Paleohydrology Workshop

Decision Center for a Desert City & Decision Theater, Arizona State University
September 11, 2009

Sponsored by the Arizona Water Institute (AWI), ASU's Decision Center for a Desert City (DCDC), and Decision Theater (DT), and the University of Arizona

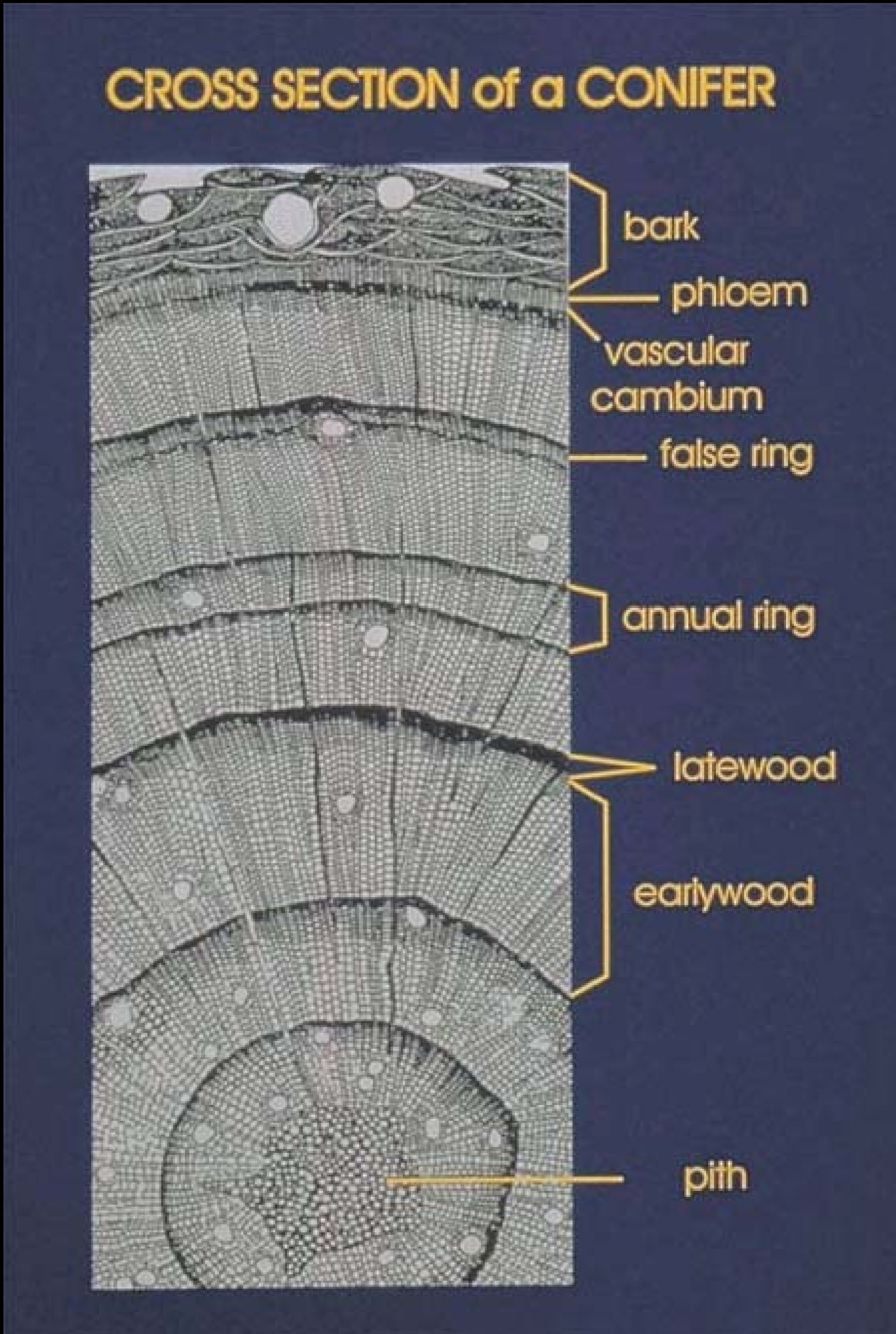
This file includes presentations on:

- An Overview of Tree Rings and Streamflow Reconstruction
- An Introduction to Applications to Water Management in the Colorado River Basin
- Information on the TreeFlow Web Site Data Resource
- Information on a new project on the North American Monsoon

Overview of Tree Rings and Streamflow Reconstruction

- How trees record climate and streamflow
- How streamflow reconstructions are developed
- Uncertainty in reconstructions
- Kinds of information from reconstructions

How tree rings record climate information



The formation of annual growth rings

- New wood forms in the vascular cambium, underneath the bark
- Earlywood + latewood = growth ring
- In temperate climates, growth ring = *annual ring*
- Ring width vary according the factor which is most limiting to growth, typically climate in the southwestern U.S.

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

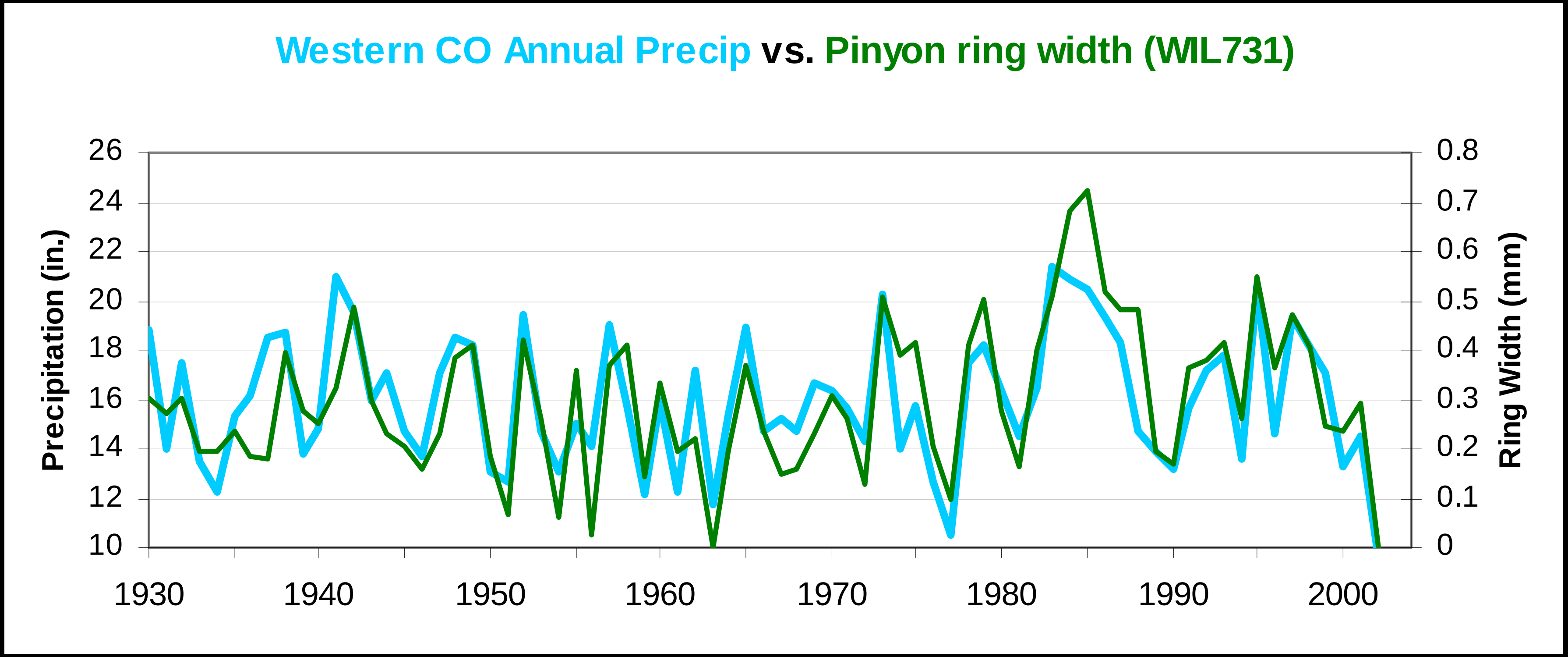
Trees that are limited by moisture, growing on open, well-drained sites, with thin soils

Douglas-fir

Pinyon pine

Ponderosa pine

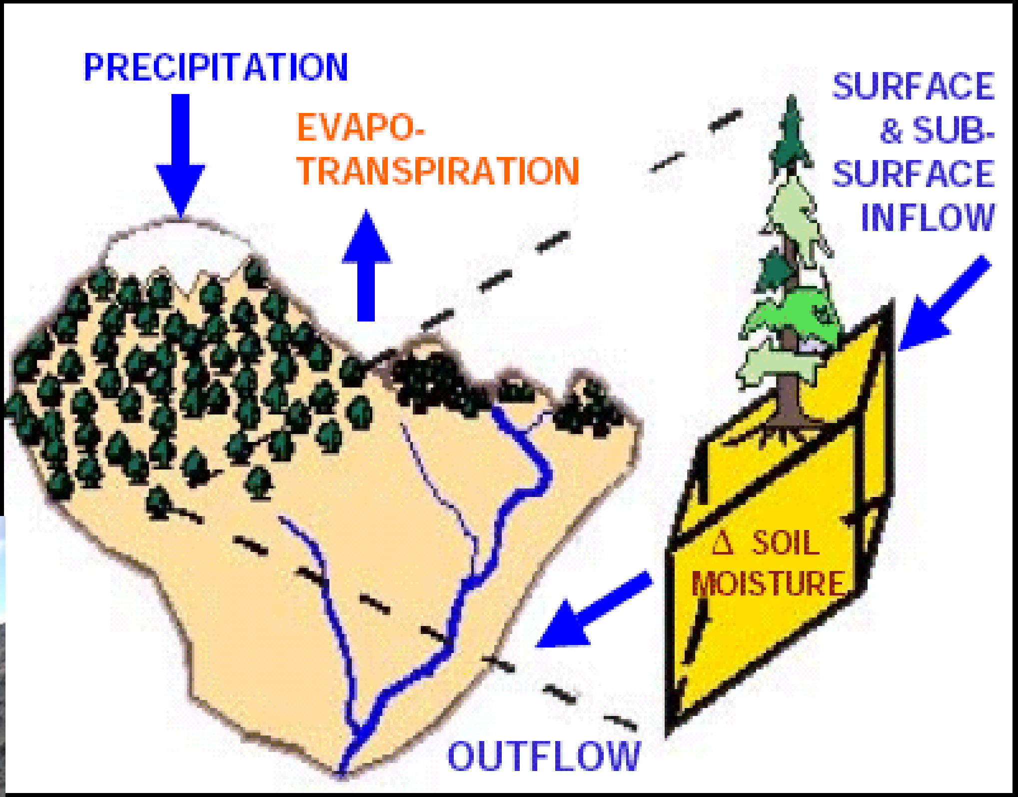
The moisture signal recorded by trees in the Southwest is particularly strong



Here, the ring widths from *one* tree are closely correlated to the western Colorado precipitation (r = 0.78) from 1930-2002

How can tree rings be used to reconstruct streamflow?

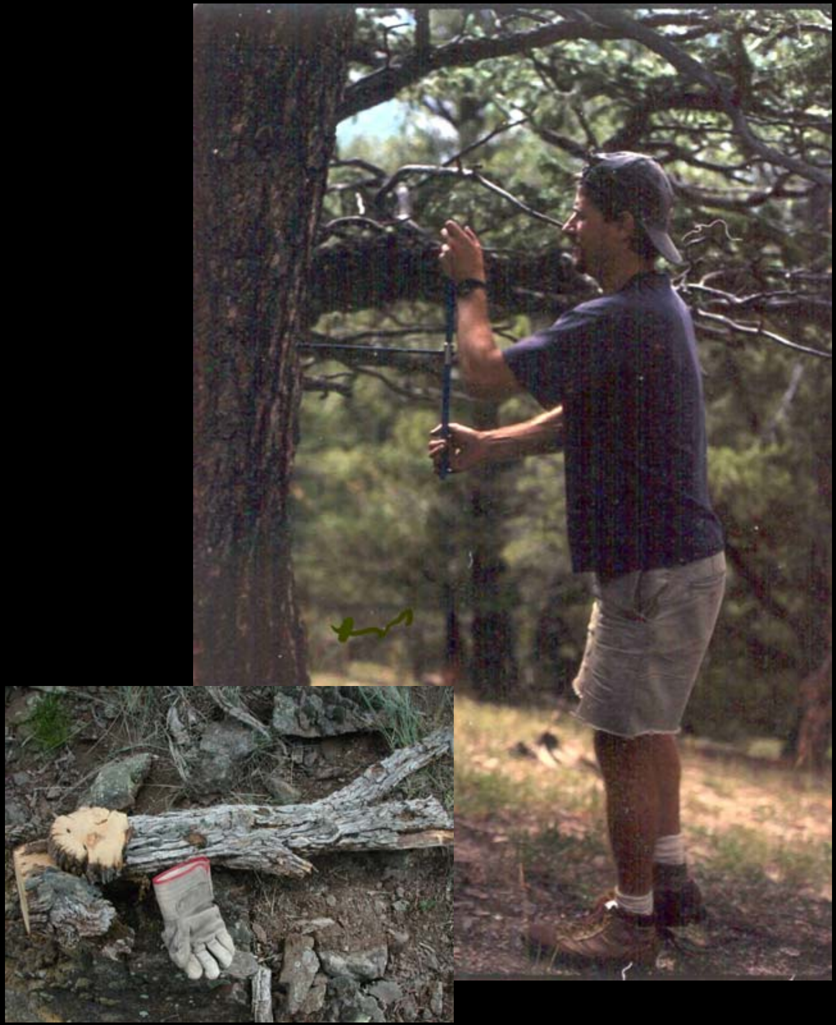
Ring widths and streamflow both integrate the effects of precipitation and evapotranspiration, as mediated by the soil, over the course of the water year.



How streamflow reconstructions are developed

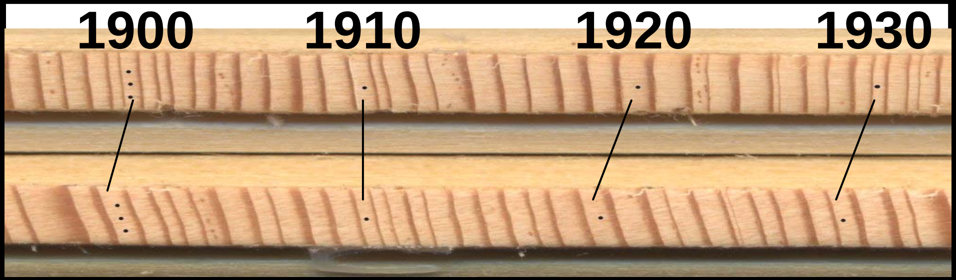
1. Field Collections

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

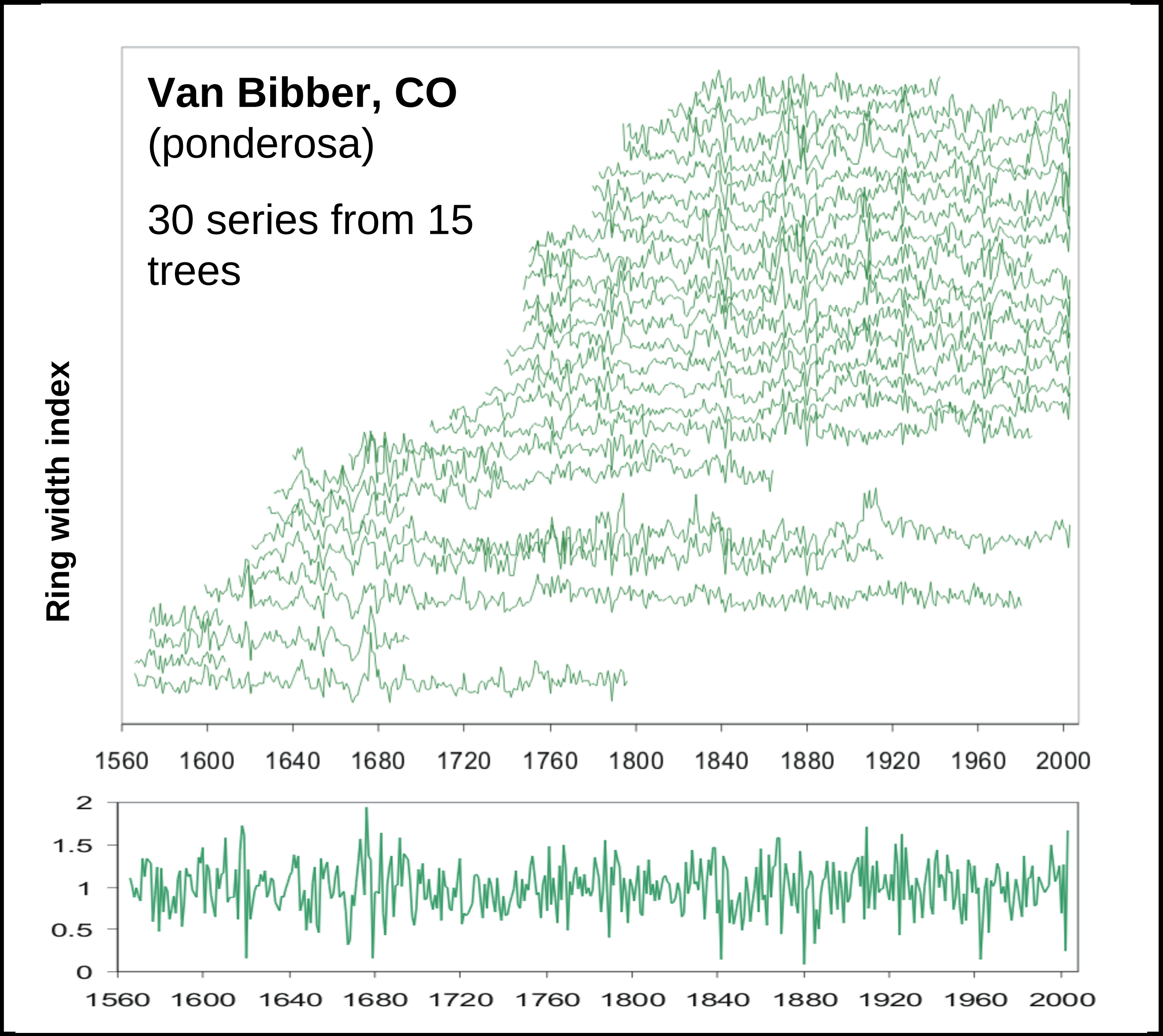


2. Sample Preparation

Cores are mounted and sanded, then dated, and measured

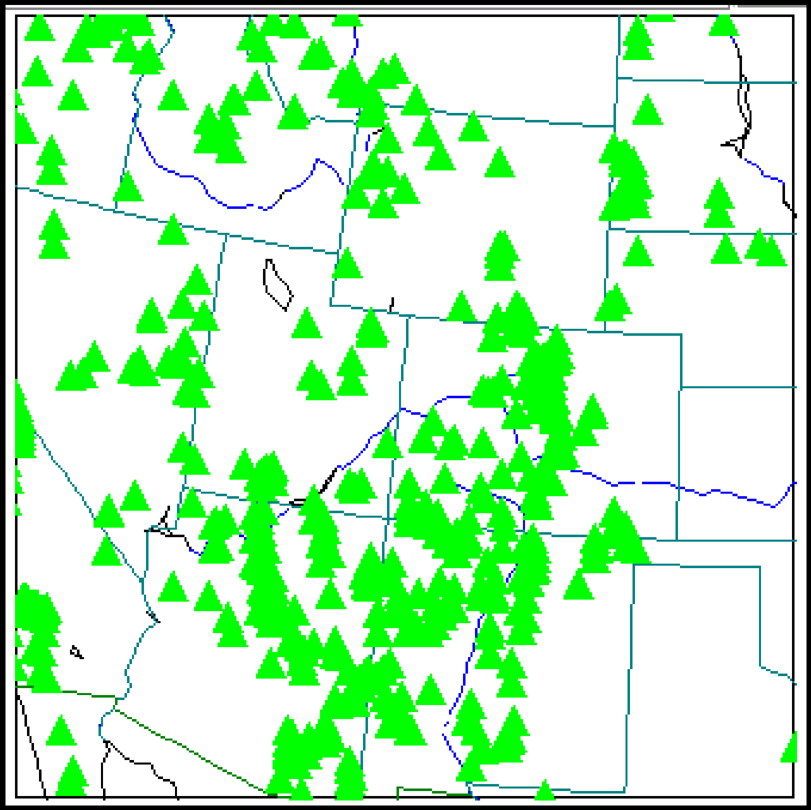


3. Compiling the Tree-Ring Chronology from the measurements from many trees



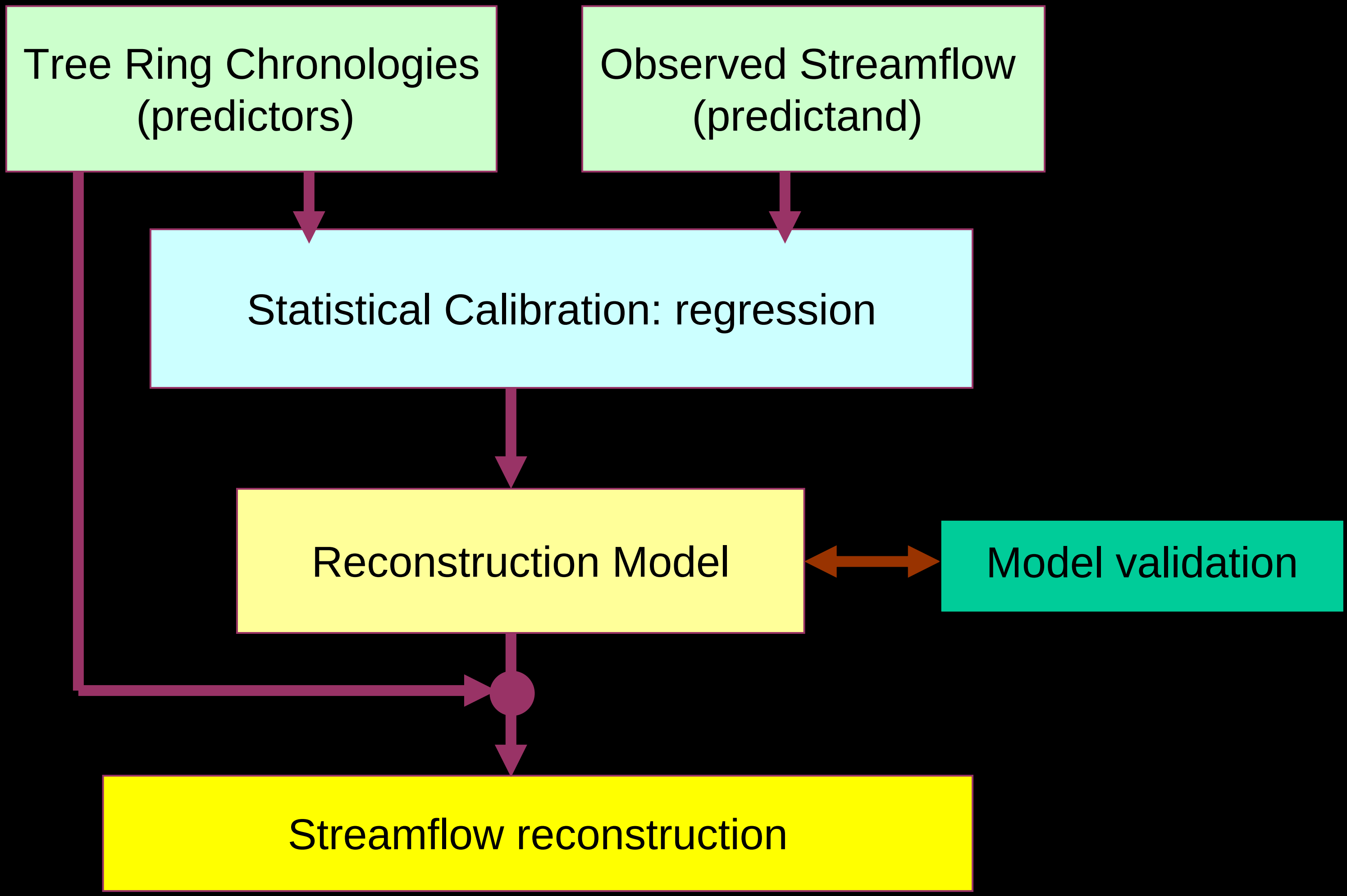
Chronology = basic unit of tree-ring data, “building block” for the flow reconstruction

Tree-ring chronologies have been collected in the Southwest over the past century



Many are archived at the International Tree-Ring Data Bank (ITRDB) http://www.ncdc.noaa.gov/paleo/treering.html

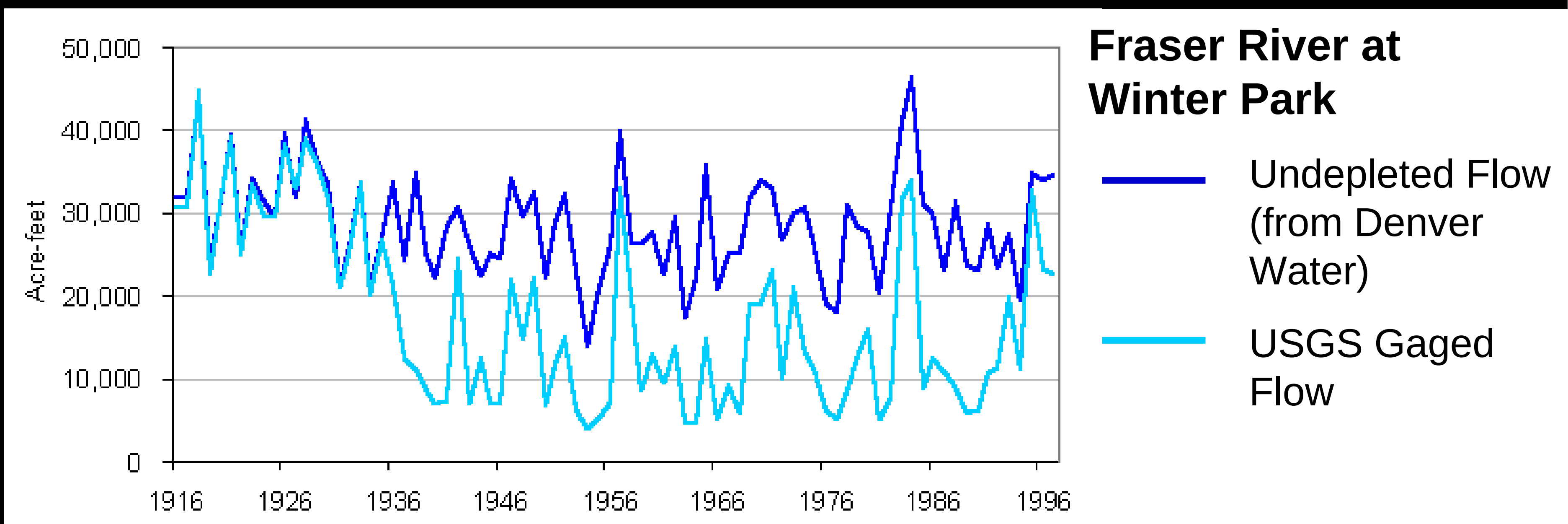
4. Generating the streamflow reconstruction



based on Meko (2005)

Requirements for observed streamflow record

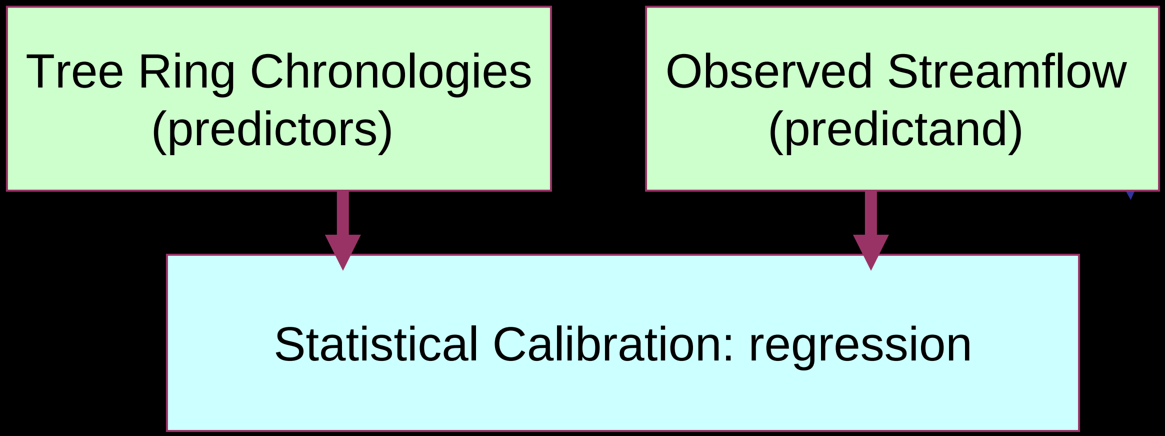
- **Length** – minimum 40 years for robust calibration with tree-ring data
- **Natural/undepleted record** – corrected for depletions, diversions, evaporation, etc.



Requirements for tree-ring chronologies

- **Moisture sensitive species** - Douglas-fir, ponderosa pine, pinyon pine (limber & southwestern white pine)
- **Location** – from a region that is climatically linked to the gage of interest
  - *Because weather systems cross watershed divides, chronologies do not have to be in same basin as gage*

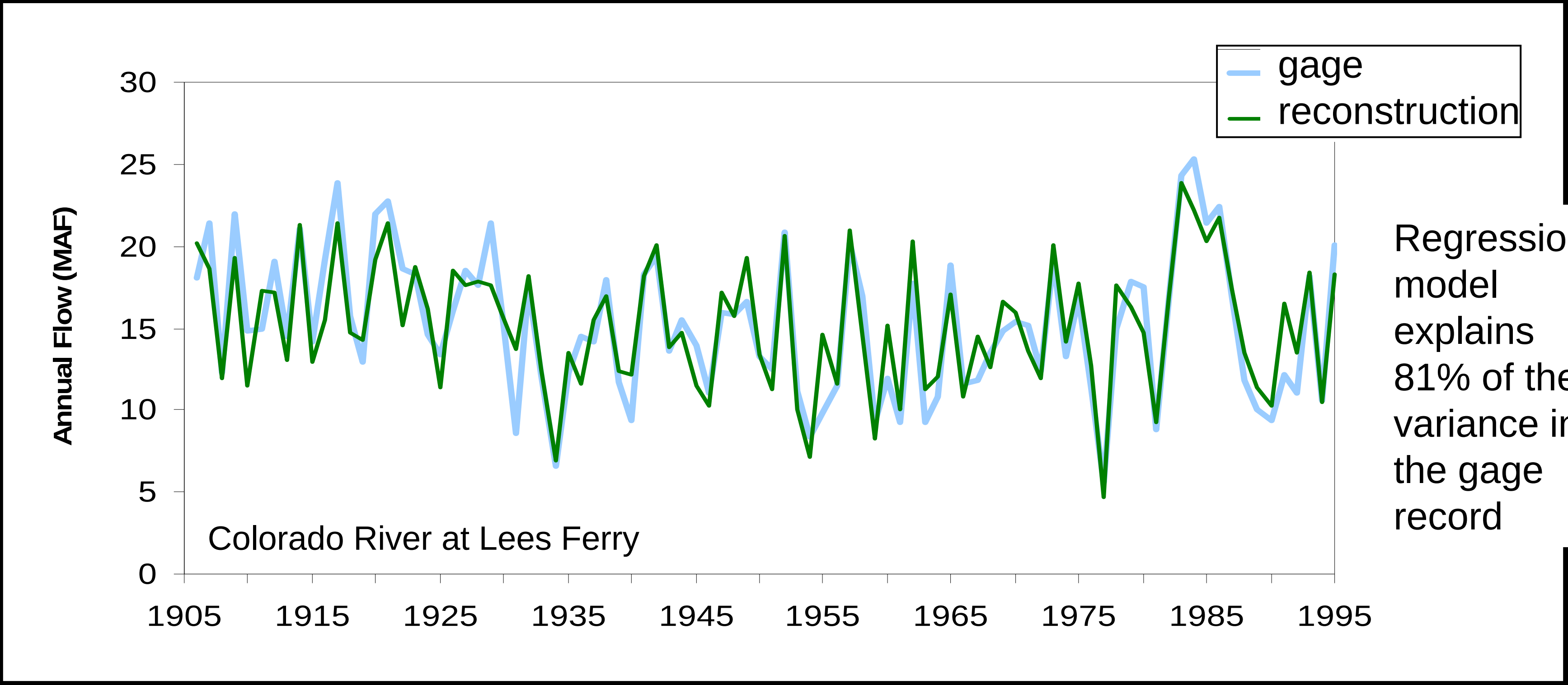
Reconstruction modeling strategies



- Linear or multiple linear regression are most common
- Other approaches are possible (e.g., quantile regression, neural networks, non-parametric methods)

5. Model validation and skill assessment

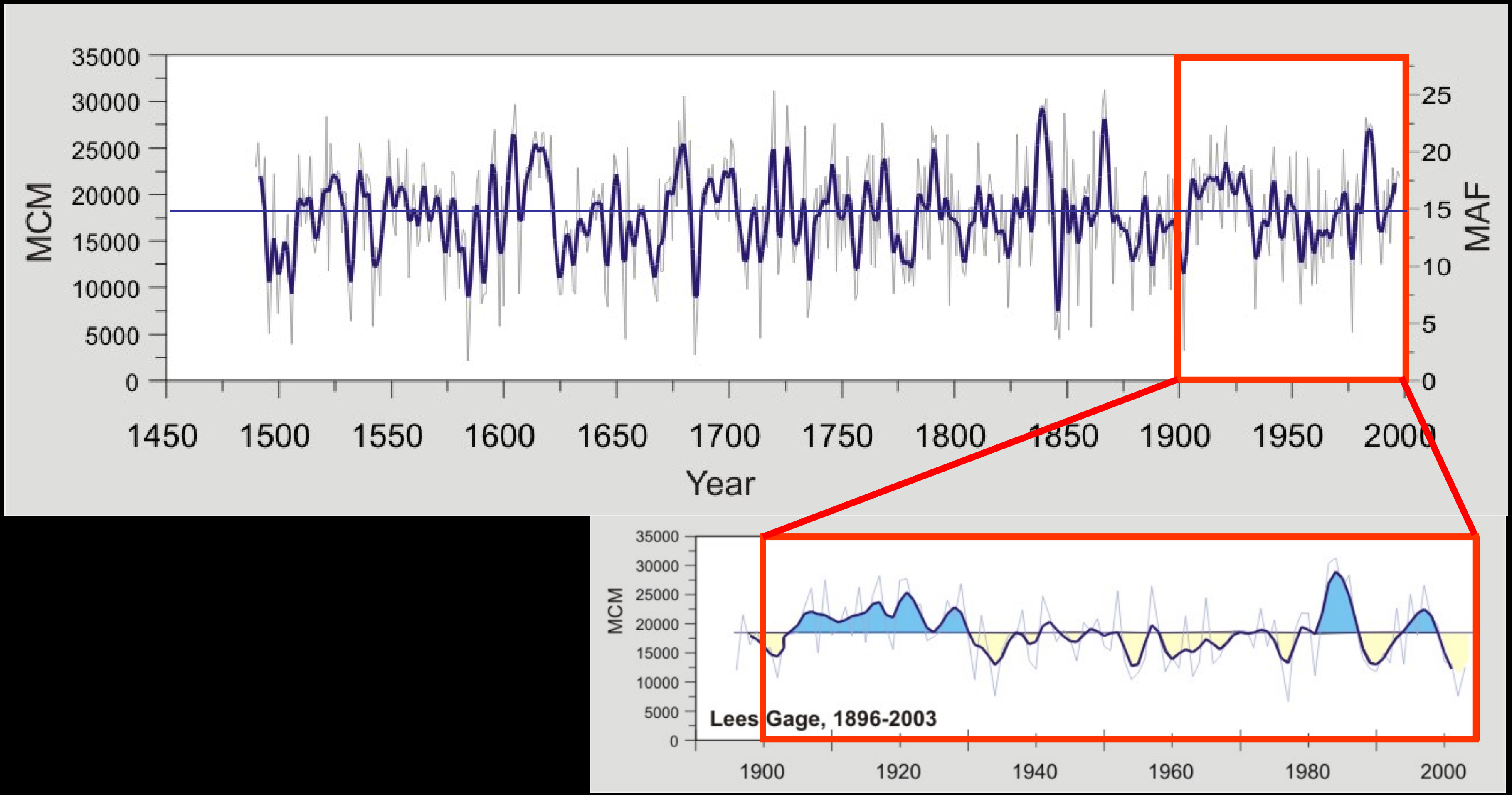
- Are regression assumptions satisfied?
- How does the model validate on data not used to calibrate the model?
- How does the reconstruction compare to the gage record?



Regression model explains 81% of the variance in the gage record

6. The model is then applied to the full-length chronologies to produce a record of past hydroclimatic variability

Reconstruction of Colorado River at Lees Ferry, 1490-1997



Woodhouse et al. 2006

Sources of Uncertainty in Streamflow Reconstructions

- Trees are imperfect recorders of streamflow.

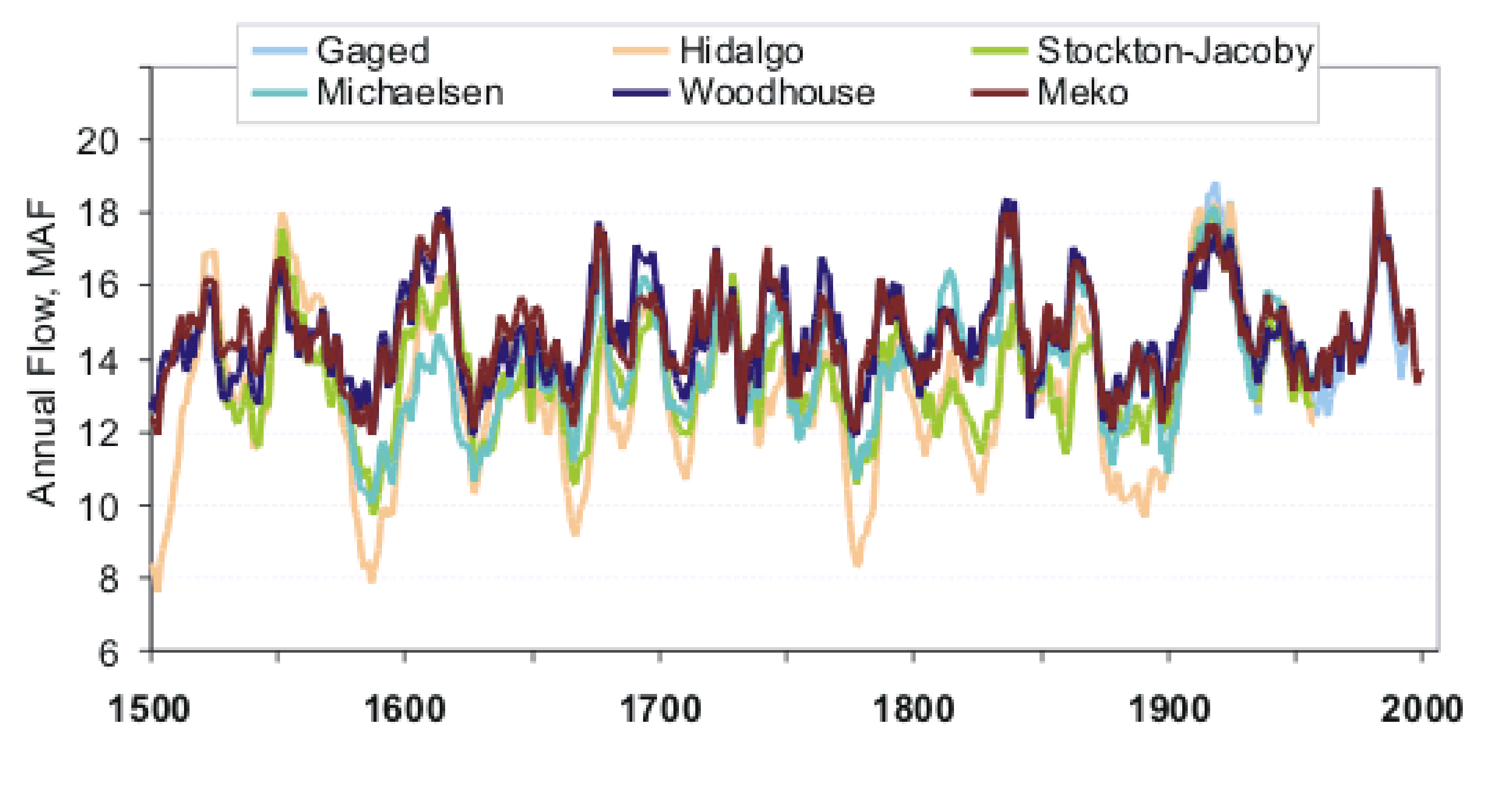
- The reconstruction model never explains 100% of the variance in the observed record.

- Streamflow data may contain errors.

- A variety of decisions are made in the reconstruction process, all of which can have an effect on the final reconstruction.

- A reconstruction is a *best estimate* of past streamflow, and each annual point represents the central tendency of a range of plausible values, given the uncertainty

Lees Ferry Streamflow Reconstructions, 1977-2007



Differences are due to a variety of factors:

- calibration data used
- selection of tree-ring data
- treatment of tree-ring data
- statistical methods for model calibration

What information is provided by reconstructions of streamflow?

What tree-ring reconstructions provide:

• context for assessing gage record over a longer time frame

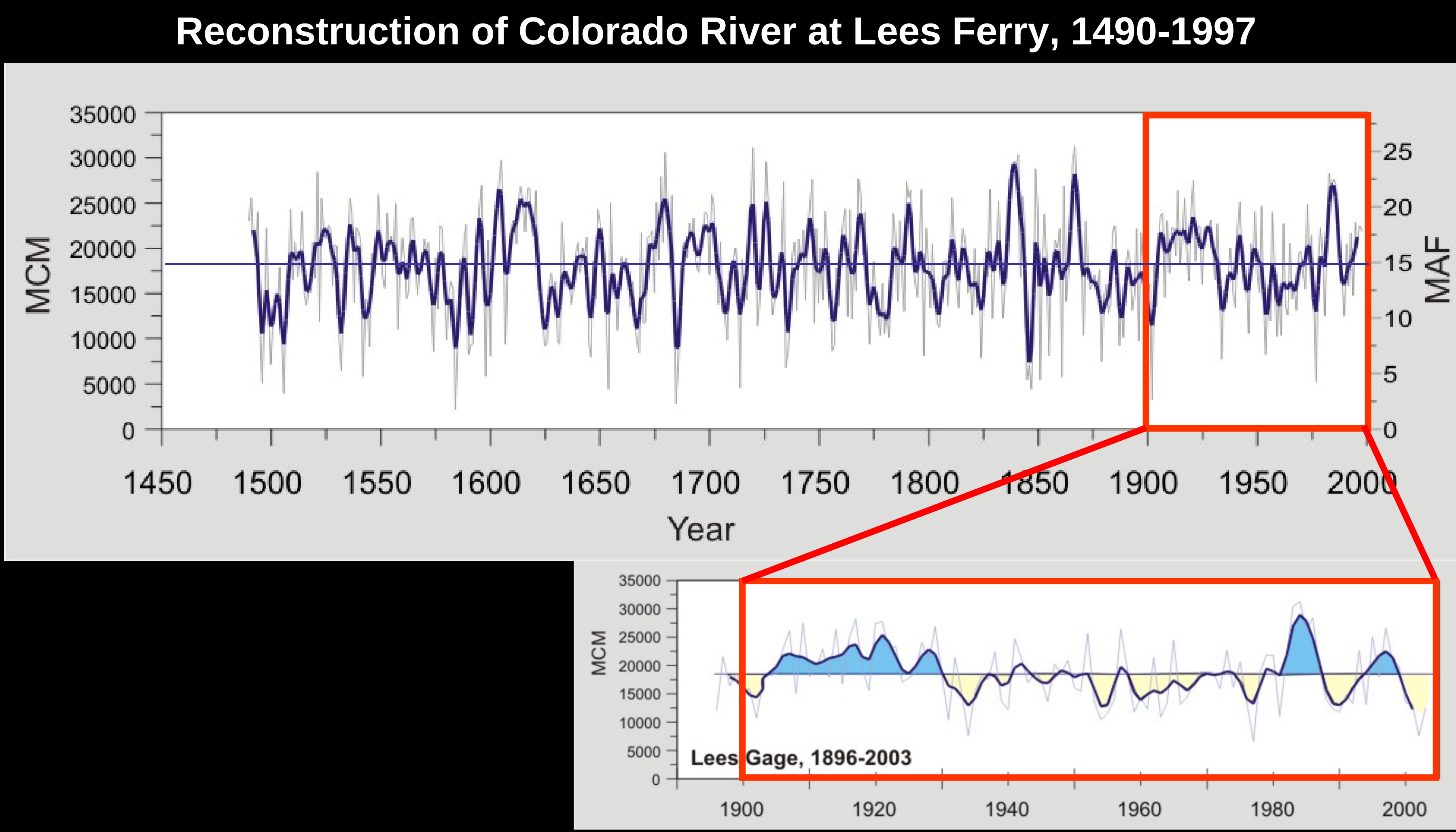
• a way to evaluate recent drought events in terms of natural variability over past centuries

• 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) variability

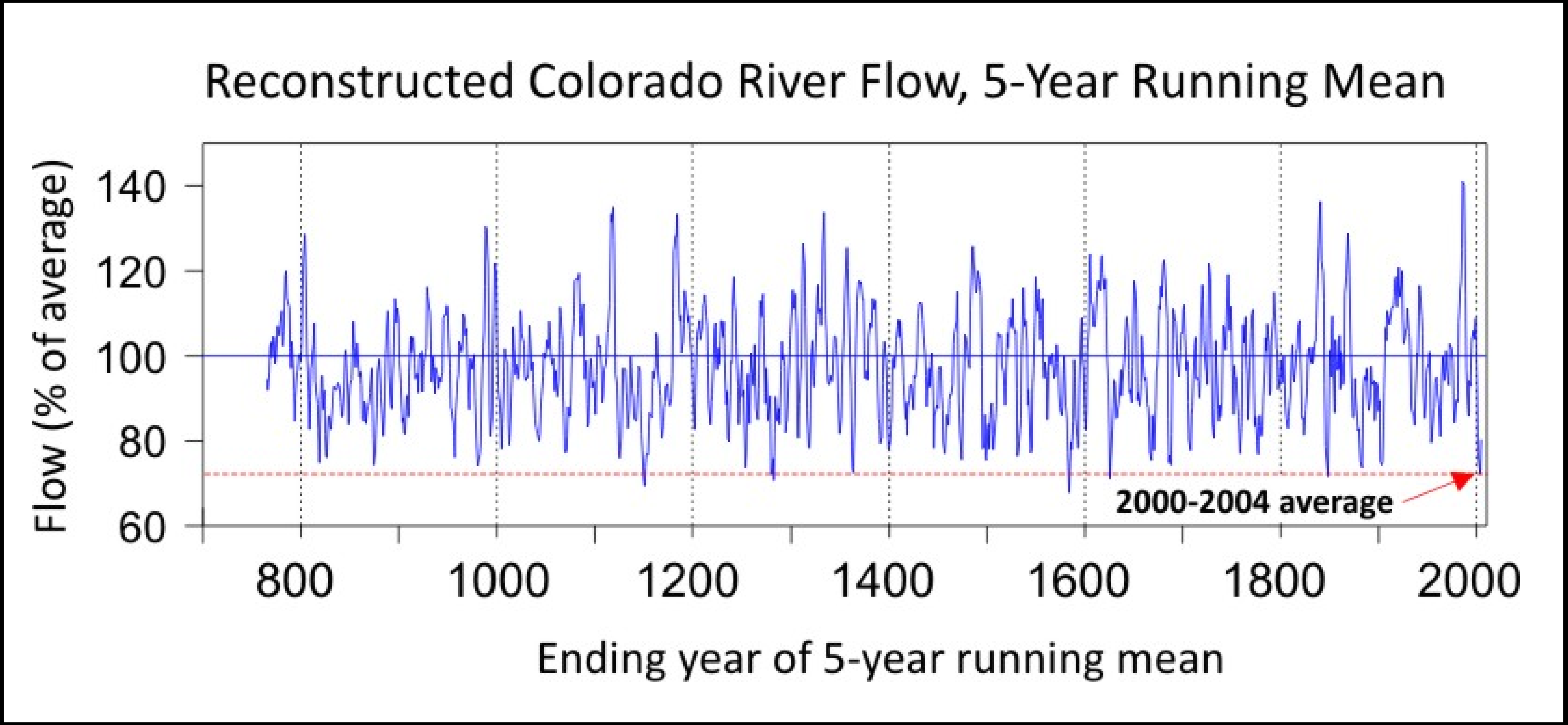
• an understanding of the rich sequence of flows that has occurred over past centuries

Context for assessing gage record in a longer time frame



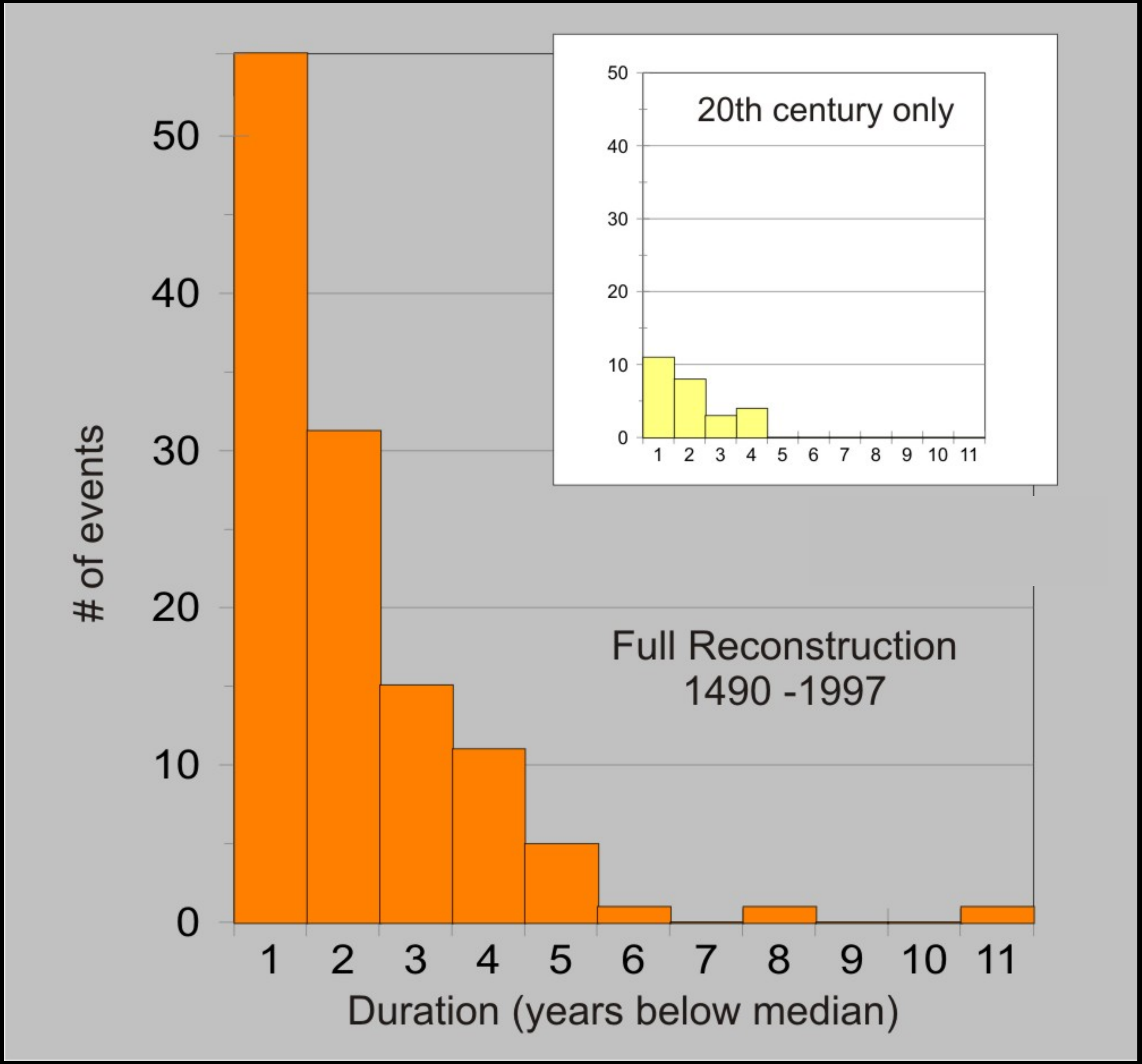
Woodhouse et al. 2006

Assessment of the 2000-2004 drought in a millennial context



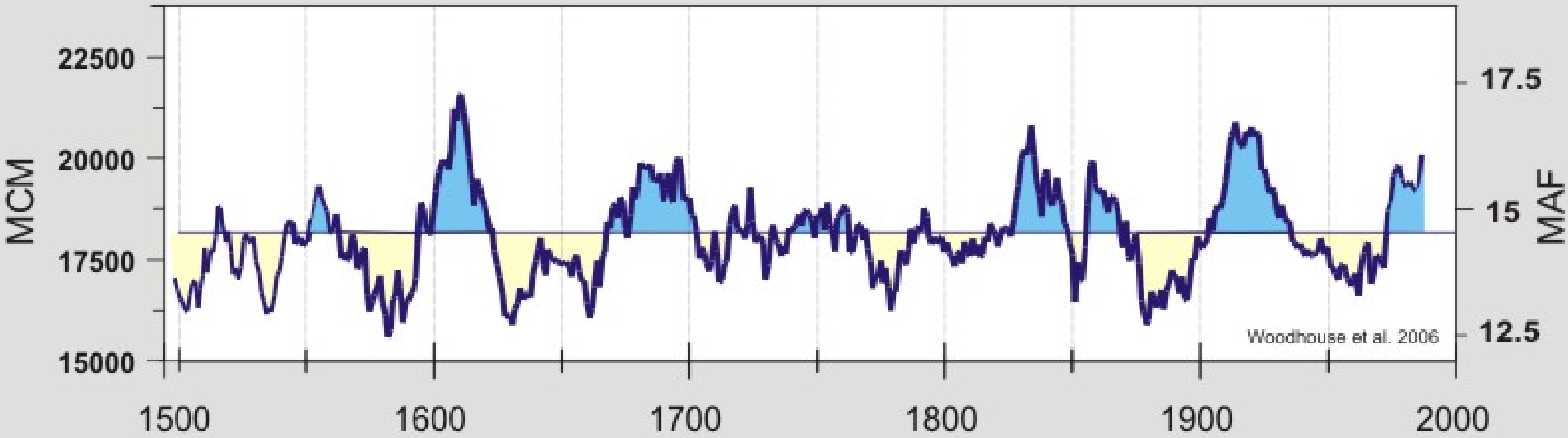
Meko et al. 2007

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



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

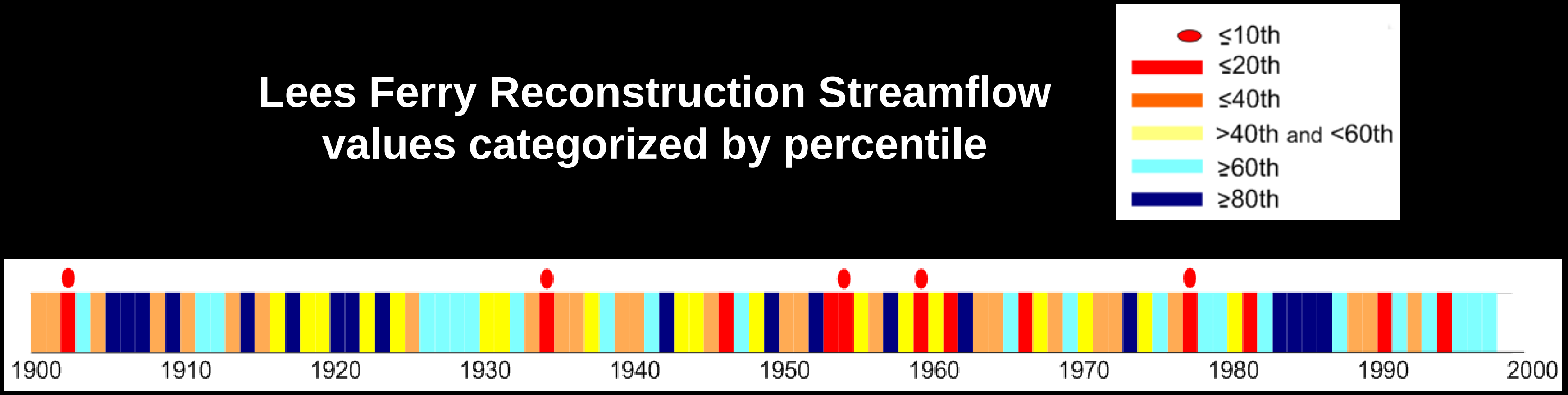
Lees Ferry Streamflow Reconstruction (20-yr moving average), 1490-1997



Pluvials 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)

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

Lees Ferry Reconstruction Streamflow values categorized by percentile



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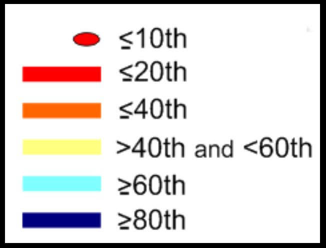

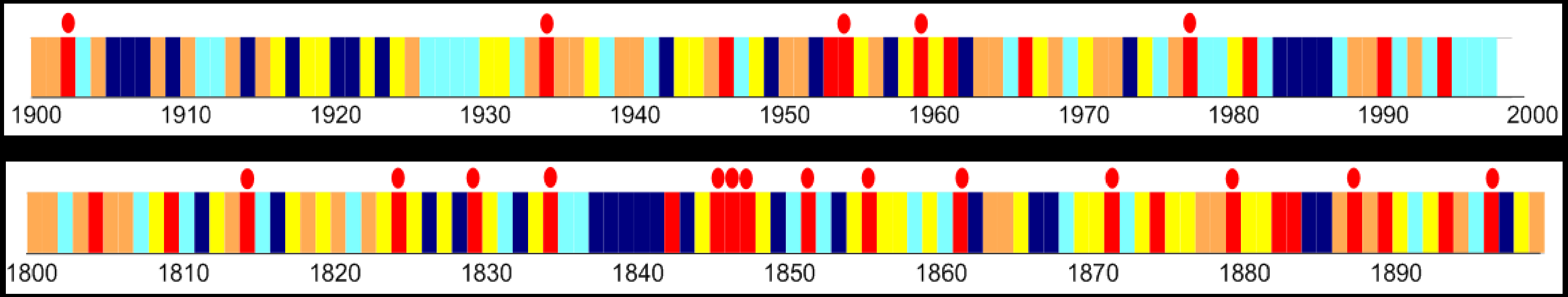

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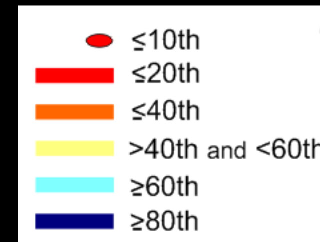

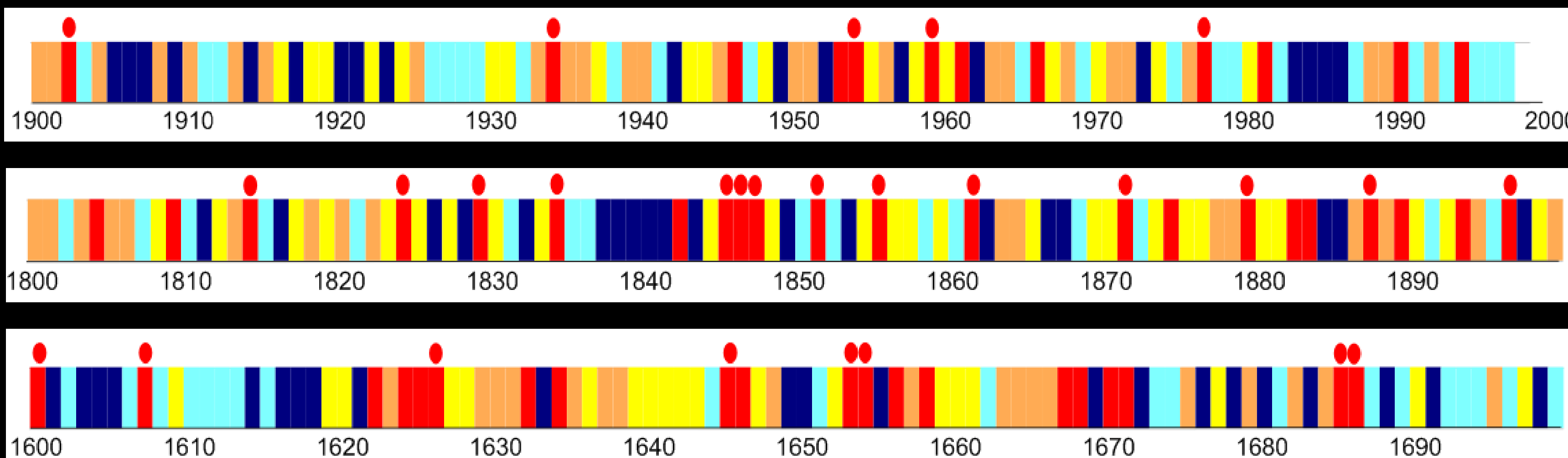

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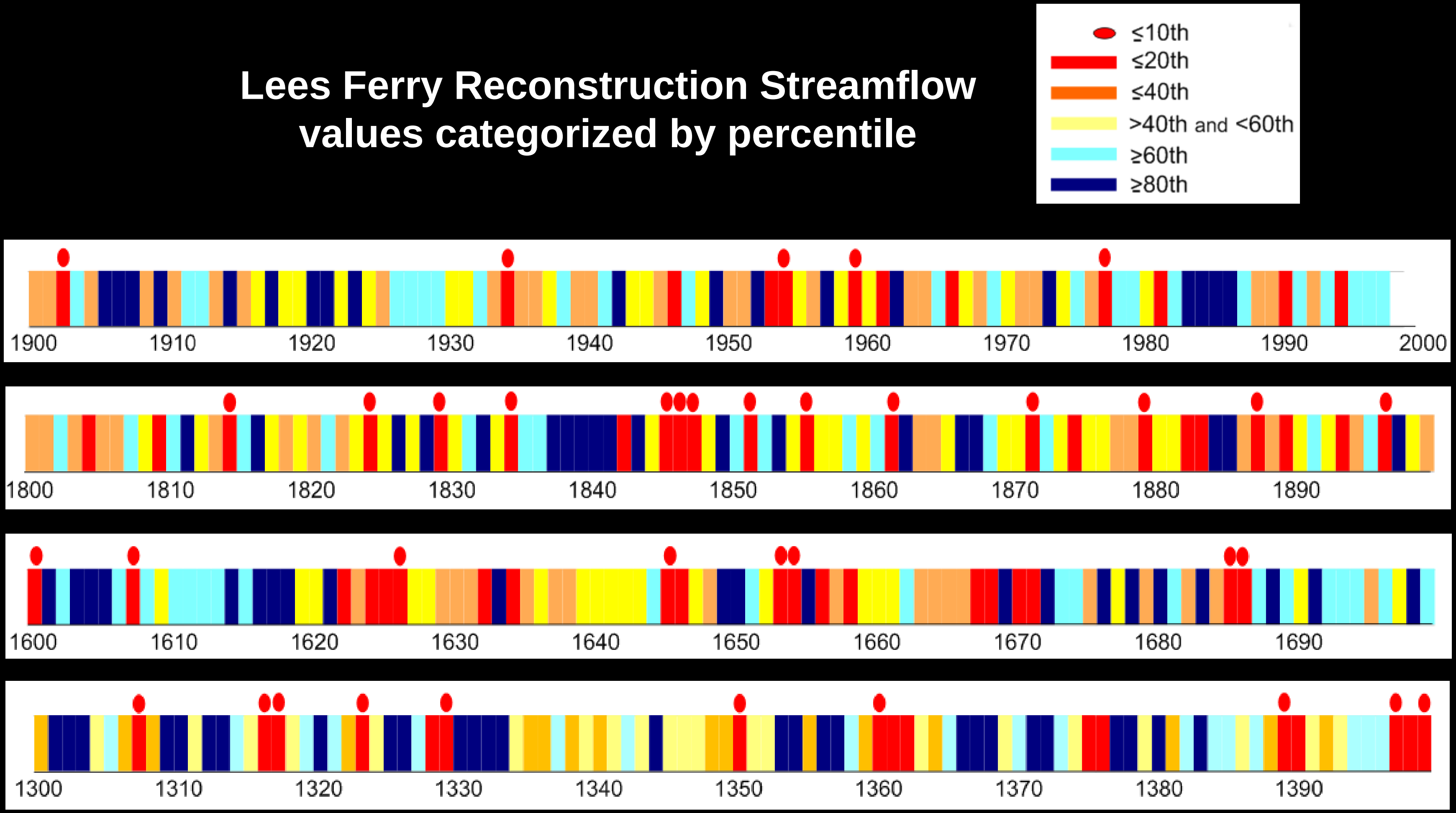

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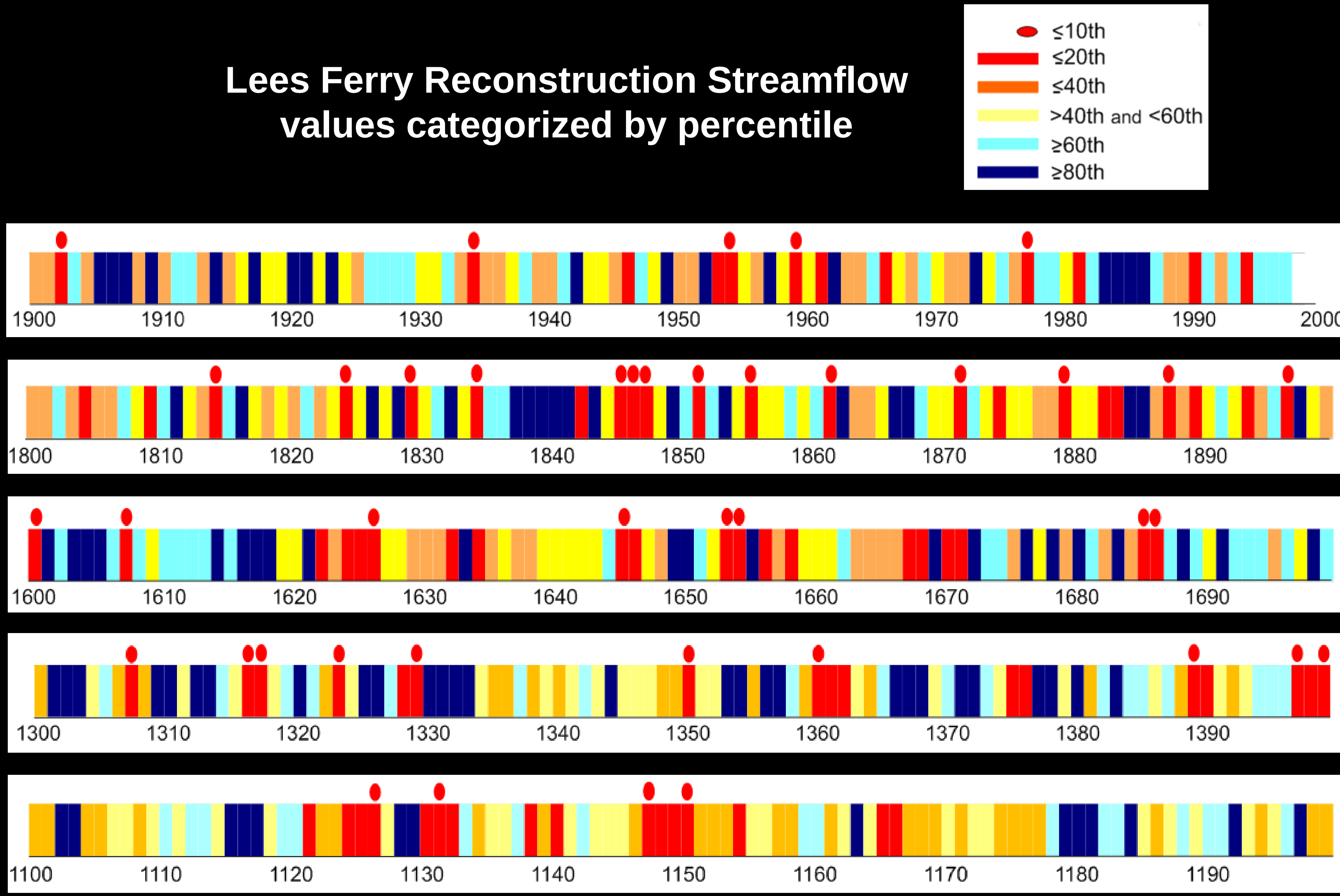
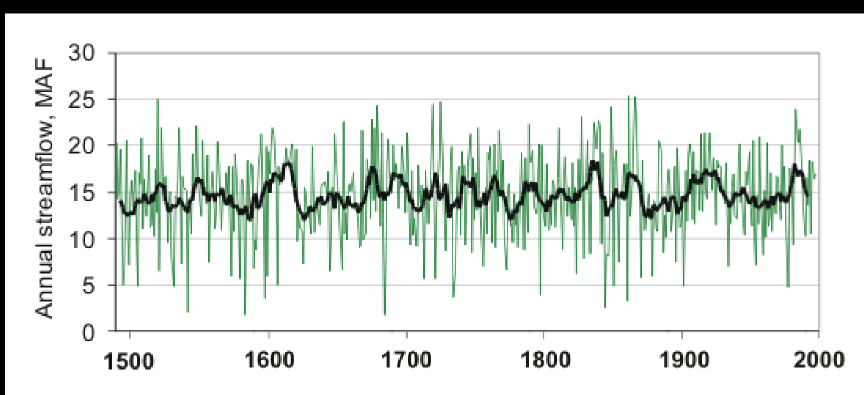


Applications to Water Management in the Colorado River Basin

- Overview

See separate presentations from:

- Salt River Project
- City of Phoenix
- Bureau of Reclamation



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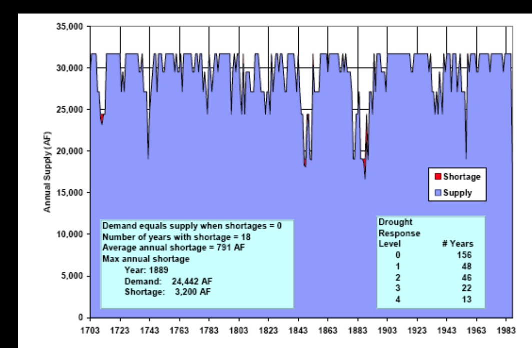

Figure 5. Demands & Supplies: 15% Reduced Flow Hydrology, Current Trends Scenario (demand = 31,700 AF/year).

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

Applications of reconstructions to water resource planning vary according to stages and types of use.

Stages of use

- initial awareness
- considered for use in some way
- incorporation into planning or models
- used in the communication of risk or in making recommendations

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AMERICAN WATER RESOURCES ASSOCIATION

SCIENCE AND DECISION MAKING: WATER MANAGEMENT AND TREE-RING DATA IN THE WESTERN UNITED STATES[1]

Jennifer L. Rice, Connie A. Woodhouse, and Jeffrey J. Lukas[2]

TABLE 3. Survey Responses to the Question "In What Area(s) Do You Work?" (respondents could select more than one answer).

Planning	56%
Operations	41%
Research	26%
Water Conservation District	15%
Water Conservancy District	0%
Private Consulting	26%
City Government	26%
County/State Government	15%
Federal Government	16%

TABLE 5. Survey Responses to the Question "How Have Tree-Ring Data Been Used by You, Your Organization, or Organizations that you Consult for?" (respondents could select more than one answer).

To broaden understanding of hydrologic variability	75%
To educate users/public	46%
To educate board and other decision makers	50%
As input into a water system model or other model	25%
For quantitative analysis, but not in a modeling environment	14%
To inform planning and decision making	54%
I have not used tree-rings in my organization	18%

N=28, 39% response

Rice et al. 2009. JAWRA, DOI: 10.1111/j.1752-1688.2009.00358.x

TreeFlow

a comprehensive web resource
for tree-ring reconstructions
of streamflow and climate

http://treeflow.info

- Download data
- Obtain background information
- See examples of water management applications

Tree Rings and the North American Monsoon

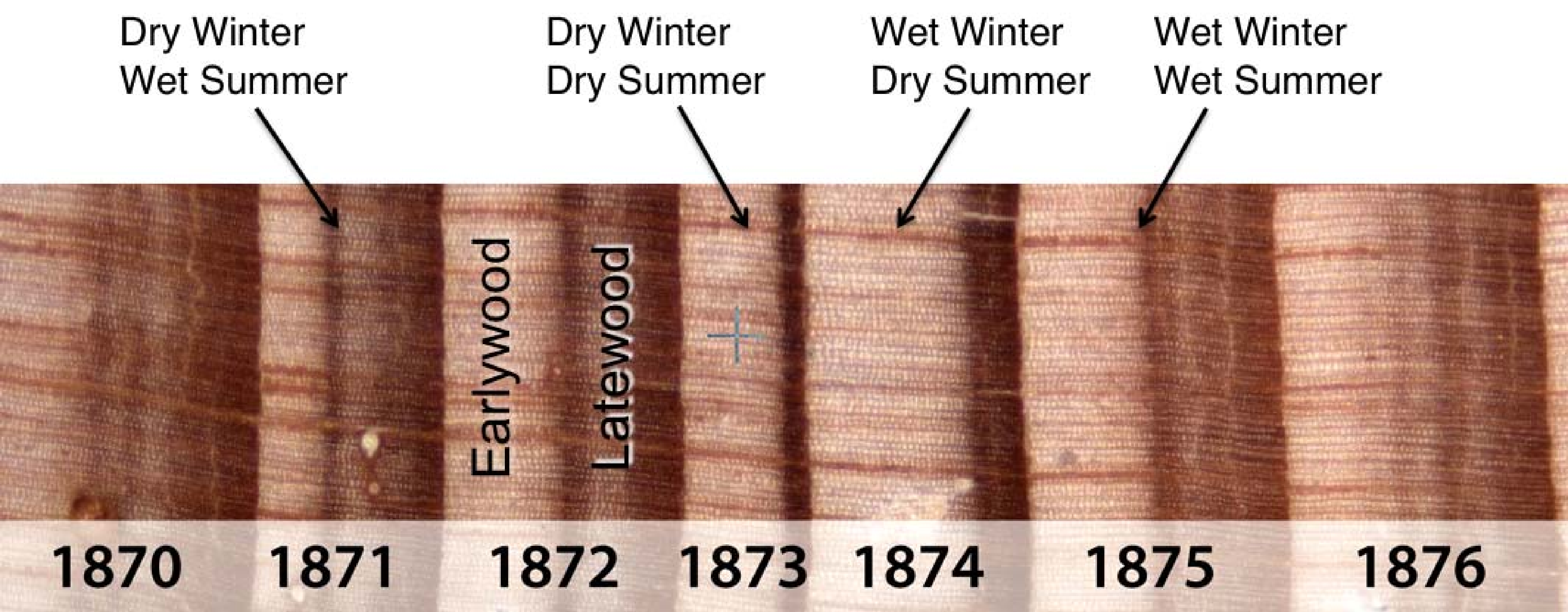
Project Goals

- Develop the first monsoon-sensitive chronology network in the SW U.S.
- Investigate long term monsoon season drought variability in SW U.S.
- Compare cool-season and monsoon-season precipitation in the paleo records
- Assess relationship between monsoon and large scale circulation (i.e., El Niño)
- Provide useful information to stakeholders

http://monsoon.ltrr.arizona.edu

Total Ring-Width vs. Earlywood and Latewood

- Most studies used total ring width
- New Potential with sub-annual detail of EW and LW
- Earlywood (light color) = winter signal
- Latewood (dark color) = summer signal
- Examples below



•Early Stages of Project

•Updating existing collections

•Re-analyze archived wood

•40 new chronologies

•Monsoon season reconstructions