The connection between climate and declining forest health in the western United States.

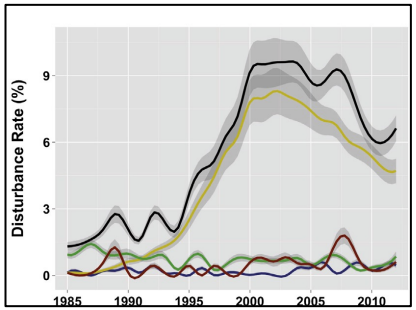
David M. Bell[1], Matthew J. Reilly[2,3], Warren B. Cohen[1], and Zhiqiang Yang[3]

1 USDA Forest Service, Pacific Northwest Research Station

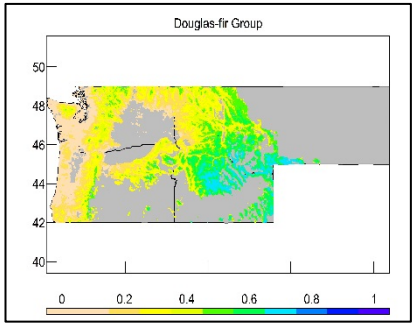
2 Humboldt State University

3 Oregon State University, College of Forestry

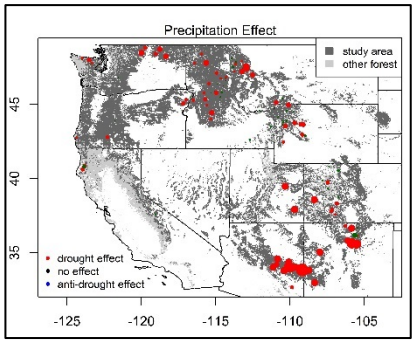
Roadmap for Presentation



- Slow, subtle forest change observed from above

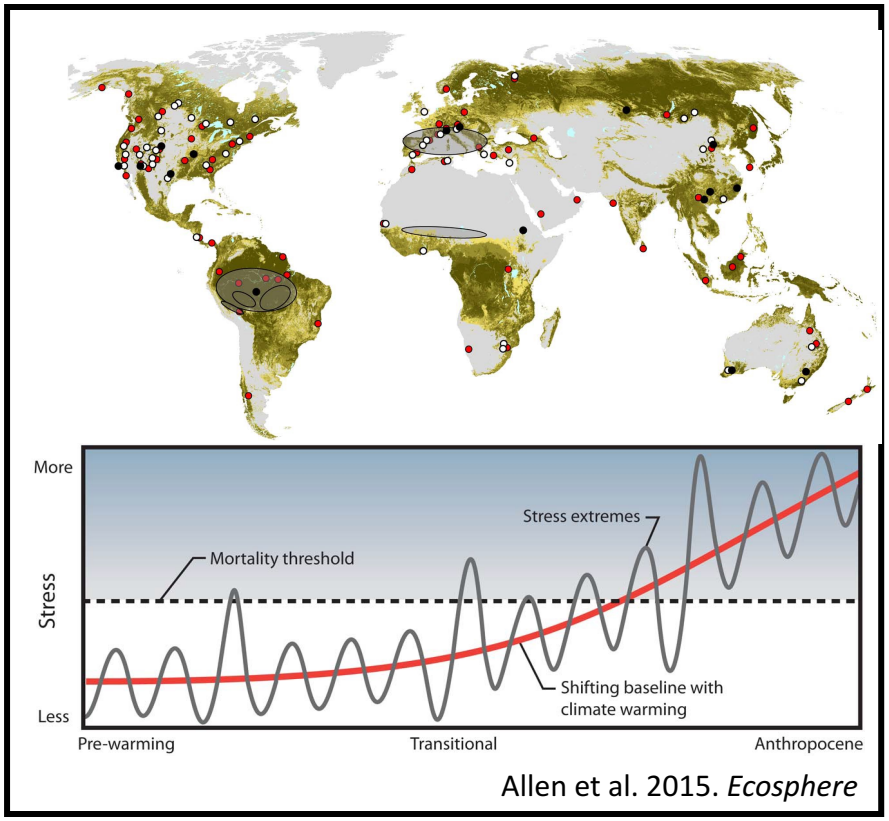


- Contemporary and future forest decline

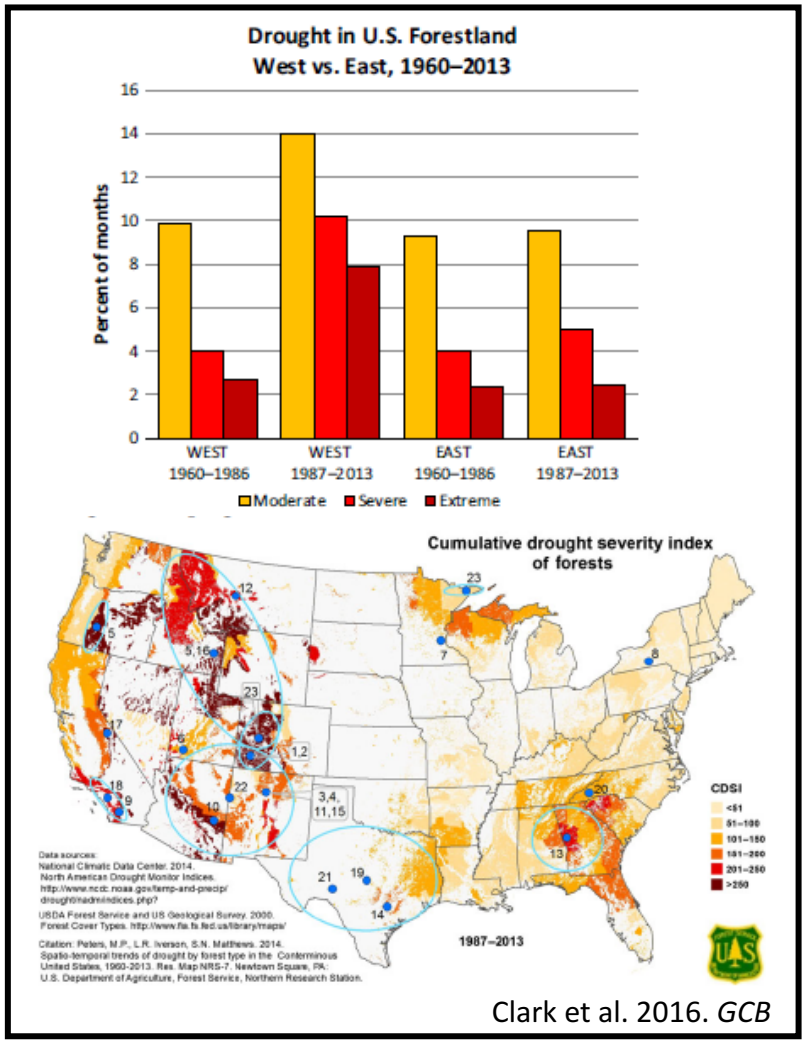


- Temporally complex drought and forest change dynamics

Forest change around the world



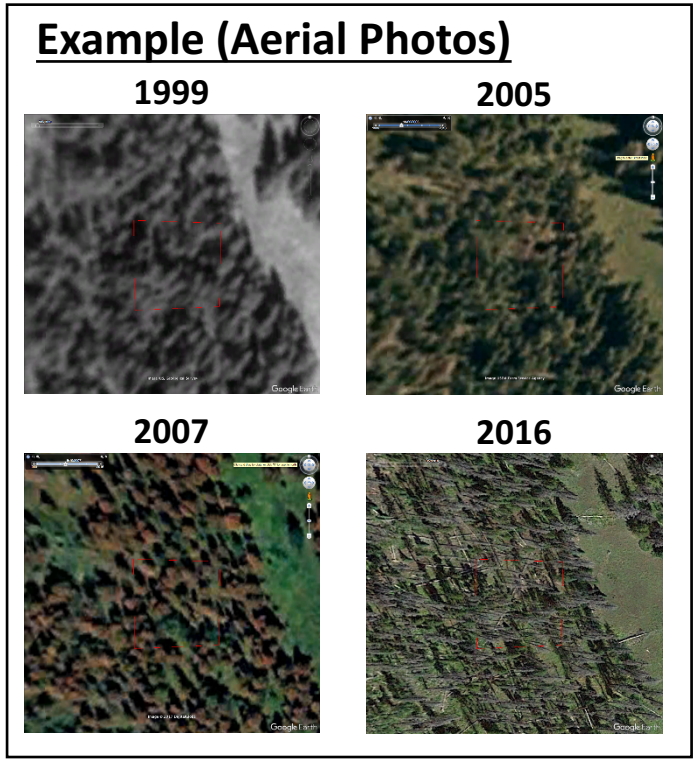
Allen et al. 2015. *Ecosphere*

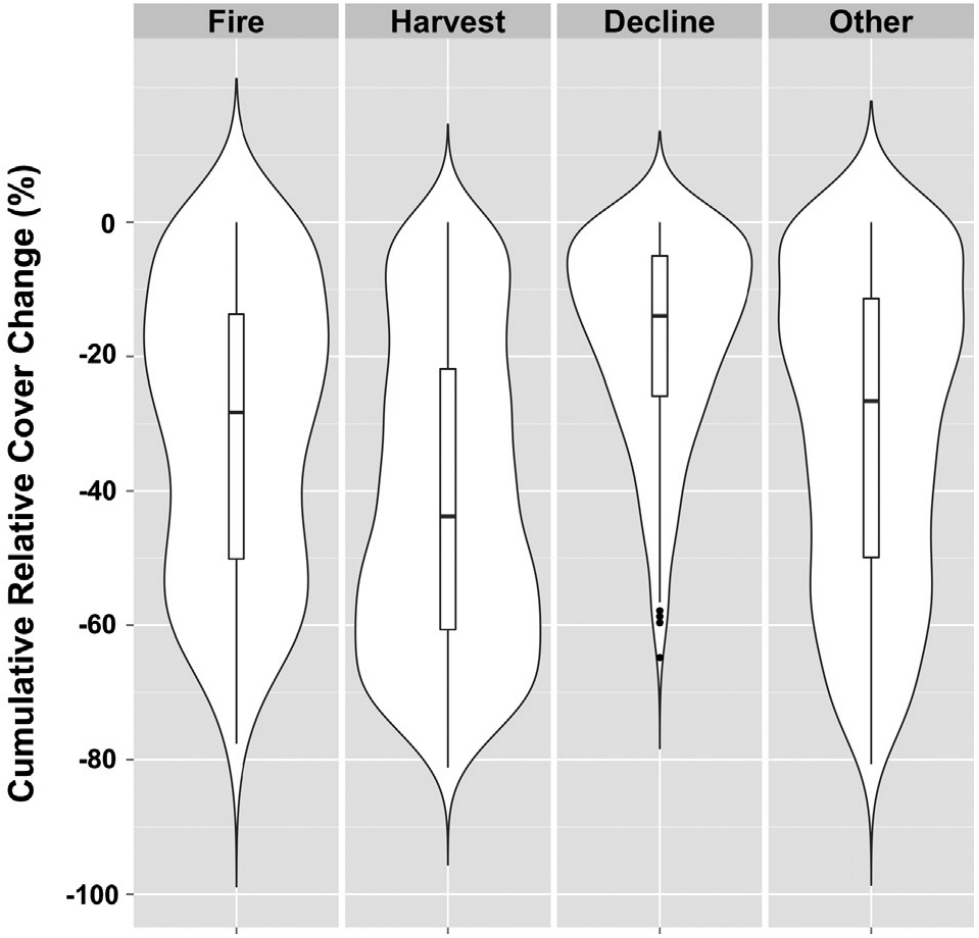


Clark et al. 2016. *GCB*

Remote Sensing of Forest Change

- Some forest change can be subtle.

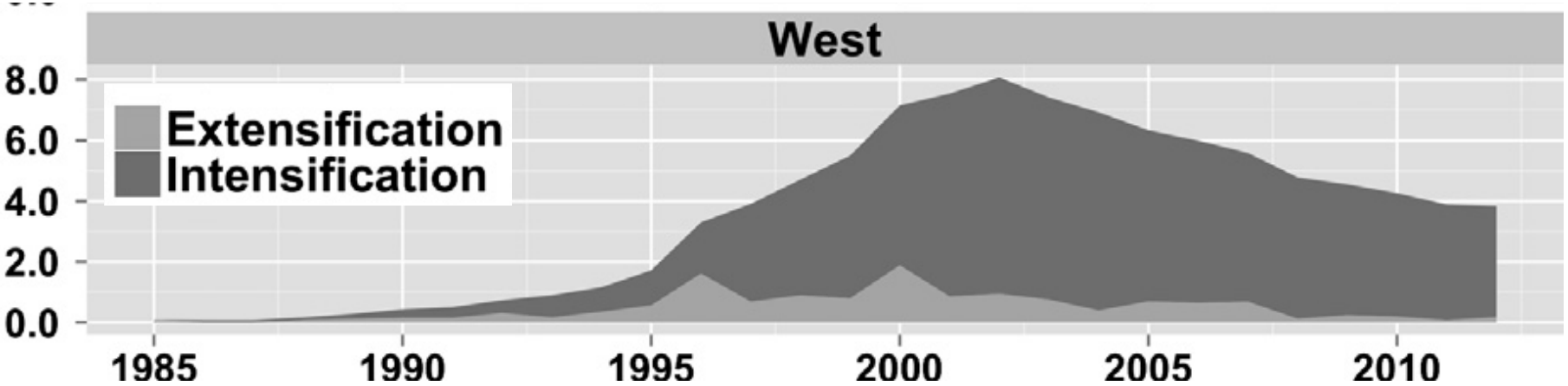




Cohen et al. 2016. *Forest Ecology and Management*

Remote Sensing of Forest Change

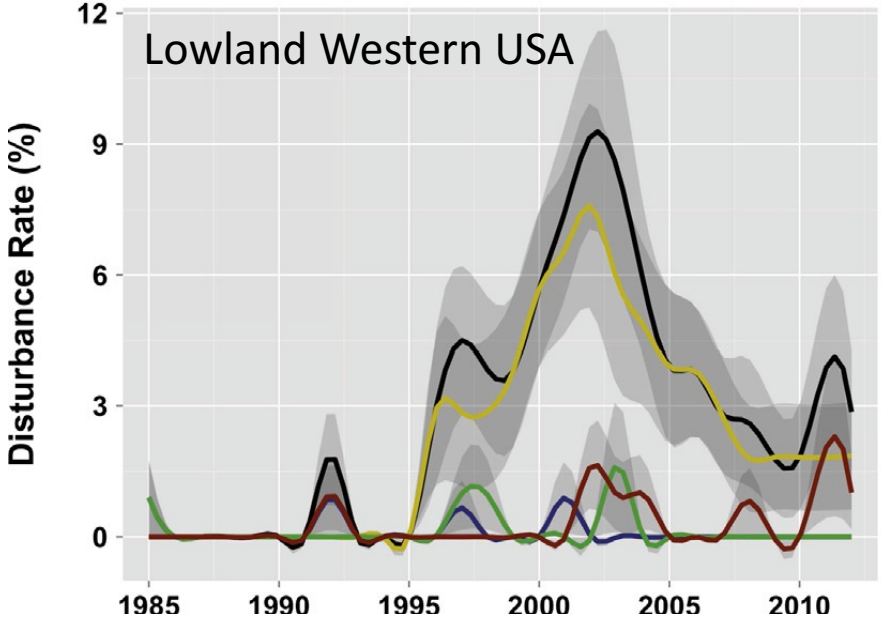
- Some forest change can be subtle.
- Subtle changes develop over several years

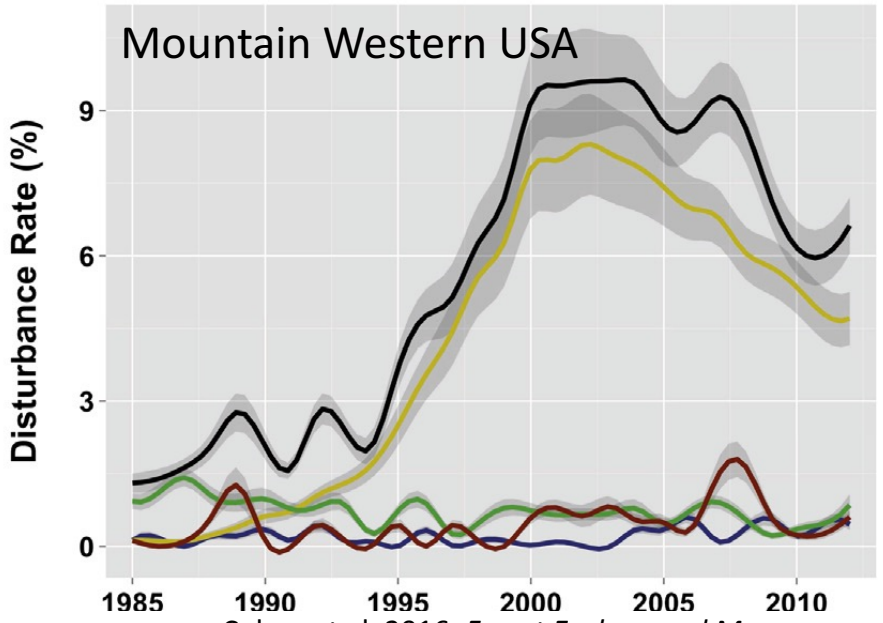


Cohen et al. 2016. *Forest Ecology and Management*

Remote Sensing of Forest Change

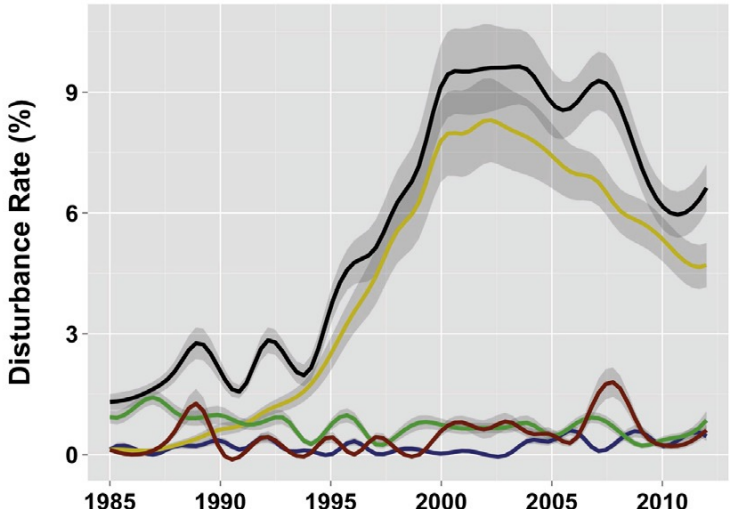
- Some forest change can be subtle.
- Subtle changes develop over several years
- Slow, subtle changes in forest canopies (e.g., declines) are now ubiquitous in the western USA.

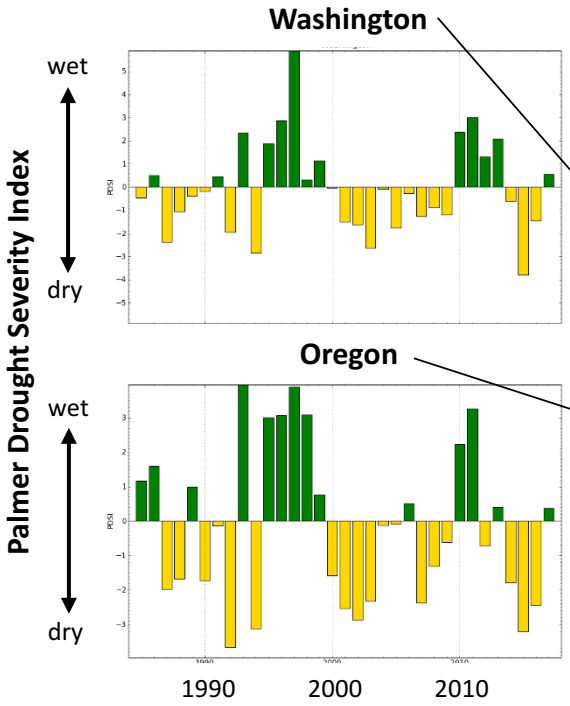


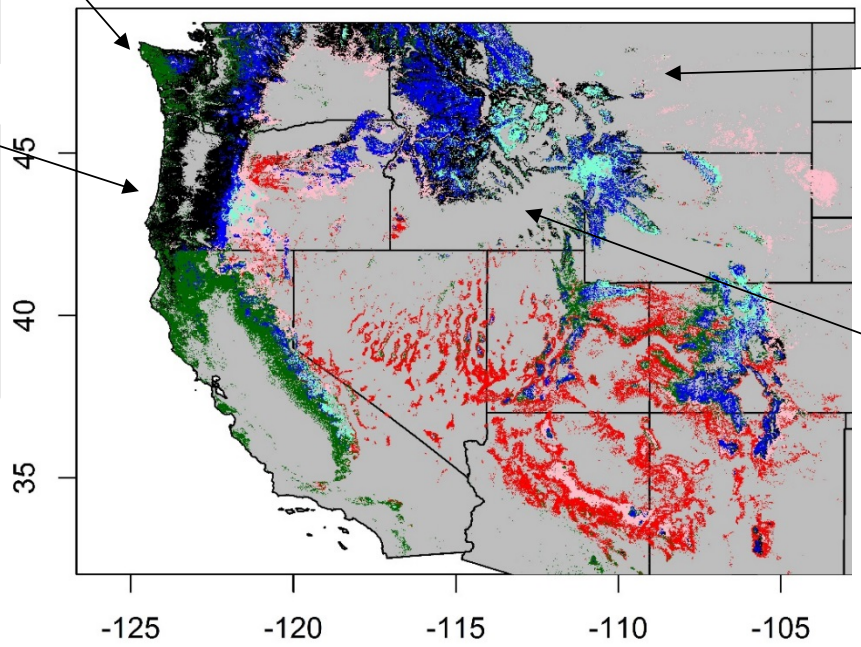


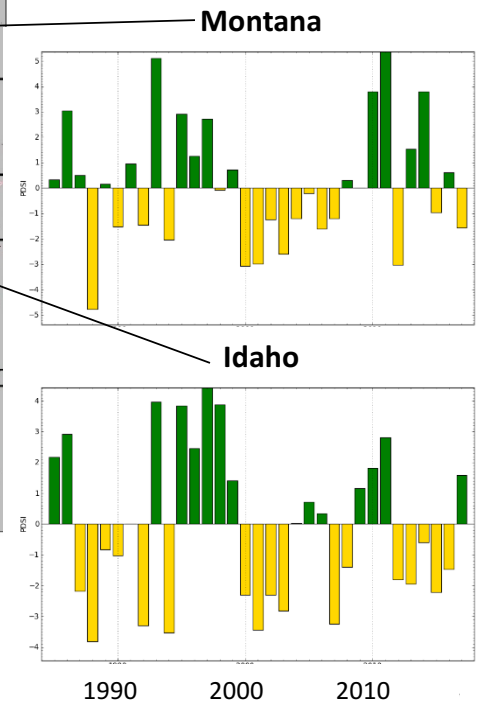
Cohen et al. 2016. *Forest Ecology and Management*

Drought as a driver?





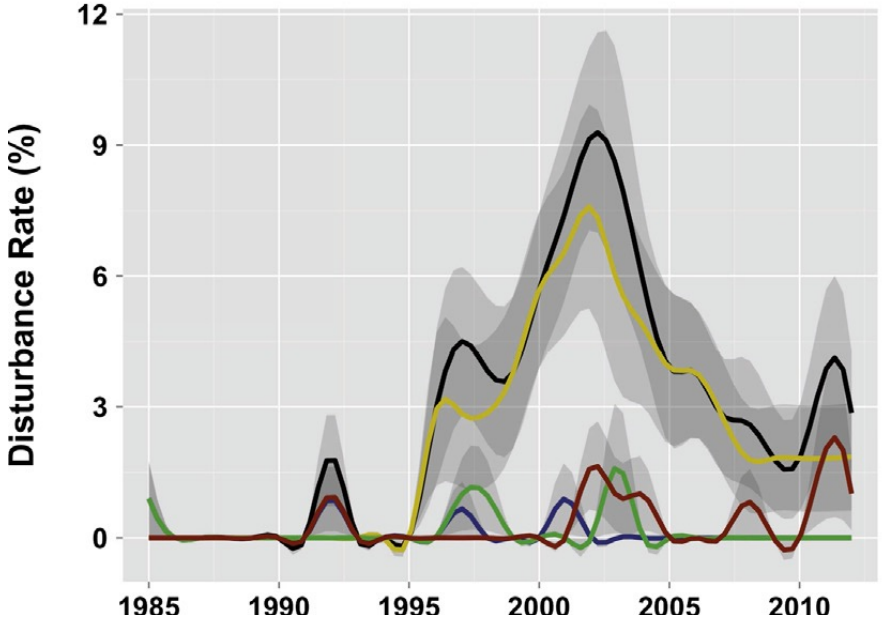


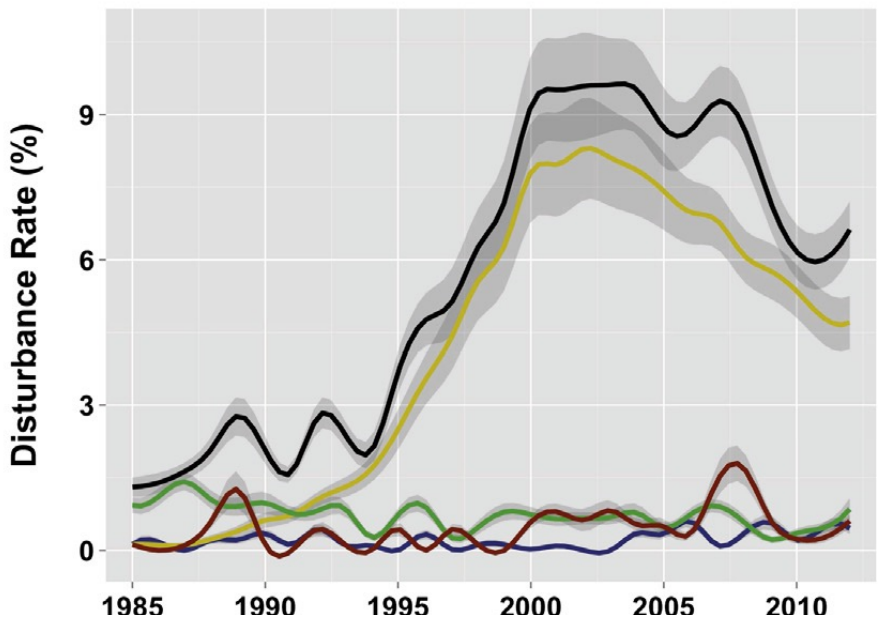


Westwide Drought Tracker; https://wrcc.dri.edu/wwdt

Research Questions

1. What role is multi-year drought playing in remotely sensed forest decline (**RSFD**) events?
2. How might RSFD behave as climate changes?

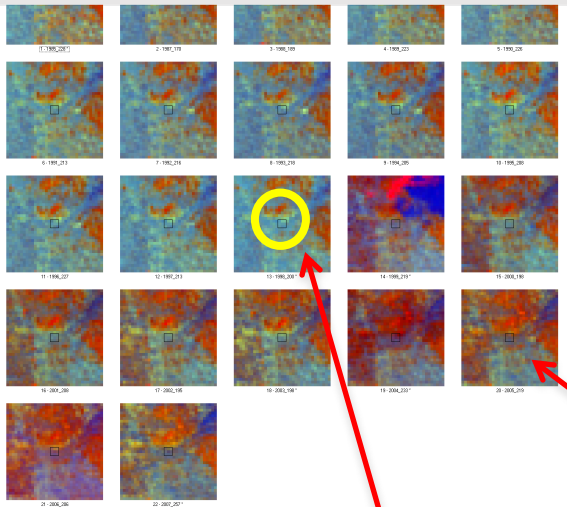


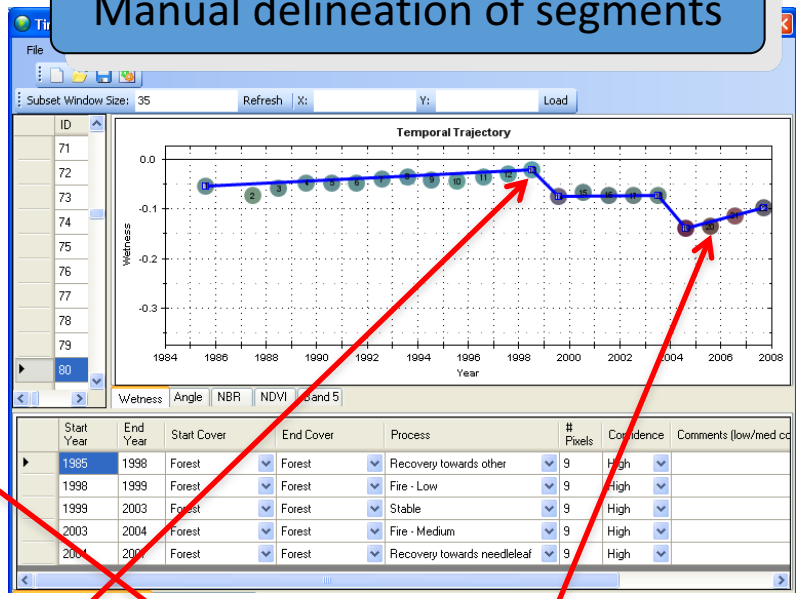


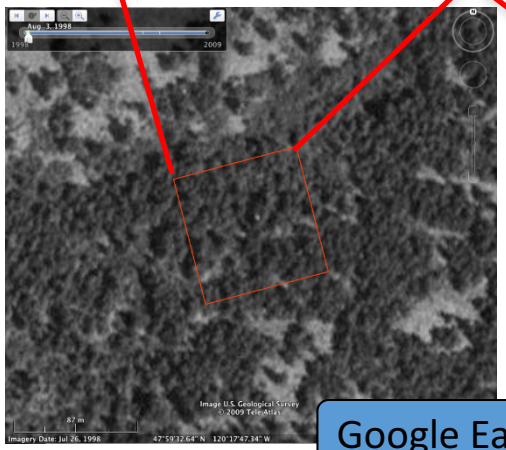
TimeSync Observations of Change

Landsat image chips for all years

Manual delineation of segments







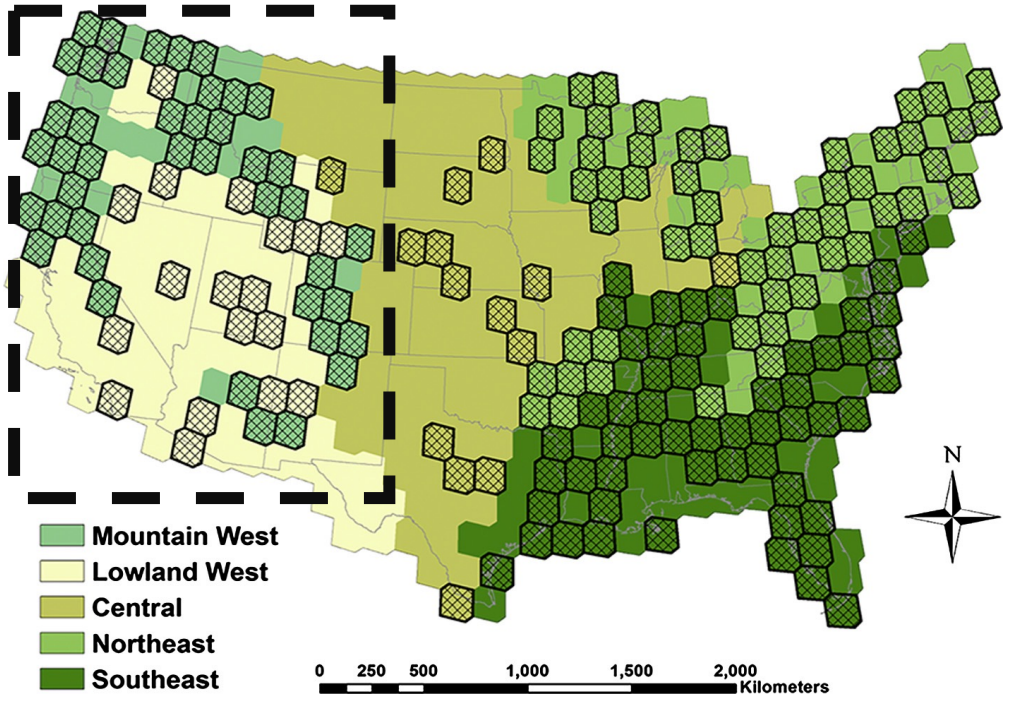
Google Earth High res

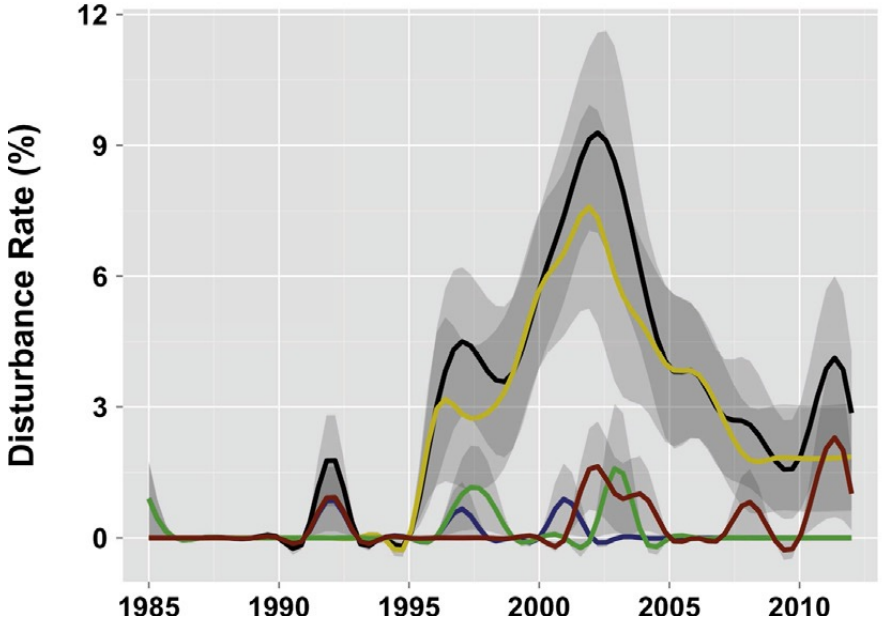
Cohen et al. 2010. *Remote Sensing of Environment*

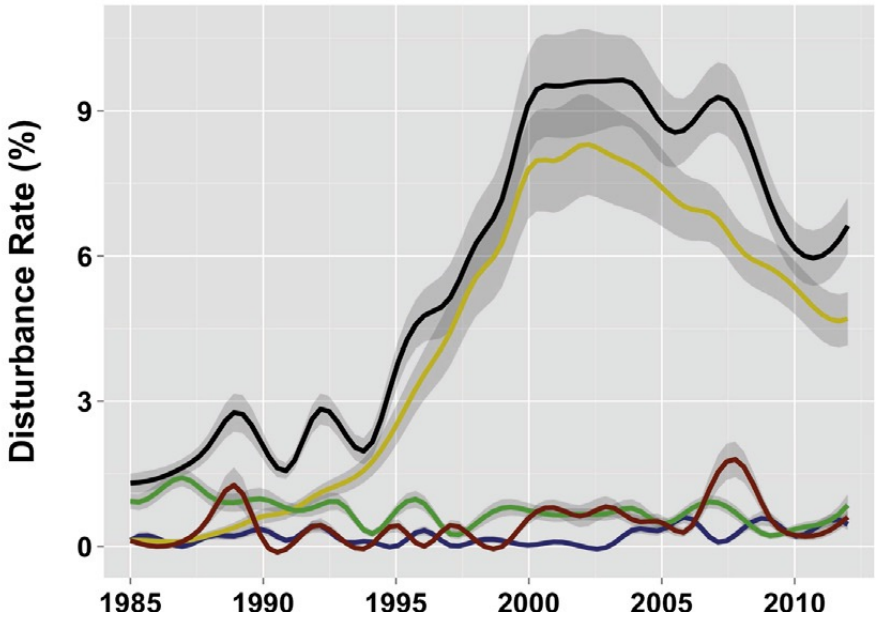
Sampling RSFD

For assessing drought impacts on RSFD

- 1194 forested locations for western US
- Two-stage stratified random sample

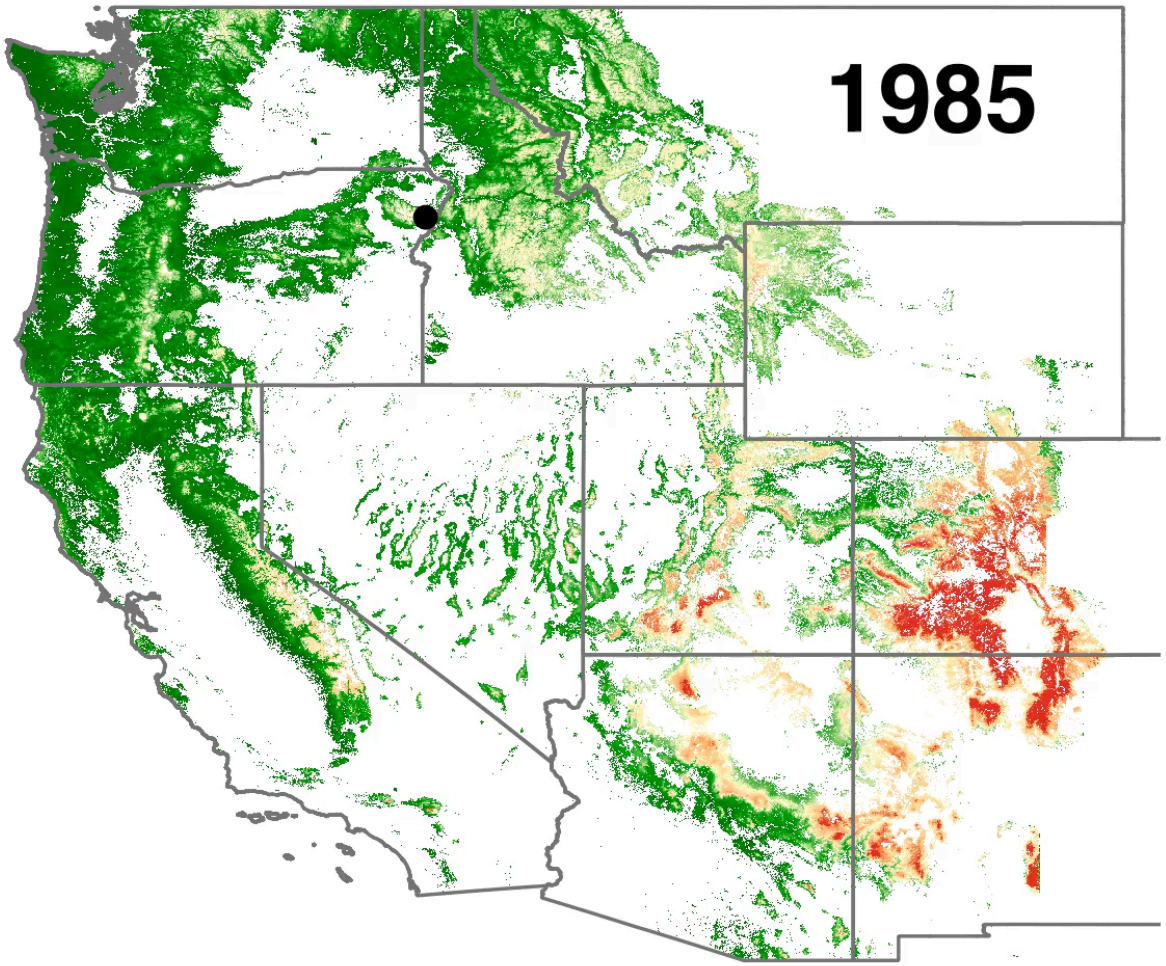




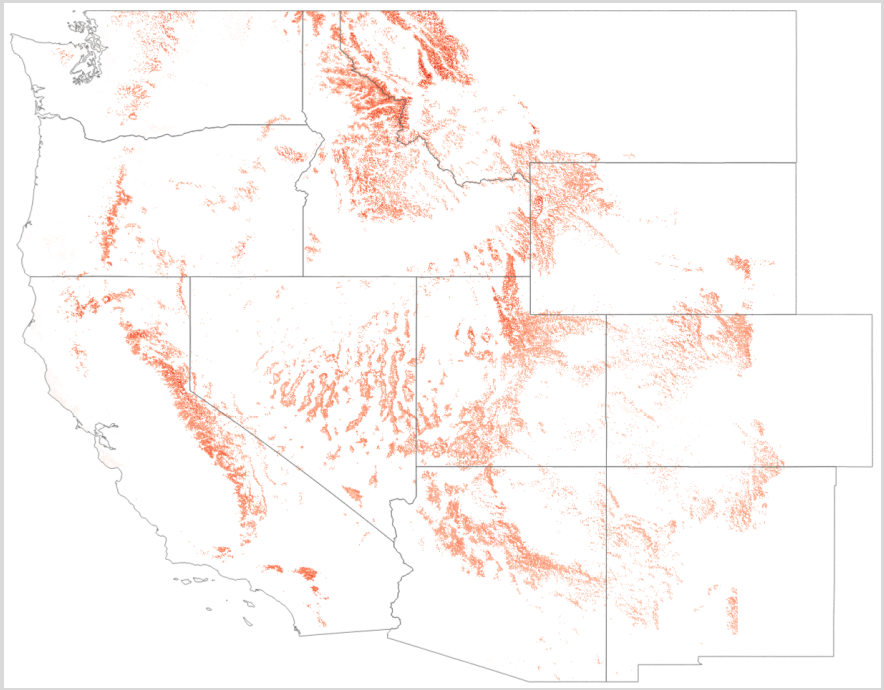


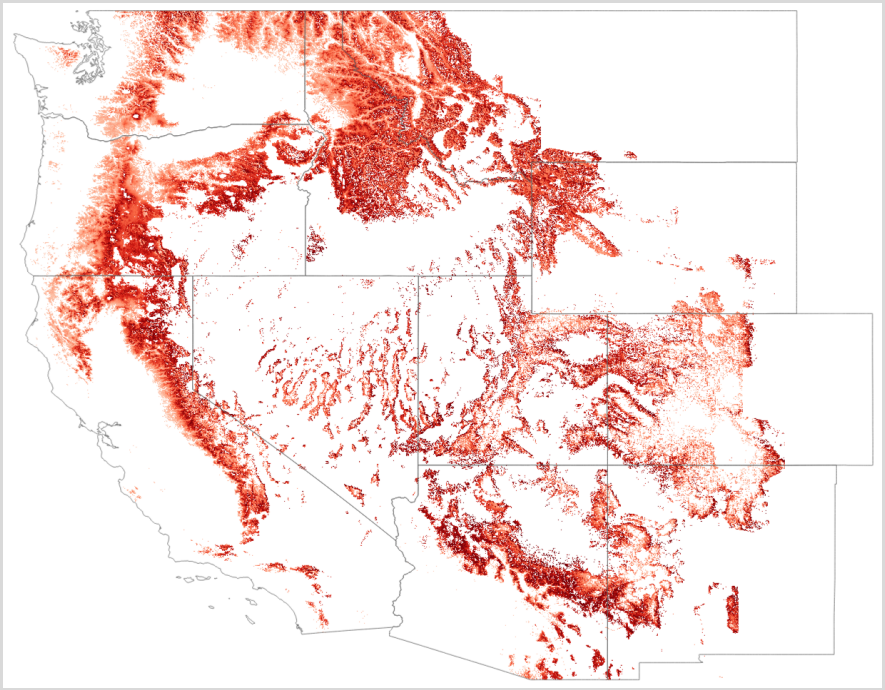
MaxEnt Model

- Low stress likelihood
- High stress likelihood
- TimeSync stress observations



Stress Probability Trend (2015-2100) – *p-value* <0.05





RCP 4.5

RCP 8.5

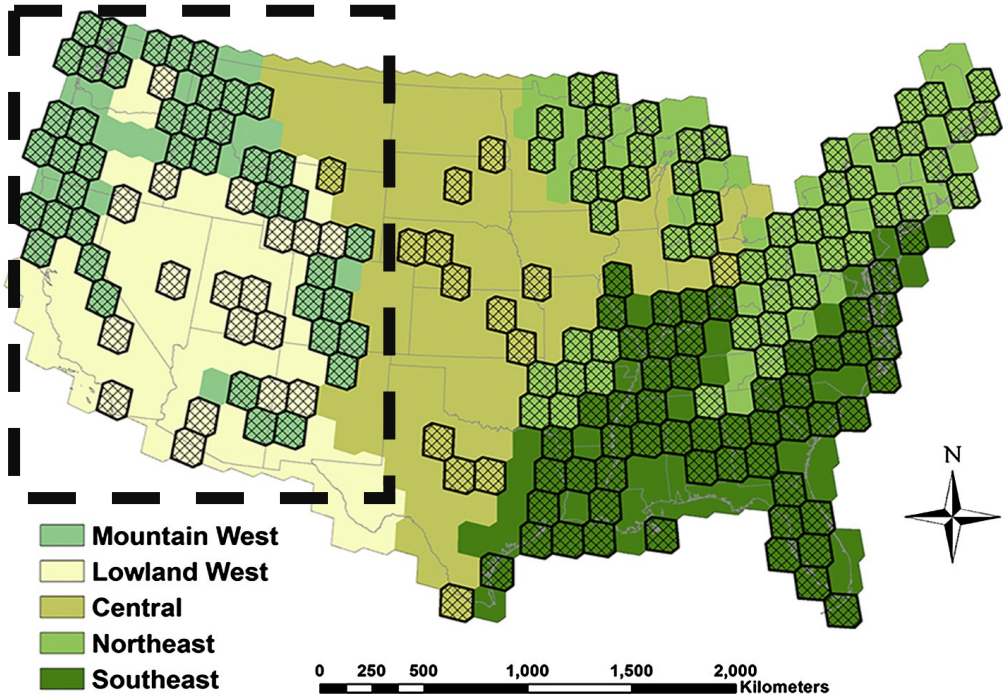
0

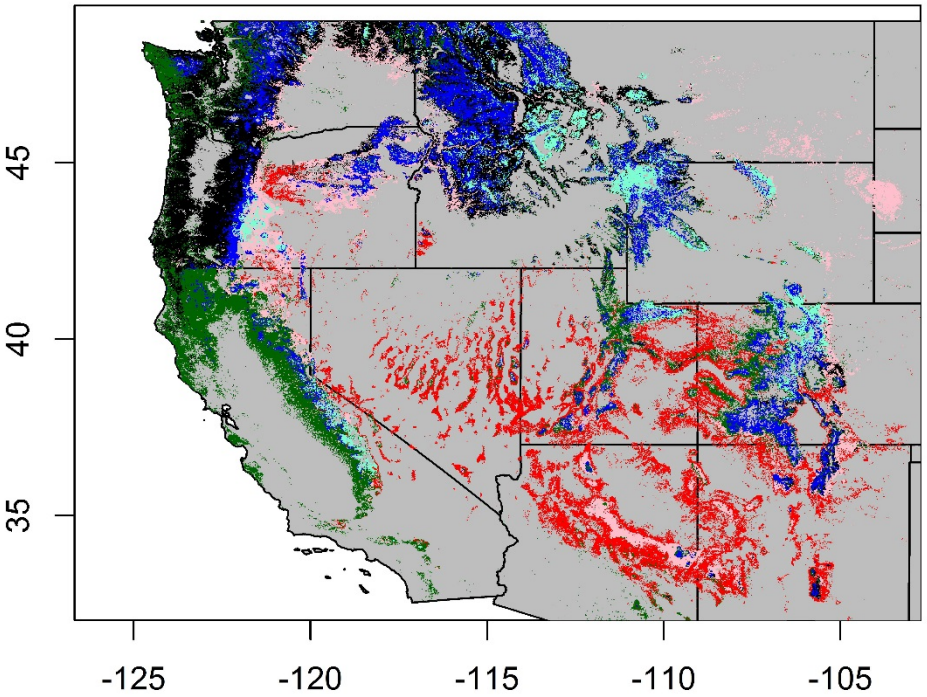
0.7

Sampling RSFD

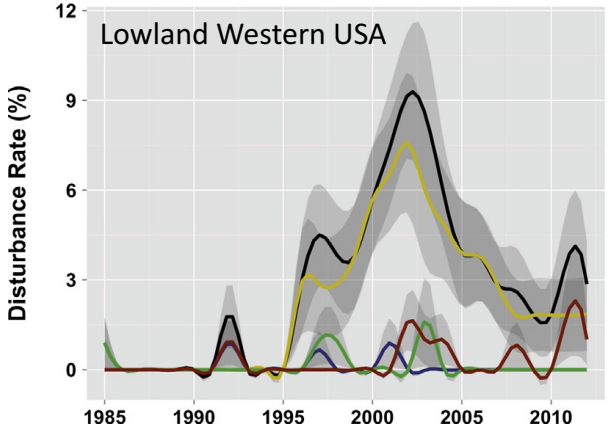
For assessing drought impacts on RSFD

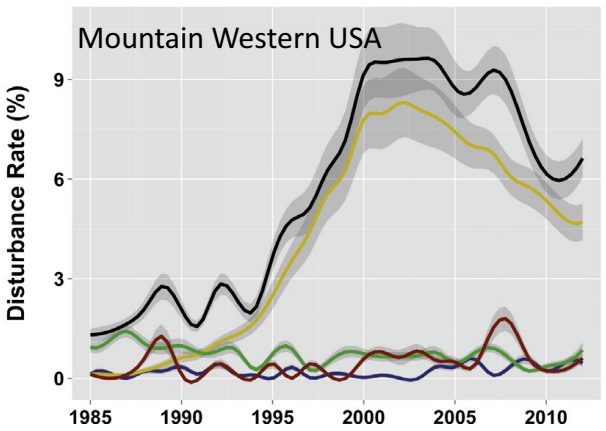
- 1194 forested locations for western US
- Two-stage stratified random sample
- Focusing in on:
  - Five dominant forest type groups
  - 127 locations experiencing forest canopy decline
  - Multi-year drought as a driver



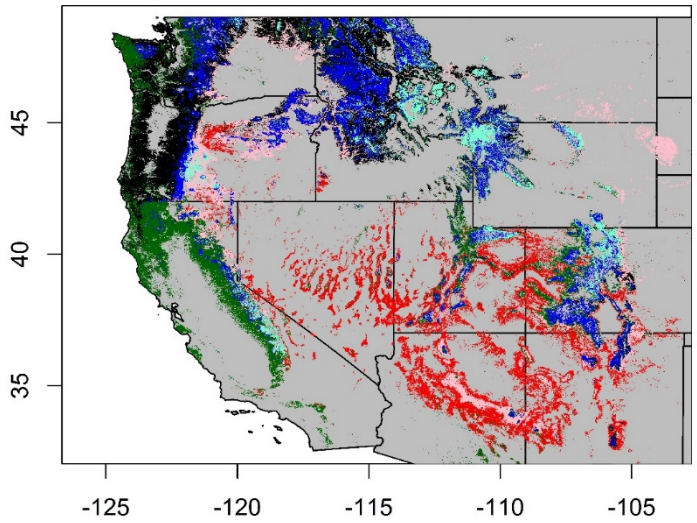


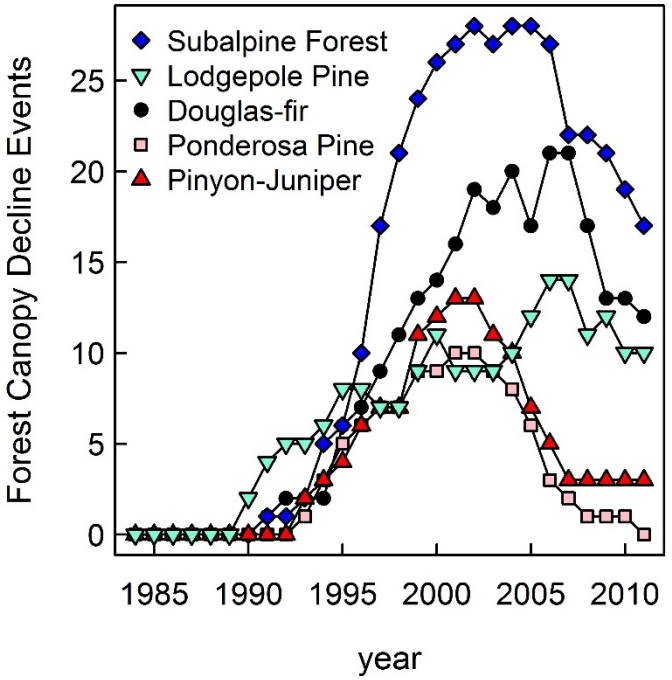
Forest Canopy Decline for All Western Forests





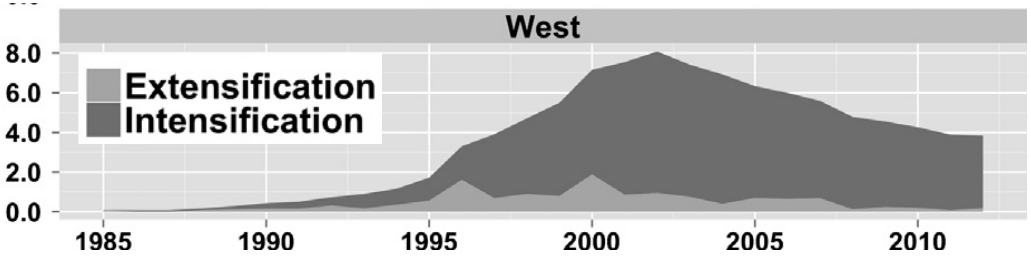
Forest Canopy Decline by Forest Type Group





Drought effects on RSFD

- Forest change likely depends on past environmental conditions and temporal trends in stress (i.e., decline)
- **Stochastic Antecedent Modeling** (SAM; Ogle et al. 2014) assesses the length, pattern, and strength of ecological memory
- Modeled the years decline events occurred
  - Seasonal mean precipitation and VPD

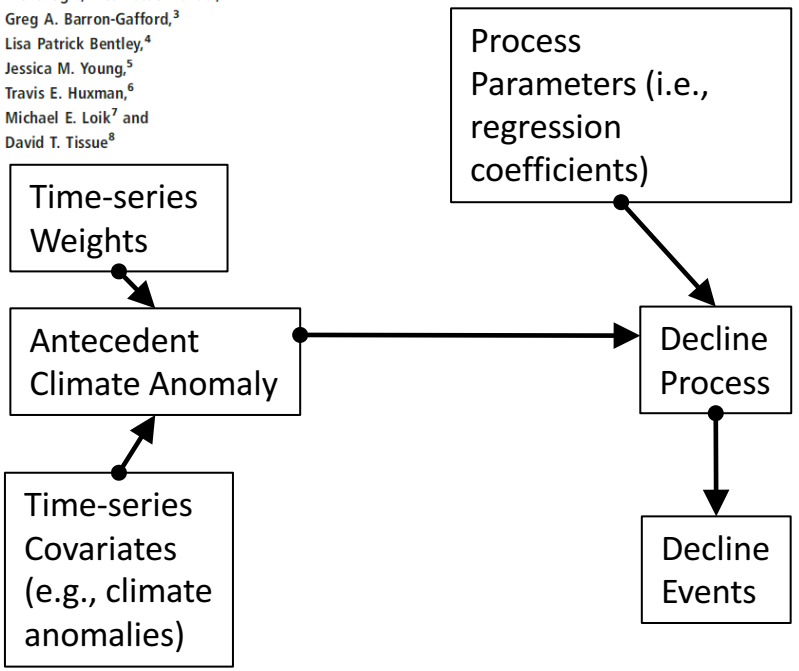


ECOLOGY LETTERS
Ecology Letters, (2014) doi: 10.1111/ele.12399

IDEA AND PERSPECTIVE

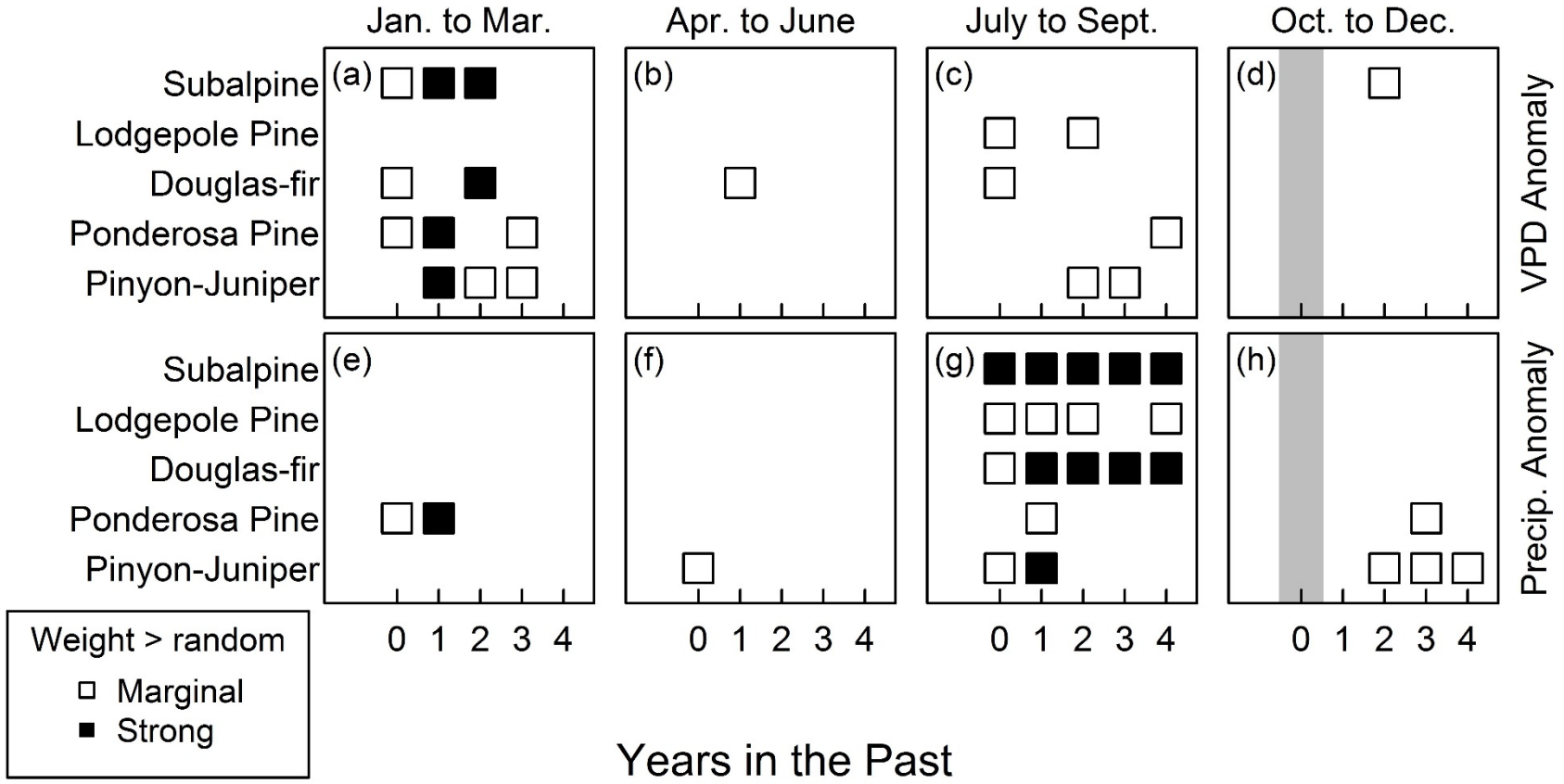
Quantifying ecological memory in plant and ecosystem processes

Kiona Ogle,[1]* Jarrett J. Barber,[2] Greg A. Barron-Gafford,[3] Lisa Patrick Bentley,[4] Jessica M. Young,[5] Travis E. Huxman,[6] Michael E. Loik[7] and David T. Tissue[8]



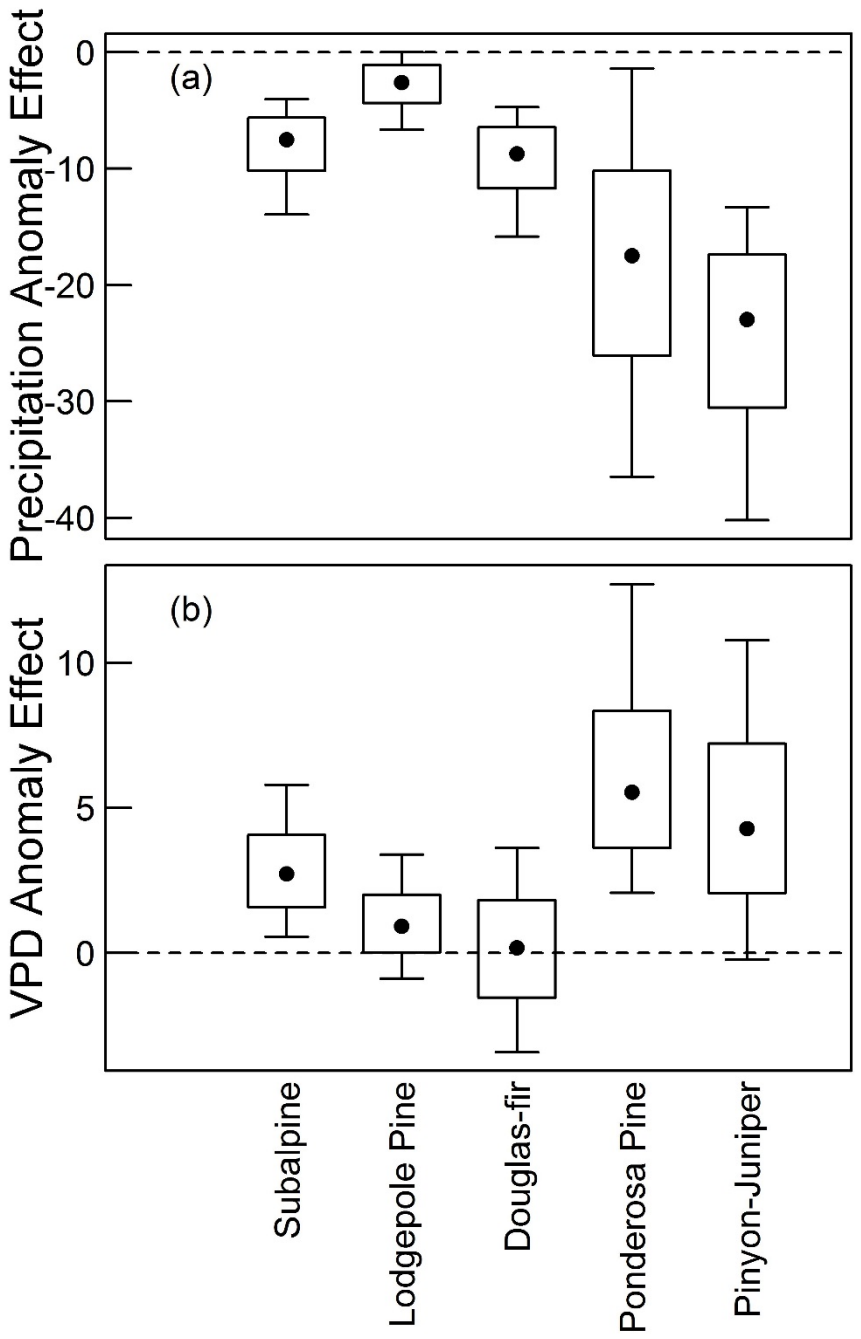
Defining climatic anomalies

- Winter VPD and summer precipitation contributed most strongly to climate anomalies.
- Lagged climate effects (1-3 years in past) were common



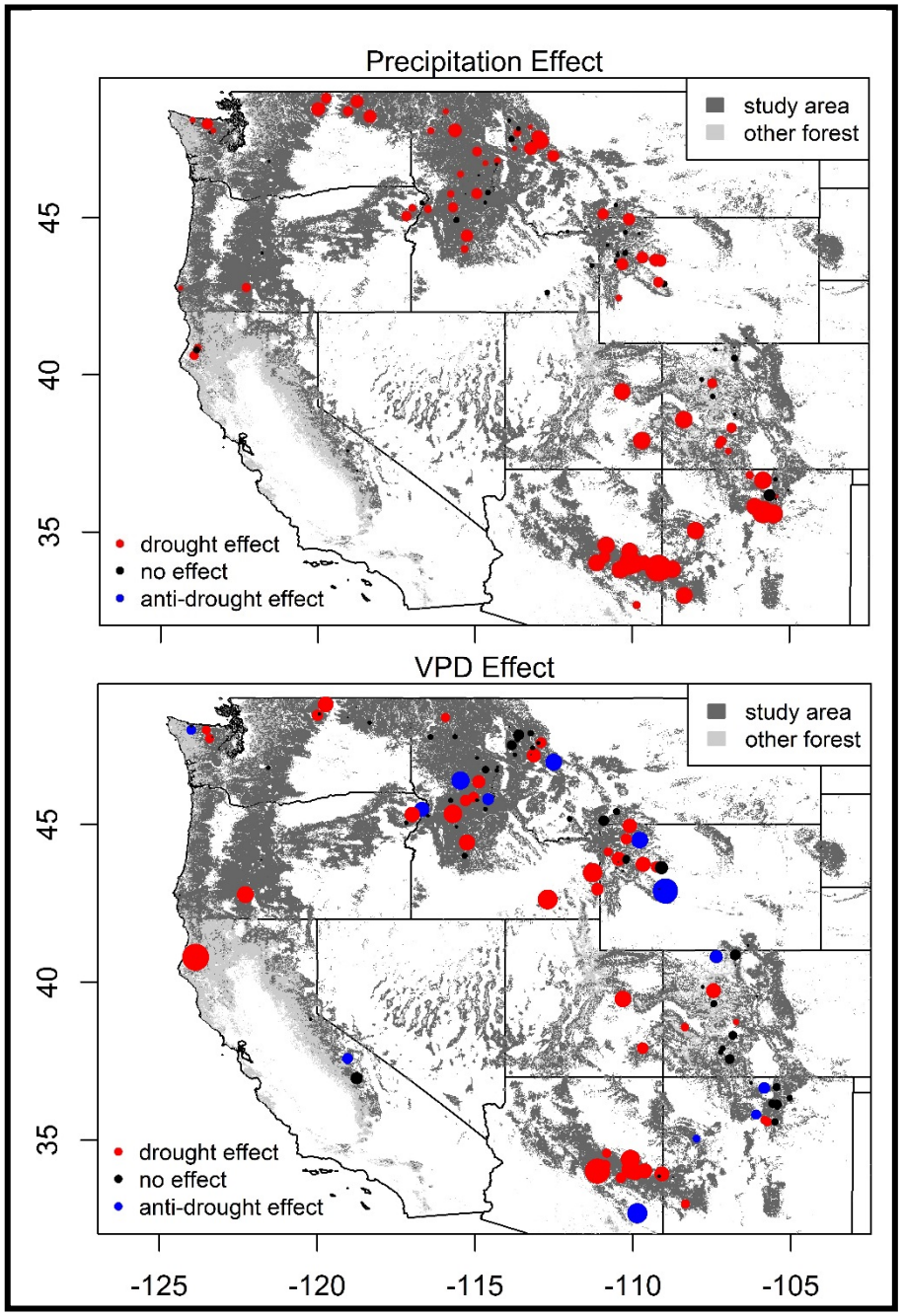
Relating climate anomalies to RSFD

- Negative precipitation and positive VPD anomaly effects imply drought as a contributor to decline across forest type groups.
  - Effect sizes greatest for dry and cold forest type groups



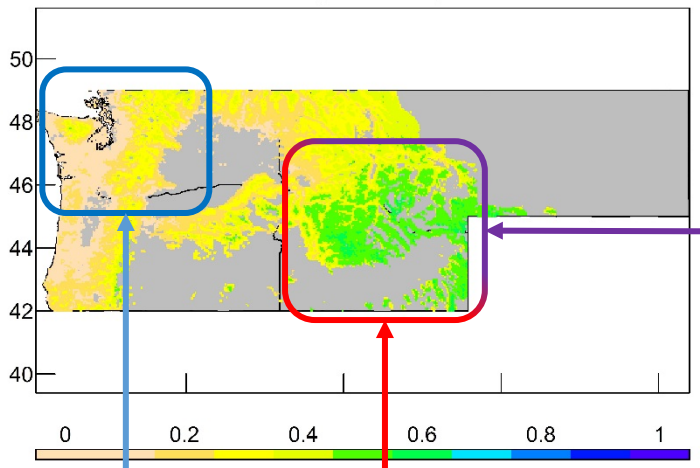
Relating climate anomalies to RSFD

- Negative precipitation and positive VPD anomaly effects imply drought as a contributor to decline across forest type groups.
  - Effect sizes greatest for dry and cold forest type groups
- Substantial variation in effect sizes across plots implies locally mediated responses

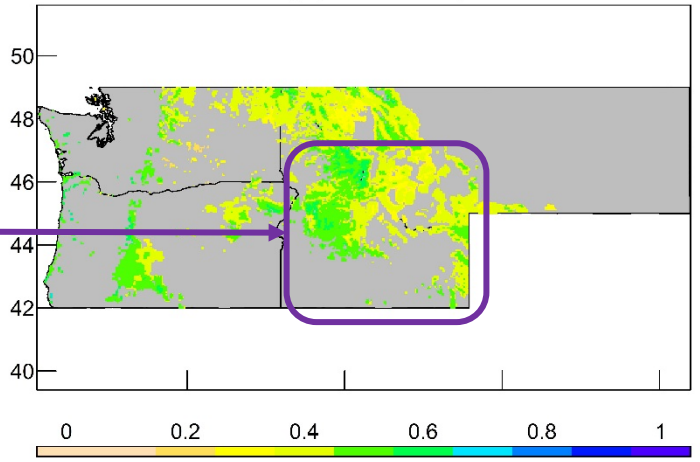


Comparing SAM vs. Maxent Maps

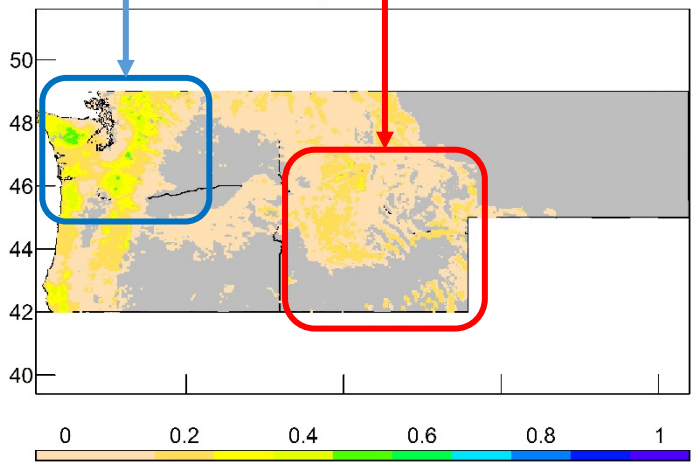
Maxent – Douglas-fir Forest Type Group



SAM – Lodgepole Pine Forest Type Group



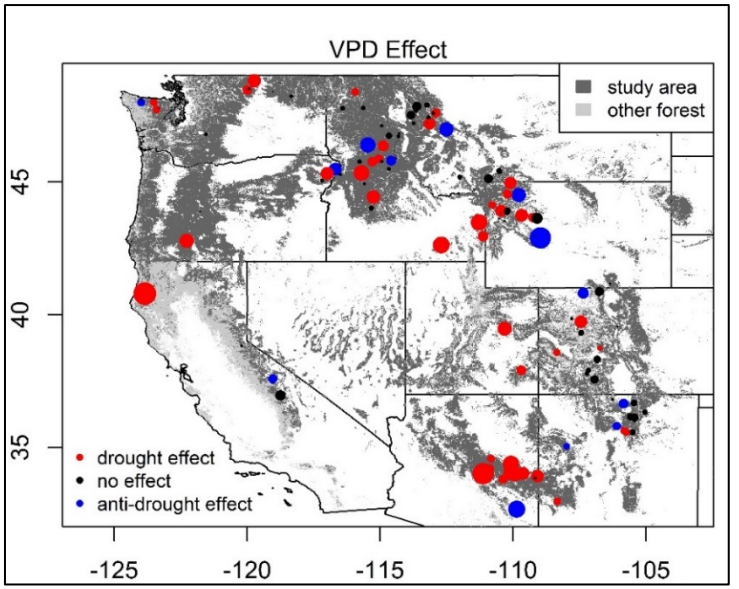
SAM – Douglas-fir Forest Type Group



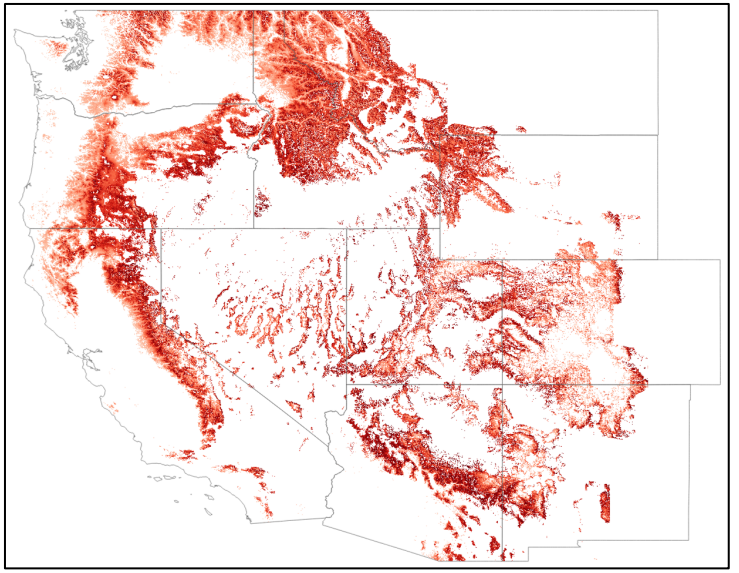
- Landscape dominance of a forest type group determine agreement among methods

Conclusions

1. What role is multi-year drought playing in remotely sensed forest decline (RSFD) events?
   - Summer precipitation shortages and warmer winters precede forest decline
   - High variation in responses imply mediating factors

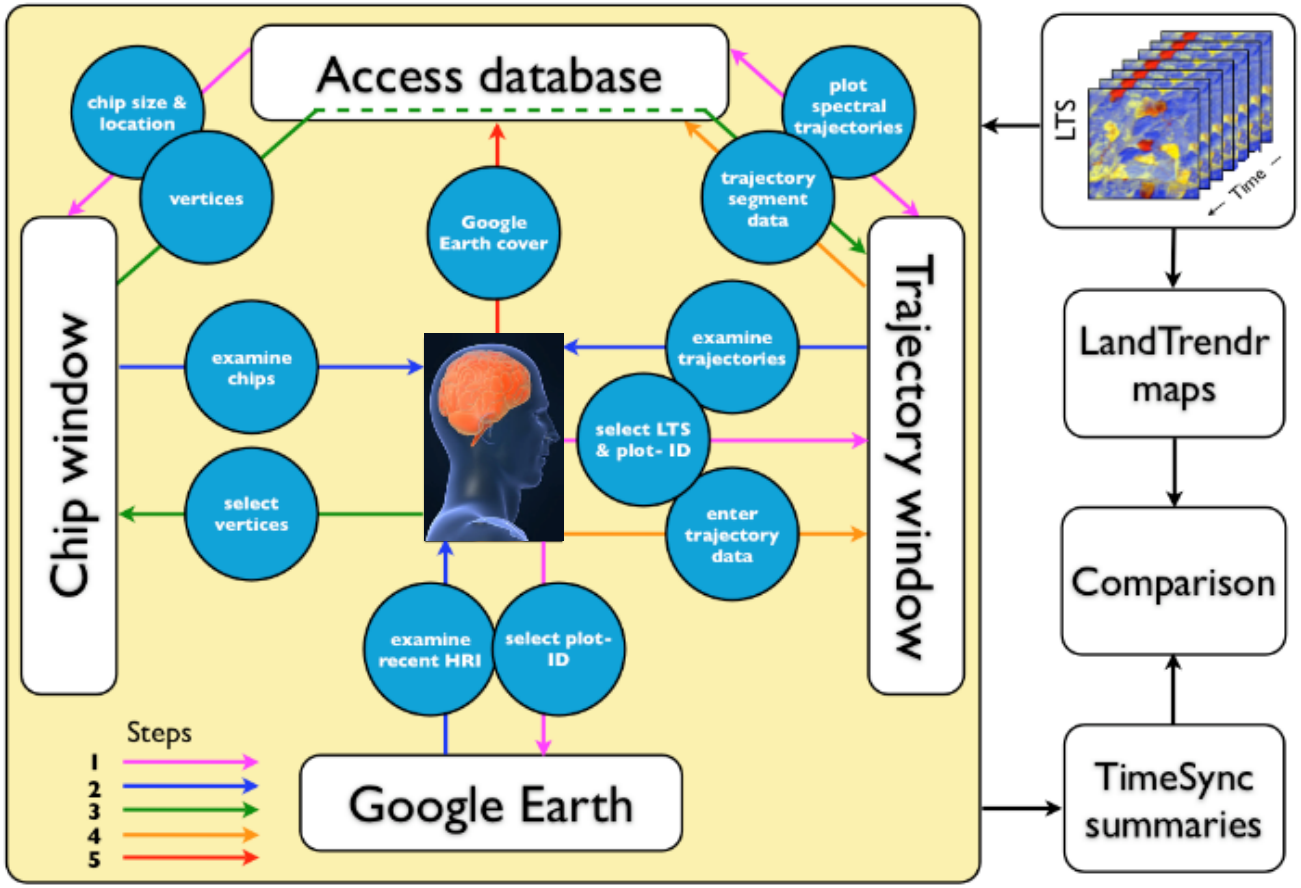


2. How might RSFD behave as climate changes?
   - Future droughts are likely to increase the prevalence of RSFD in the PNW.
   - More must be learned about how local factors (e.g., forest composition) alter sensitivity to drought



Thank You!

Remote Sensing of Forest Change, including RSFD



Cohen et al. 2010. *Remote Sensing of Environment*

Is There A Climate Connection?

- Use MaxEnt to explore the relationship of observed stress with climate
  - Previous year's annual precipitation (October-September)
  - Current year's mean maximum temperature (July-September)
  - Slope (and p-value) for the previous five years of precipitation and temperature
  - Elevation, slope, aspect
  - Forest type group