Tree-rings, hydrology, and reconstruction: a short primer

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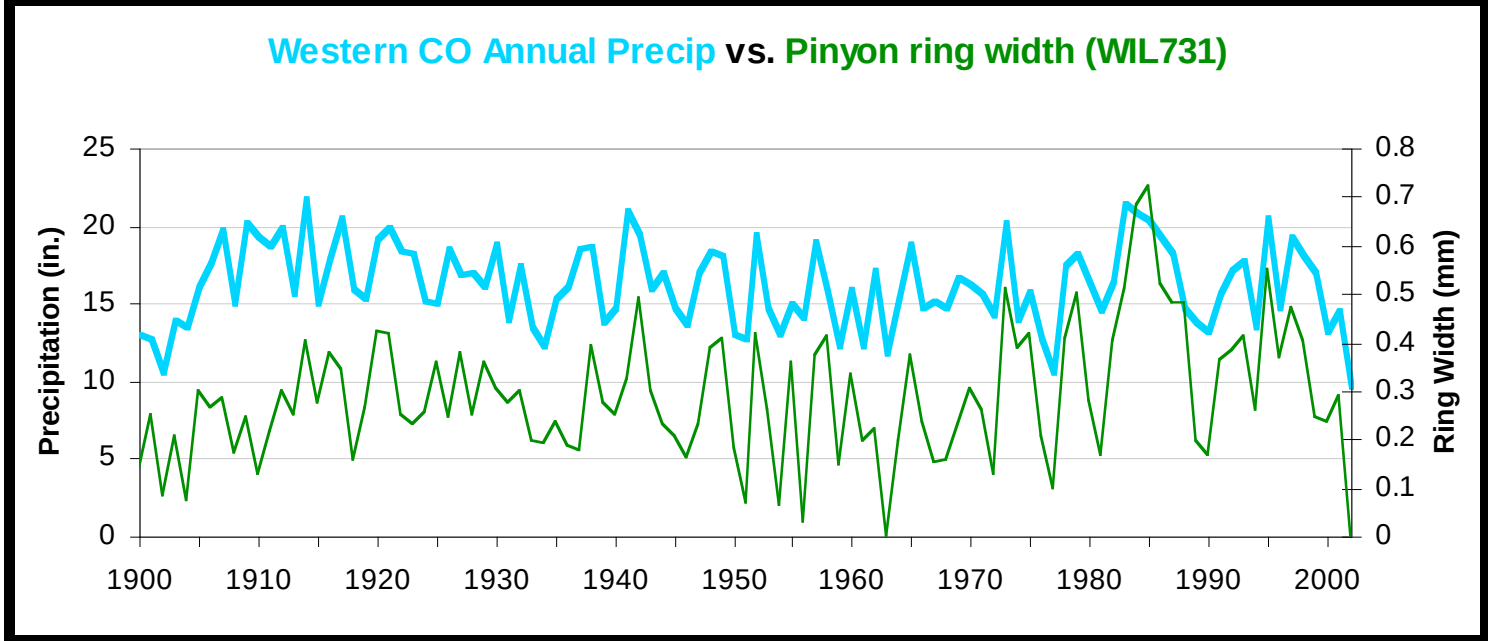
How are tree ring sites located?

How are tree rings for reconstructions sampled?

How are tree rings related to streamflow?

How are tree rings used to reconstruct past streamflow?

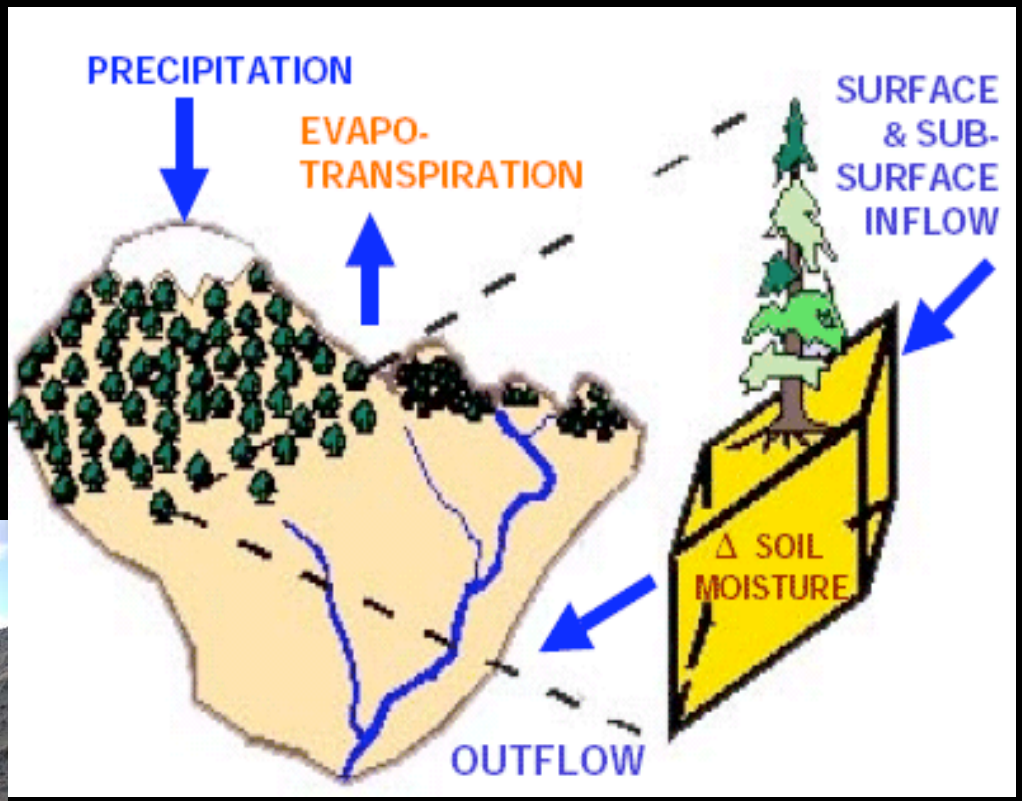
Moisture-stressed trees closely track variations in precipitation



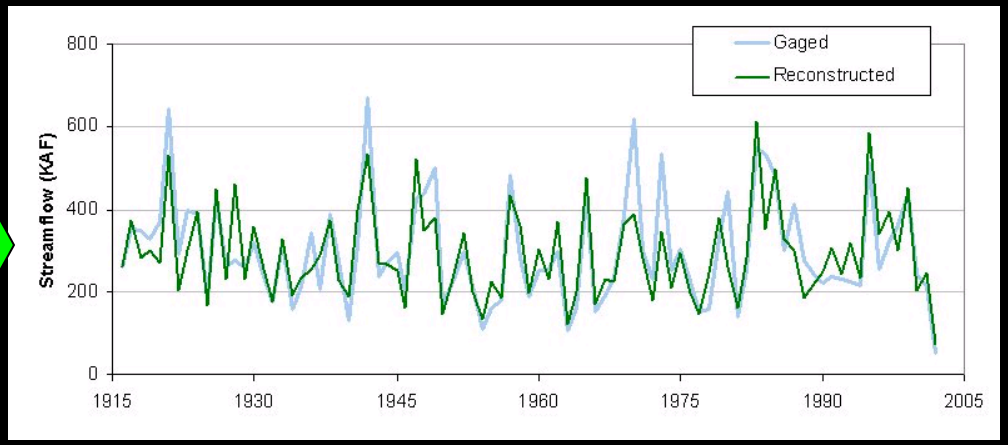
Ring widths from a single tree near Grand Junction are plotted with annual precipitation in the Colorado River basin. (r = 0.69).

What the connection between tree rings and streamflow?

Ring widths and streamflow both integrate the effects of precipitation and evapotranspiration, as mediated by the soil, over the course of the water year.

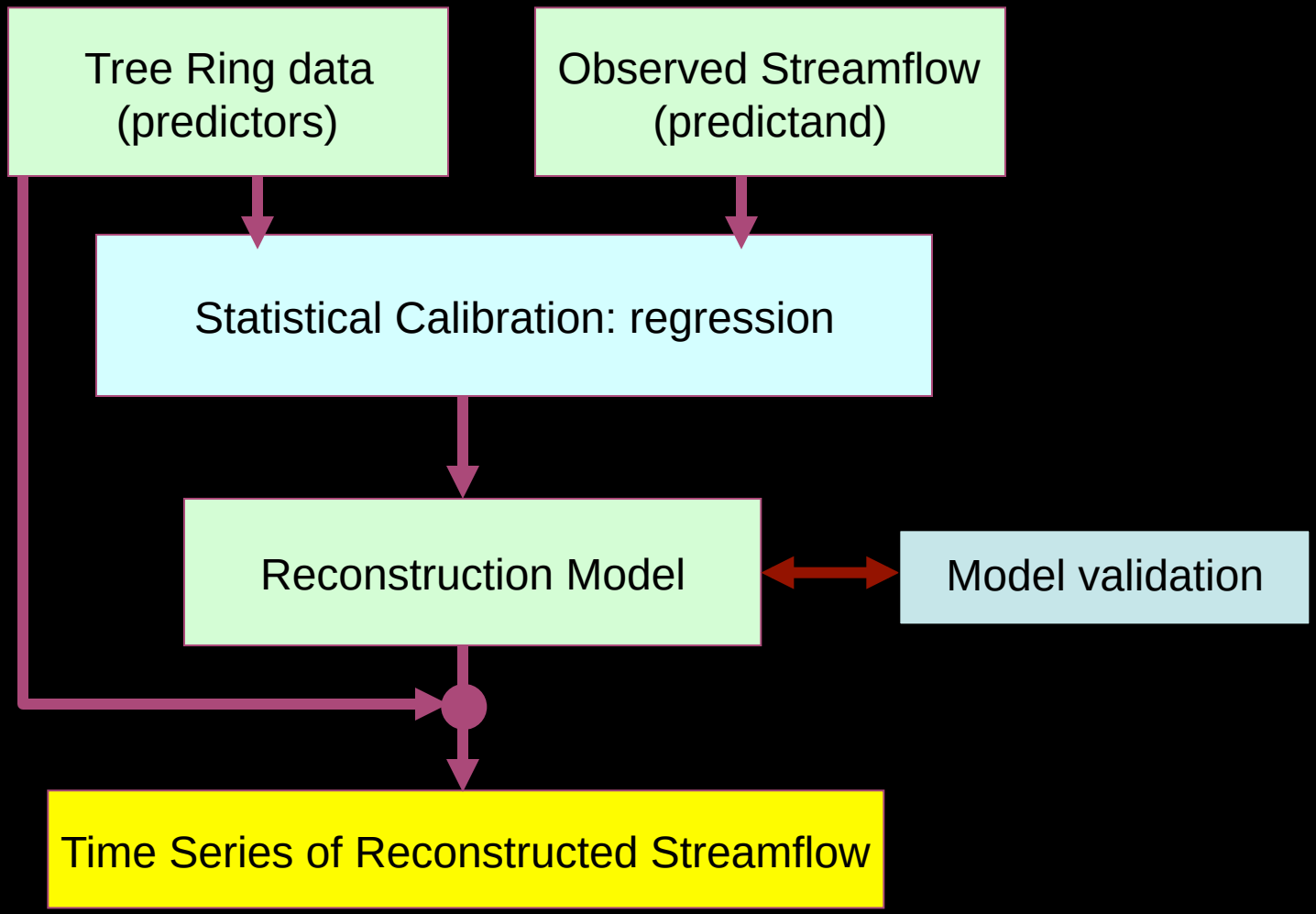


Generating A Streamflow Reconstruction



Reconstruction = best estimate of past flows, based on the relationship between the tree-ring data and gaged flows

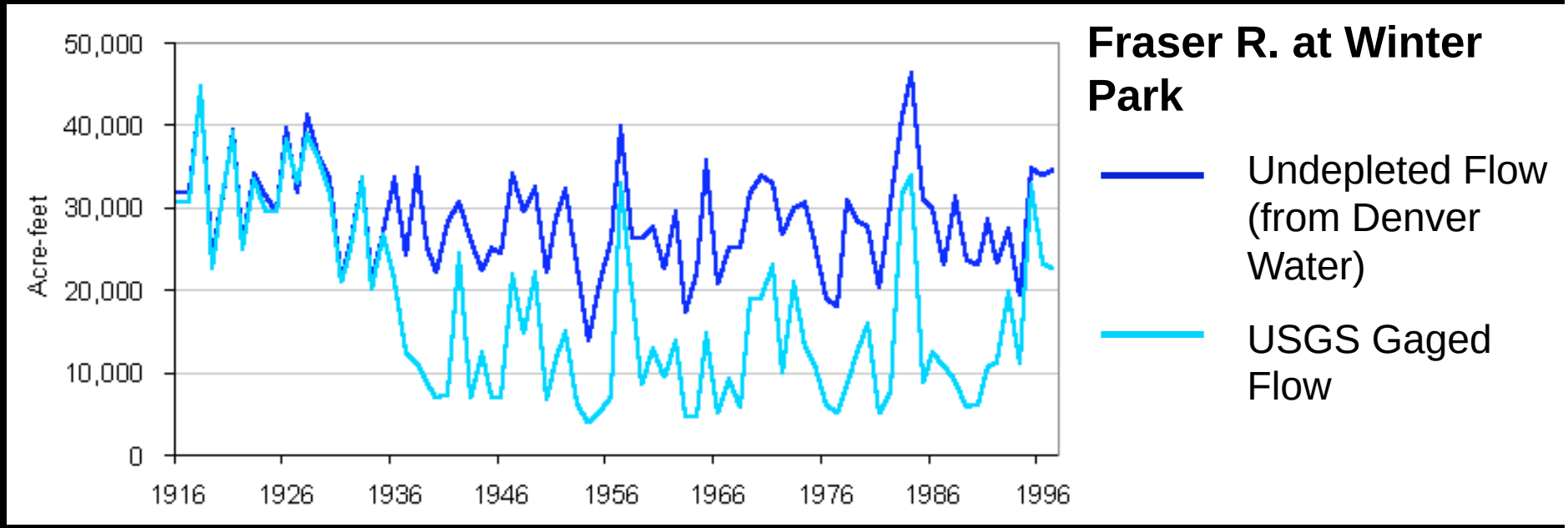
Overview of Reconstruction Methodology



based on Meko 2005

Selecting A Gage Record for Calibration the Reconstruction

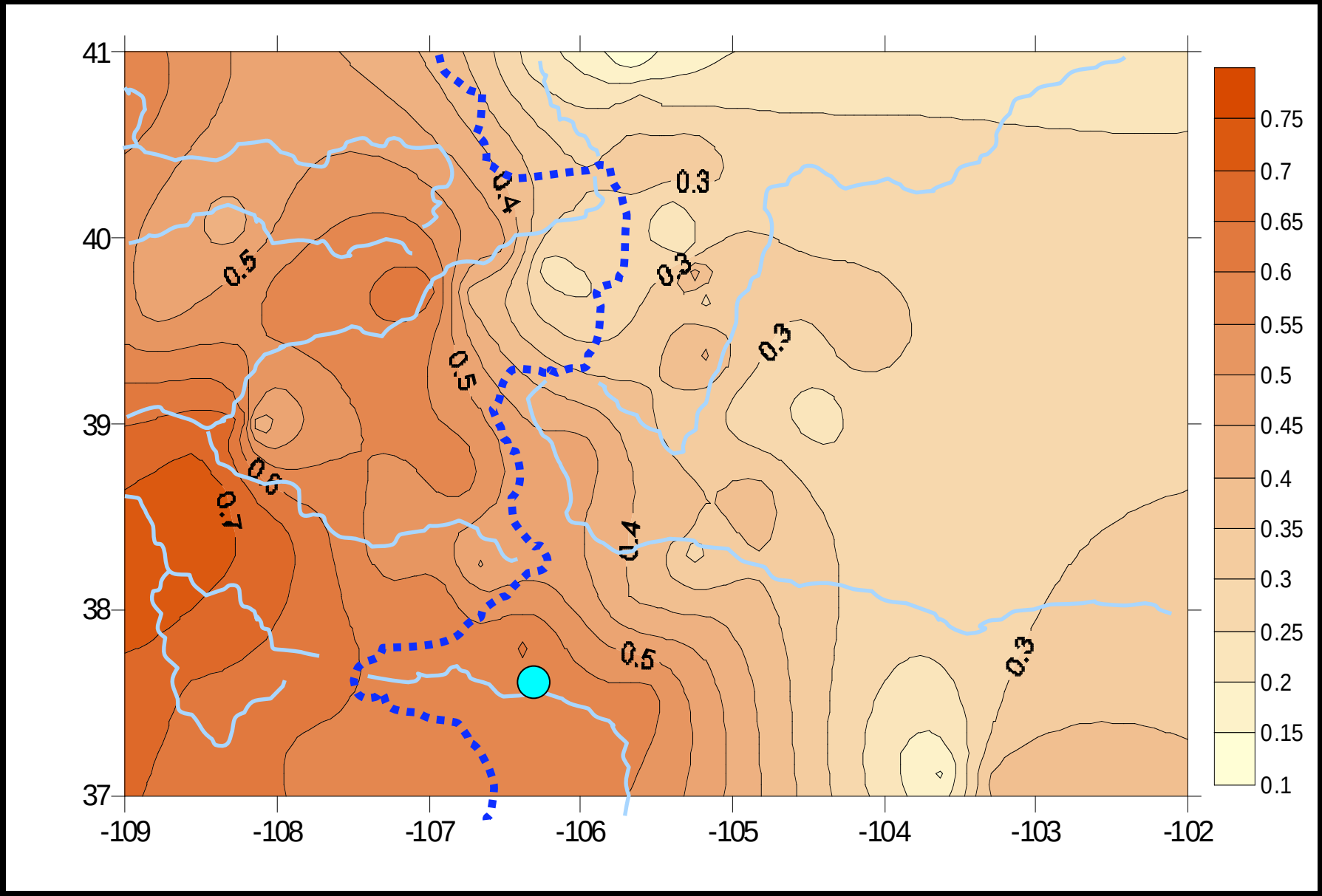
- **Length** – ideally >50 years for robust calibration with tree-ring data
- **Natural/undepleted record** – must be corrected for depletions, diversions, evaporation



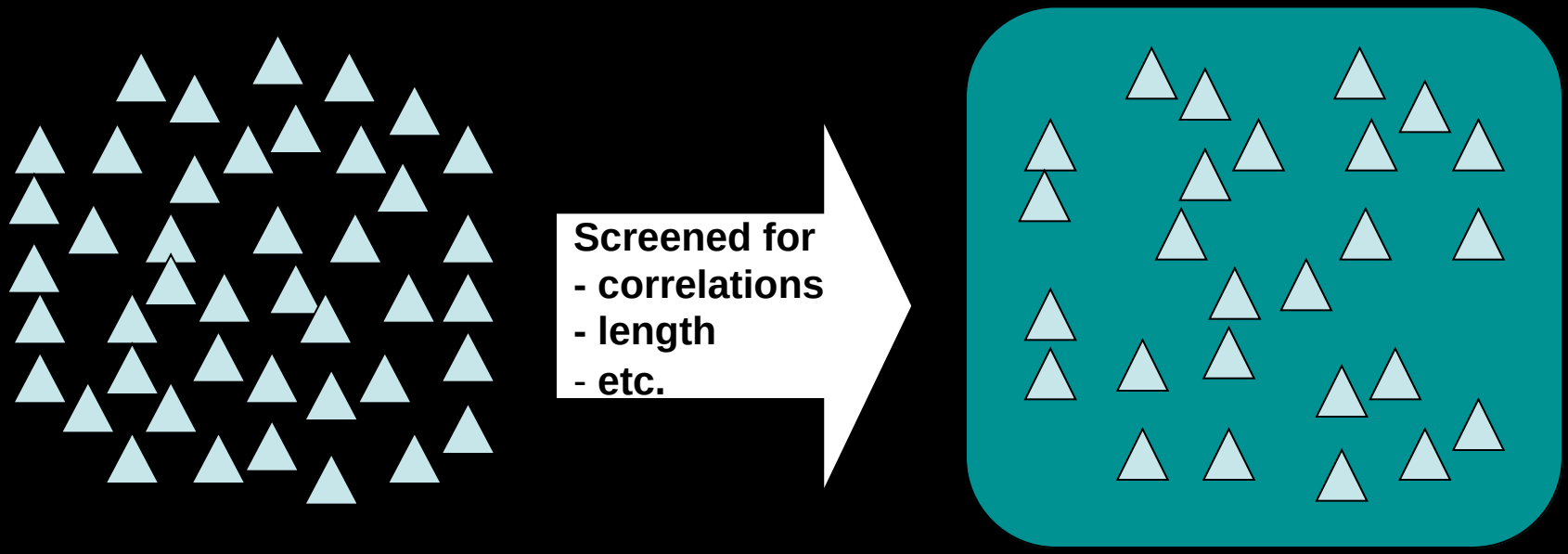
Selecting Tree Ring Data for the Reconstruction

- **Moisture sensitive species**
- **Location** – from a region that is climatically linked to the gage of interest
- **Significant relationship to gage of interest**

• Select chronologies from a region that is climatically linked to the gage of interest: Example for the Del Norte gage on the Rio Grande (blue dot)



Chronologies are screened using correlation analysis to determine which have significant relationship with streamflow at the selected gage



Screening results in a pool of potential tree-ring chronology predictors

Calibration of the Reconstruction Model

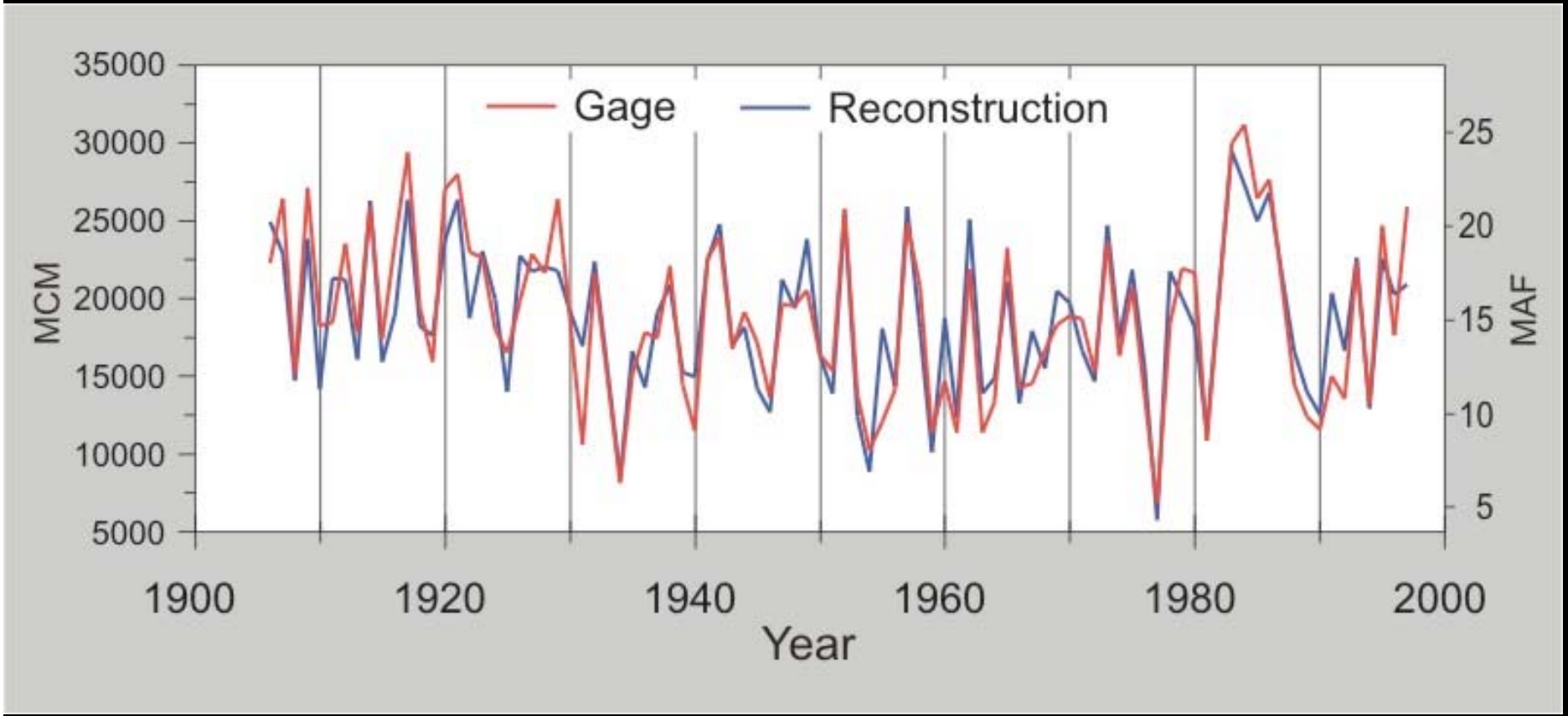
A statistical model is generated, using some type of multiple linear regression, by calibrate tree-ring chronologies with the gage record over the period of time common to both.

The result is an equation in which annual streamflow is estimated by a set of tree-ring chronologies.

An Example for the Colorado River at Lees Ferry:

ColoLeesFerry = - 2462 + DJM x 3878 + DOU x 4258 + NPU x 1766 + PUM x 5417 – RED x 5588 + TRG x 6416 + WIL x 4612

Lees Ferry reconstruction and gage values 1906-1995



The reconstruction model explains 80.6% of the variance in the Lees Ferry gage record.

19.4% of the variance in the gage record is unexplained, representing the uncertainty in the reconstruction.

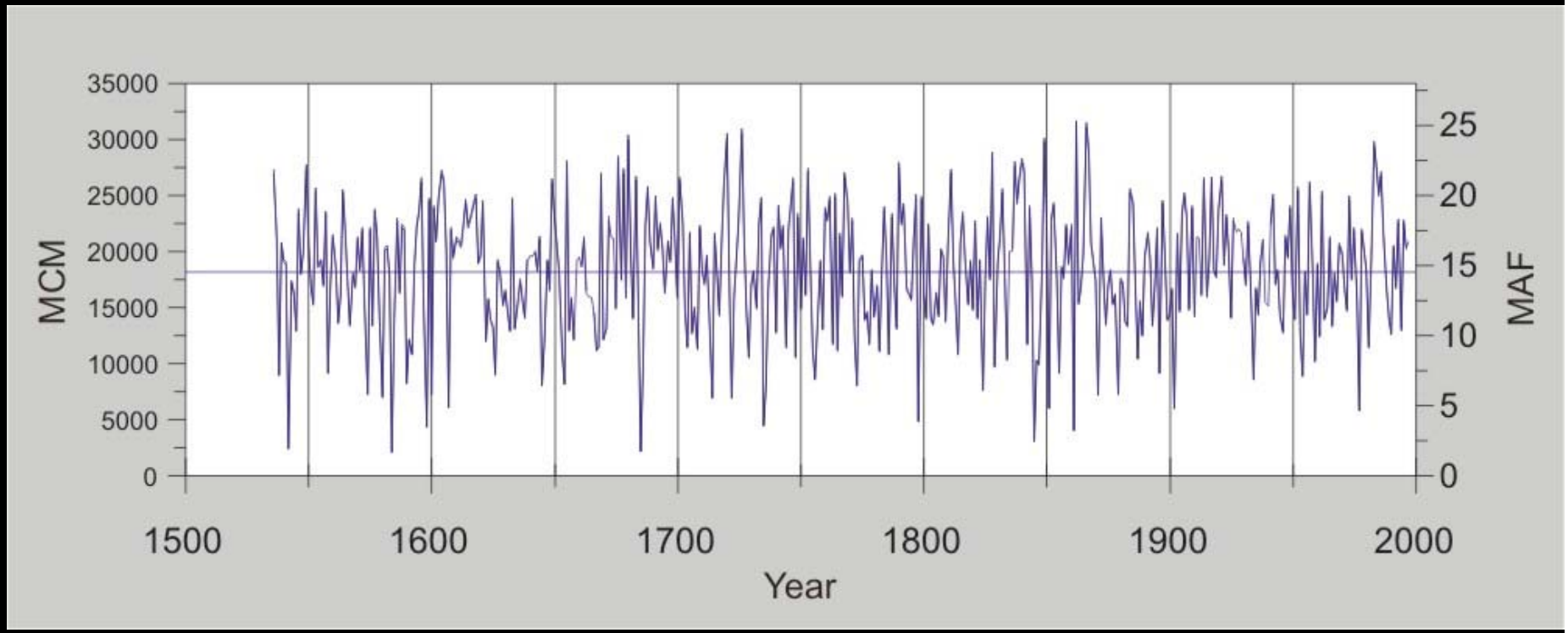
Model Validation and Skill Assessment

- Are statistical assumptions satisfied?
- How does the model validate on data not used to calibrate the model?
- How does the reconstruction compare to the gage record?

Generating the Final Reconstruction

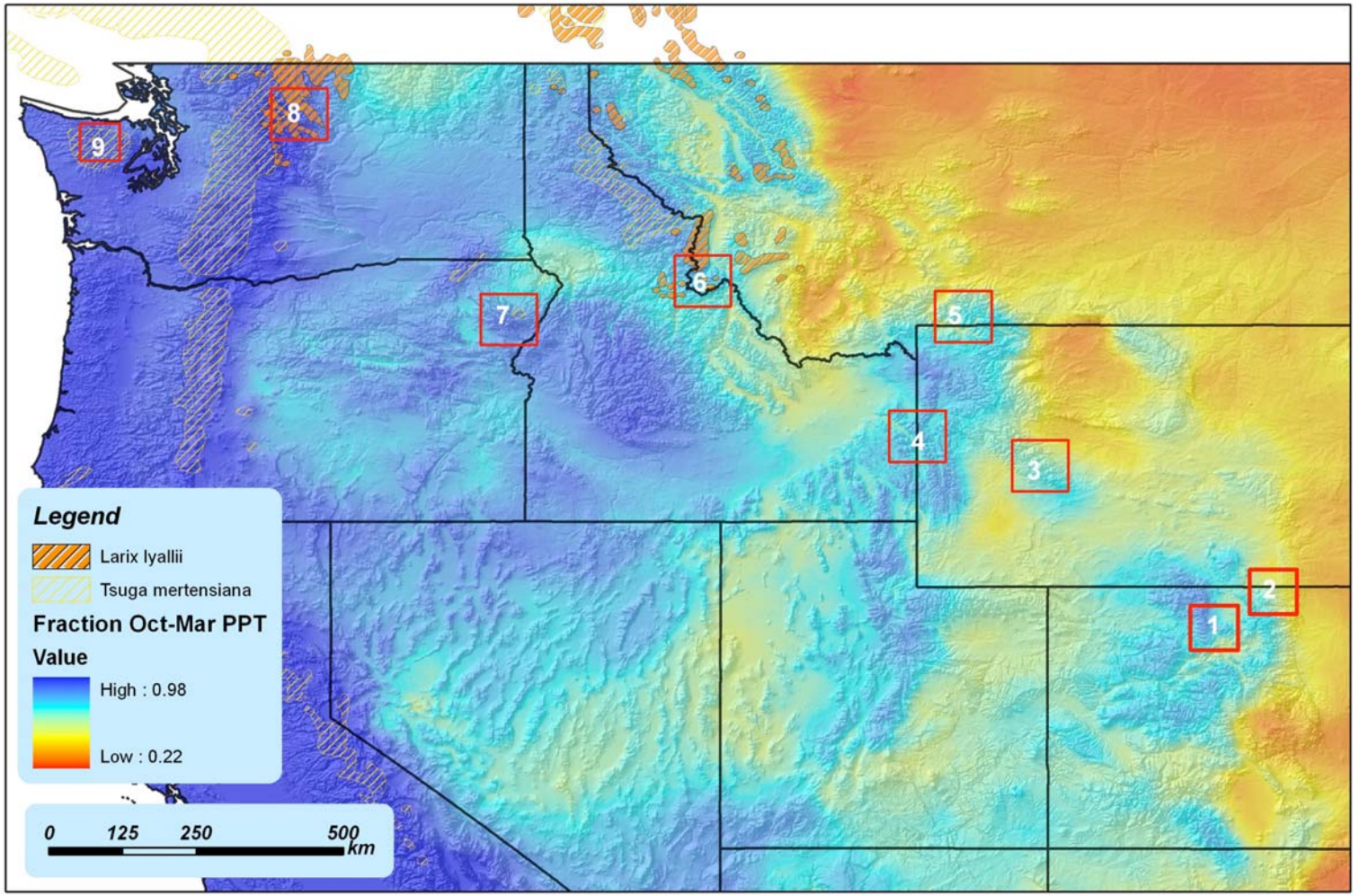
The final step is to plug the full length chronologies into the reconstruction equation to generate the full reconstruction

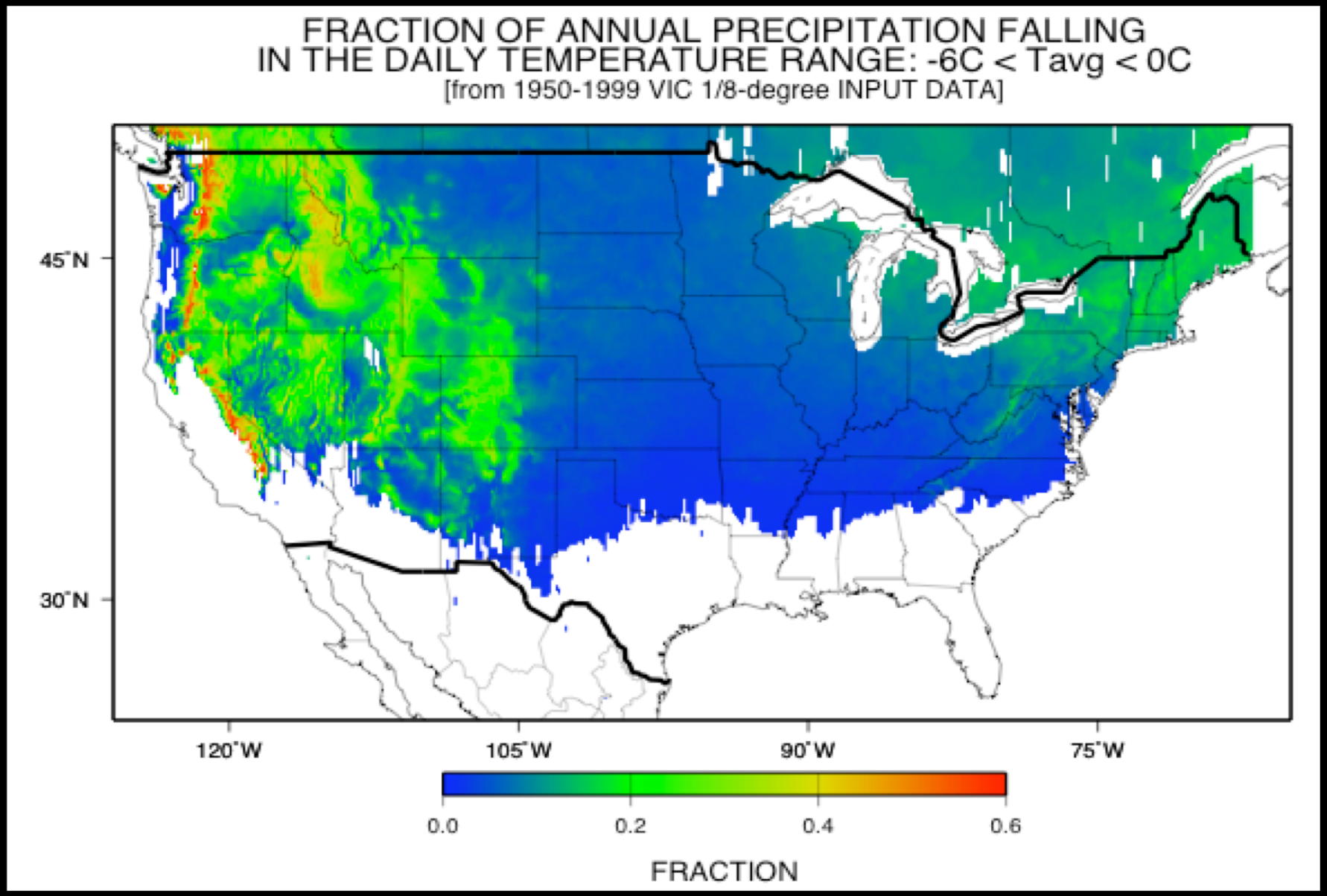
Reconstruction of Lees Ferry Streamflow, Water Year, 1536-1997



What makes trees sensitive to hydroclimate in the PNW?

What kinds of trees (and in what settings) can we use for reconstructions?


9
8
7
6
5
4
3
2
1
Legend
Larix lyallii
Tsuga mertensiana
Fraction Oct-Mar PPT
Value
High : 0.98
Low : 0.22
0
125
250
500
km

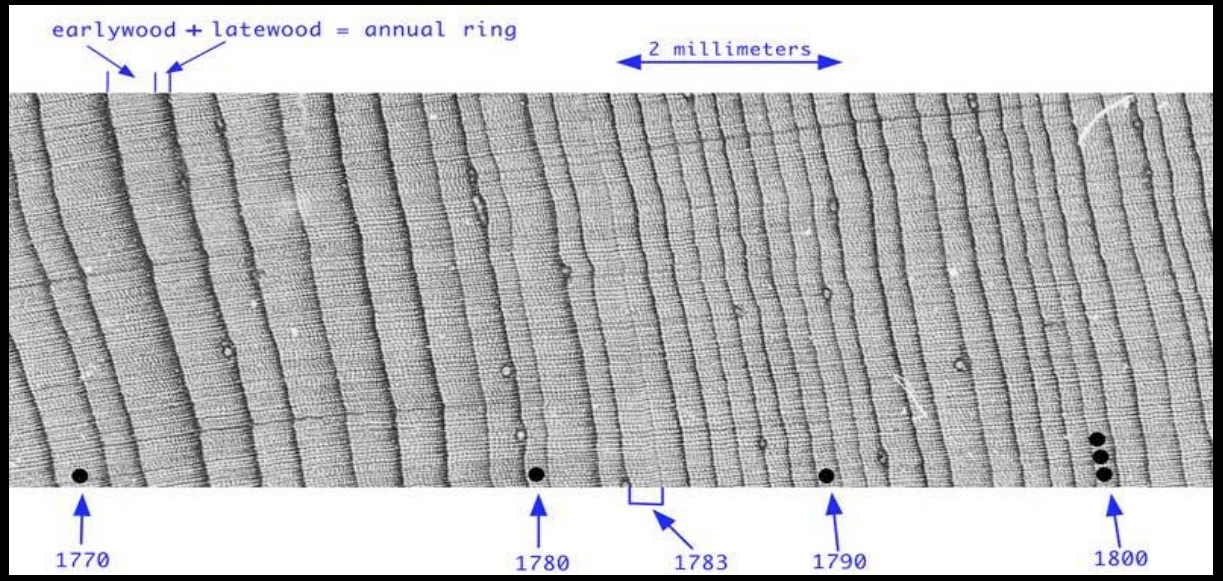


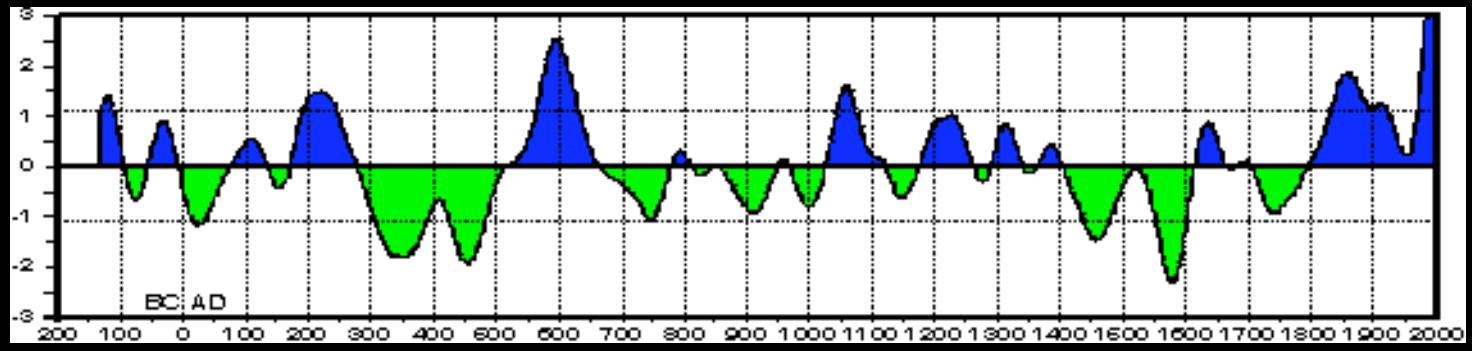
Preliminary unpublished figure courtesy of Mike Dettinger, Scripps.

Tree growth and limiting factors

- Combinations of limiting factors affect growth in all but the most sensitive trees:
  - Light
  - Nutrients
  - Water
  - Energy (thermal)
- Replication in space, time, and environmental conditions essential for identifying regional patterns
- Choice of site, species and trees all intended to maximize variable of interest

Advantages: annual resolution and sometimes deep time

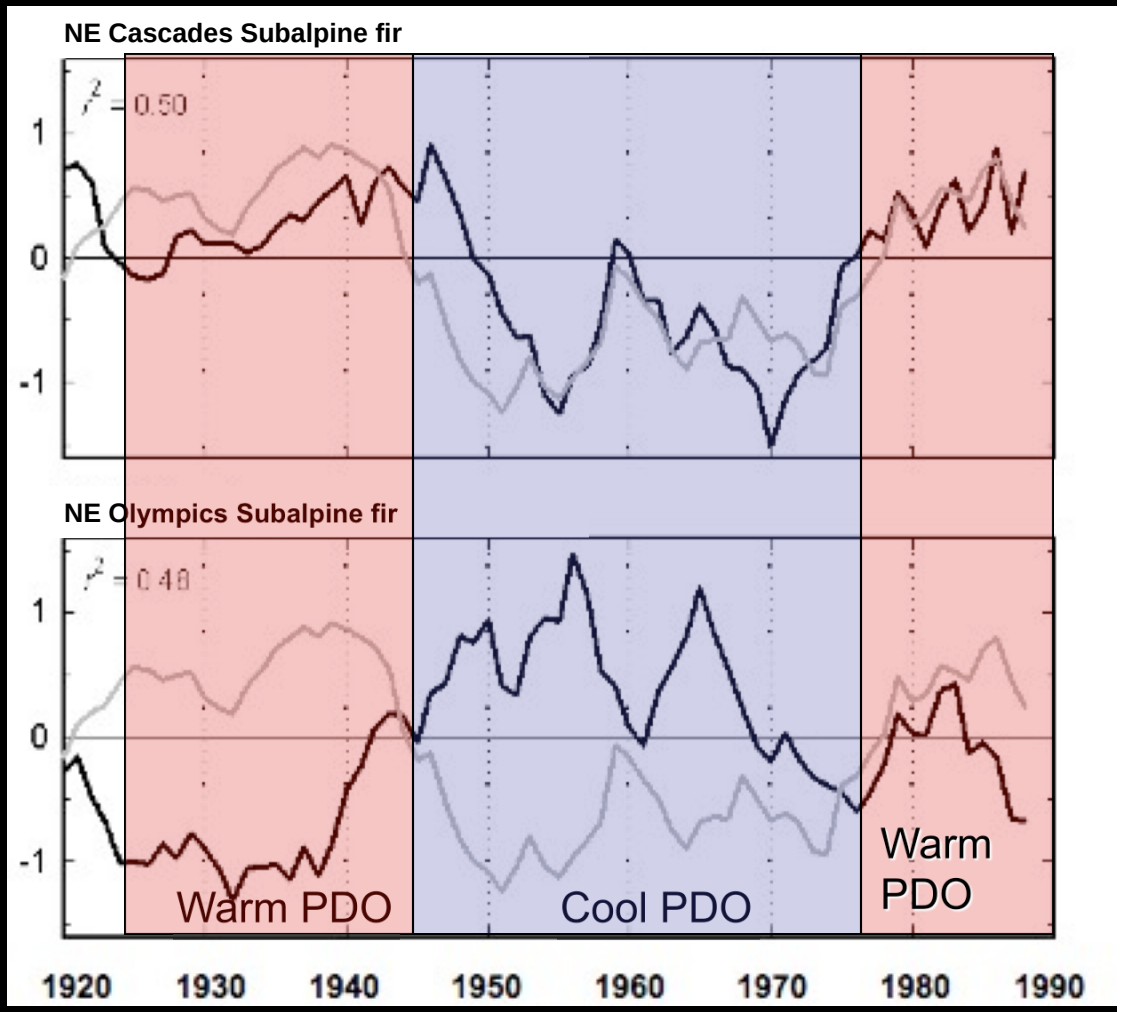




Tree-ring reconstruction of precipitation in northern New Mexico (Grissino-Mayer)

Climatic limitation of tree growth

- The same species can have different growth climate relationships depending on the limiting factors in its environment
- The key is to find the locations and species with very strong climate limitations with relatively little influence form other factors



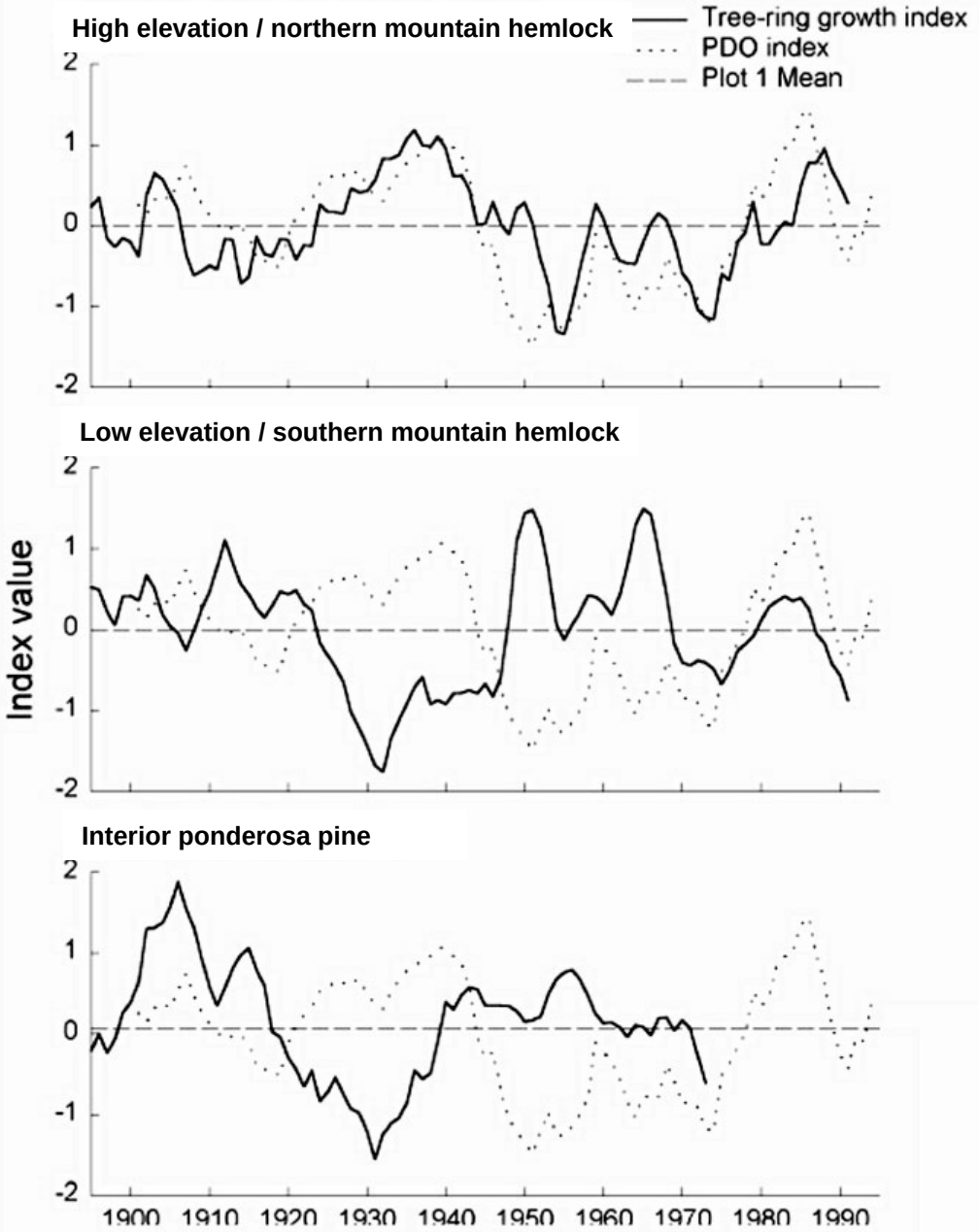
Peterson, Peterson, and Ettl

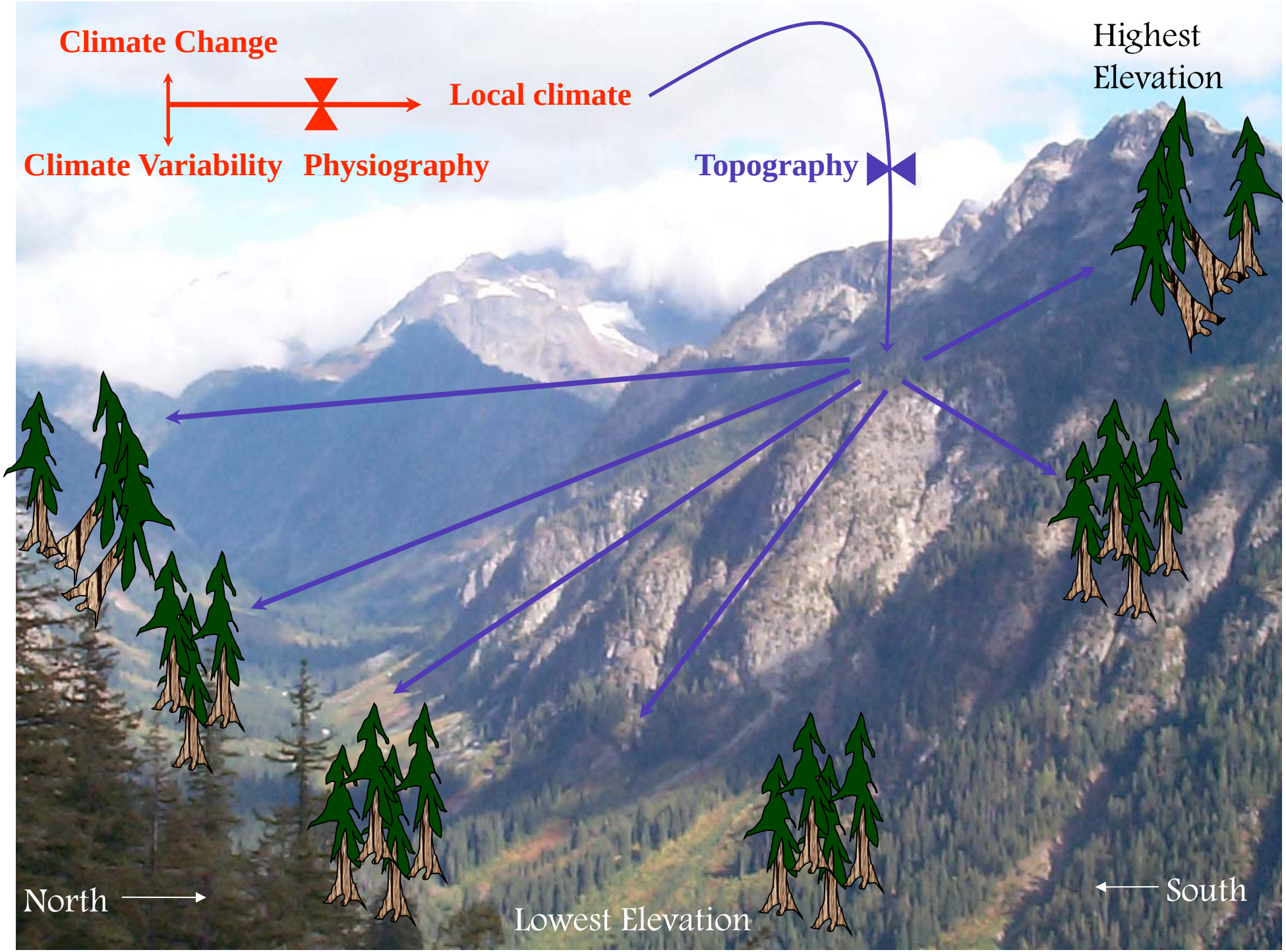
Photo: J. Littell

Photo: C. Webber

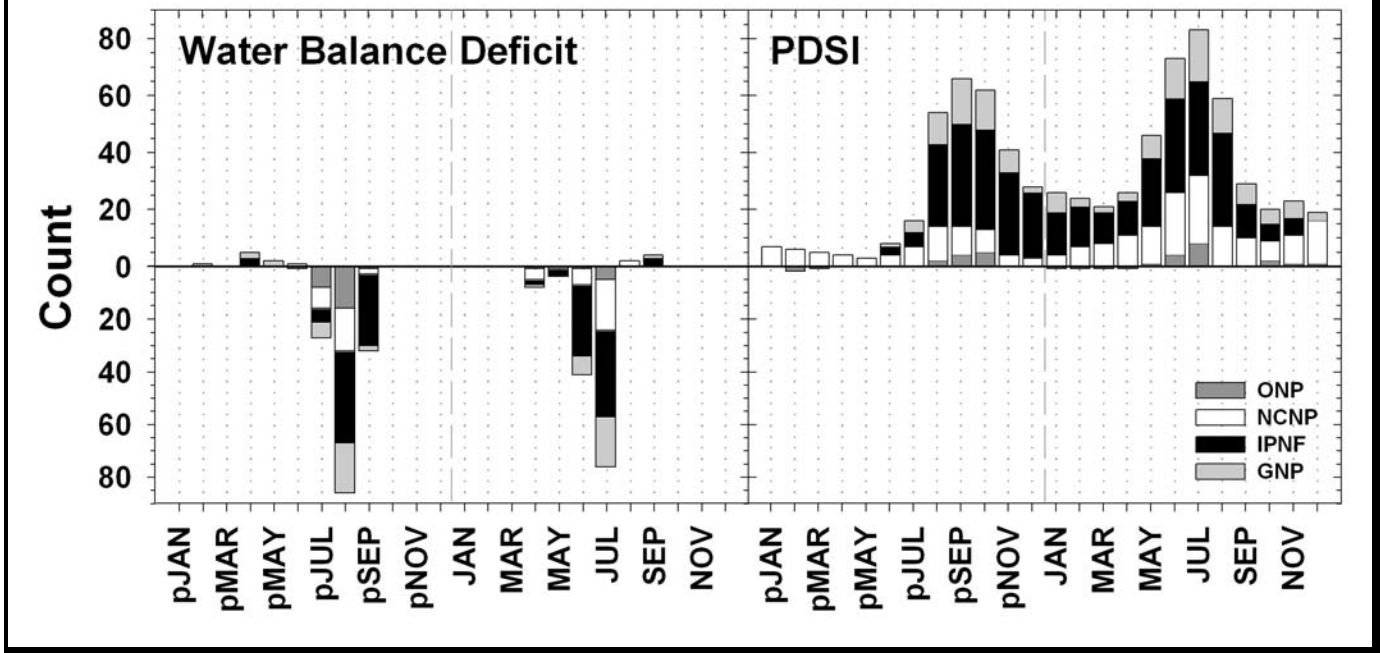
Photo: C. Woodhouse

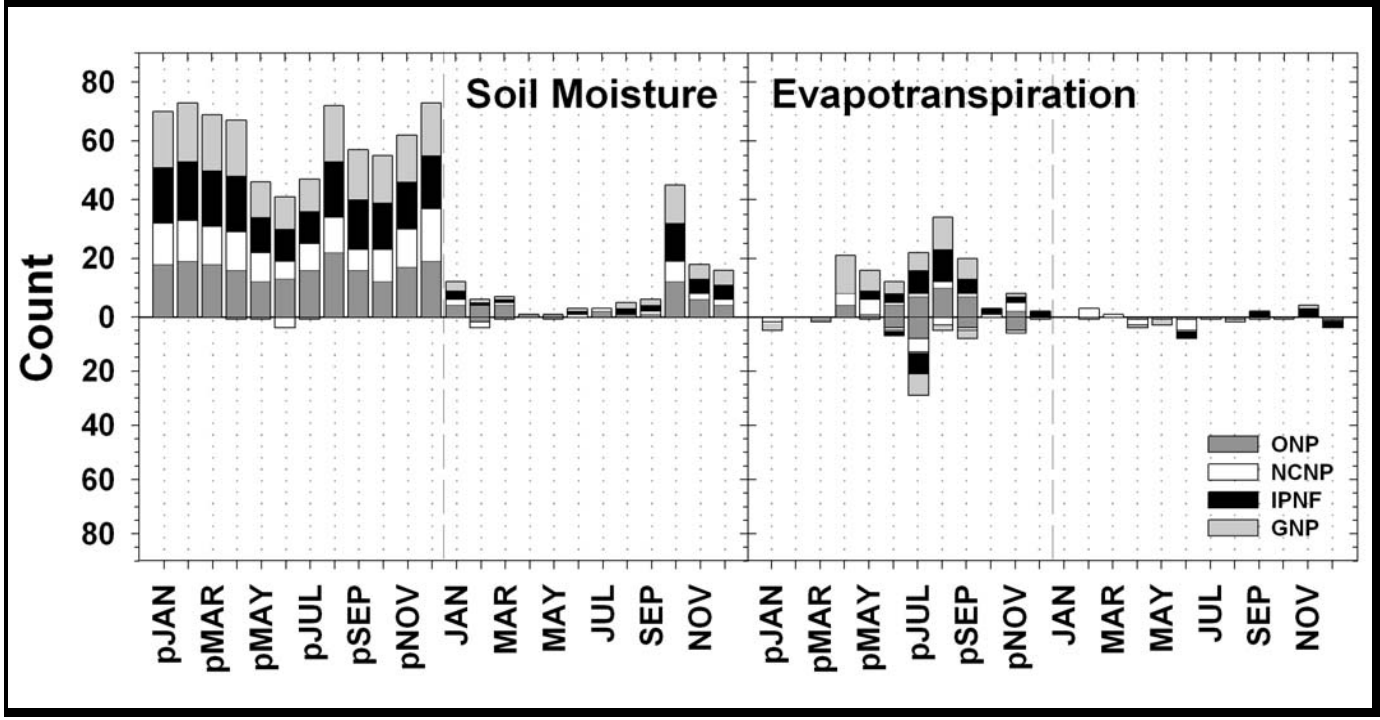
Tree Growth and Inter-Decadal Climate Variability




Climate Change
Local climate
Climate Variability
Physiography
Topography
Highest Elevation
North
Lowest Elevation
South

Littell et al in press





Deficit (Div.)

-JJ year of growth

-JAS year prior

PDSI (Div.)

+May.-Sep

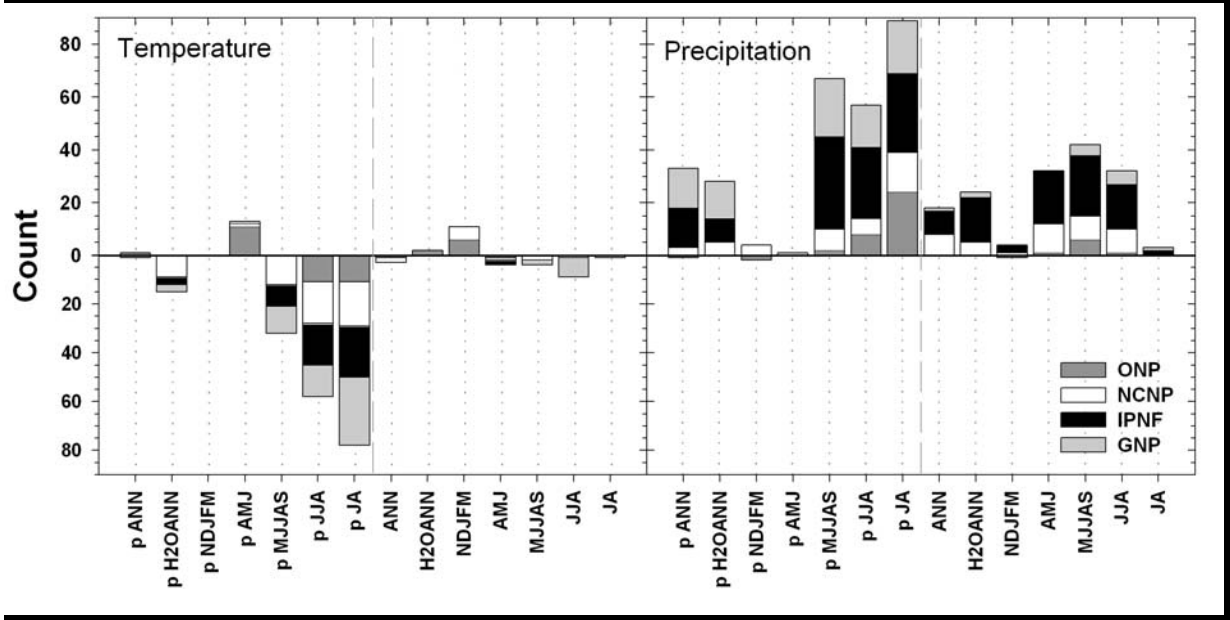
+ASO year prior

Soil Moisture (VIC)

Entire year prior

Evapotransp. (VIC)

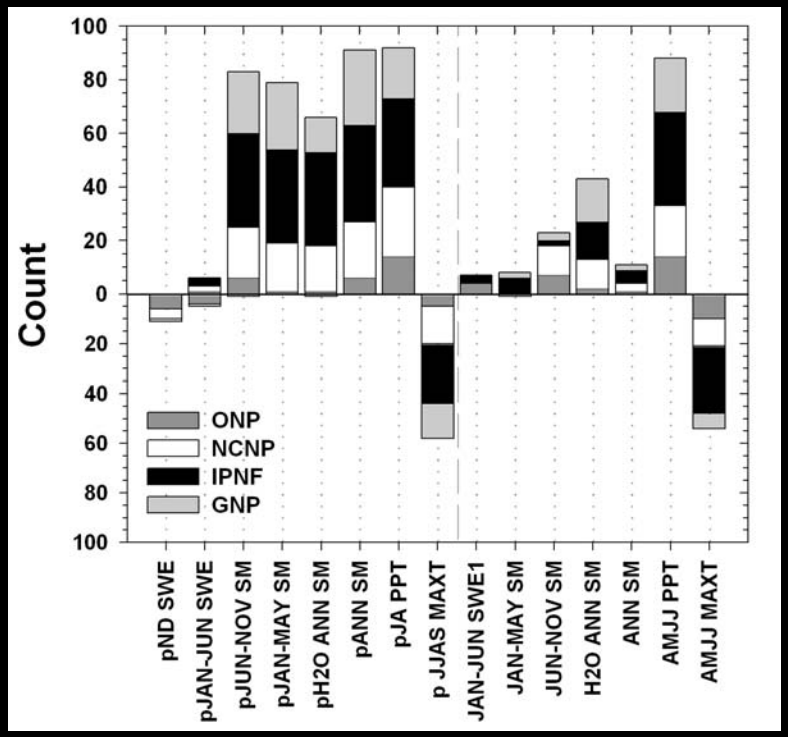
Mixed (AET context varies with PET)



Seasonal Aggregation

Divisional Climate

- Prior JA temperature
- Prior JA precipitation



VIC Climate

- Prior JA precipitation
- Prior JJAS max. temp.
- current AMJJ precip.
- current AMJJ max. temp.
- Prior ANN. soil moisture

Littell et al in press