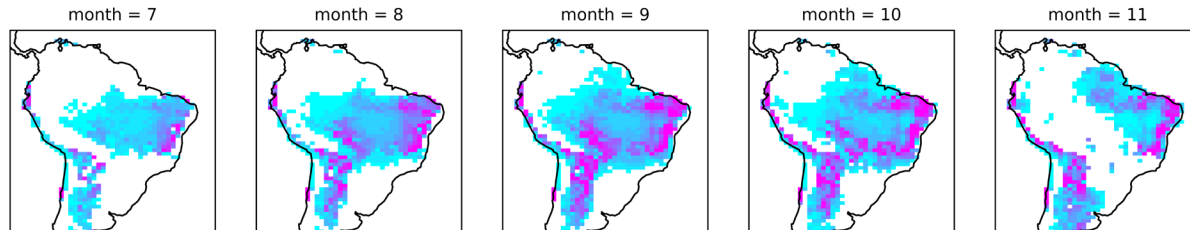
Fire Season



Observations
GFED4s
Burned
Fraction
[% yr⁻¹]



FATES
Burned
Fraction
[% yr⁻¹]



FATES Fire
Intensity
[kW m⁻¹]

Vegetation traits as determinant of forest

Size-structure and bark thickness

fates_levscls = 0.0

fates_levscls = 5.0

fates_levscls = 10.0

fates_levscls = 15.0

fates_levscls = 20.0

fates_levscls = 30.0

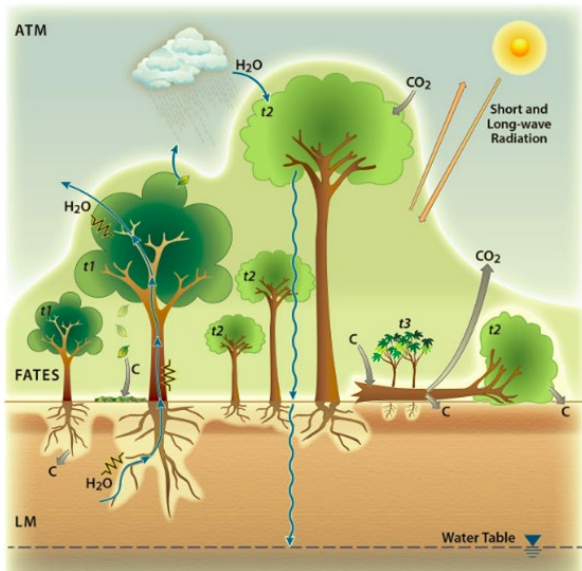
Thin bark tree

Thick bark tree



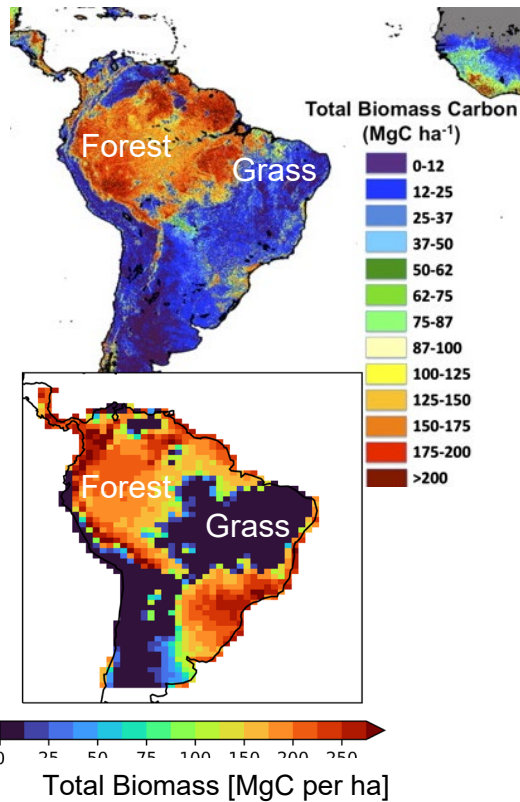
Fire mortality [fraction yr⁻¹]

CTSM-FATES-SPITFIRE: Dynamic disturbance and forest structure

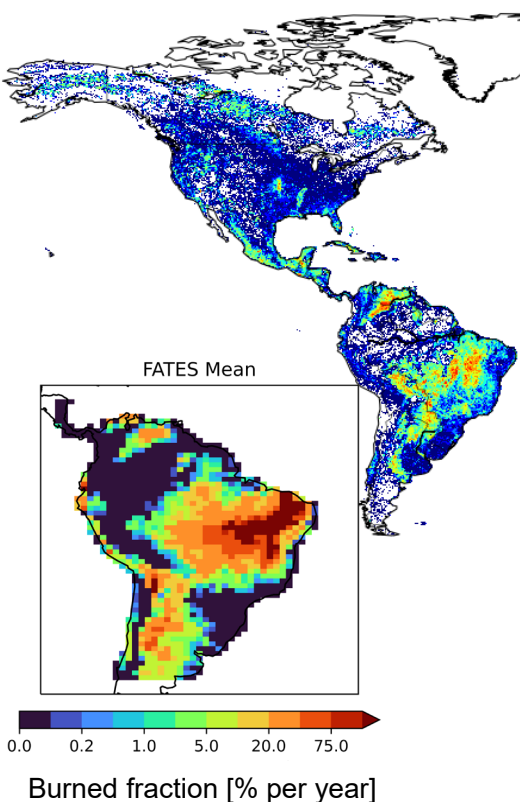


- Assembles ecosystem dynamically with plant interactions, degradation & loss
- Fire interacts with climate, fuel & vegetation
- **Increased fire feedback in grass areas**
- **Size and bark matters for fire survival**

Biomass observations
Saatchi et al 2011 PNAS



Burned area observations (1997-2014)
Van der Werf et al 2017





Vegetation traits as determinant of forest

Size-structure and bark thickness

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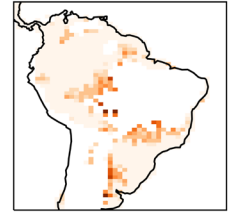
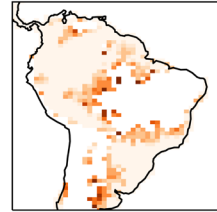
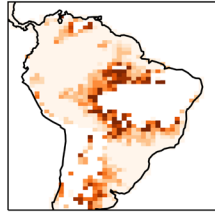
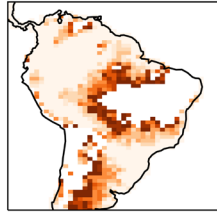
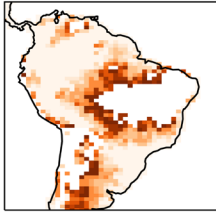
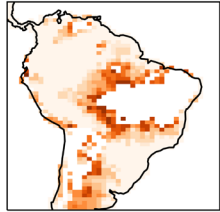
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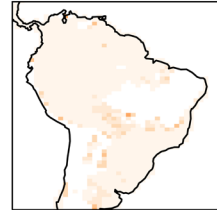
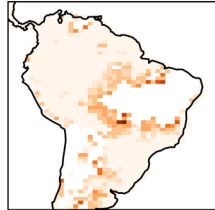
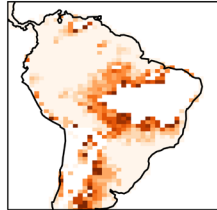
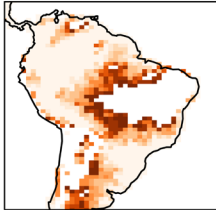
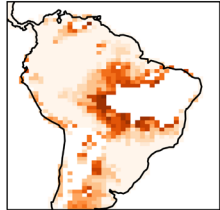
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Thin bark tree



Thick bark tree



Fire mortality [fraction yr⁻¹]