

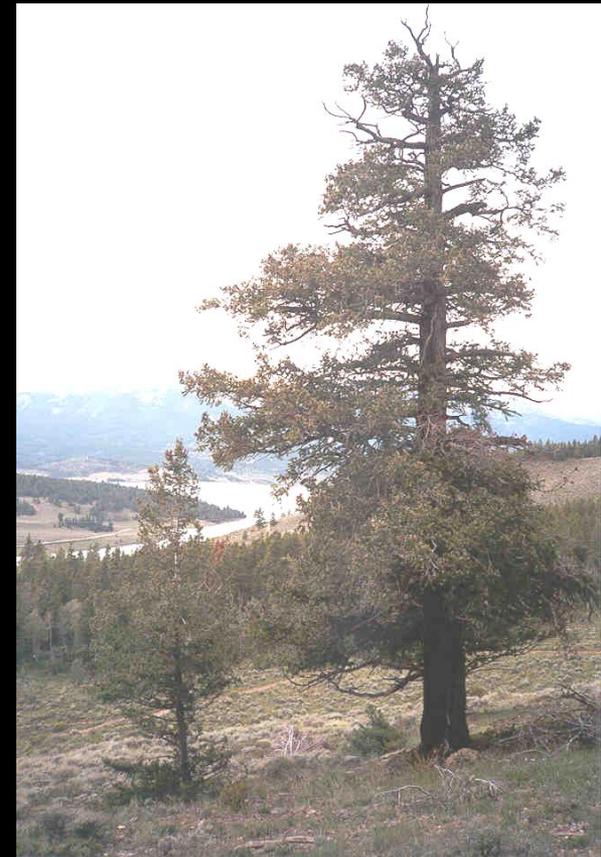
Dendrochronology and Tree-Ring Reconstructions of Streamflow for the Colorado River Basin

Tucson Water Citizens' Advisory Committee

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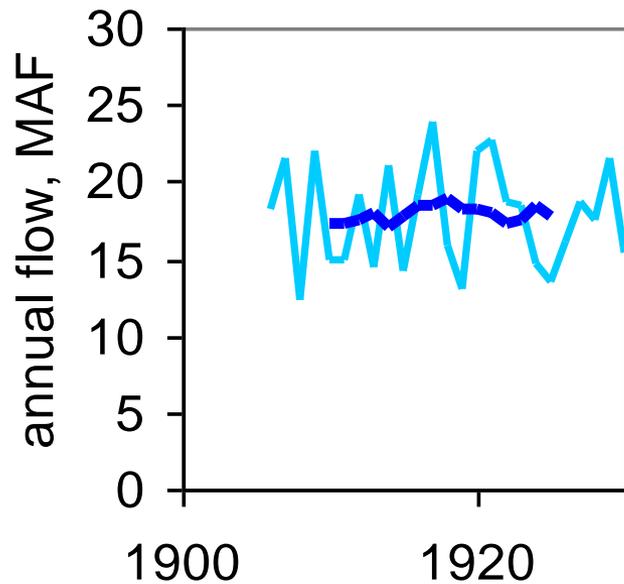


*This presentation contains the
contributions of many of my colleagues

- Overview of tree rings and streamflow reconstruction
- Reconstructions for the Colorado River basin
- What information reconstructions provide
- How streamflow reconstructions are being used by water providers and other decision makers

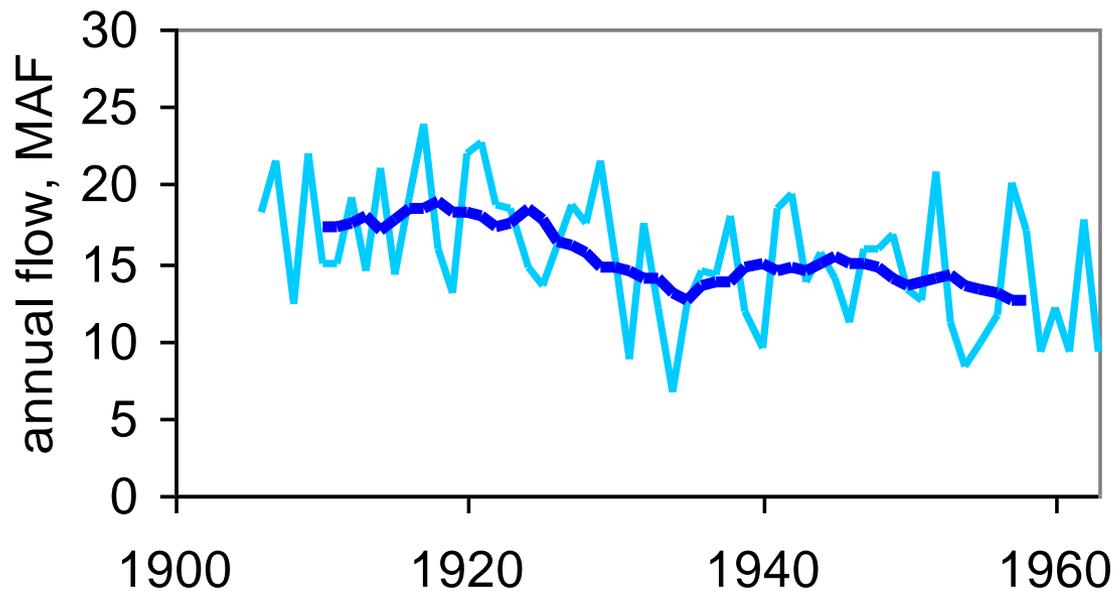
But first, why look at tree rings?

Historically, compacts, water policy and management have been based on the available gage records



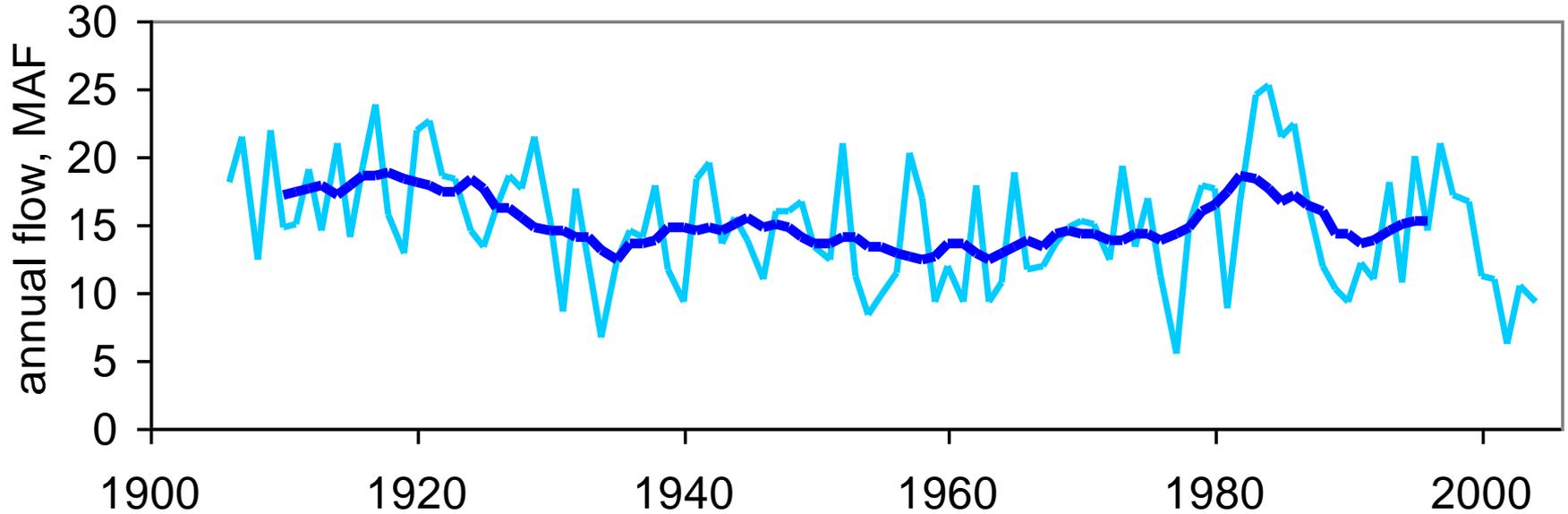
Colorado River at Lees Ferry, 1906-1930

Historically, compacts, water policy and management have been based on the available gage records



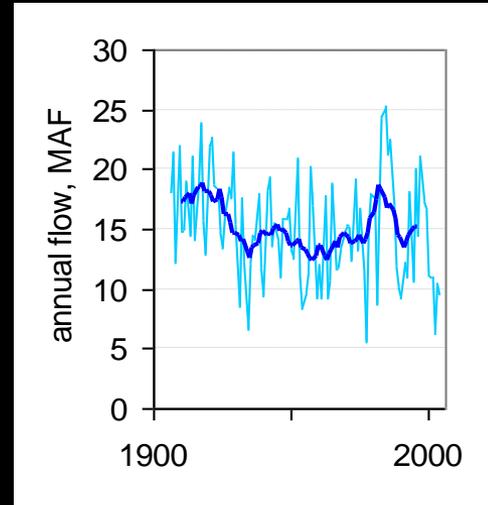
Colorado River at Lees Ferry, 1906-1960

Historically, compacts, water policy and management have been based on the available gage records



Colorado River at Lees Ferry, 1906-2004

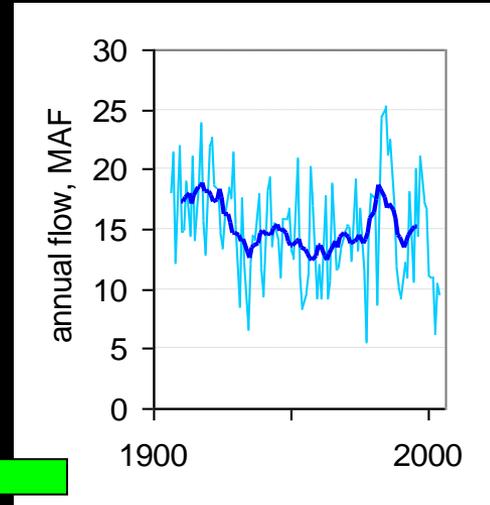
How representative is the gage record over a longer time frame?



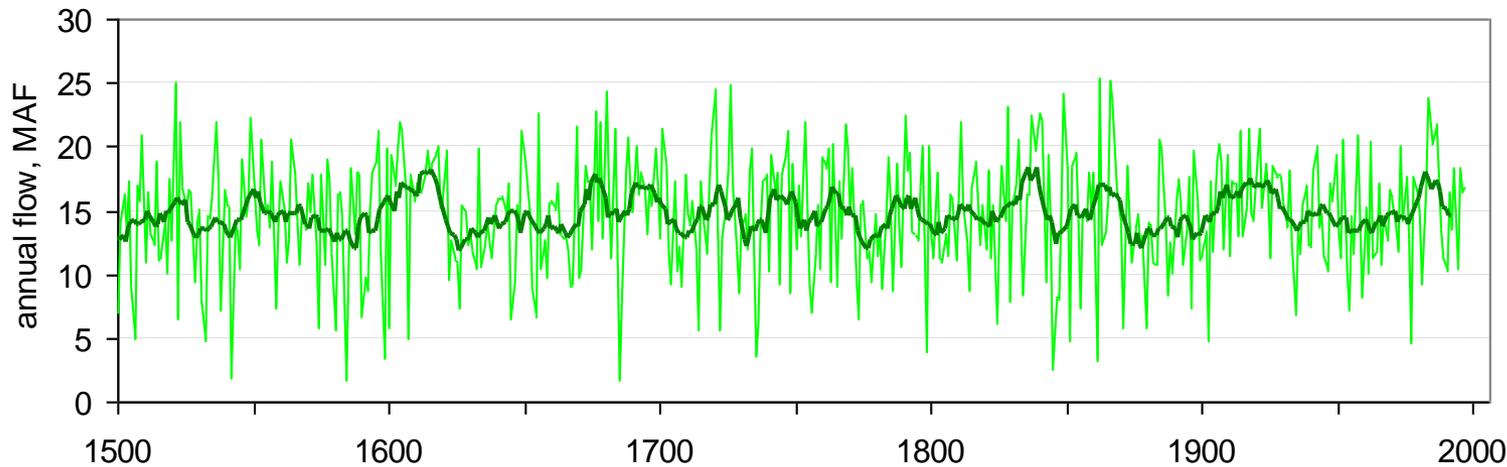
Colorado River at Lees Ferry, 1906-2004

How representative is the gage record over a longer time frame?

By extending the gaged hydrology by hundreds of years into the past, the reconstructions provide a more complete picture of hydrologic variability



Colorado River at Lees Ferry, 1906-2004



Tree-ring reconstruction of Colorado R., 1490-1997

Overview of Tree Rings and Streamflow Reconstruction

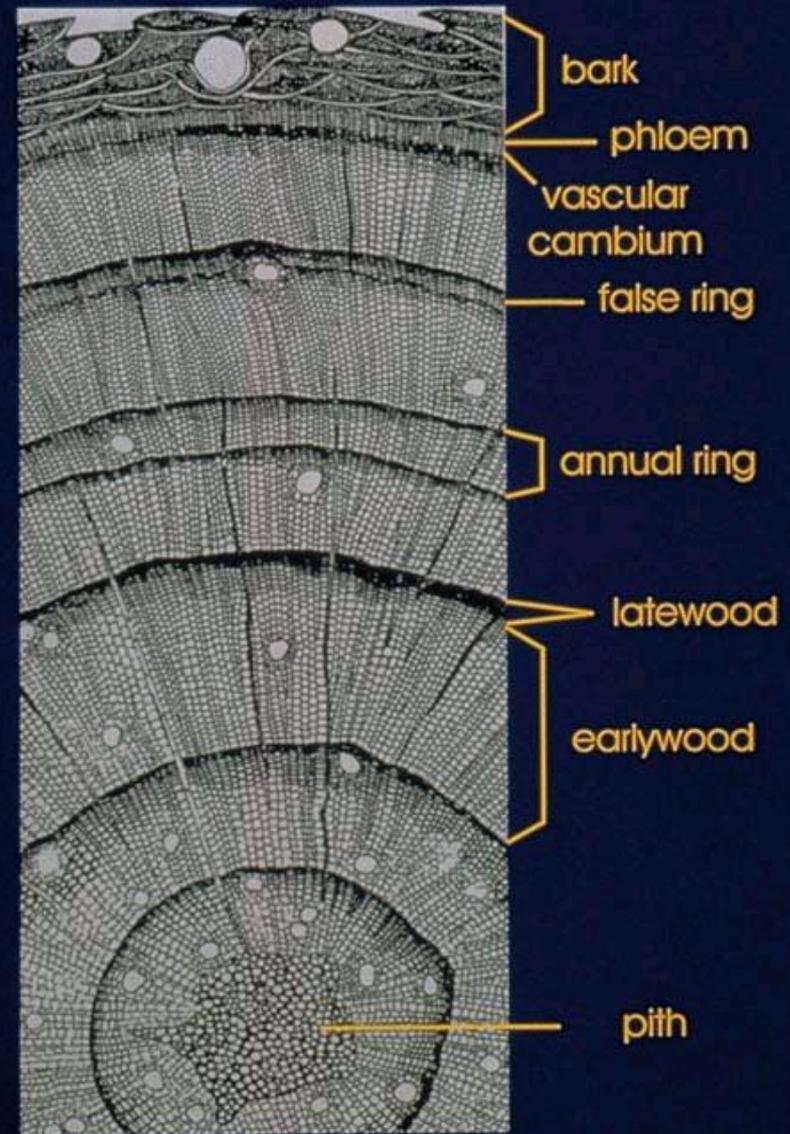
How tree rings record climate information

Variations in annual ring widths reflect the conditions that influence tree growth.

Climate is often the primary influence on growth.

Because of this, ring widths can be used as a proxy for past climate.

CROSS SECTION of a CONIFER



What trees are the best recorders of precipitation, streamflow and drought?

Moisture-sensitive tree species growing on open, well drained sites reflect moisture variability in their ring widths



Douglas-fir

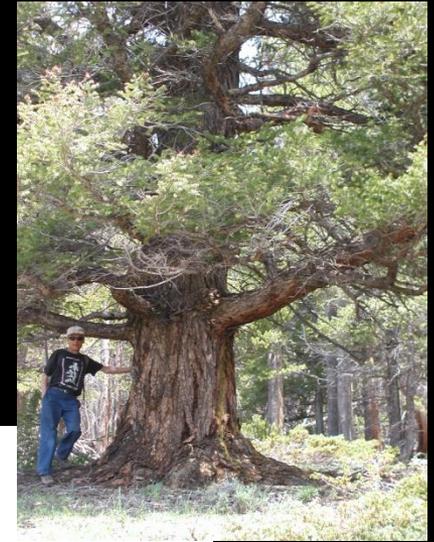


Pinyon pine

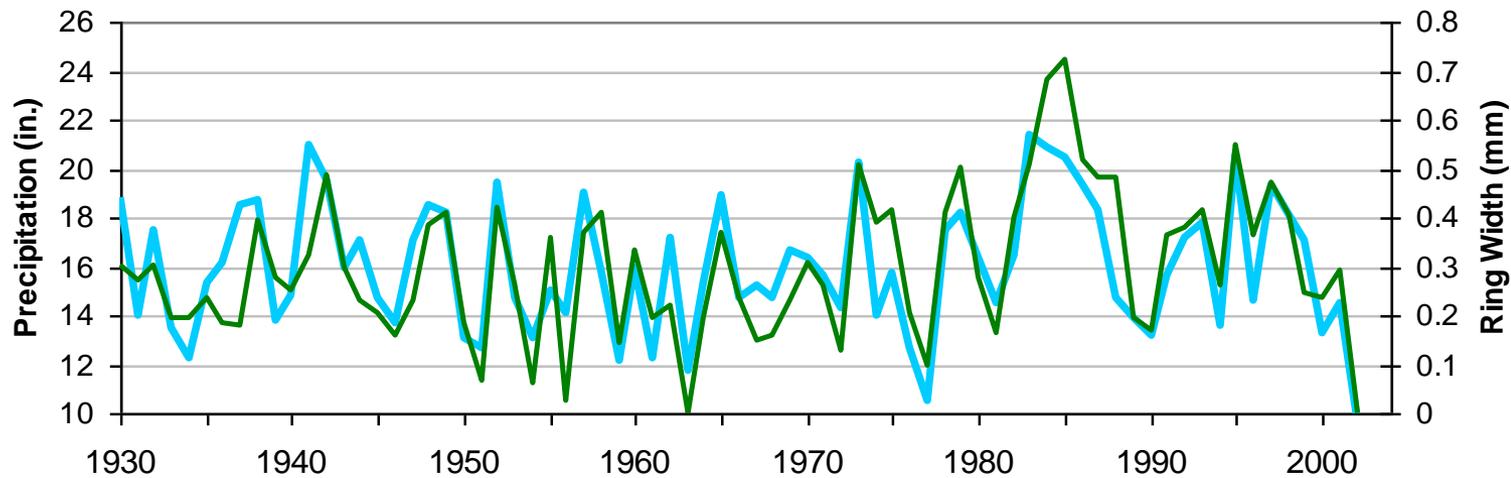


Ponderosa pine

Moisture-stressed trees closely track variations in precipitation



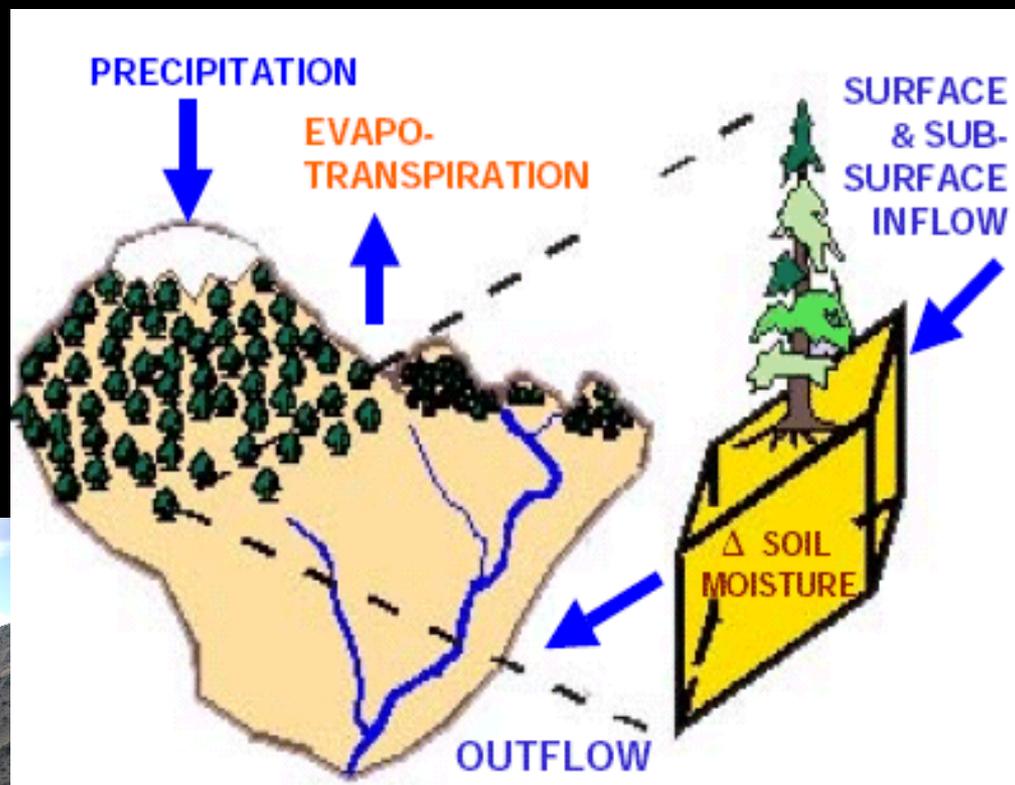
Western CO Annual Precip vs. Pinyon ring width (WIL731)



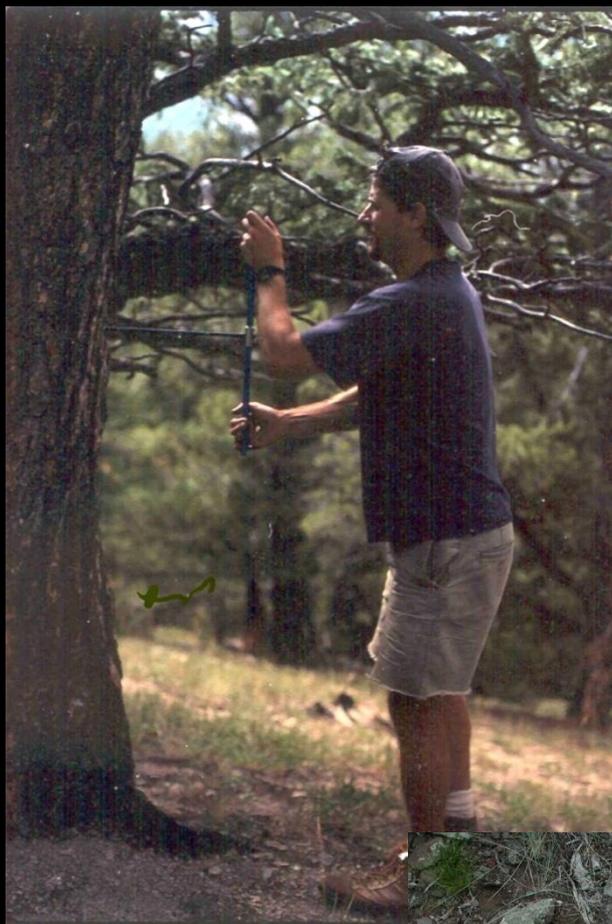
Ring widths from a single tree near Grand Junction, CO are plotted with annual precipitation in western Colorado. The correlation between the two is 78% ($r = 0.78$).

How can tree rings be used to reconstruct streamflow?

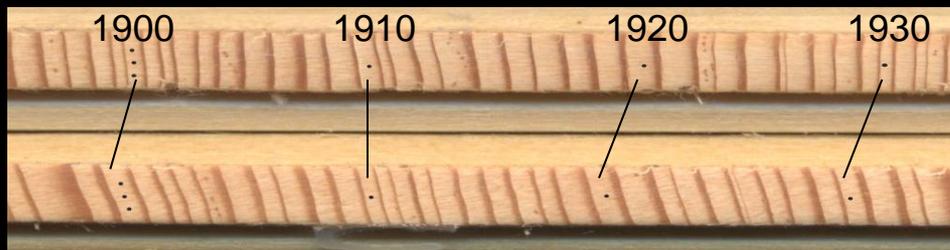
Ring widths and streamflow both integrate the effects of precipitation and evapotranspiration, as mediated by the soil, over the course of the water year.



Collecting tree ring data and compiling site tree-ring chronologies



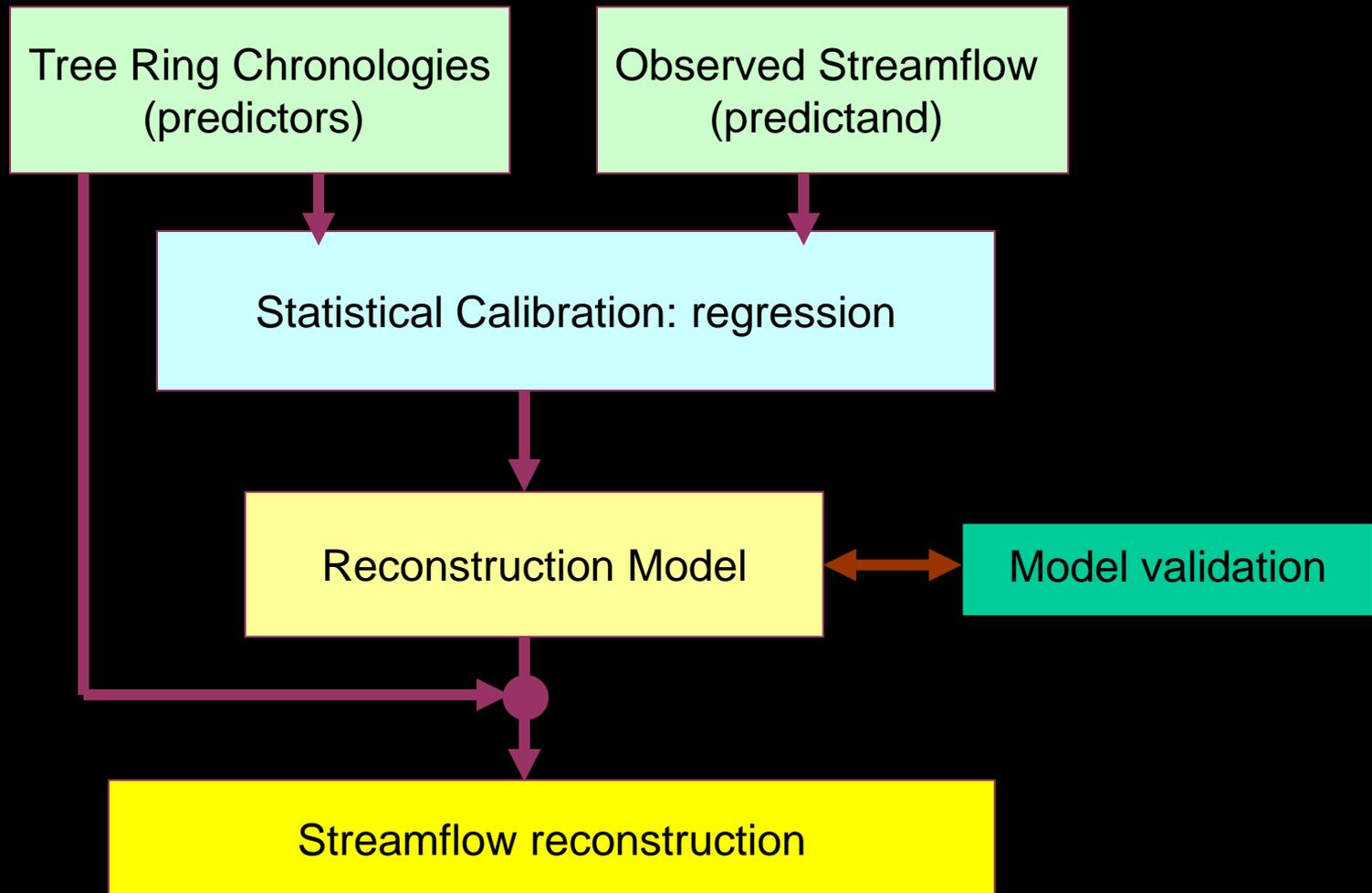
An increment borer is used to sample cores from about 20 trees at a site



Cores mounted and sanded, then dated, measured, and averaged into site tree-ring chronologies



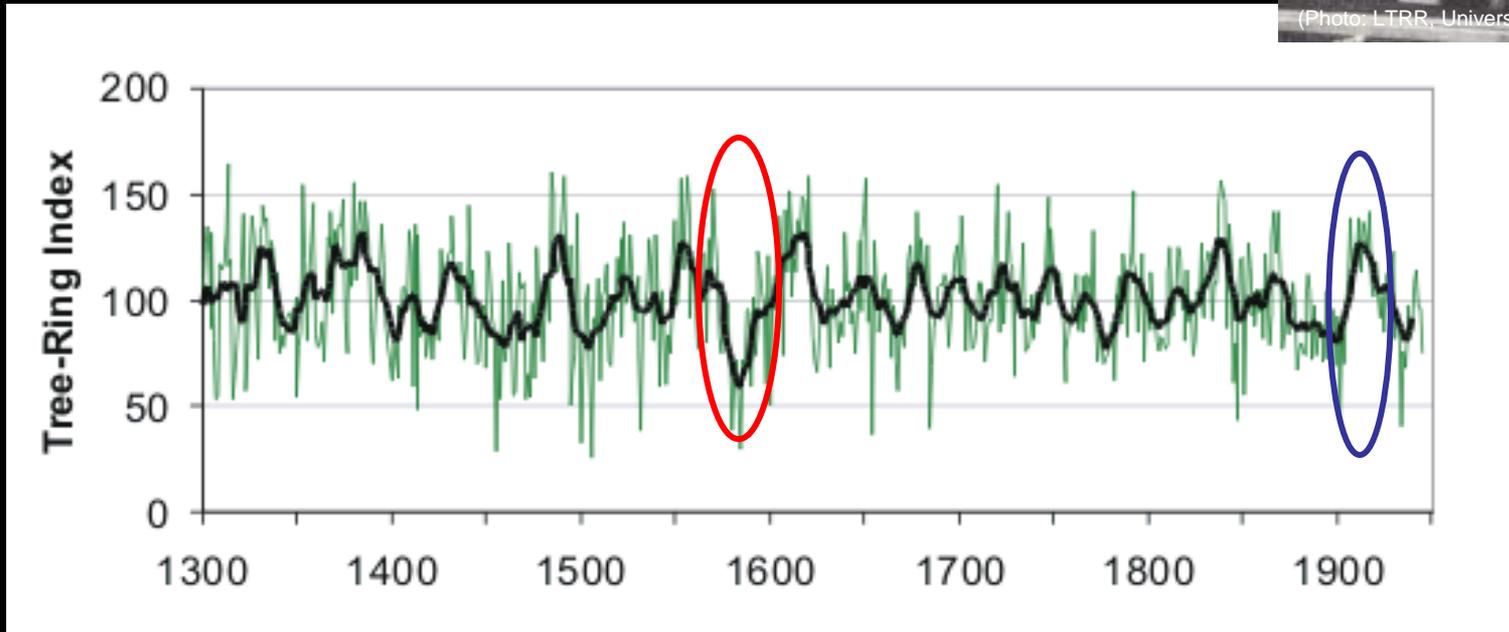
Generating the streamflow reconstruction



Reconstructions for the Colorado River Basin

Early Tree-Ring Records of Colorado River Flow

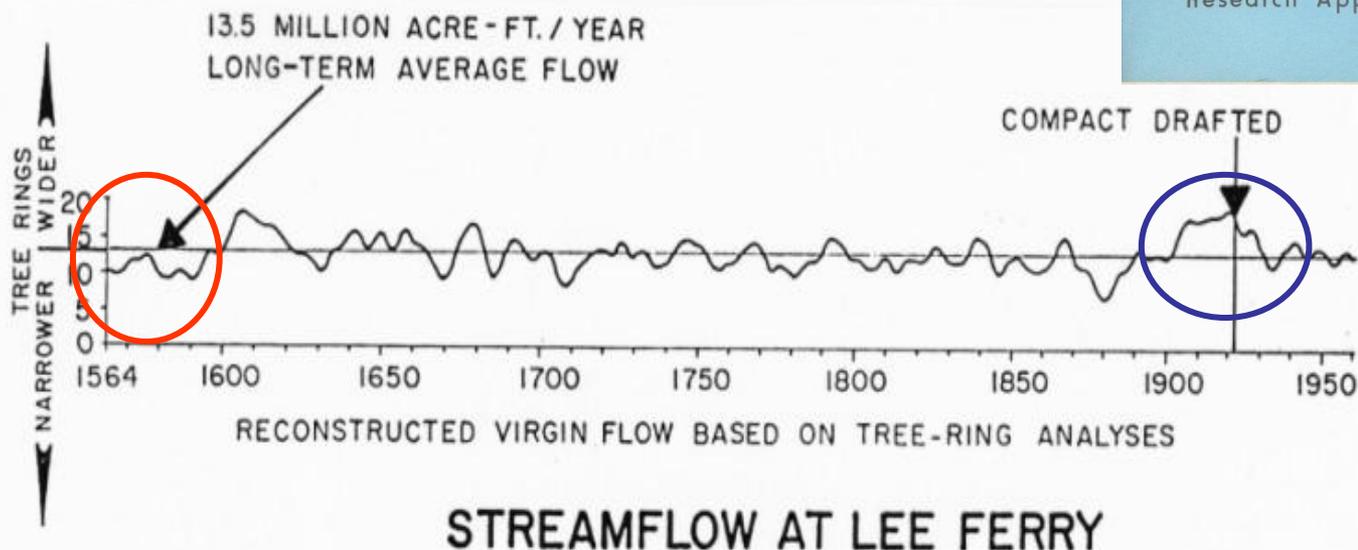
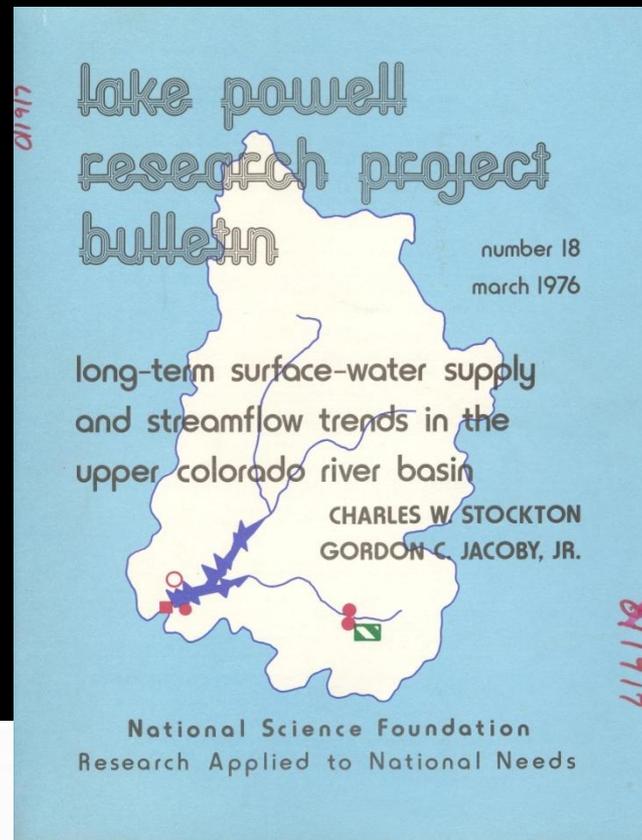
In the 1940s, Edmund Schulman found tree rings reflected variations in moisture and could be used as a proxy for annual streamflow.



Schulman's Colorado River basin Douglas-fir tree-ring index (1300-1945) from "Tree-Ring Hydrology of the Colorado Basin", 1945.

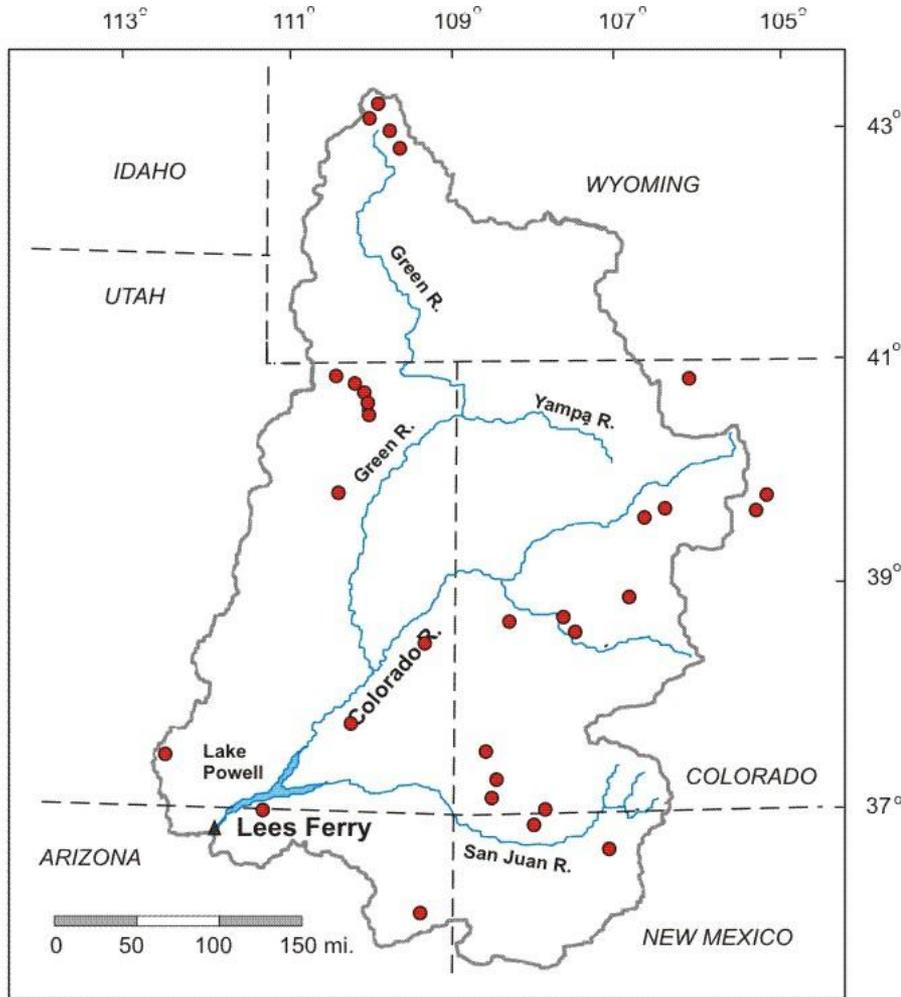
The first Colorado River reconstruction was generated by Stockton and Jacoby in 1976.

It supported Schulman's findings regarding high flows in the 20th century and droughts in past centuries.

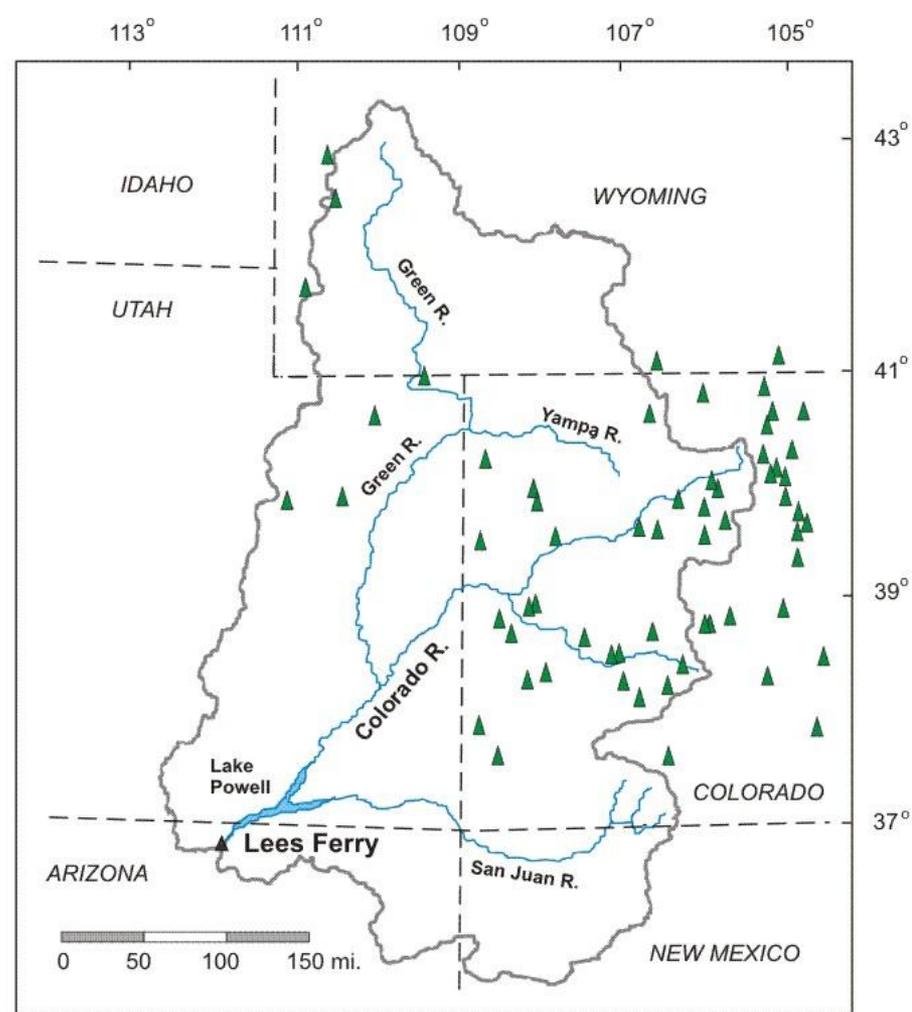


Stockton and Jacoby 1976

Stockton and Jacoby's reconstruction was updated in 2006 with new tree-ring collections



(adapted from Stockton and Jacoby 1976)



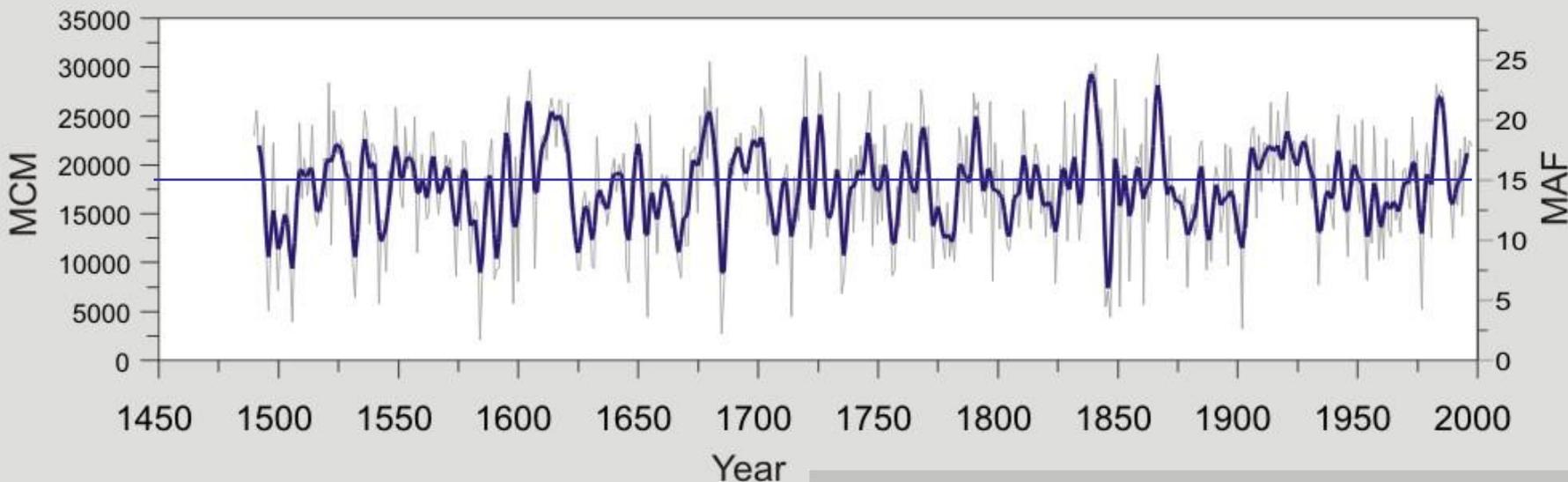
(adapted from Stockton and Jacoby 1976)

Stockton and Jacoby tree-ring sites

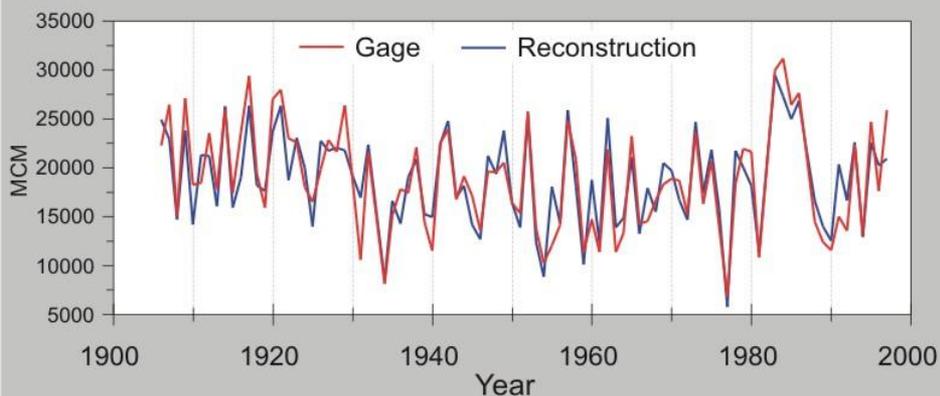
New network of tree-ring sites

This work extended the Lees Ferry reconstruction to 1997 and back to 1490

Reconstruction of Colorado River at Lees Ferry, 1490-1997



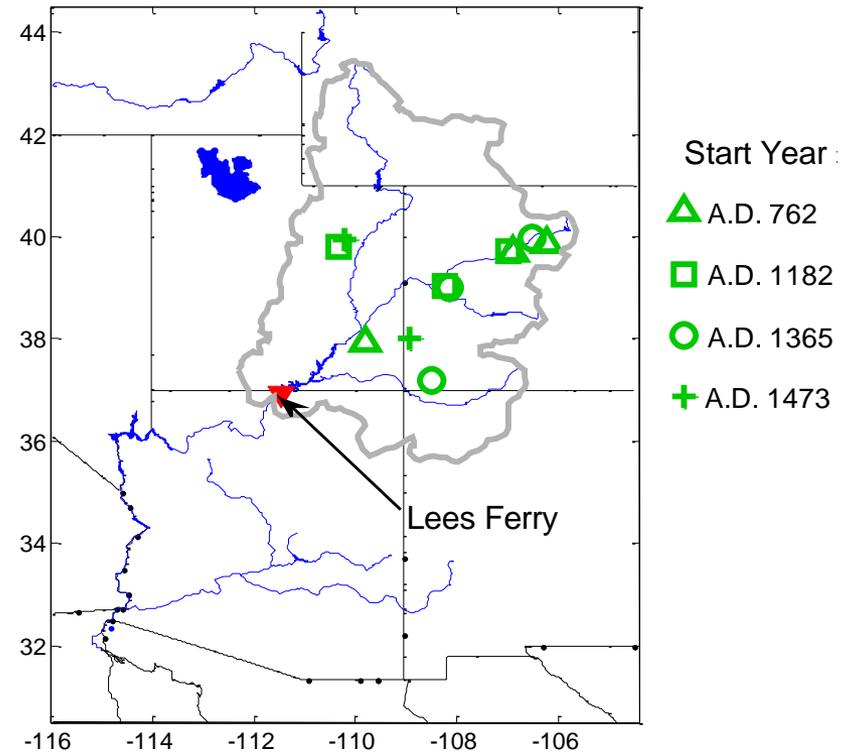
The reconstruction explains about 80% over variance in the gage record



The Lees Ferry reconstruction has now been extended even further back in time using stumps, logs, and remnants of wood

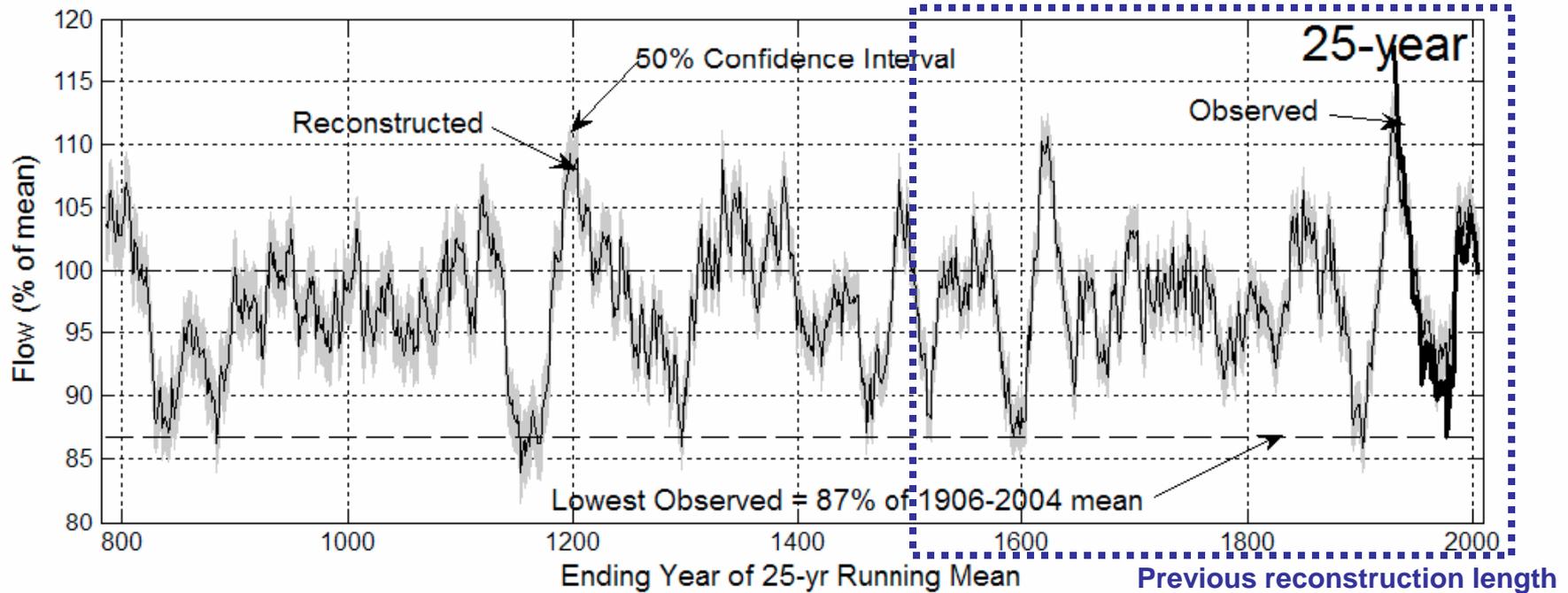


Locations of chronologies used in the extended Lees reconstruction



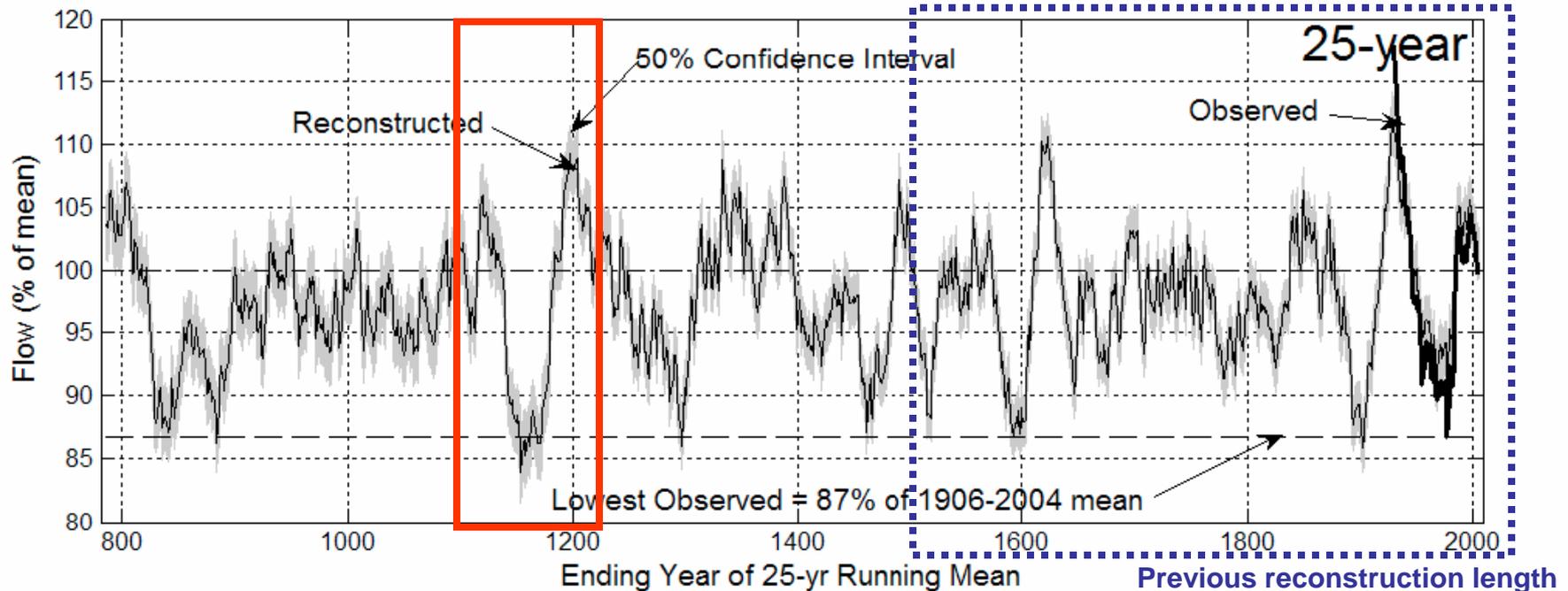
Meko et al. 2007

Reconstruction of Colorado River at Lees Ferry, AD 762 - 2005



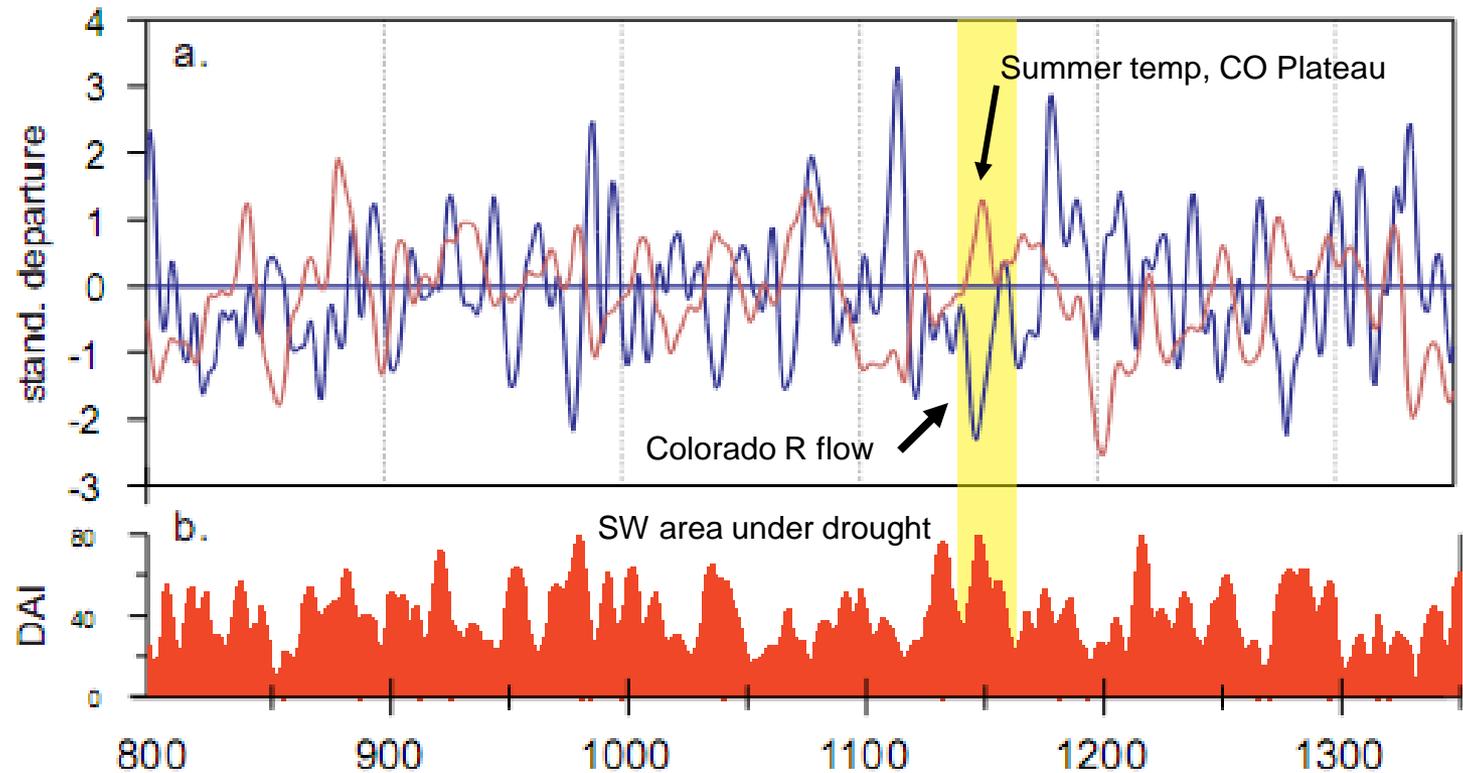
25-yr running means of reconstructed and observed annual flow of the Colorado River at Lees Ferry, expressed as percentage of the 1906-2004 observed mean (Meko et al. 2007).

Reconstruction of Colorado River at Lees Ferry, AD 762 - 2005



25-yr running means of reconstructed and observed annual flow of the Colorado River at Lees Ferry, expressed as percentage of the 1906-2004 observed mean (Meko et al. 2007).

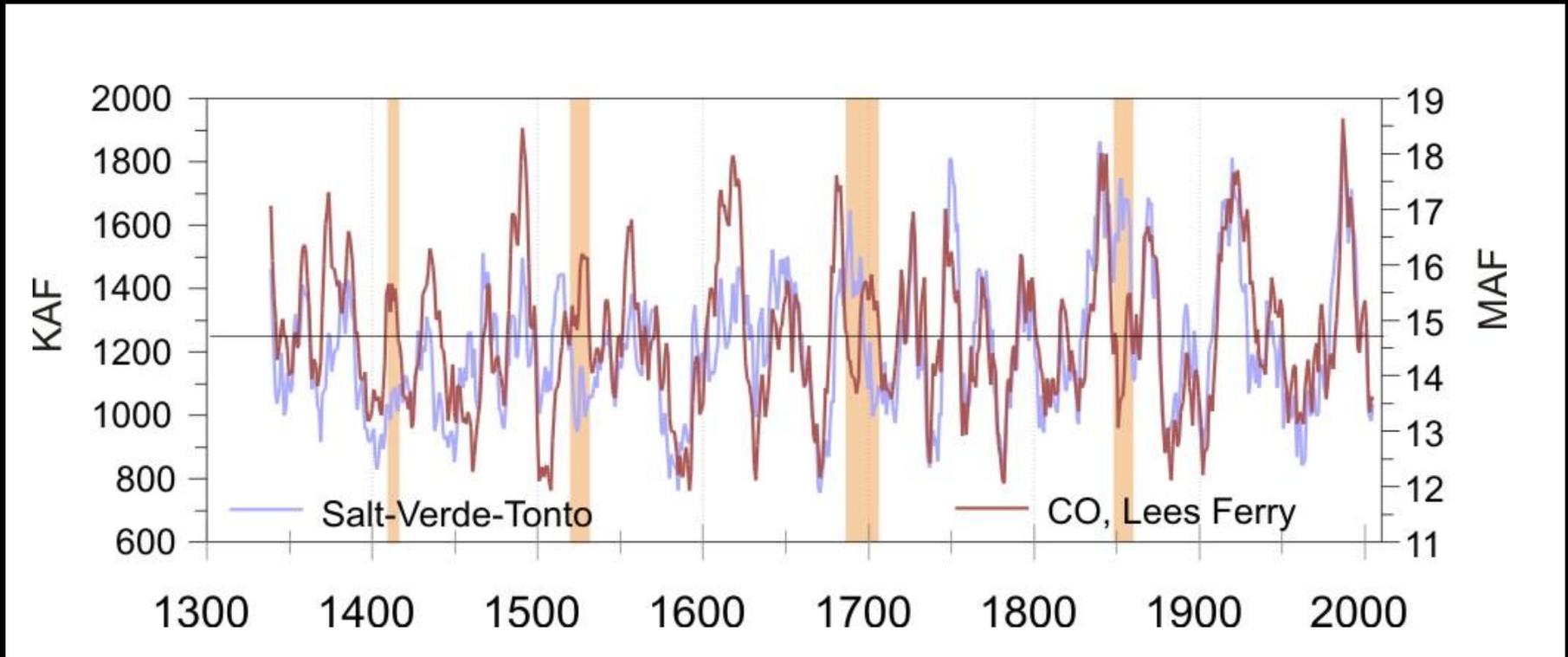
“Heart” of the Medieval Drought in the Colorado R. Basin



a. Salzer and Kipfmueller 2005; Meko et al. 2007

b. Cook et al. 2009

Comparison of Upper and Lower (Salt-Verde-Tonto) Colorado River Reconstructions, 1330-2005



From Meko et al. 2007
Meko and Hirschboeck 2008

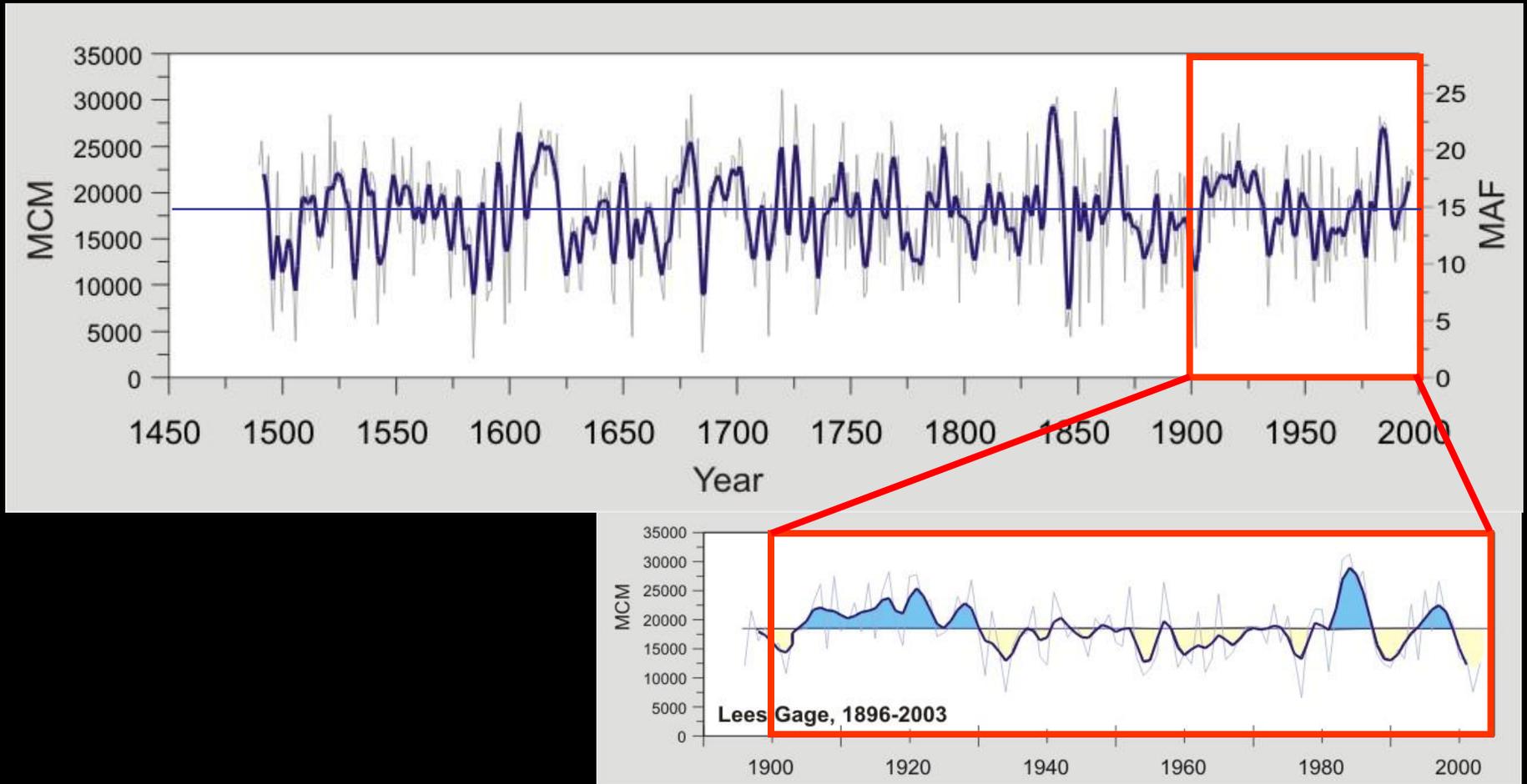
Mostly in synch, but there are exceptions...

What the Colorado River reconstructions provide:

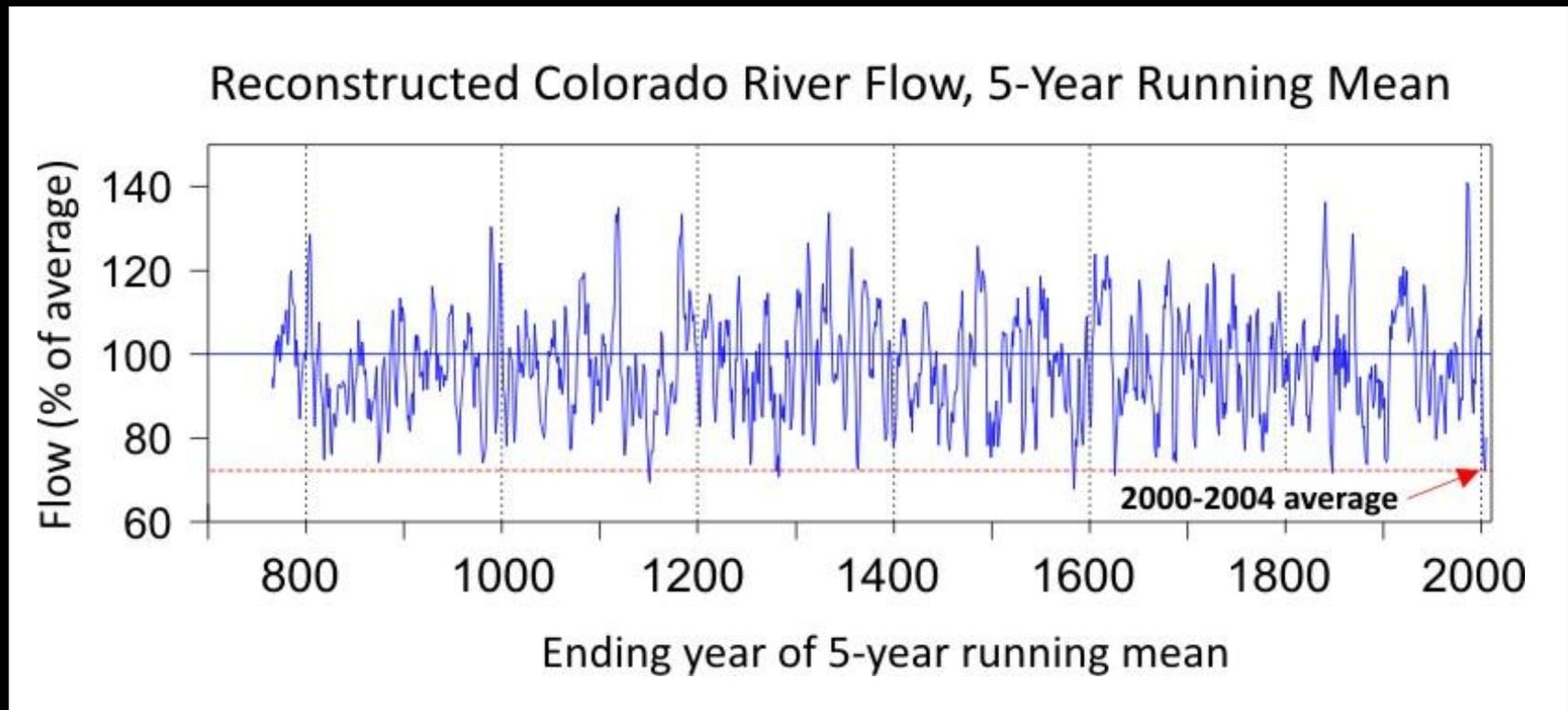
- context for assessing gage record over a longer time frame
- a way to evaluate the recent drought in terms of natural variability over past centuries
- a framework for understanding the range of drought characteristics (intensity, duration, magnitude) that has occurred
- insights on low-frequency (scale of decades to half century) hydrologic variability
- an understanding of the rich sequence of flows that has occurred over past centuries

Context for assessing gage record in a longer time frame

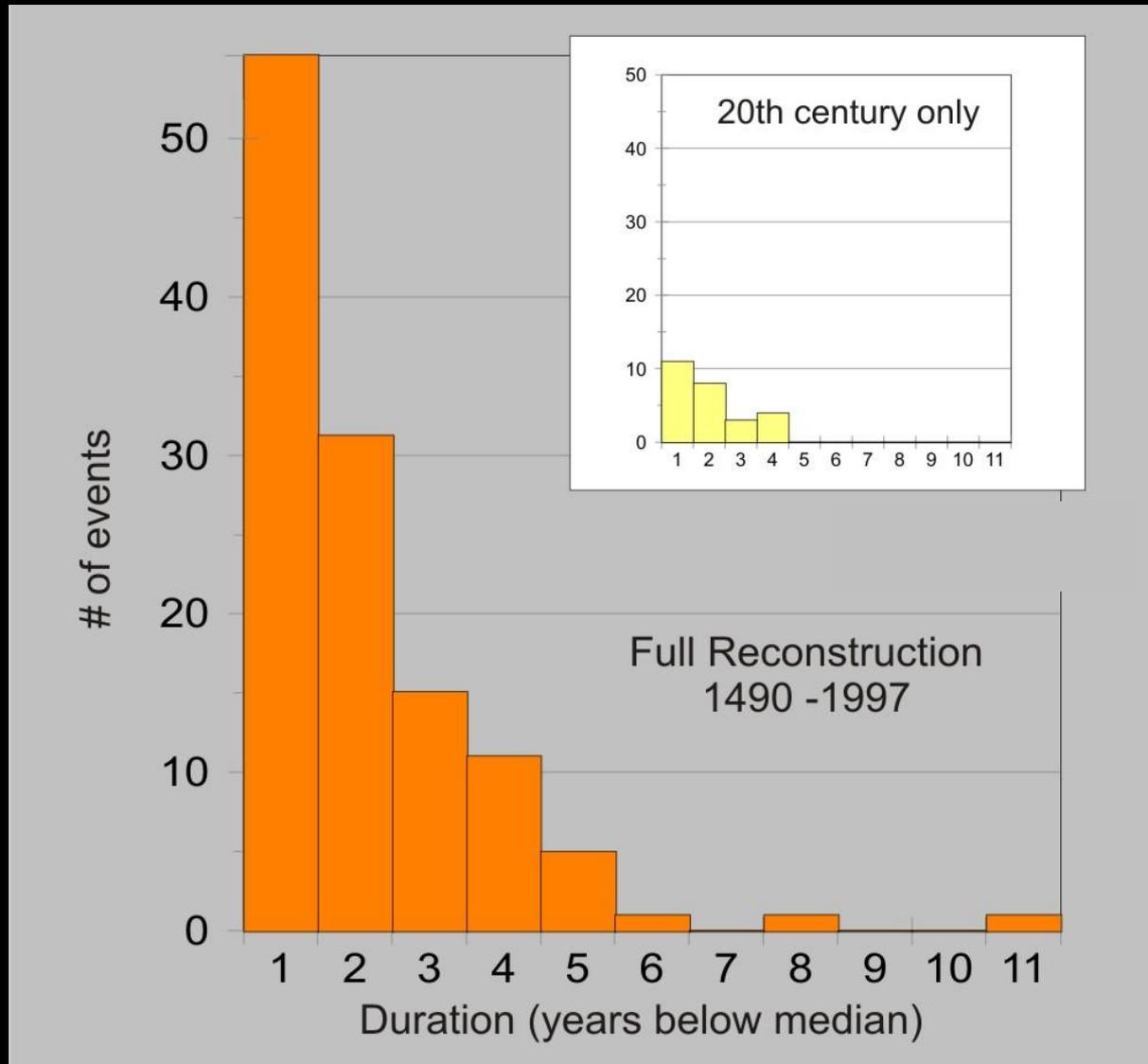
Reconstruction of Colorado River at Lees Ferry, 1490-1997



Assessment of the 2000-2004 drought in a millennial context

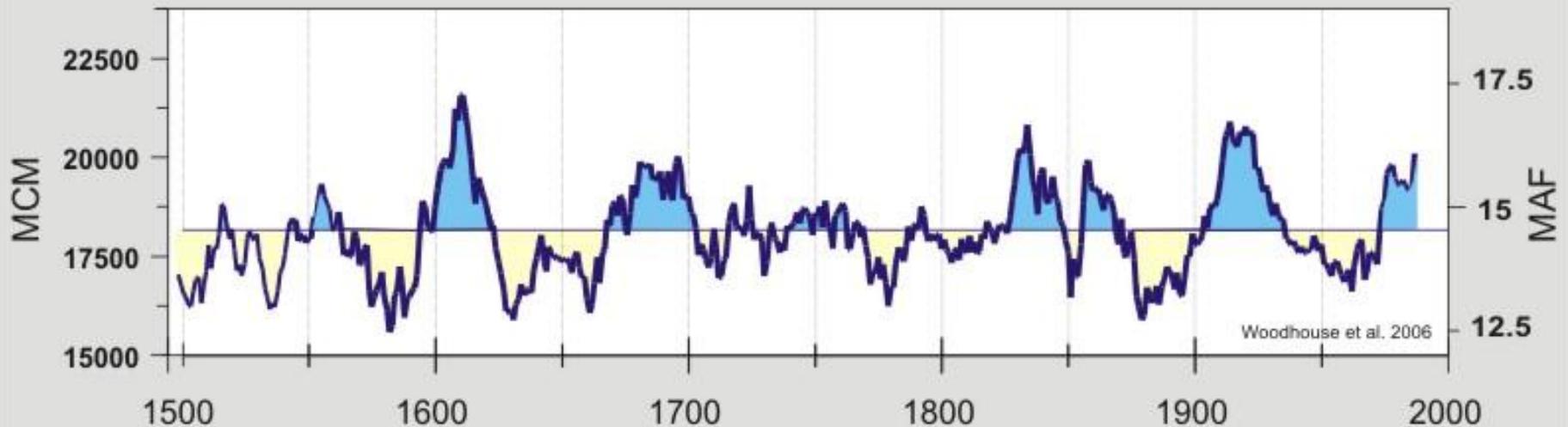


Colorado River drought duration and frequency 1490-1997 compared to the 20th century



Insights on low-frequency (scale of decades to half century) variability

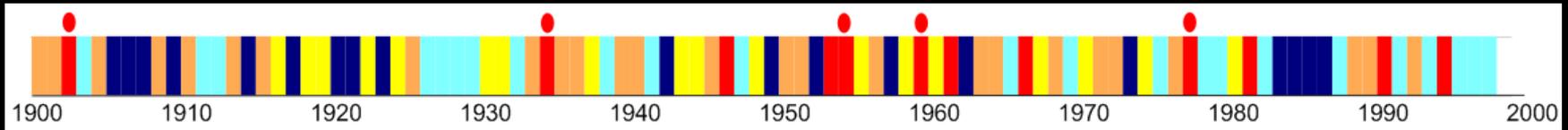
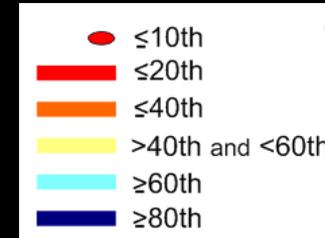
Lees Ferry Streamflow Reconstruction (20-yr moving average), 1490-1997



| Pluvials | Droughts |
|---------------------------------------|--------------------------------------|
| Wettest non-overlapping 20-yr average | 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) |

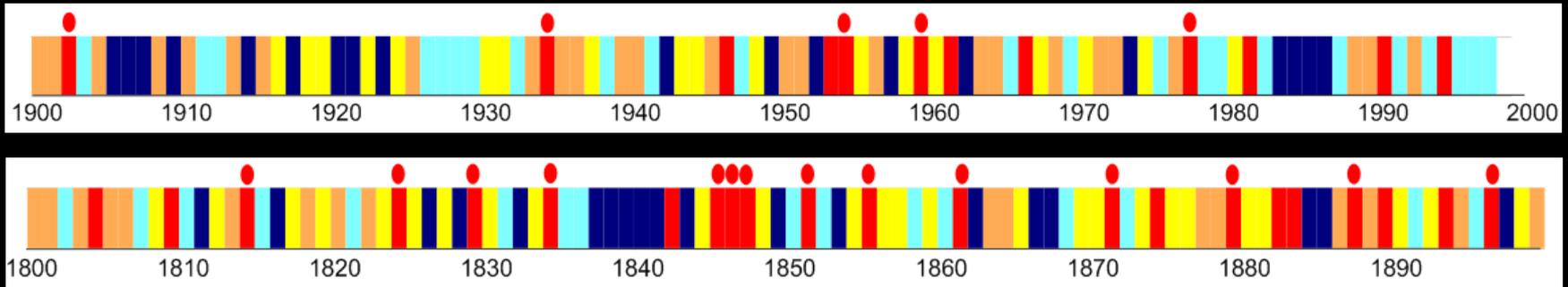
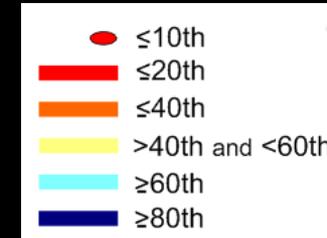
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



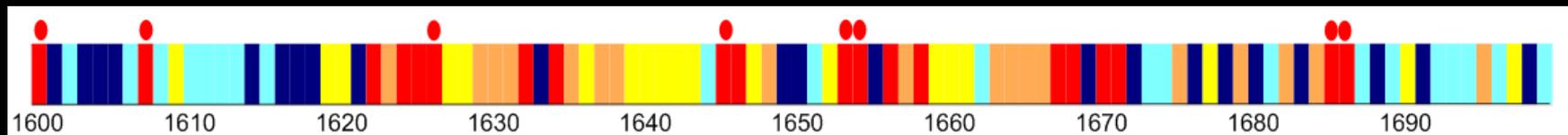
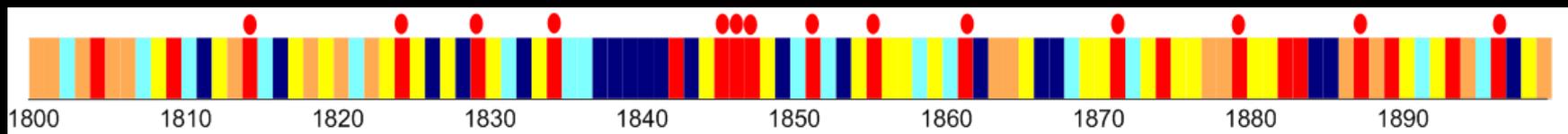
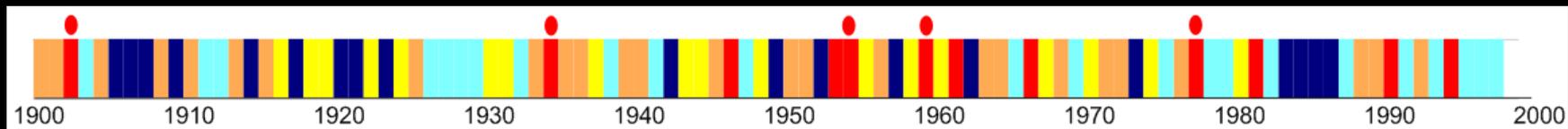
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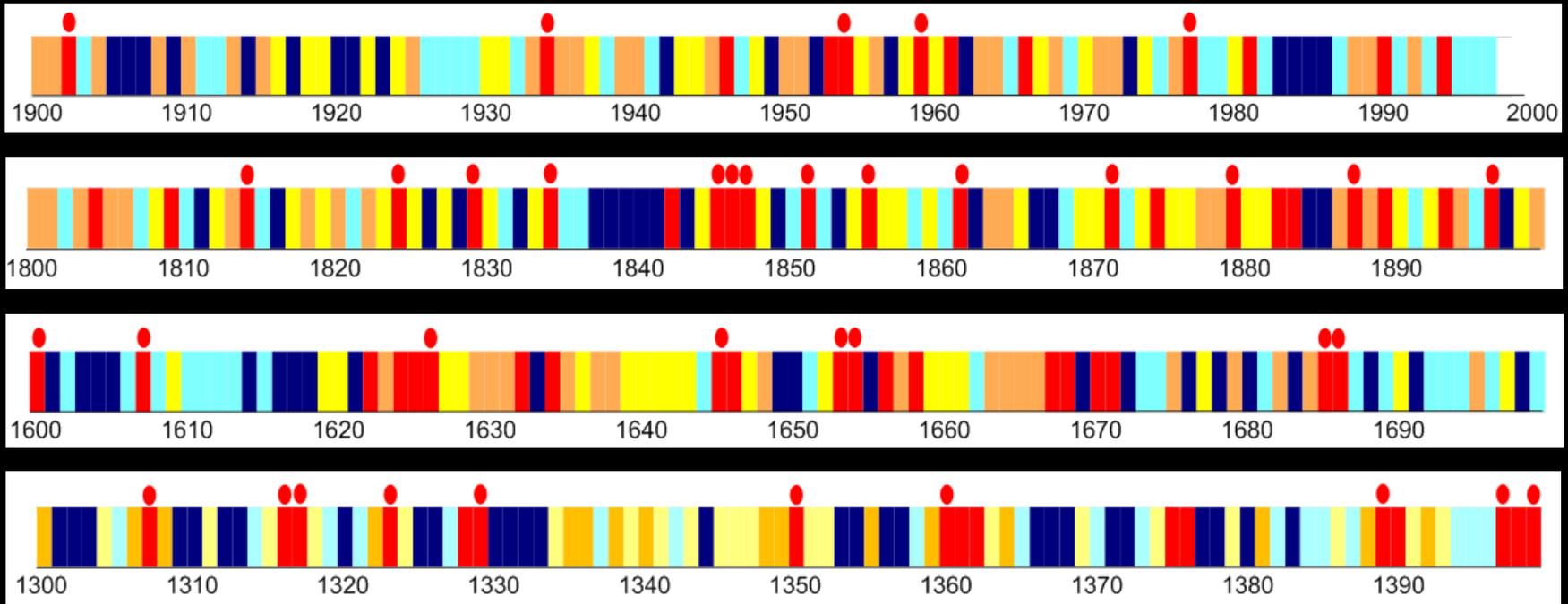
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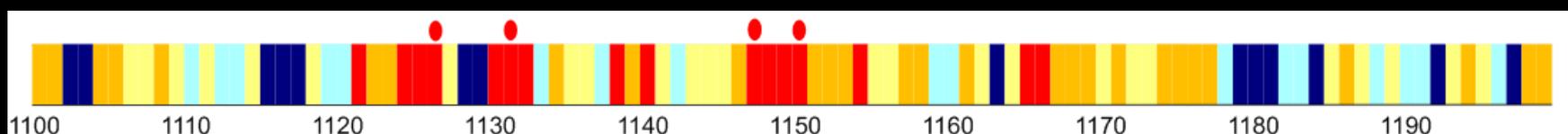
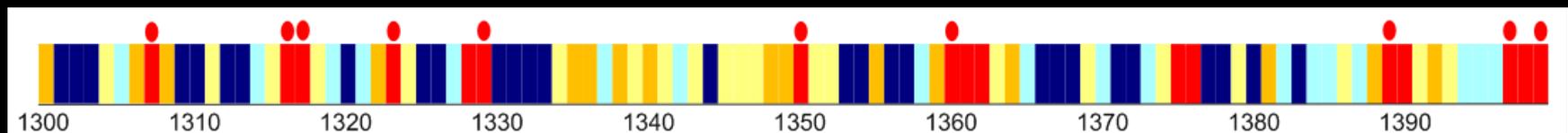
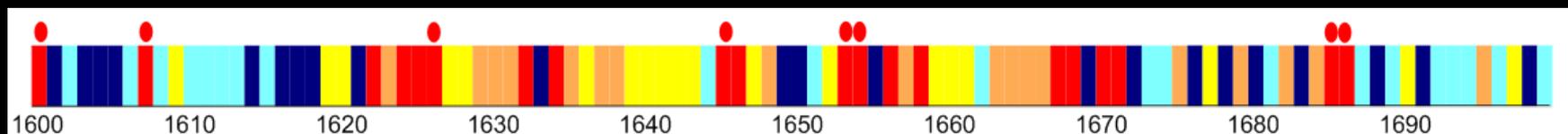
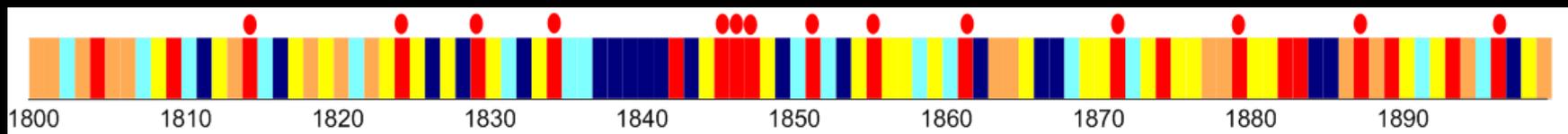
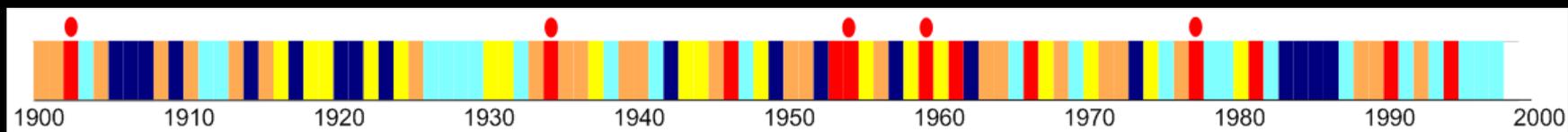
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



How are streamflow reconstructions being used by water providers and other decision makers?

- To provide an awareness of a broader range of hydrologic variability than contained in the gage record
- As the basis for determining a drought “worst-case scenarios”
- To test system reliability under a broader range of conditions by incorporating reconstruction data into water supply models
- To communicate risk or to aid in making recommendations
- When used in combination with climate change projections, to assess a range of plausible future scenarios

How relevant is the record of past streamflow to the future?

- 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.
- Information about past natural hydrologic variability is needed to plan for a future that includes warmer temperatures and increased demands on water resources in the western U.S.



North American Monsoon Reconstructions Project

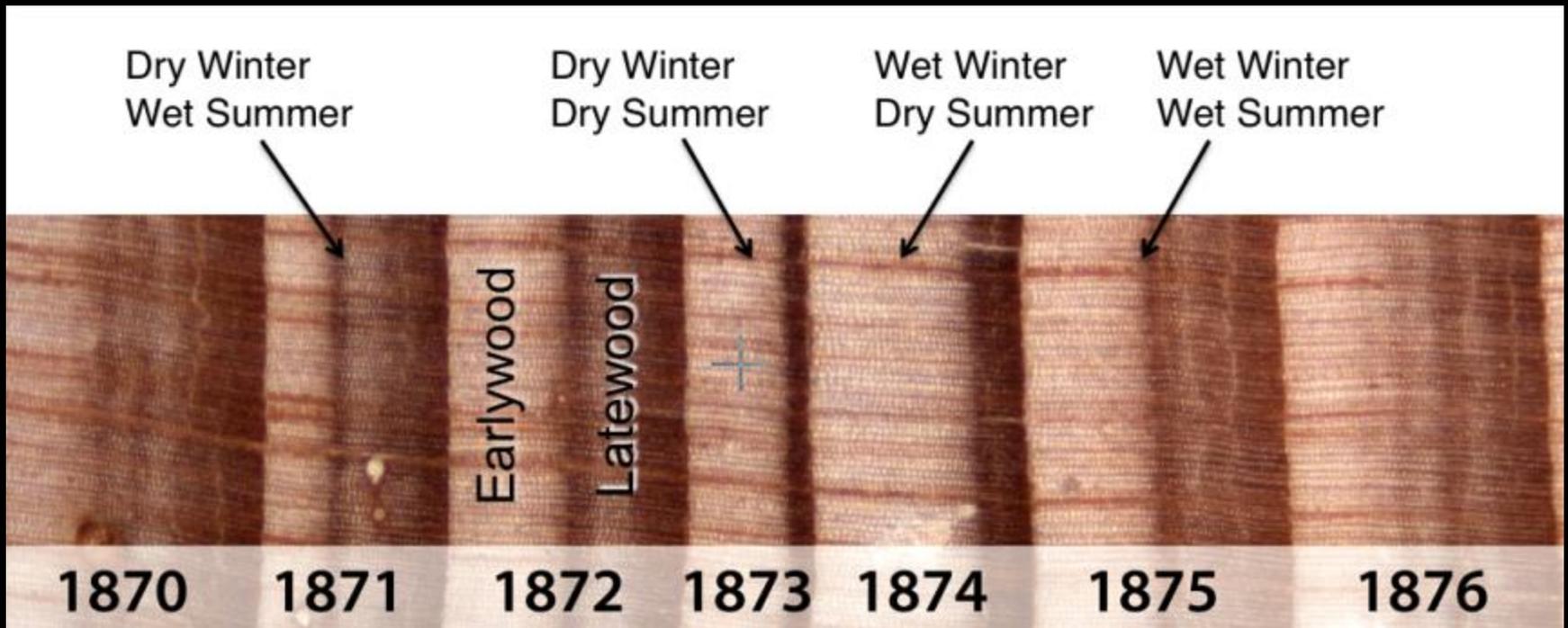


Image: Dan Griffin