Climate Change: A Perspective from Paleoclimatology and Observations

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Climate Change Effects on Biological Indicators

March 27-29, 2007

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How do we know that human-induced climate change is occurring?

• In order to assess whether current climate conditions are different from that expected under natural conditions, we first need to know the range of natural climate variability.

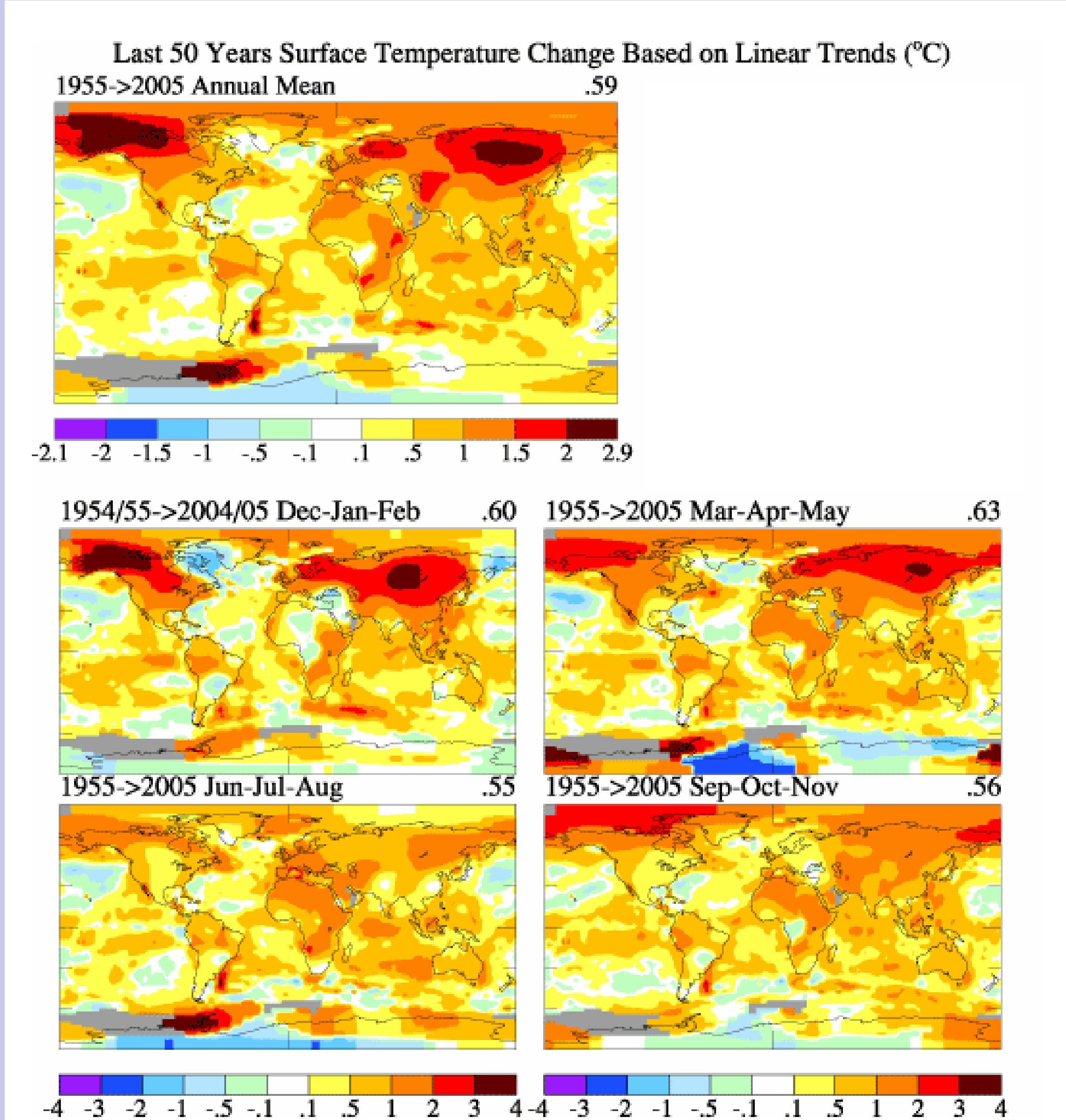
• The 20th and 21st century records of climate (observations) provide some context for assessing this, but do they provide the full range of natural variability that has occurred in the past?

• Information about climate prior to instrumental measurements, paleoclimatology, from environmental recorders of climate can provide a broader context from which to access the current climate.

Overview

- What climate trends have been observed?
- Environmental recorders of past climate
- Northern Hemisphere temperatures from paleoclimatic data
- Drought from paleoclimatic data, continental and regional scales
- Paleoclimatology and resource management
- How relevant is the past with regard to future?

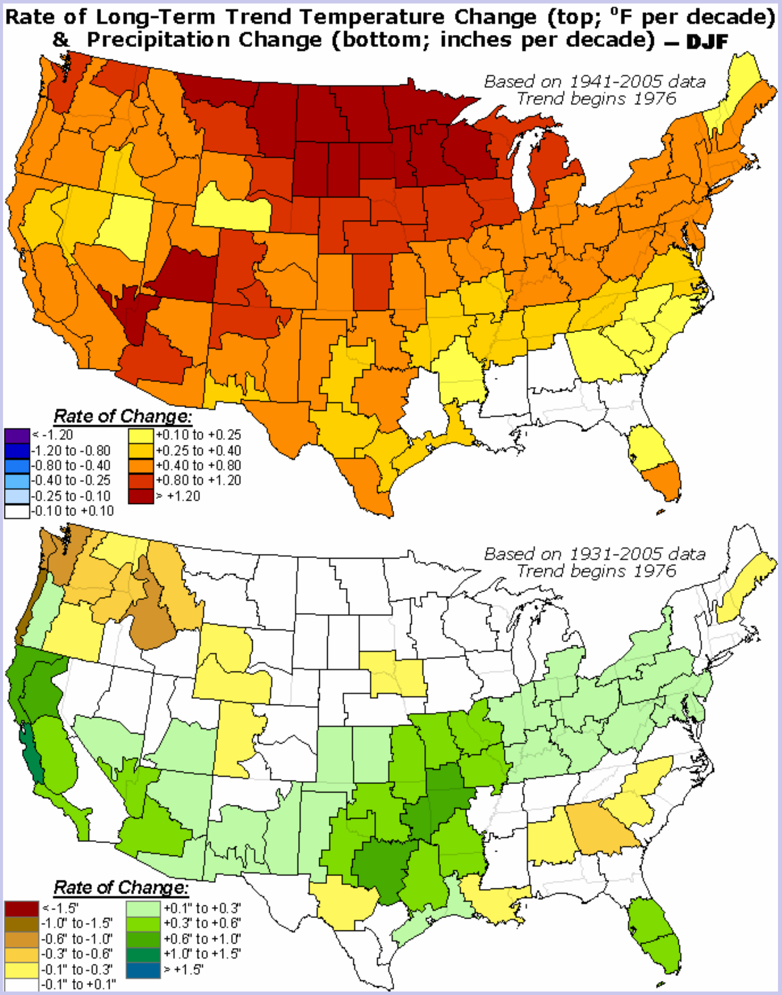
Global Seasonal Temperature Change over the Past 50 Years



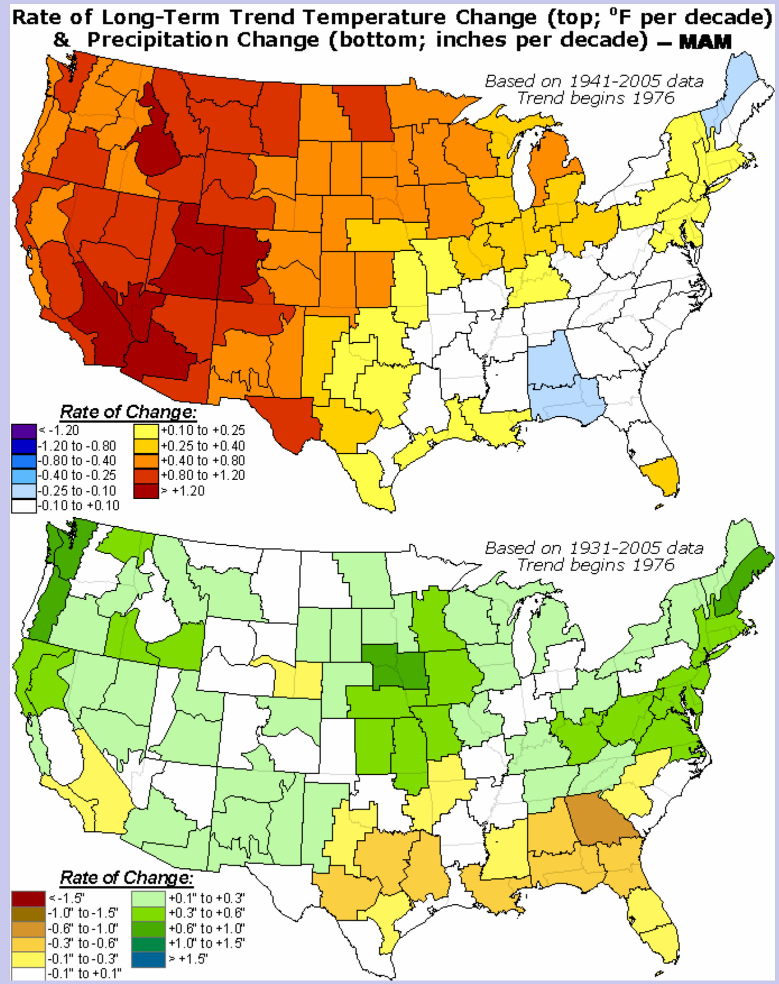
http://data.giss.nasa.gov/gistemp/2005/

Top: Rate of temperature change, ^{0}F per decade, 1941-2005, trend begins 1976
Bottom: Rate of precipitation change, inches per decade, 1931-2005, trend begins 1976

WINTER



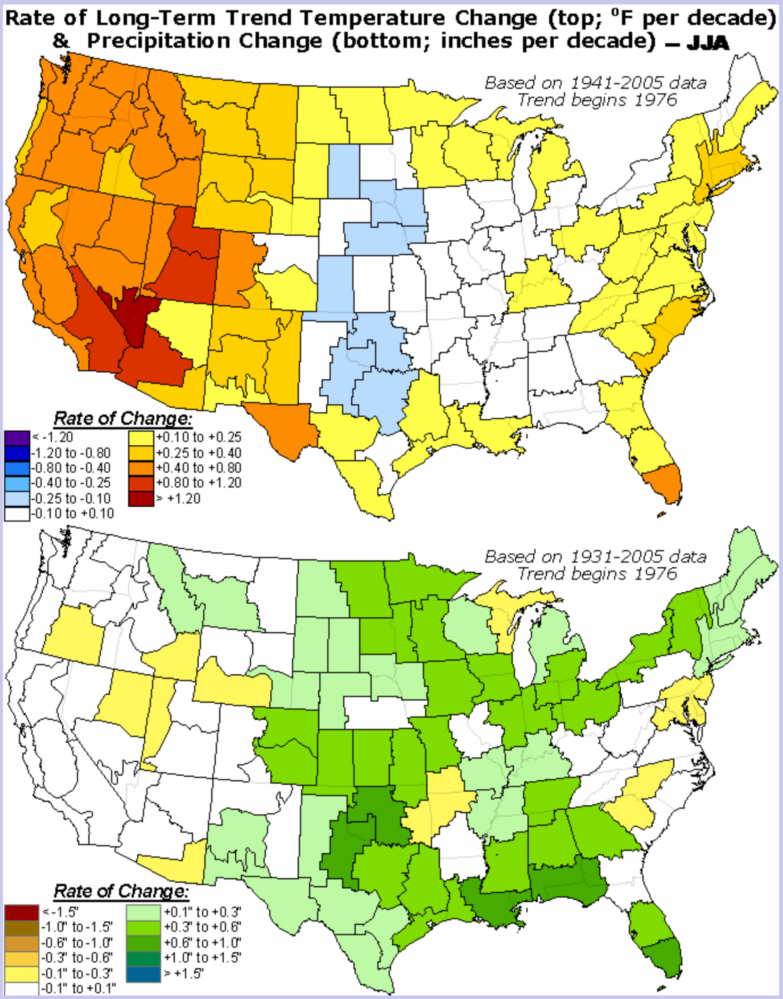
SPRING



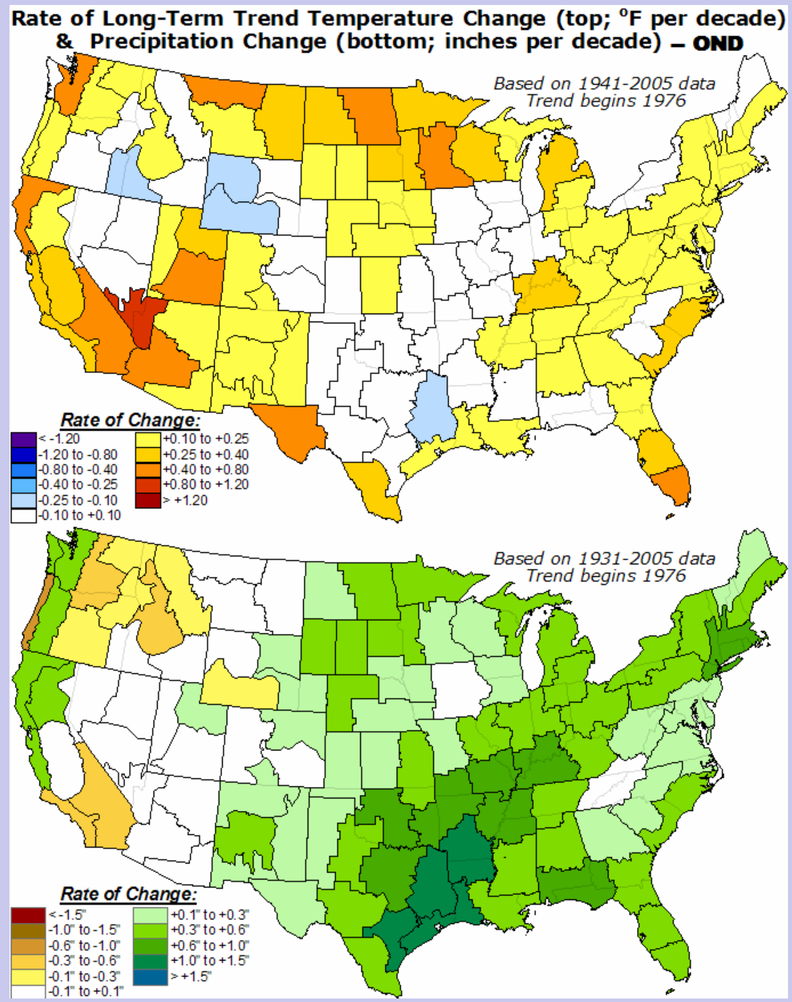
National Weather Service, Climate Prediction Center: http://www.cpc.noaa.gov/charts.shtml

Top: Rate of temperature change, ^{0}F per decade, 1941-2005, trend begins 1976
Bottom: Rate of precipitation change, inches per decade, 1931-2005, trend begins 1976

SUMMER



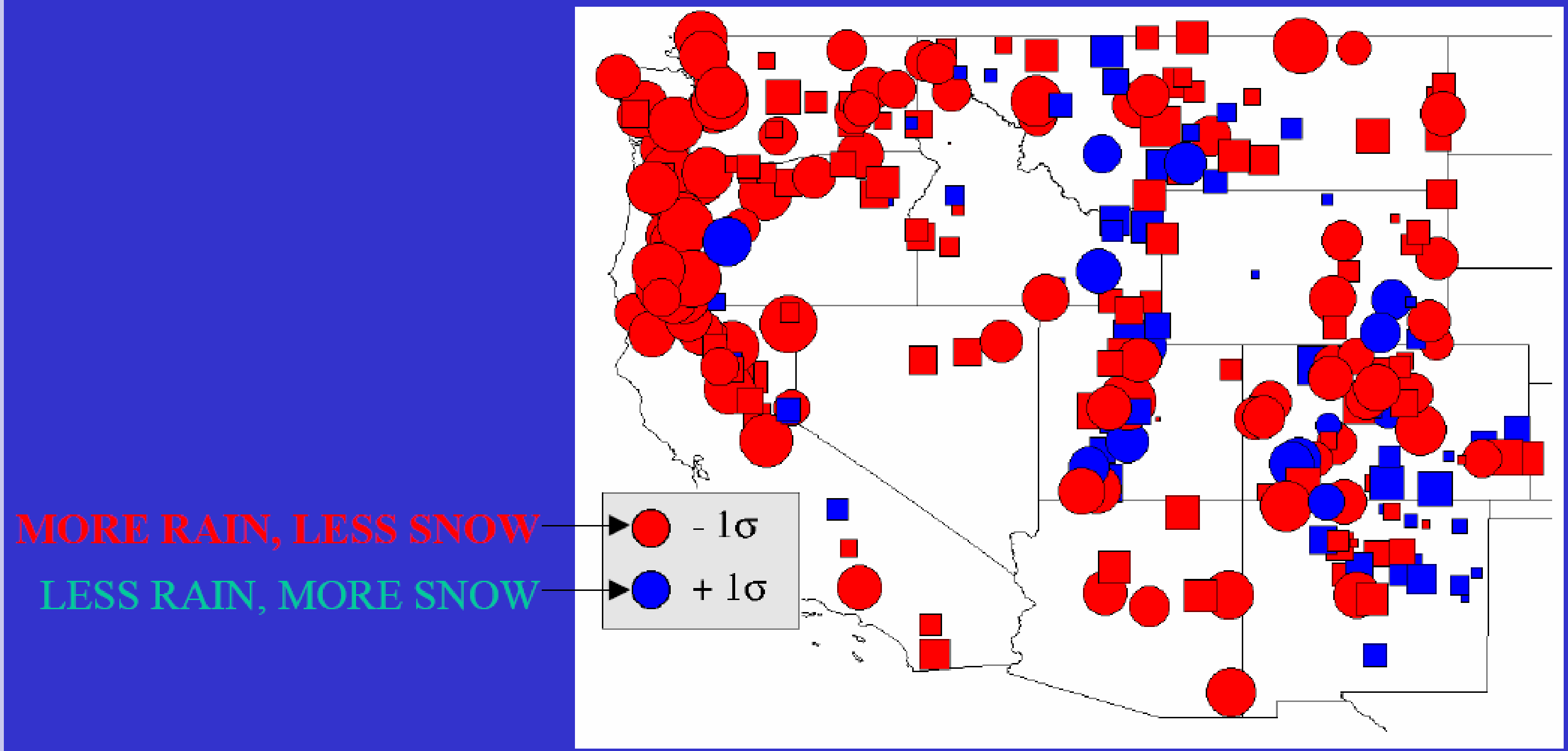
FALL



National Weather Service, Climate Prediction Center: http://www.cpc.noaa.gov/charts.shtml

Changes in temperature have impacts on other climate variables.

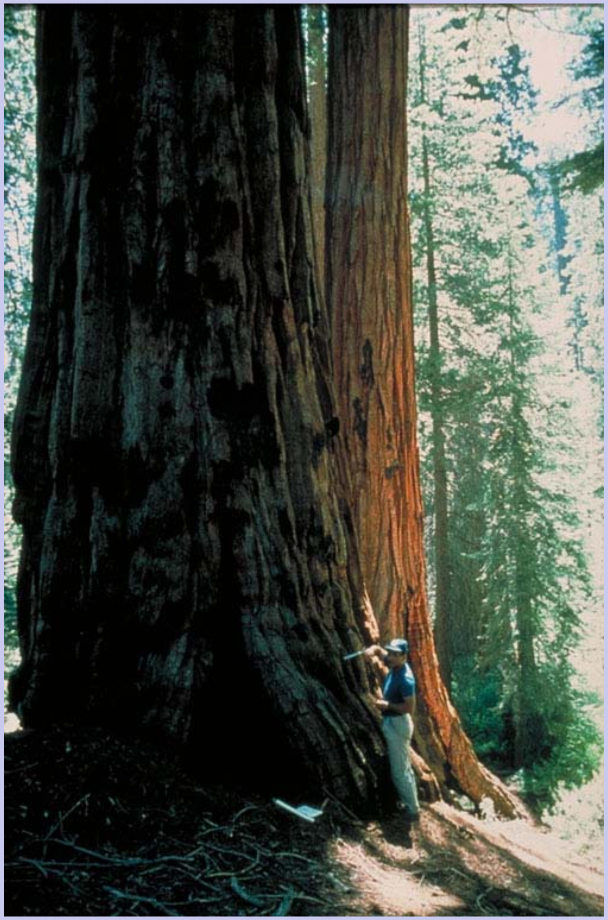
Shift from Snowfall to Rainfall



Trends in ratio of winter (Nov-Mar) snowfall water equivalent (SFE) to total winter precipitation (rain *plus* snow) for the period WY1949-2004. Circles represent significant ($p<0.05$) trends, squares represent less significant trends.

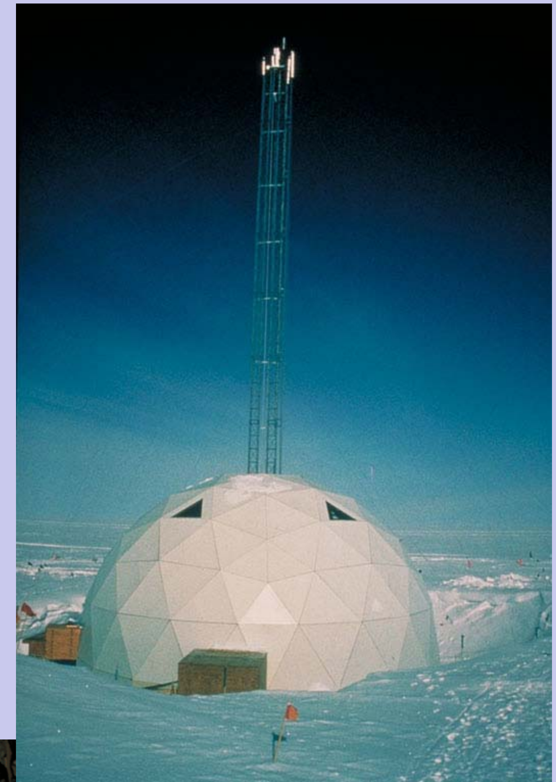
Knowles et al. 2005, AGU

Environmental Recorders of Climate: Paleoclimatic Data



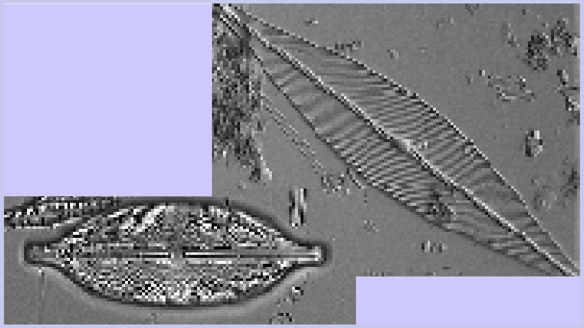
The longest records come from Ocean Sediments and Ice Cores

Ice core records, up to 740,000 years long, provide information on temperature, gas concentrations, atmospheric particulates.

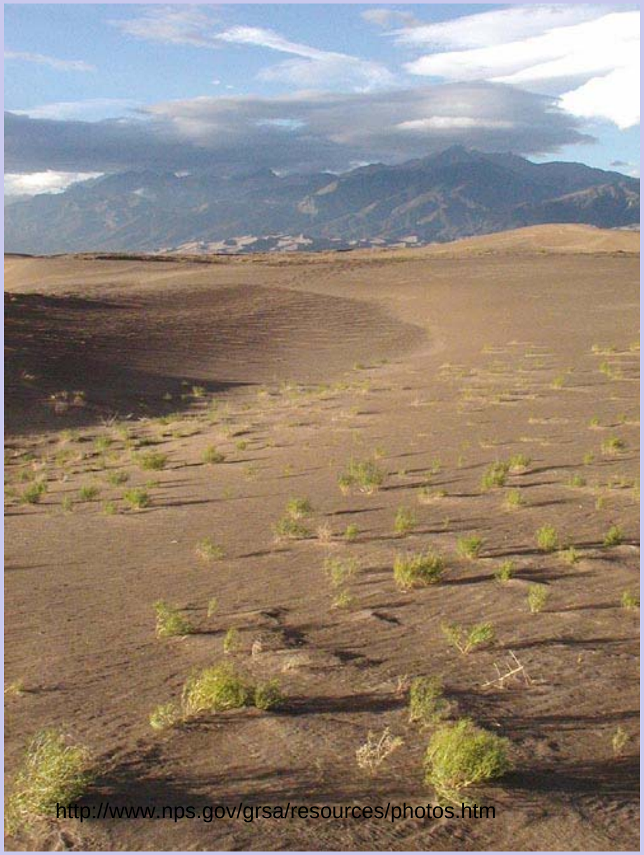


Ocean sediment records, up to 10s of millions of years, proved information on ocean conditions, land areas.

Records for the past 10,000 years come from Lake and Dune Sediments



Lake sediments reflect conditions in the lake (organisms, water chemistry) or the surrounding environment (pollen, charcoal, soil) at the time of deposition.

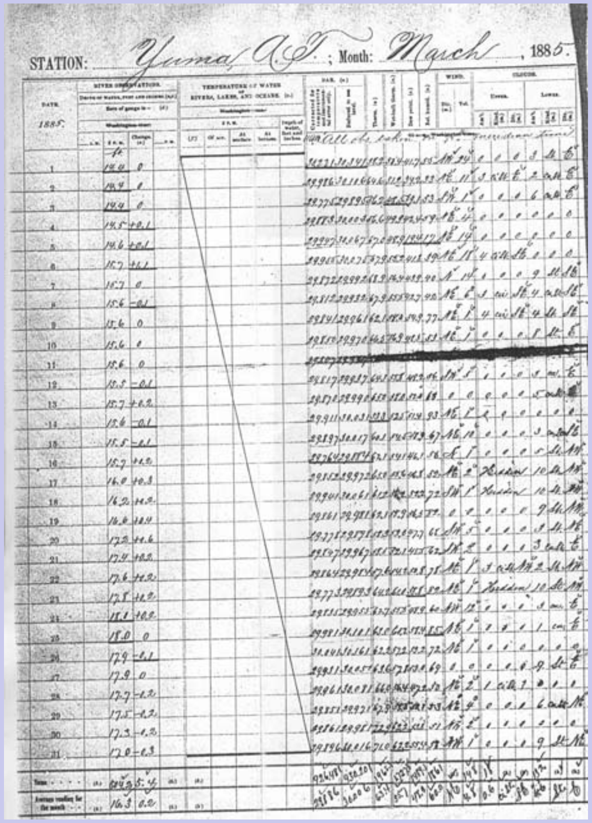


Dune sediments record episodes of aridity when dunes were active, interspersed with wetter periods indicated by layers of soil.

The Shortest Records come from Tree Rings, Corals, Historical Documents but contain information on annual and sub-annual scales

Annual ring widths and other characteristics, records typically 100s of years

Corals bands reflect ocean conditions with annual to sub-annual resolution, most are several centuries long at best.



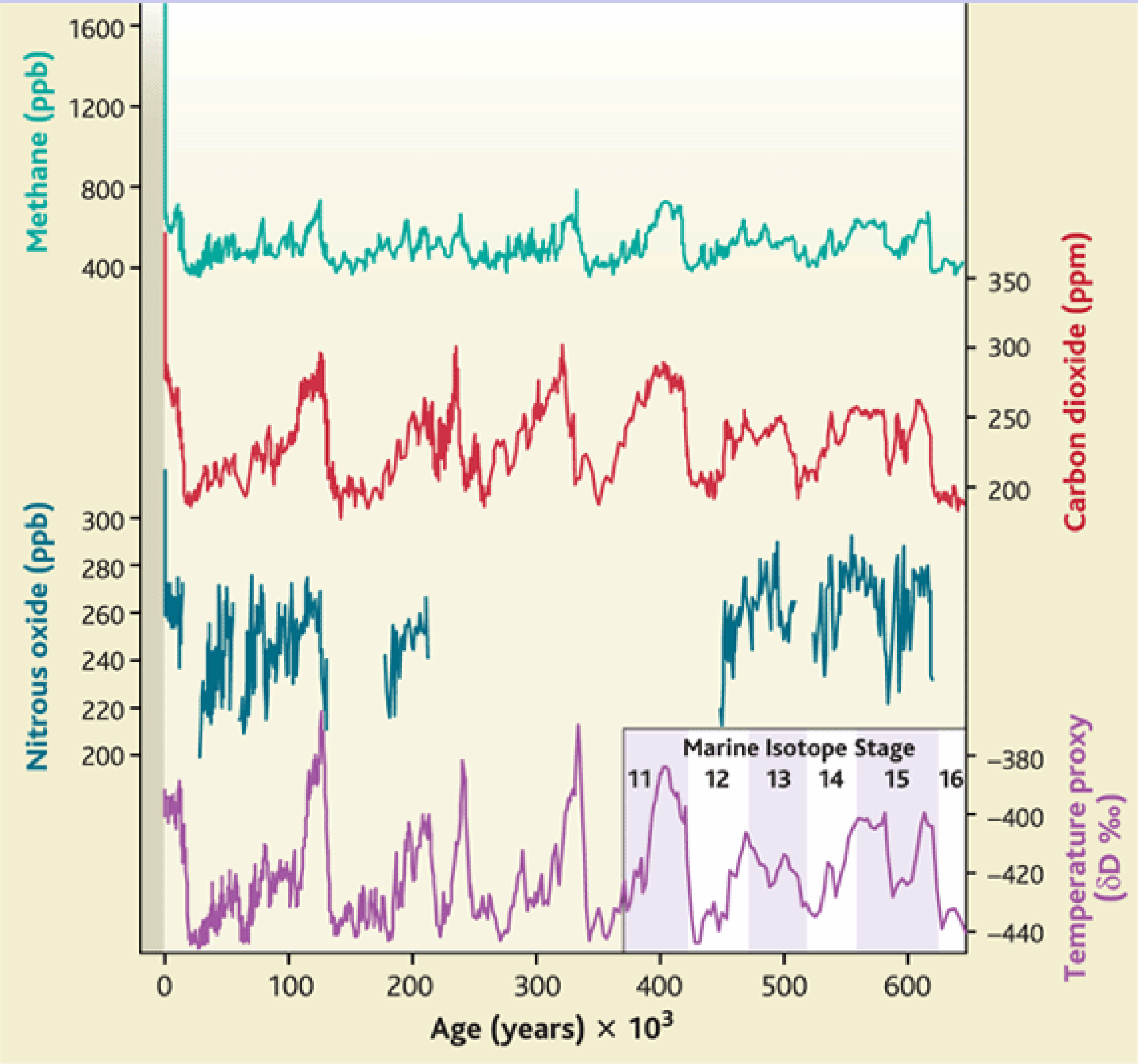
Historical documents contain much detail, but are not widely available for more than a century or two over much of the U.S.

Records of Past Temperature

National Ice Core Laboratory (NICL)
Denver, CO

Greenhouse gas (methane, CO2, and nitrous oxide) and temperature proxy records for the past 650,000 years from Antarctica ice cores.

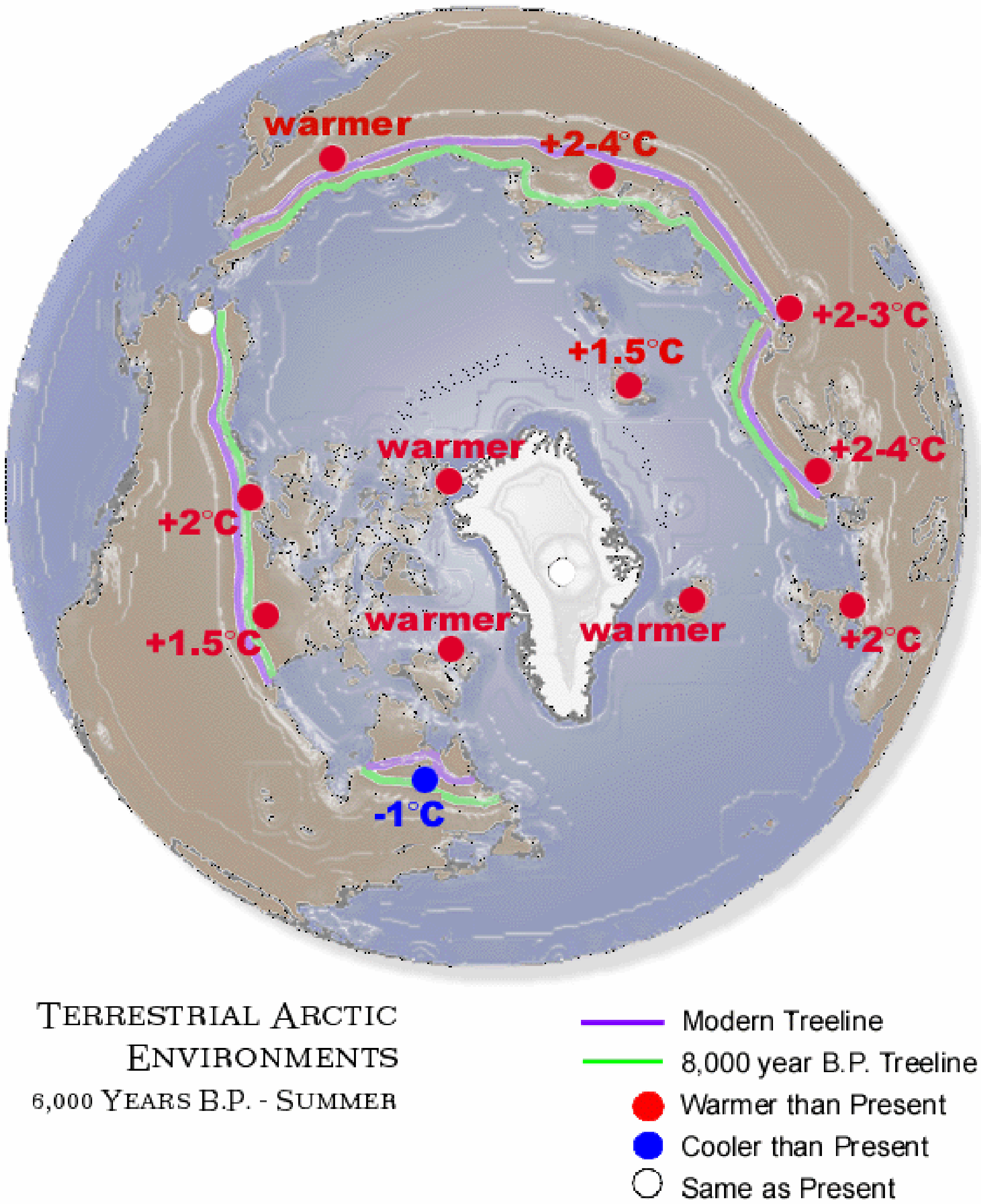
Temperature comes from the deuterium/hydrogen ratio of the ice, More positive values indicate warmer conditions.



From: Brook, Science 310, 25 November 2005

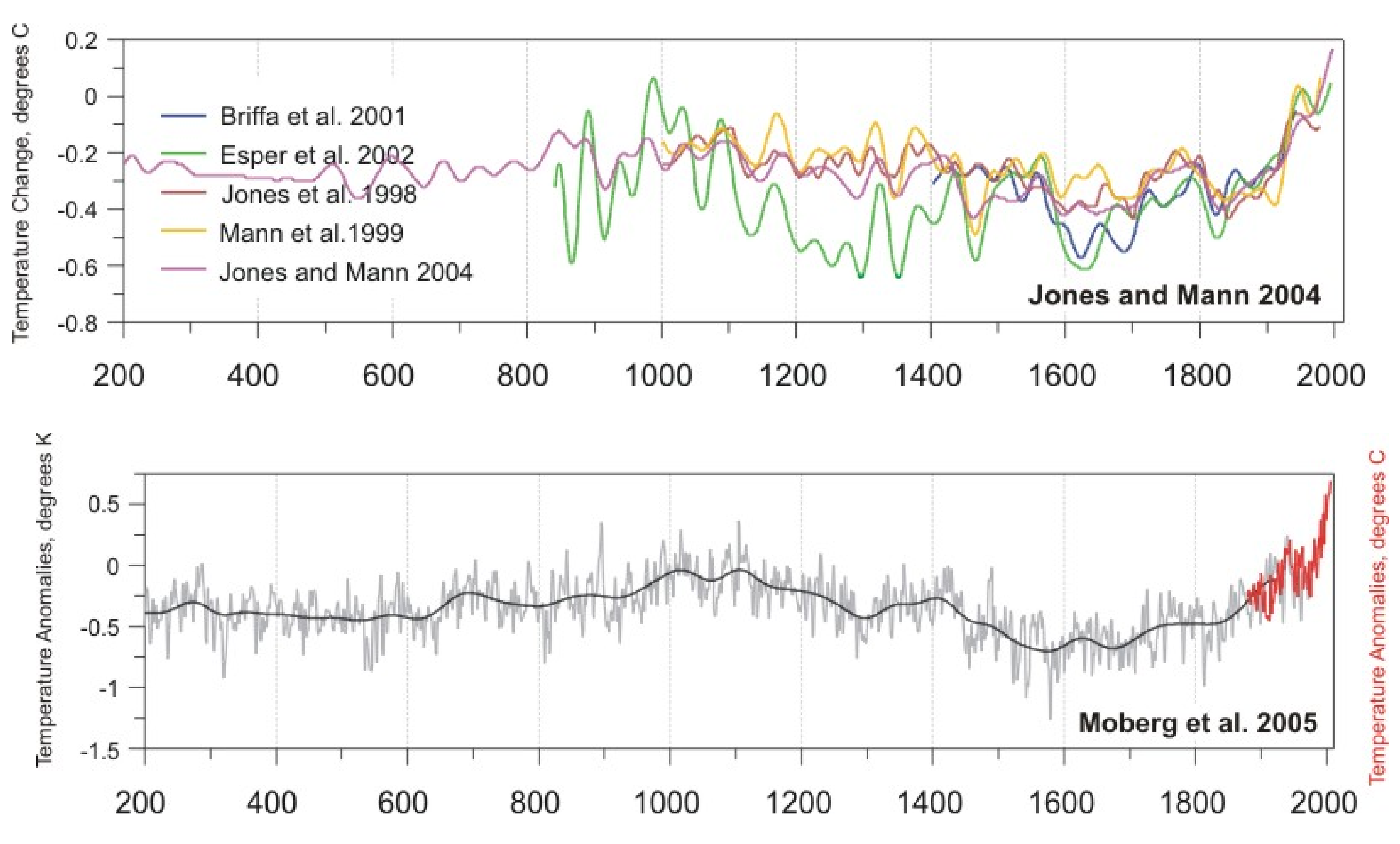
The Holocene is the period of time since the last glacial period, the past 10,000 years.

The mid-Holocene, was generally warmer than today, but only in summer and only in the northern hemisphere. This warming was due to the earth's orbit relative to the sun.



From Kerwin et al., 1999 in
http://www.ncdc.noaa.gov/paleo/globalwarming/holocene.html

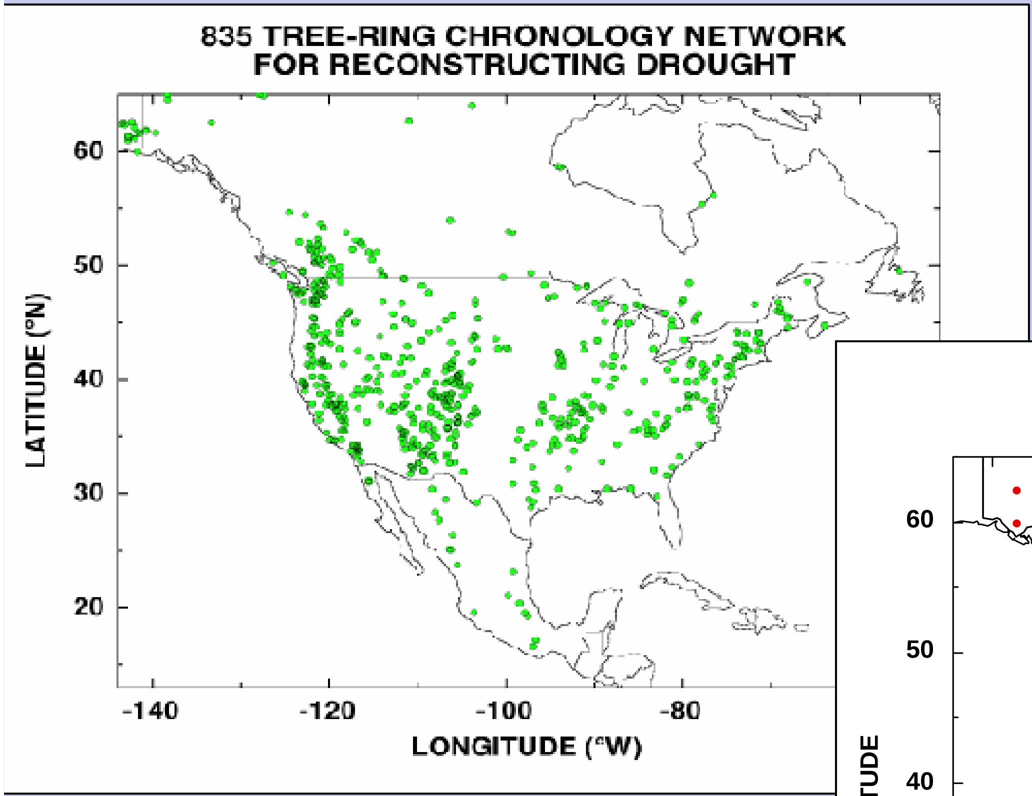
Northern Hemisphere annual temperatures over the past 1800 years from variety of proxy data

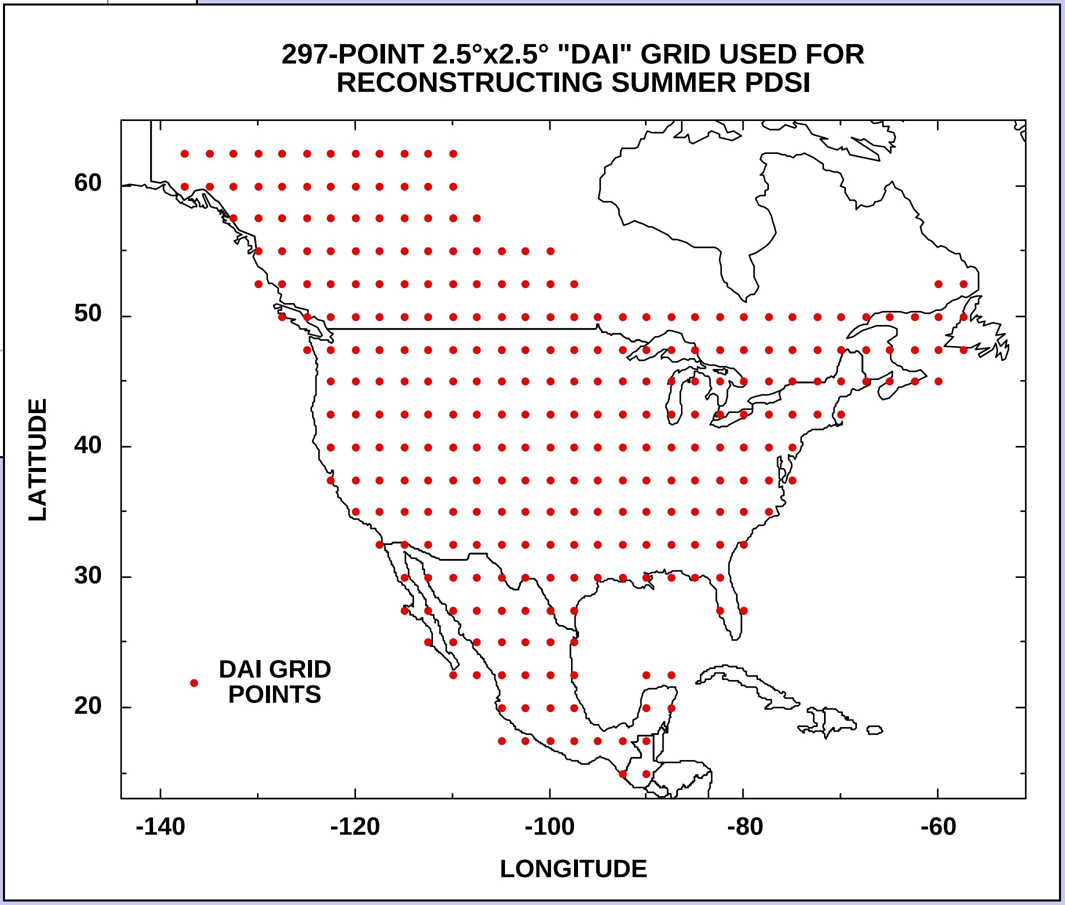


http://www.ncdc.noaa.gov/paleo/globalwarming/paleolast.html

Records of Past Drought: The Past 2000 years, Continental Scale

North American Drought Atlas

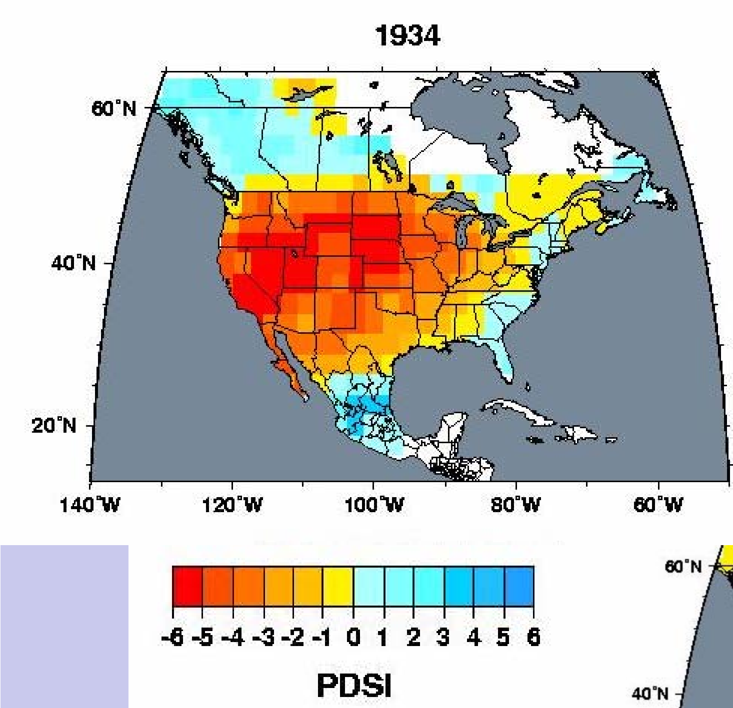




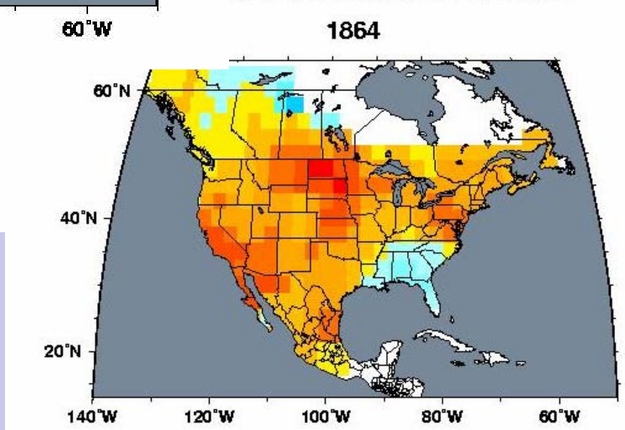
A network of tree-ring chronologies has been used to generate gridded summer PDSI reconstructions extending back 500-2000 years.

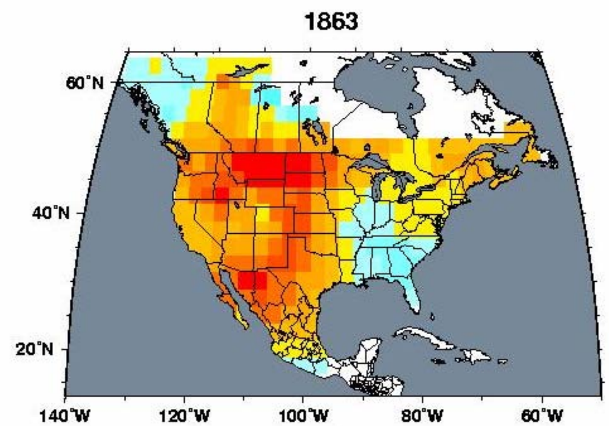
Cook and Krusic 2004

http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html

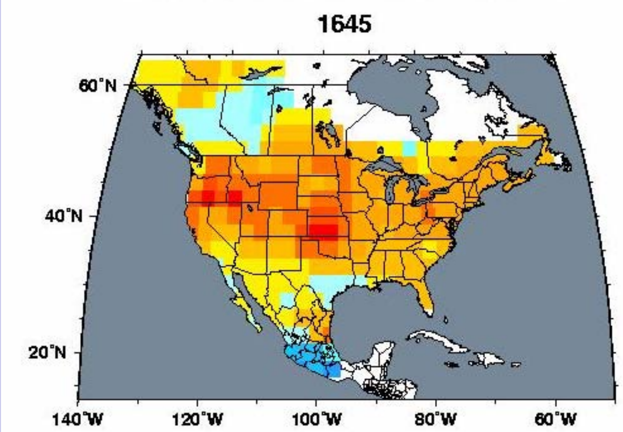


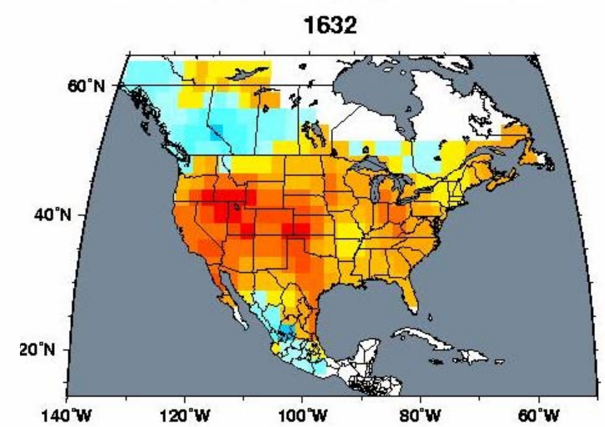
Assessing the 1934 Drought in the Context of Past Five Centuries





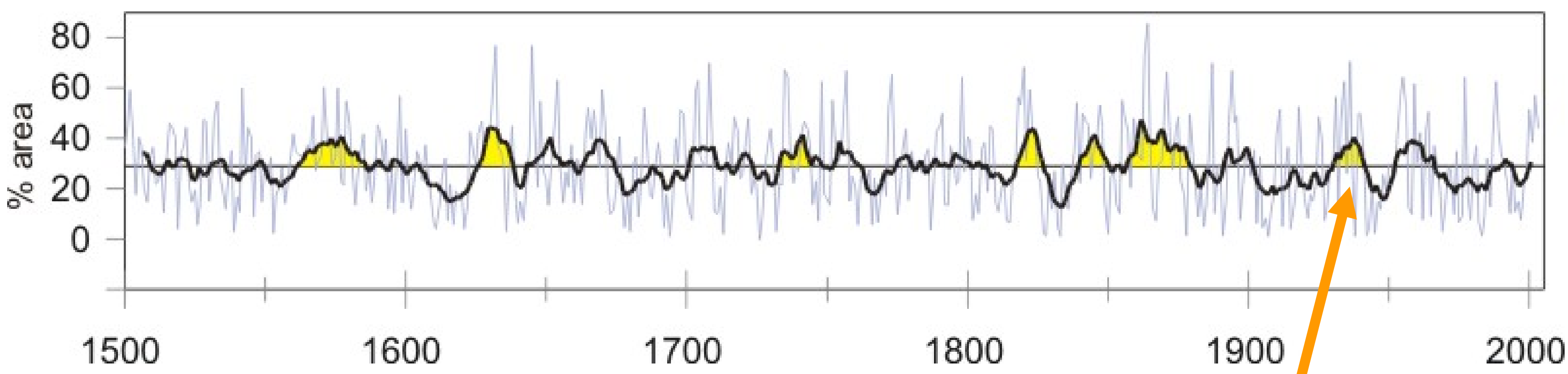
The spatial extent of drought in 1934 has been surpassed in a handful of years, but the area under severe drought conditions may still be the greatest in 1934.





When continental-scale drought is considered on a decadal scale, a number of periods in the past show more widespread drought conditions than the Dust Bowl drought.

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

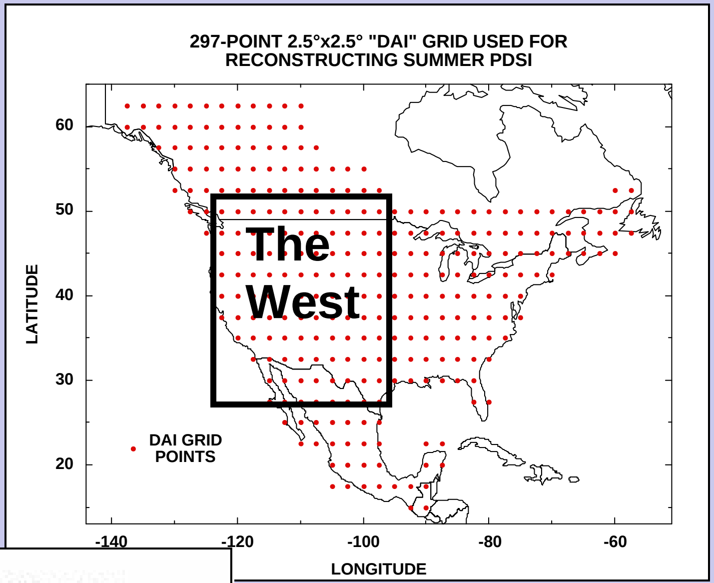


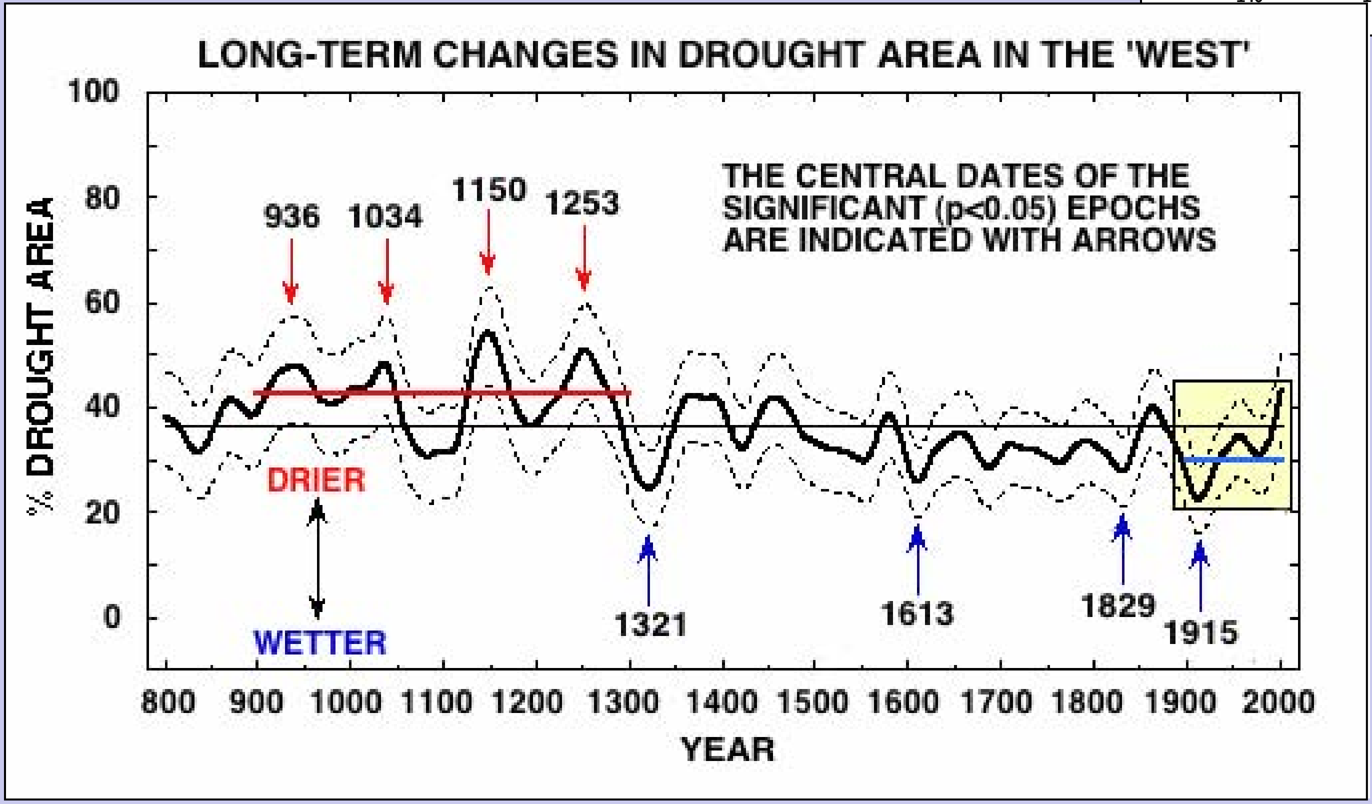
Ranked non-overlapping 10-year periods with largest area with PDSI < -1

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

Looking Further Back in Time: Periods of Persistent Aridity in the Western U.S.

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

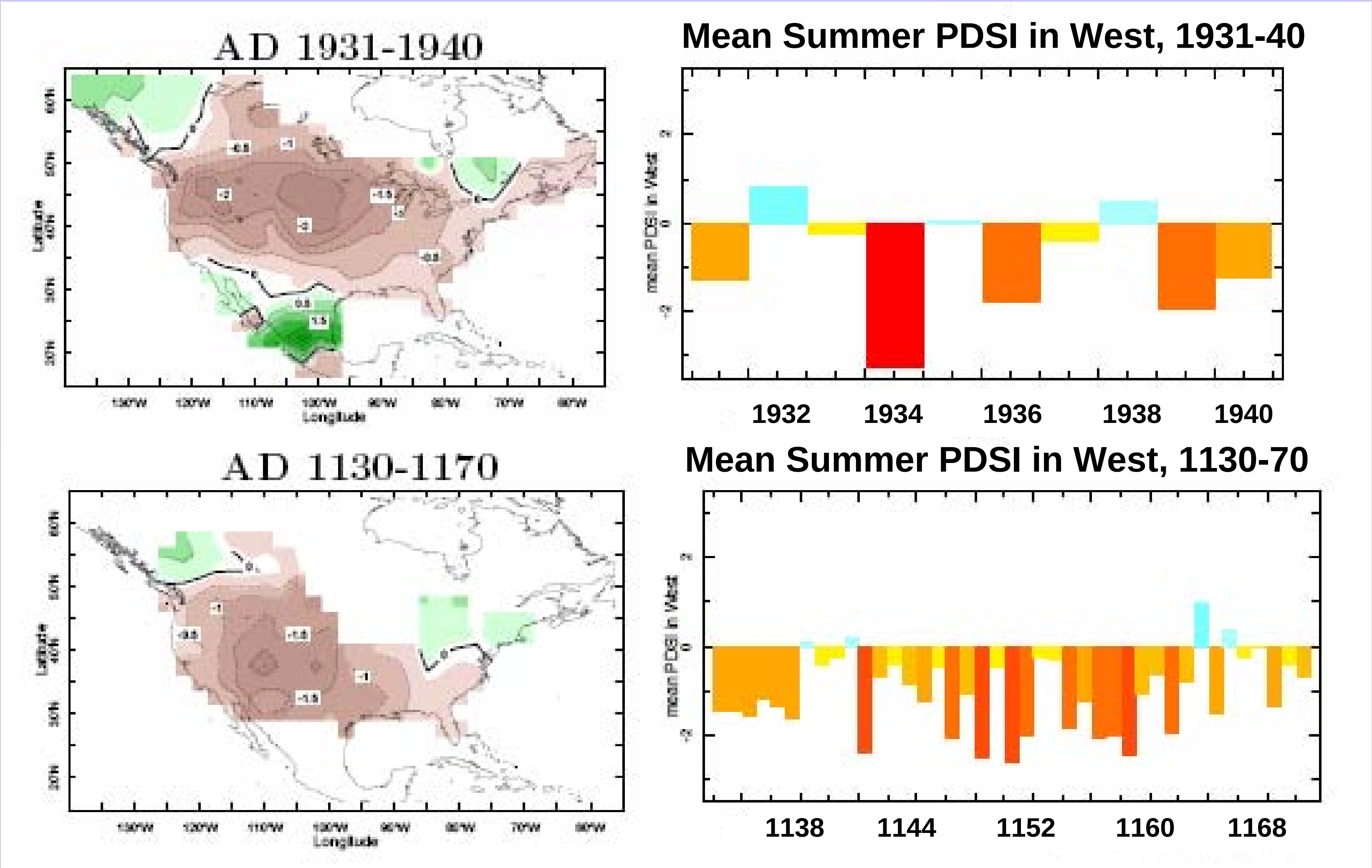




From Cook et al. 2004

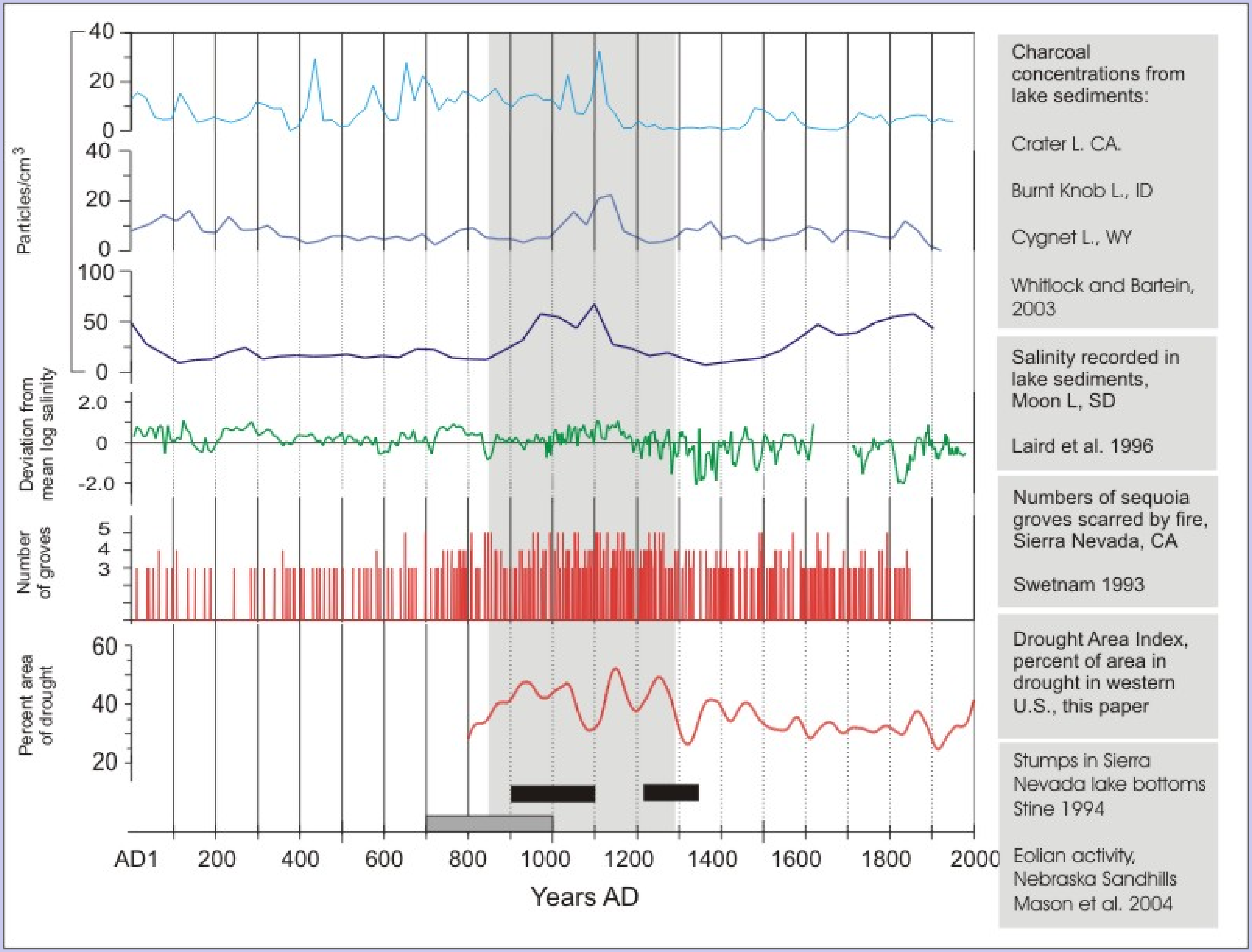
Large-Scale Patterns of Drought

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



Herweijer et al., in press, *Journal of Climate*

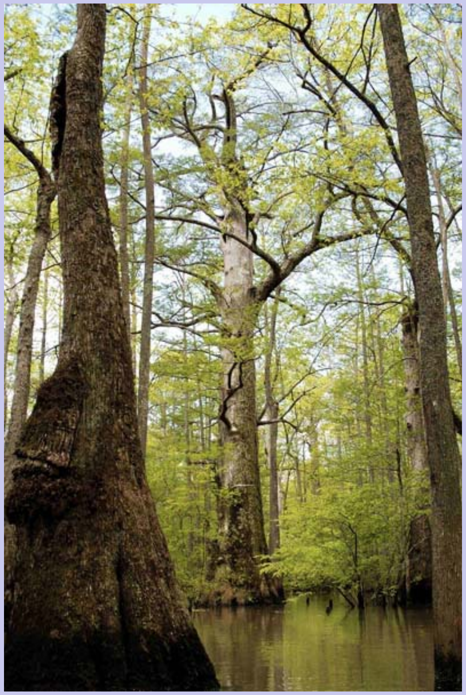
Proxy records that document drier conditions ~AD 850-1300



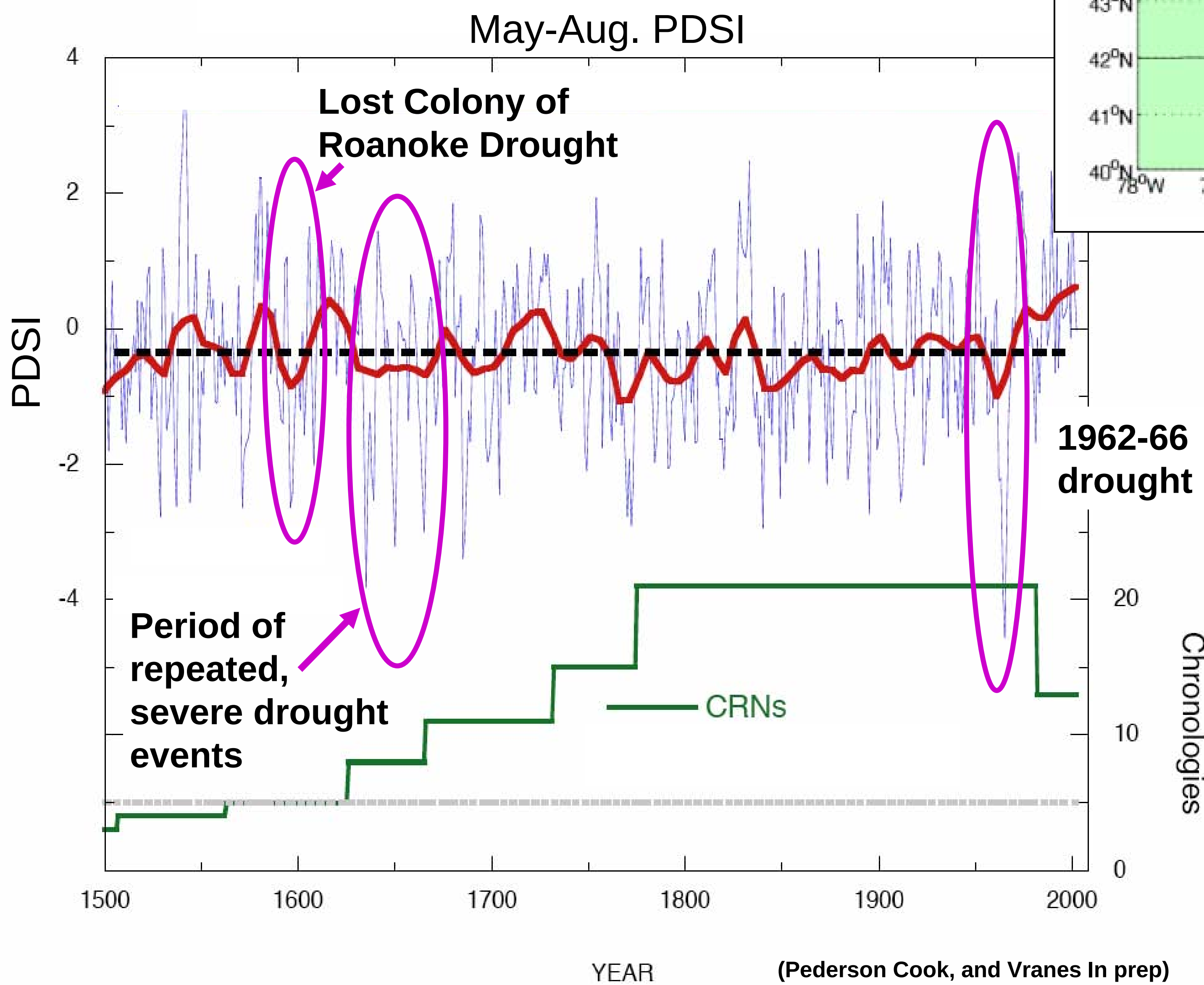
Past Drought at Regional Scales

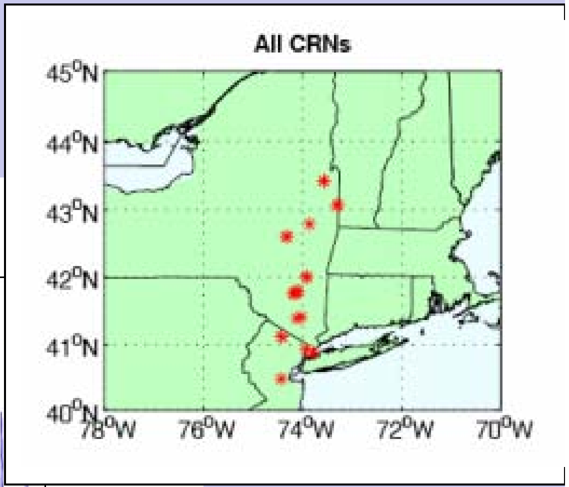
Examples for:

- Hudson River Valley
- Northeastern Arkansas
- Colorado/Sacramento River basins



Five Centuries of Drought in the Hudson River Valley

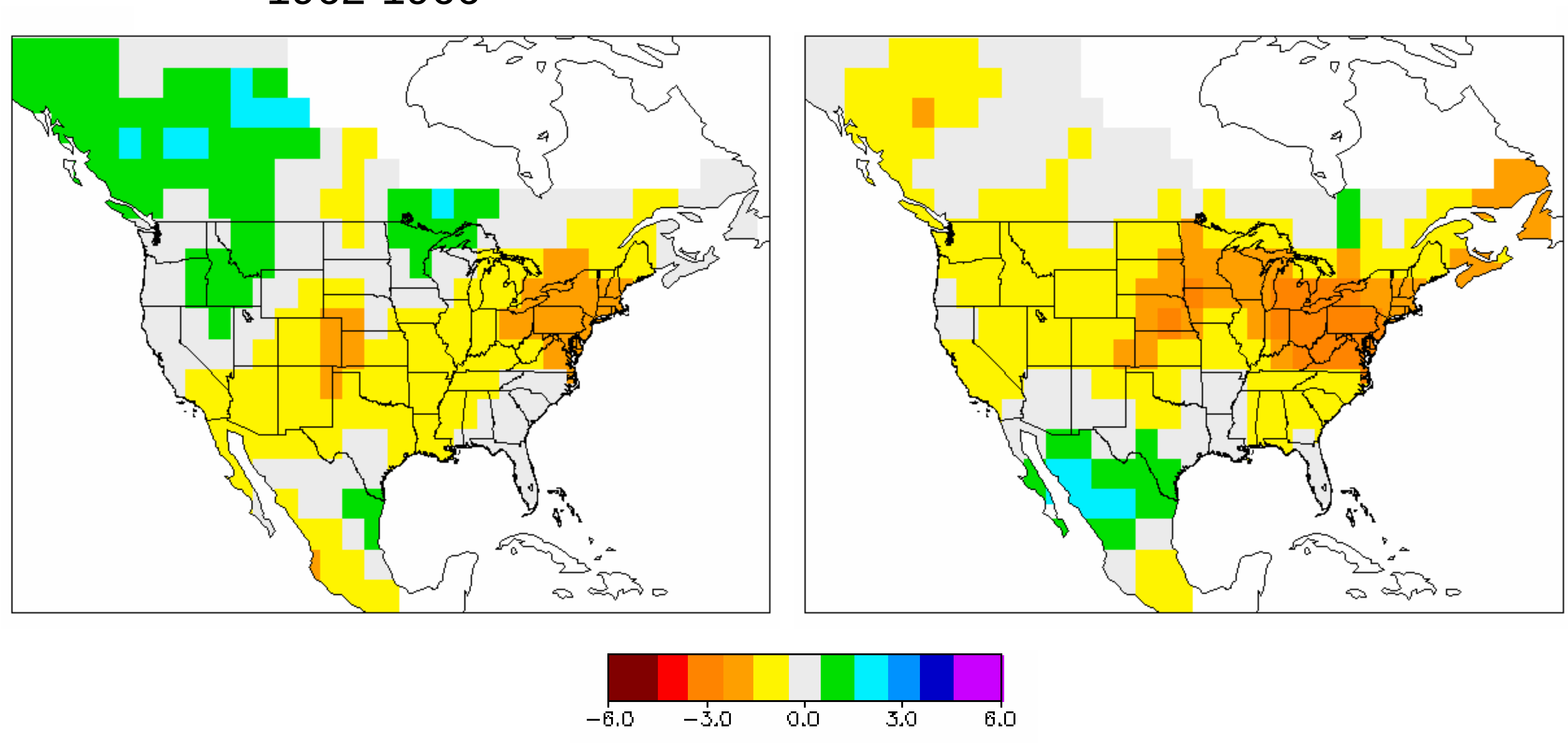




(Pederson Cook, and Vranes In prep)

Hudson Valley Droughts, 1960s and 1620-30s

1962-1966 | 1627-1635

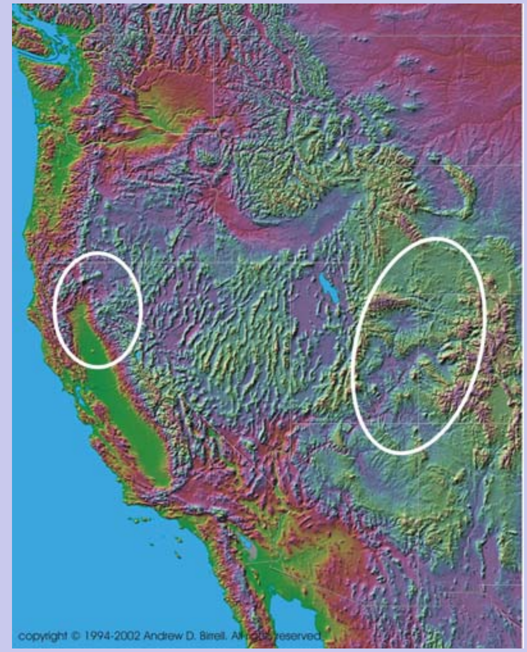


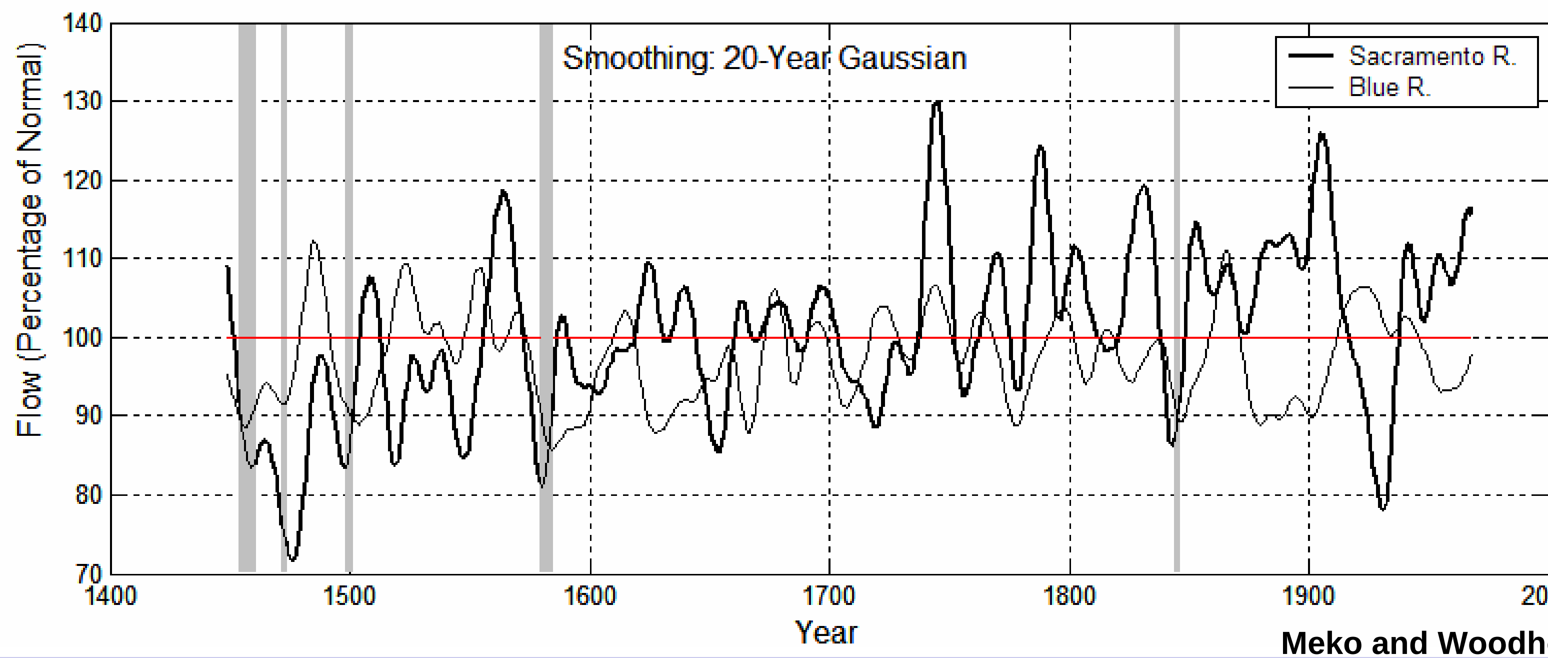
Summer PDSI

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.





Meko and Woodhouse 2005

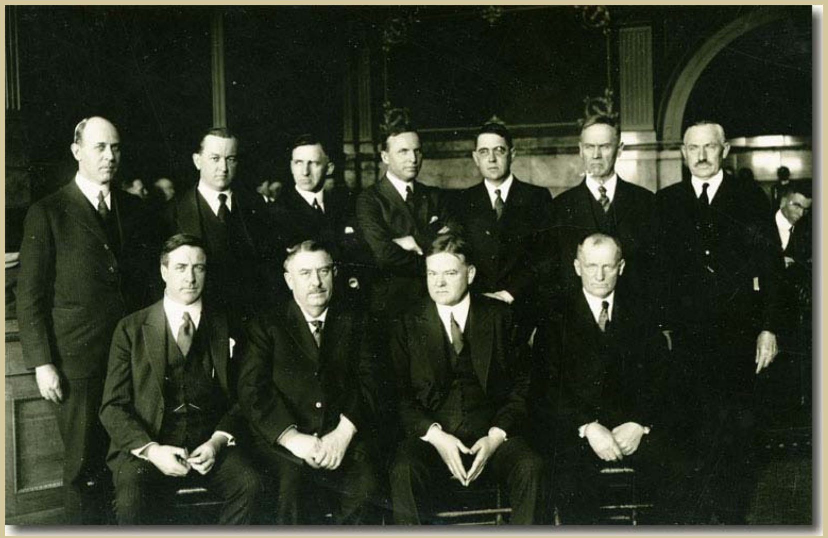
Paleoclimatology and Resource Management

Assessing planning baselines: An example from the Colorado River basin

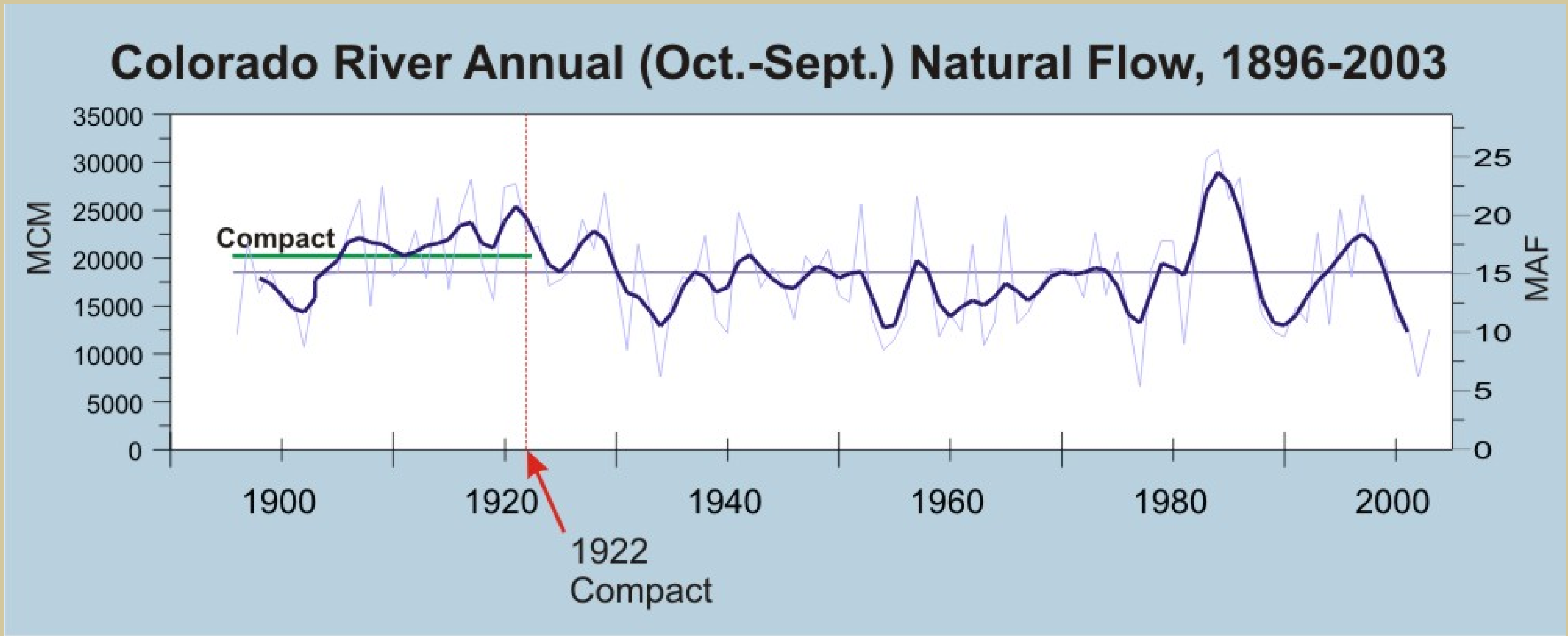
John Wesley Powell Photographs / Grca 14768
Grand Canyon National Park Museum Collection

The Colorado River Compact, signed in 1922, was based on an assumed flow of 16.4 million acre feet (MAF) a year.

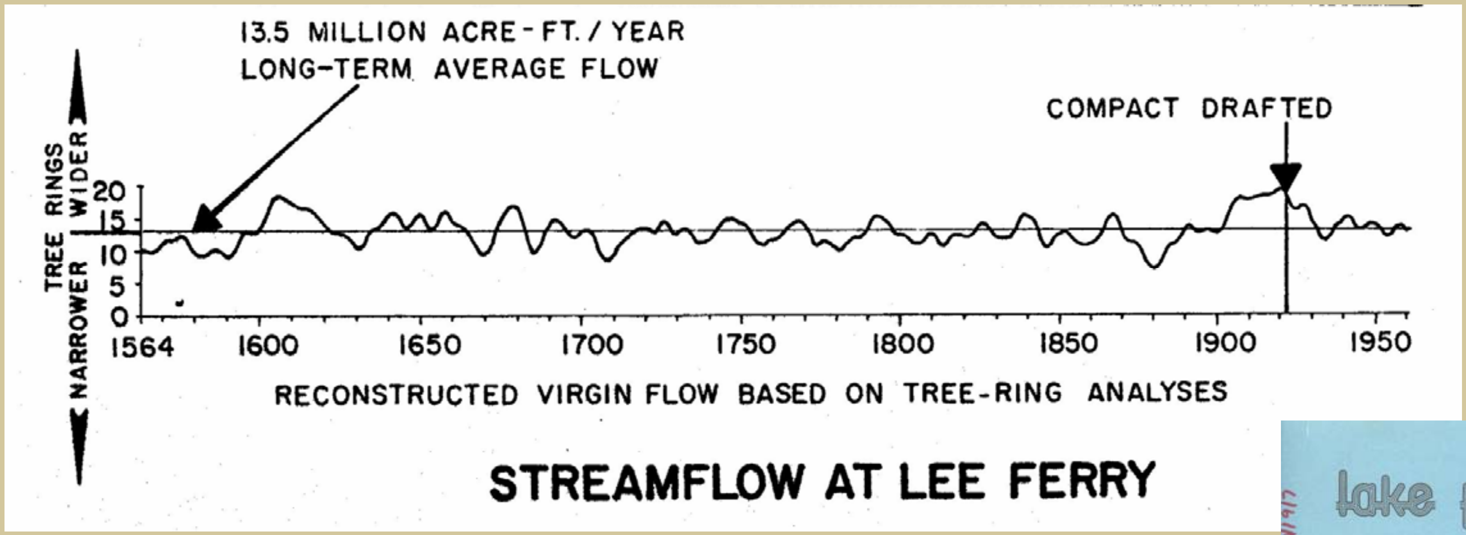
Based on the gage record today, flows in the early 20th century appear to be unusually high. How unusual is this period in a longer-term context?



Colorado River Commission, 1922, from Water Resources Archive, CSU

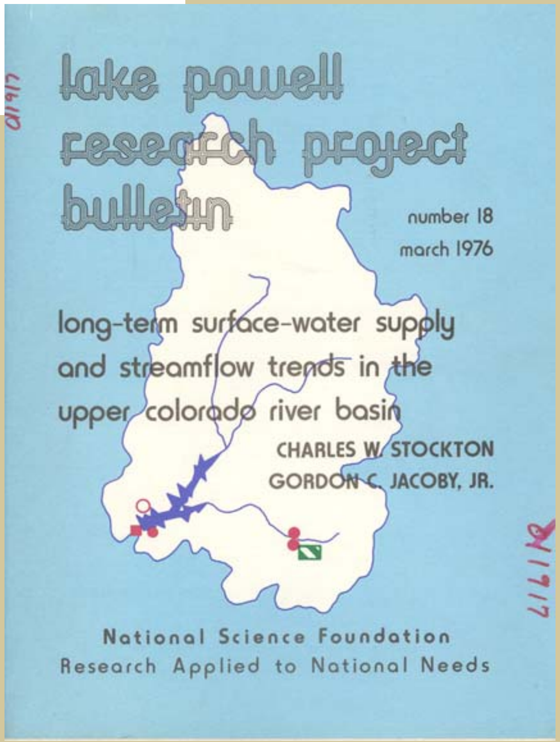


In 1976, the first Colorado River reconstruction from tree rings was generated by Stockton and Jacoby

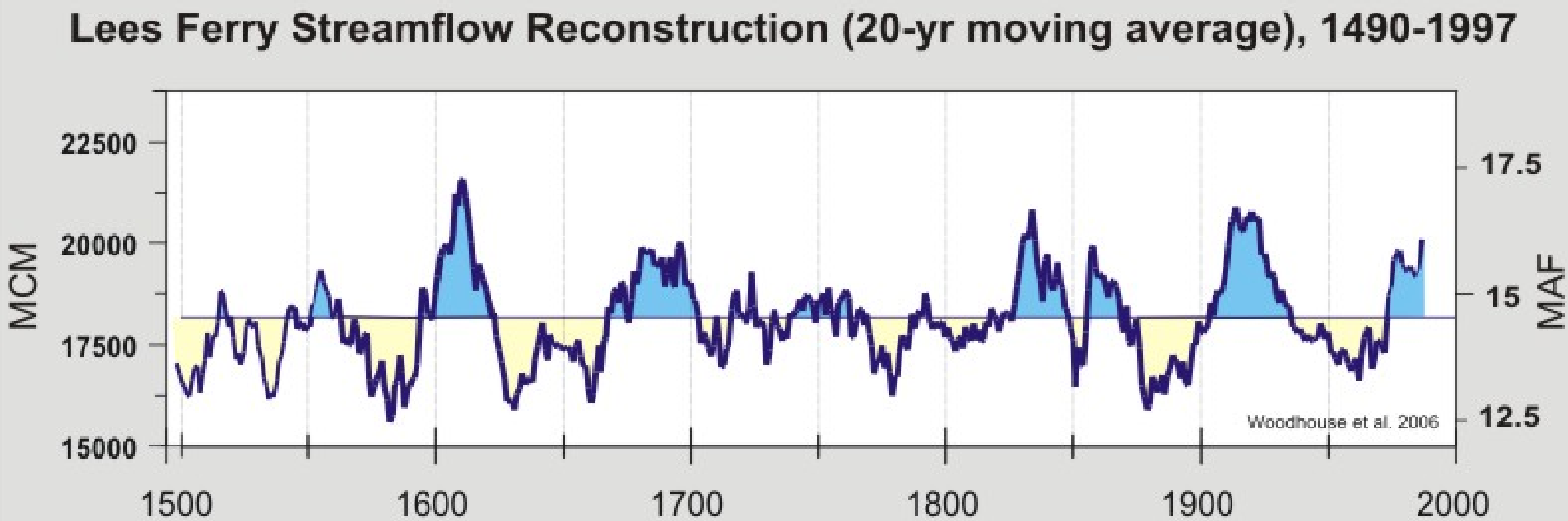


"…the timing of the drafting of the Compact was an unfortunate event, in that it did not occur during a representative flow period."

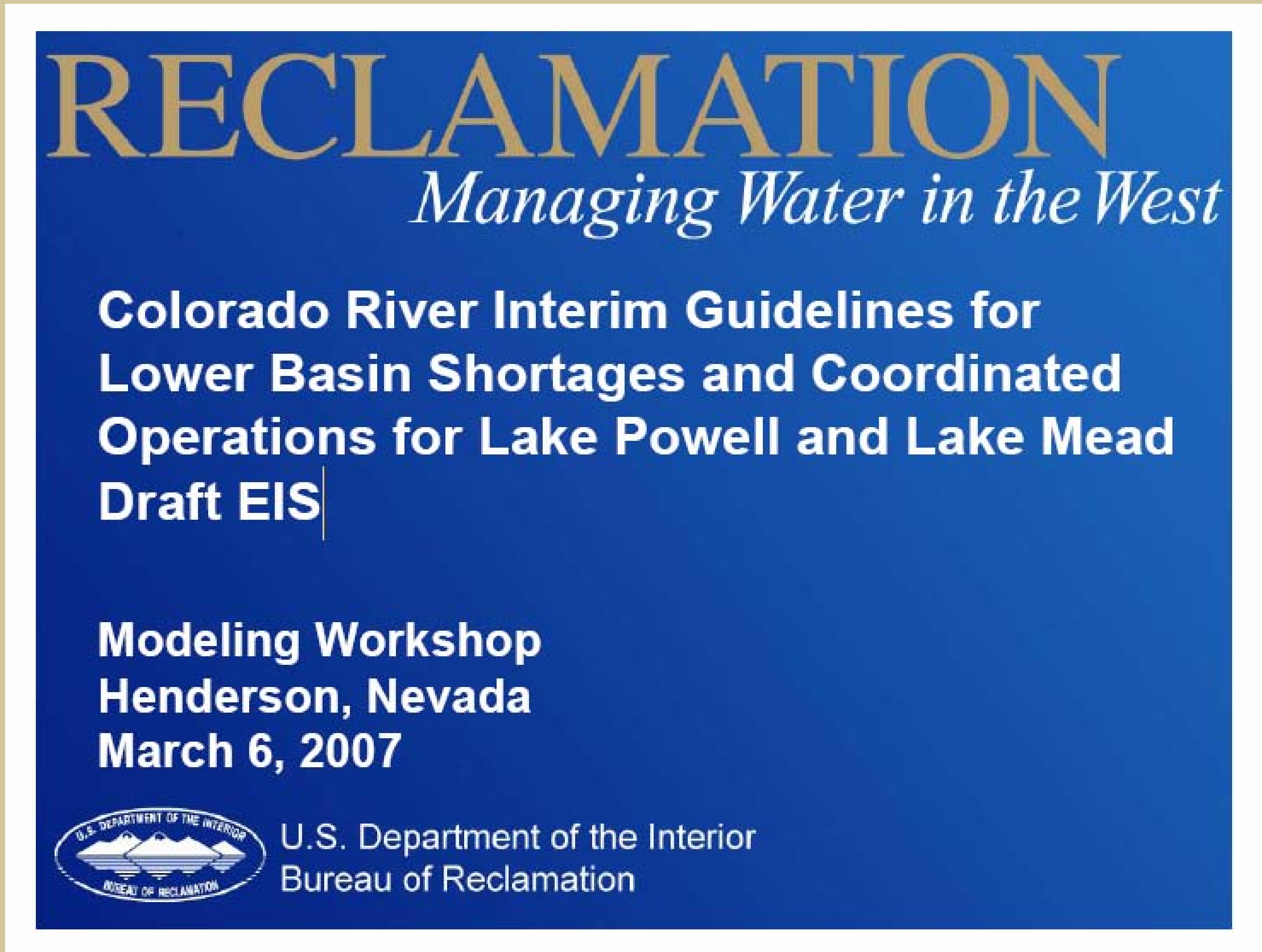
"The general picture of a collision between water demand and supply in the UCRB in the not-too-distant future is all too apparent."



Reconstruction of Lees Ferry Streamflow
smoothed to show low-frequency variability and 5 wettest/driest 20-yr periods

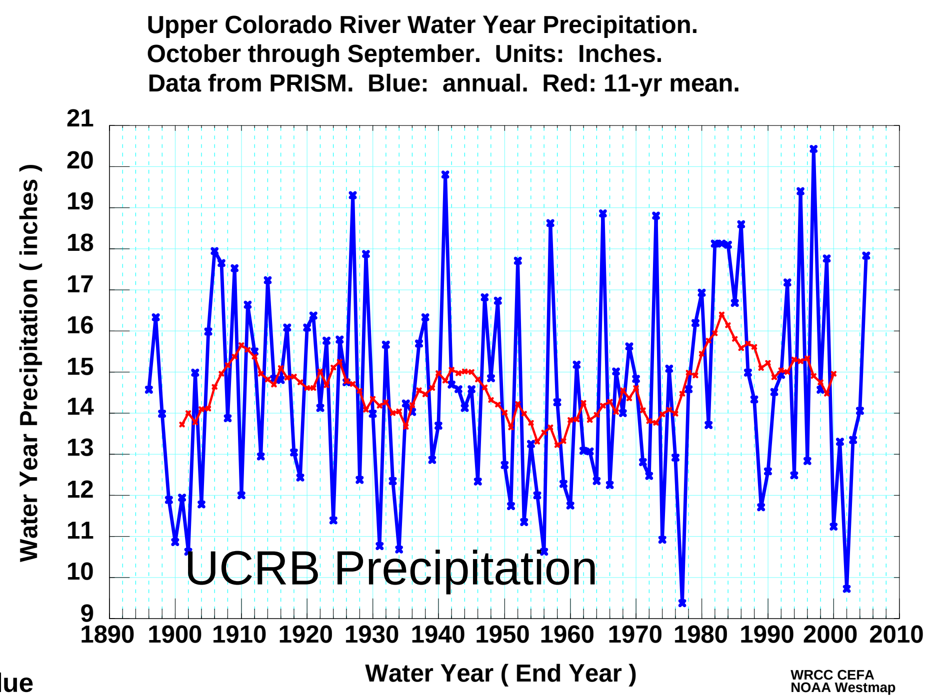


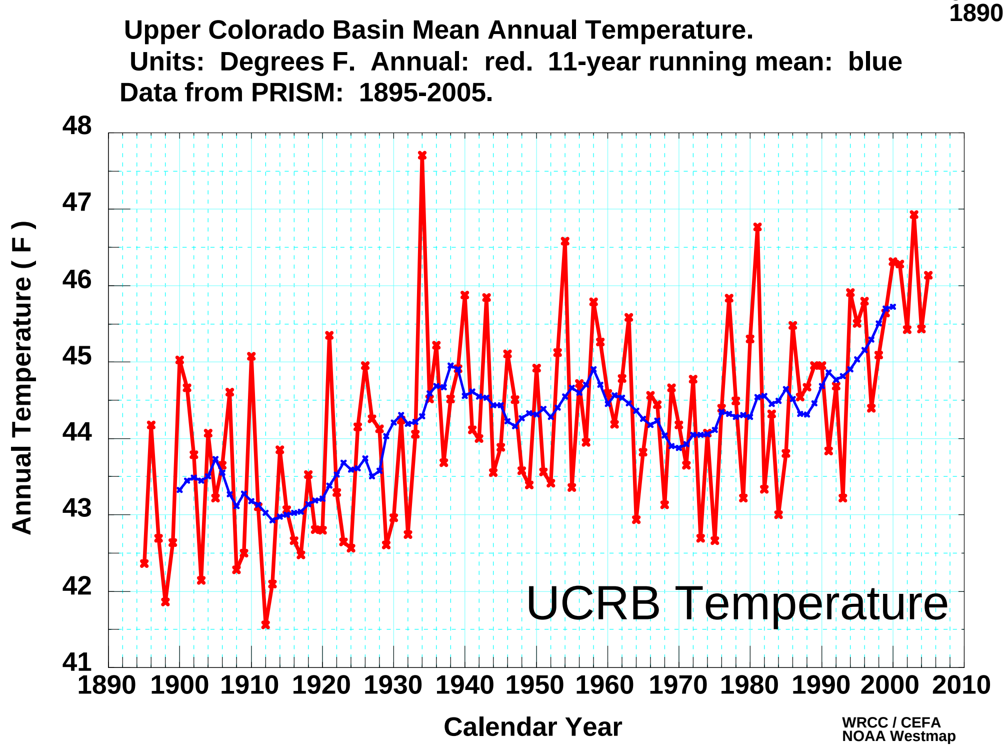
Pluvials Wettest non-overlapping 20-yr average	Droughts Driest non-overlapping 20-yr average
1602-1621	**1573-1592**
→ **1905-1924**	**1622-1641**
1825-1844	**1870-1889**
→ **1978-1997**	**1652-1671**
1687-1706	**1526-1545**
	1953-1972 (8th) ←



The tree-ring based reconstruction of the Colorado River is now being considered as an "alternative hydrologic sequence" in the development of guidelines for drought management.

How relevant is the past to current and future conditions?





Annual temperatures have risen over the past 110 years, but clear trends in precipitation are not evident. Temperatures are projected to increase, but projections for precipitation are less clear in this area.

Role of Paleoclimatology in Climate Change

- **Paleoclimatic records have been critical to the evaluation and attribution of the warming over the past century. Records indicate that global temperatures of the recent decades were the warmest in at least the past four centuries, and possibly over the past 1000 years or more.**

- **In contrast, paleoclimatic data indicate that droughts of the past century do not appear to be beyond the range of natural variability over past millennia.**

- **The climate of the past is unlikely to be replicated in the future, but natural climate variability –particularly moisture variability -- is likely to continue, underlying human-induced changes to climate. This variability may be a useful analogue for the future.**

Many of the graphics presented here came from the NCDC Paleoclimatology Branch web site: http://www.ncdc.noaa.gov/paleo/paleo.html, through donations from many scientists.