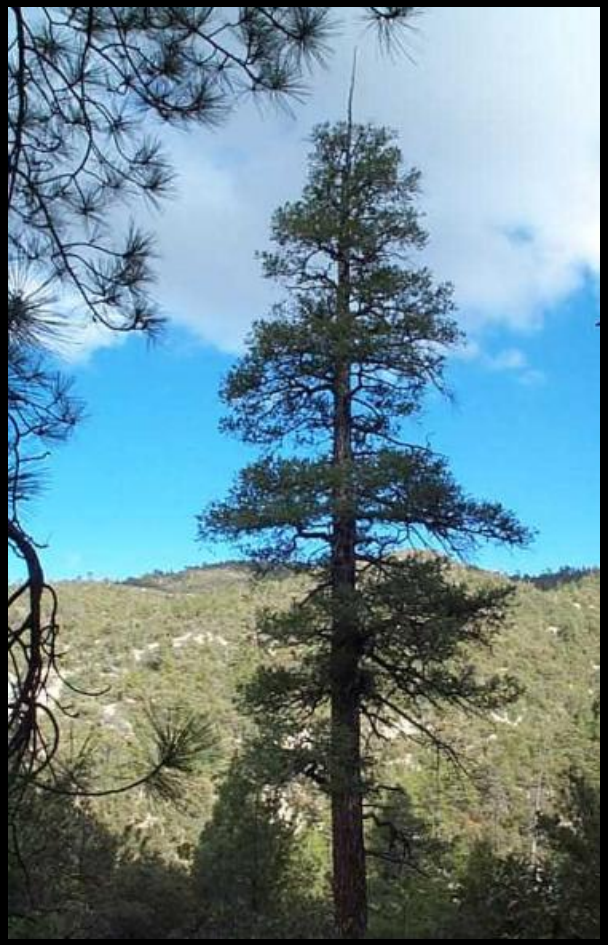
Drought History of the Southwest Reconstructed from Tree Rings

Pima County Local Drought Impact Group

January 12, 2011

Connie Woodhouse*

School of Geography and Development and
Laboratory of Tree-Ring Research
University of Arizona



CLIMAS

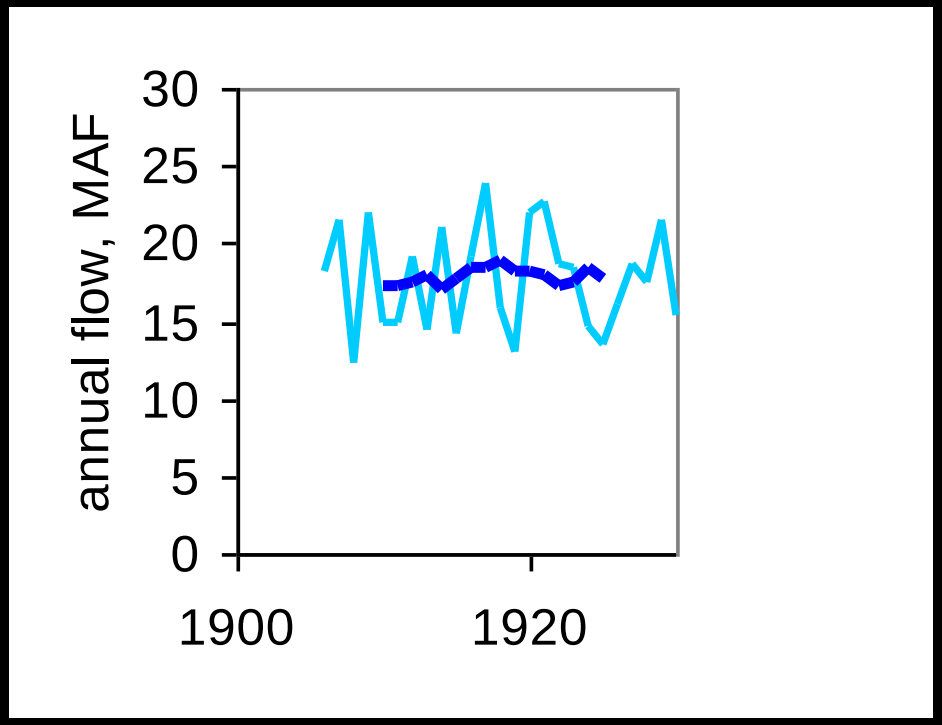
THE UNIVERSITY OF ARIZONA

*This presentation contains the contributions of many of my colleagues

- Overview of tree rings and drought reconstruction
- Reconstructions
  - Colorado River flow (upper and lower basin)
  - Spatial patterns of drought
  - Monsoon/winter precipitation for SE Arizona
- What information reconstructions provide

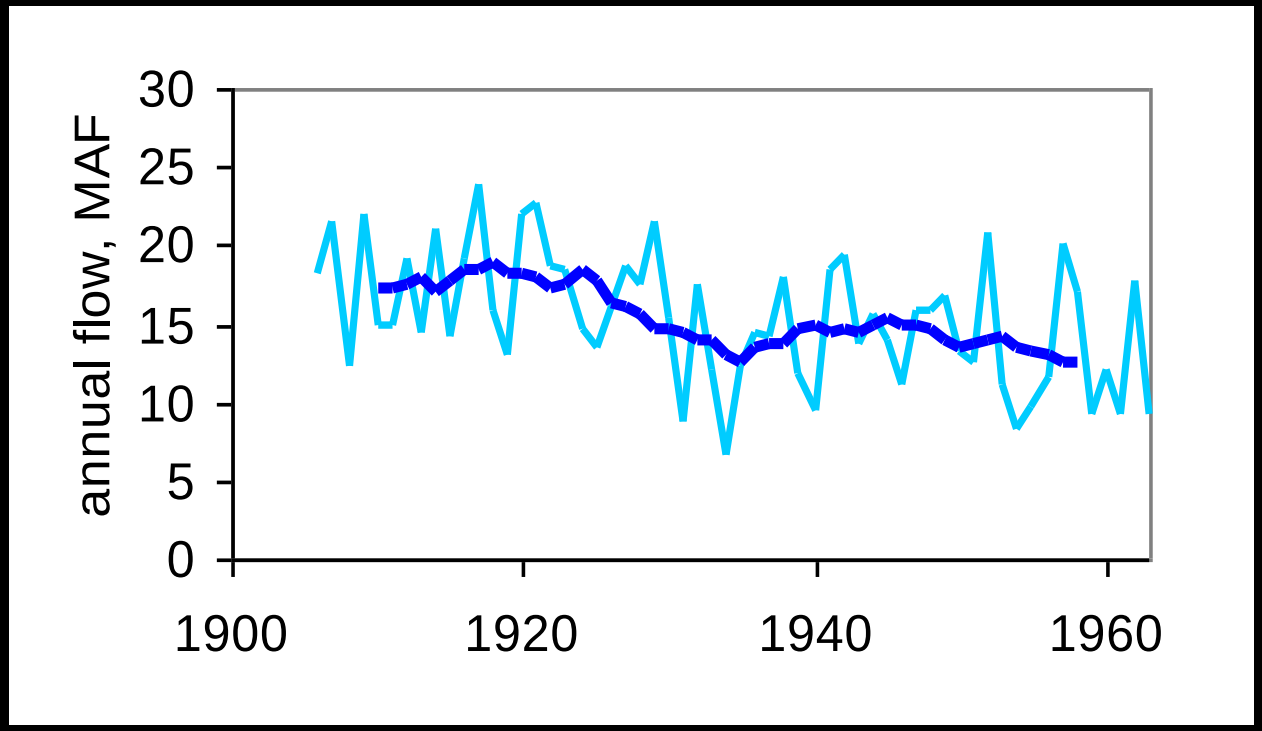
Why consider droughts of the past?

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



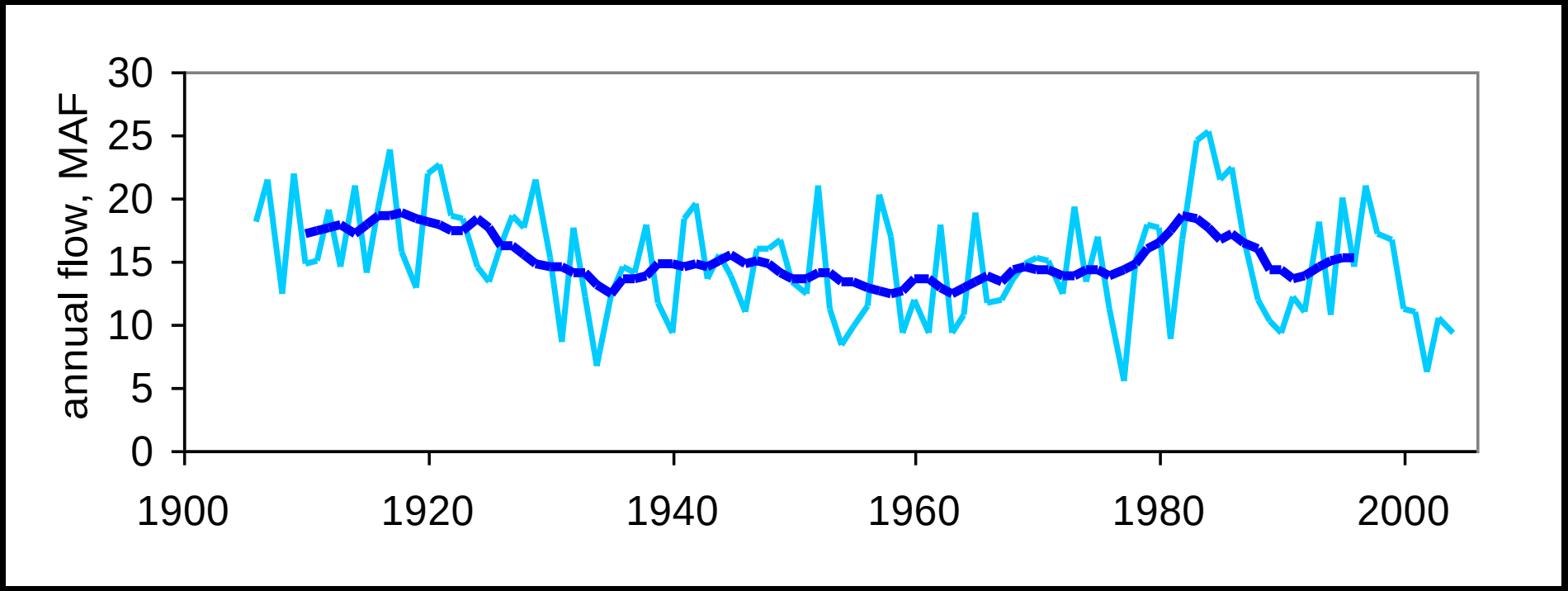
Colorado River at Lees Ferry, 1906-1930

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



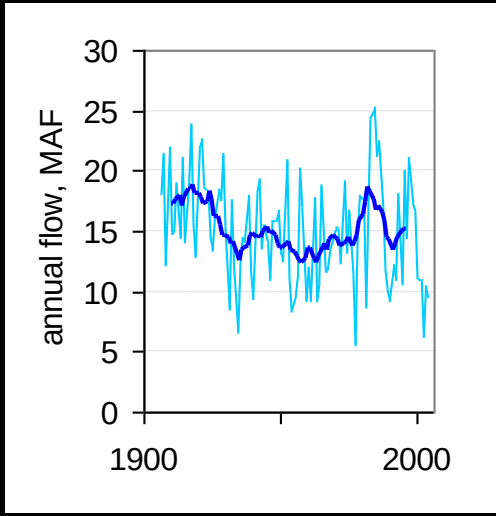
Colorado River at Lees Ferry, 1906-1960

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



Colorado River at Lees Ferry, 1906-2004

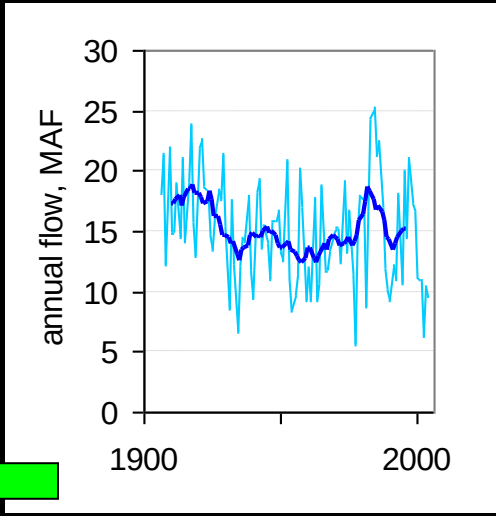
How representative is the gage record over a longer time frame?



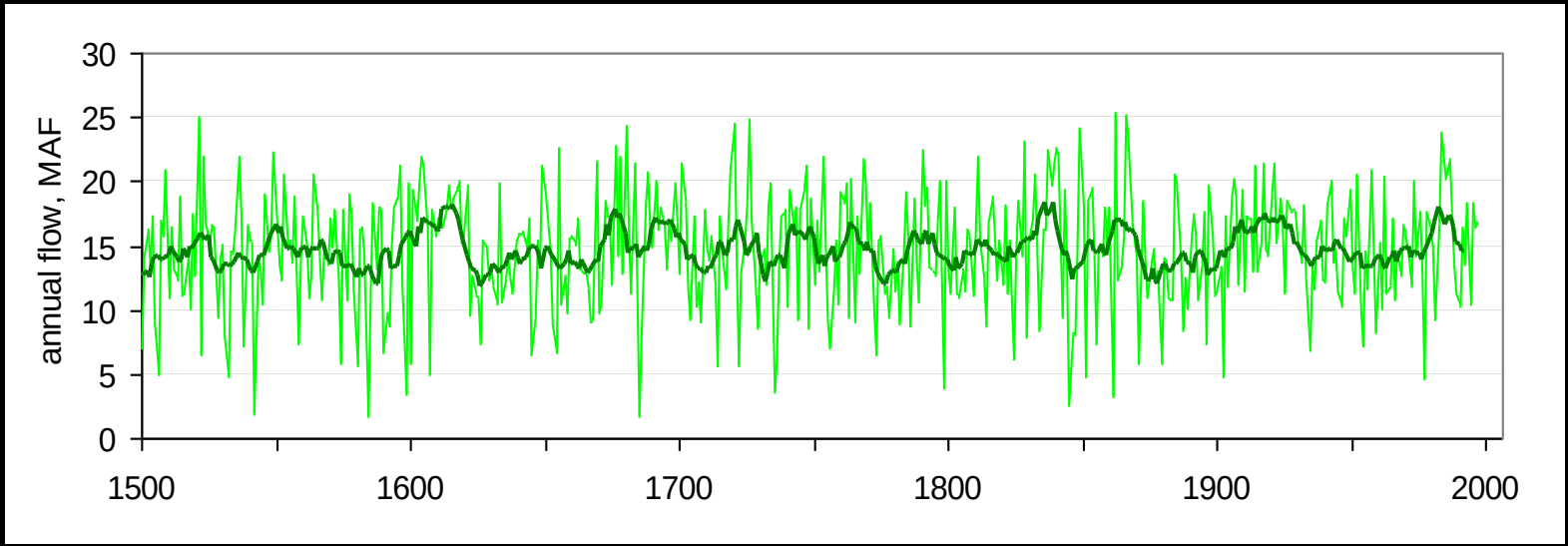
Colorado River at Lees Ferry, 1906-2004

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



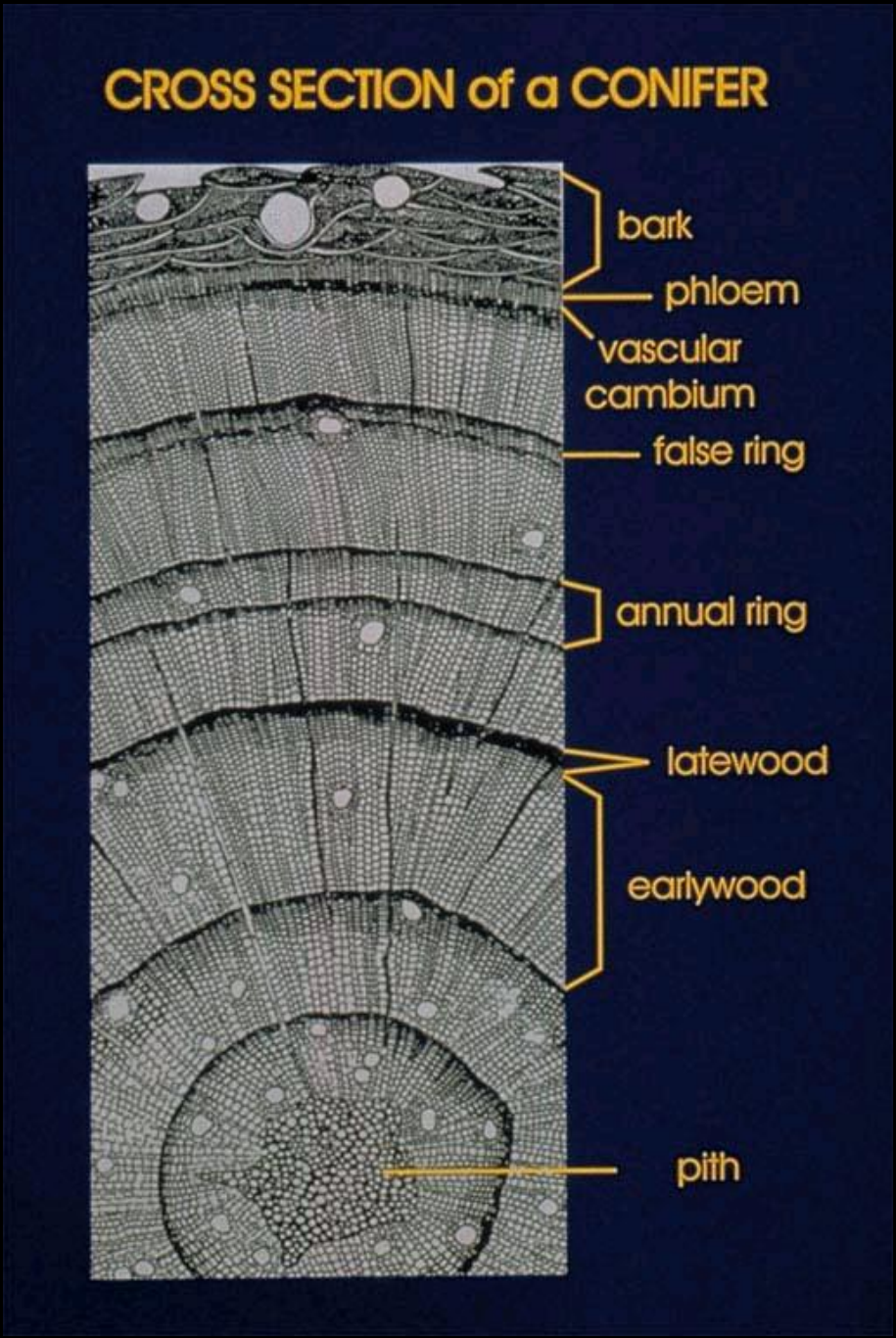
Tree-ring reconstruction of Colorado R., 1490-1997

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.



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

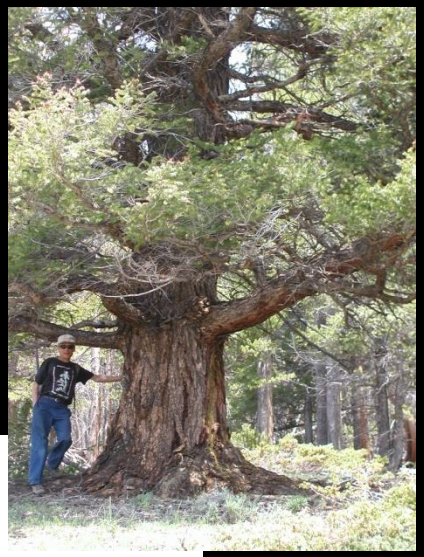
Moisture-sensitive tree species growing on open, well drained sites reflect moisture variability in their ring widths

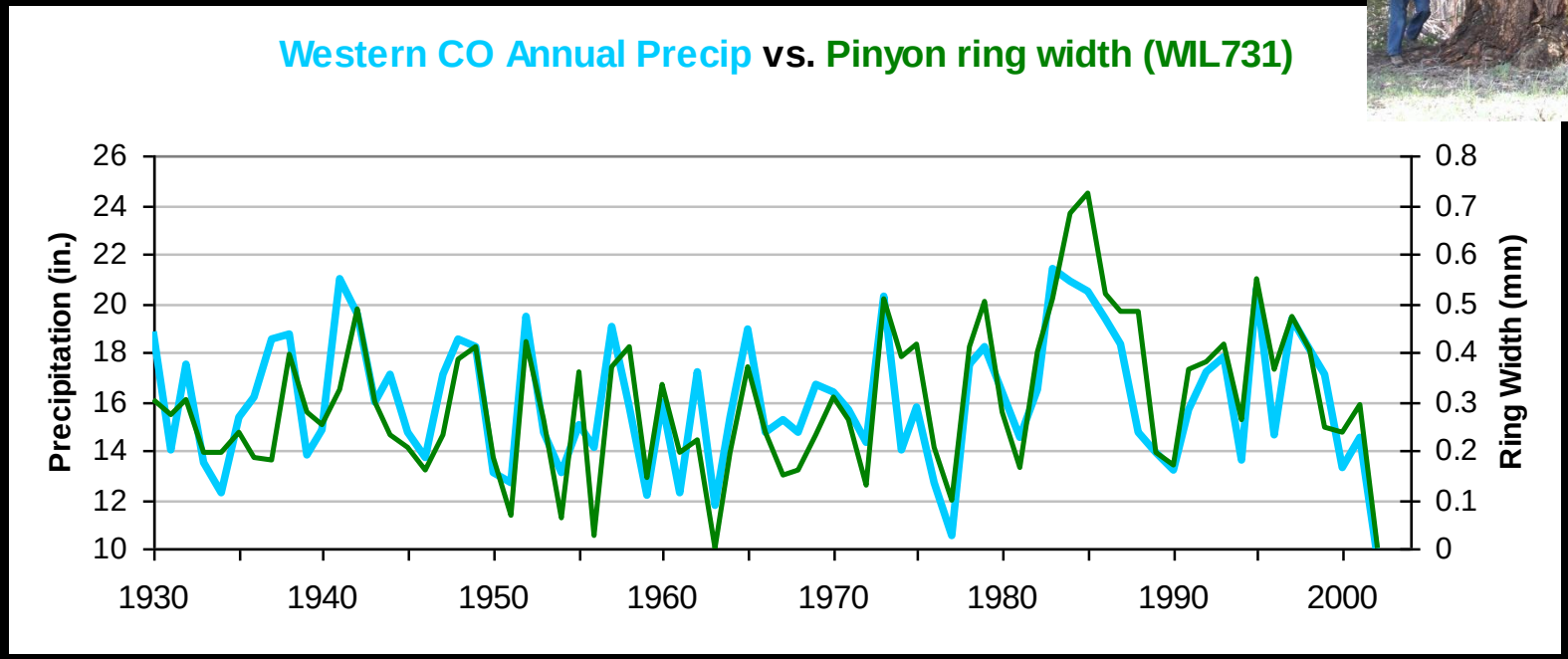
Douglas-fir

Pinyon pine

Ponderosa pine

Moisture-stressed trees closely track variations in precipitation

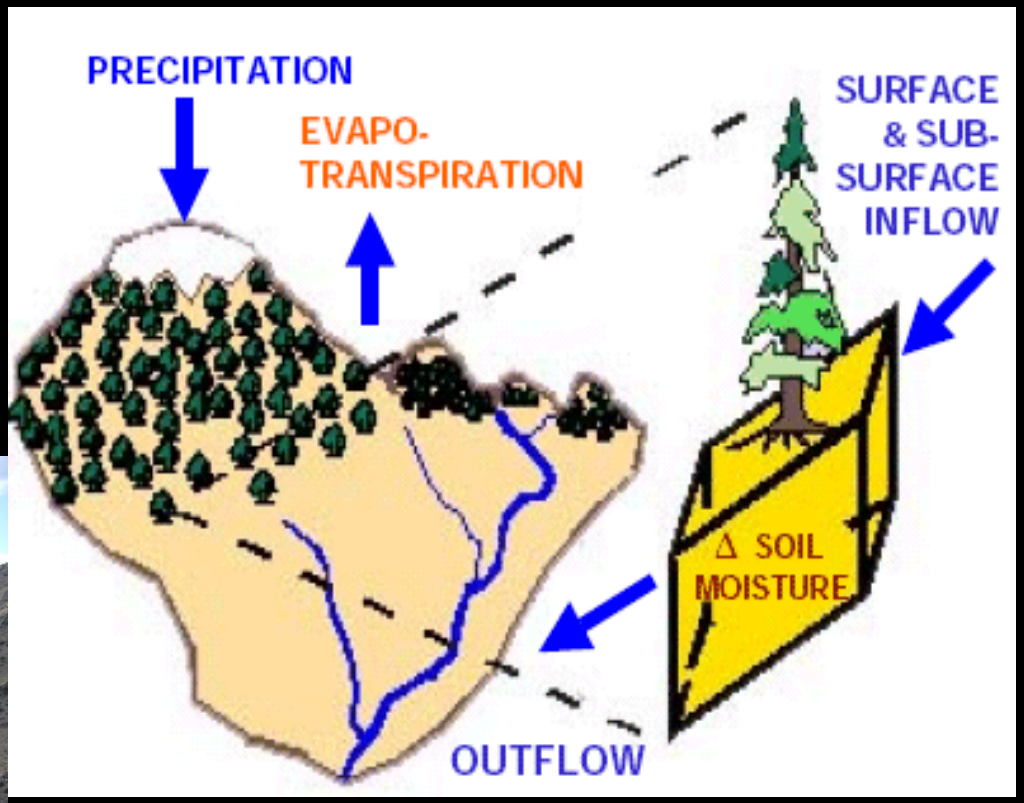




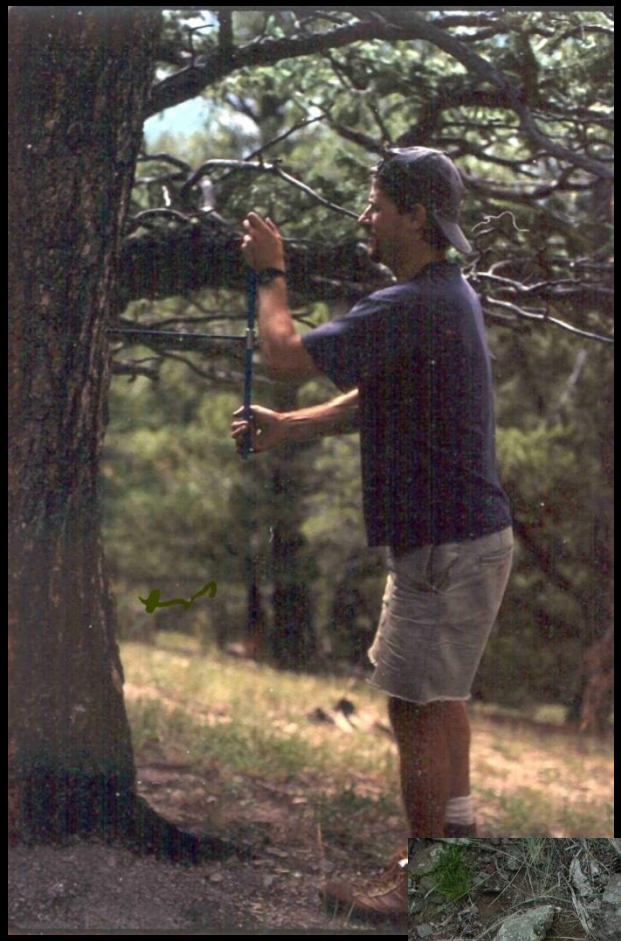
Ring widths from a single tree near Grand Junction, CO are plotted with annual precipitation in western Colorado. The correlation between the two is 78% (r = 0.78).

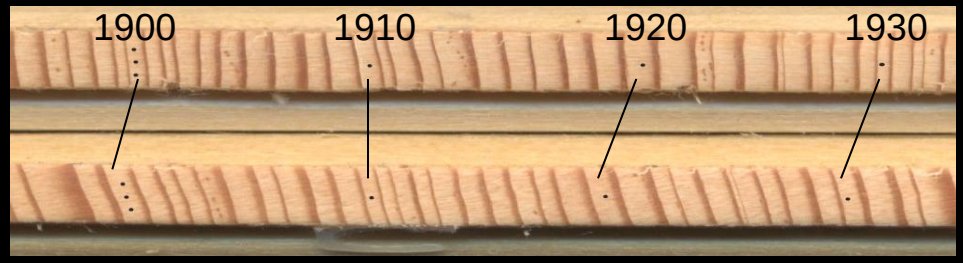
How can tree rings reflect variations in streamflow?

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

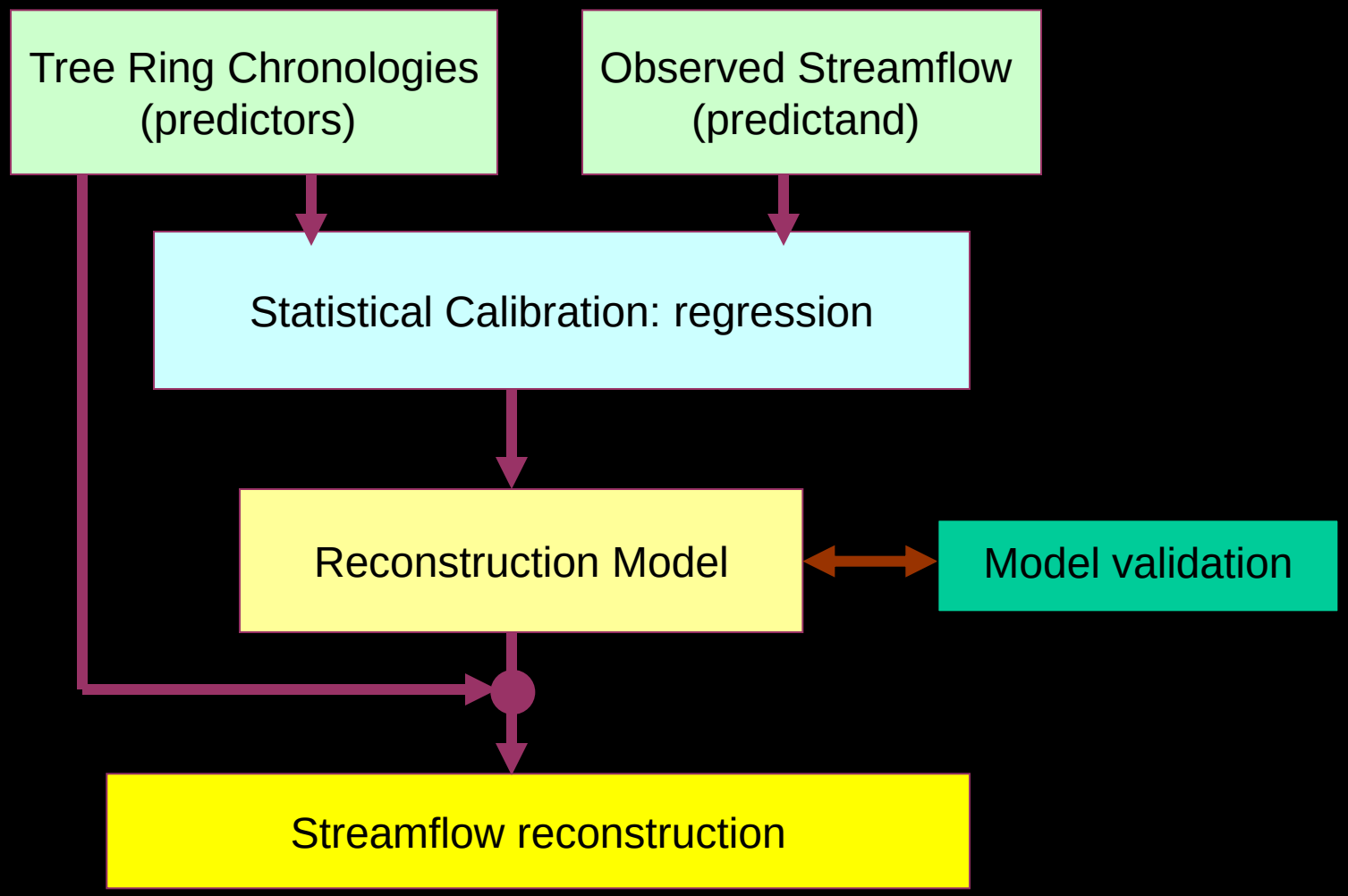




Cores mounted and sanded, then dated, measured, and averaged into site tree-ring chronologies

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

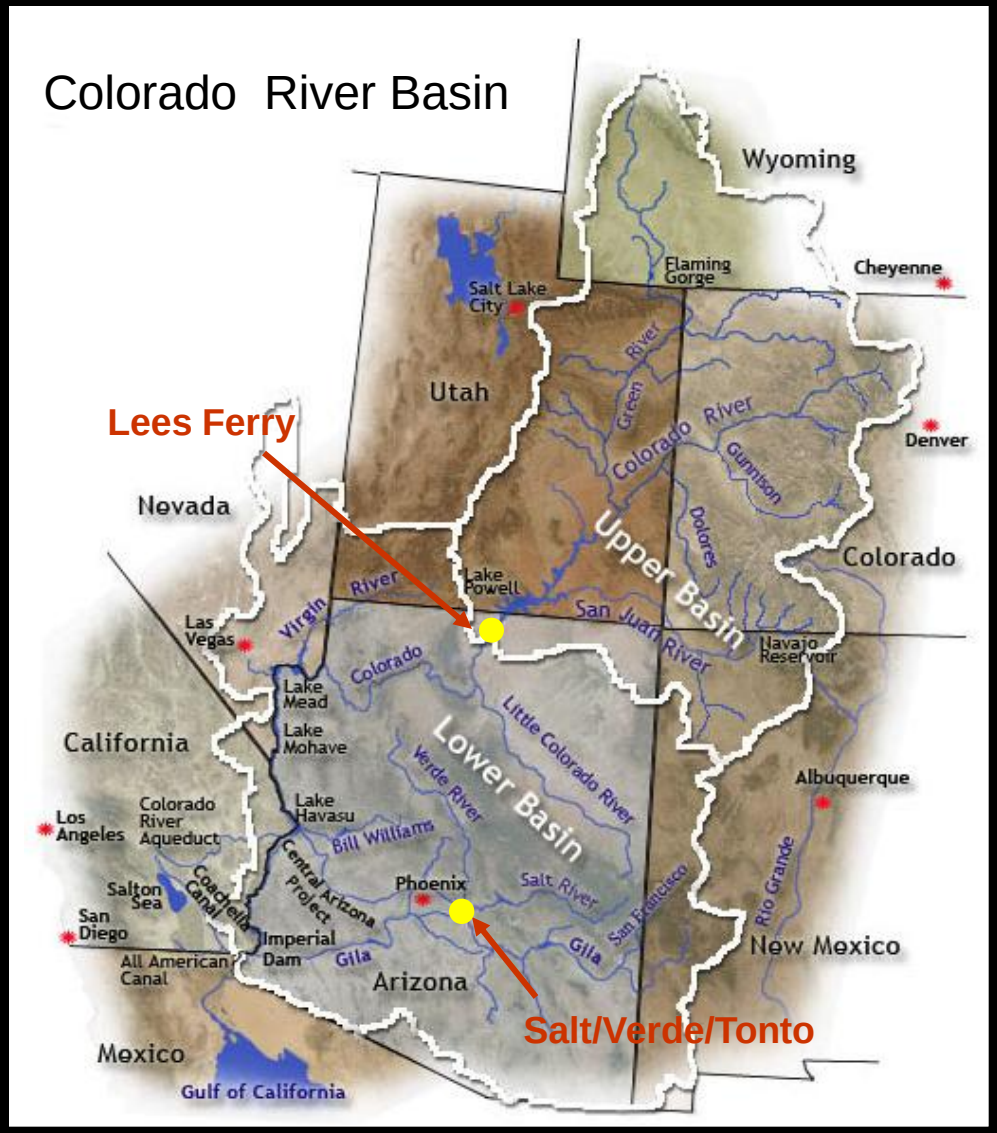
Generating the streamflow reconstruction



based on Meko (2005)

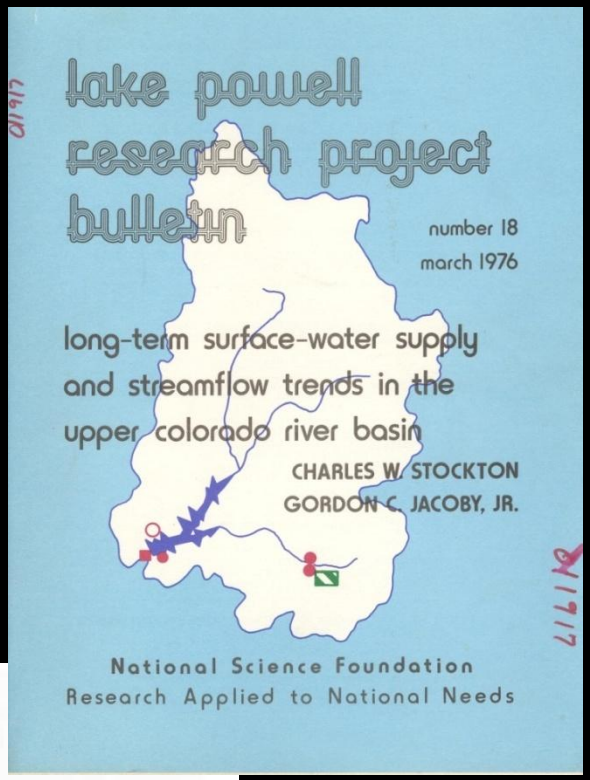
Reconstructions for the Colorado River Basin

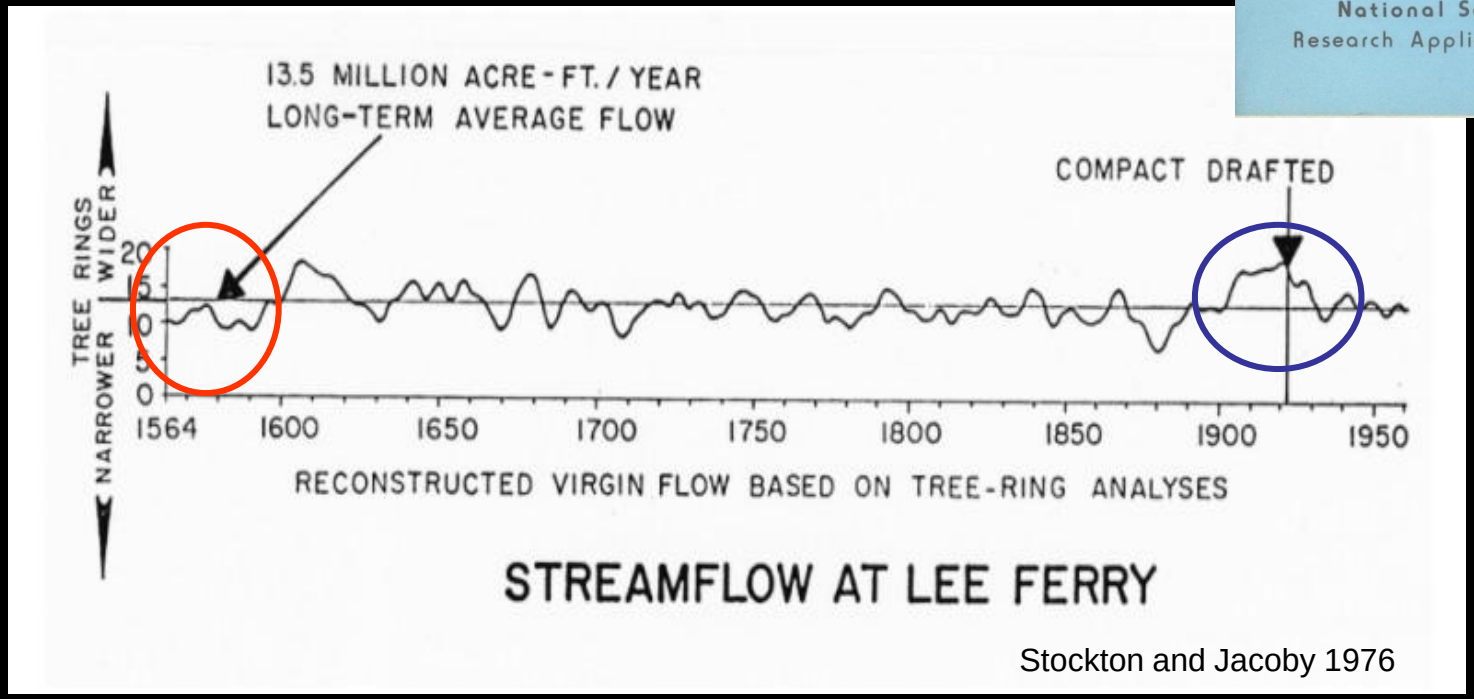
- Upper Colorado River (Lees Ferry gage)
- Lower Colorado River basin (Salt/Verde/Tonto Ck)



http://www.crwua.org/coloradoriver/index.cfm?action=rivermap

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

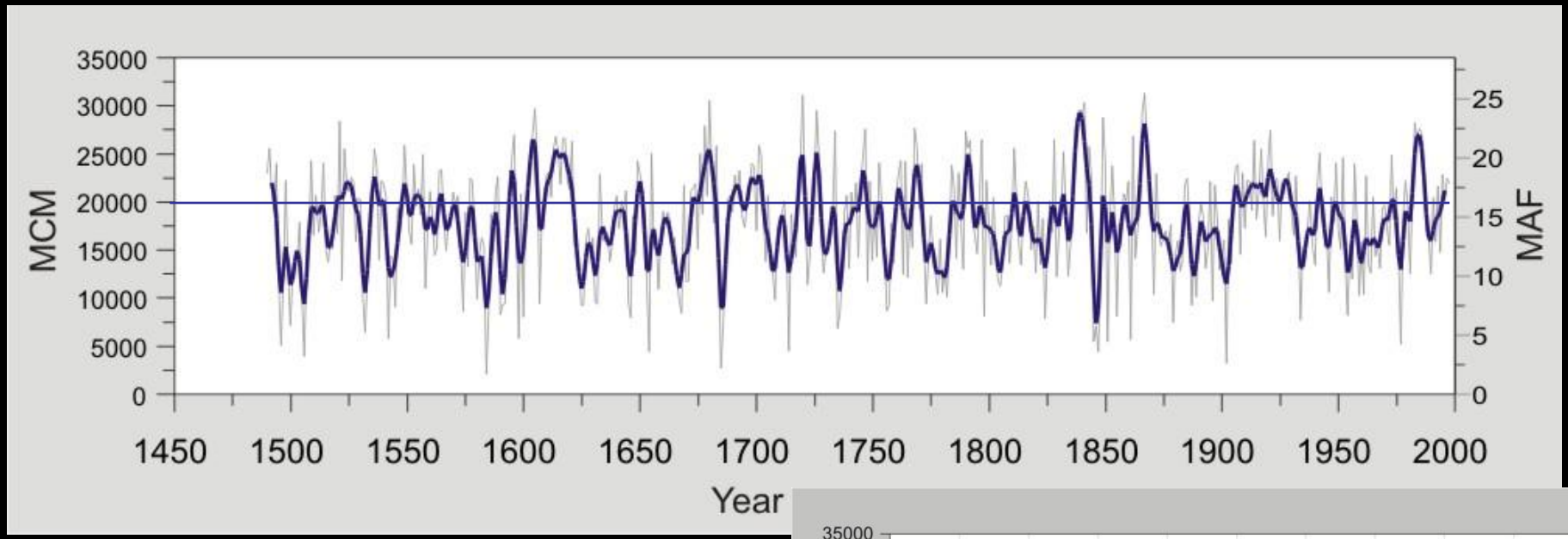


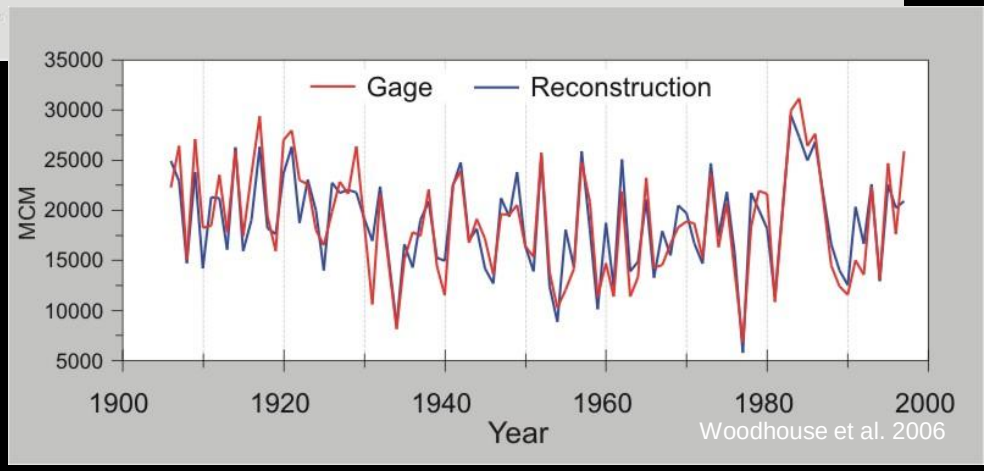


Stockton and Jacoby 1976

Stockton and Jacoby's work was updated with new tree-ring collections in 1997, extending the Lees Ferry reconstruction to 1997 and back to 1490

Reconstruction of Colorado River at Lees Ferry, 1490-1997



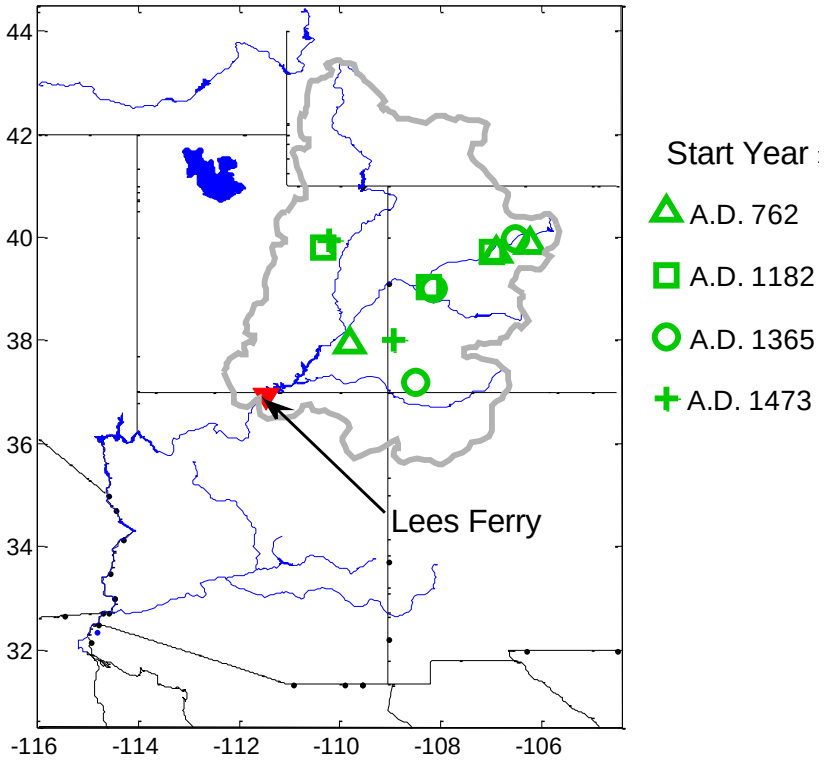


Woodhouse et al. 2006

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

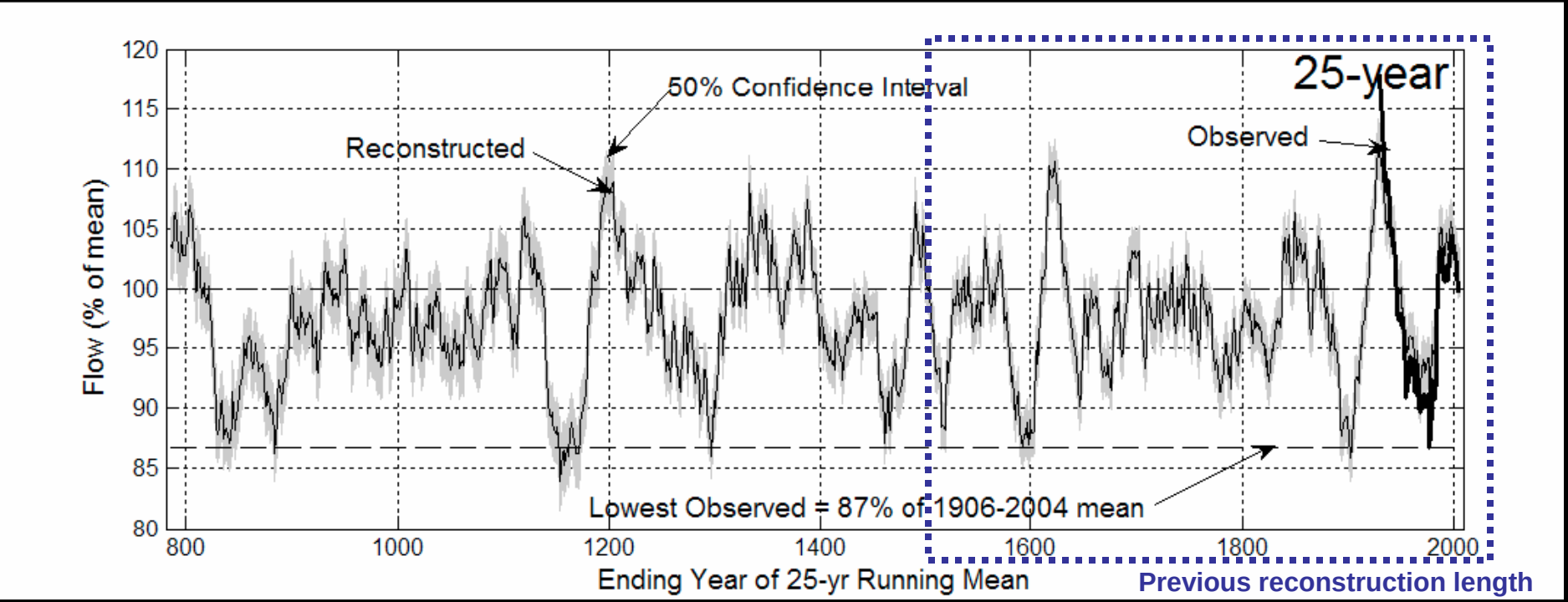
The Lees Ferry reconstruction has now been extended even further back in time using stumps, logs, and remnants of wood

Locations of chronologies used in the extended Lees reconstruction



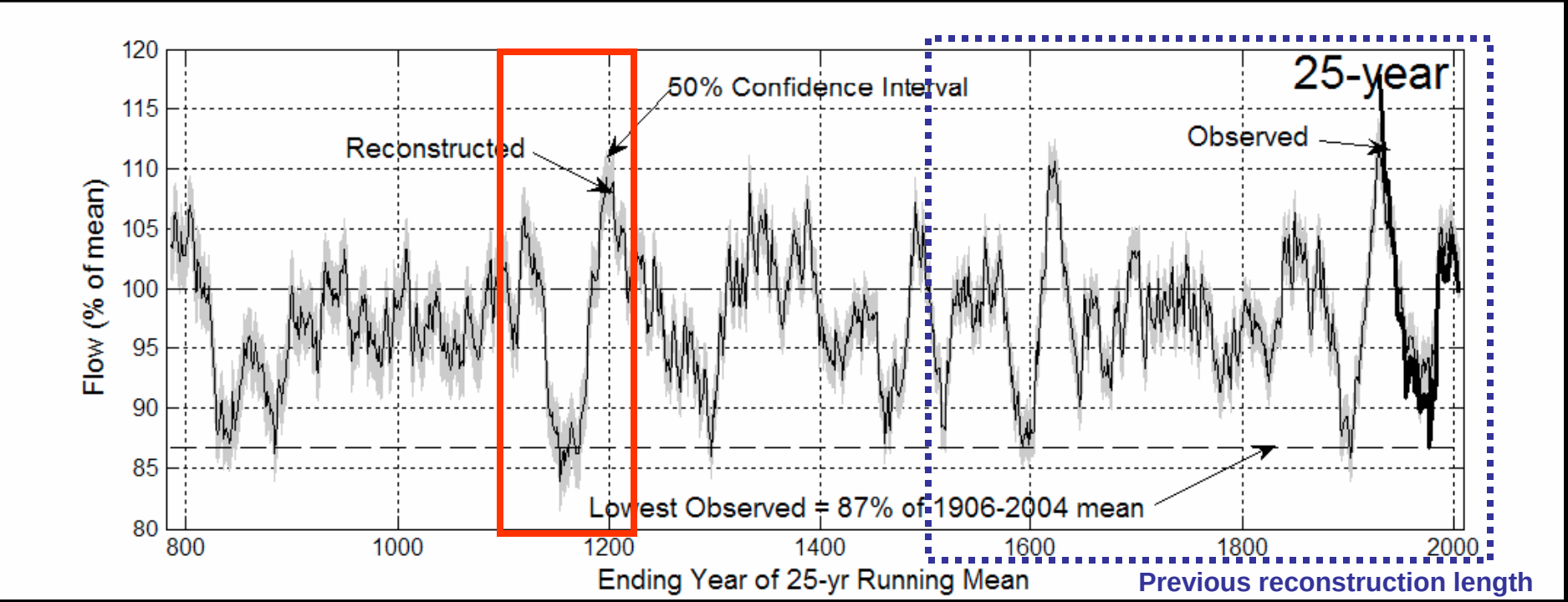
Meko et al. 2007

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

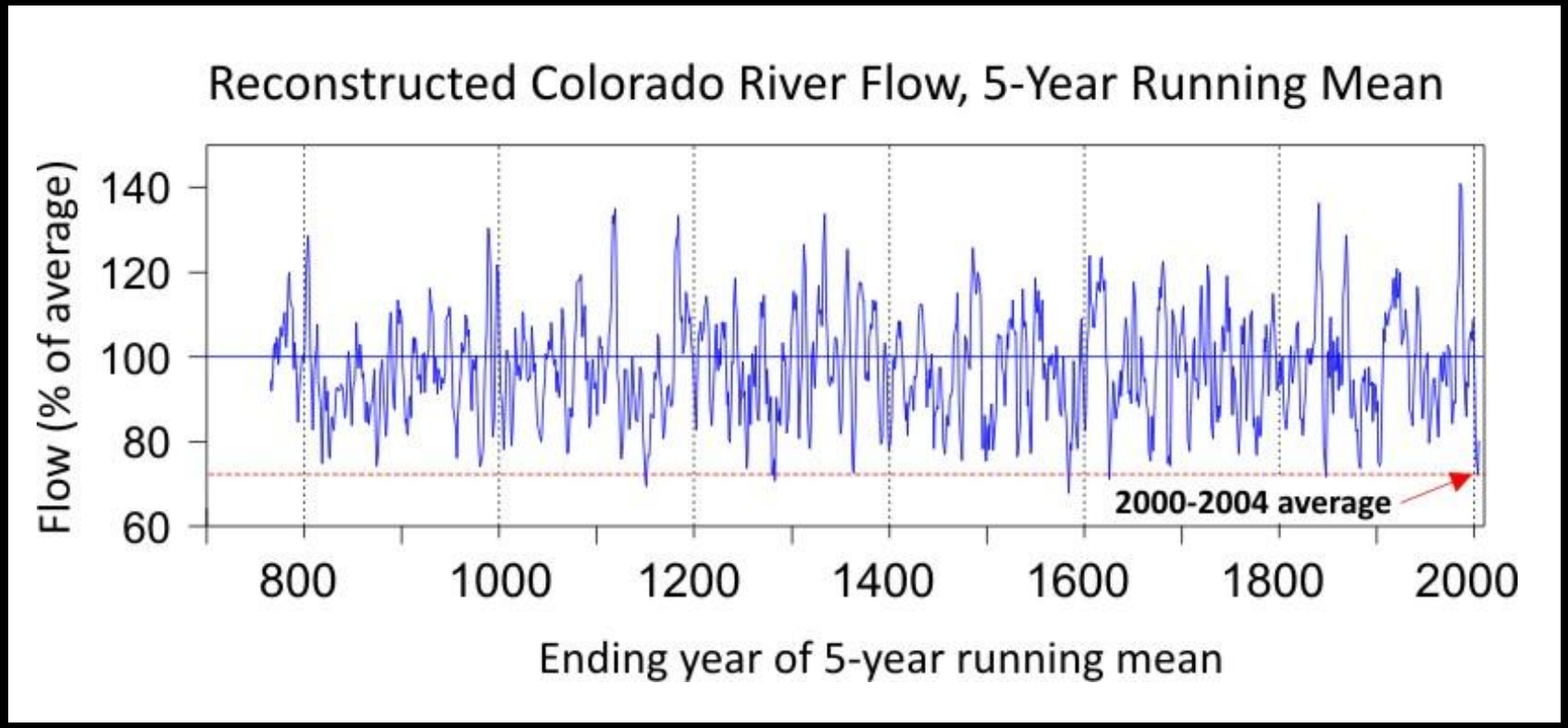


25-yr running means of reconstructed and observed annual flow of the Colorado River at Lees Ferry, expressed as percentage of the 1906-2004 observed mean (Meko et al. 2007).

What the Colorado River reconstructions provide:

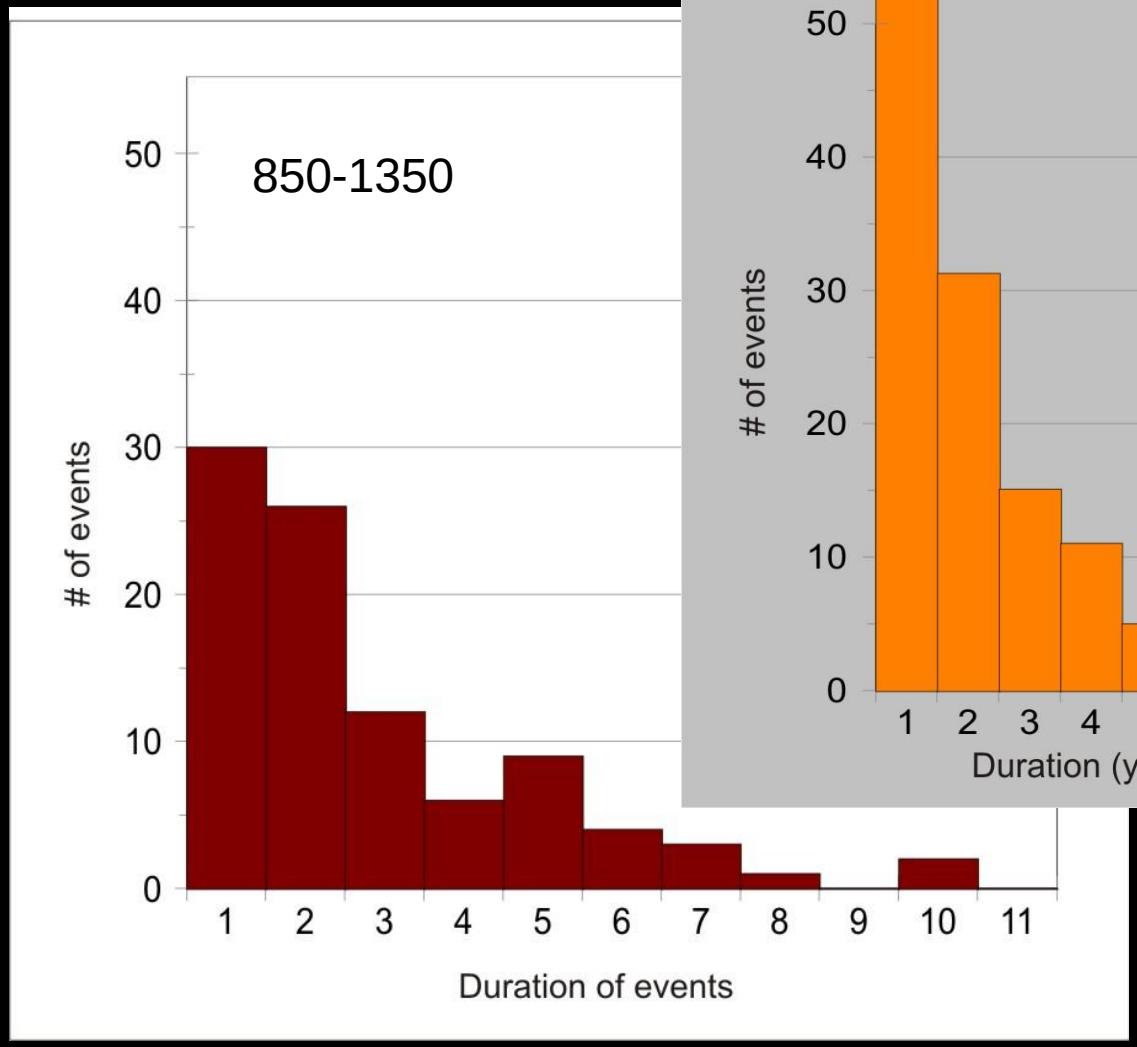
- context for assessing gage record over a longer time frame
- a way to evaluate the recent drought in terms of natural variability over past centuries
- a framework for understanding the range of drought characteristics (intensity, duration, magnitude) that has occurred
- an understanding of the rich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

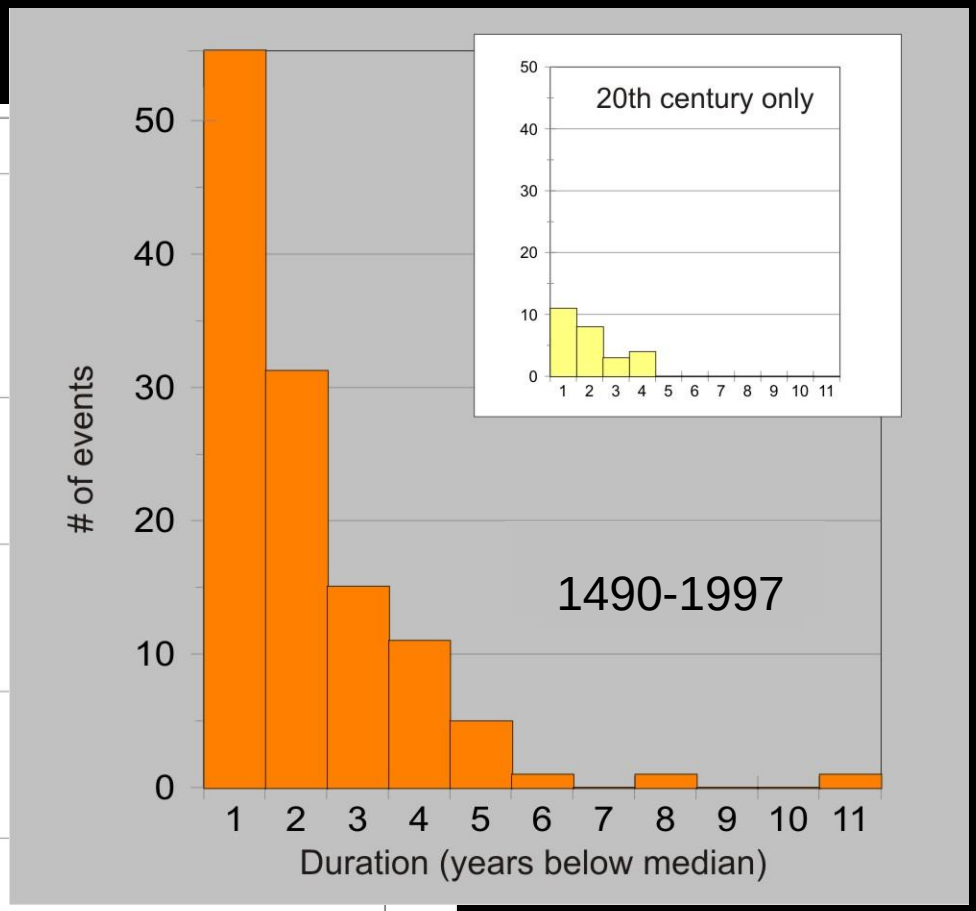
Assessment of the 2000-2004 drought in a millennial context



Meko et al. 2007

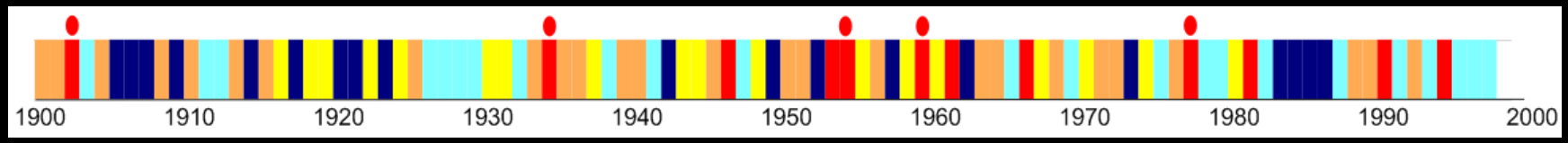
Drought duration and frequency during the medieval period (850-1350) compared to 1490-1997, and the 20th century





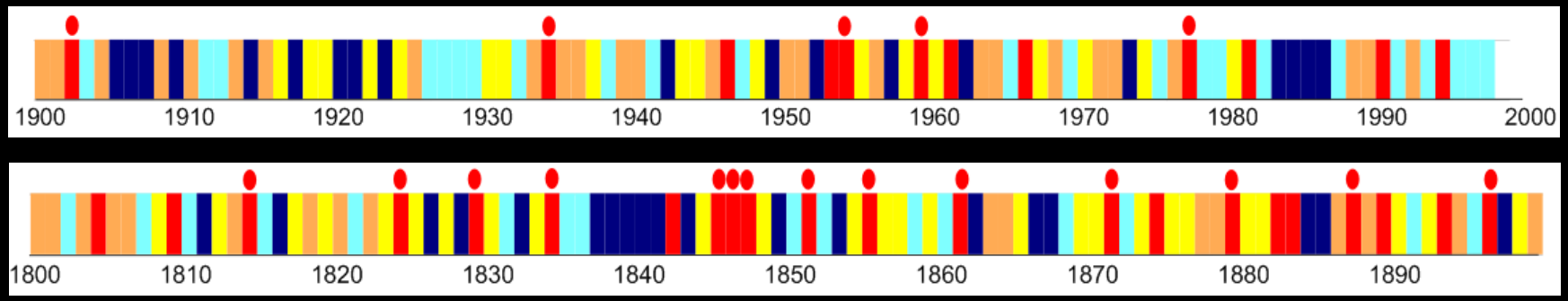
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



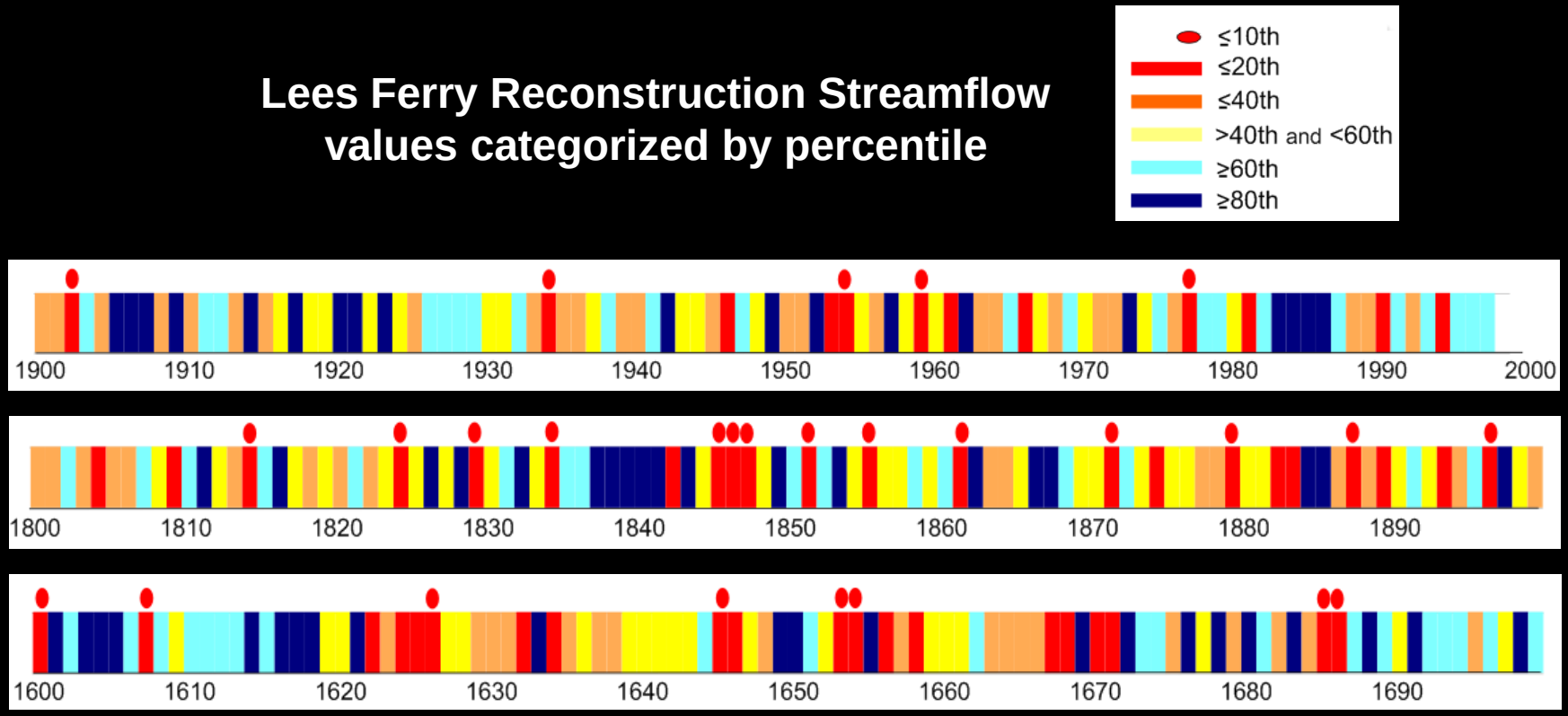
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



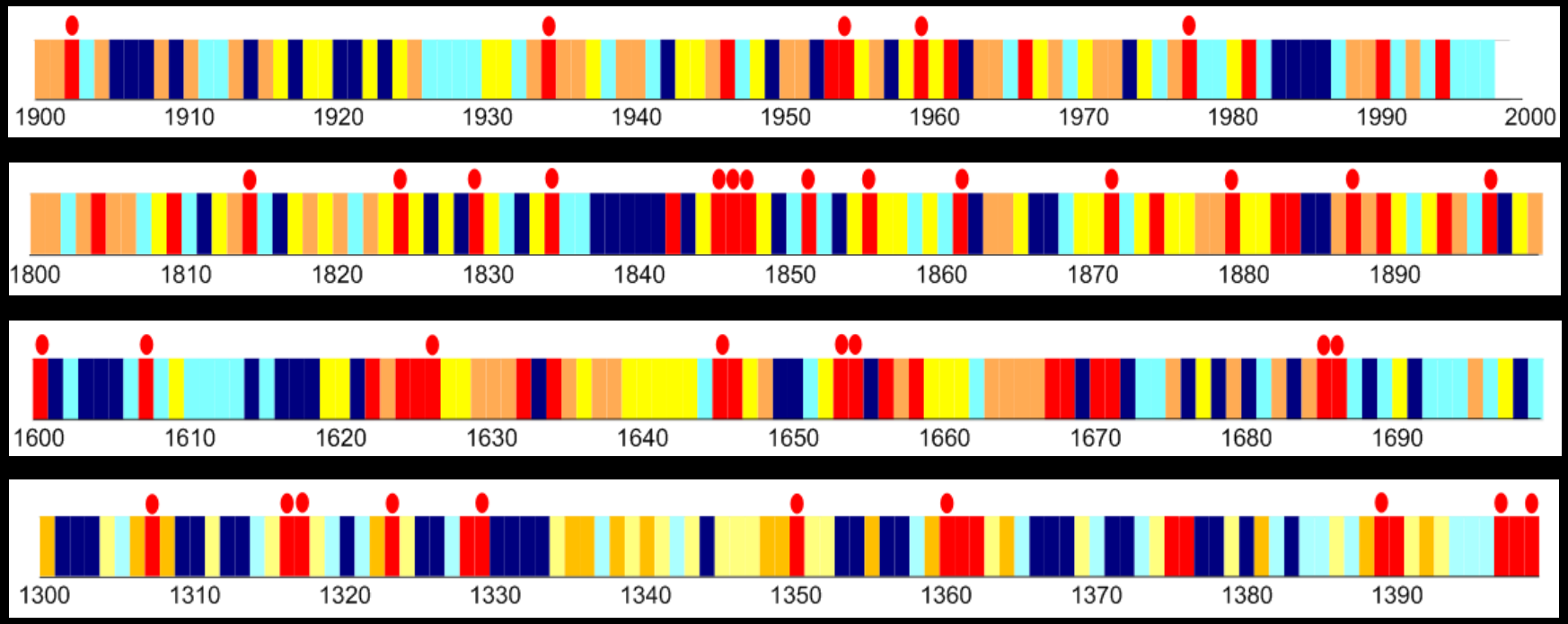
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



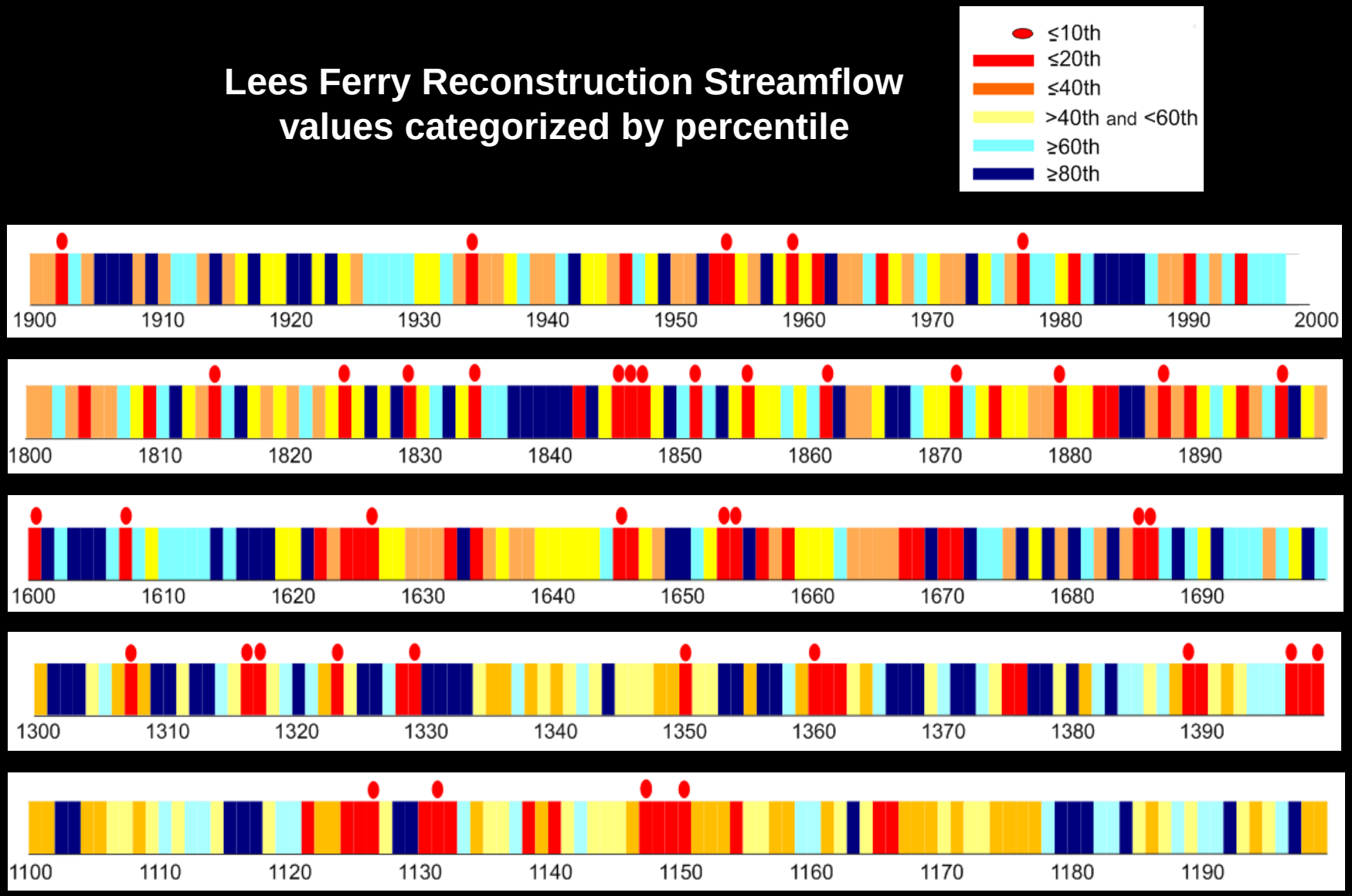
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile

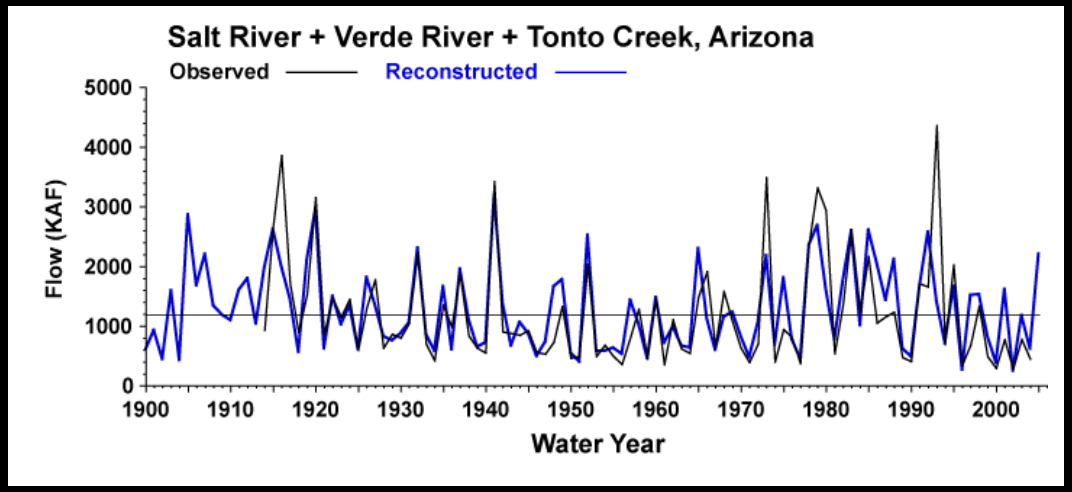


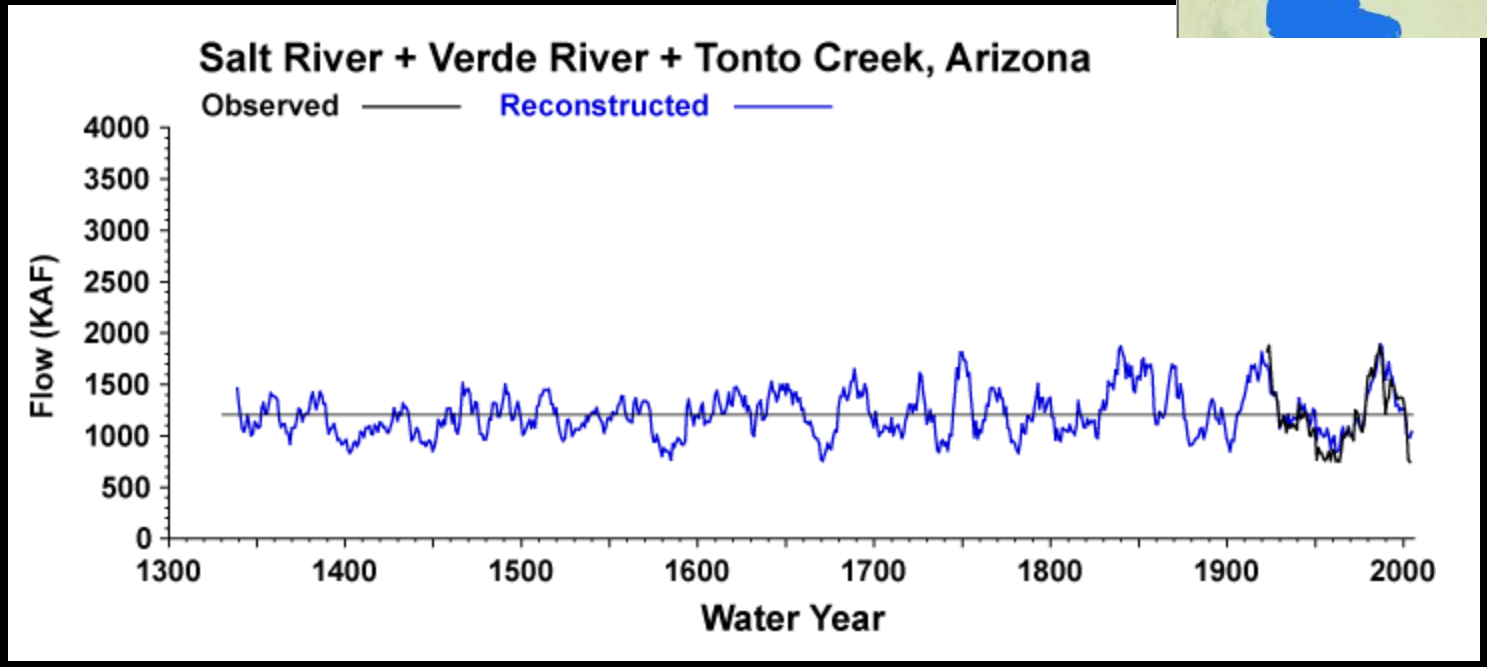
A richer sequence of flows than provided by the gage record alone

Lees Ferry Reconstruction Streamflow values categorized by percentile



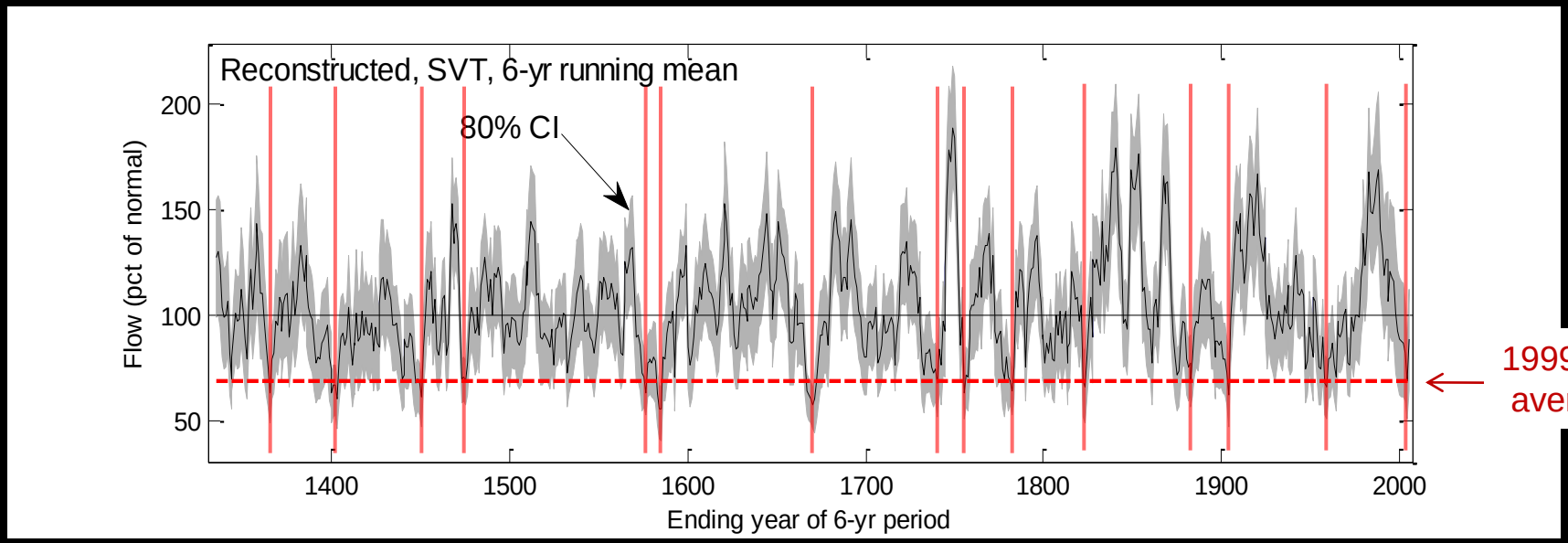
Reconstruction of Lower Colorado River tributaries, Verde R, Salt R. and Tonto Ck





Hirschboeck and Meko, 2008 for SRP

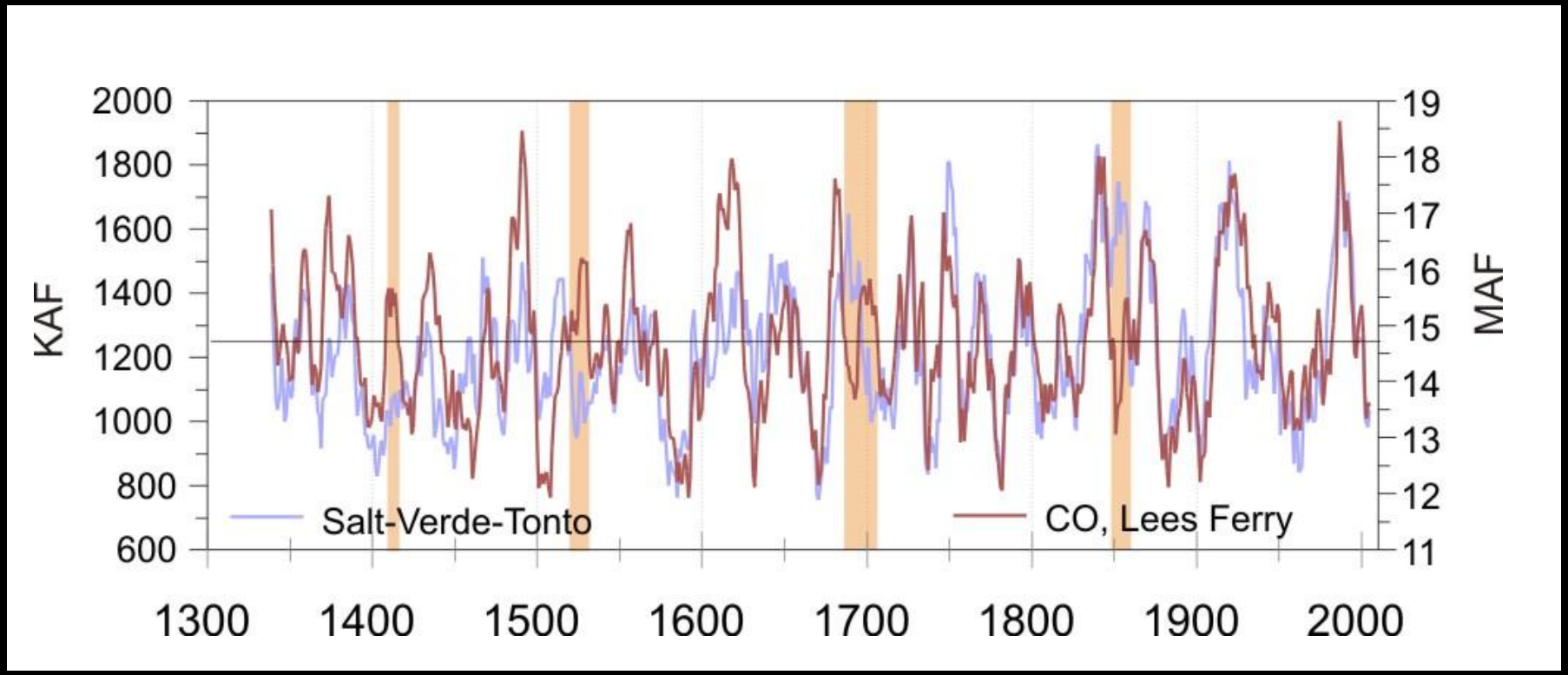
The Salt-Verde-Tonto1999-2004 drought in the context of the past centuries



- 14 non-overlapping 6-year averages with flows as low as 1999-2004 average
- 1- 3 occurrences in each century
- Most severe conditions at ~1590 and ~1670

Hirschboeck and Meko, 2008 for SRP

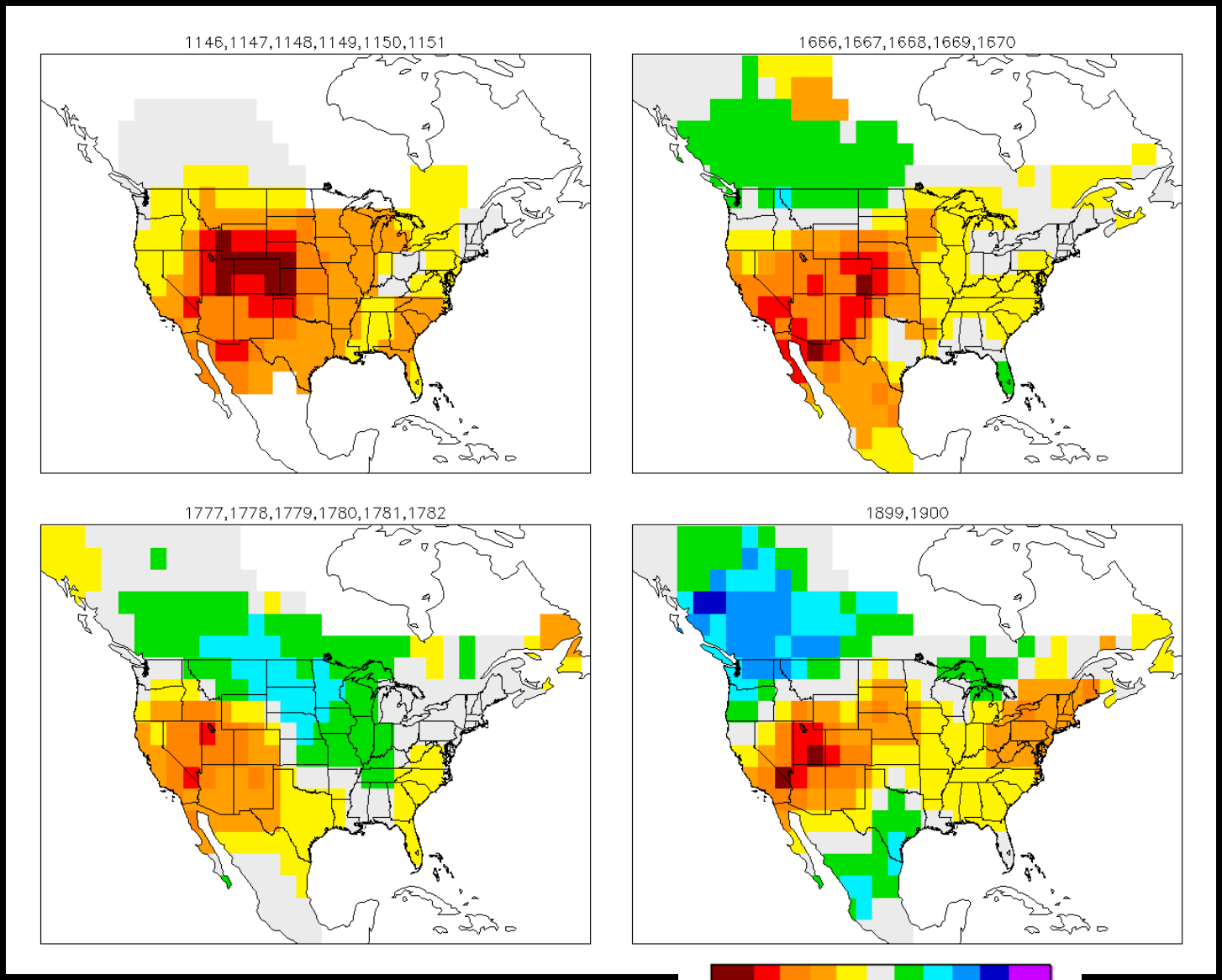
Comparison of Upper and Lower (Salt-Verde-Tonto) Colorado River Reconstructions, 1330-2005



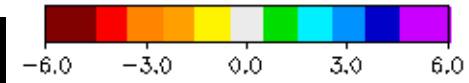
From Meko et al. 2007
Meko and Hirschboeck 2008

Flows are mostly synchronous, but there are exceptions…

Drought coverage for some period with concurrent drought in the Upper and Lower Colorado River basins

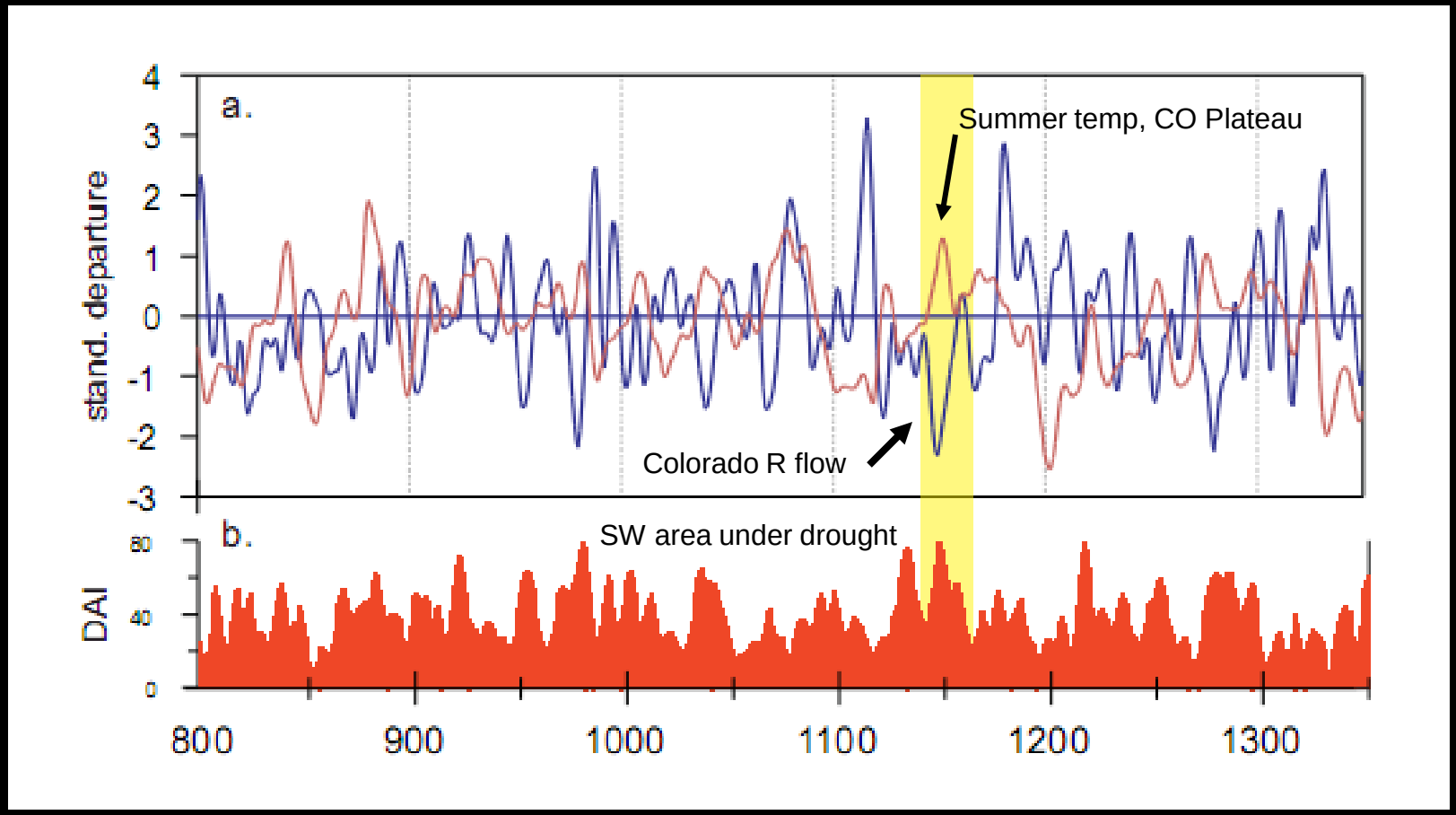


Palmer Drought Severity Index



Cook et al. 2008

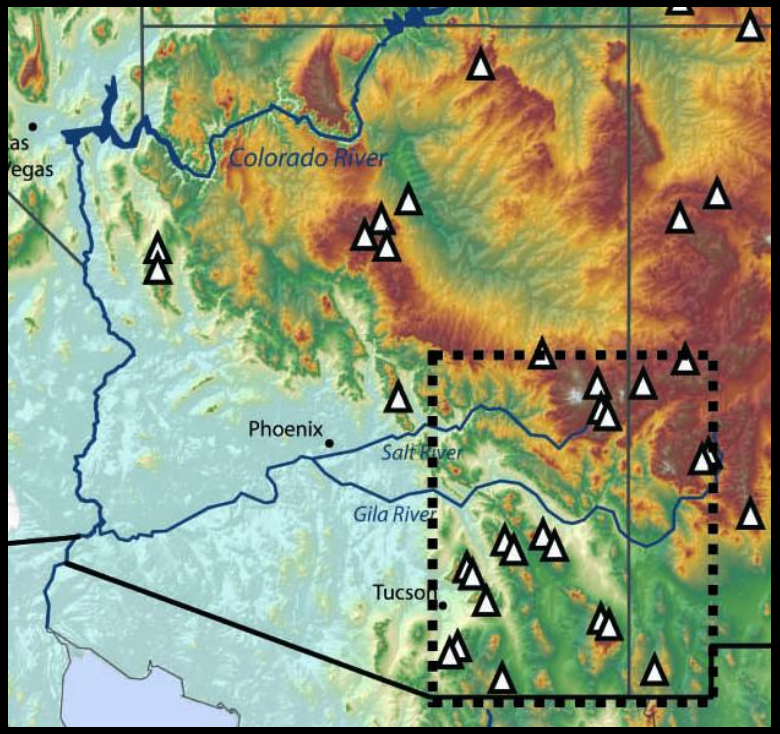
“Heart” of the Medieval Drought in the Colorado R. Basin



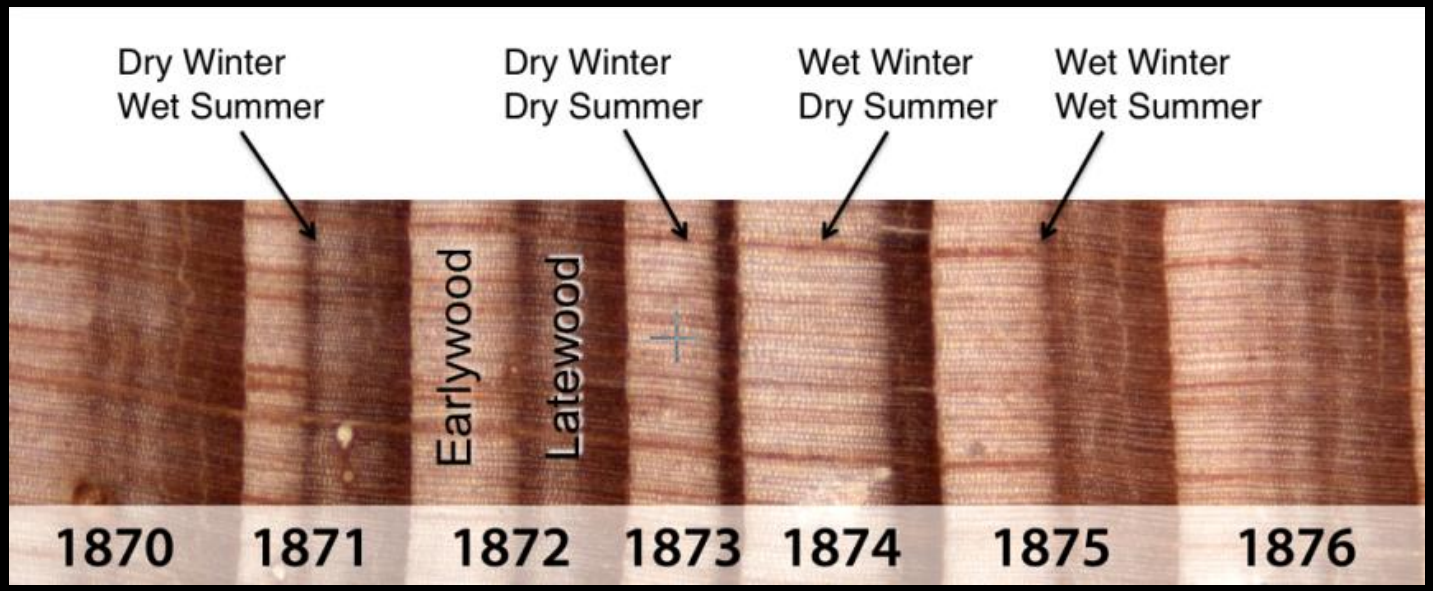
a. Salzer and Kipfmueller 2005; Meko et al. 2007
b. Cook et al. 2009

New Research:

Reconstructions of Winter and Monsoon rainfall from early wood and latewood ring widths



Tree-ring chronology locations and region of reconstruction



Images: Dan Griffin

How relevant is the record of past drought 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 southwestern U.S.

TreeFlow

streamflow reconstructions from tree rings

http://treeflow.info/

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)
National Climatic Data Center
U.S. Department of Commerce

WDC for Paleoclimatology

Search NCDC

Home • Research • Data • Education • What's New • Features • Perspectives • Site Map

North American Drought Atlas PDSI Reconstructions, Version 2a(2008) - Annual Maps

http://www.ncdc.noaa.gov/cgi-bin/paleo/pd08plot.pl

Investigating North American Monsoon Variability in the Southwestern USA using Instrumental and Tree-Ring Data

http://www.u.arizona.edu/~dgriffin/monsoon/

Connie Woodhouse, conniew1@email.arizona.edu