

# The Past Record of North American Drought

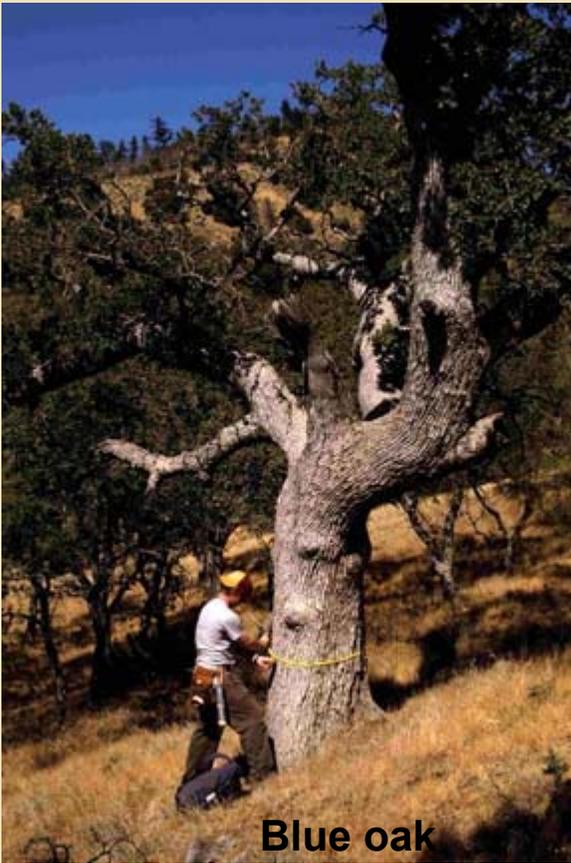
Connie A. Woodhouse

National Climatic Data  
Center, Paleoclimatology  
Branch, Boulder, CO



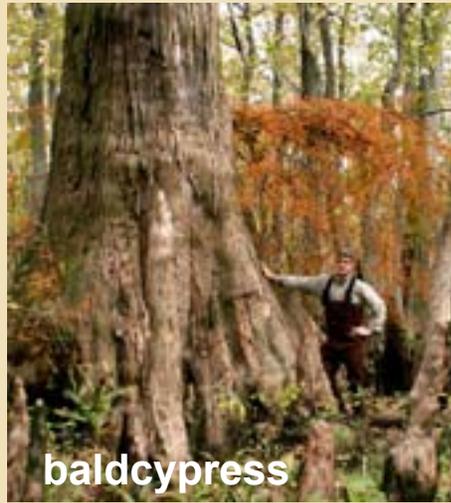
Assistance from many including Jeff Lukas, Robin Webb, Brad Udall, David Meko, Stephen Gray, and funding from NOAA CCDD and WWA Program, Denver Water and the National Science Foundation.





**Blue oak**

D. Stahle



**baldcypress**

D. Stahle

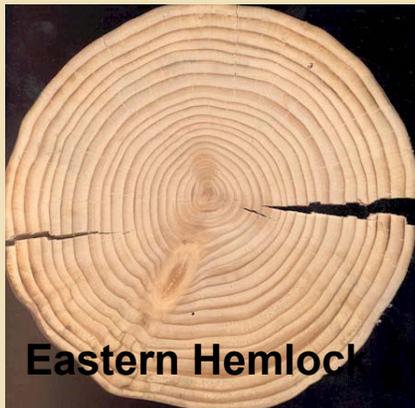


**Ponderosa pine**



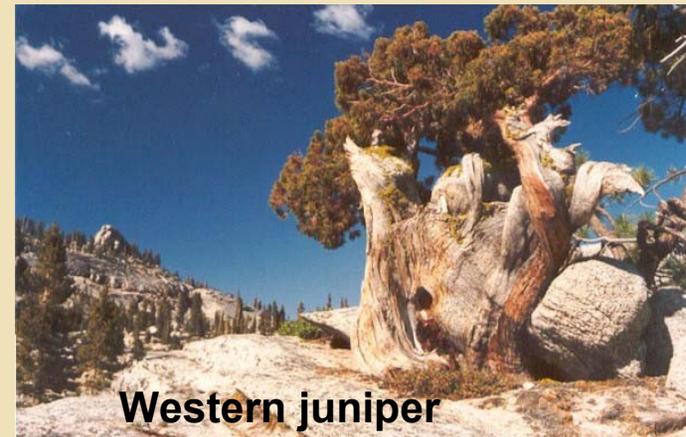
**Douglas-fir**

**Some tree species and site characteristics corresponding to moisture sensitivity**



**Eastern Hemlock**

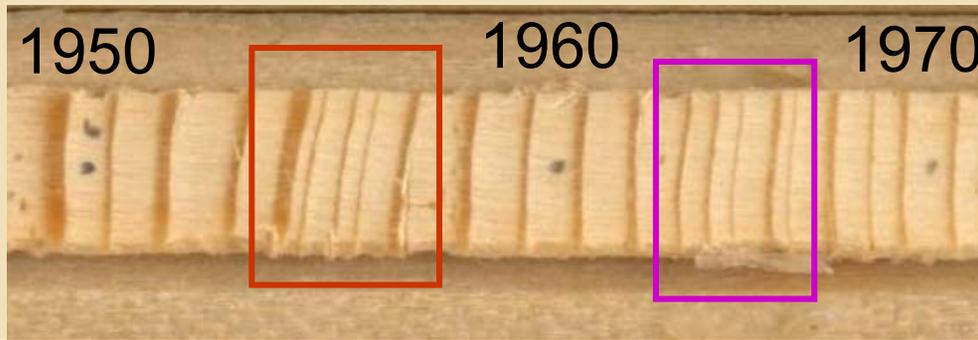
R. Adams



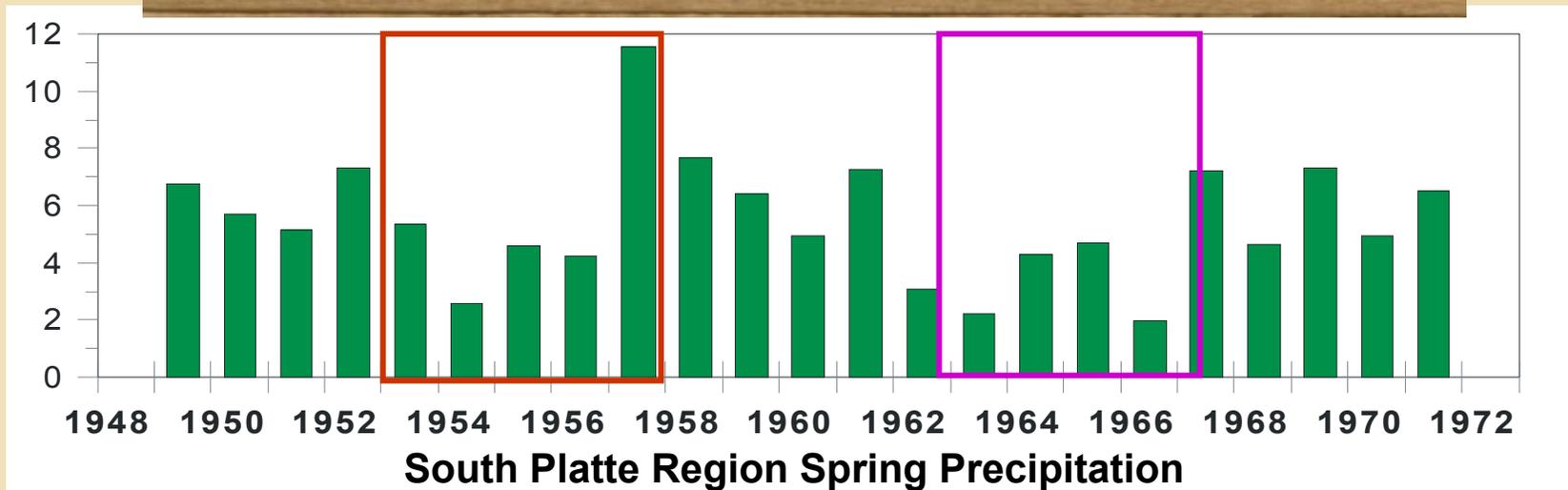
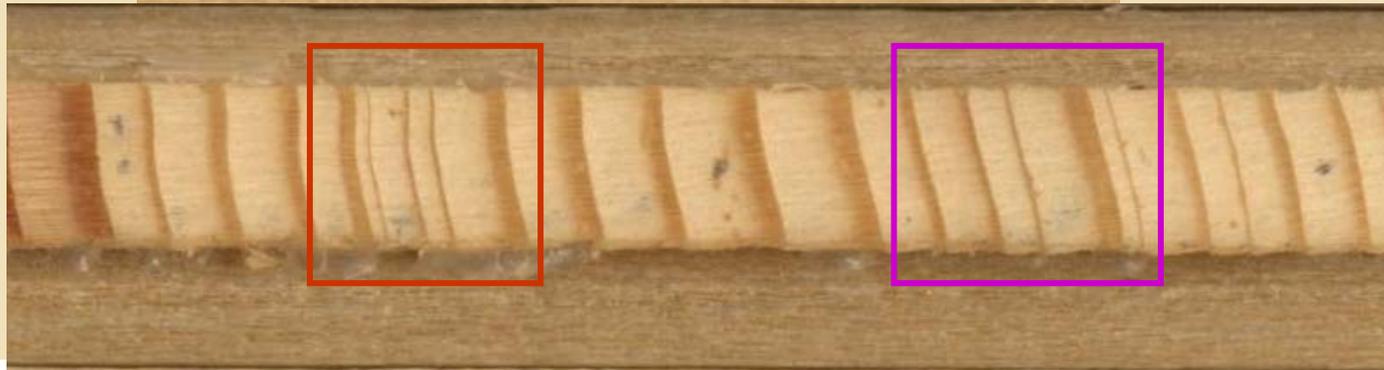
**Western juniper**

P. Kelly

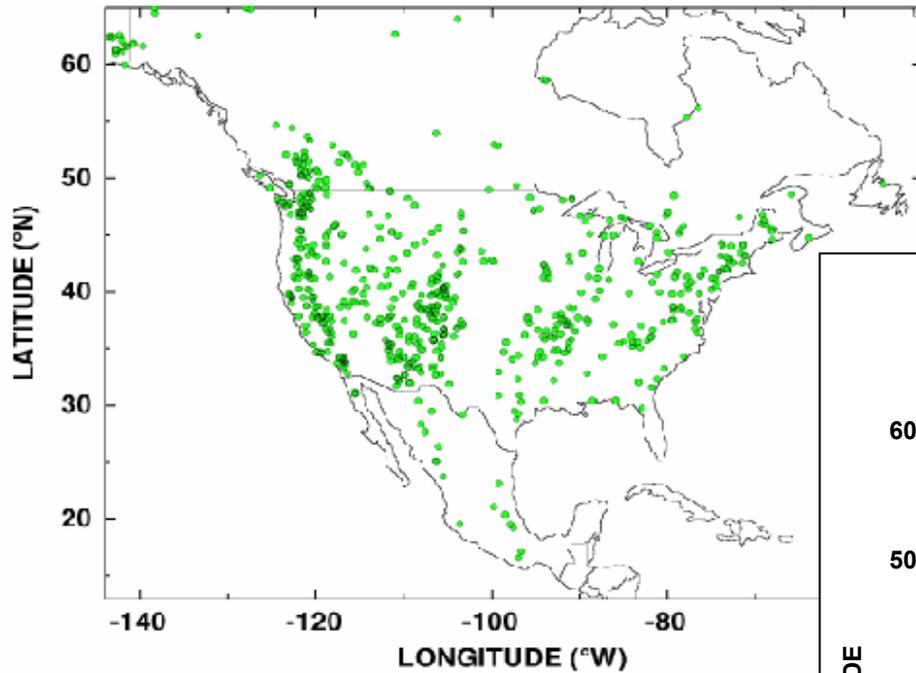
# In these species, ring widths closely track variations in precipitation



Eldorado Canyon  
Douglas-fir

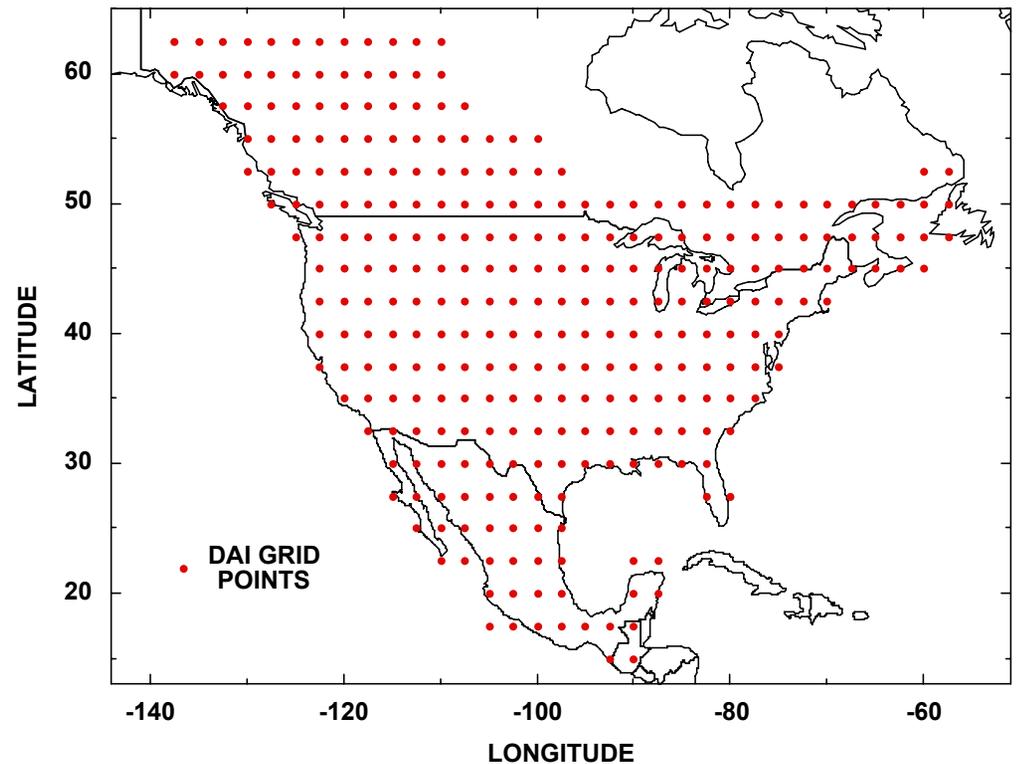


### 835 TREE-RING CHRONOLOGY NETWORK FOR RECONSTRUCTING DROUGHT



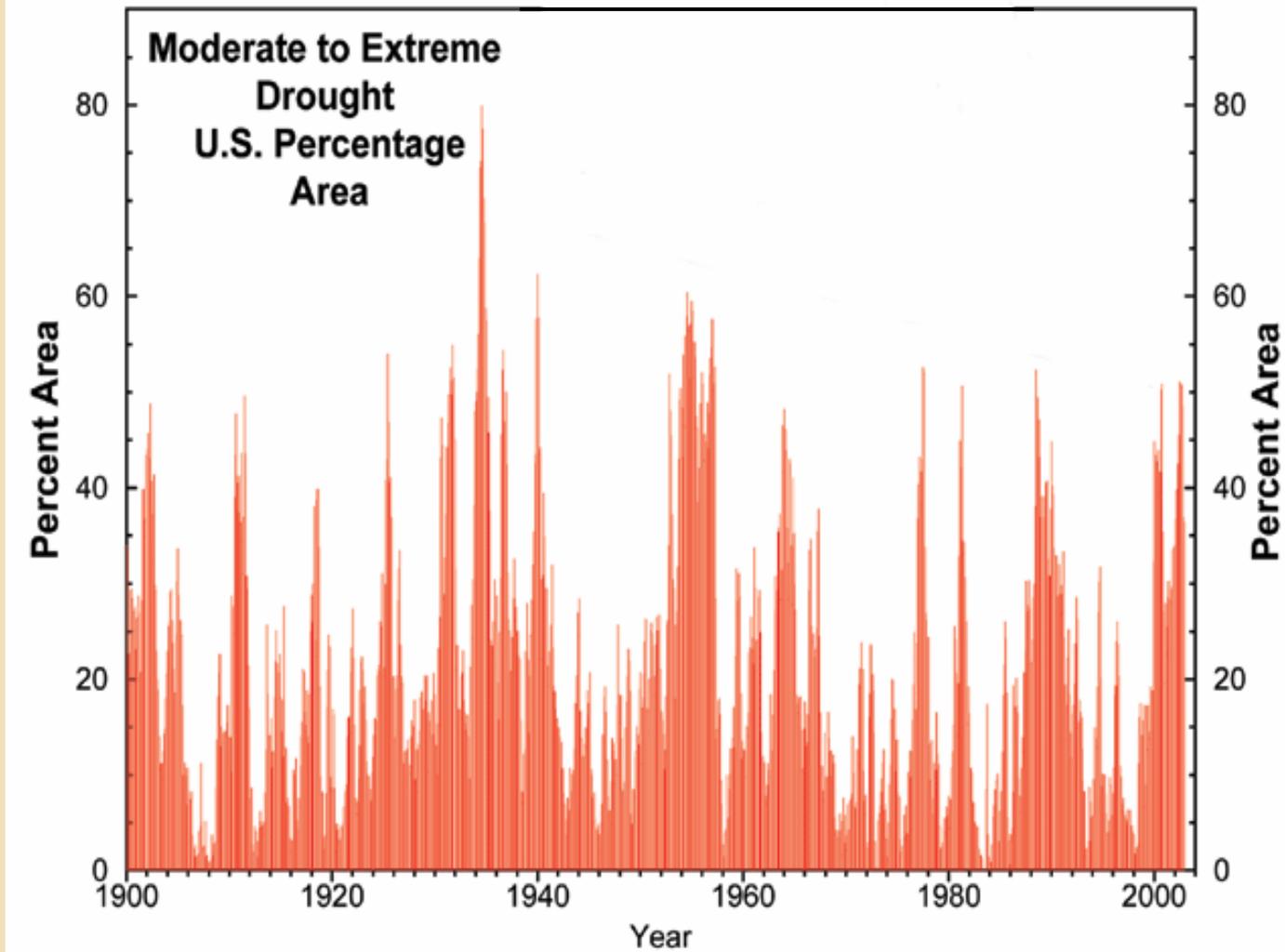
# North American Drought Atlas

### 297-POINT 2.5°x2.5° "DAI" GRID USED FOR RECONSTRUCTING SUMMER PDSI



A network of tree-ring chronologies has been used to generate gridded summer PDSI reconstructions

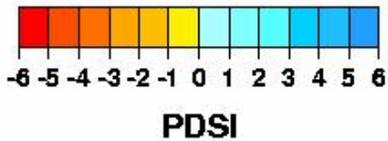
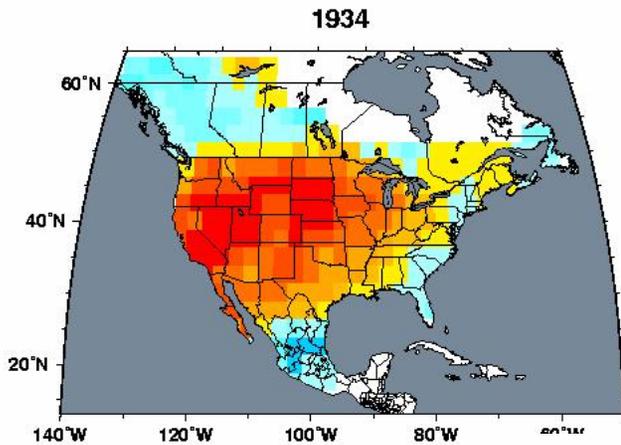
# Continental Scale Droughts, 1895-2002



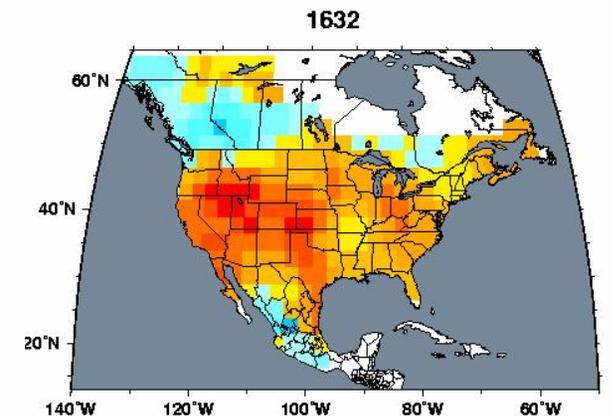
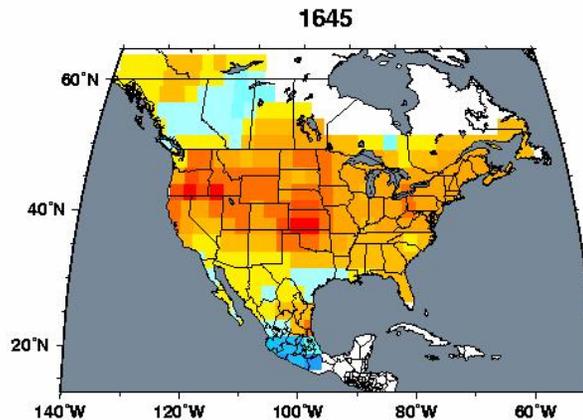
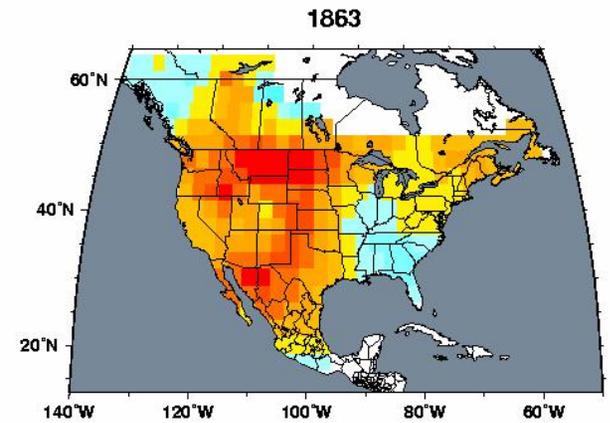
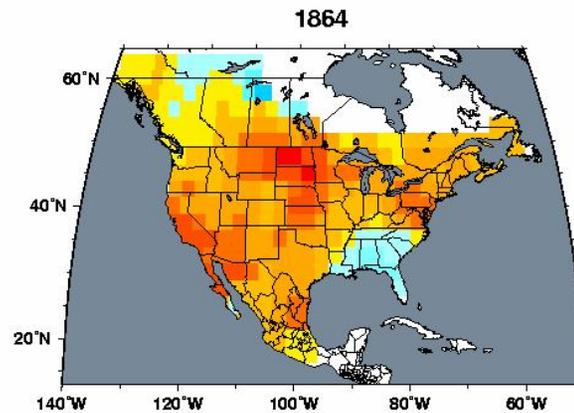
NOAA National Climatic Data Center

<http://lwf.ncdc.noaa.gov/oa/climate/research/2002/ann/drought-summary.html>

# Assessing 1934 in the Context of Past Centuries

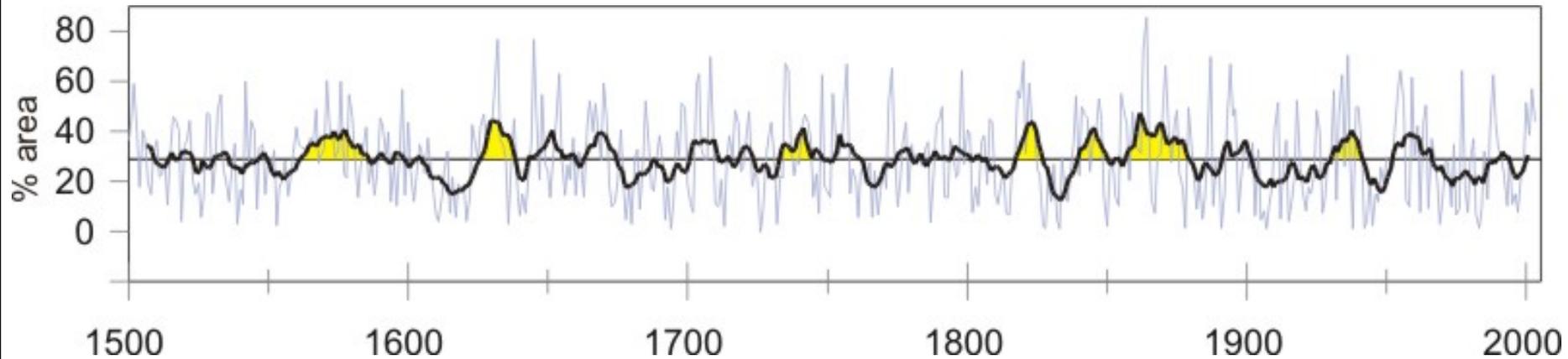


The spatial extent of drought in 1934 has been surpassed in a handful of years, but the area under severe drought conditions may still be the greatest in 1934.



**When duration of continental-scale drought is considered, a number of periods in the past show more persistent, widespread drought conditions.**

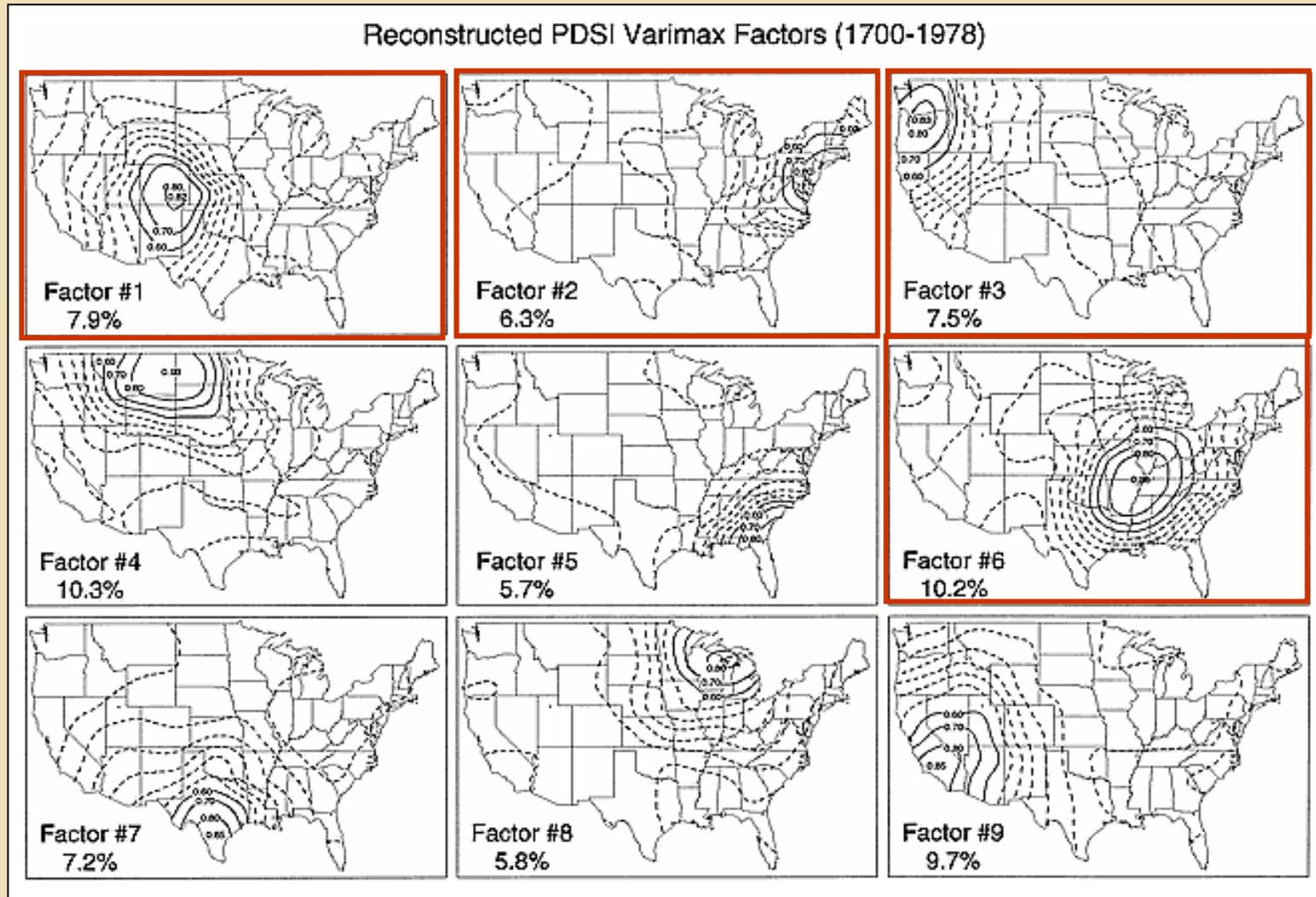
Percentage of grid points with PDSI values  $< -1$   
annual and 10-year running average



Ranked non-overlapping  
10-year periods with  
largest area under  
PDSI  $< -1$

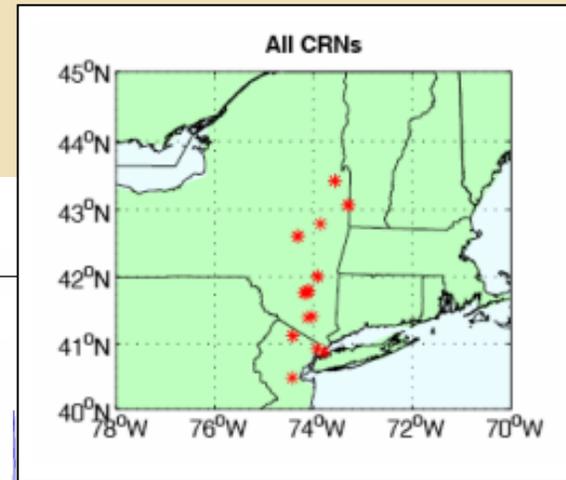
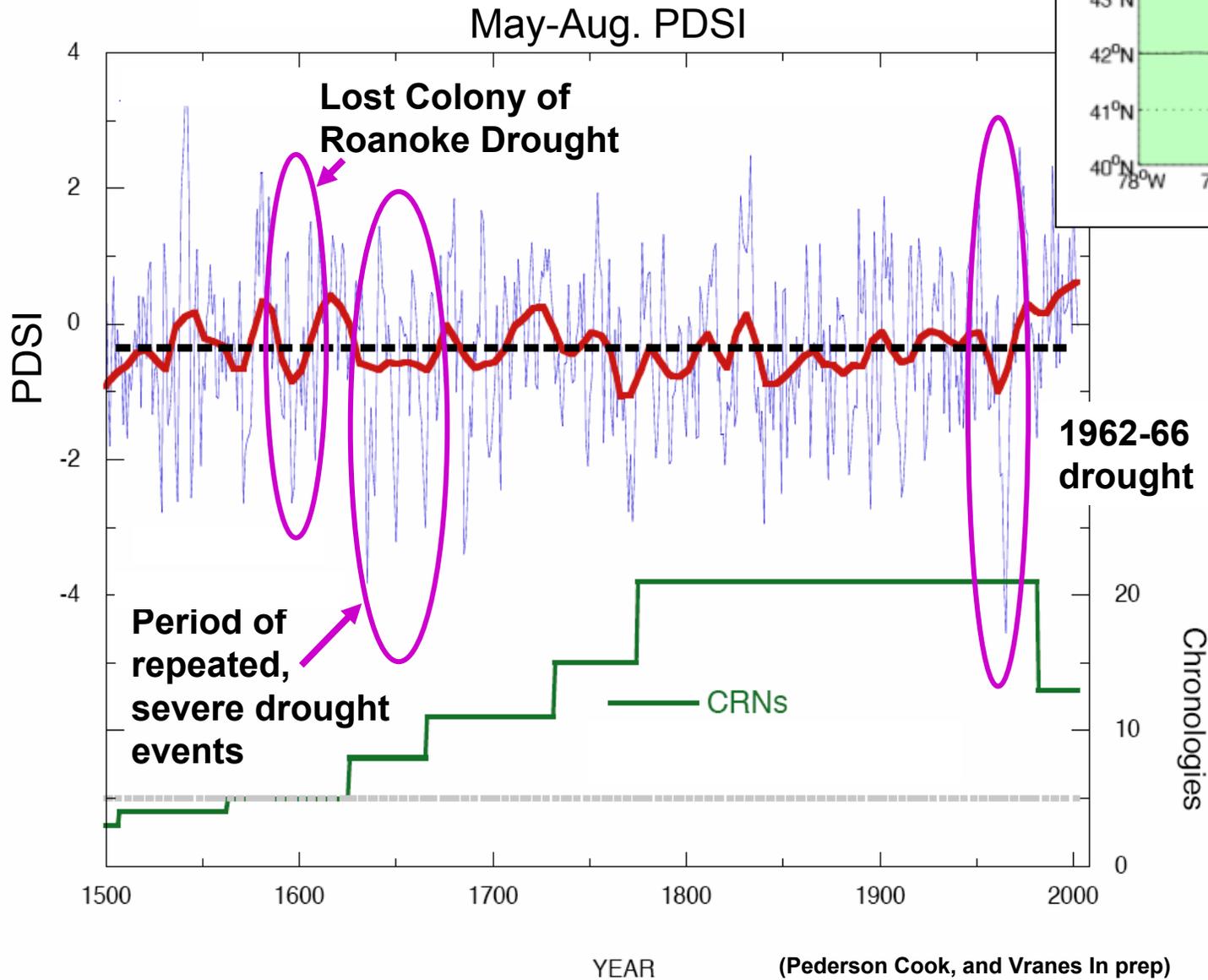
1	1855-1864
2	1623-1632
3	1816-1825
4	1839-1848
5	1735-1744
6	1571-1580
7	1931-1940

# Drought regions based on summer PDSI reconstructions, 1700-1978



Reconstructed summer drought varimax factors for the U.S. The percent variance accounted for by each is indicated in each map (Cook et al. 1999).

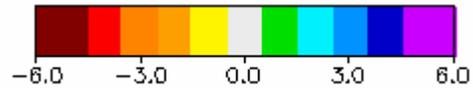
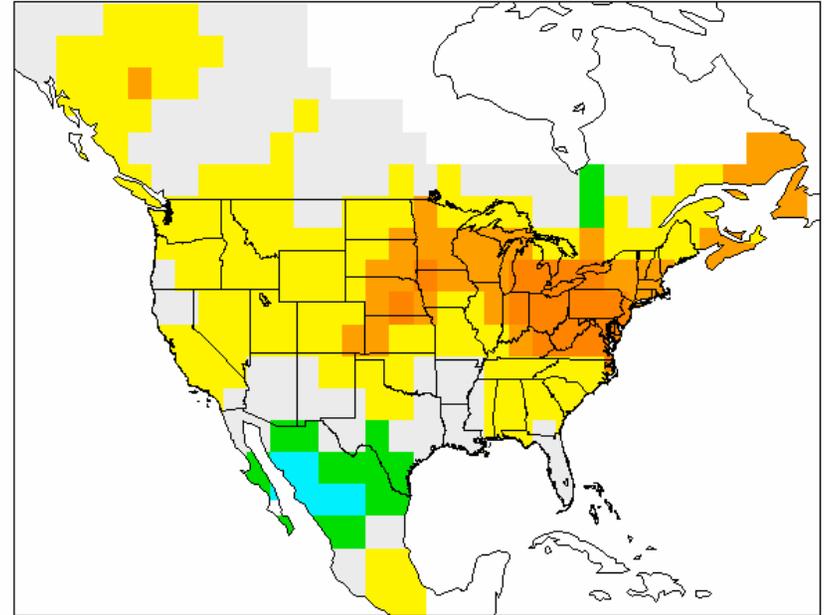
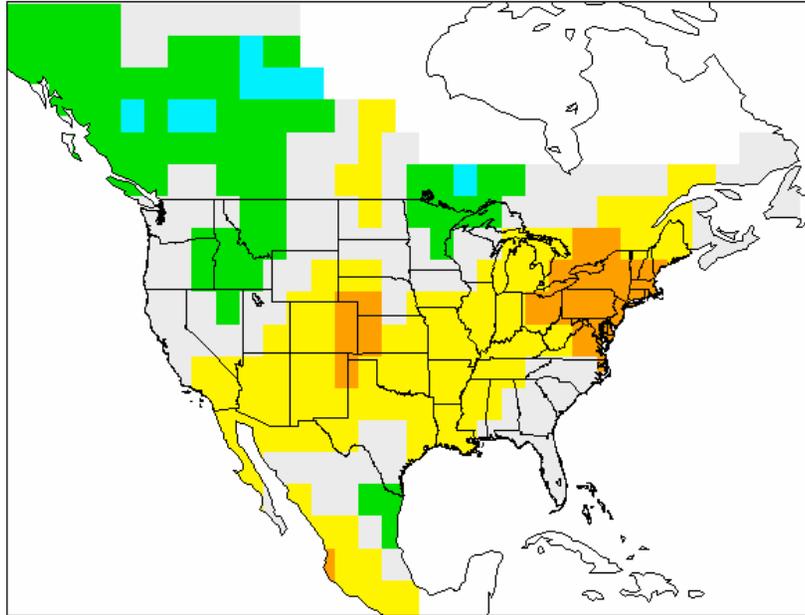
# Five Centuries of Drought in the Hudson River Valley



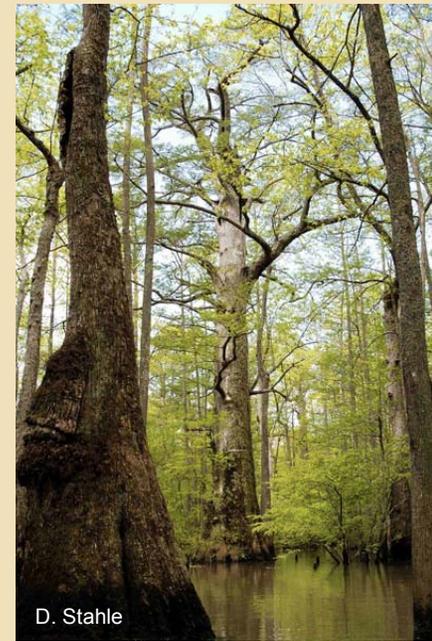
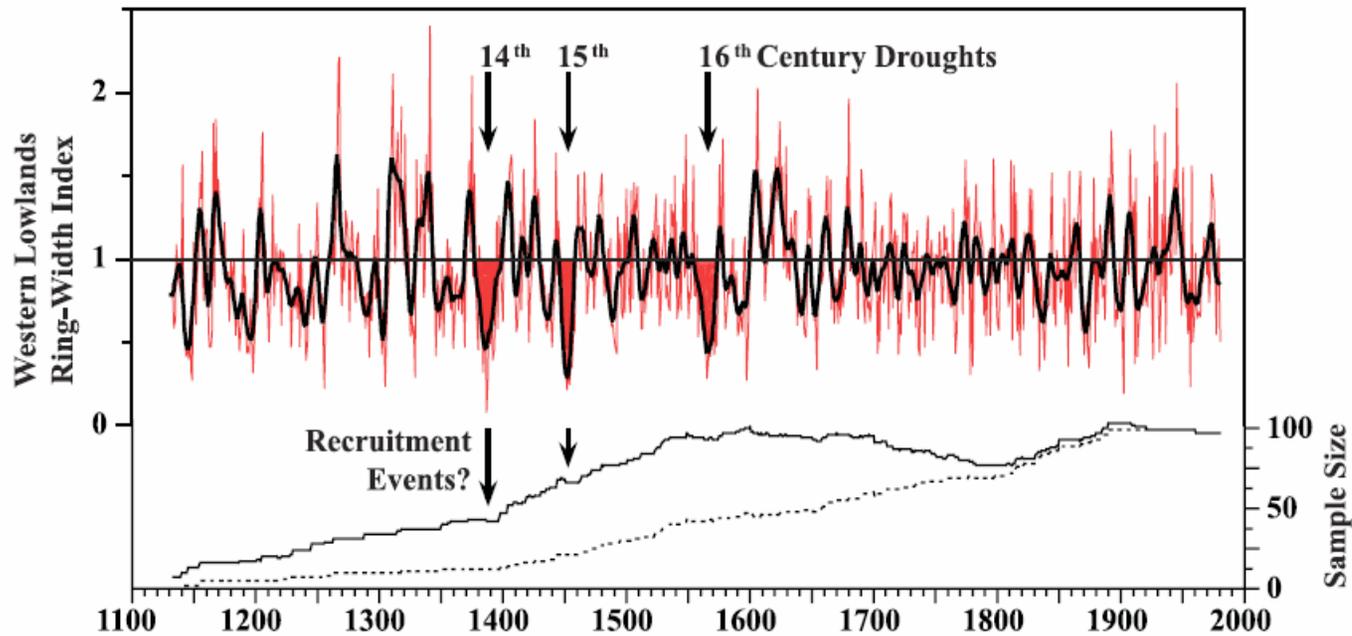
# Hudson Valley Droughts, 1960s and 1620-30s

1962-1966

1627-1635

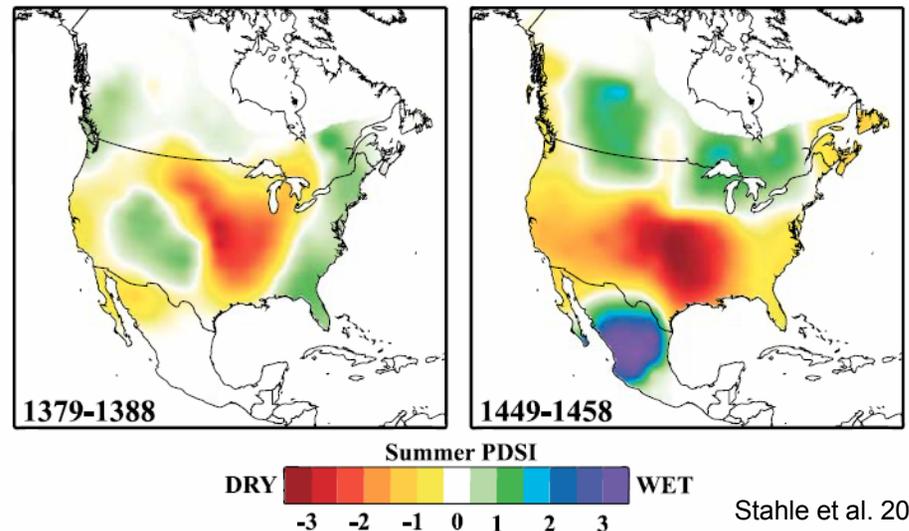


Summer PDSI



## Drought in northeast Arkansas as documented by baldcypress

A small cohort of trees appear to have survived 3 major droughts, but droughts may also have resulted in pulses of regeneration, which requires persistent low water conditions.

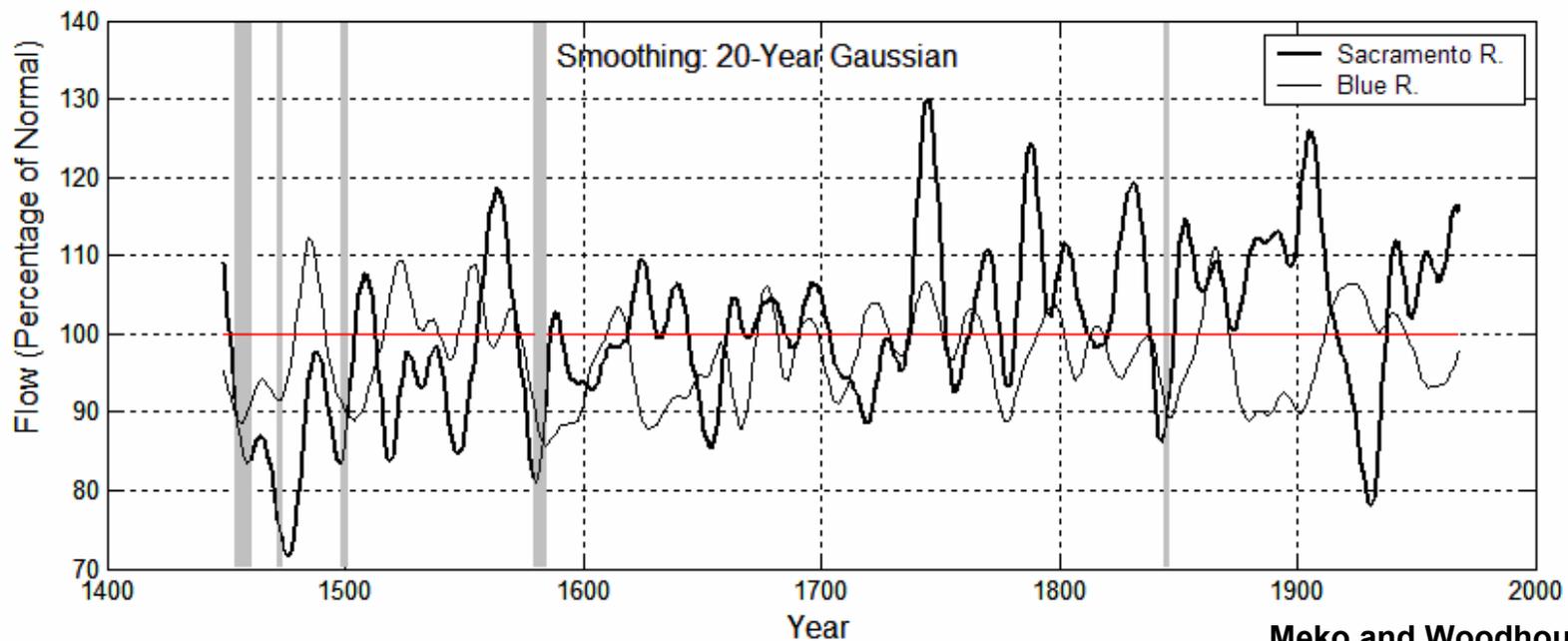
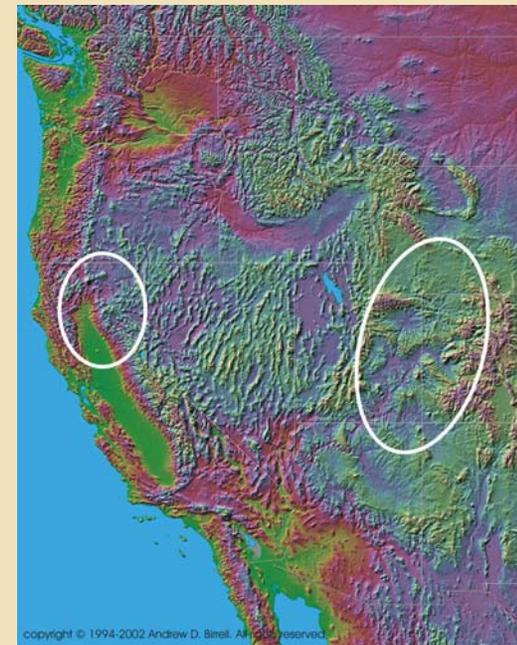


Stahle et al. 2006

# Regional patterns of drought in the western US

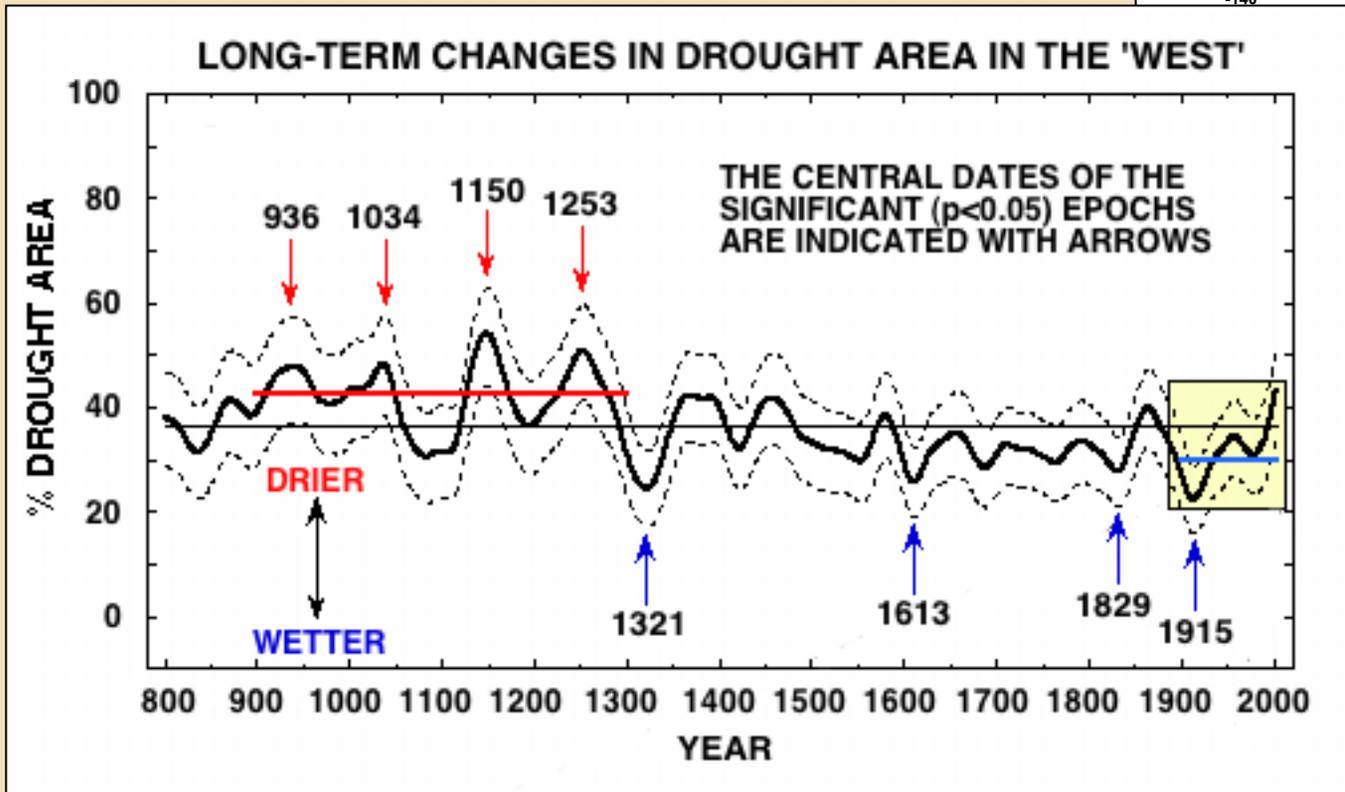
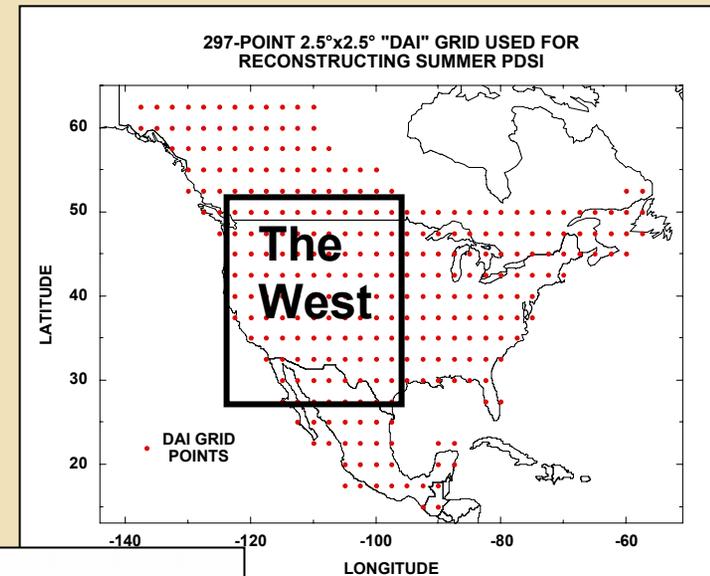
Coherence of drought in the Sacramento and the Upper Colorado River basins over the past five centuries.

Although flows between the two basins are only weakly correlated over the full reconstruction period, widespread periods of drought have affected both basins at intervals in the past.



# Large-Scale Patterns of Long-Term Drought

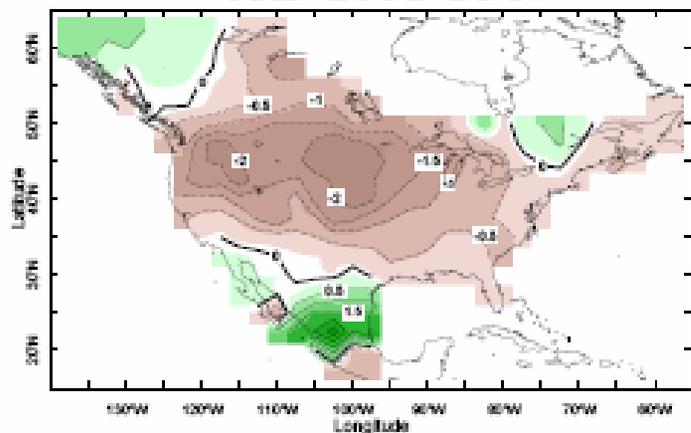
Reconstructed Drought Area from a gridded network of summer PDSI reconstructions, AD 800-2000 (% of the West with PDSI < -1)



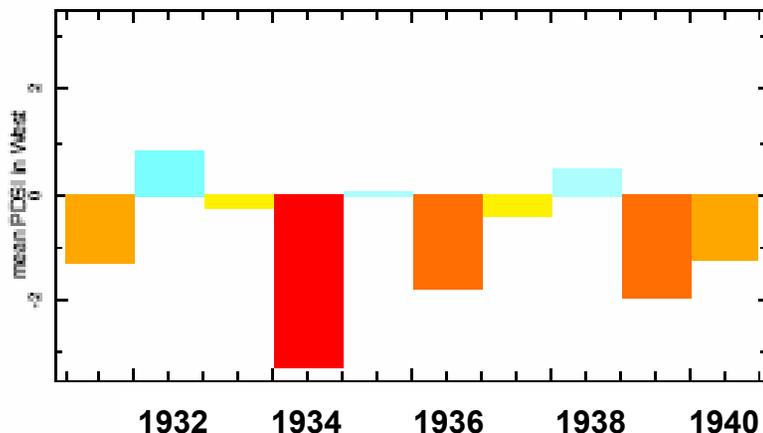
# Large-Scale Patterns of Drought

Spatial and temporal patterns of drought area averaged over the West for the most persistent drought in the 20<sup>th</sup> century, the 1930s, compared to a period from 1130-1170

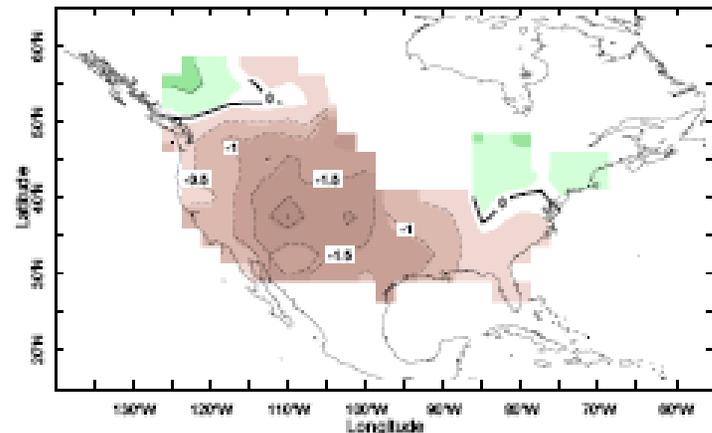
### AD 1931-1940



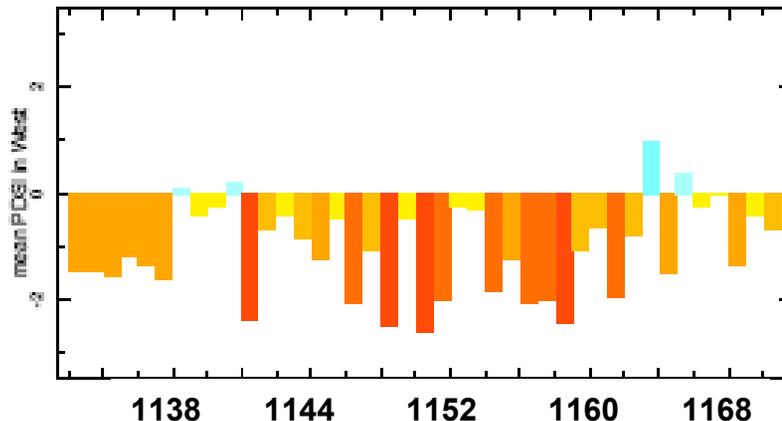
### Mean Summer PDSI in West, 1931-40



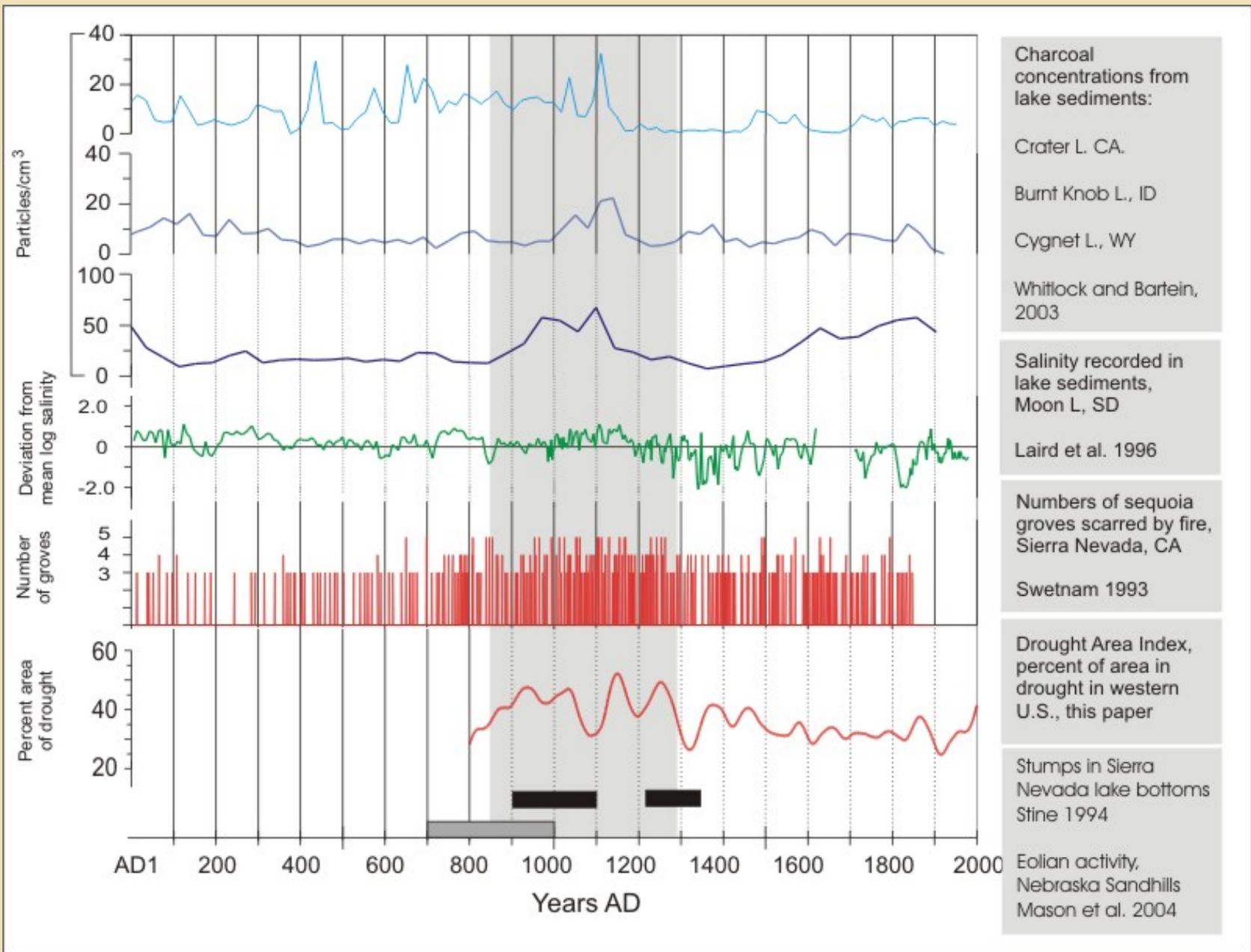
### AD 1130-1170



### Mean Summer PDSI in West, 1130-70



# Proxy records that document drier conditions ~AD 850-1300

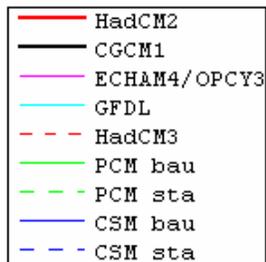
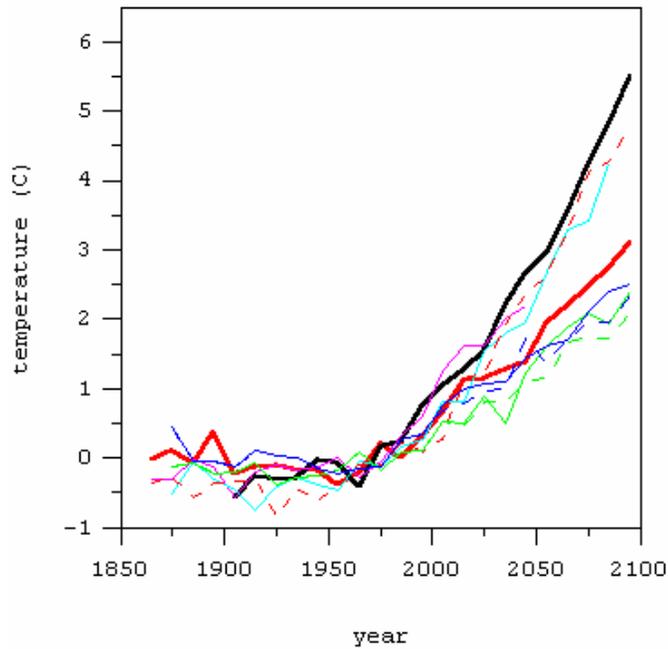


# **How relevant is the past to planning for drought in the future?**

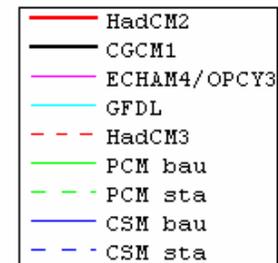
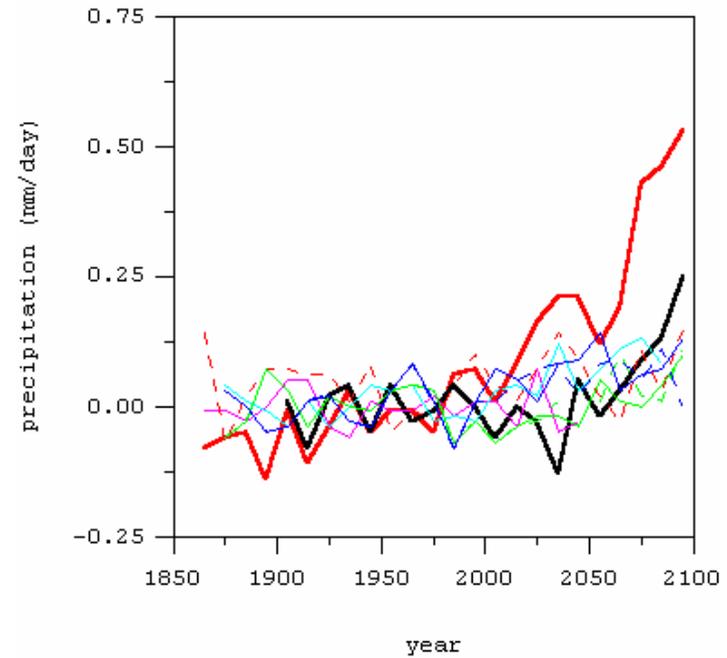
**The climate of the past is unlikely to be replicated in the future because of the impact of human activities on climate.**

# Climate Scenarios for the U.S. to 2100

## U.S. Mean Temperature Anomalies



## U.S. Precipitation Anomalies



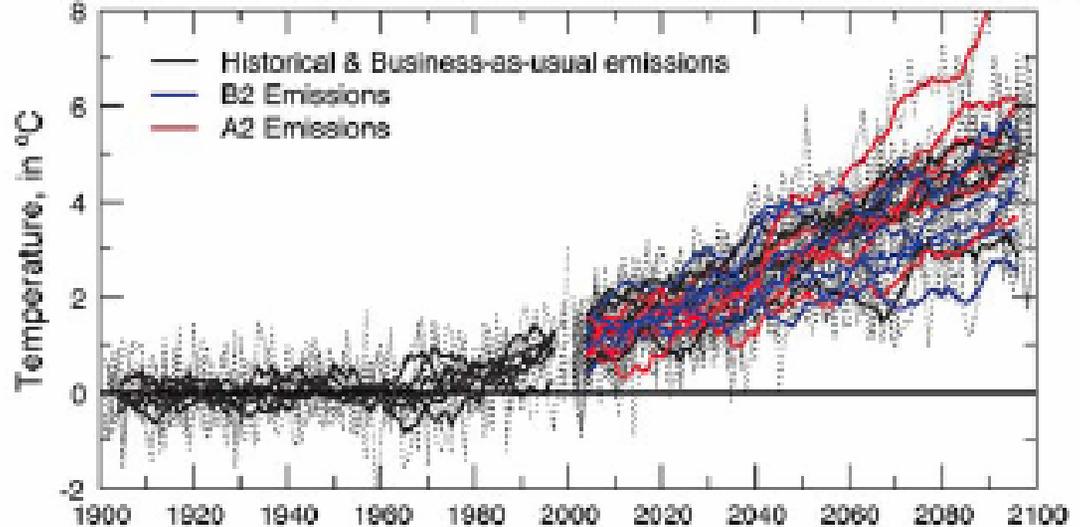
# Projected regional patterns and trends vary

Example for northern California

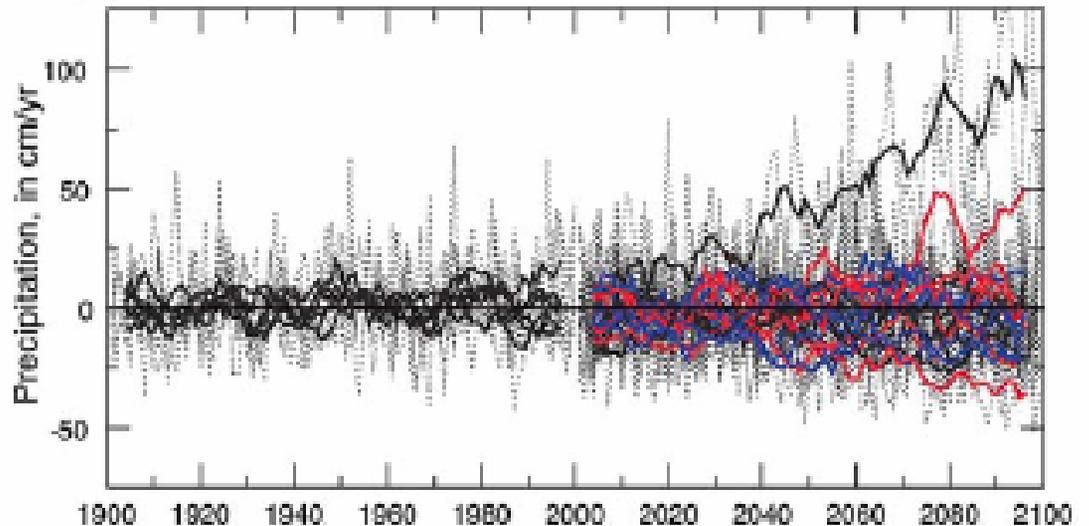
Ensemble projections from 6 coupled models, historical, and three different emissions scenarios.

Results are quite similar for central Rockies/Colorado River watershed.

a) PROJECTED CHANGES IN ANNUAL TEMPERATURE NORTHERN CALIFORNIA



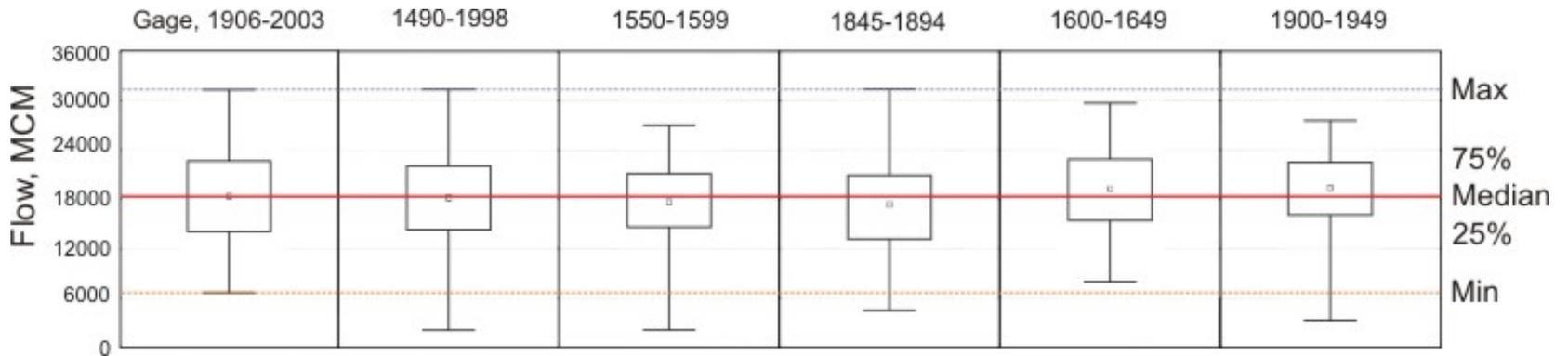
b) PROJECTED CHANGES IN ANNUAL PRECIPITATION, NORTHERN CALIFORNIA



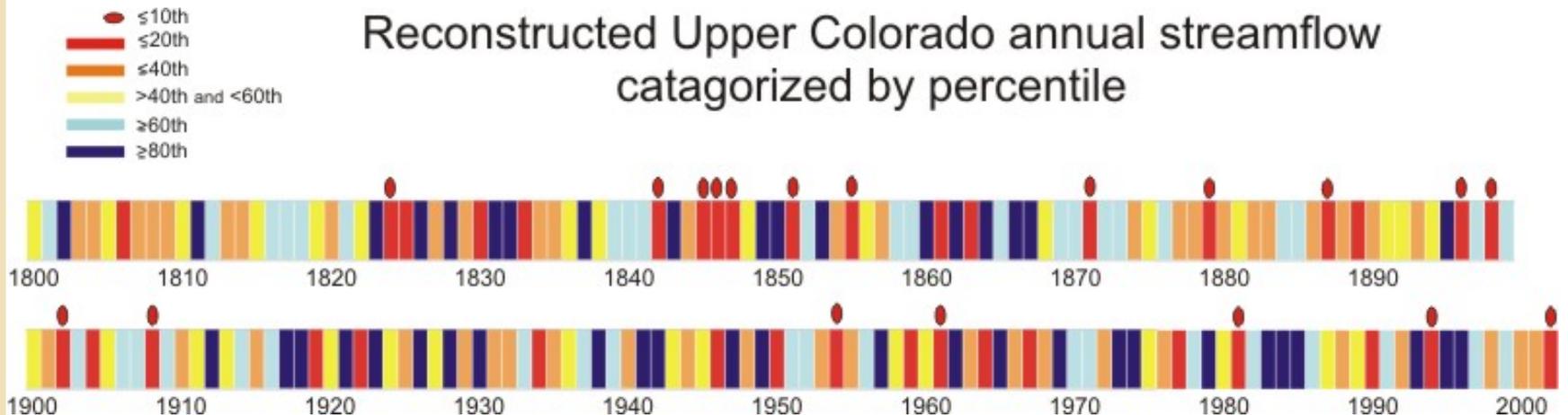
One consequence of global warming maybe increased hydroclimatic variability.

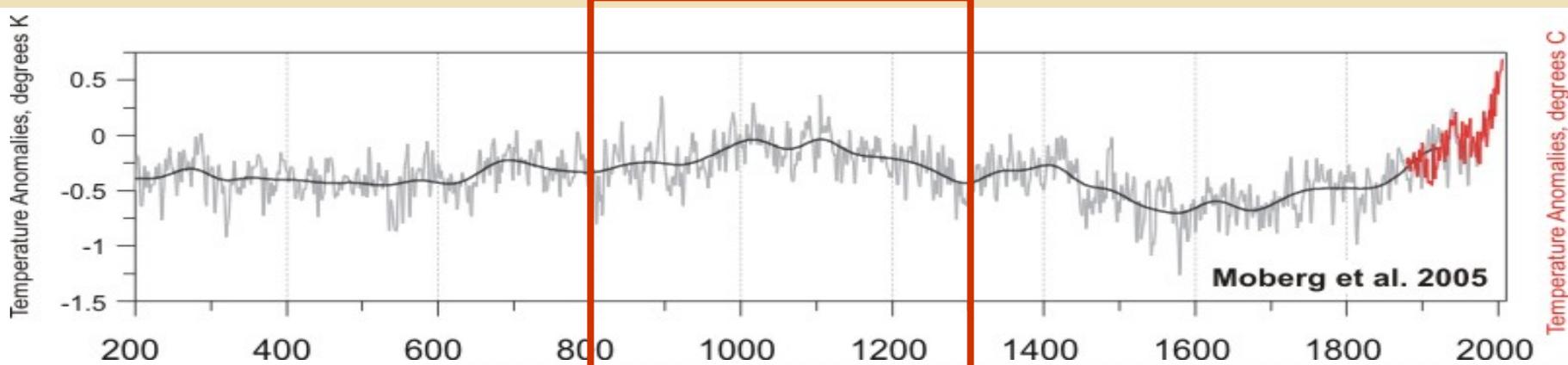
Paleo records often document a broader range of variability than instrumental records.

### Colorado River gage and reconstructed data



### Reconstructed Upper Colorado annual streamflow categorized by percentile



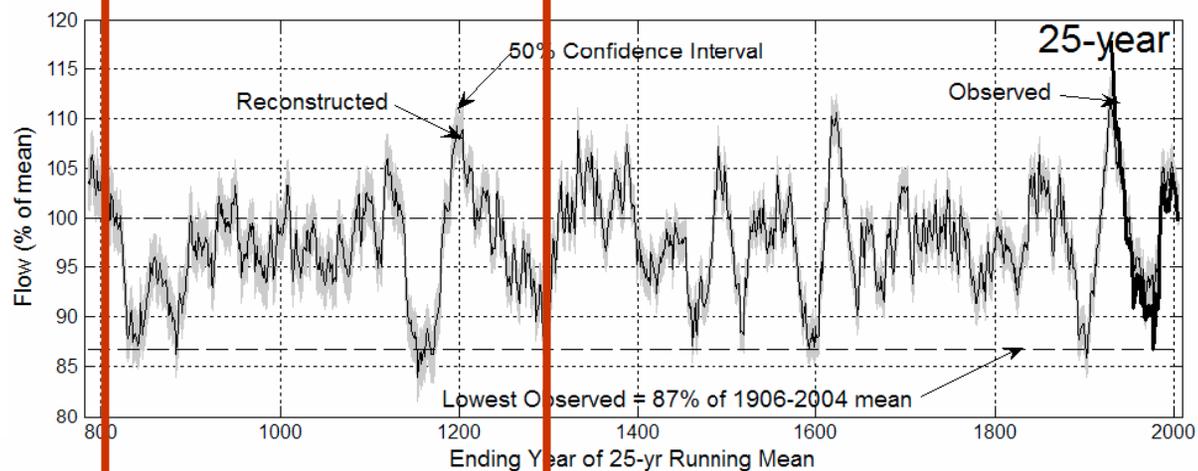
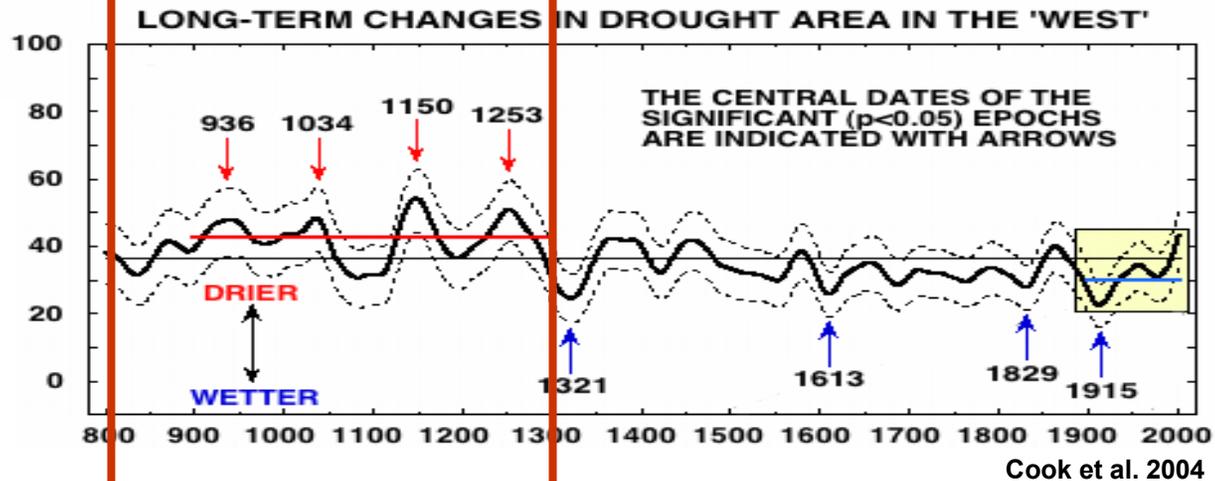


## Climate during the Medieval period

- Warmer conditions, on average, across the Northern Hemisphere, 800-1300?

- Larger area under drought in The West, 850-1300

- Colorado River flow, more persistent low flows before 1200?



# Implications for Future Drought Management

- **Paleorecords allow 20<sup>th</sup> and 21<sup>st</sup> century events to be assessed on a long-term perspective, and document a broader range of variability than the gage record.**
- **Paleorecords are particularly important for documenting variability over decadal and longer time scales, critical for understanding the relationship between regional drought and low-frequency ocean/atmosphere interactions.**
- **In at least some regions, future scenarios of precipitation are not in agreement with regard to increasing or decreasing trends**
- **Even if precipitation does not decrease, temperature increases, already evident in many area, will exacerbate drought conditions.**
- **Warming added to the range of droughts that have occurred under natural variability over the past centuries may result in more persistent and/or widespread droughts .**