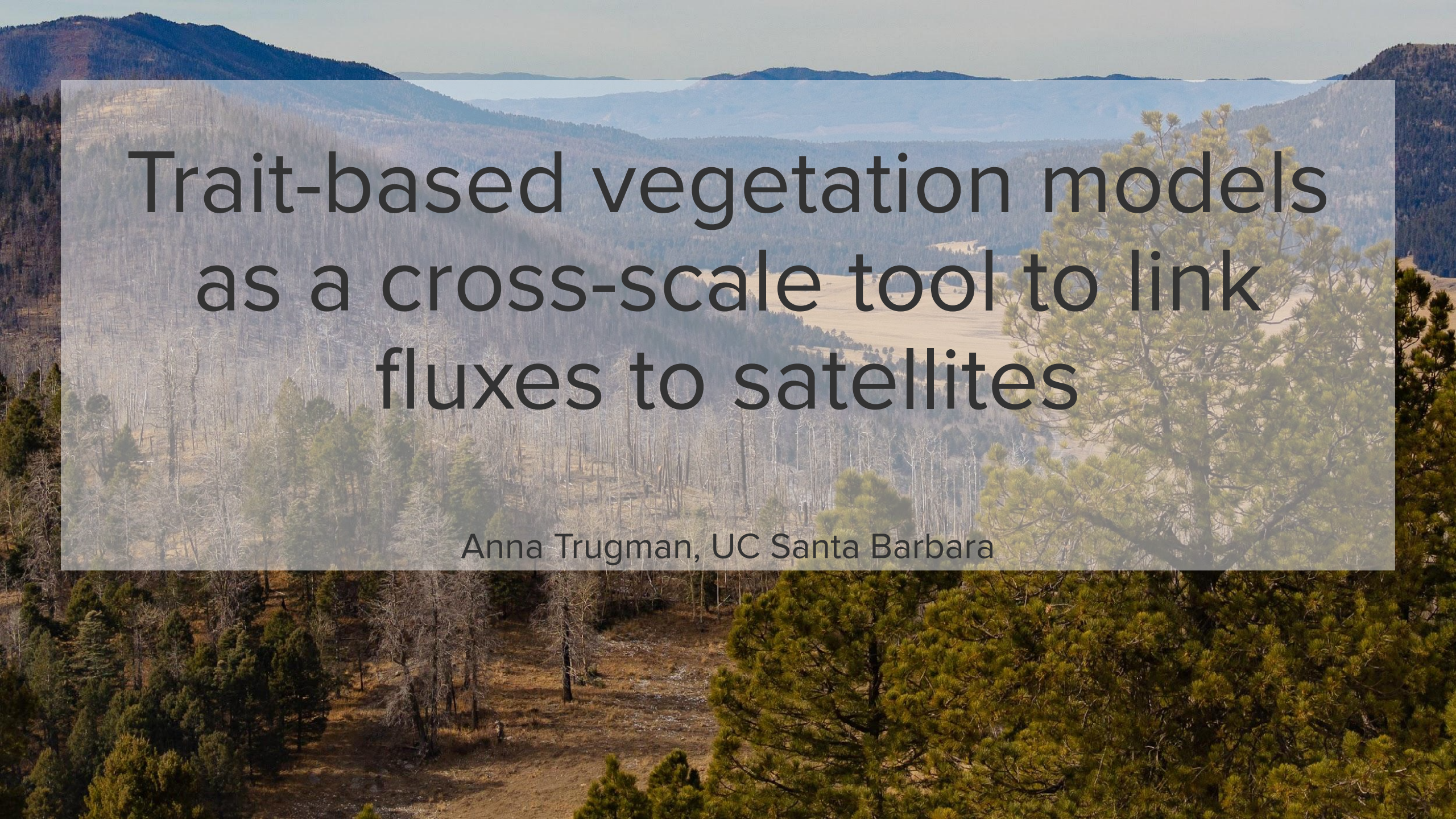

Trait-based vegetation models as a cross-scale tool to link fluxes to satellites

Anna Trugman, UC Santa Barbara

Acknowledgements


Justin Mathias


Angie Wu


Jean Allen


Greg Quetin


Kris Daum

Collaborators: LDL Anderegg, WRL Anderegg, M Venturas, AJ Das, NL Stephenson, Daniel Kennedy

Roadmap

- What are trait-based vegetation models and why are they useful for understanding cross-scale processes?
- Forests in a water limited world
- Using trait-based models to understand the ***why*** underlying patterns of forest health in a changing climate

Roadmap

- What are trait-based vegetation models and why are they useful for understanding cross-scale processes?
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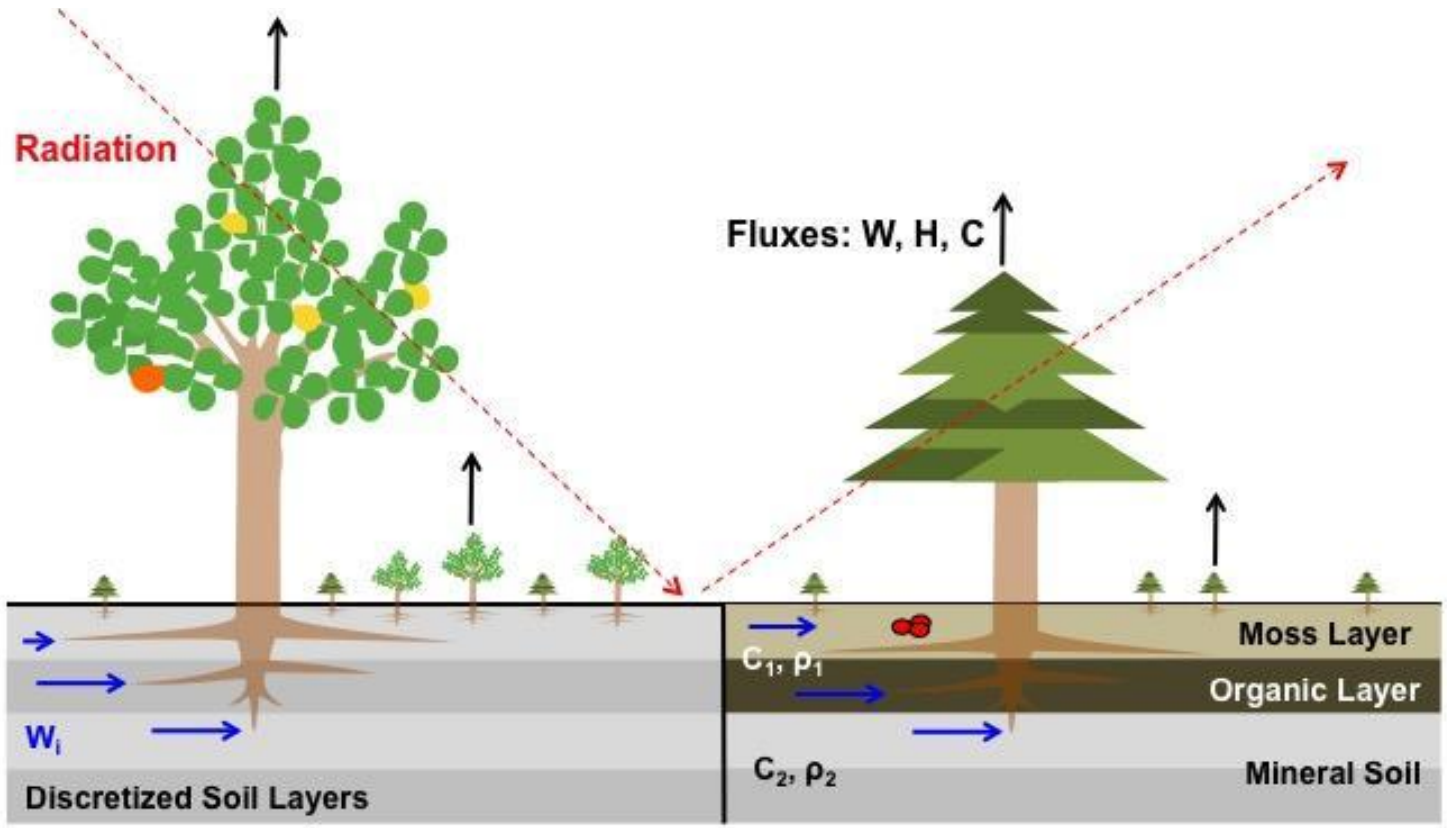
What are trait-based vegetation models?



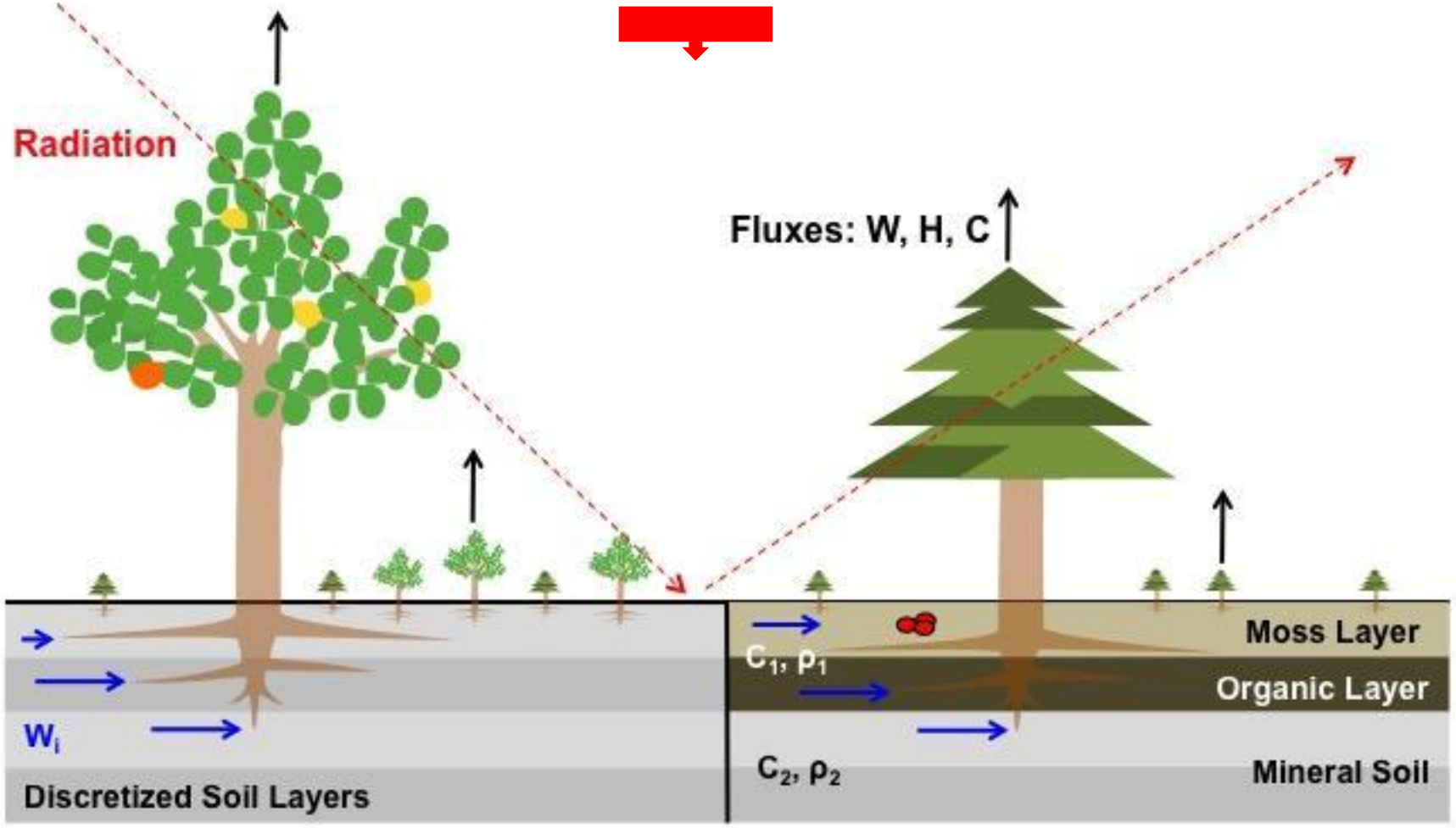
Pools and fluxes

- Different vegetation carbon pools
- Carbon fluxes
- Energy fluxes
- Water fluxes

What are trait-based vegetation models?

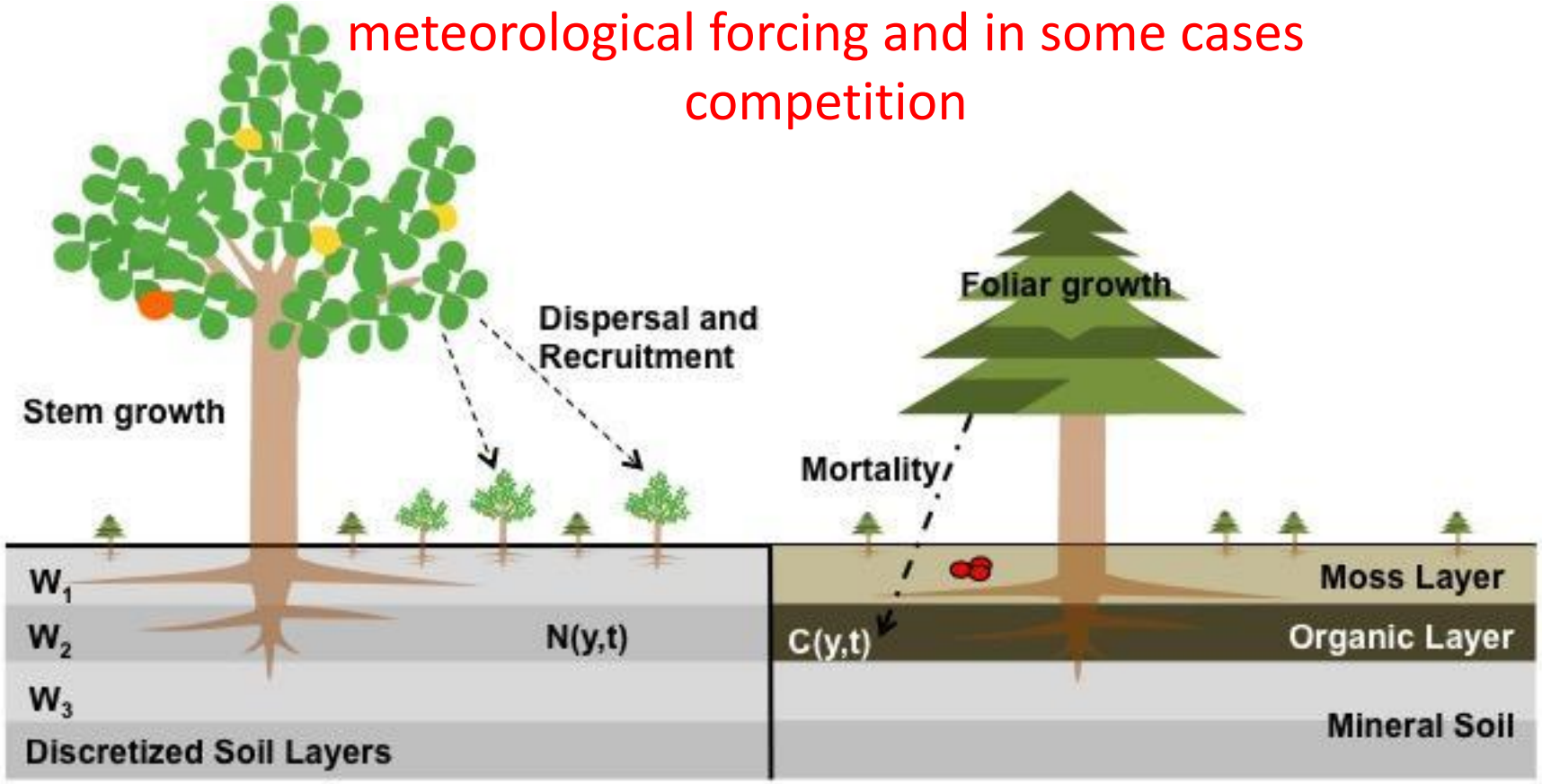
Temperature, Precipitation, Radiation, Humidity, Pressure, Wind Speed, CO_2

Input meteorological forcing

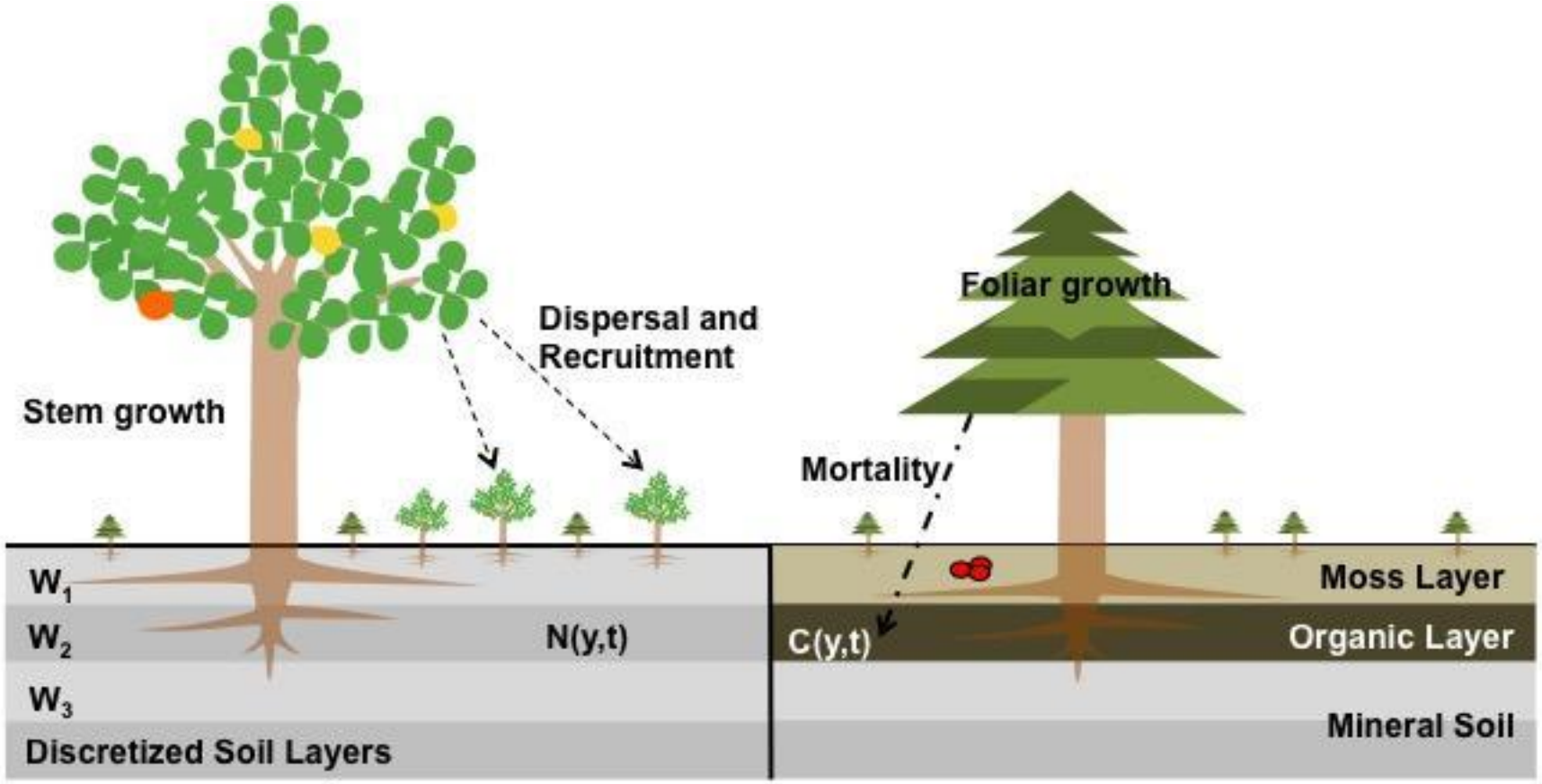


What are trait-based vegetation models?

Trees respond to various axes of limiting resources (light, water, nutrients) due to variations in meteorological forcing and in some cases competition



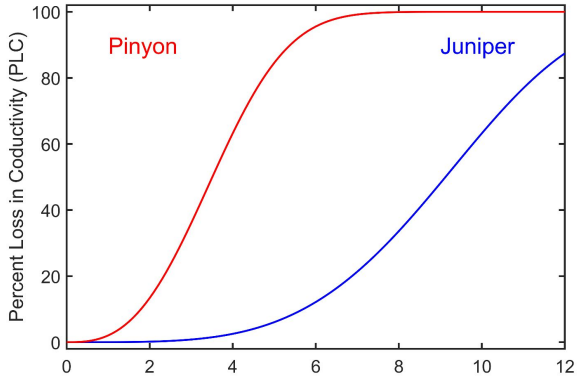
What are trait-based vegetation models?



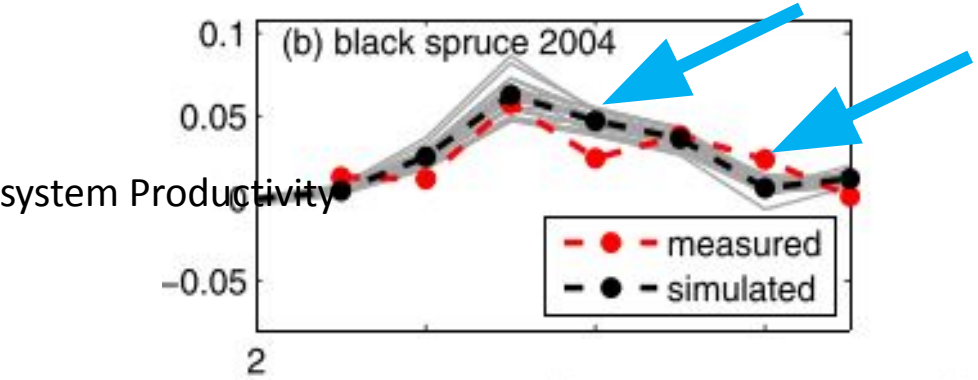
Outputs

Ecosystem diagnostics such as GPP, ET, SH, and biomass at a variety of spatial scales

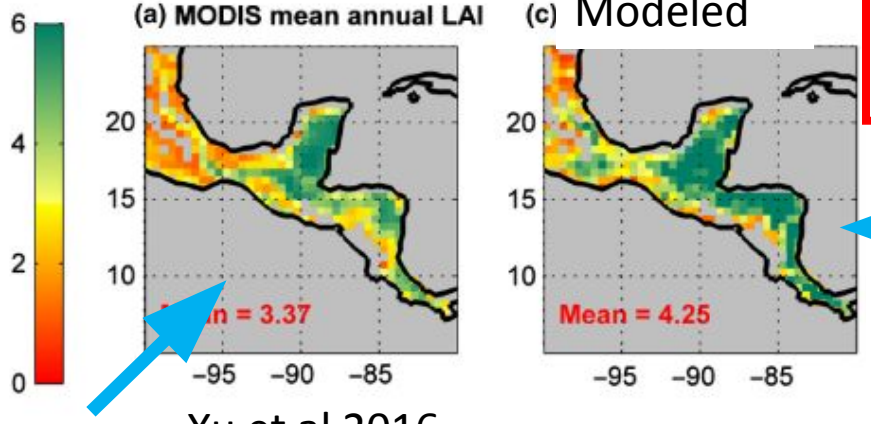
Why trait based vegetation models?



Different types of vegetation respond differently to water limitation. We can measure these traits and model their differential responses



Trugm



Xu et al 2016

Have the potential to:

- Link organismal processes to satellite-grid scale responses
- Provide both spatial and temporal continuity
- Tell us the physiological and ecological ***why*** behind the patterns we see in remote sensing a flux data
- Better understand possible ecosystem responses to future emission states and climate

Roadmap

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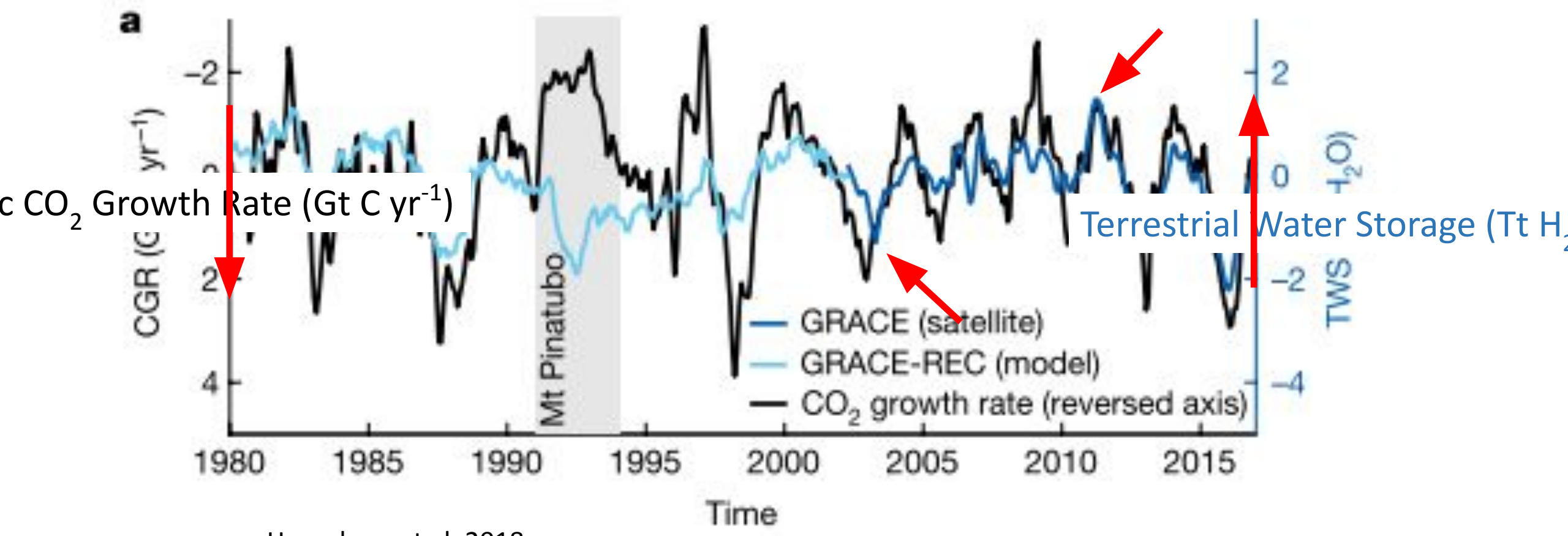
A satellite view: water availability strongly influences the land carbon sink

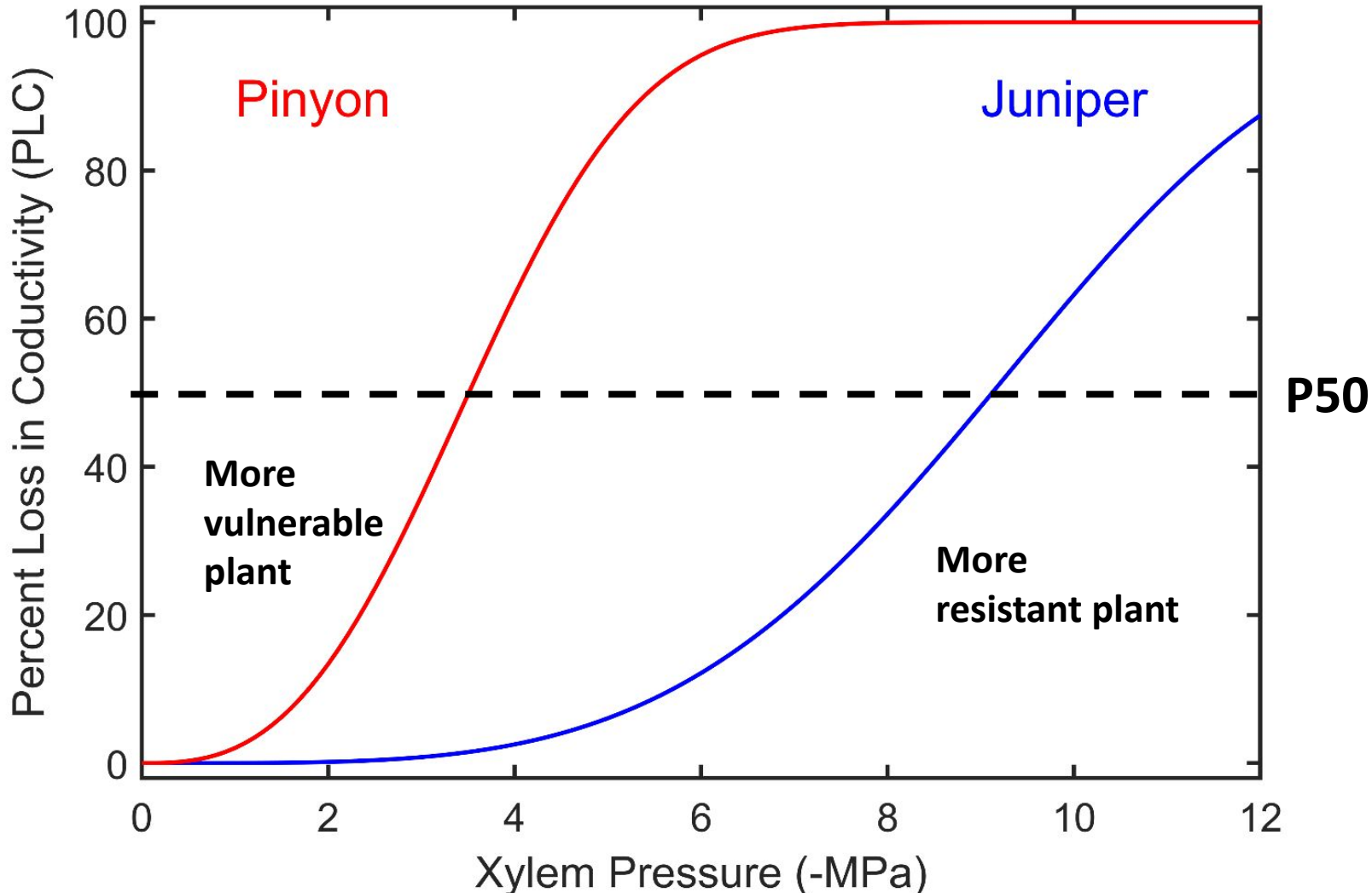


c CO_2 Growth Rate (Gt C yr^{-1})

Terrestrial Water Storage (Tt H_2

Humphrey et al. 2018

How can forests cope with water stress? Plant hydraulic traits



Roadmap

- What are trait-based vegetation models and why are they useful for understanding cross-scale processes?
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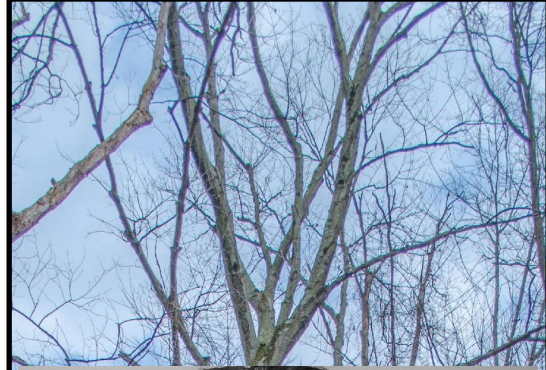
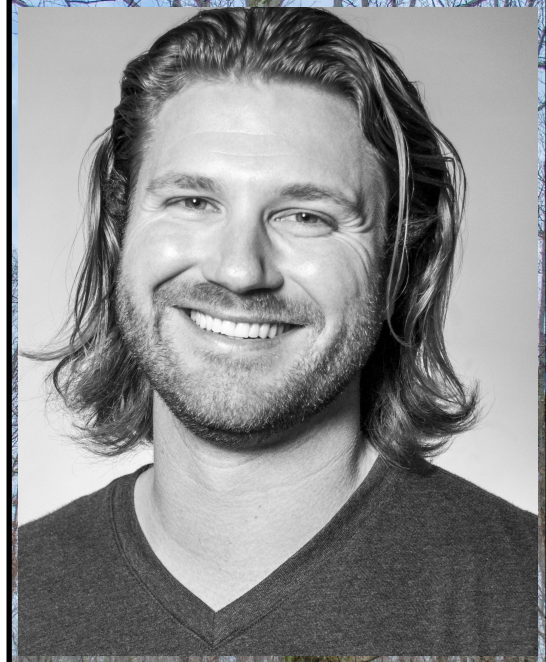
Questions

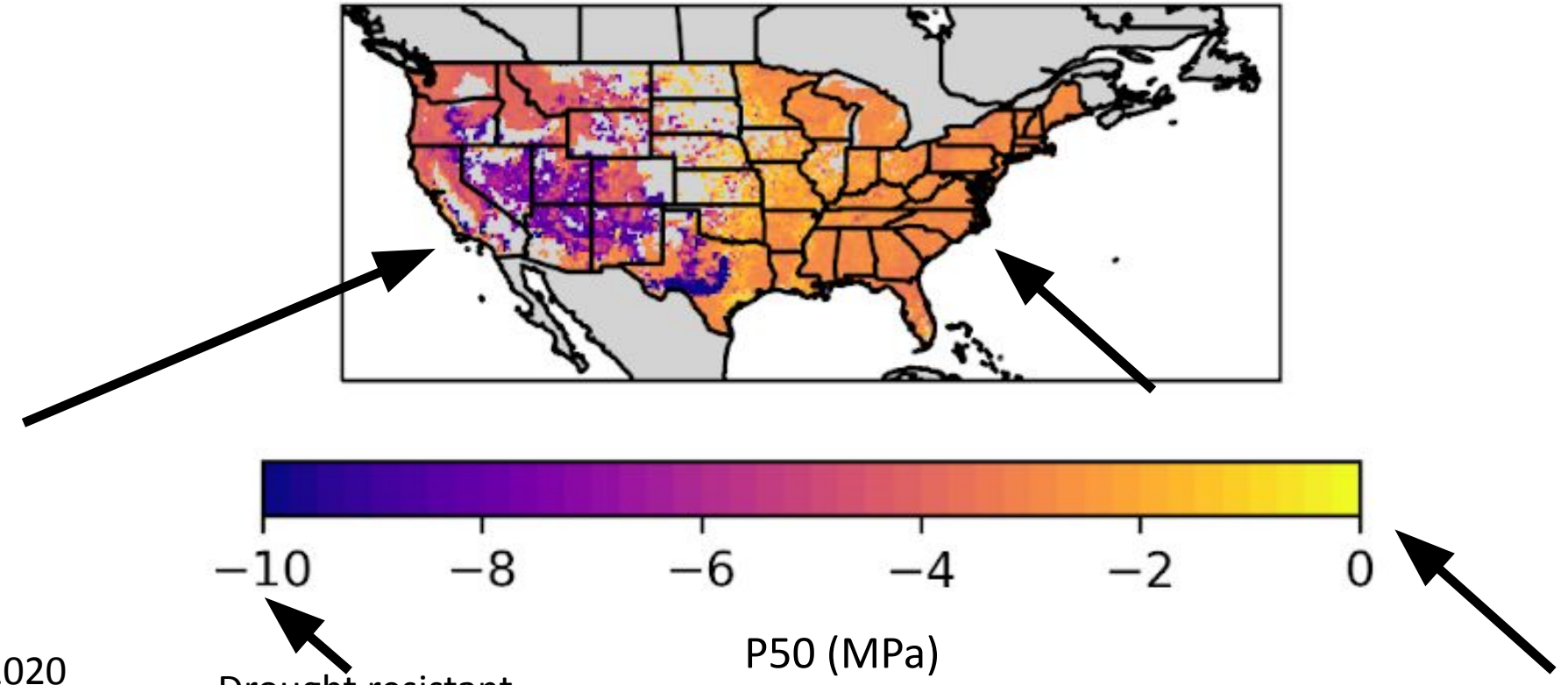
- How can we use trait-based vegetation models to scale functional diversity to a satellite grid cell in a physiologically meaningful way?
- Should we expect systematic changes in vegetation stress with projected changes in climate and increases CO_2?
- To what extent can current forest trait diversity buffer future increases in water stress?





Maps of community weighted hydraulic traits and trait diversity allow for quantification of drought resistant and drought vulnerable trait compositions of US forests

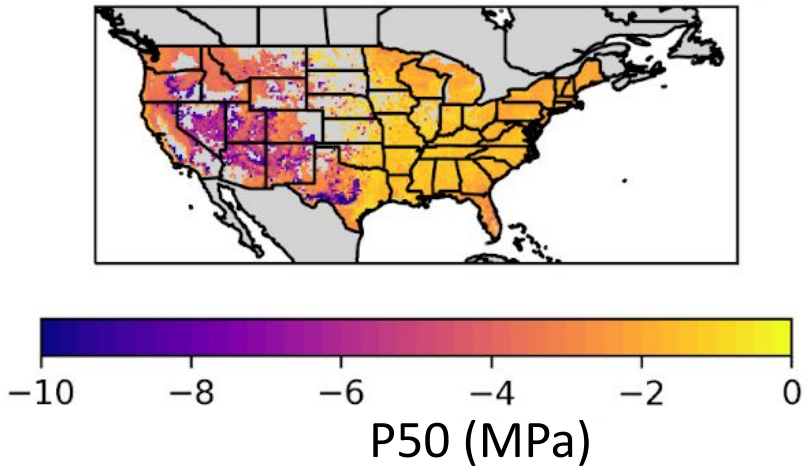
Community Weighted P50 derived from US Forest Inventory



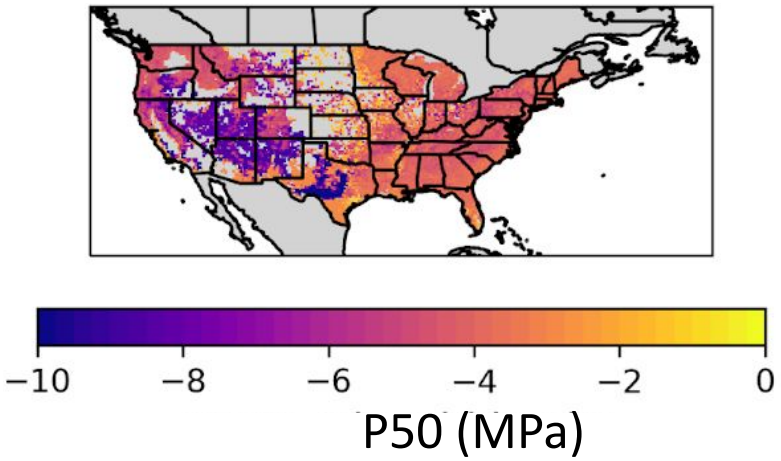
Trugman et al 2020

How do we bracket the uncertainty in ecosystem responses based on sub-grid scale hydraulic diversity?

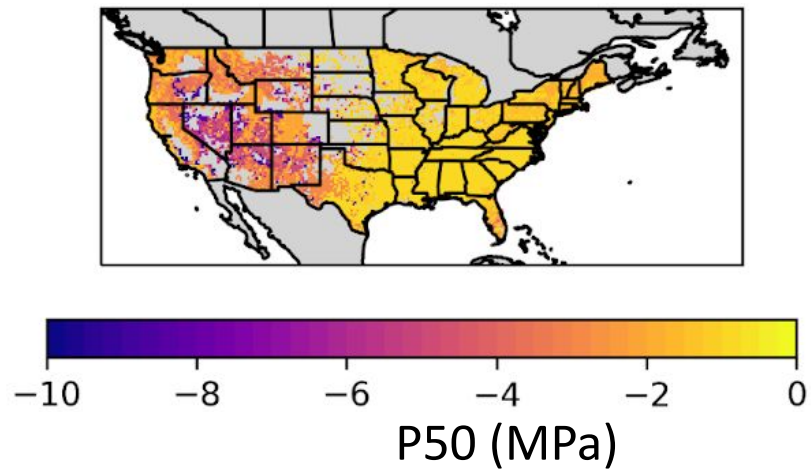
Within-plot most drought vulnerable



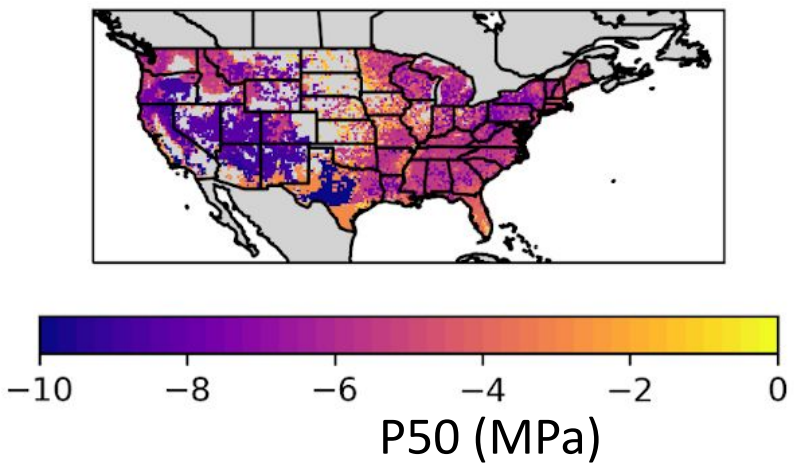
Within-plot most drought resistant



Regional species - drought vulnerable



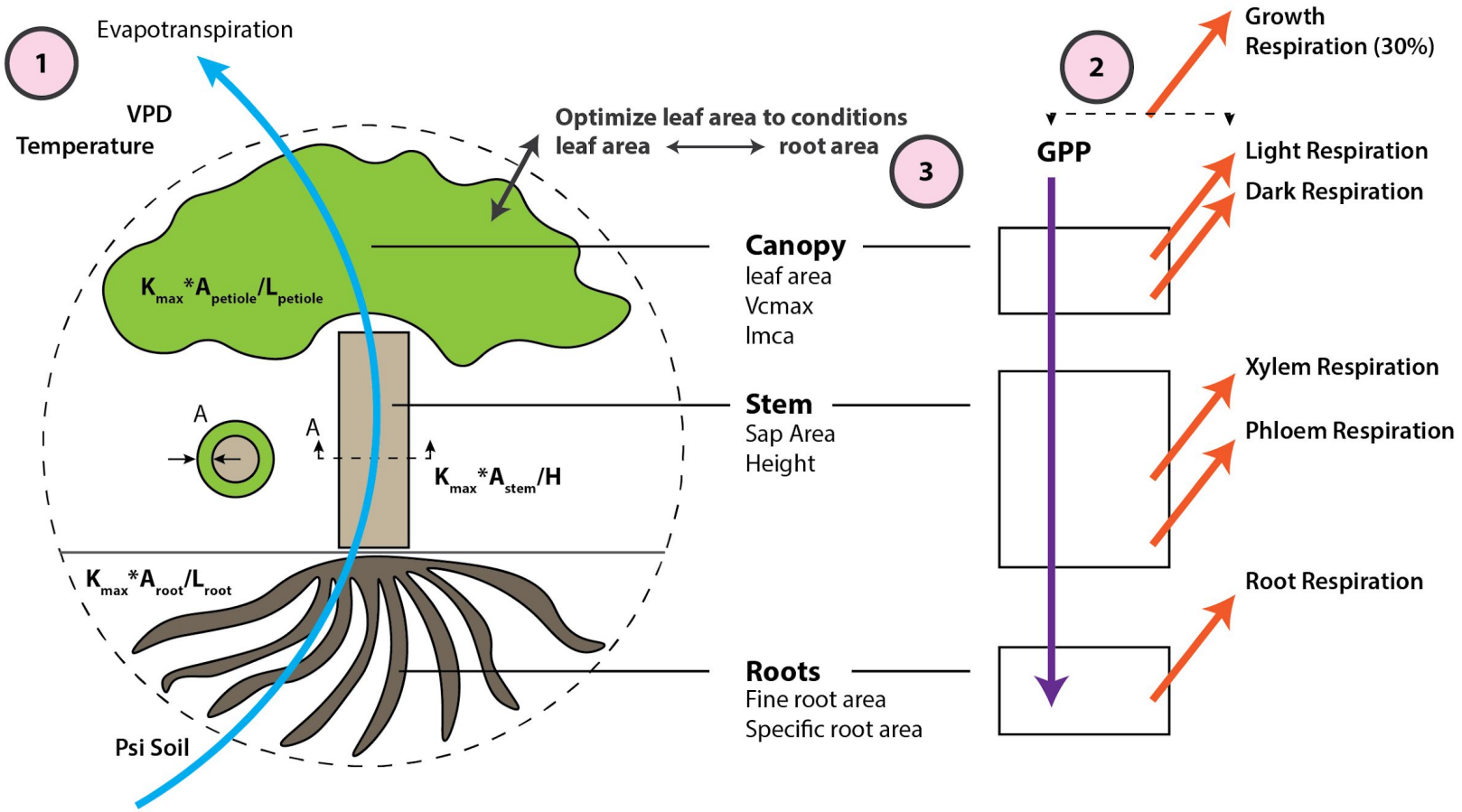
Regional species - drought resistant



Trugman et al 2020

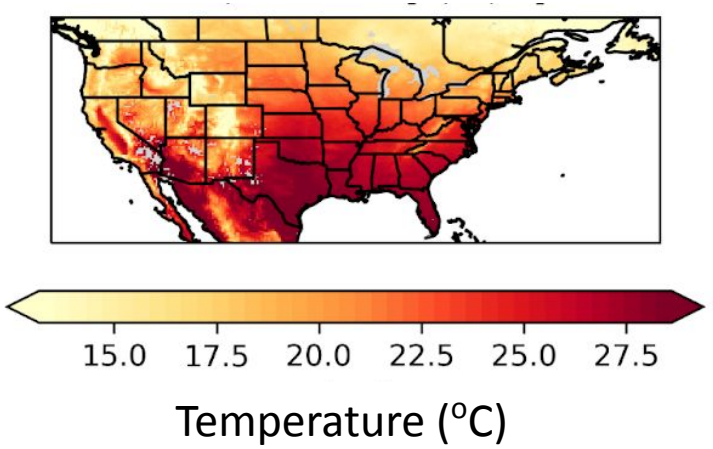
The Model

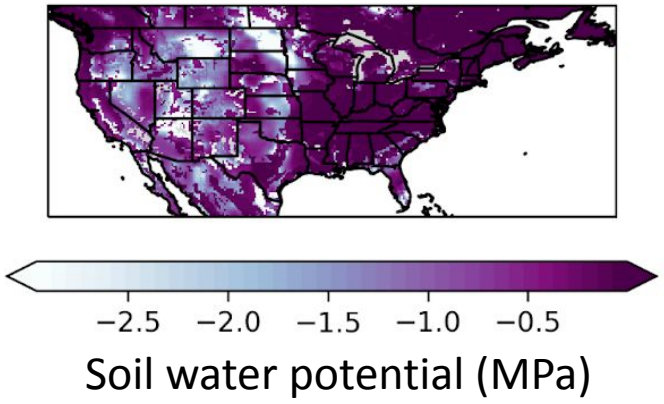
- Optimization-based tree model
- Realistic gas exchange
- Detailed plant hydraulics
- Photosynthesis= ***f***(traits, climate)
- Predicts how environmental conditions impact plant hydraulic function and carbon gain

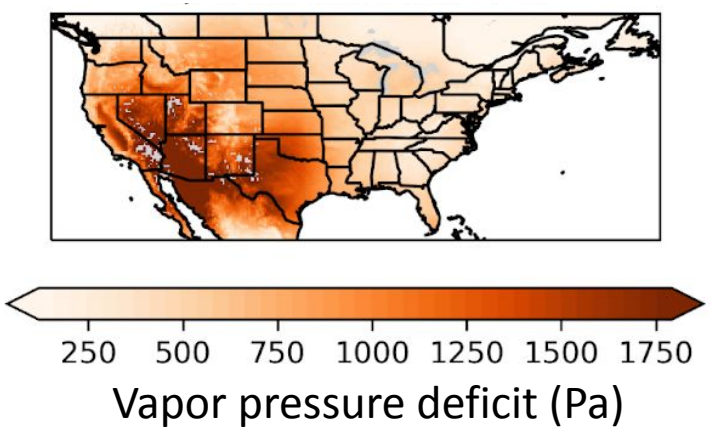


The experiments

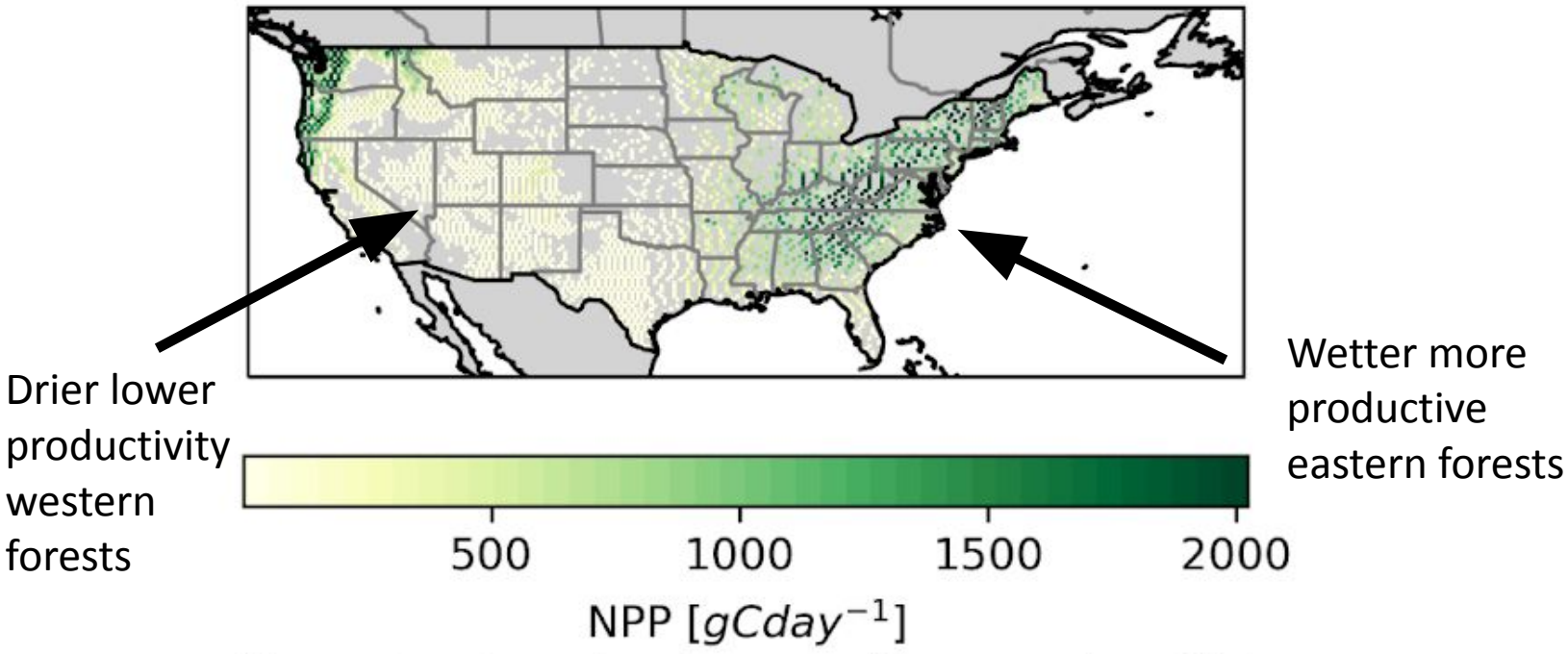
- Parameterized with plant hydraulic trait maps and trait diversity
- Forced with historical (1995-2014) and future (SSP3-7.0, 2081-2100) growing season climate





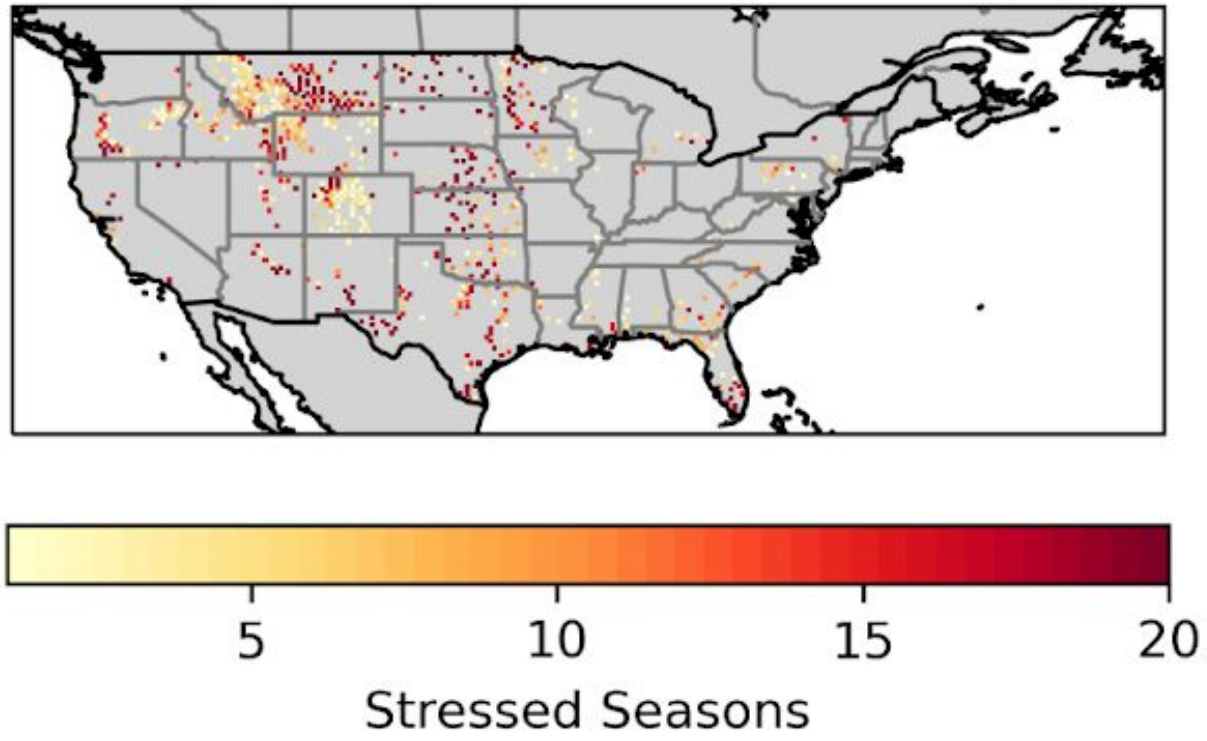


Both climate and hydraulic traits mediate patterns of current productivity

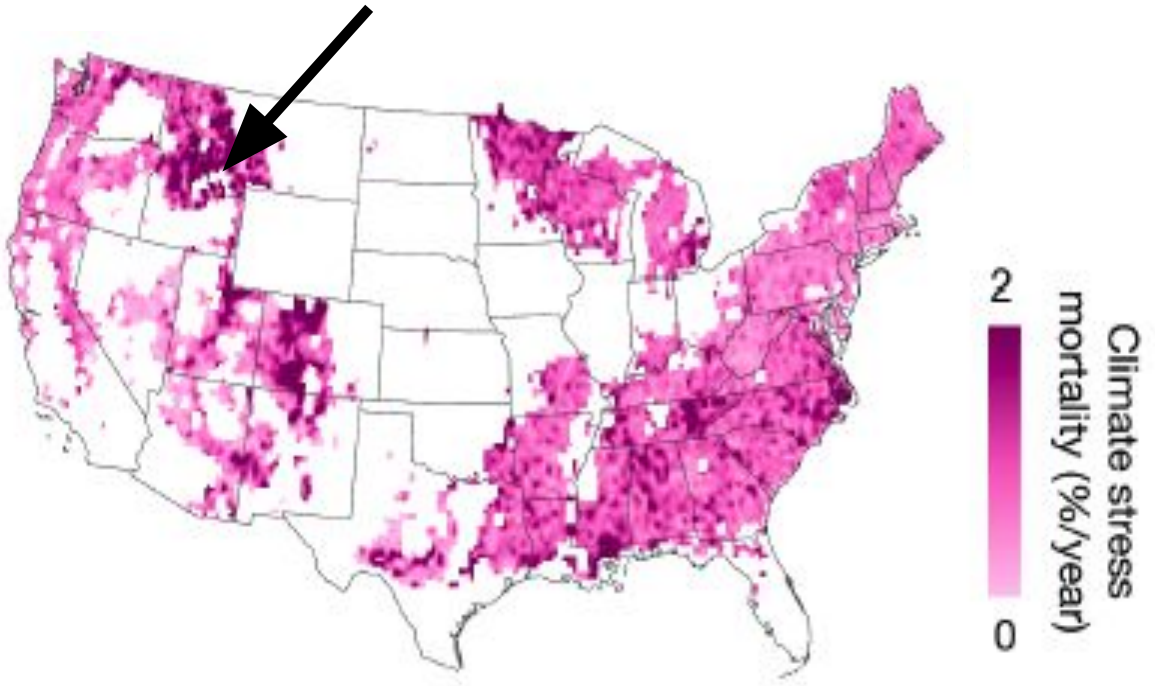


Quetin et al in prep

Both climate and hydraulic traits mediate patterns of water stress

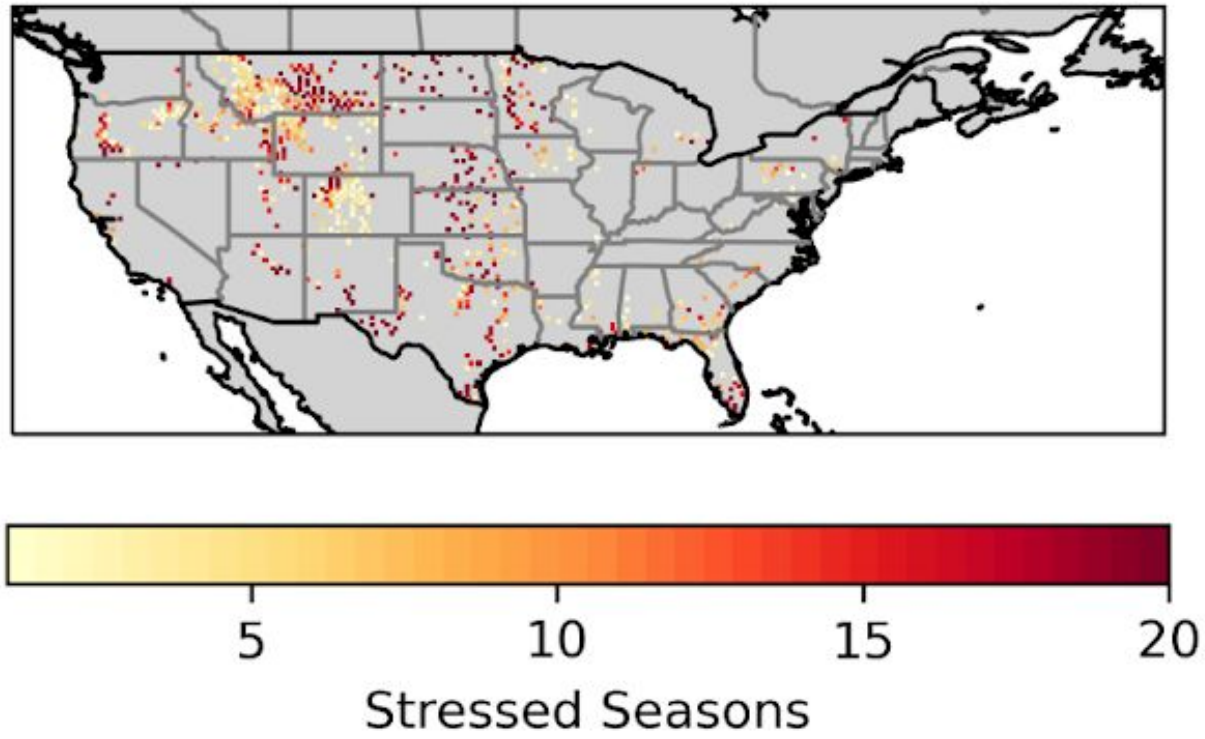


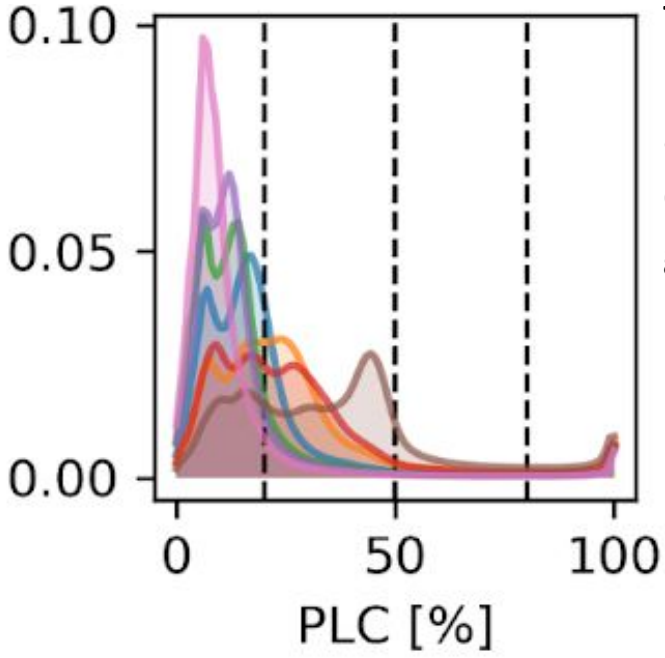
Quetin et al in prep



Anderegg et al 2022

Both climate and hydraulic traits mediate patterns of water stress



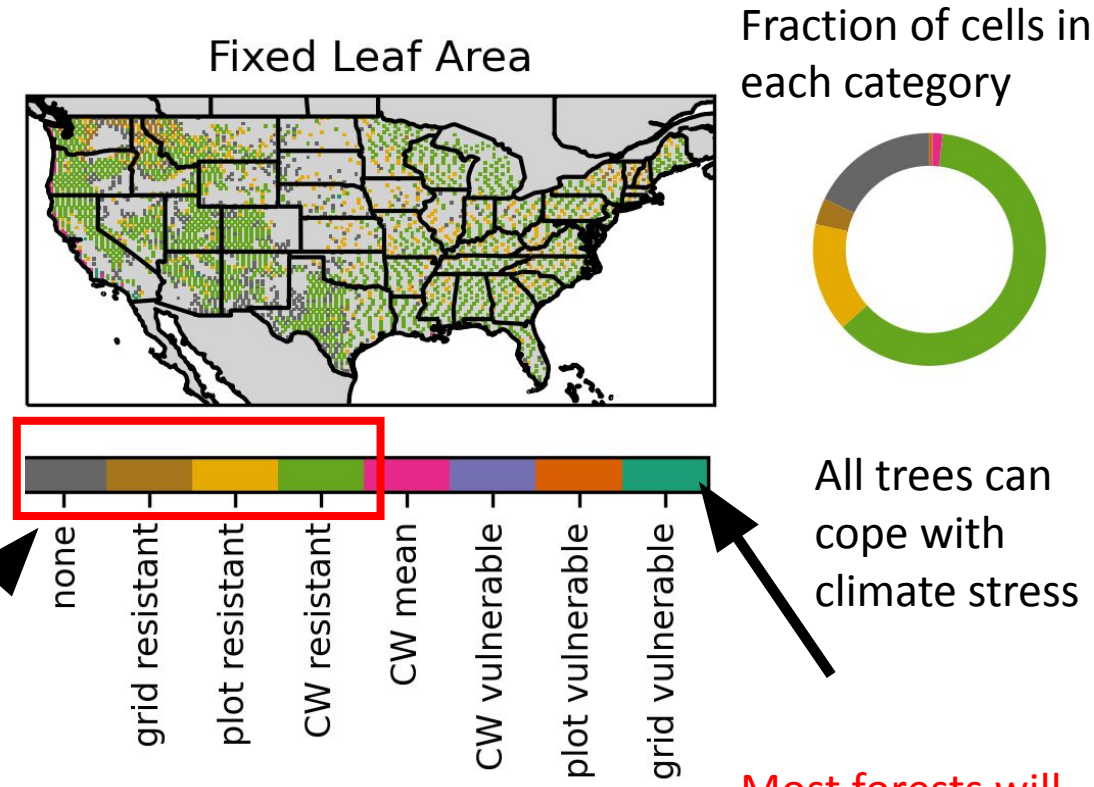


Trait diversity mediates PLC across climate gradients

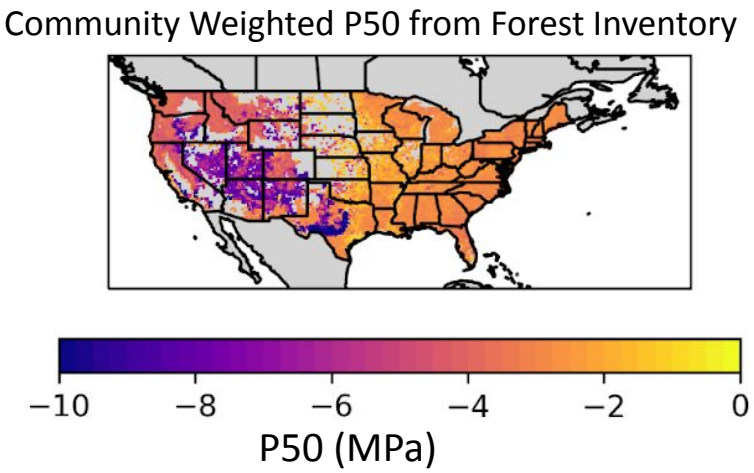
CW mean
CW vulnerable
CW resistant
plot vulnerable
plot resistant
grid vulnerable
grid resistant

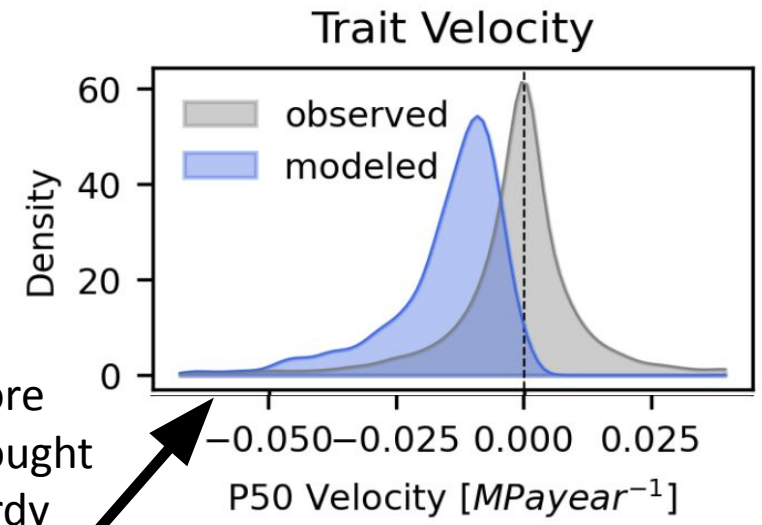
Quetin et al in prep

Hydraulic trait diversity is sufficient to protect ecosystems against increased risk in some locations, but composition is not shifting fast enough to keep up with climate stress



Most forests will need at least some
nposition





More drought hardy

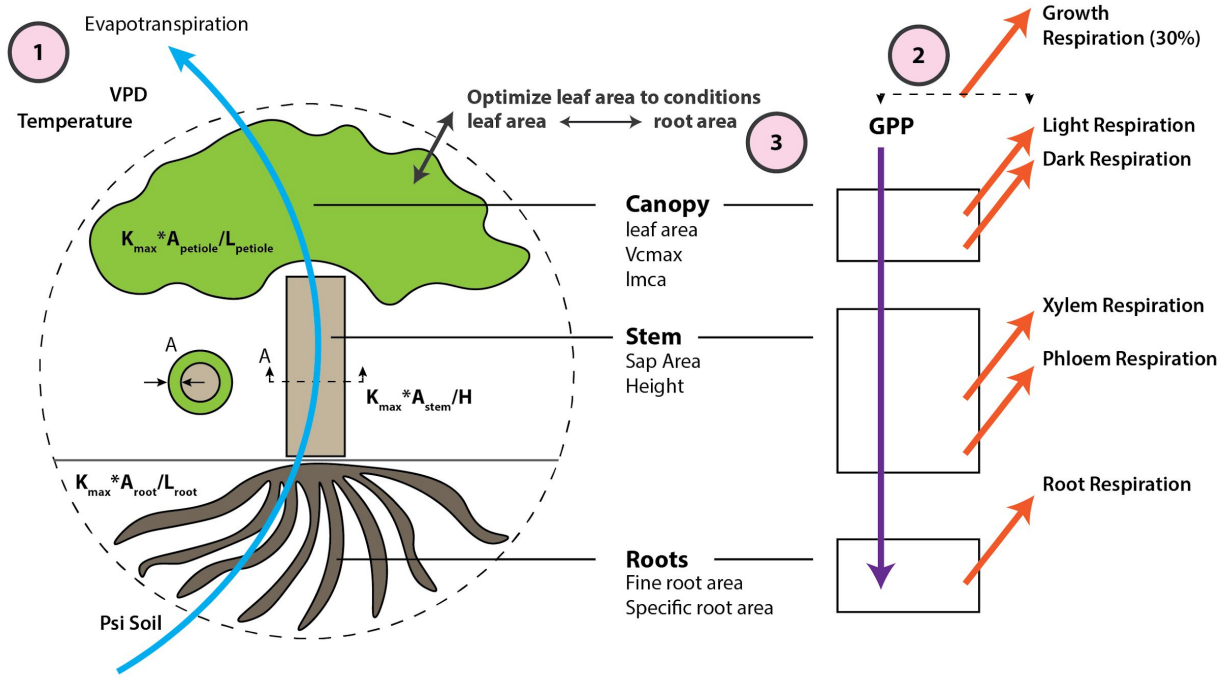
Quetin et al in prep

Summary

- Trait-based vegetation models enable us to scale organismal processes to predict ecosystem fluxes and satellite grid cell responses
- Trait-based vegetation models enable us to ask the ***why*** underlying patterns we see in eddy covariance and remotely-sensed diagnostics
- Both climate and hydraulic traits mediate patterns of current productivity and water stress
- Many forests may require at least some shift in species composition to mediate climate stress

The Model

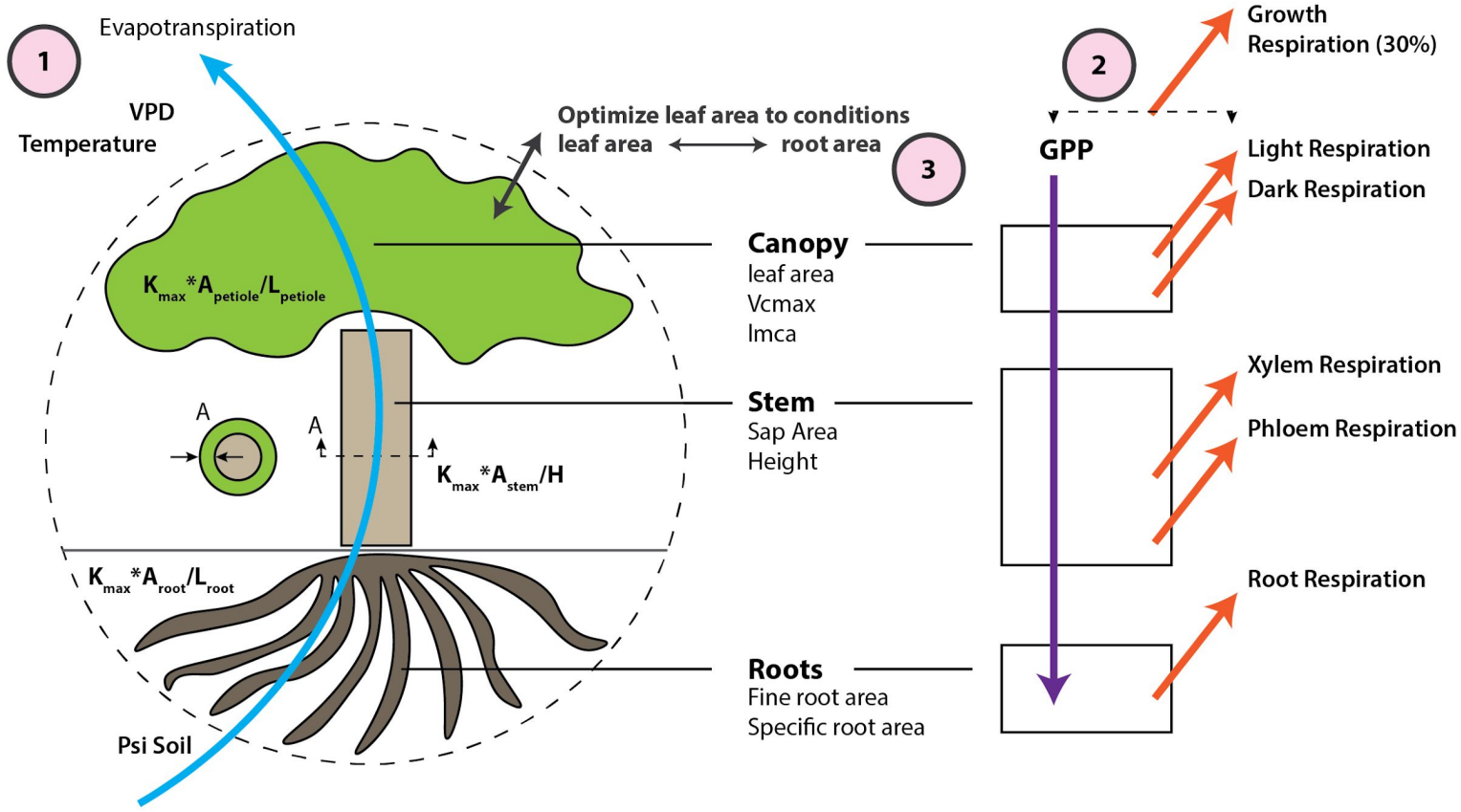
- Daily timestep
- **Meteorological forcings include:** radiation, temperature, root zone soil water potential, atmospheric vapor pressure deficit, CO_2
- **Outputs include:** transpiration, net carbon assimilation, plant water potentials (e.g. water status), and percent loss in hydraulic conductivity



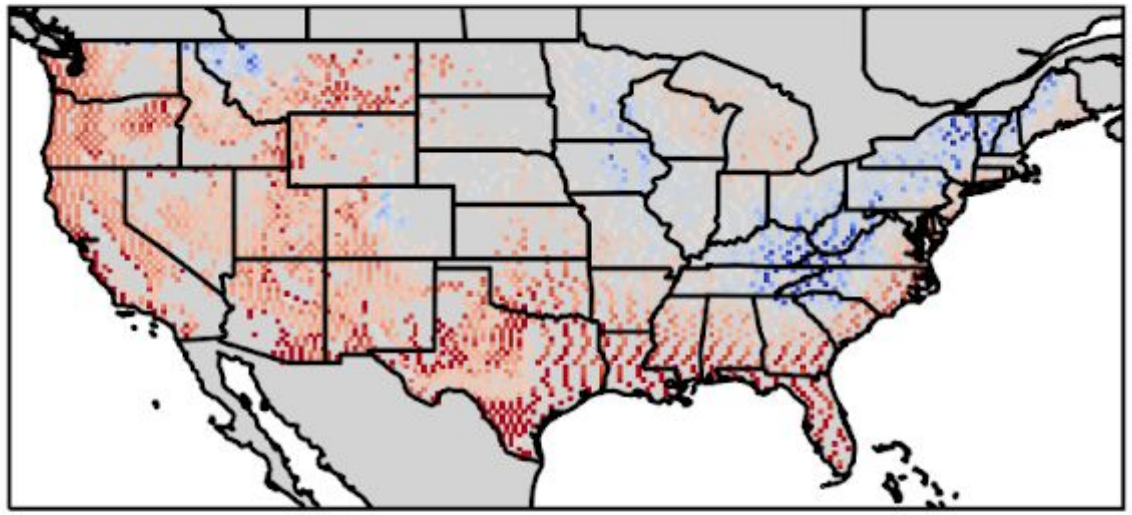
The Model

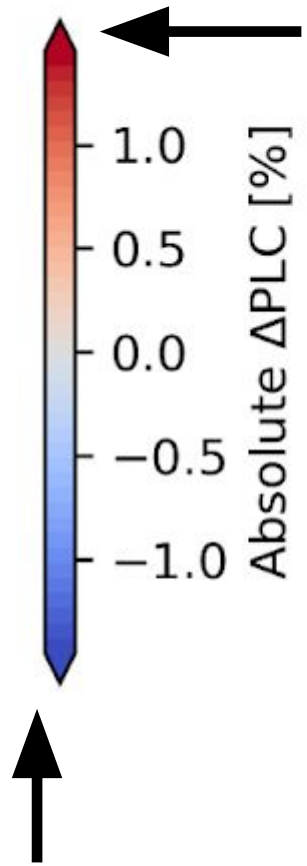
Model validated against observations of:

- Leaf:sapwood area (*Trugman et al 2019, GCB*)
- Carbon use efficiency (*Mathias and Trugman 2022, Ecology Letters*)
- ET, GPP, tree mortality (*Quetin et al in review*)

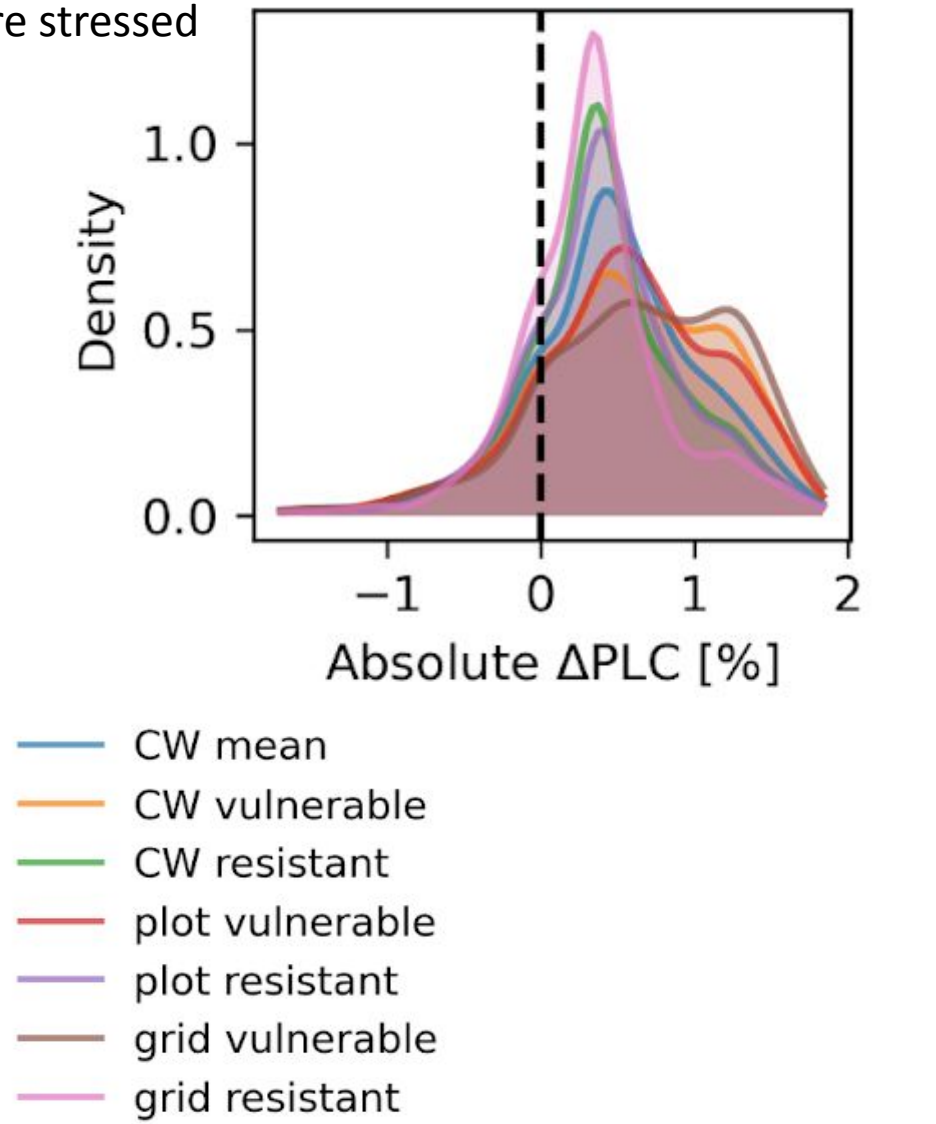


Projected climate change increases systematic daily stress





Trait diversity mediate stress distributions across climate gradients



Quetin et al in prep