Forest responses to increasing aridity and warmth in the southwestern United States

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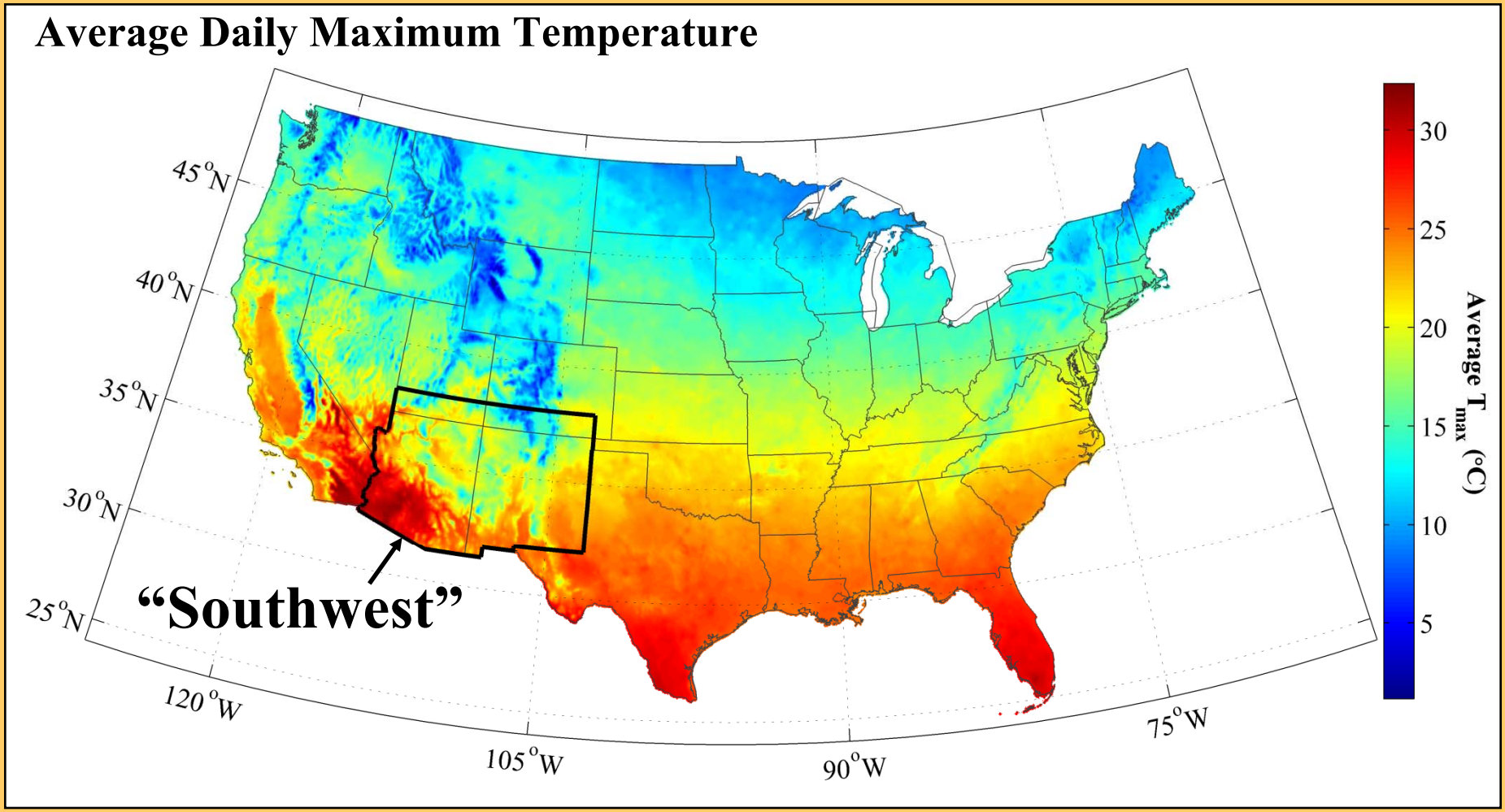
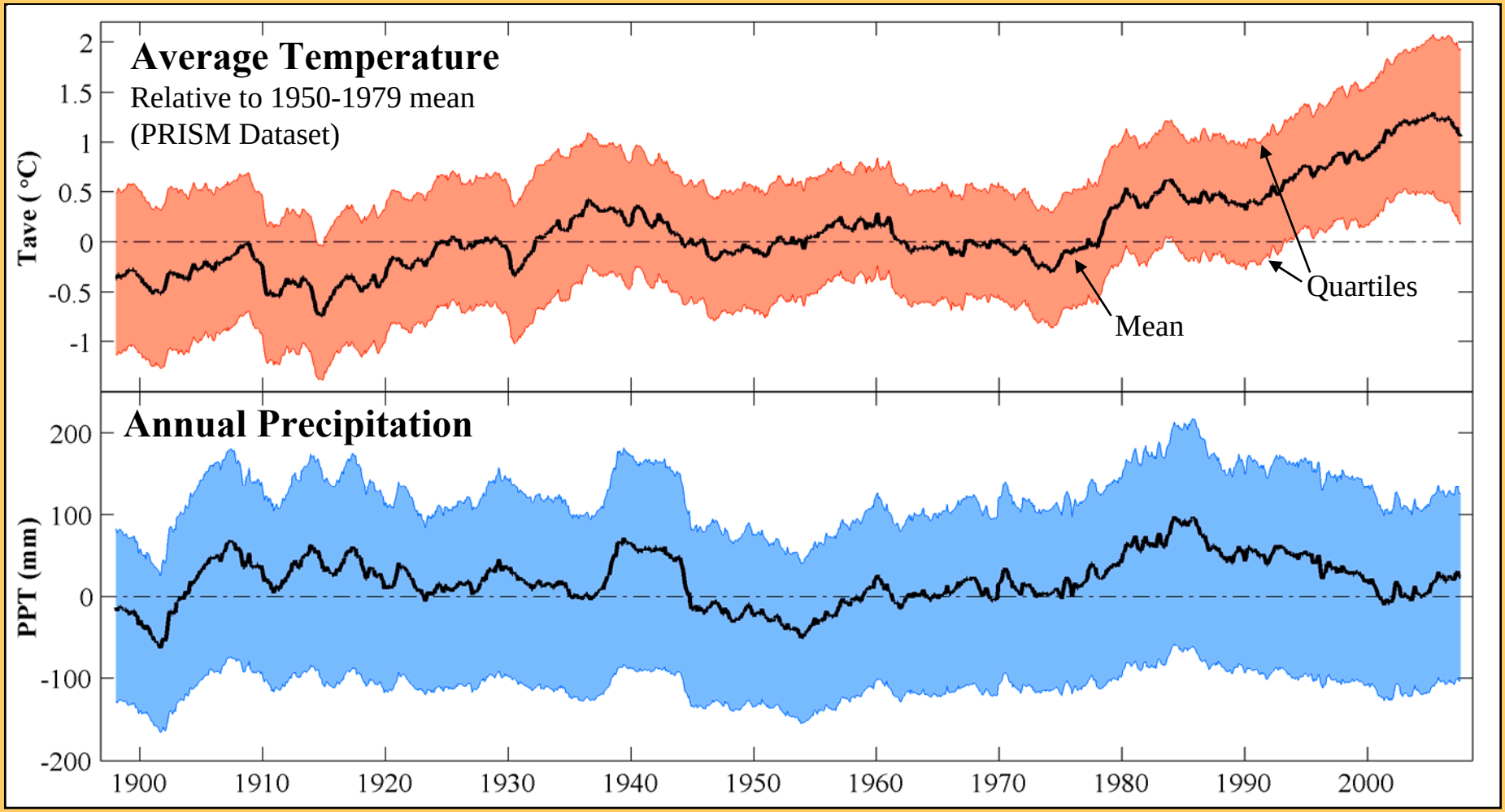
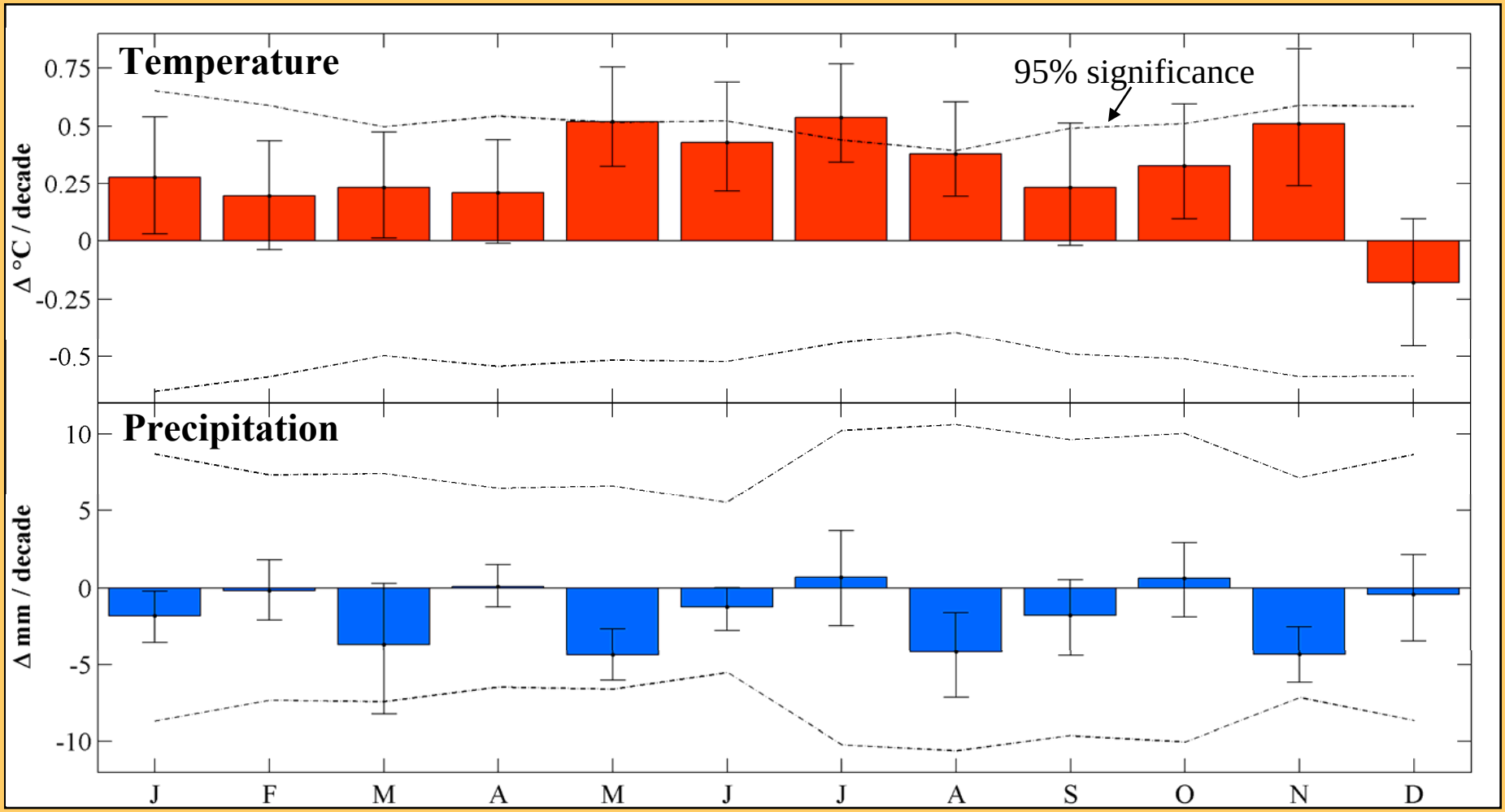
Region of Focus: Southwestern United States



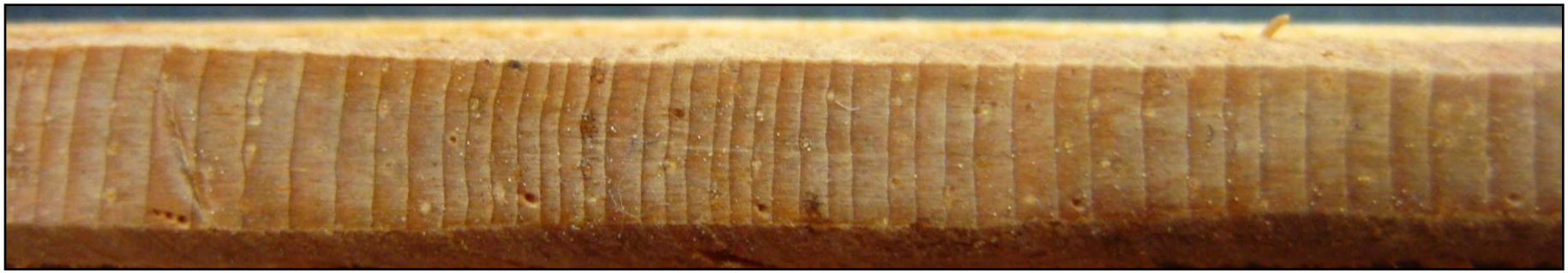
Climate in the Southwest since 1895



Change Per Decade Since 1979



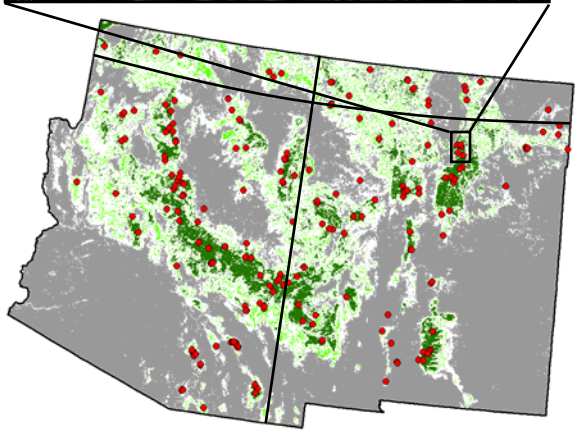
Tree-Ring Analysis



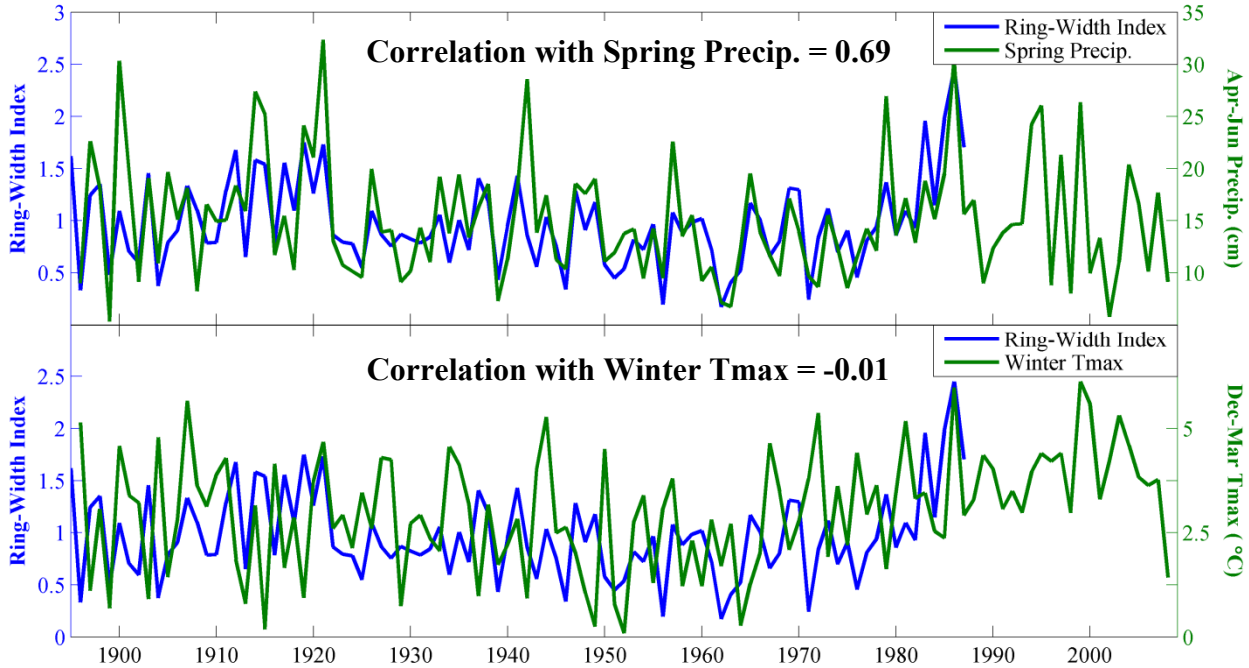
Simple Goal:

Use relationships between *past* climate and *past* tree growth to predict the response of *future* tree growth to *future* climate.

Ring Widths vs. Climate



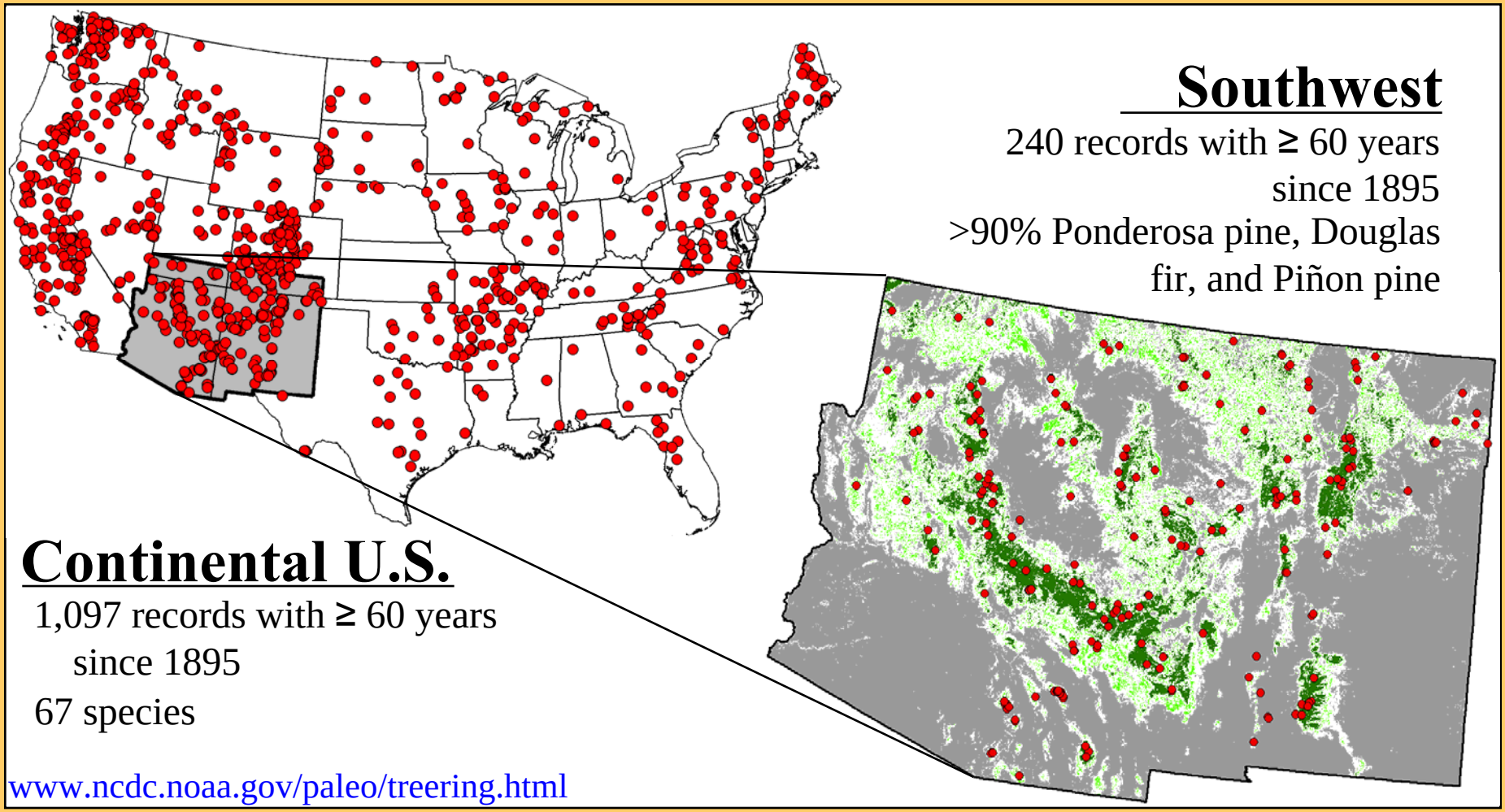
Limber pine, Italian Canyon, New Mexico; Elevation: 2984 m



Collected by TW Swetnam, AC Caprio, & AC Lynch, 1988

International Tree-Ring Data Bank (ITRDB)

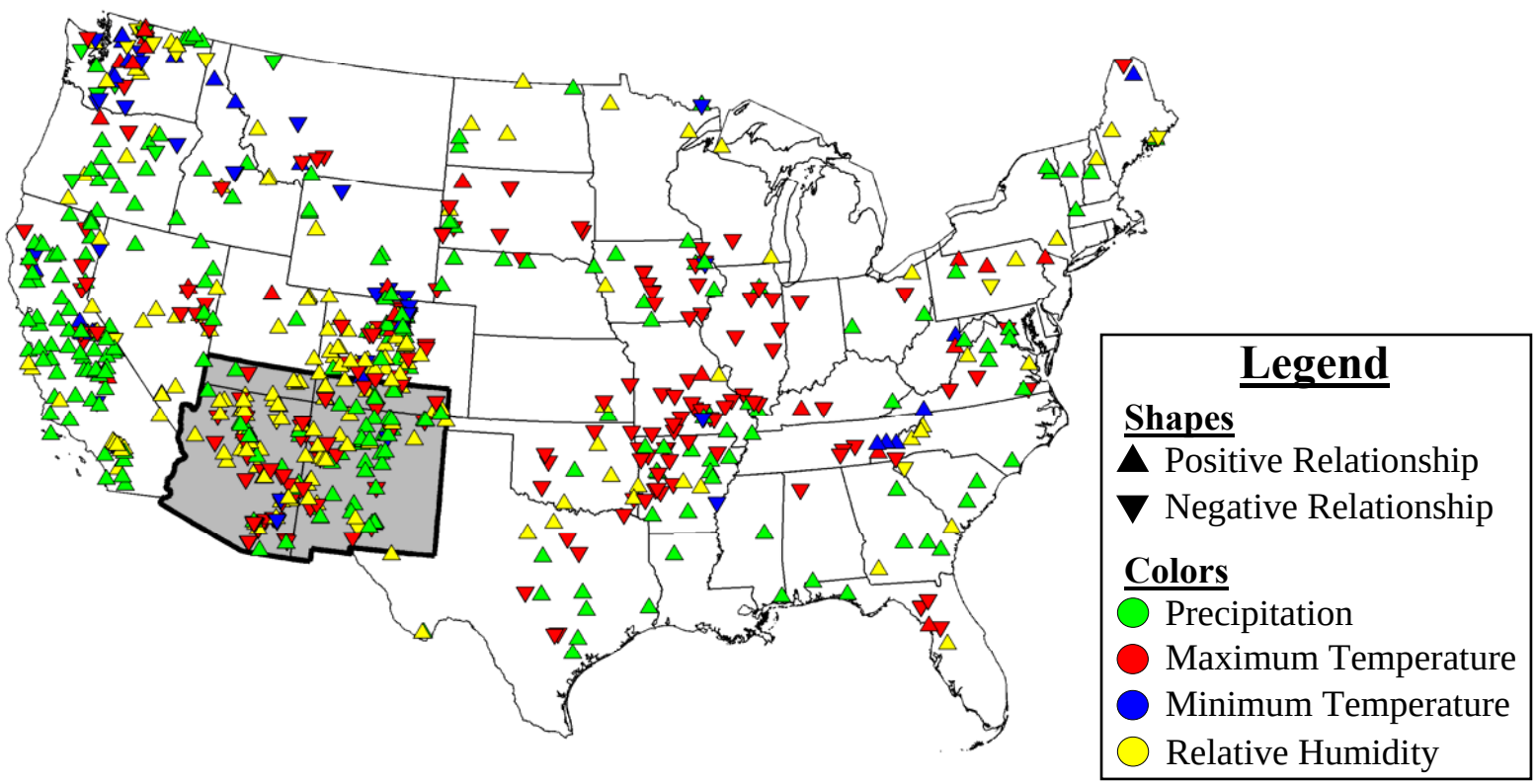
1,097 Tree-Ring Width Records in the Continental U.S.



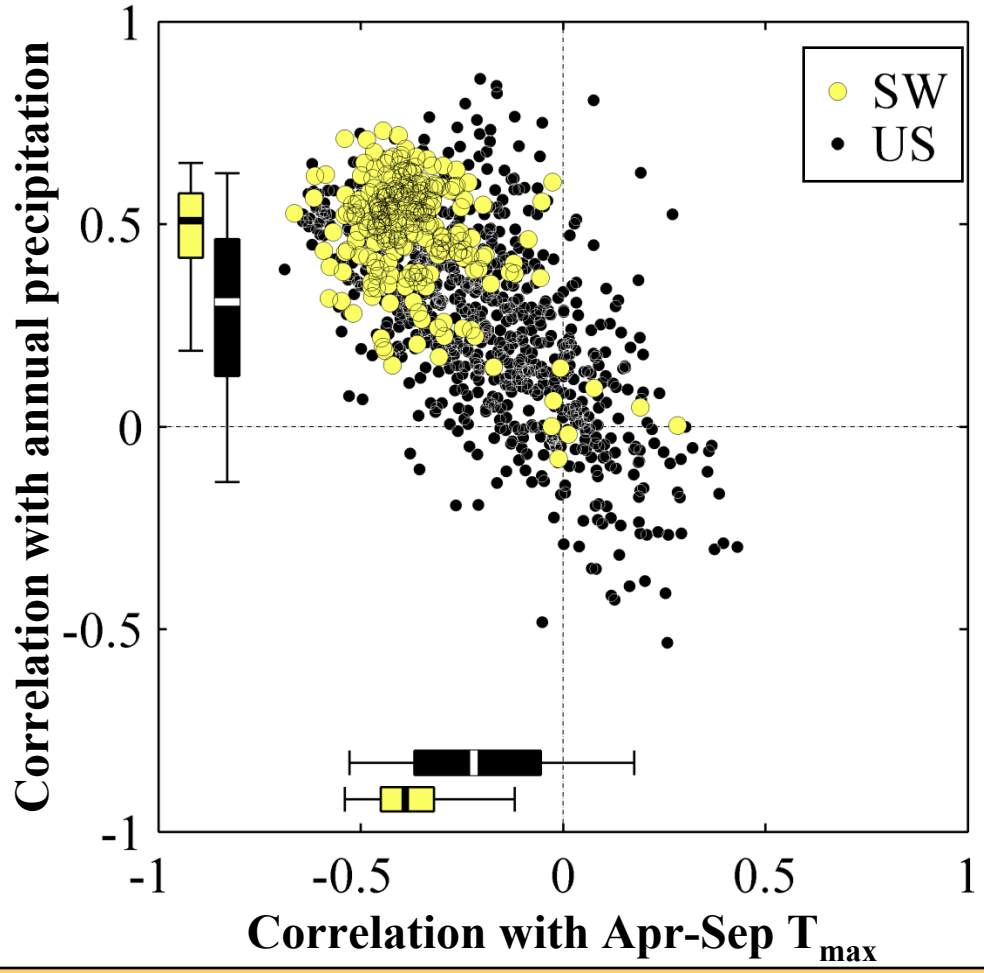
www.ncdc.noaa.gov/paleo/treering.html

Tree Rings and Climate

Best Growth Predicting Variable

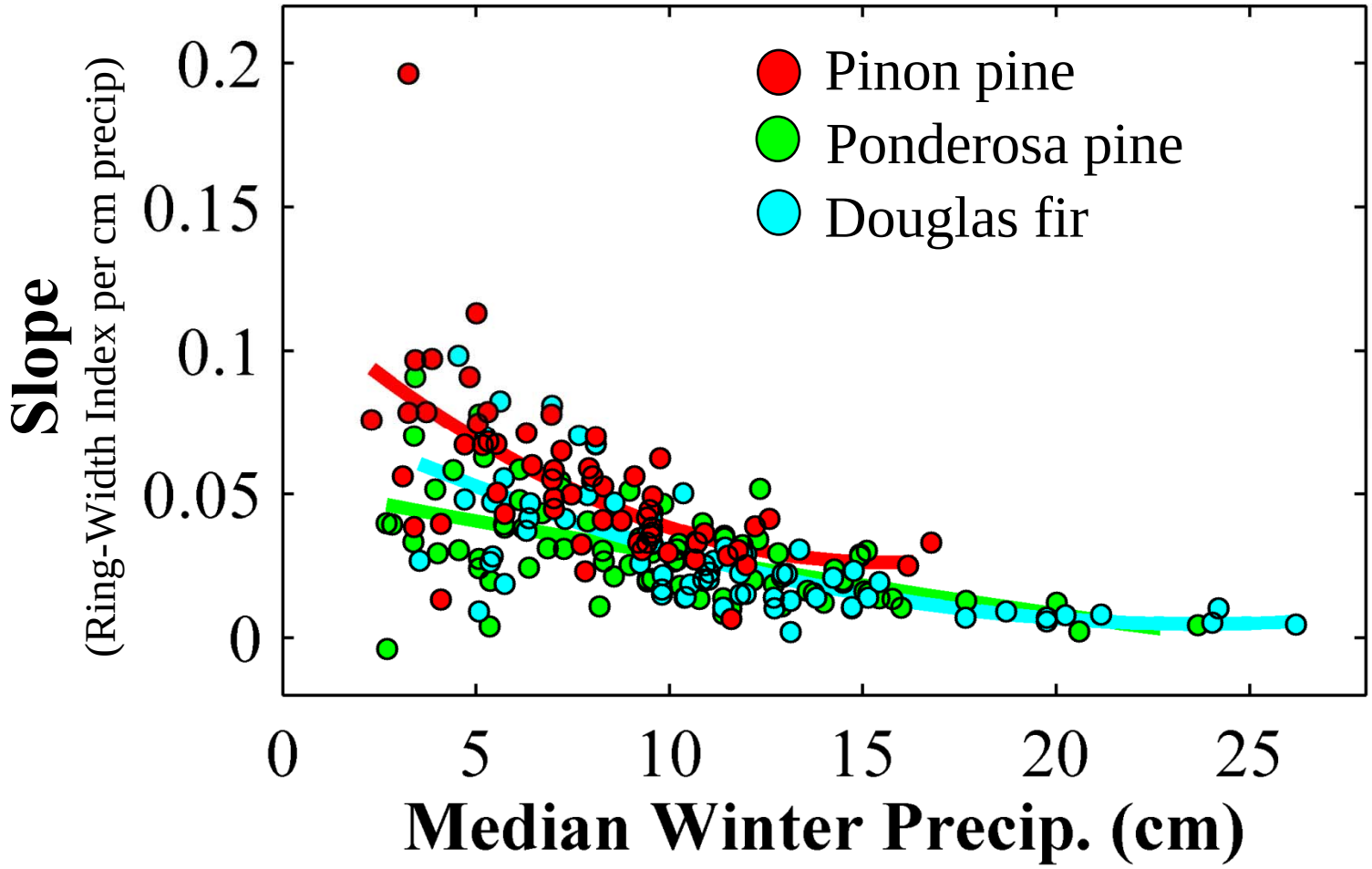


Tree Rings and Drought



- Trees in the Southwest are especially sensitive to drought.
- They tend to grow best when it is cool and wet.
- They grow poorly when it is warm and dry.

Tree Rings and Drought



Ring-Width Modeling

4 Potential Climate Variables

1. Precipitation
2. Maximum Temperature
3. Minimum Temperature
4. Relative Humidity

X 4 Potential Seasons

1. Fall: October - December
2. Winter: January - March
3. Spring: April - June
4. Summer: July - September

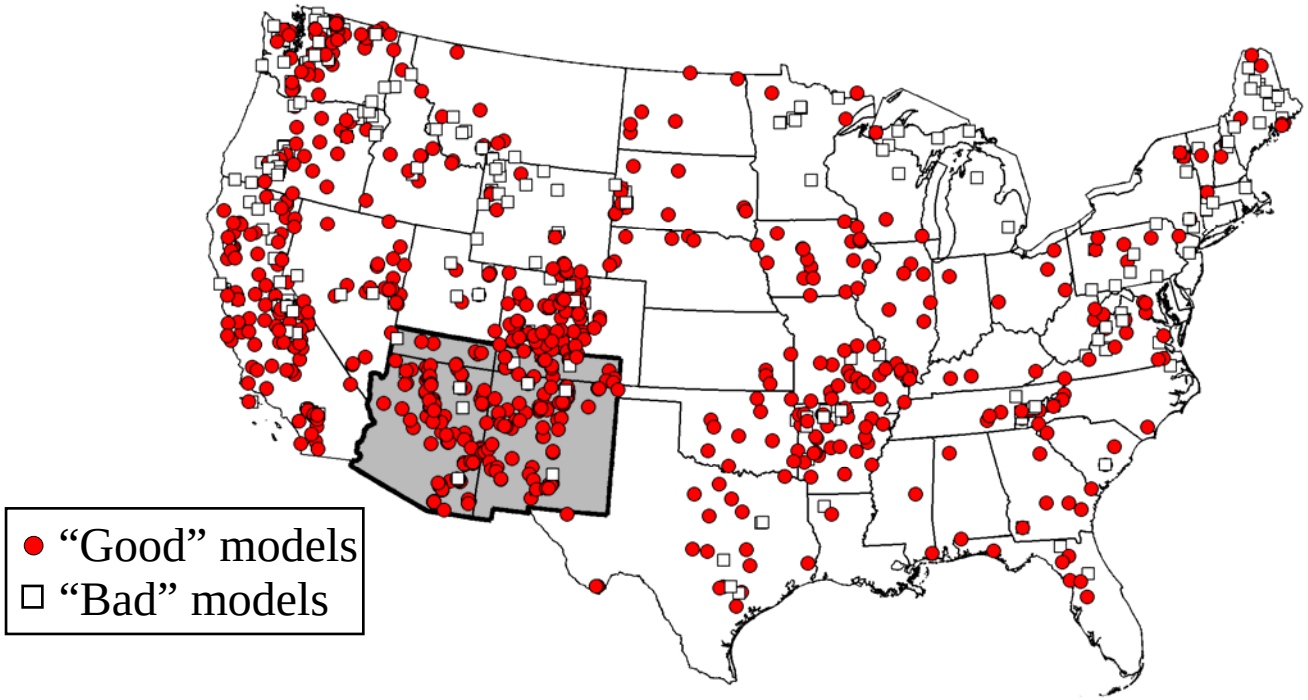
= **16 Potential Predictors**

Step-wise Linear Regression

Ring-Width Modeling

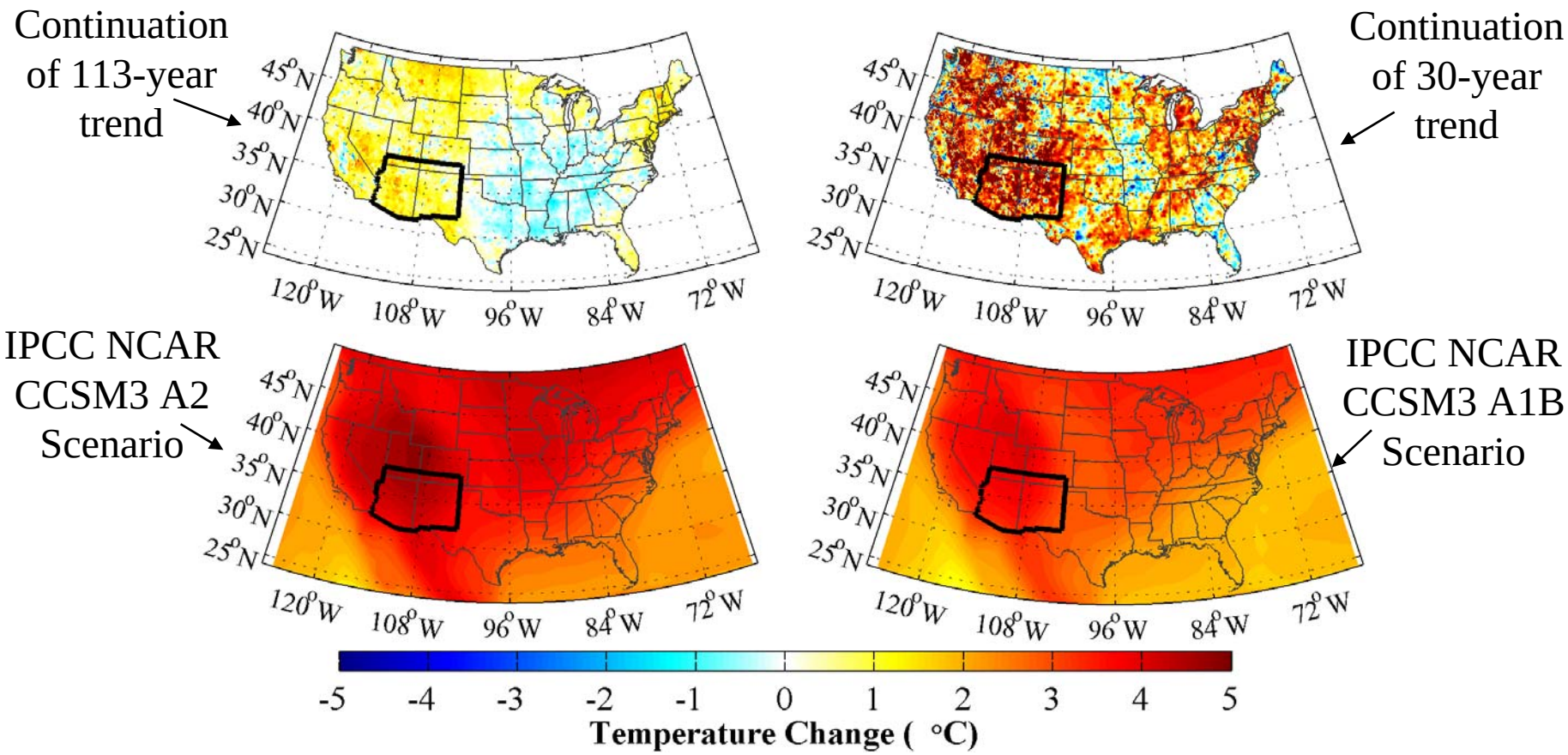
"Good" models produced cross-validated ring-widths that correlated with actual ring widths at a >99.9% confidence level ($p < 0.001$).

- **78% (853) of models were "good".**
- **97% (228) of models were "good" in the Southwest.**



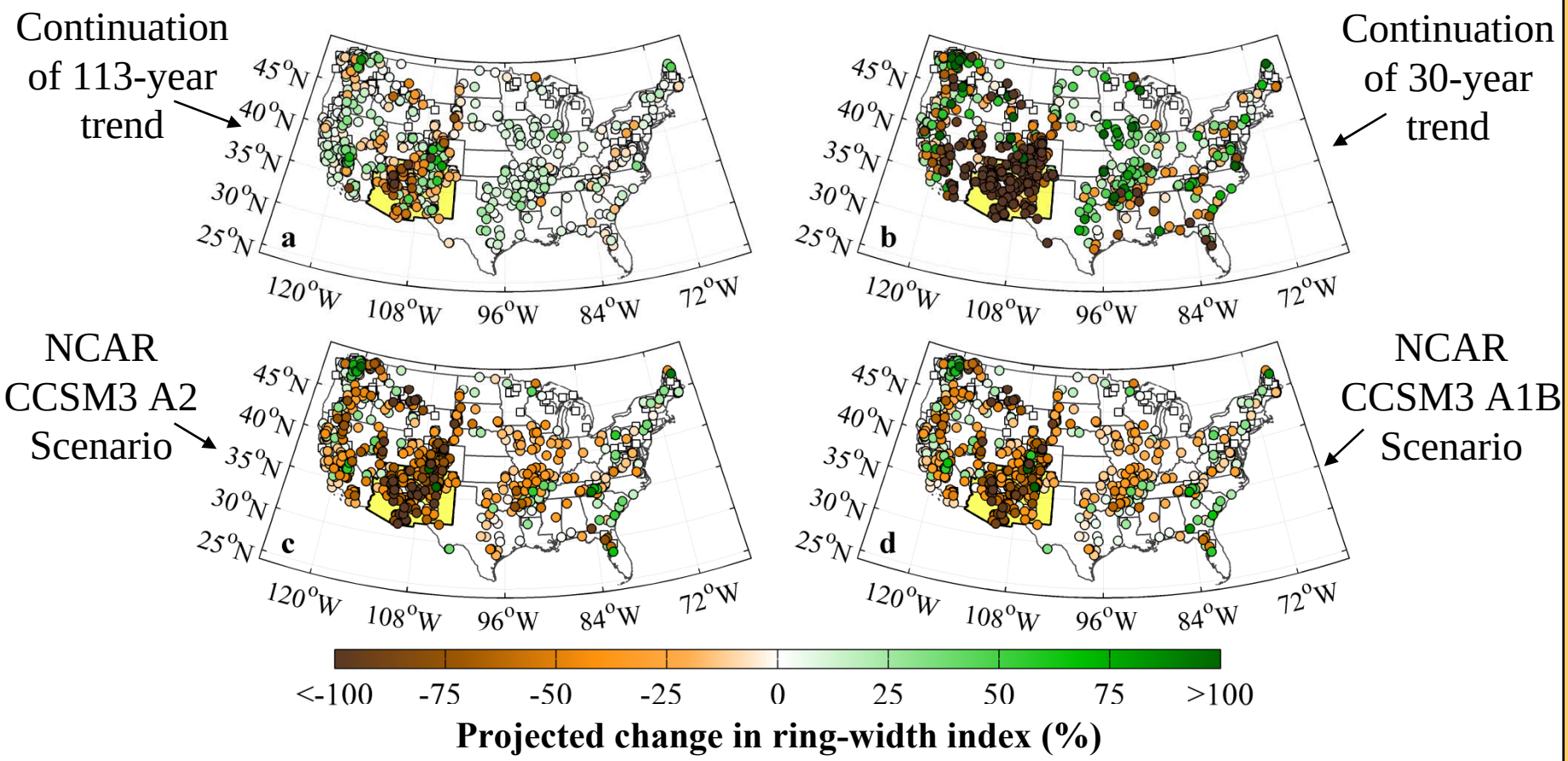
21st Century Temperature Change

Average (2050-2099) minus average (1950-1999)



21st Century Ring-Width Change

Average (2050-2099) minus average (1950-1999)



So What?

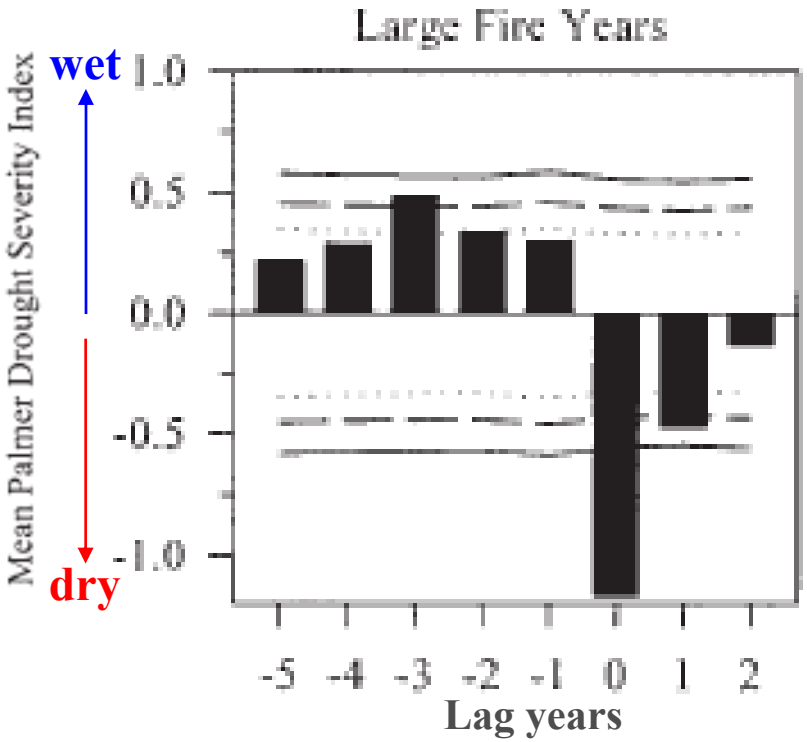
- Maybe the most drought sensitive trees were preferentially sampled in the Southwest.

- Maybe the high drought sensitivity in Southwestern tree-ring records is a testament to trees' ability to strategically shut down during tough times.

- Who cares what the tree rings say? Tree ring records only represent growth rates…they say nothing about mortality.

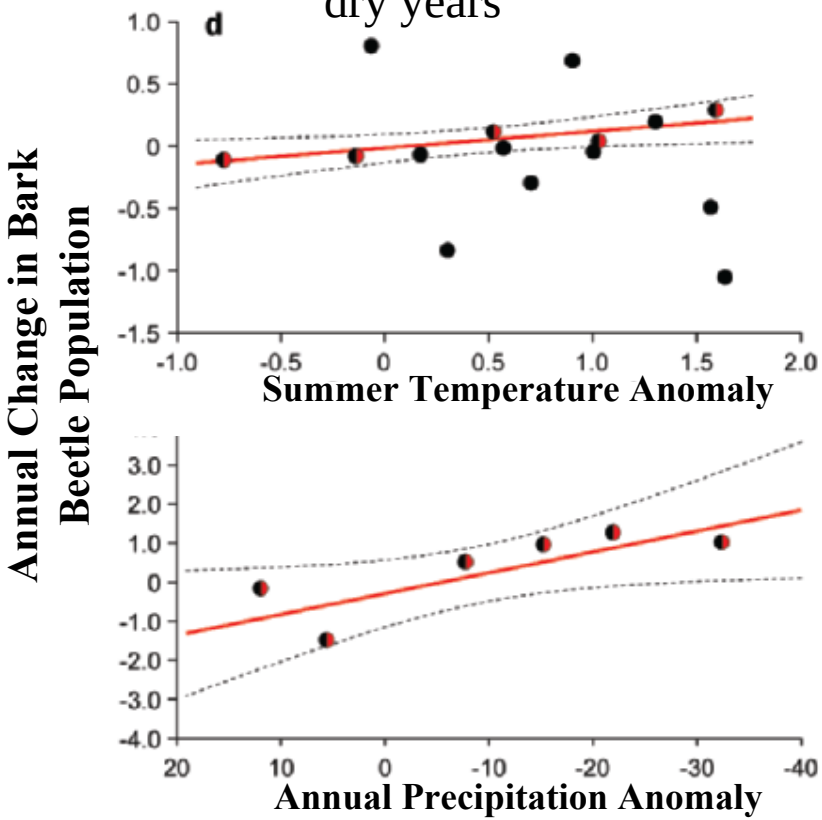
Wildfire & Bark Beetles

Historically, large fire years in the Southwest have been associated with drought conditions.



Swetnam & Baisan (2003)

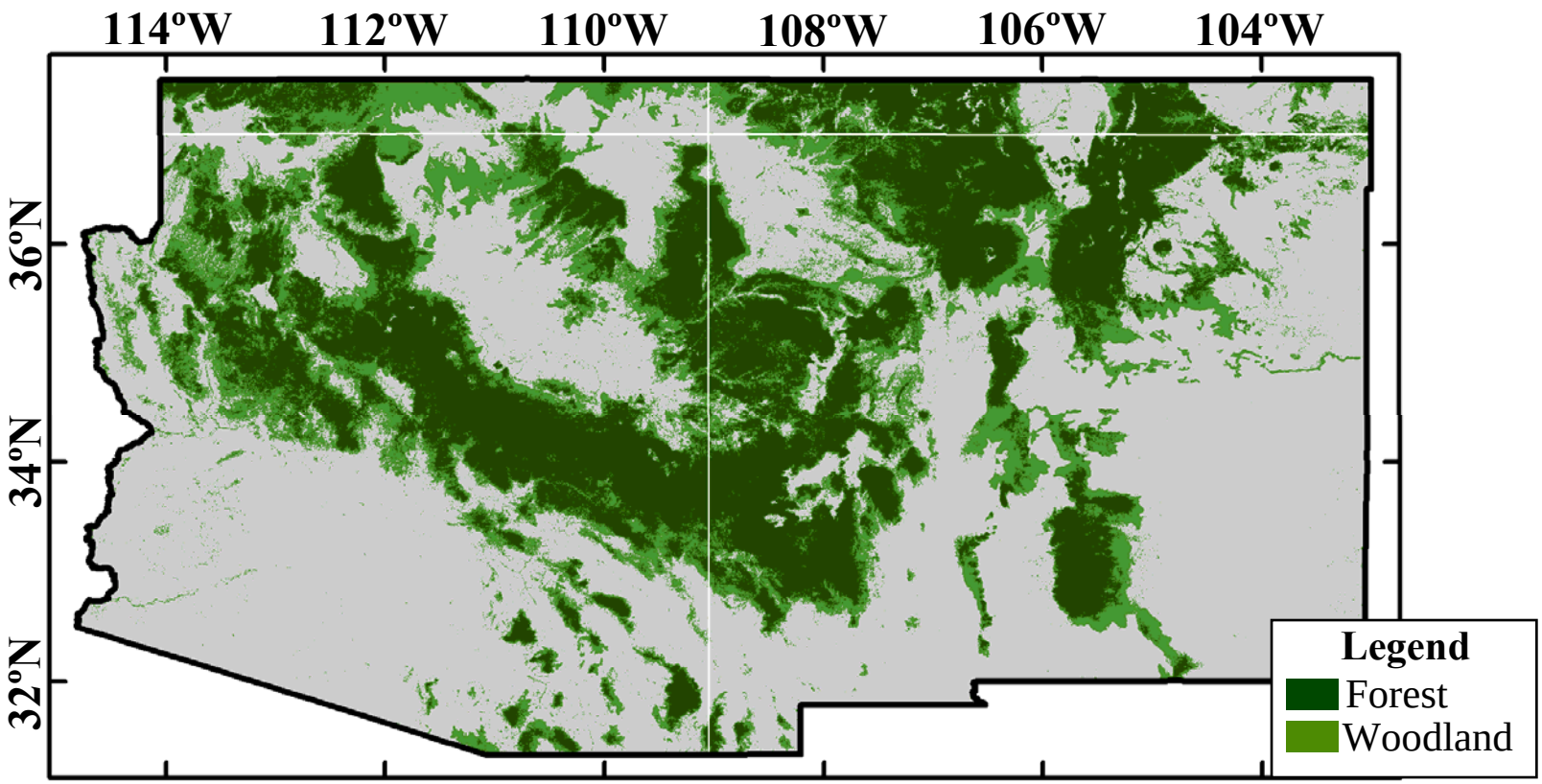
Beetle populations tend to grow during warm, dry years



Rafa et al. (2008)

Forest and Woodland Area

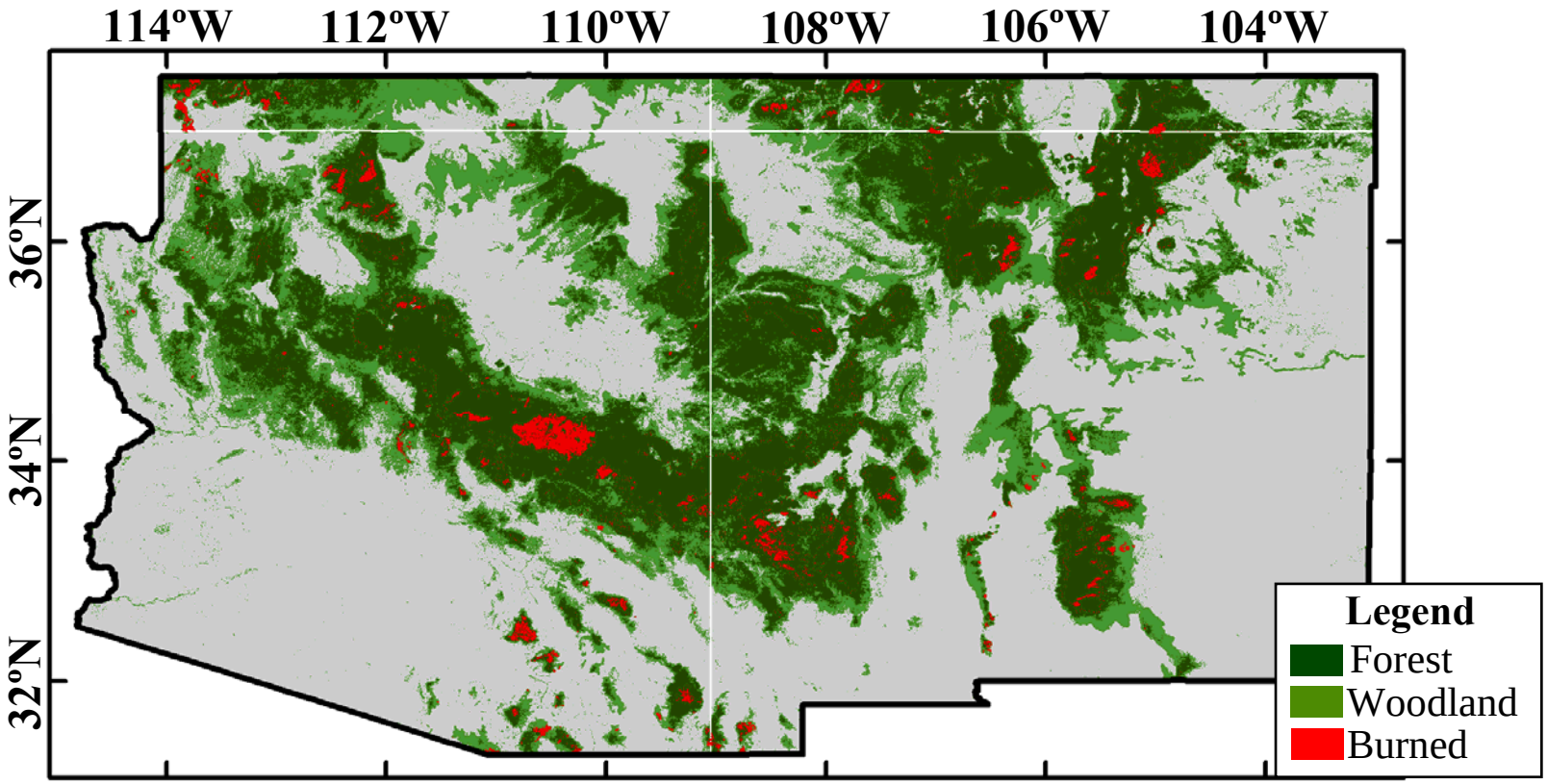
Sources: Brown and Lowe, NLCD, ReGAP



Mortality Area due to Wildfire 1984 - 2006

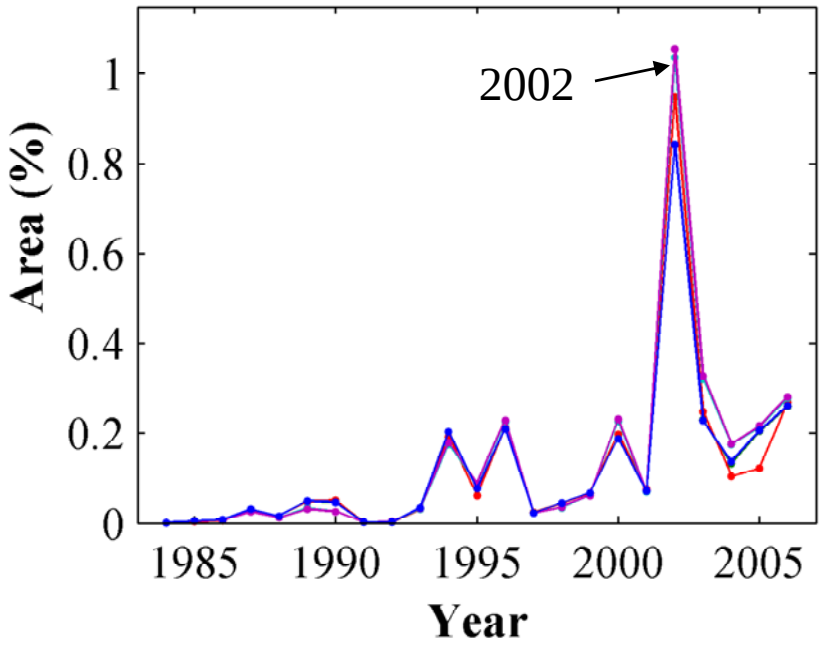
Data Source: U.S. Government – Monitoring Trends in Burn Severity (MTBS) product

Area Killed: Forest: 4.1 – 5.5%, Woodland: 0.9 – 1.5%

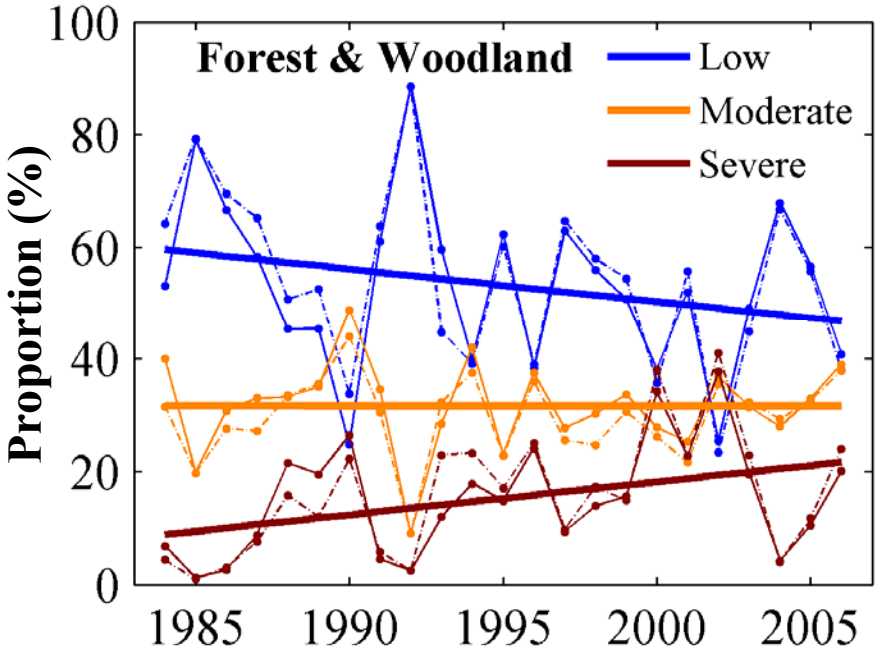


Estimate of Area Burned by Wildfire 1984 - 2006

Total Area "Moderately" or "Severely" Burned



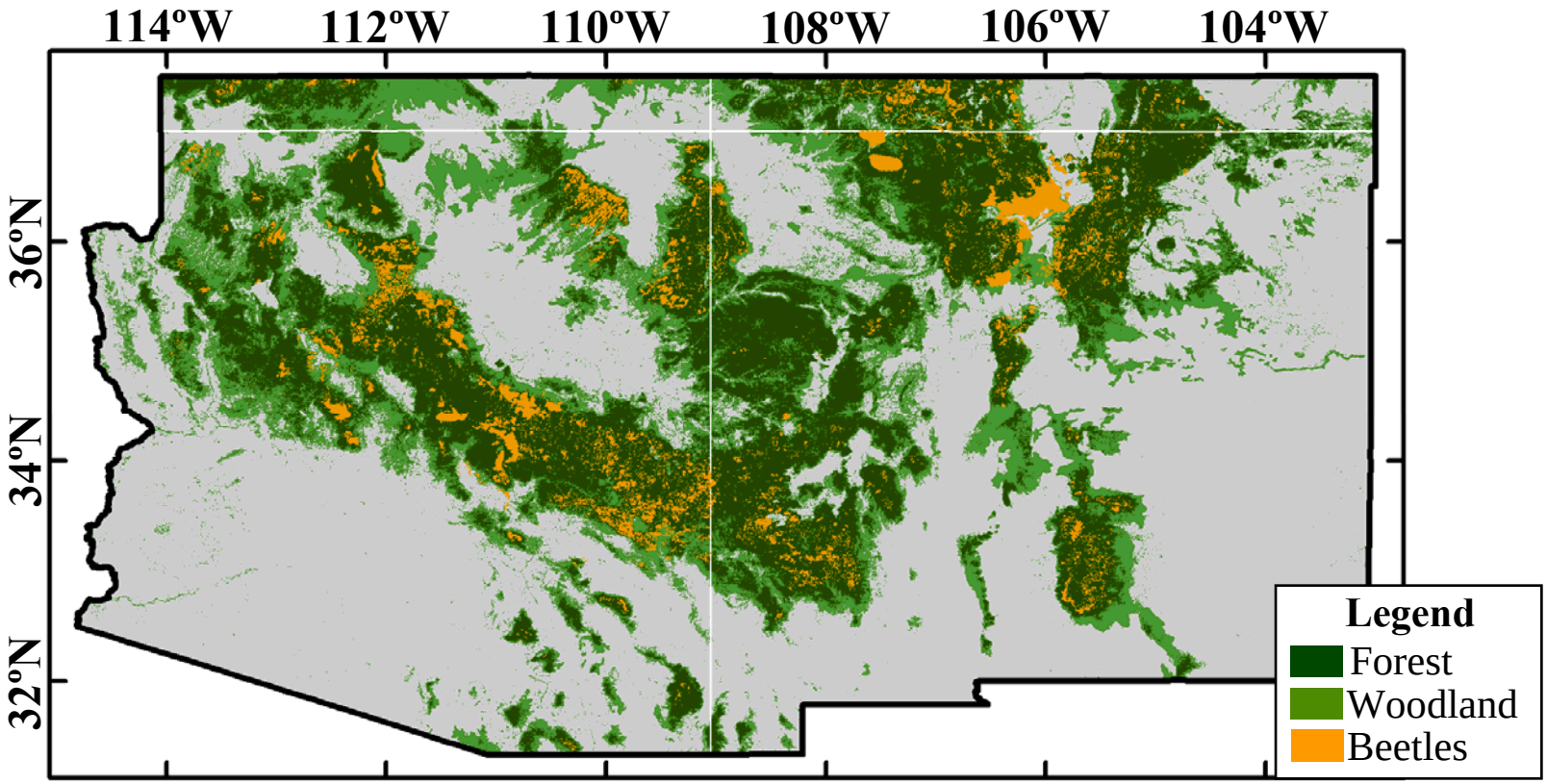
Proportion Area Called "Low", "Moderate", and "Severe"



Mortality Area due to Bark Beetles 1997 - 2008

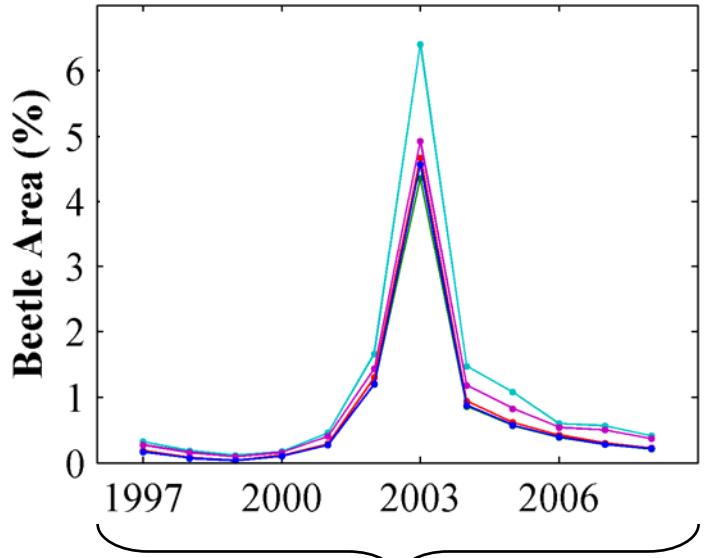
Data Source: U.S. Forest Service – Forest Health Technology Enterprise Team (FHTET)

Area Killed: Forest: 10.7 – 13.0%, Woodland: 7.3 – 11.3%

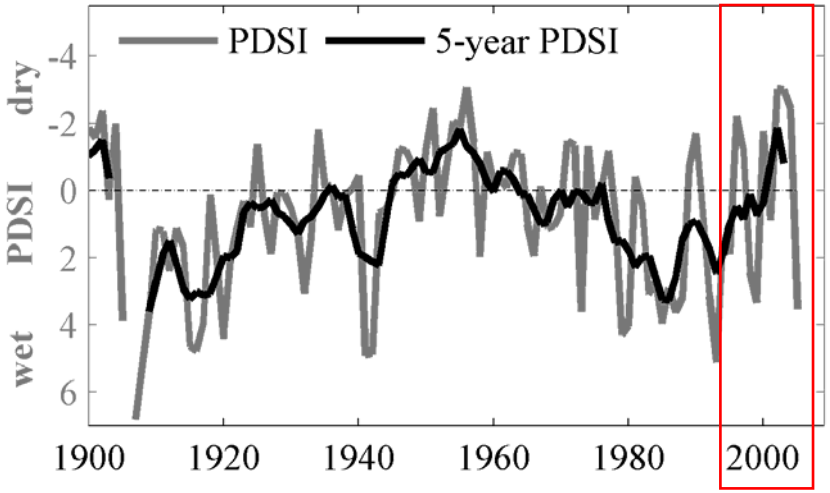


Mortality Area due to Bark Beetles 1997 - 2008

Annual Area Killed by Beetles

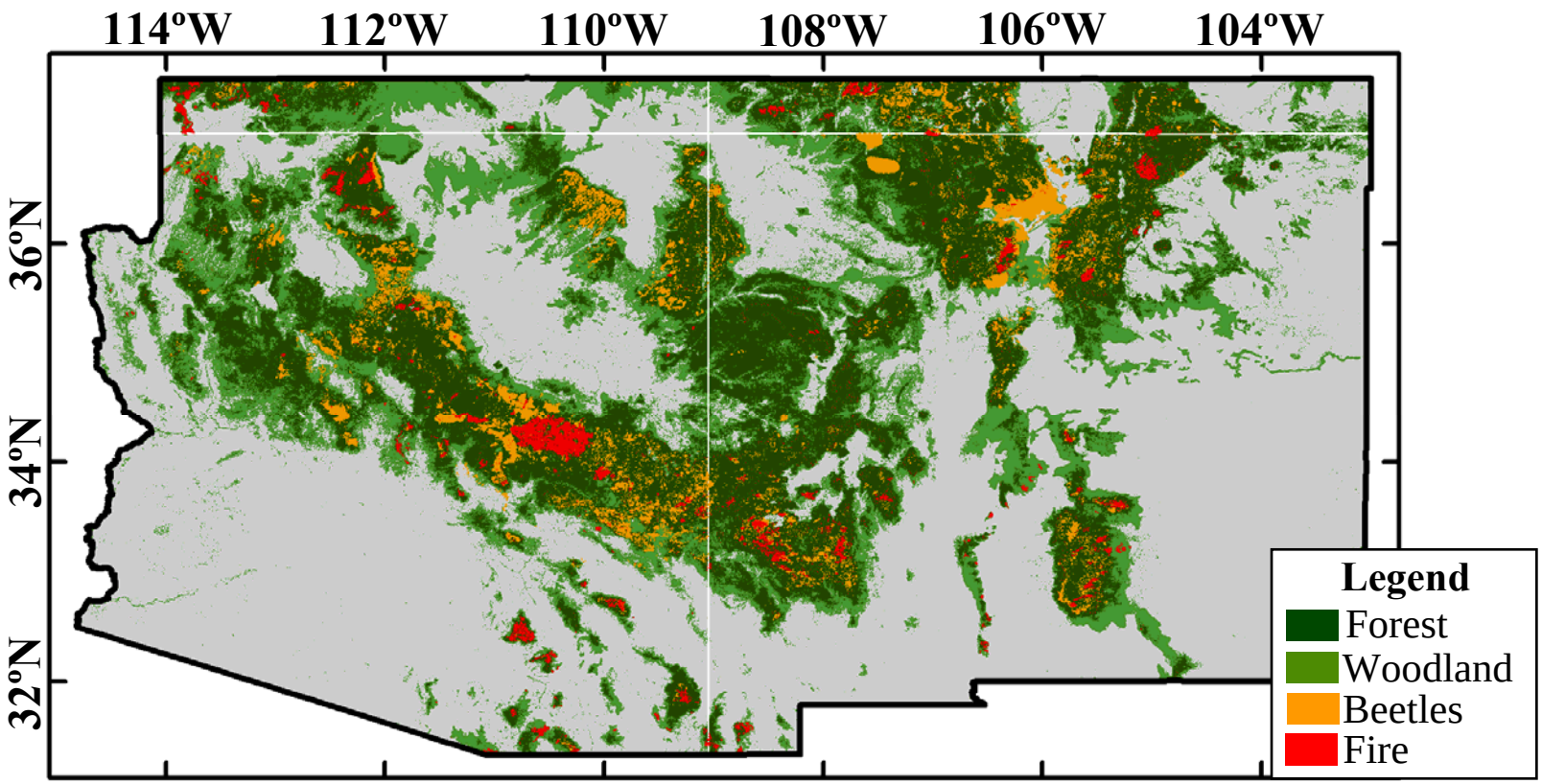


Palmer Drought Severity Index

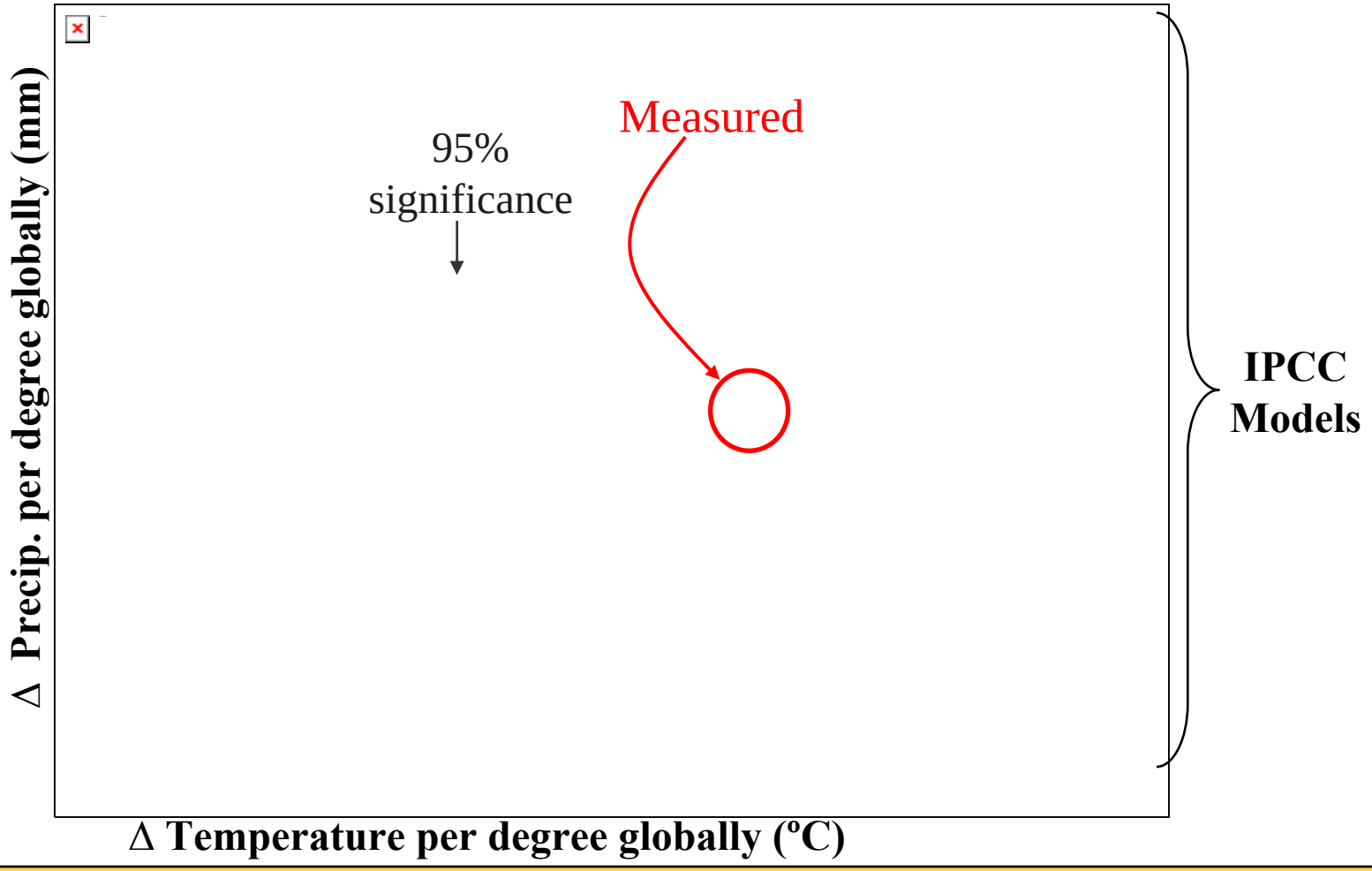
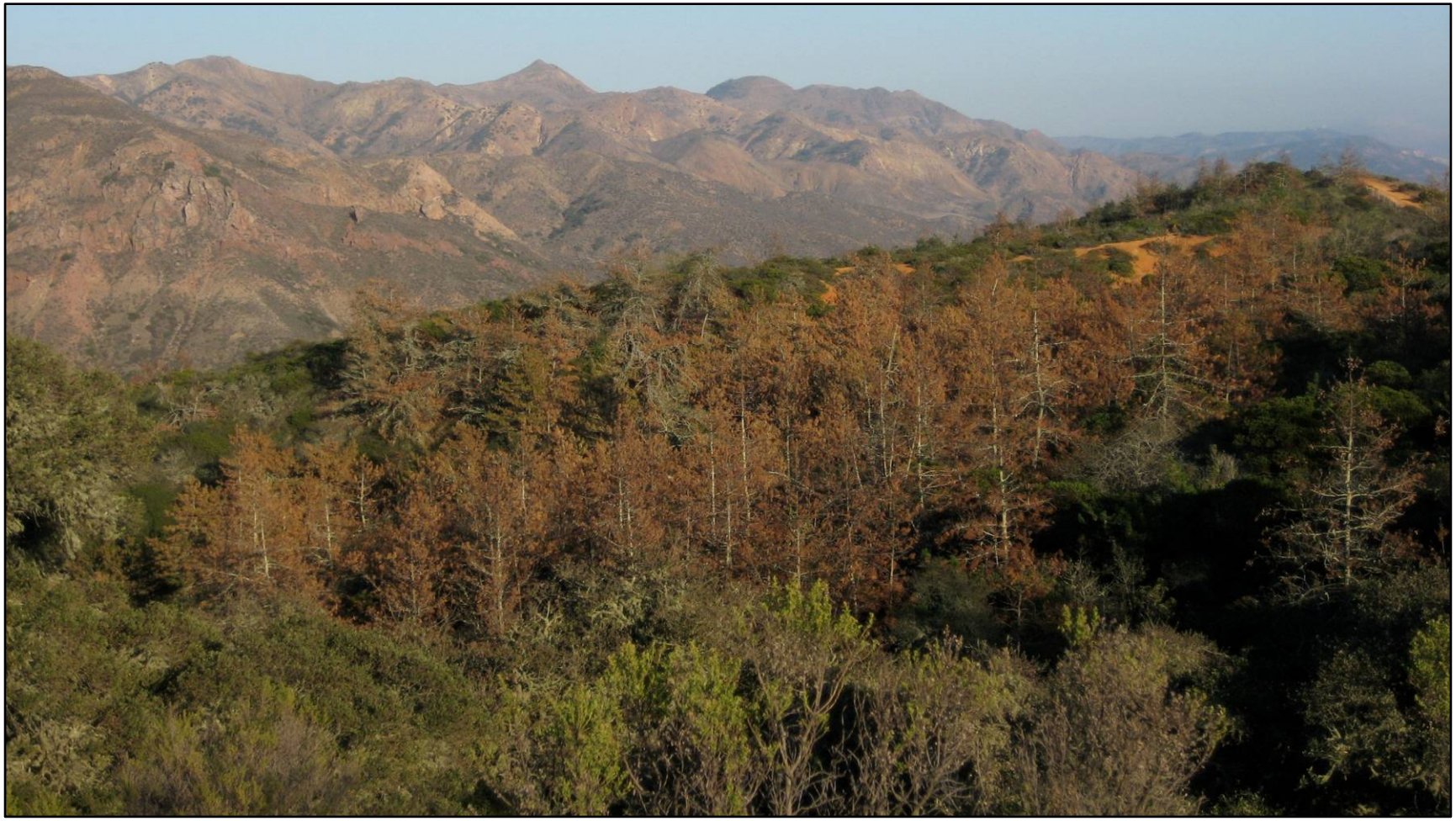


Mortality Area due to Fire and/or Bark Beetles Since 1984

<u>Area Killed</u>: Forest: 14.5 – 17.9%, Woodland: 4.8 – 7.3%



Modeled Relationships between Southwestern Climate and Global Temperature



Thank You