

Disturbance and Vegetation Dynamics in Earth System Models

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Disturbance and Vegetation Dynamics in Earth System Models

Workshop Report

- March 15-16, 2018
Gaithersburg, MD
- Co-organized by Jim Clark, Duke University & Lara Kueppers, UC Berkeley/LBL
- [Report](#) published November 2018
- Excellent support from ORNL staff
- Engaged BER program staff
- Review paper under development (led by Nate McDowell)

Workshop participants

Expertise in

- Earth system modeling
- plant demography
- individual-based models
- fire, wind/hurricane, insect disturbances and impacts
- ecophysiology
- remote sensing
- statistical methods
- field experiments

James Clark, Workshop Co-Leader
Duke University

Lara Kueppers, Workshop Co-Leader
University of California, Berkeley, and
Lawrence Berkeley National Laboratory

Brian Aukema
University of Minnesota

Ben Bond-Lamberty
University of Maryland and
Pacific Northwest National Laboratory

Kyla Dahlin
Michigan State University

Mike Dietze
Boston University

Andrew Eckert
Virginia Commonwealth University

Rosie Fisher
National Center for Atmospheric Research

Jane Foster
University of Vermont

Jennifer Holm
Lawrence Berkeley National Laboratory

Robert Jackson
Stanford University

Charlie Koven
Lawrence Berkeley National Laboratory

Beverly Law
Oregon State University

Jeremy Lichstein
University of Florida

Nate McDowell
Pacific Northwest National Laboratory

Sean McMahon
Smithsonian Institution

Rebecca Montgomery
University of Minnesota

Kiona Ogle
Northern Arizona University

Benjamin Poulter
National Atmospheric and Space Administration
and Montana State University

Karina Schäfer
Rutgers University

Erin Schliep
University of Missouri

Shawn Serbin
Brookhaven National Laboratory

Jacquelyn Shuman
National Center for Atmospheric Research

Monica Turner
University of Wisconsin

Maria Uriarte
Columbia University

Anthony Walker
Oak Ridge National Laboratory

Chonggang Xu
Los Alamos National Laboratory

Department of Energy
Andrew Flatness

Gary Geernaert
Justin Hnilo

Renu Joseph
Dorothy Koch

David Lesmes
Sally McFarlane

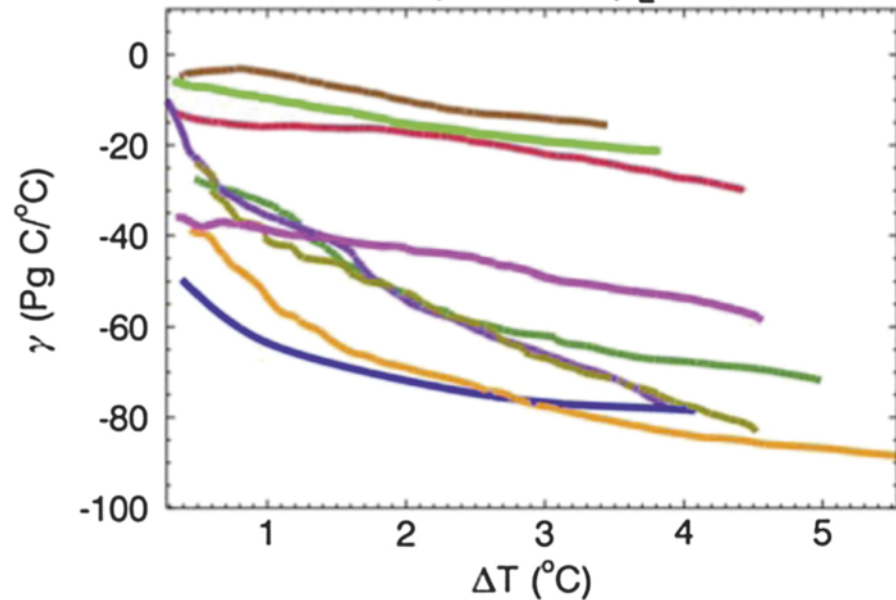
Shaima Nasiri
Rick Petty

Daniel Stover
Tristram West

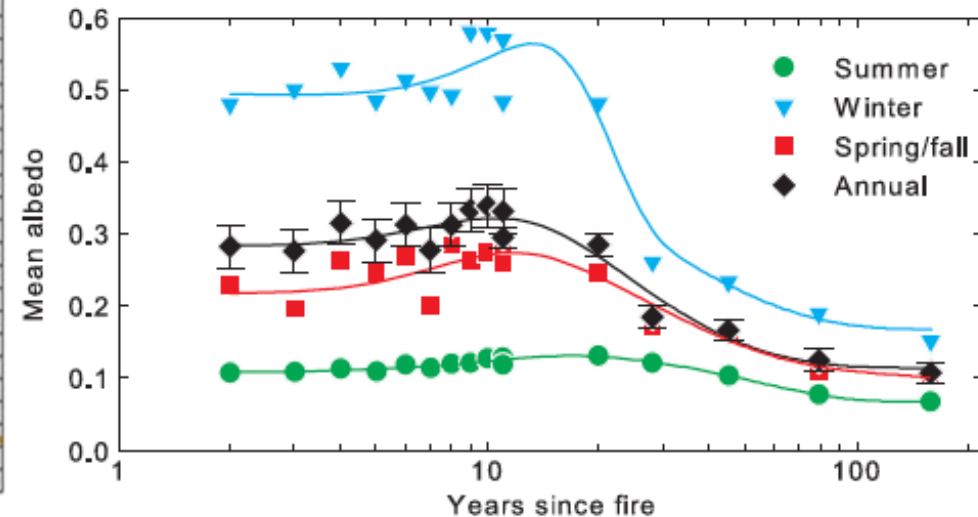
Peter Wykoff (AAAS Science and Technology Policy
Congressional Fellow; University of Minnesota)

Vegetation change is a key uncertainty in climate prediction

Global land carbon feedback to climate

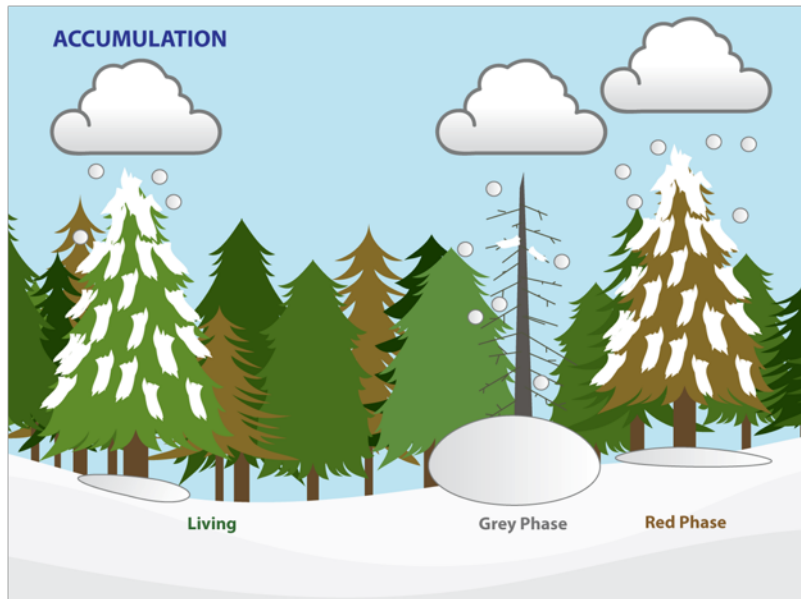


Boreal forest albedo following fire



- Carbon cycle and biogeophysical (energy balance) effects

Vegetation change affects watersheds

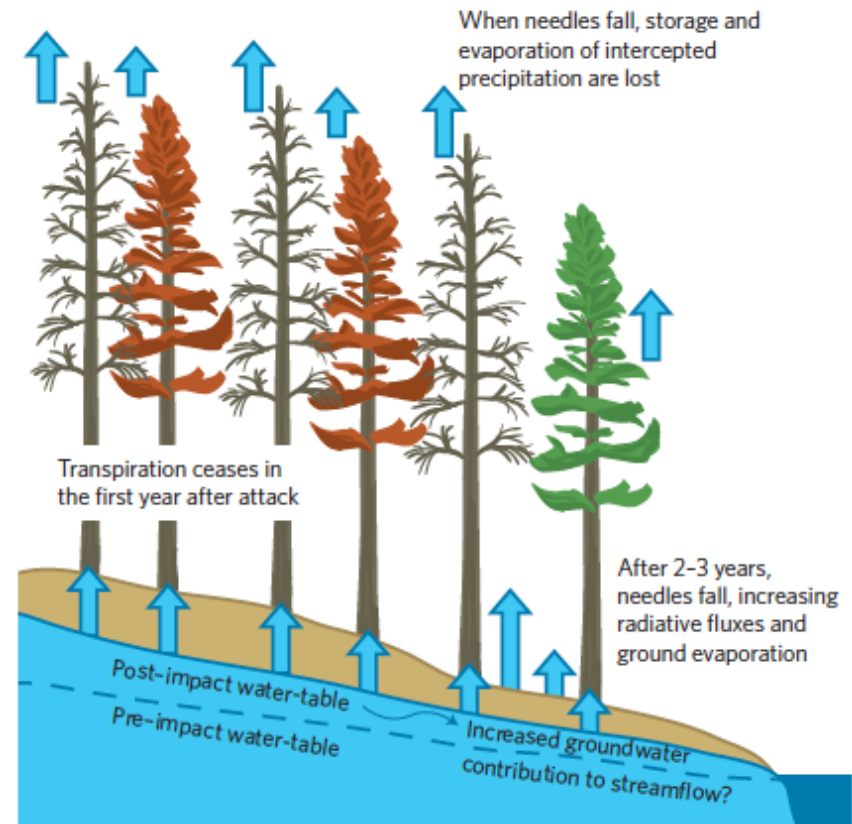


Bark beetle tree mortality can alter

- Snow accumulation
- Transmission of radiation

(Pugh & Small 2012; Bearup et al. 2014)

- Transpiration & evaporation
- Recharge/discharge

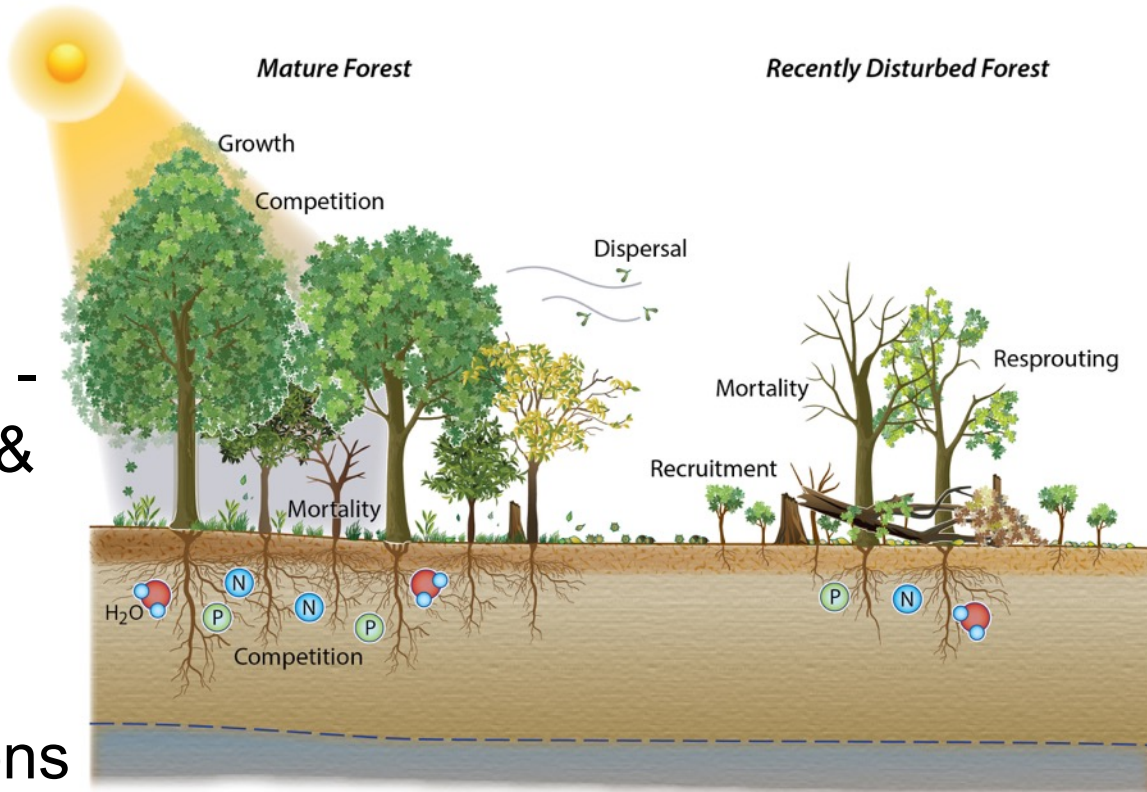


Workshop goals

- To identify key uncertainties in current dynamic vegetation models limiting the ability to adequately represent vegetation in Earth System Models
- To identify and prioritize research directions that can improve models, including forest structural change and feedbacks and responses to disturbance.

Terms

- **Vegetation dynamics** – plant demographic processes (growth, death & reproduction), competition for resources, seed dispersal
- **Disturbance** – discrete events that disrupt the structure and function of an ecosystem
- Disturbance **regime** - frequency, severity, & size of disturbances resulting from environment-vegetation interactions



Modeling approaches

- *Dynamic global vegetation models* – simulate “big-leaf” vegetation distributions with climate envelopes; fire
- *Individual-based models* – simulate vegetation dynamics at scale of individual trees; spatially explicit disturbance
- *Vegetation demographic models* – simulate dynamics at scale of individuals or cohorts; predict demography, fire

(a) Model Types

Big leaf model



Cohort model

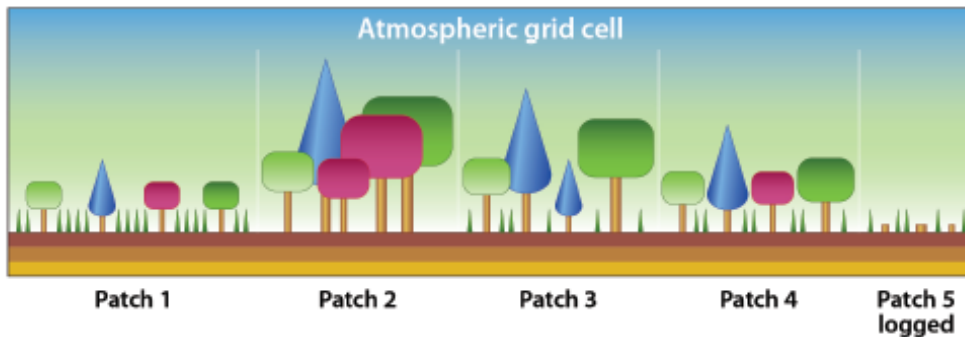


Individual-based model

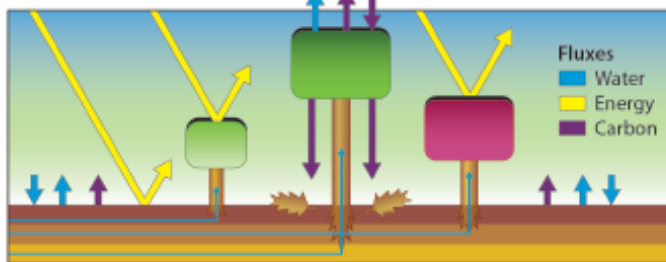


Cohort VDMs – *intermediate solution*

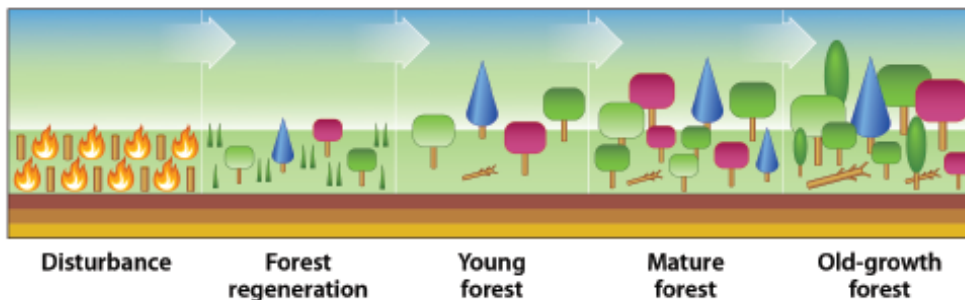
(b) Cohort Model: Multiple Patches



(c) Cohort Model: Fluxes



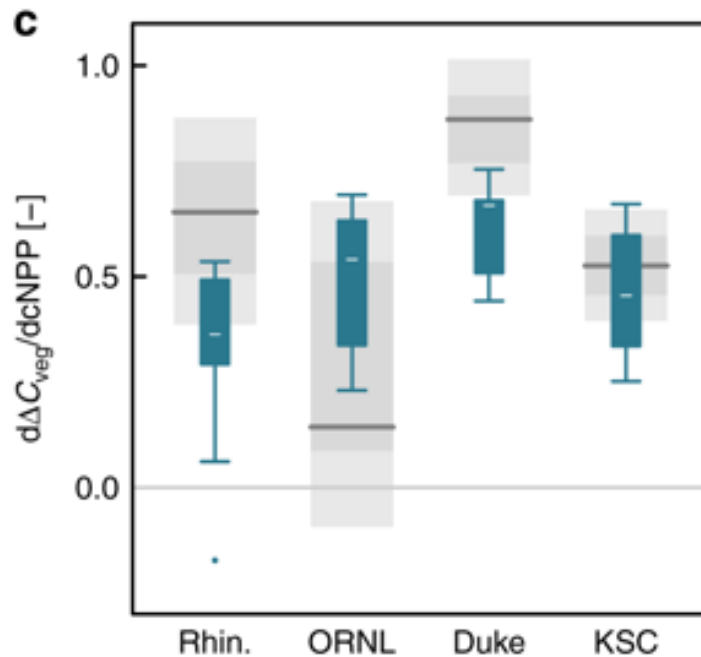
(d) Cohort Model: Time Since Disturbance



- Emerging across leading ESMS
- DOE is supporting development of FATES (Functionally Assembled Terrestrial Ecosystem Simulator)
- Show promise – require testing and development

Growth

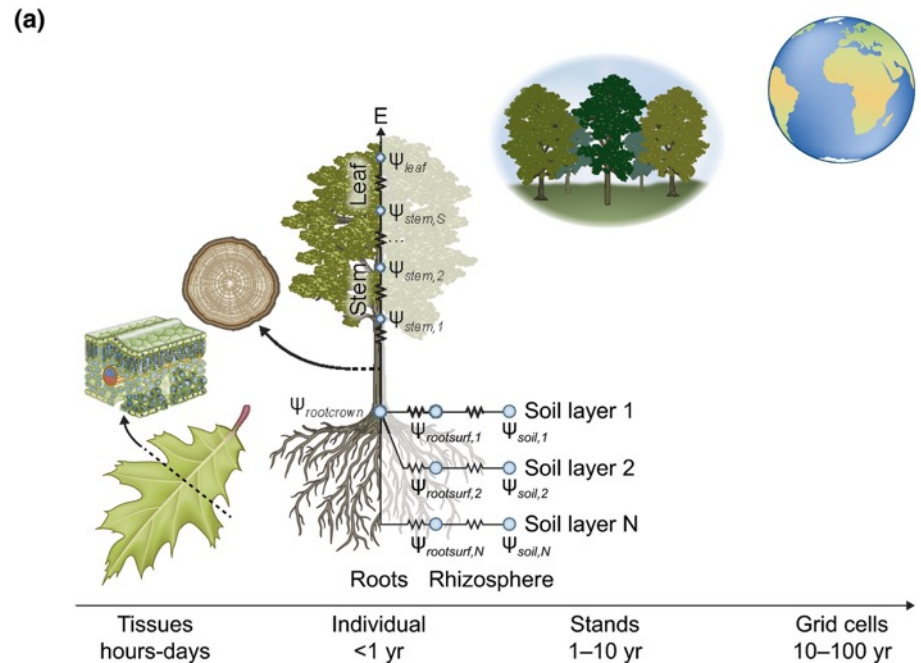
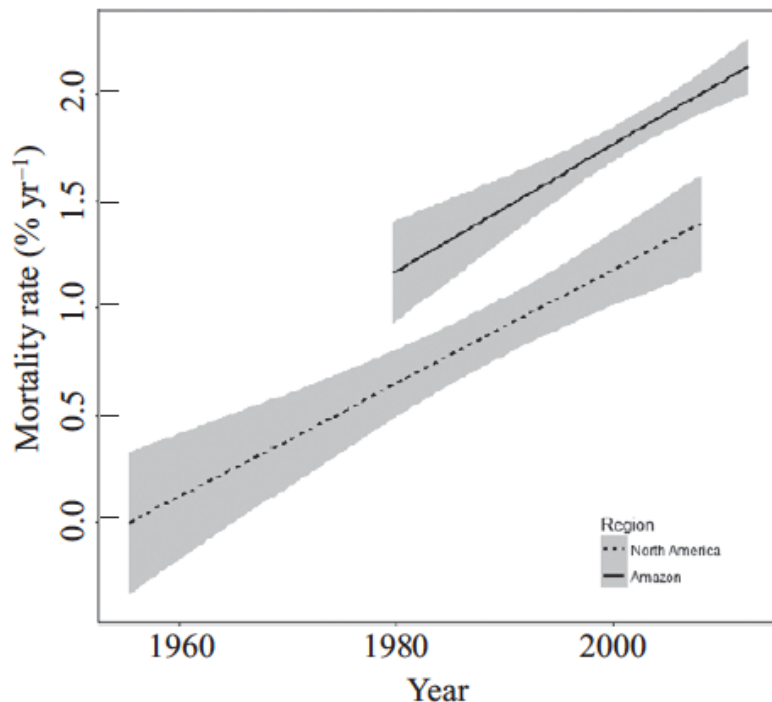
- eCO₂ increases tree growth in early-successional forests; nutrients, tree size may be limiting later
- Models simulate growth responses, but require evaluation across tree ages, canopy positions, PFTs



(Walker et al. 2019)

Mortality

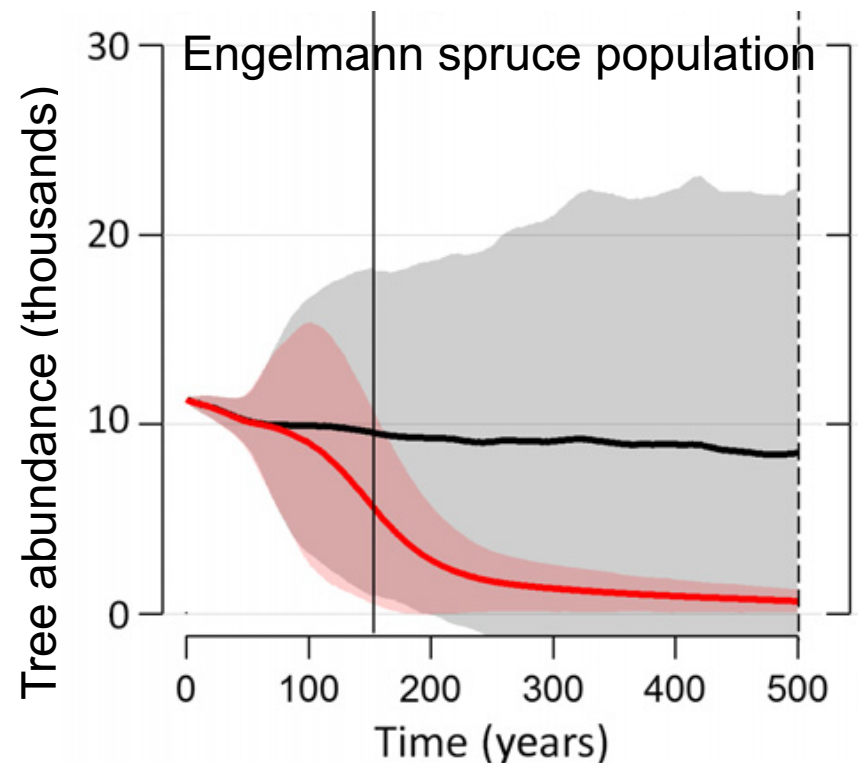
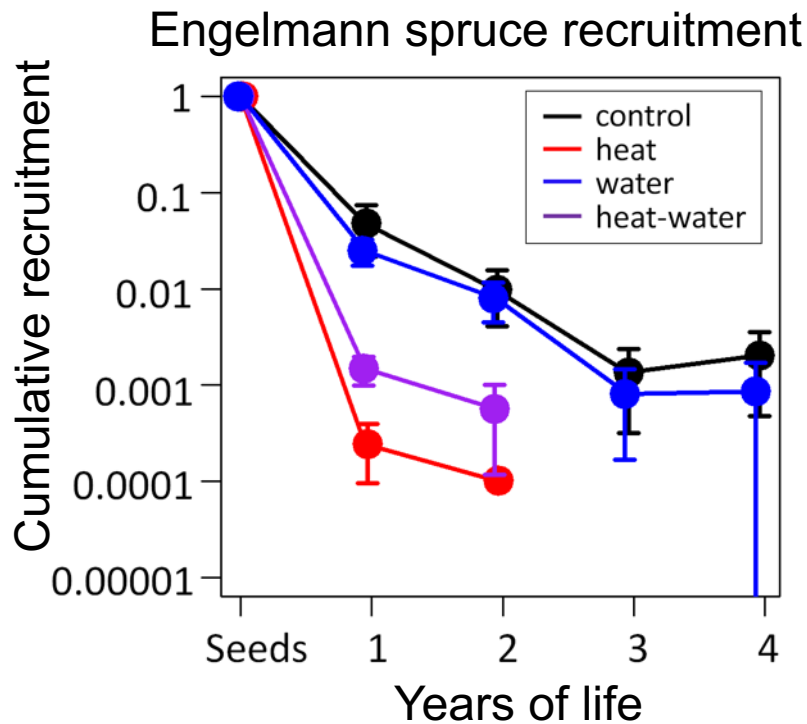
- Mortality is increasing in North America and the Amazon due to water stress or elevated CO₂
- VDMs better suited to capture size- and species-dependent sensitivity; mortality modes require testing



(McDowell et al. 2018, Mencuccini et al. 2019)

Reproduction

- Recruitment declines with warmer temperatures in subalpine forest; population collapse over centuries
- Environmentally sensitive reproduction missing in models; data synthesis, model improvements needed



(Kueppers et al. 2017; Conlisk et al. 2017)

Fire

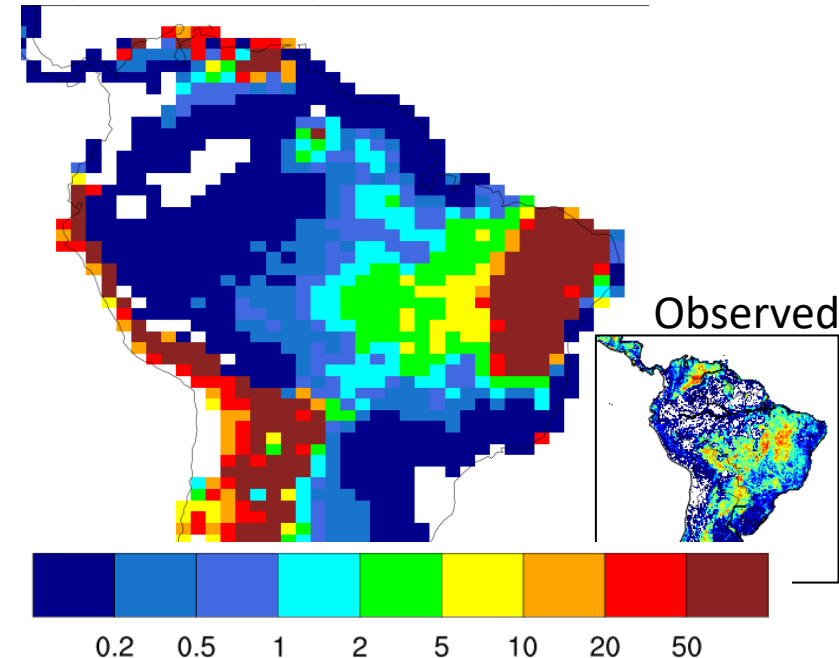
- Important control on the forest-savannah ecotone
- Spatially explicit processes (e.g., large fire spread, dispersal limitation), vegetation feedbacks, land use are not well developed in models

Landscape pattern in Yellowstone fire



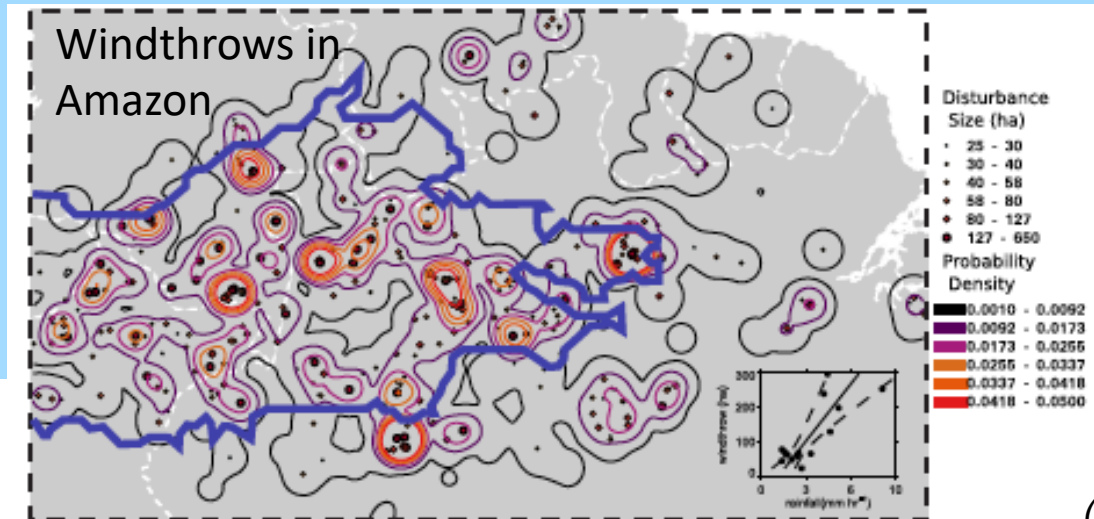
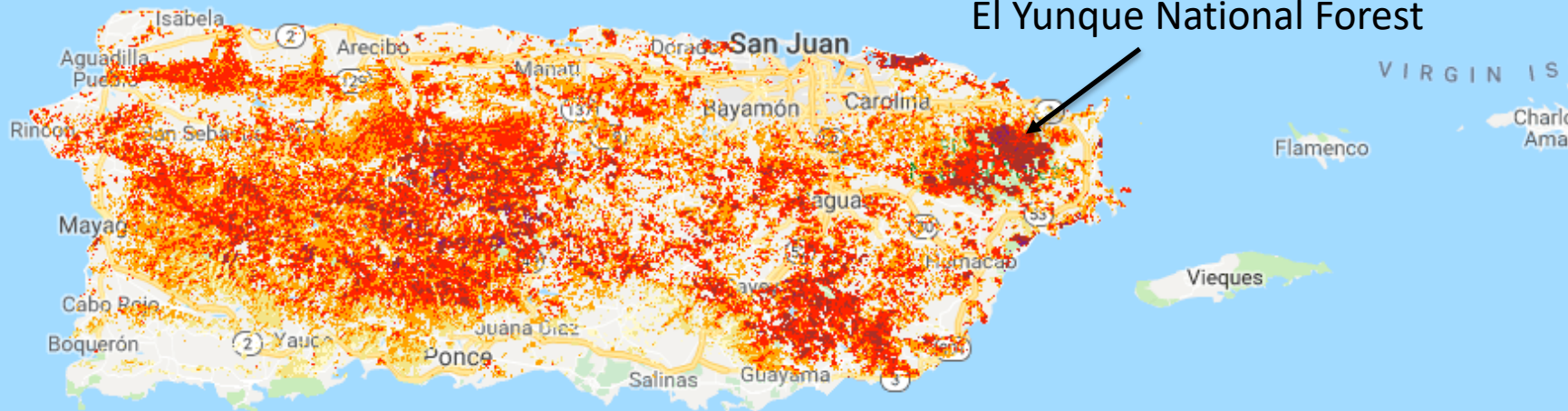
(Shuman et al. in prep)

Fraction burned in FATES-SPITFIRE (S. Am)



Intense wind and hurricanes

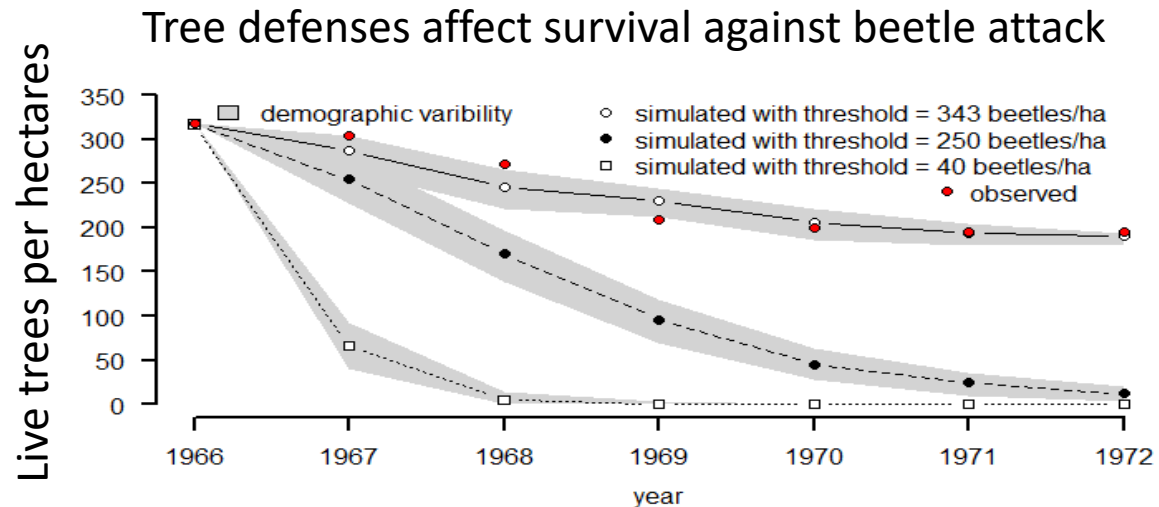
Disturbance intensity following hurricanes Irma and Maria, 2017



(Feng et al. 2018, Negrón-Juárez et al. 2019)

Insects outbreaks

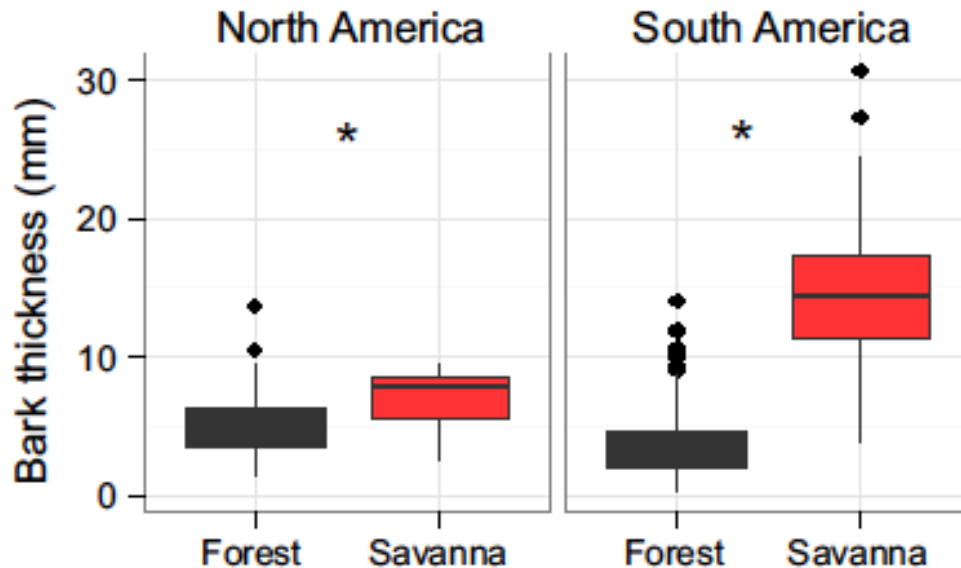
- Bark beetles affected more area than fire over last 30 years; rising temperatures are promoting outbreaks
- Challenging to model given species specificity, interaction between tree and insect; progress needed on all fronts



(Huang et al. in review)

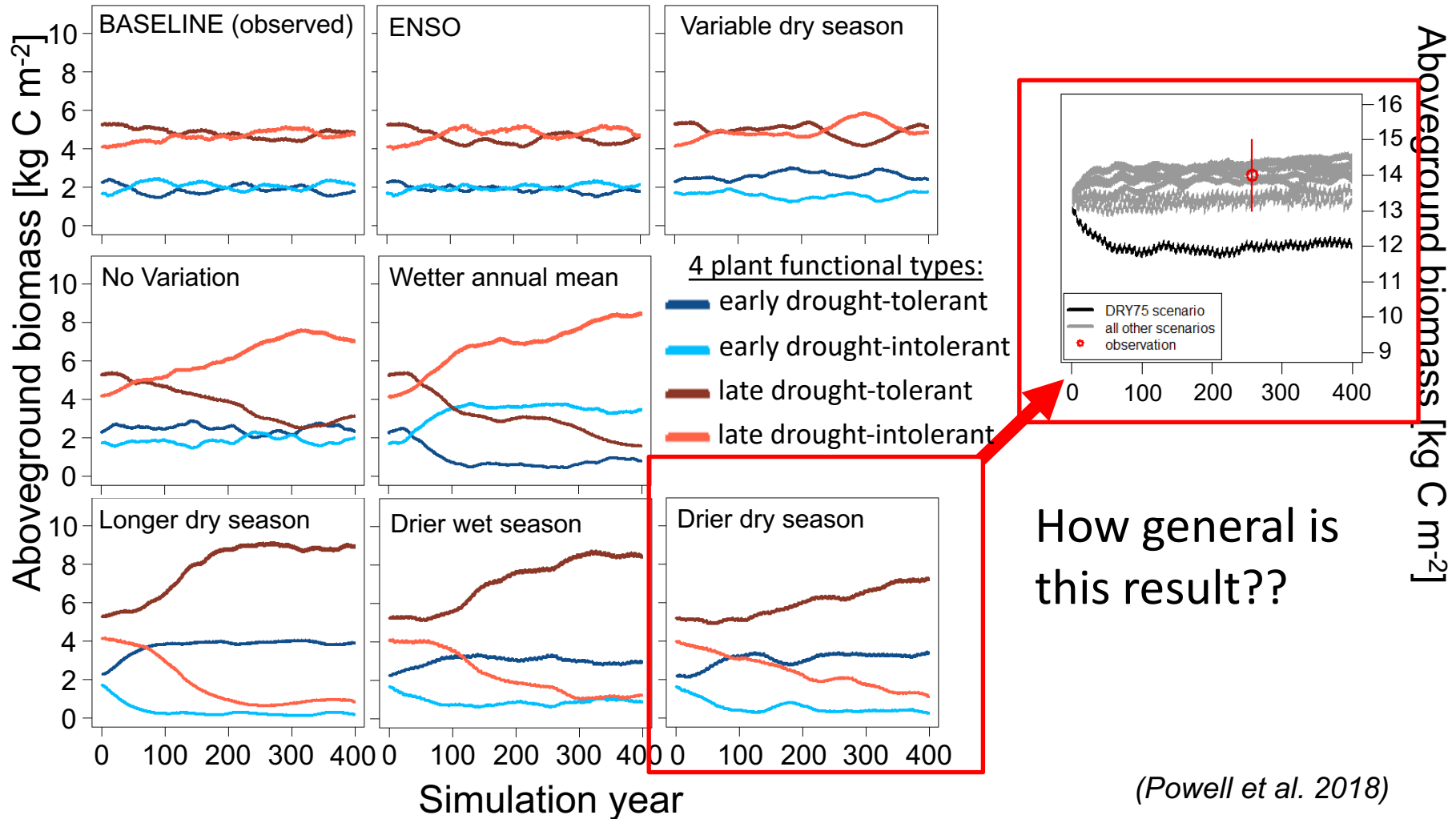
Traits determine resistance and resilience

- Ecological strategies are adapted to disturbance regimes
 - Frequent fire → thicker bark (3:1, savanna:forest)
 - Resprouting following wind and fire speeds regeneration
- Not captured in current models; potential in VDMs



(Pellegrini et al. 2017)

Functional diversity provides resilience to hydroclimate change



(Powell et al. 2018)

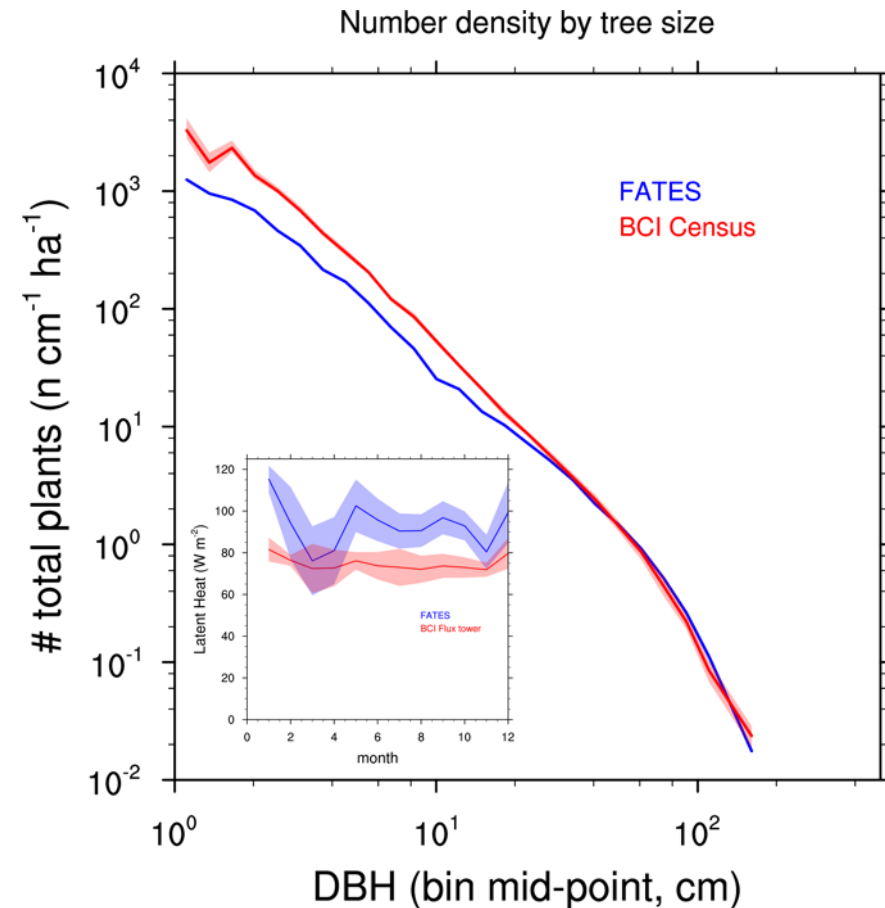
Priority needs

- Synthesis efforts to exploit existing data and design new observations and experiments to inform future vegetation modeling efforts.
- New empirical data that better quantify climate-disturbance-vegetation interactions to constrain vegetation model projections.
- New modeling approaches that adequately represent both process-based vegetation dynamics and disturbances.

Observational testbeds for VDM evaluation and development

- Site scale
 - Demographic measurements + flux data + meteorology + land use history
- Landscape-regional scale targeting disturbance-recovery dynamics
- Environmental gradients to test turnover in ecological strategies

Example: Barro Colorado Island, Panama



(Koven et al. in prep)

Thanks!

Workshop participants

Jennifer Holm, Maria Uriarte, Monica Turner, Henry Adams, Jeff Mitton for photos and figures



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