MODELING TROPICAL FOREST RESPONSE TO A CHANGING CLIMATE SYSTEM

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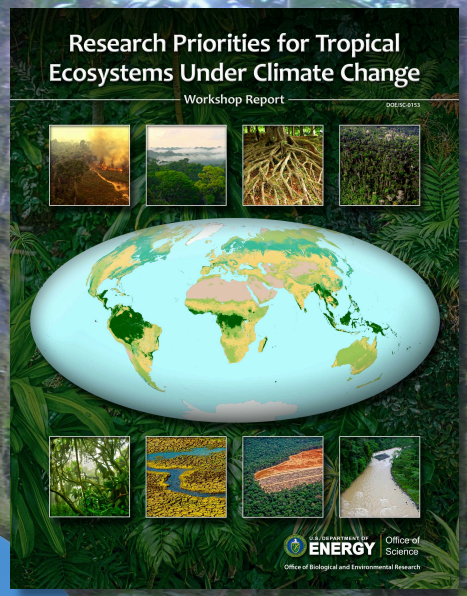
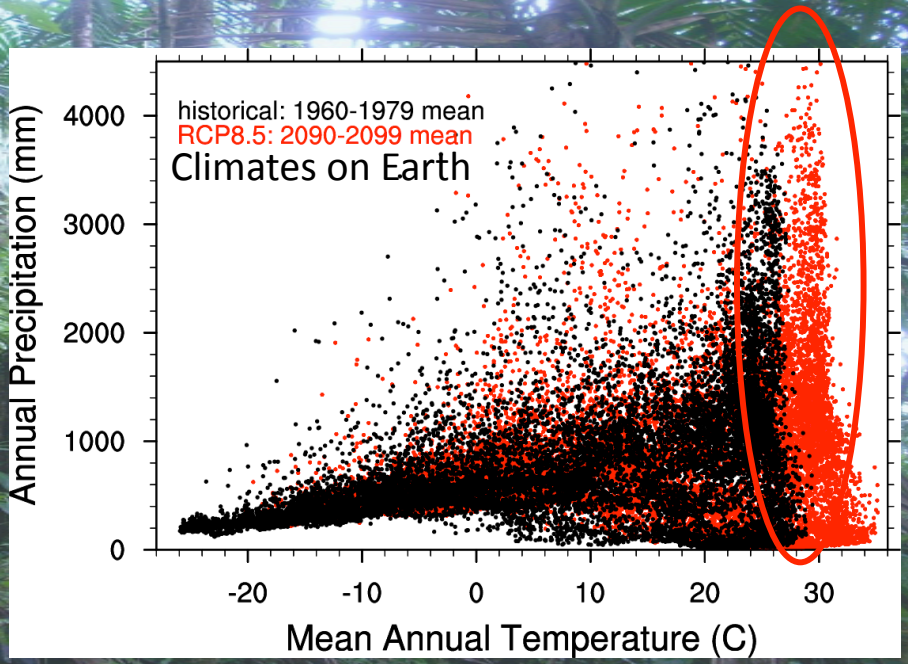
Why do we care about the tropical forests?

- Cycle more carbon and water than any other biome
- Play a critical role in determining the Earth's energy balance
- Provide climate regulation services; carbon sequestration
- Major component in land surface modeling in ESMs





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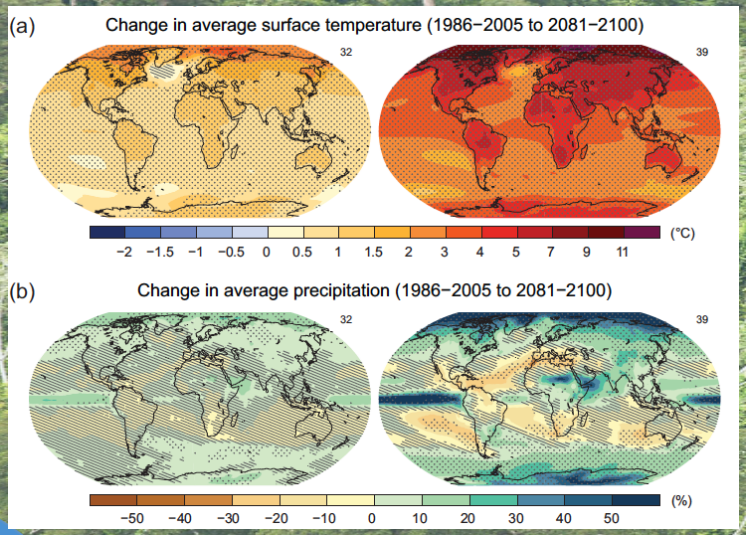
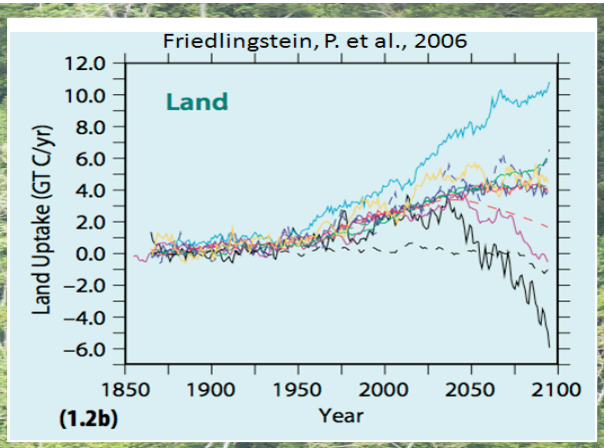
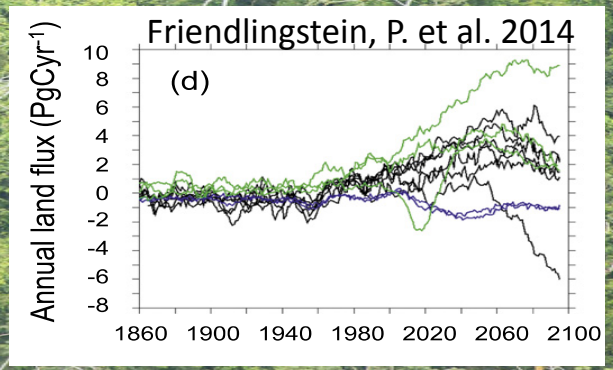
How are tropical forests changing?

- Land-use changes, increase in natural disturbances
- Novel ecosystems; Will be exposed to climates without analog on today's Earth
- Uncoordinated individual efforts can't tackle the difficulties of:
  - Integrating processes across vast scales
  - Developing highly-complex integrated computational models







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What are the model predictions?

- Increase in average surface temperature (C)
- Uncertainties in precipitation change (likely drying in the tropics)
- Wide range in land carbon uptake in ESM predictions (ranging from carbon source to sink)
- CMIP5 had participation of climate models with and without the carbon cycle

“ModEx” approach to develop modeling framework

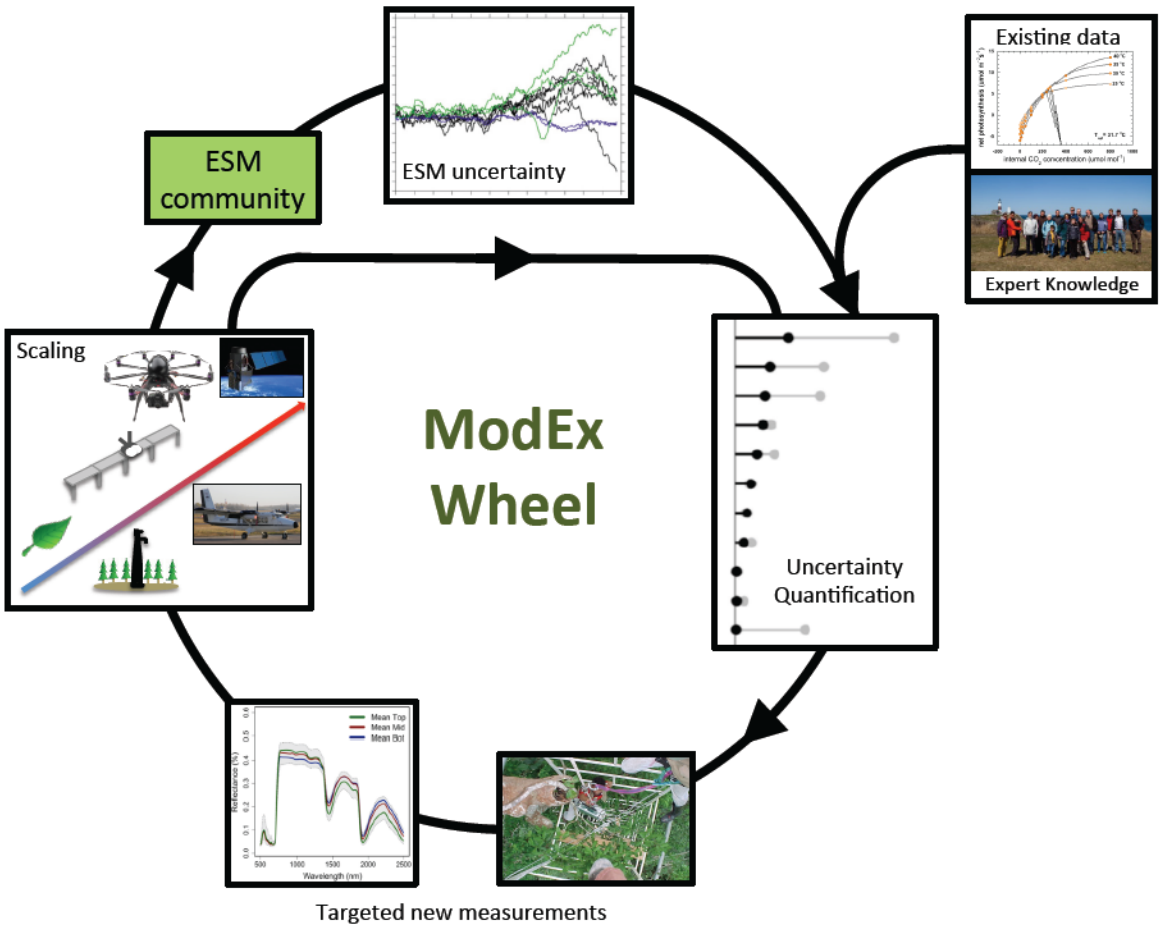
Develop Modeling Framework

Knowledge assessment
UQ, meta analysis, structural uncertainty

Prioritization
of gaps

Design and execute **ModEx loop** for priority gaps

Integrate
new model in Terrestrial Land Model

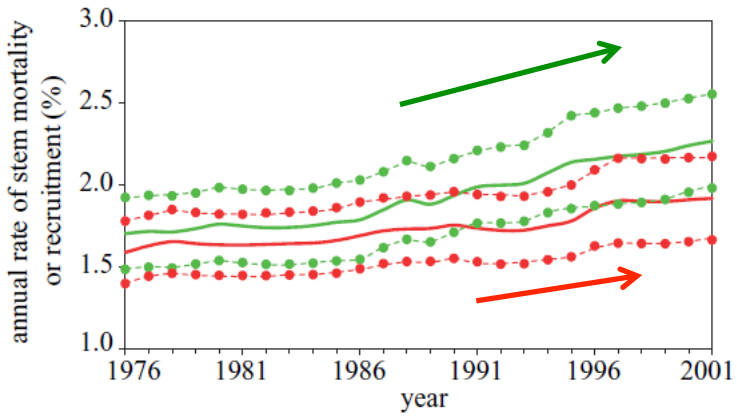


Increasing turnover rates in Amazon

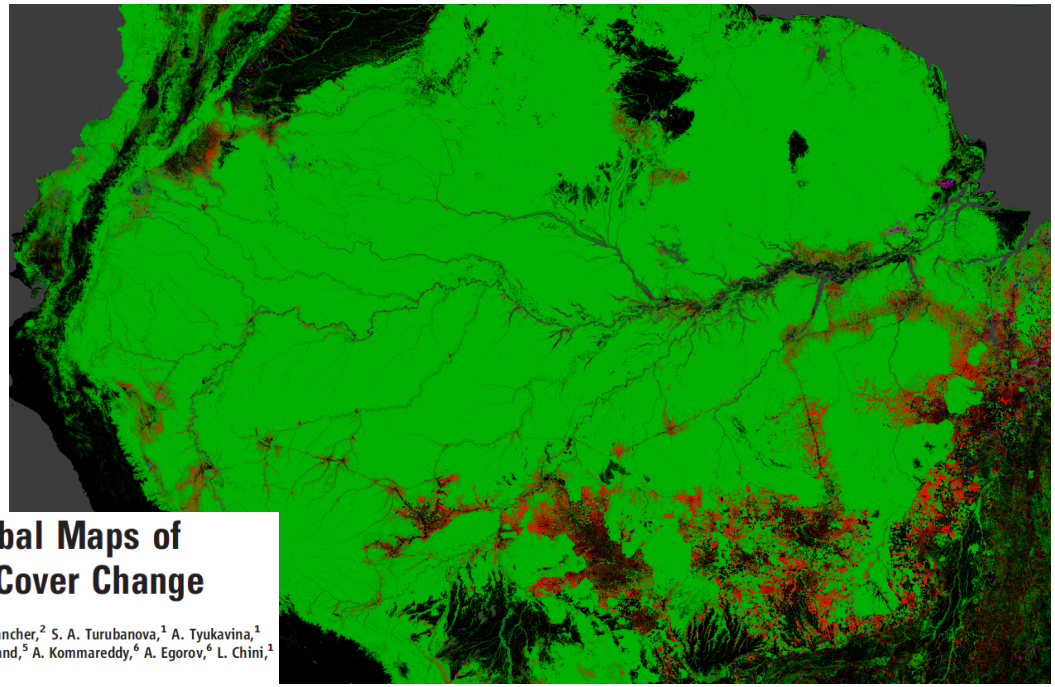
Turnover = average of mortality and recruitment rates

Driving Motivation: Increased disturbance rates associated with climate change remains a major global change issue for Amazon forests.

Turnover (Phillips et al. 2004)



Amazon Deforestation 2000-2012

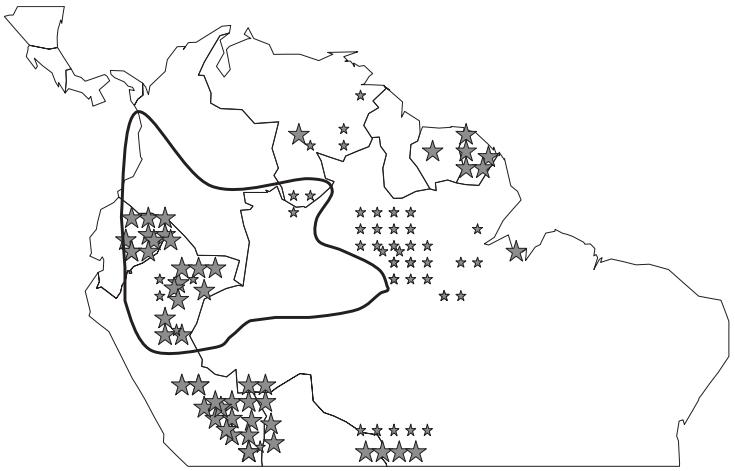


High-Resolution Global Maps of 21st-Century Forest Cover Change

M. C. Hansen,[1]* P. V. Potapov,[1] R. Moore,[2] M. Hancher,[2] S. A. Turubanova,[1] A. Tyukavina,[1] D. Thau,[2] S. V. Stehman,[3] S. J. Goetz,[4] T. R. Loveland,[5] A. Kommareddy,[6] A. Egorov,[6] L. Chini,[1] C. O. Justice,[1] J. R. G. Townshend[1]

Varying gradients across Amazon

- Higher turnover in W&S Amazon vs. C&E Amazon

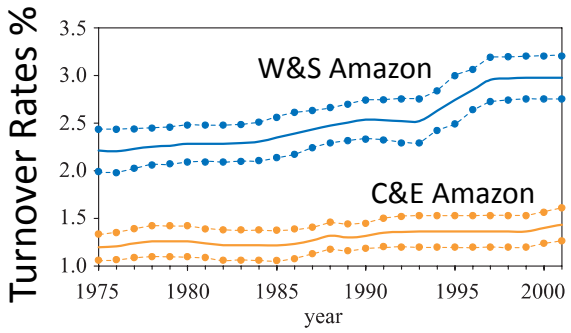


RAINFOR dataset

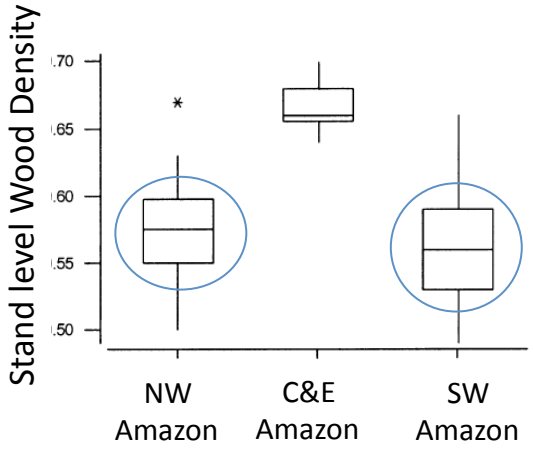
Research Questions:

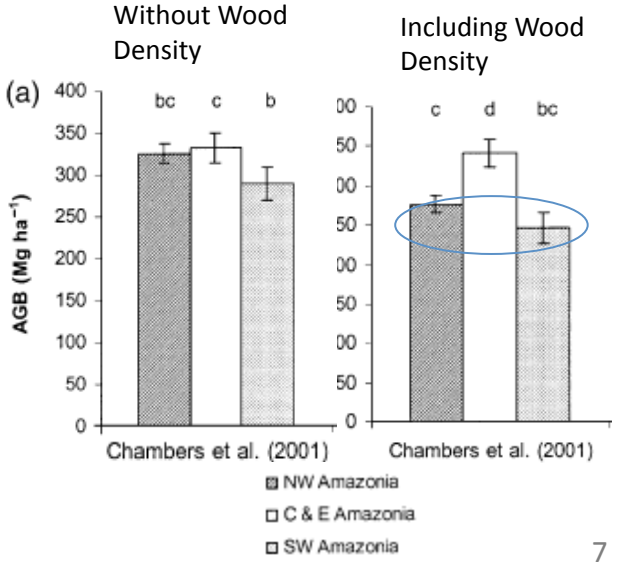
1) What are the long-term consequences of increased disturbance rates in the Central Amazon?

2) Can the variability in forest dynamics and carbon stocks between the W&S Amazon and the C&E Amazon forests be explained by the variability in the natural disturbance regime?



Baker et al. 2004. GCB
Phillips et al. 2004. Phil. Trans. R. Soc.





Modeling approach to look at disturbance gradients

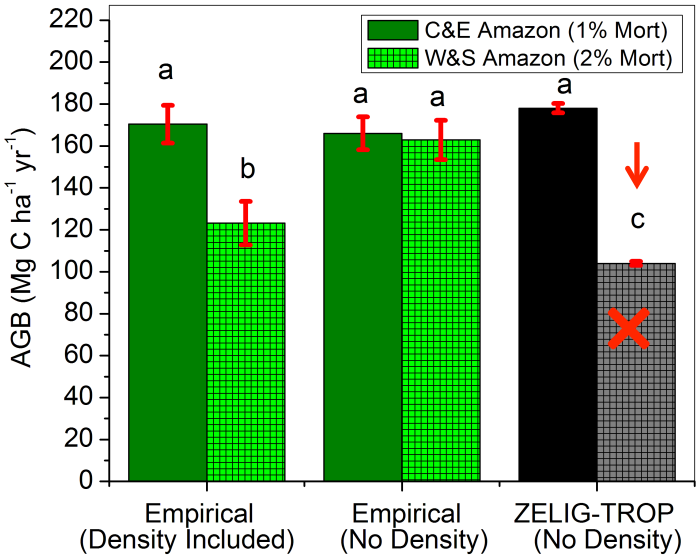
To address this issue, we parameterized and calibrated ZELIG-TROP, a dynamic vegetation gap model, to simulate a complex Central Amazon forest toward evaluating disturbance-recovery processes under scenarios of increased disturbance rates.

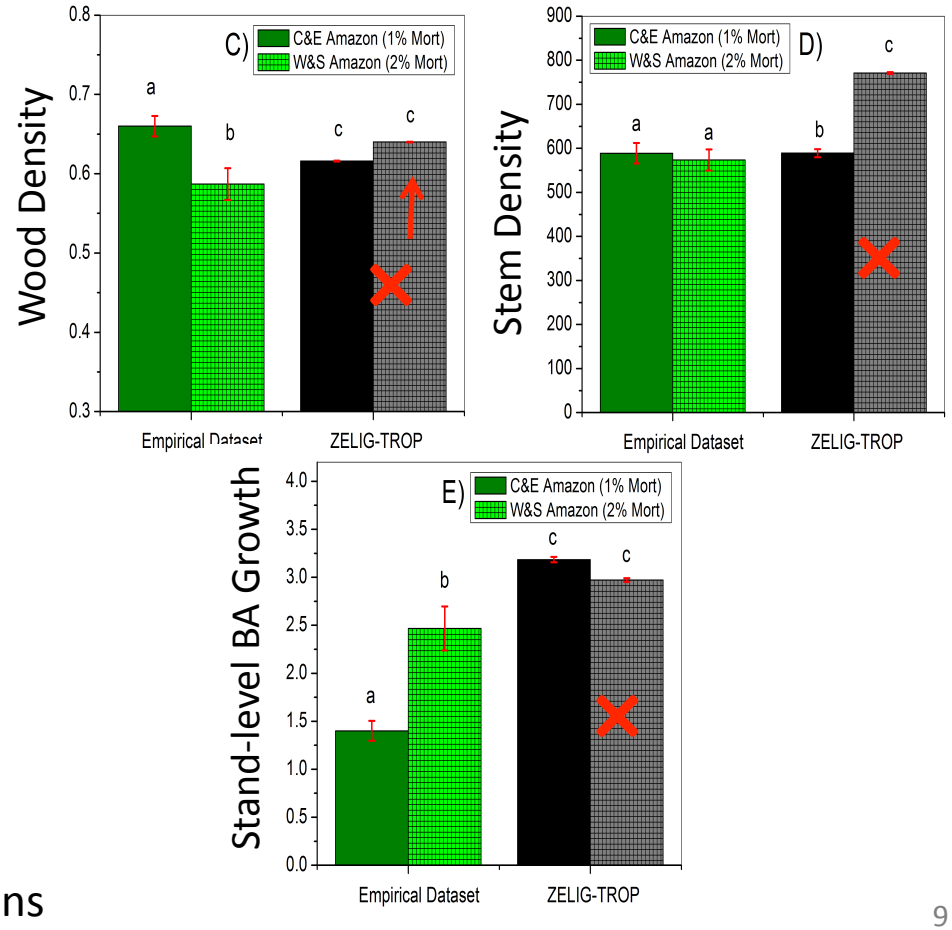
What are the differences after increasing disturbance rates in ZELIG-TROP vs. the Community Land Model (CLM-CN 4.5) for the Central Amazon?

- ZELIG-TROP: Species specific parameterization (90 tropical tree species, Laurance et al. 2004)
- ZELIG-TROP: stochastic and mechanistic mortality algorithm
- CLM-CN 4.5: constant annual mortality of 2% yr^{-1}

Impacts of high disturbance – carbon stocks

- Disturbance may not be an indicator of gradients across the Amazon
- But rather potentially sensitive to intrinsic environmental factors and/or community composition
- Getting the right answer (loss in biomass) for the wrong reason
- CLM did a poor job at capturing tropical forest processes

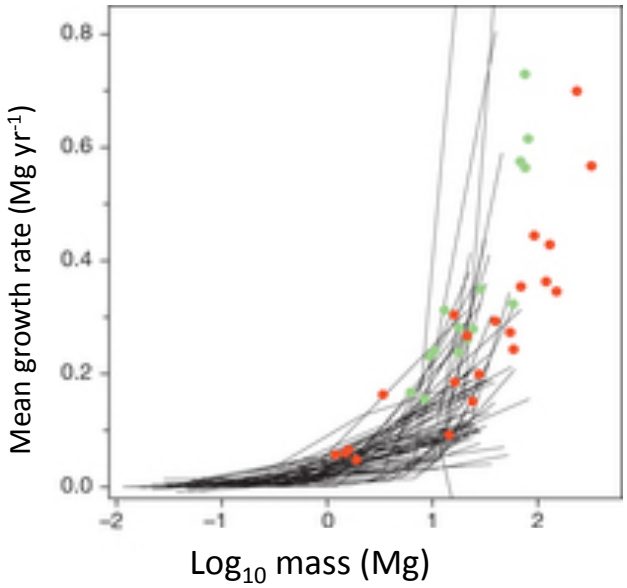


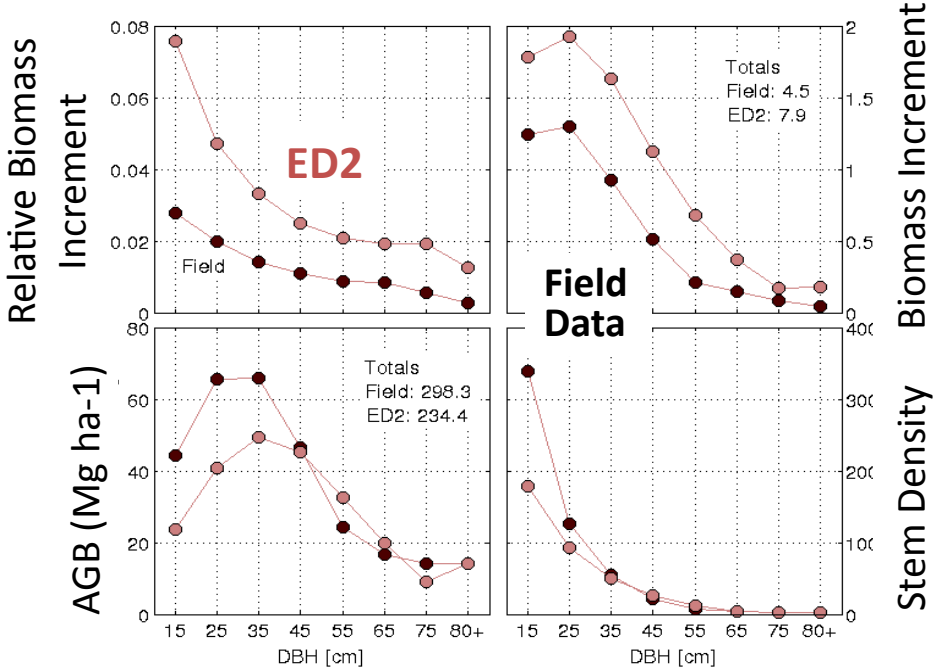


Holm et al. 2014. Biogeosciences Discussions

CLM-ED & Tropical Forest Carbon Sink

What are the key uncertainties associated with the old-growth tropical forest carbon sink and how can we improve model treatment of these processes?



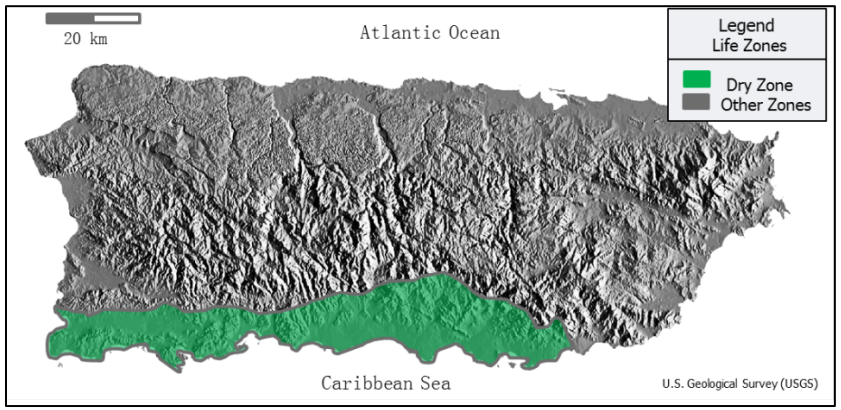


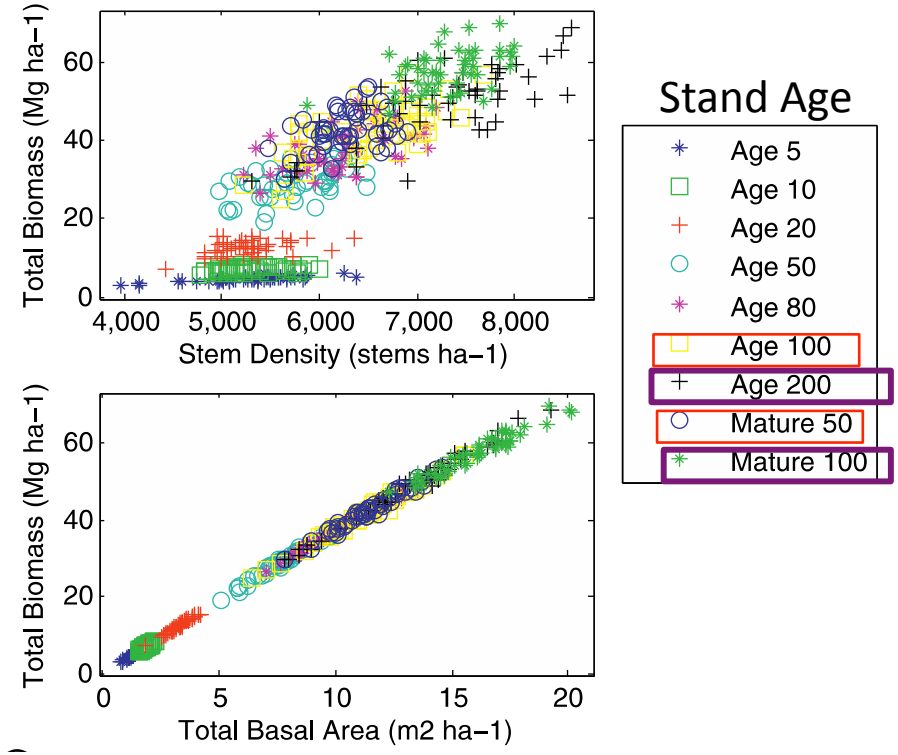
Stephenson et al. 2014 (Nature). Global analysis shows mass growth rates increase continuously with tree size.

- Tropical dataset shows opposite result. Larger relative biomass increment in smaller DBH size classes (15-25 cm DBH). Likely due to higher stem density in smaller size classes.
- Biomass increment is larger in ED2 compared to field measurements.

Using demographic forest models to evaluate recovery from land use change

- Location: subtropical dry forests in Puerto Rico (high land use history)
- History: extensive clearing for intensive agriculture; but fields abandoned in 1940's; natural recovery monitoring for 70 yrs.
- Recovery of abandoned fields on degraded soils conditions can take 50-100 years to reach mature status.
- Lag-time for recovery
- At edge of "analog" climates; hot and dry





Holm et al. 2012. Ecological Modelling

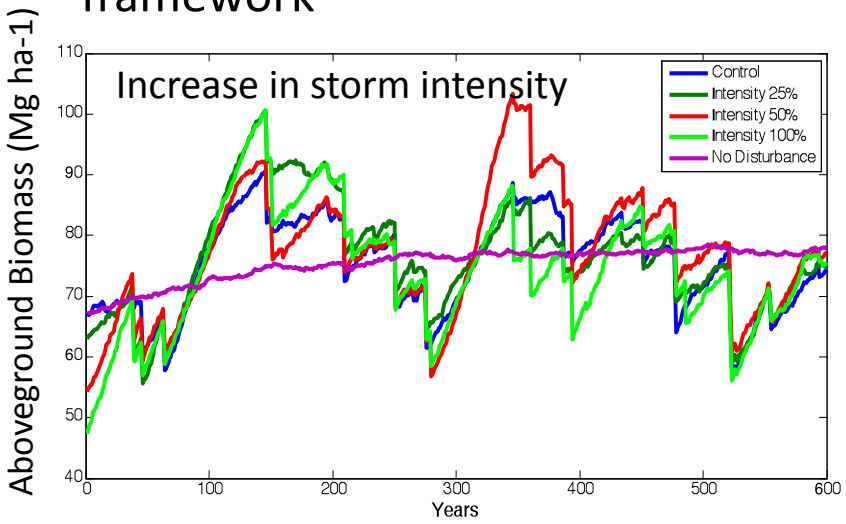
Modeling hurricane impacts as a result of changing climates

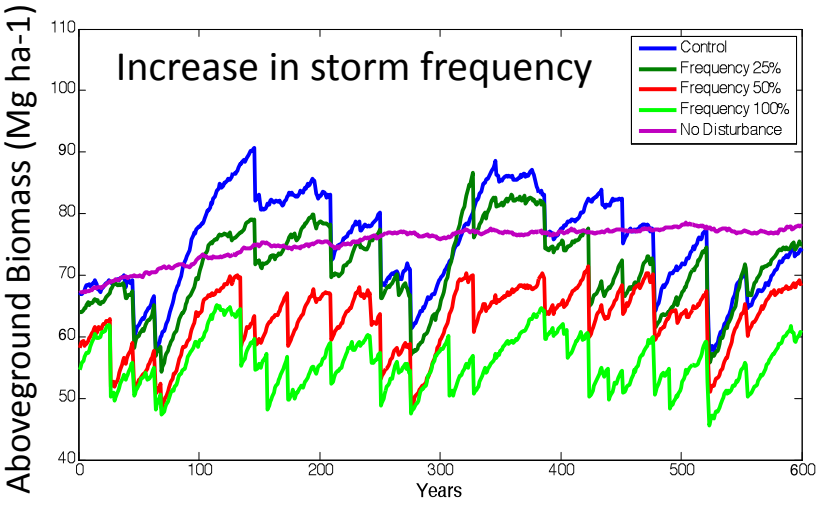
Location: subtropical forests in Puerto Rico (high hurricane frequency)

- 5% to 40% decrease in biomass depending on treatment
- Increase in storm intensity = low biomass decrease
- **Increase in storm frequency = higher biomass decrease**

Management application:

- REDD+ carbon emissions
- Successfully incorporating disturbance in an integrated Earth System Modeling framework





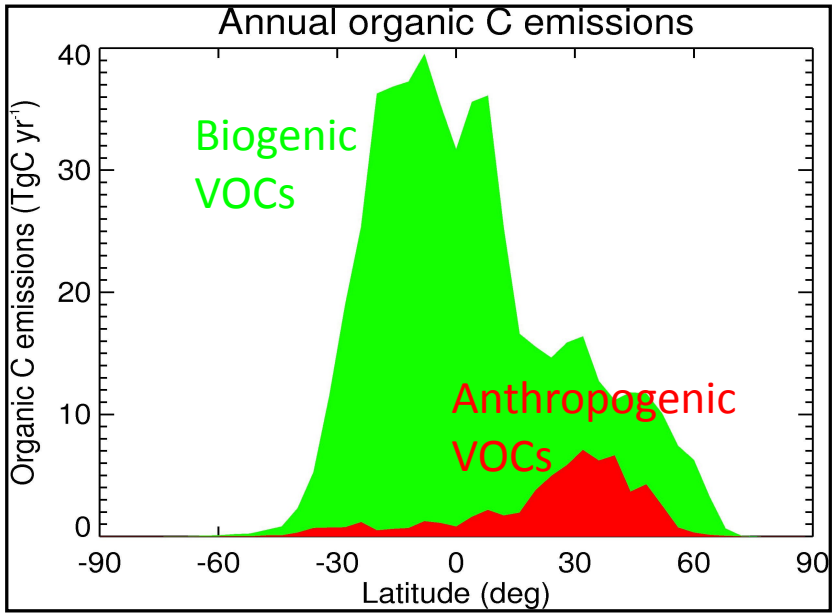
Holm et al. 2012. Ecological Modelling

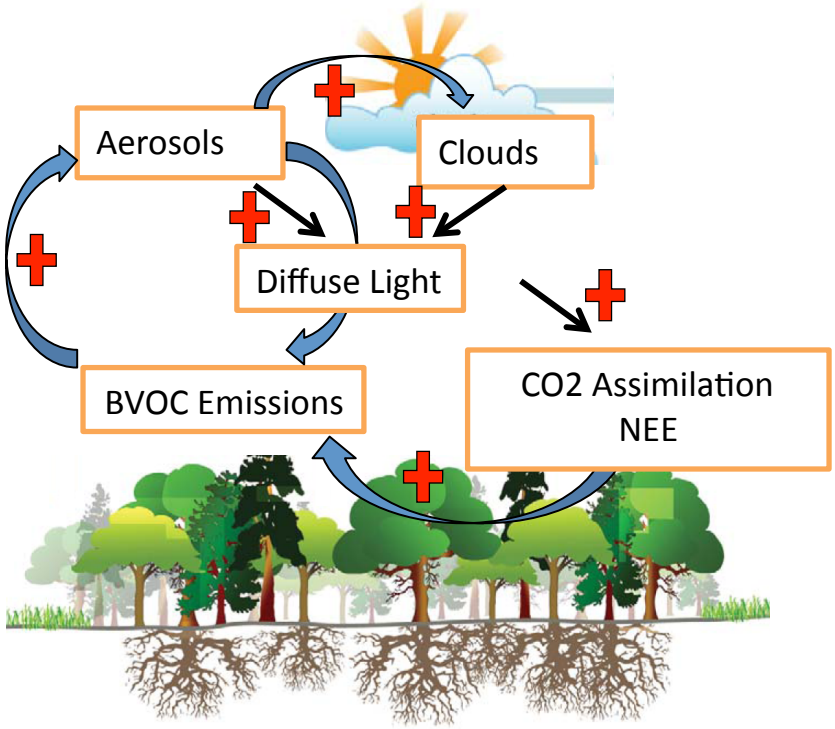
Modeling biosphere-atmosphere interactions and BVOC emissions

How can we improve our capacity to represent BVOC emissions and coupled biosphere-atmosphere processes in Earth System Models (ESMs)?

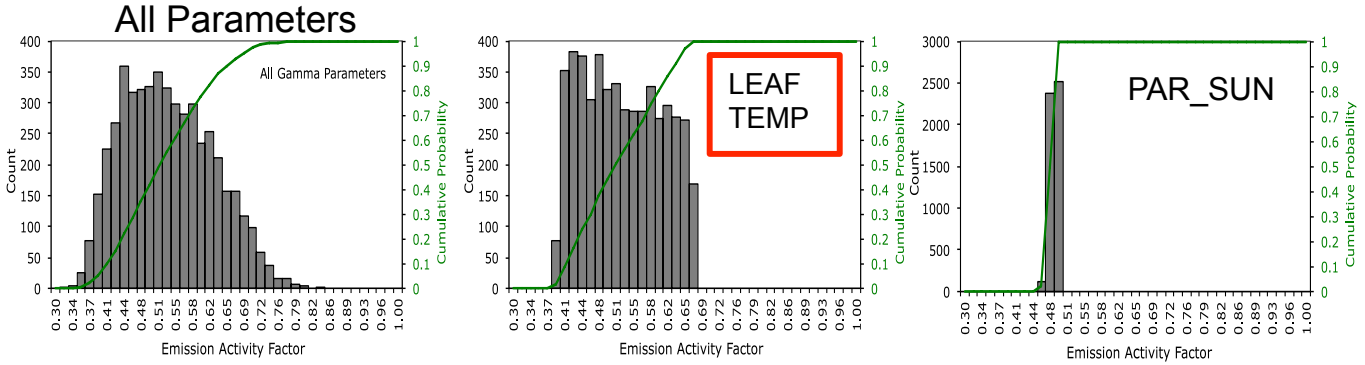
But constrained by a poor understanding on the mechanistic controls over BVOC emissions.

BVOC emissions from Amazon forests are known to affect key atmospheric processes including aerosol and cloud lifecycles, atmospheric chemistry, and the radiative balance of the atmosphere.





BVOC sensitivity in MEGAN-CLM

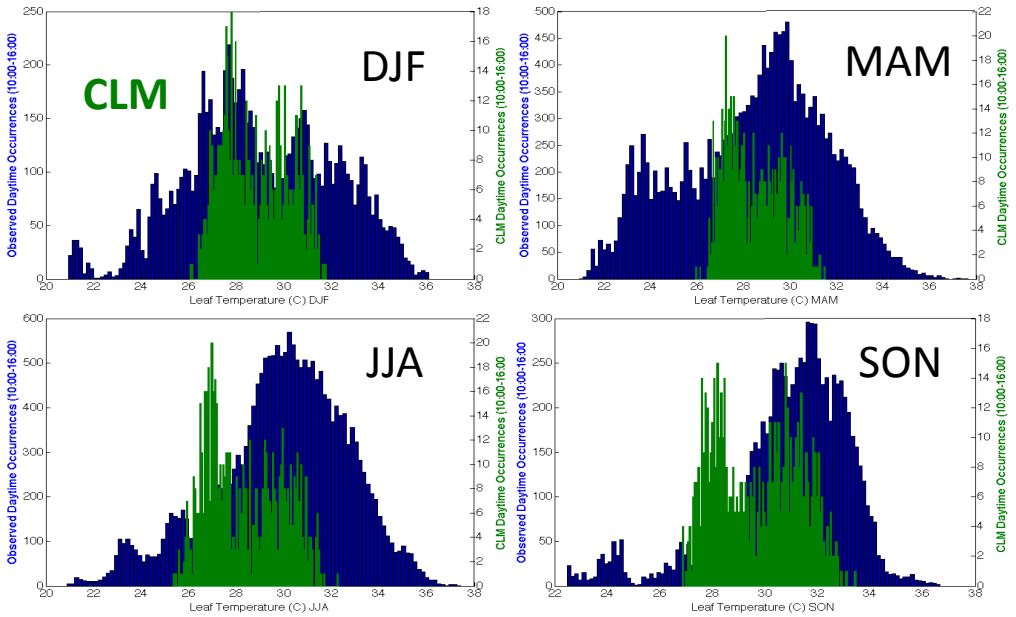


Uncertainty in BVOC emissions is two-fold:

1) the environmental controls over isoprene emissions are highly uncertain
2) Accurately represent these environmental controls within models is lacking

- 61% of the uncertainty in isoprene emissions was caused by uncertainties related to leaf temperature
- The land surface model (CLM) in CESM is not capturing tropical leaf temp.
- Missing upper 10-14 °C of leaf temperatures

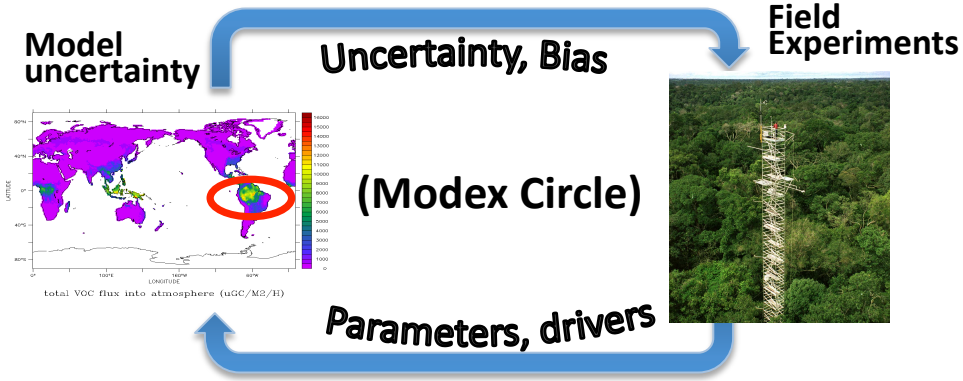
Amazonian seasonal leaf temperature (°C)

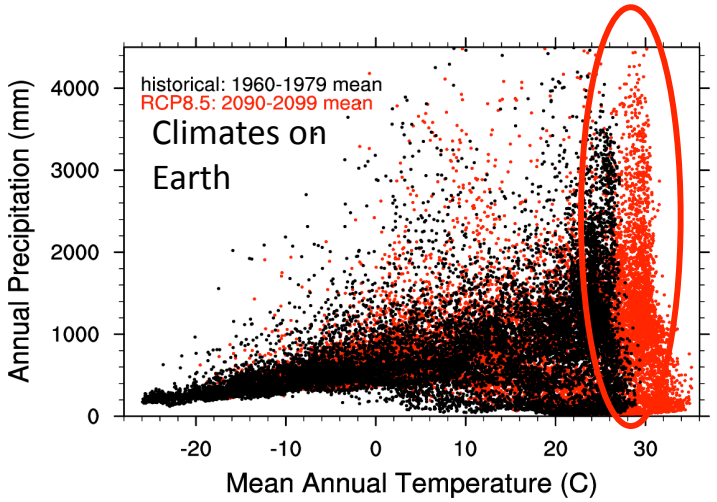


Holm et al. 2014. ACP, submitted

Modeling tropical forest response under a changing climate system

- Many interactions that are critical to the Earth System and climate!
- Turnover is increasing (mortality and recruitment)
- Disturbance is also increasing, thus affecting carbon storage
- Dynamic vegetation is an important tool in modeling the tropical forest carbon sink
  - And critical in capturing carbon fluxes with disturbance events
- Dry tropical forests might have longer time to recover from land-use change
- Increase in hurricane frequency will have larger impacts on biomass loss (resilience vs. resistance)
- CLM not accurately capturing high leaf temperatures, but important for decreasing uncertainty in BVOC emissions
- Back to "Modex" approach: Model inspired experiments





Thank you!

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