Rio Grande Tree-Ring Monsoon Workshop

NMSU Albuquerque Center, Albuquerque NM

May 14, 2012

Connie Woodhouse and Daniel Griffin

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

Photos: Bureau of Reclamation

Welcome

Introductions – who we are, who you are

Laboratory of Tree-Ring Research
The University of Arizona

CLIMAS

Climate Assessment
for the Southwest

The University of Arizona

Today's Agenda

- Tree-ring workshops background
- Tree Rings 101 in brief: using tree rings to reconstruct past climate
- Quick review of Rio Grande/Otowi reconstruction
- Reconstructing monsoon precipitation with latewood tree-ring widths
- Comparison of records of past streamflow and monsoon precipitation over past centuries
- Discussion and suggestions for next steps

Workshop #1: Tree-Ring Reconstructions of Hydroclimatic Variability in the Rio Grande Basin, NM, November 2, 2007

Connie Woodhouse, University of Arizona/WWA; Jeff Lukas, Brad Udall, University of Colorado/WWA; Deborah Bathke, New Mexico State University/NM Assistant State Climatologist/CLIMAS, Gregg Garfin, Holly Hartman, University of Arizona/CLIMAS and others

- The goal of this workshop was to expand and improve the usability of tree-ring based reconstructions for drought planning and resource management in the Rio Grande basin.

Workshop #2: A Follow-Up on Tree-Ring-Based streamflow reconstructions for the Rio Grande Basin, NM, May 30, 2008

Connie Woodhouse, University of Arizona and Jeff Lukas, University of Colorado, with Dave Meko, Ramzi Touchan, University of Arizona and others

- We convened a follow-up workshop to deliver new reconstructions for the Otowi gage, and create TreeFlow web page for New Mexico to feature Rio Grande region reconstructions

CLIMAS

Western Water Assessment

NOAA

USGS
science for a changing world

NM STATE

Workshop #3: Tree-Ring Reconstructions of Monsoon Variability in the Rio Grande Basin, NM, May 14, 2012

Purpose of this workshop

- Provide you with information about how tree-rings document not only past streamflow but monsoon precipitation
- Learn from you how this information could be made more useful for planning and management

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WHERE DISCOVERIES BEGIN

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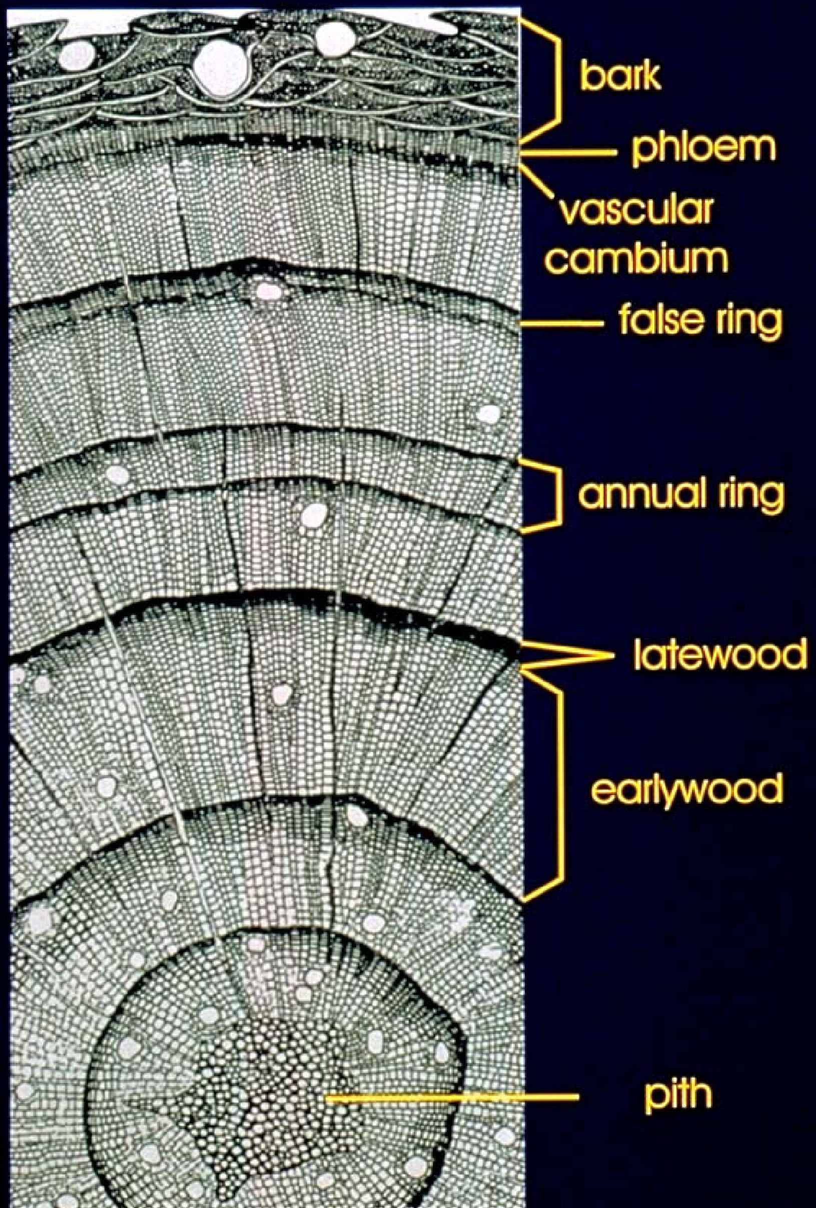
Part 1.

Overview of Tree Rings and Climate Reconstruction

- how trees record climate
- how climate 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?

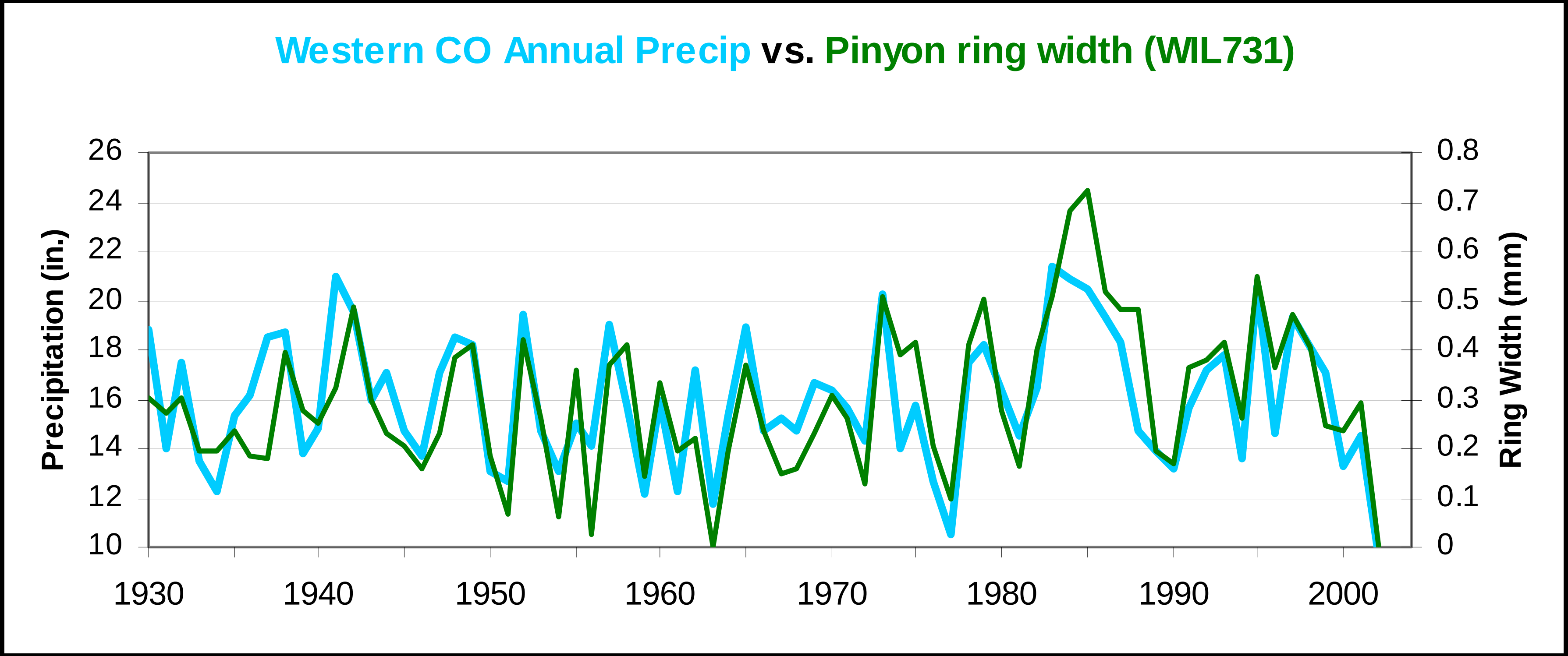
Typically (but not always), trees that are limited by moisture, growing on open, well-drained sites, with thin soils

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

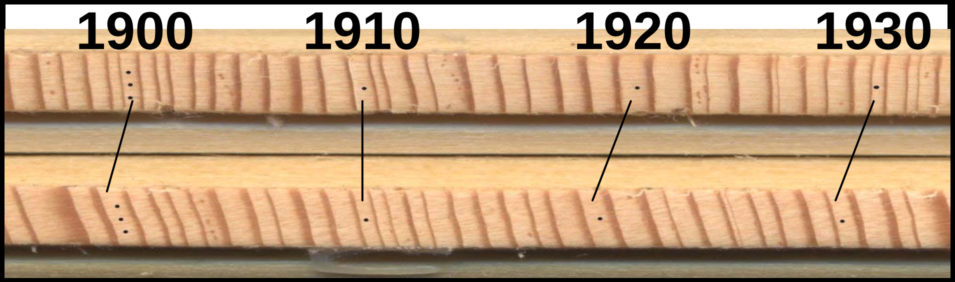
How climate reconstructions are developed : field work to statistical model

1. Field Collections

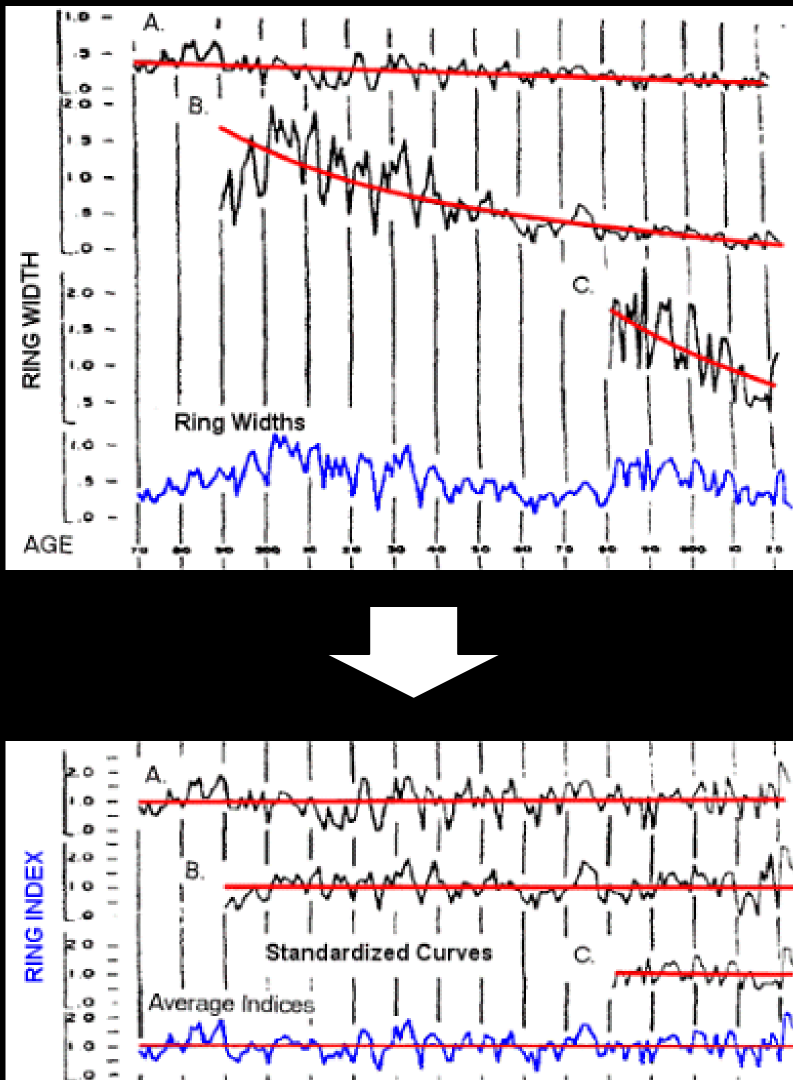
An increment borer is used to sample cores from about 20 trees at a site

2. Sample Preparation

Cores are mounted and sanded, then dated, and measured

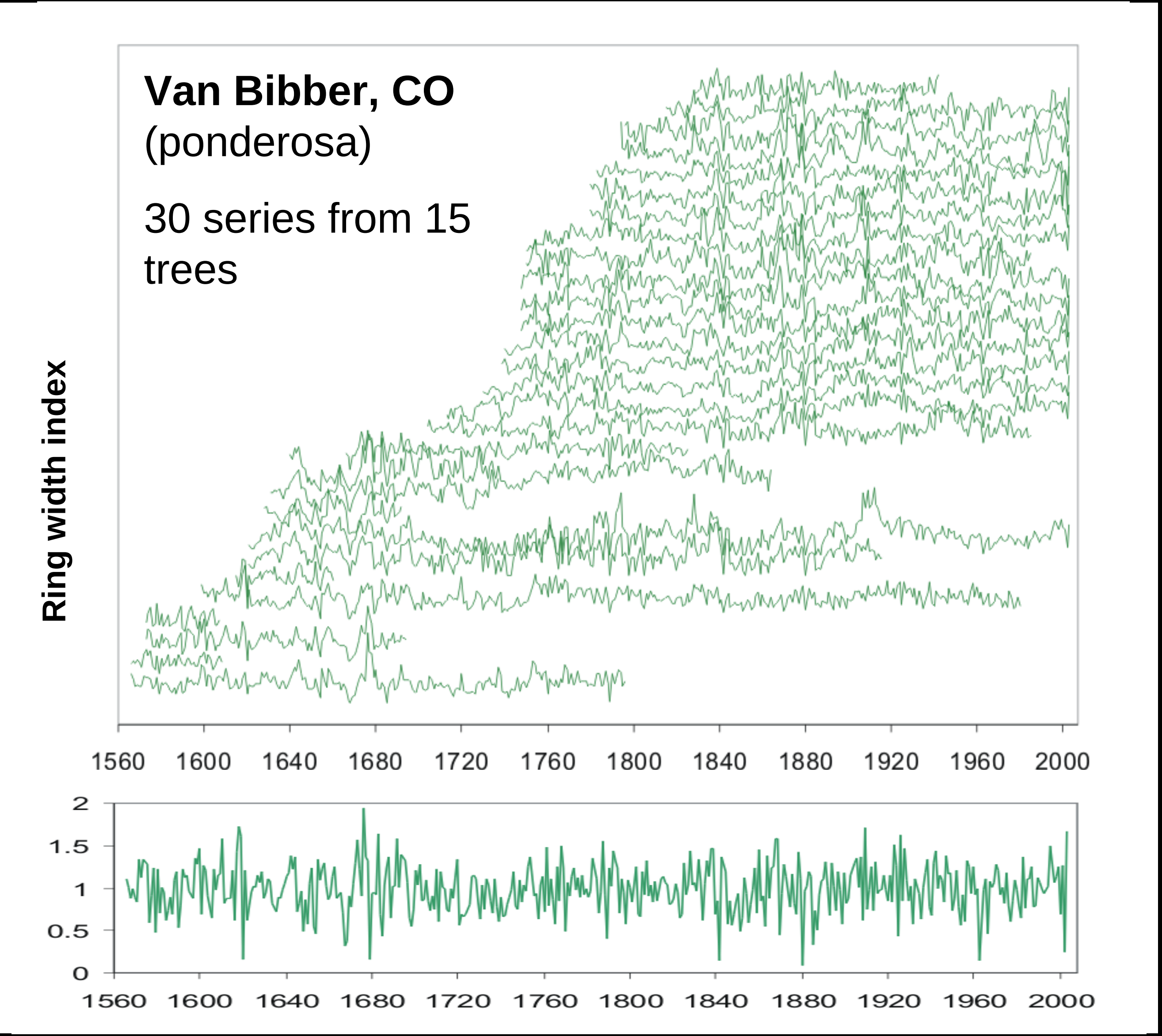


3. Detrending the measured series



- Ring-width series typically have a declining trend with time because of tree geometry
- These biological trends are not related to climate so are removed
- Raw ring series are detrended with straight line, exponential curve, or spline
- These *standardized* series are compiled into the site chronology

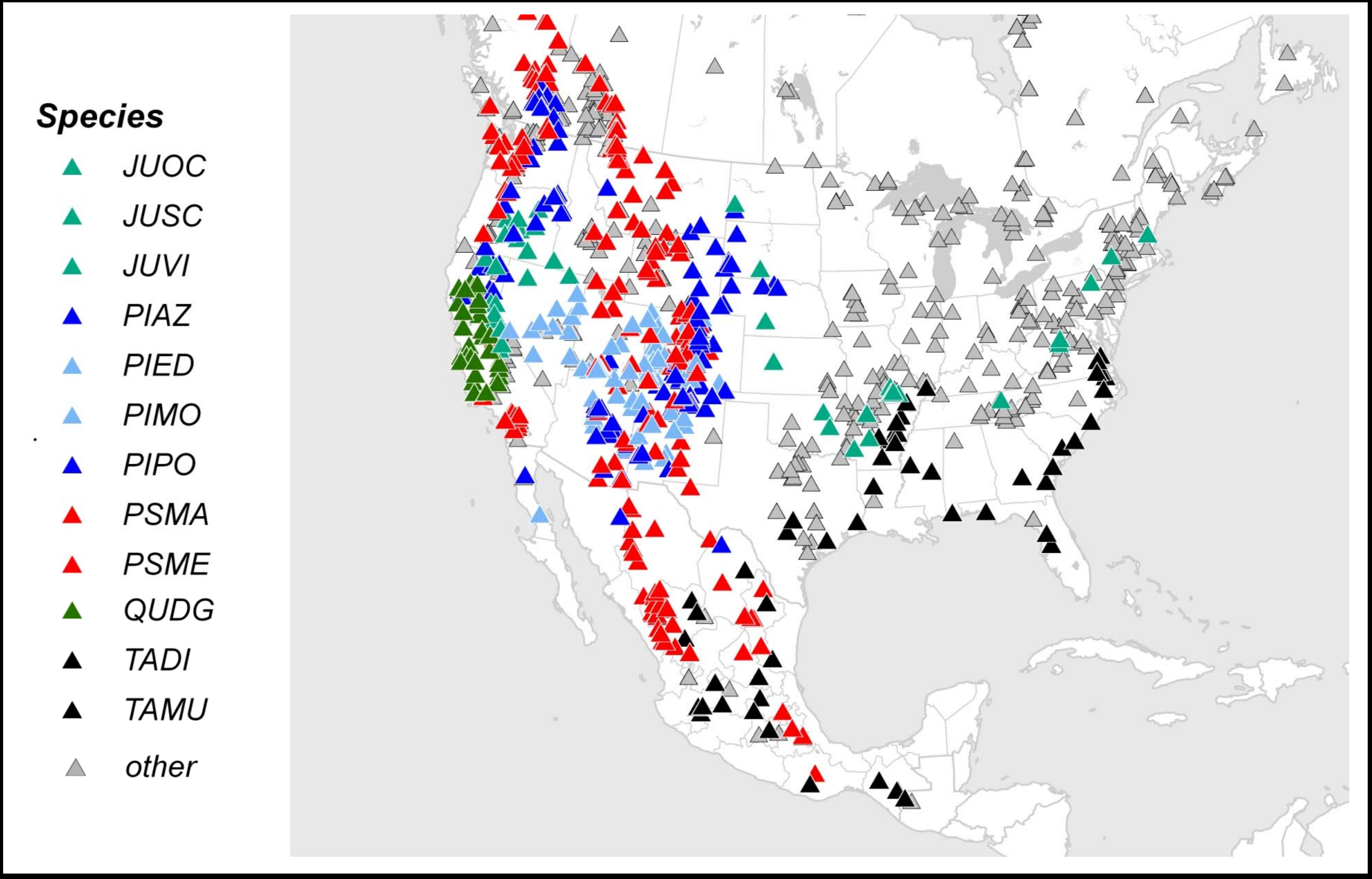
4. Compiling the Tree-Ring Chronology from the measurements from many trees



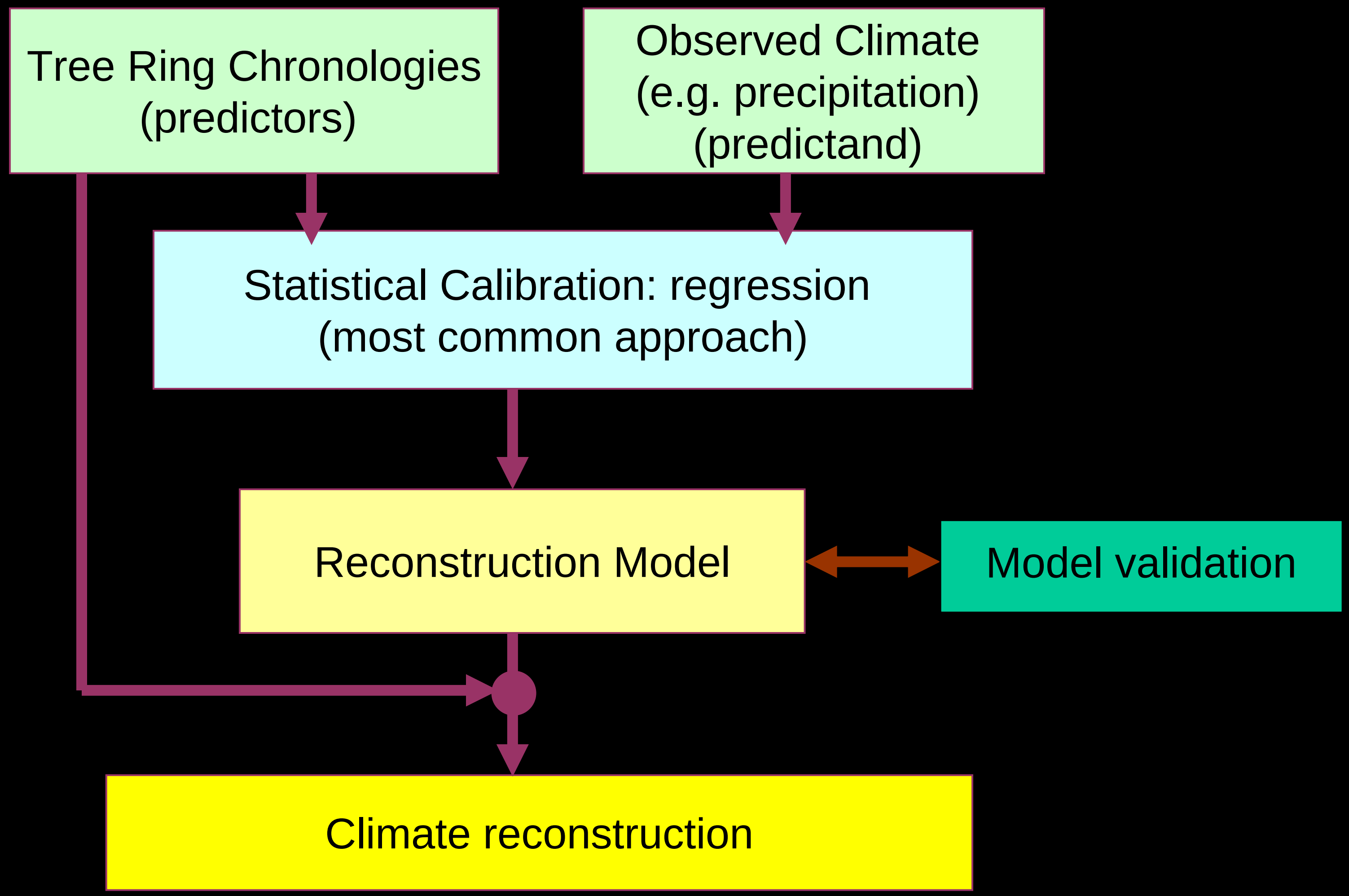
Chronology = basic unit of tree-ring data, “building block” for the climate reconstruction

Tree-ring chronologies in North America > 200 years

Colored triangle are moisture sensitive chronologies



5. Generating the climate reconstruction



based on Meko (2005)

Requirements for observed climate record

- **Length** – minimum 40 years for robust calibration with tree-ring data
- **Quality –** screened for station moves, changes in instrumentation, natural flows.
- Increasingly, we are using gridded climate data (0.5 degree) derived from all sources of observed climate station data (PRISM dataset is commonly used: Parameter-elevation Regressions on Independent Slopes Model).

Requirements for tree-ring chronologies

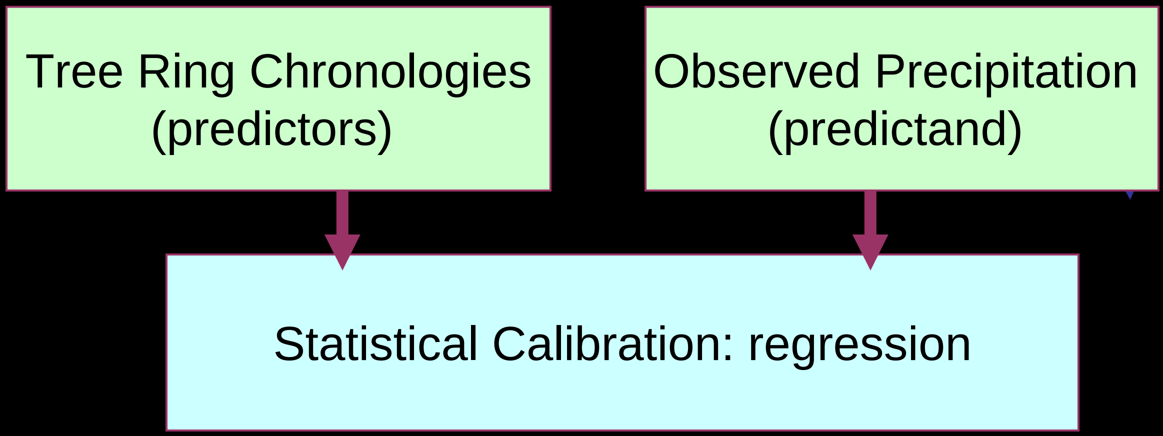
- **Moisture sensitive species** – primarily Douglas-fir, ponderosa pine, pinyon pine
- **Location** – from a region that is climatically linked to the region of interest
- Length tradeoff: fewer chronologies available further back in time, and in recent years, to some extent

Douglas-fir

Pinyon pine

Ponderosa pine

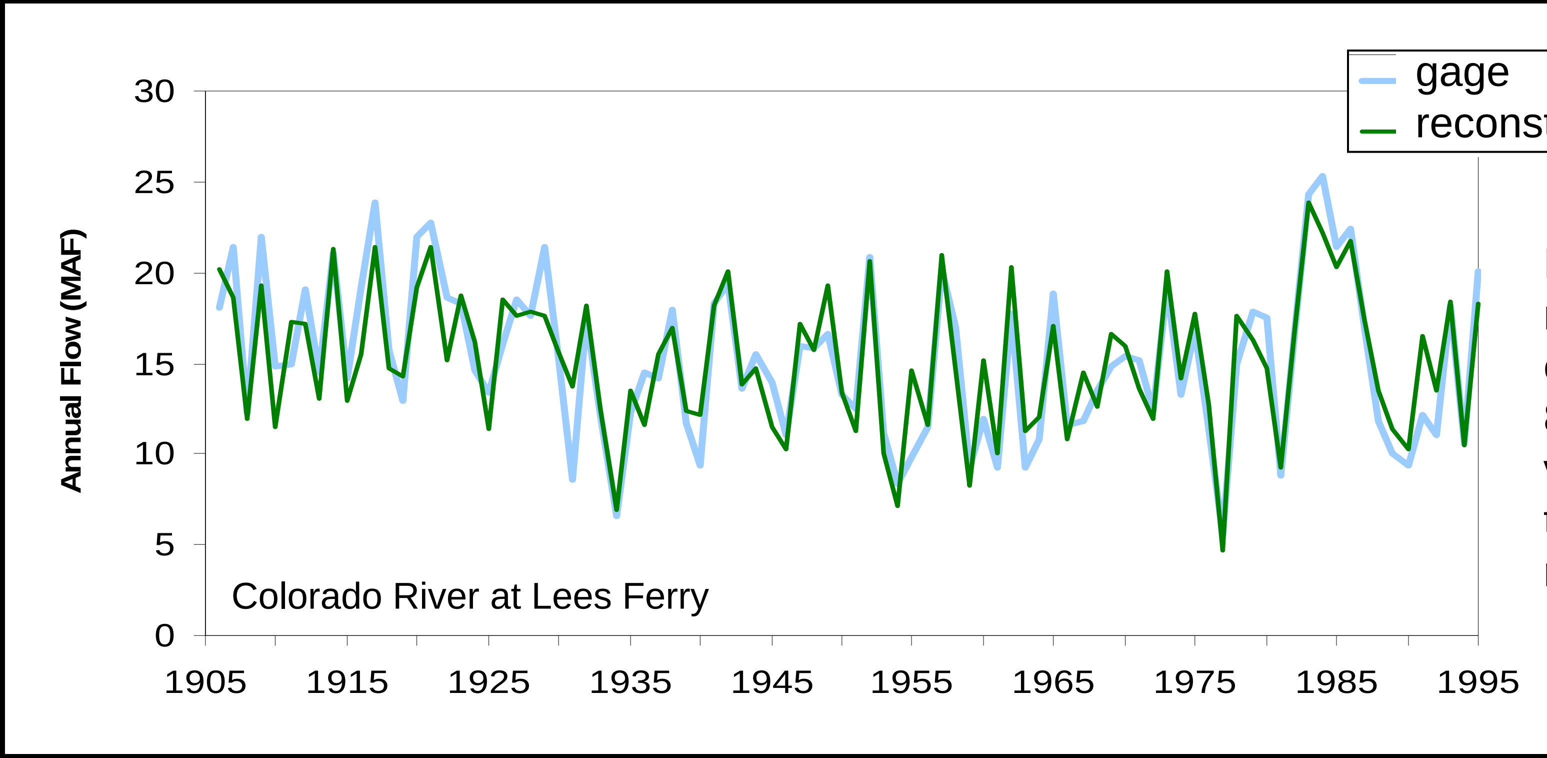
Reconstruction modeling strategies



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

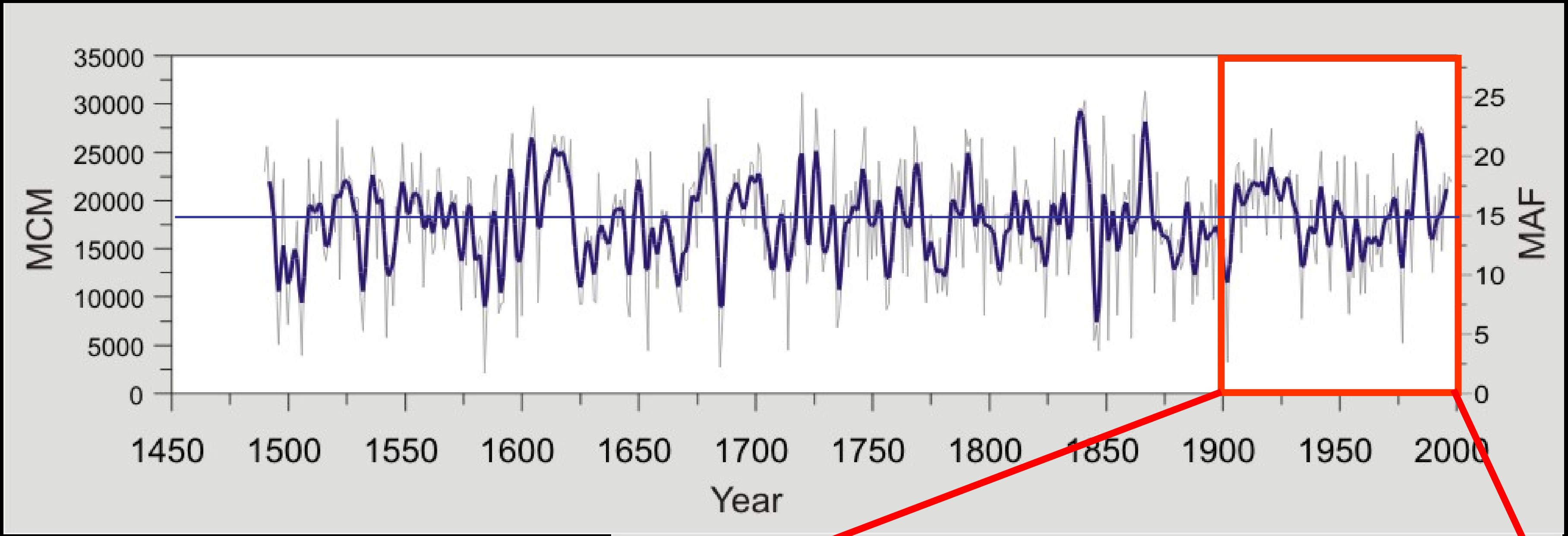
6. Model validation and skill assessment

- 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?

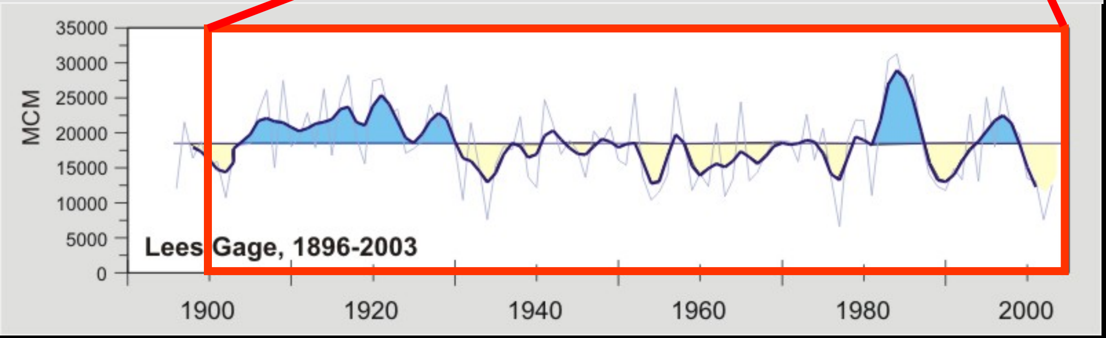


Regression model explains 81% of the variance in the gage record

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



Reconstruction of Colorado River at Lees Ferry, 1490-1997



Woodhouse et al. 2006

Sources of Uncertainty in Climate Reconstructions

- Trees are imperfect recorders of climate.

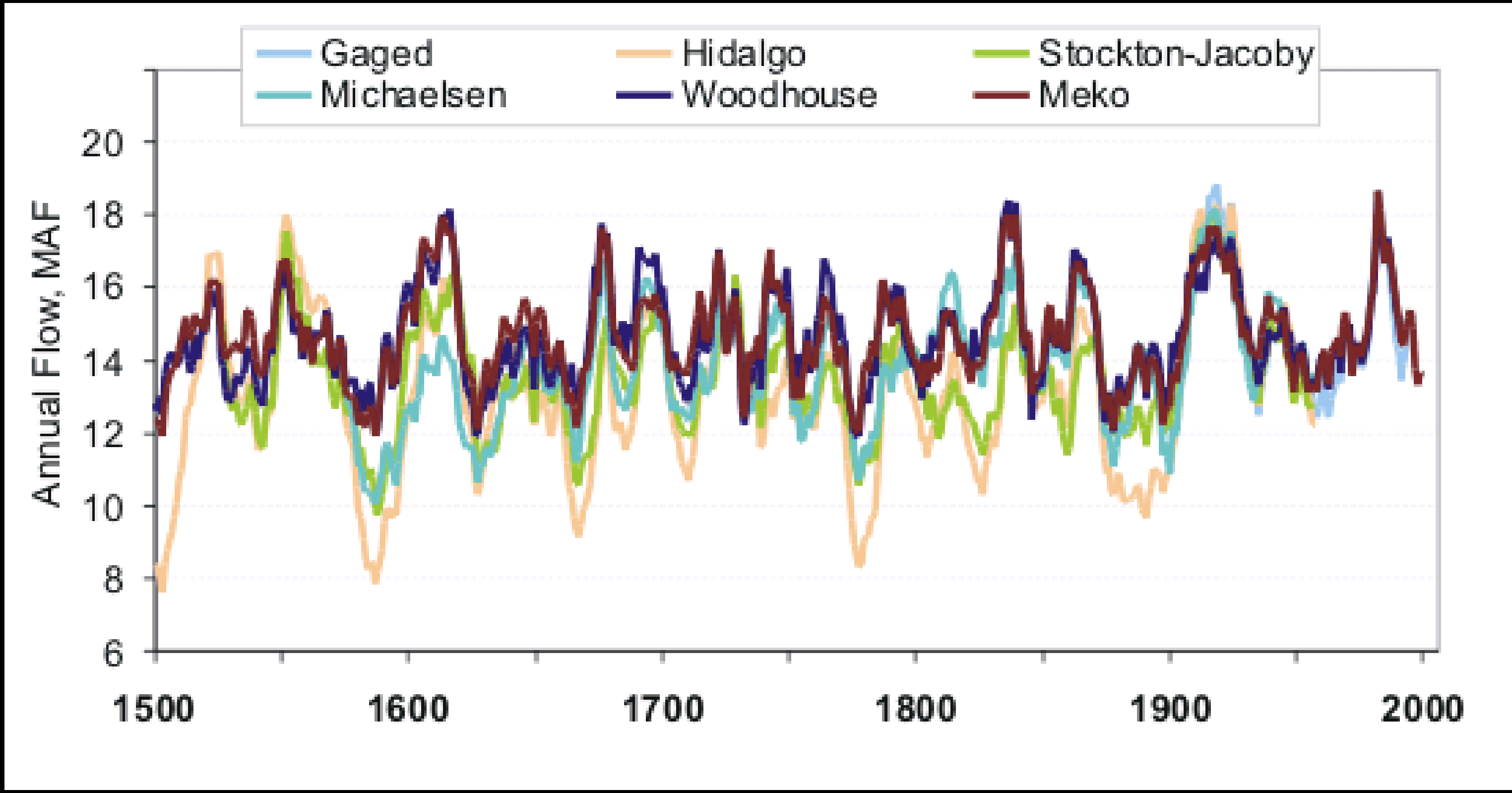
- The reconstruction model never explains 100% of the variance in the observed record.

- Climate 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 climate, and each annual point represents the central tendency of a range of plausible values, given the uncertainty

An Example: Colorado River at 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 (e.g., detrending)
- statistical methods for model calibration

What tree-ring reconstructions provide:

• context for assessing instrumental climate 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

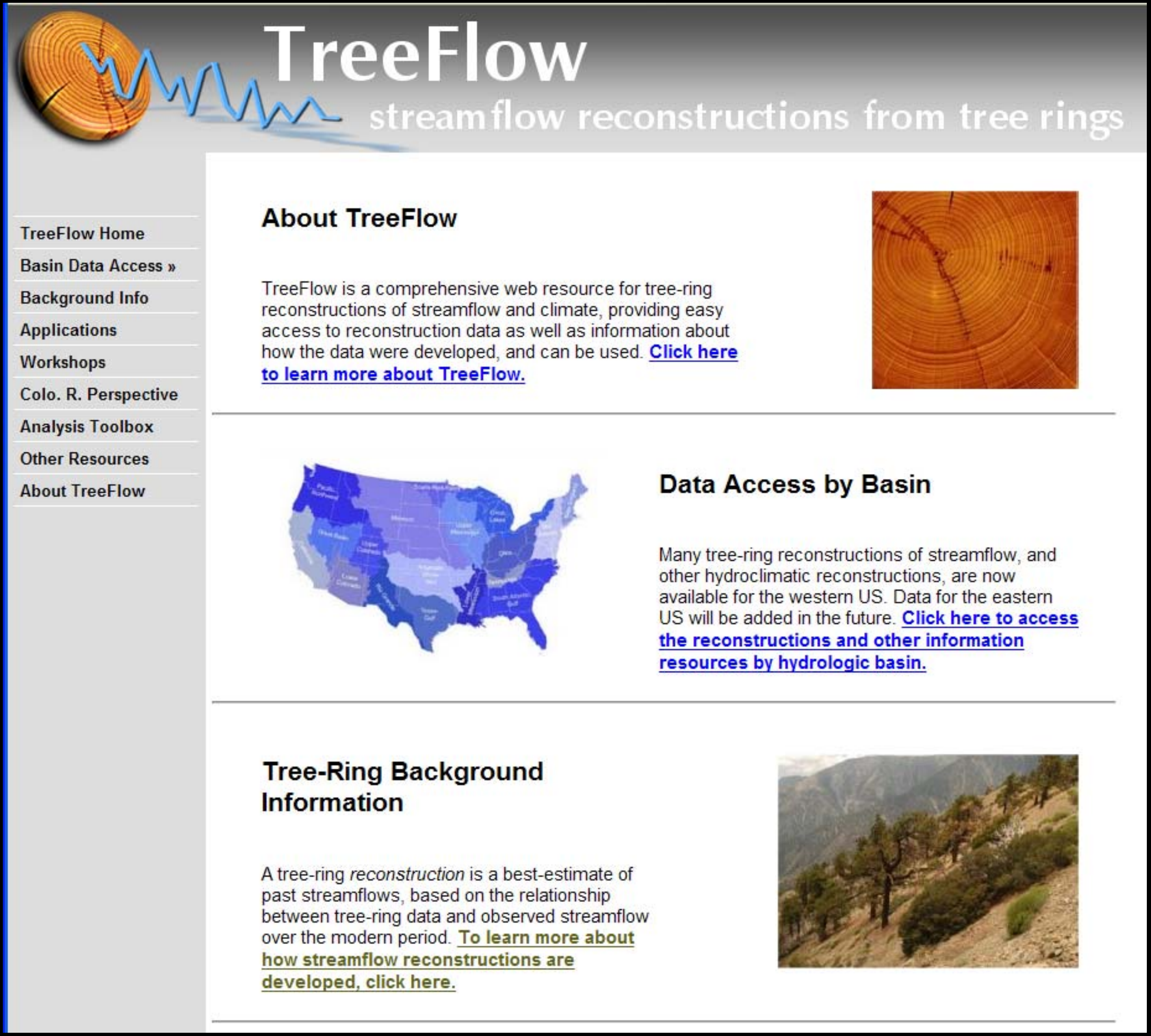
• insights on low-frequency (scale of decades to half century) variability

• an understanding of the rich sequences of wet and dry years that have occurred over past centuries

TreeFlow web pages: A resource for water managers

- tree-ring basics
- reconstruction and gage data
- workshop presentations
- applications examples
- references
- NEW: tools for analysis

http://treeflow.info/



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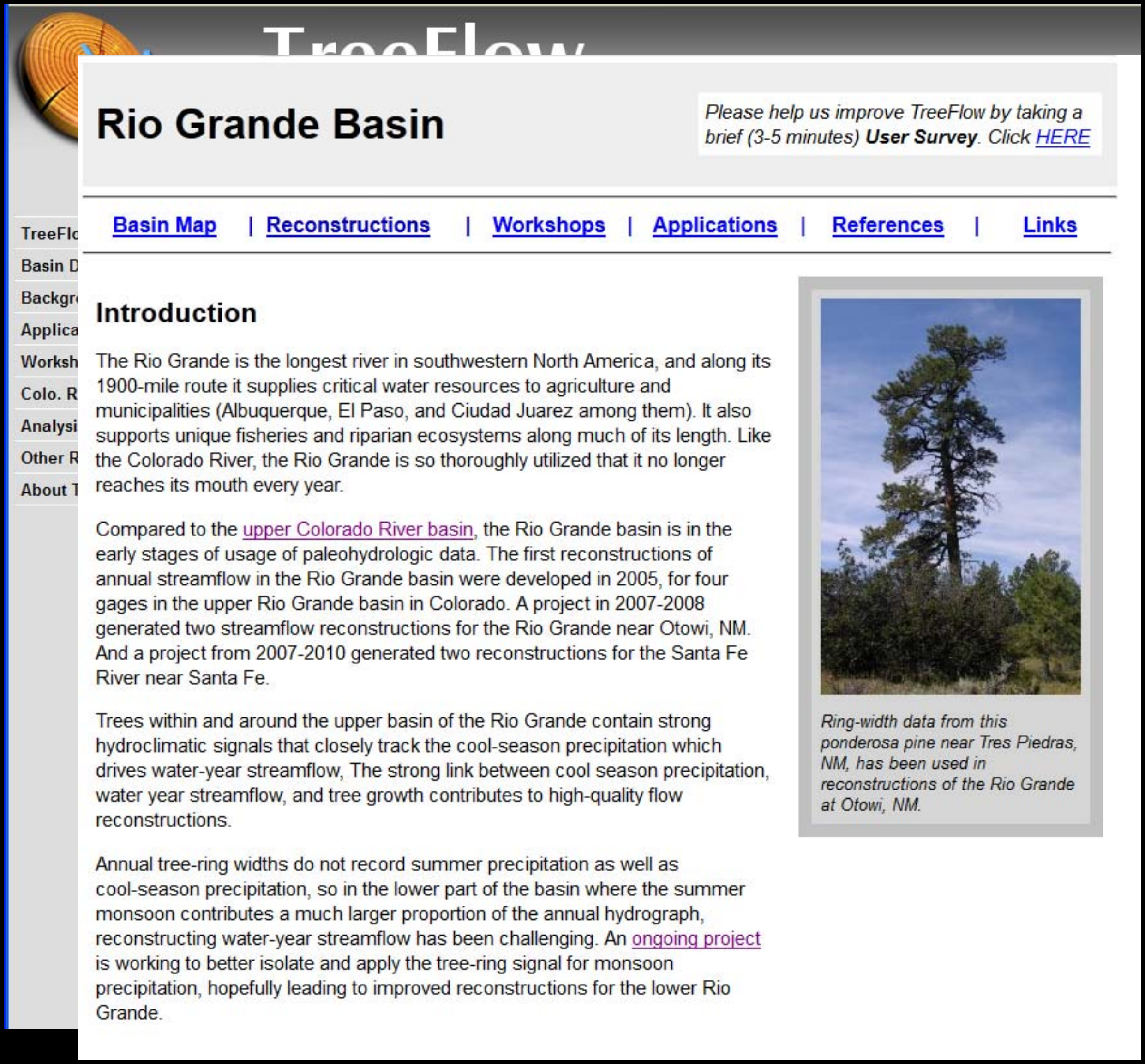

http://treeflow.info/

TreeFlow we
managers

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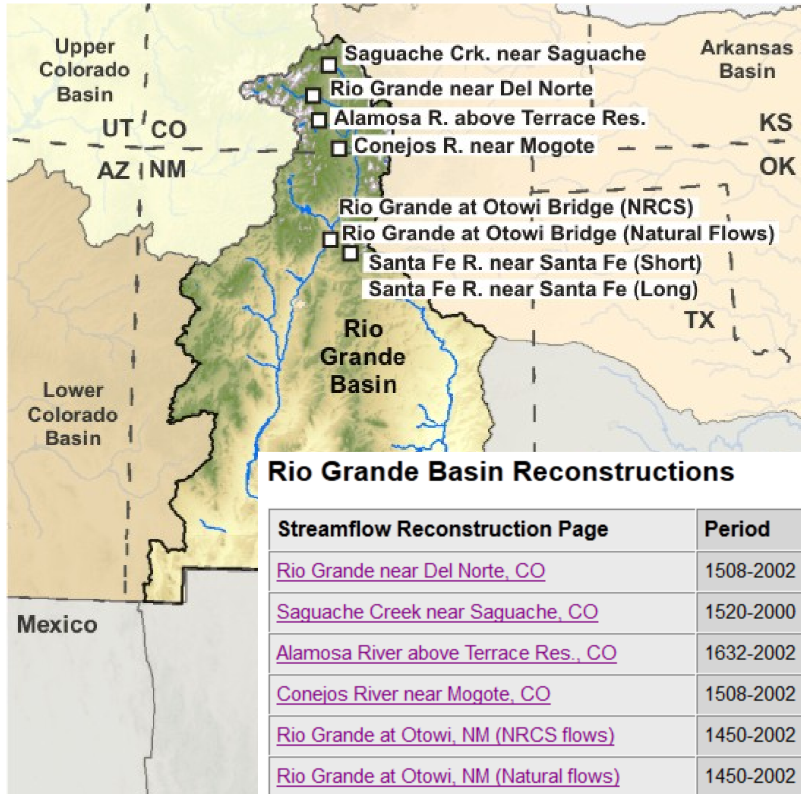
Basin Map

The map below shows the streamflow reconstructions currently available for the Rio Grande Basin. Select a gage to view the page for that reconstruction. Select an adjacent basin to visit the TreeFlow homepage for that basin. A list of the reconstructions available for the basin is presented below the map.



Rio Grande Basin Reconstructions

Streamflow Reconstruction Page	Period	Data File
Rio Grande near Del Norte, CO	1508-2002	riograndedelnorte.txt
Saguache Creek near Saguache, CO	1520-2000	saguache.txt
Alamosa River above Terrace Res., CO	1632-2002	alamosa.txt
Conejos River near Mogote, CO	1508-2002	conejos.txt
Rio Grande at Otowi, NM (NRCS flows)	1450-2002	riograndeotowiNRCS.txt
Rio Grande at Otowi, NM (Natural flows)	1450-2002	riograndeotowinatural.txt
Santa Fe River near Santa Fe, NM (Short)	1592-2007	santafeshort-santafelong.xls
Santa Fe River near Santa Fe, NM (Long)	1305-2007	santafeshort-santafelong.xls

Other Hydroclimatic Reconstructions developed for, or including, the Rio Grande Basin:

Summer (JJA) Palmer Drought Severity Index (PDSI), covering most of North America on 2.5-degree grid

Cool season (Nov-Mar) precipitation for each climate division in New Mexico and Arizona, extending back 1000 years (Ni et al. 2002)

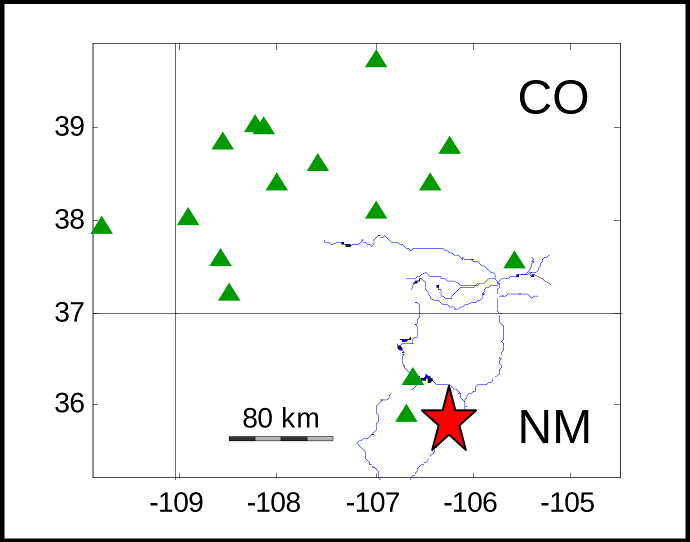
Annual (June-June) precipitation for northwestern New Mexico, extending back 2100 years (Grissino-Mayer 1996)

http://treeflow.info/

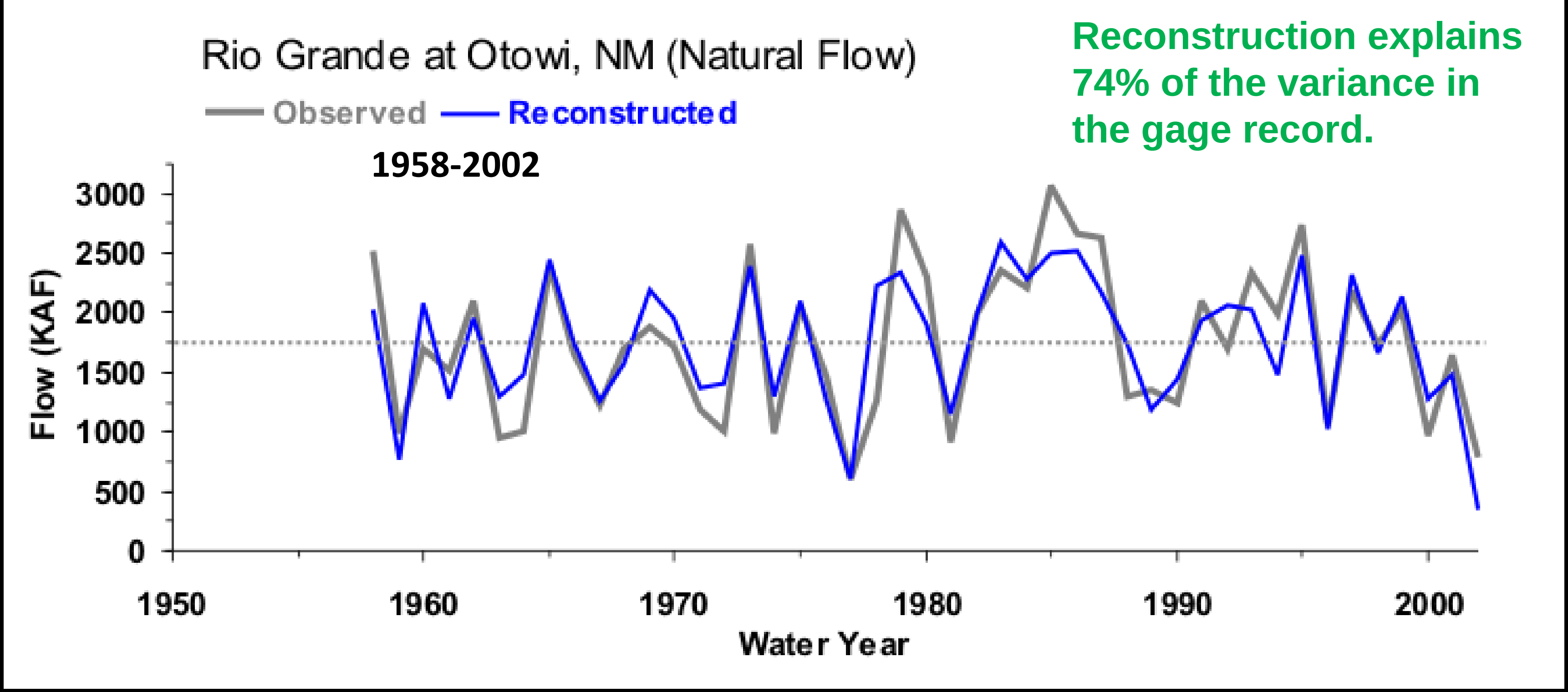
Part 2.

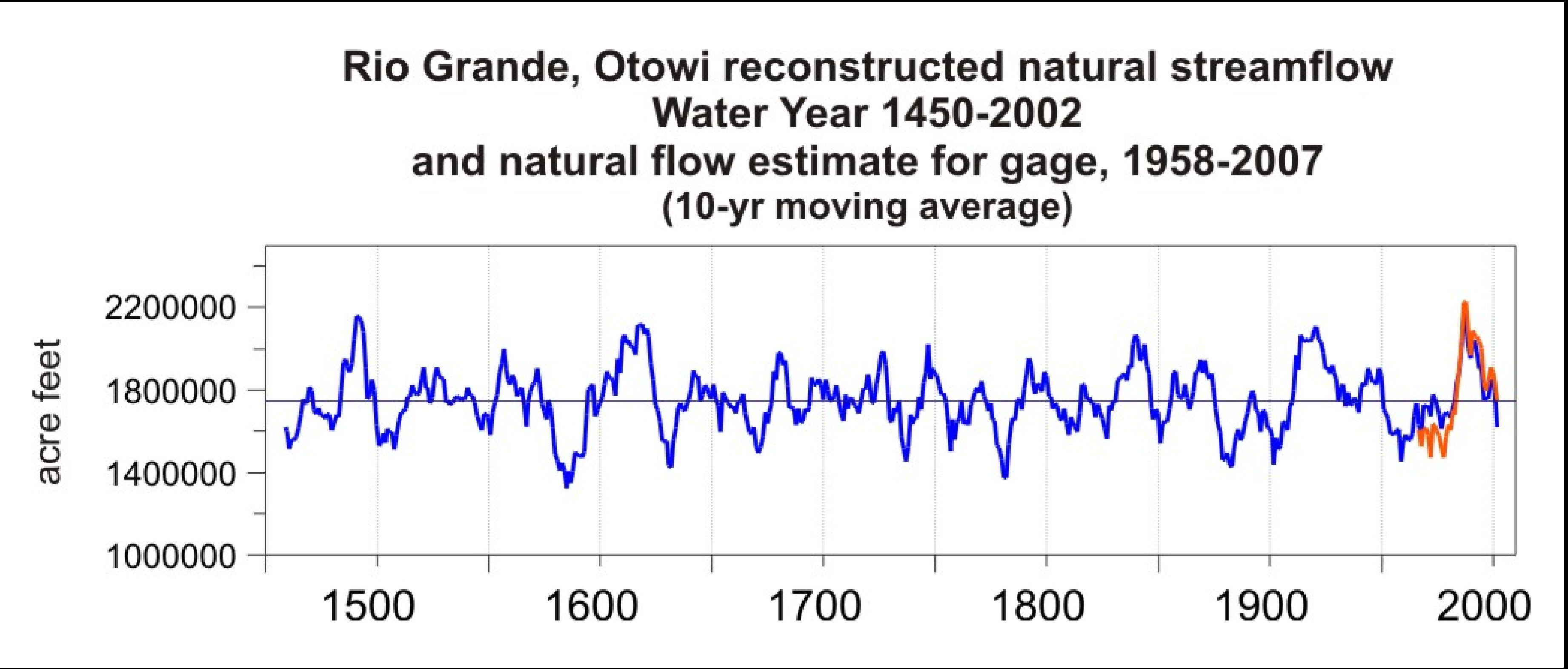
Streamflow Reconstruction for the Rio Grande at Otowi (a review)

Streamflow Reconstruction for Rio Grande at Otowi, NM



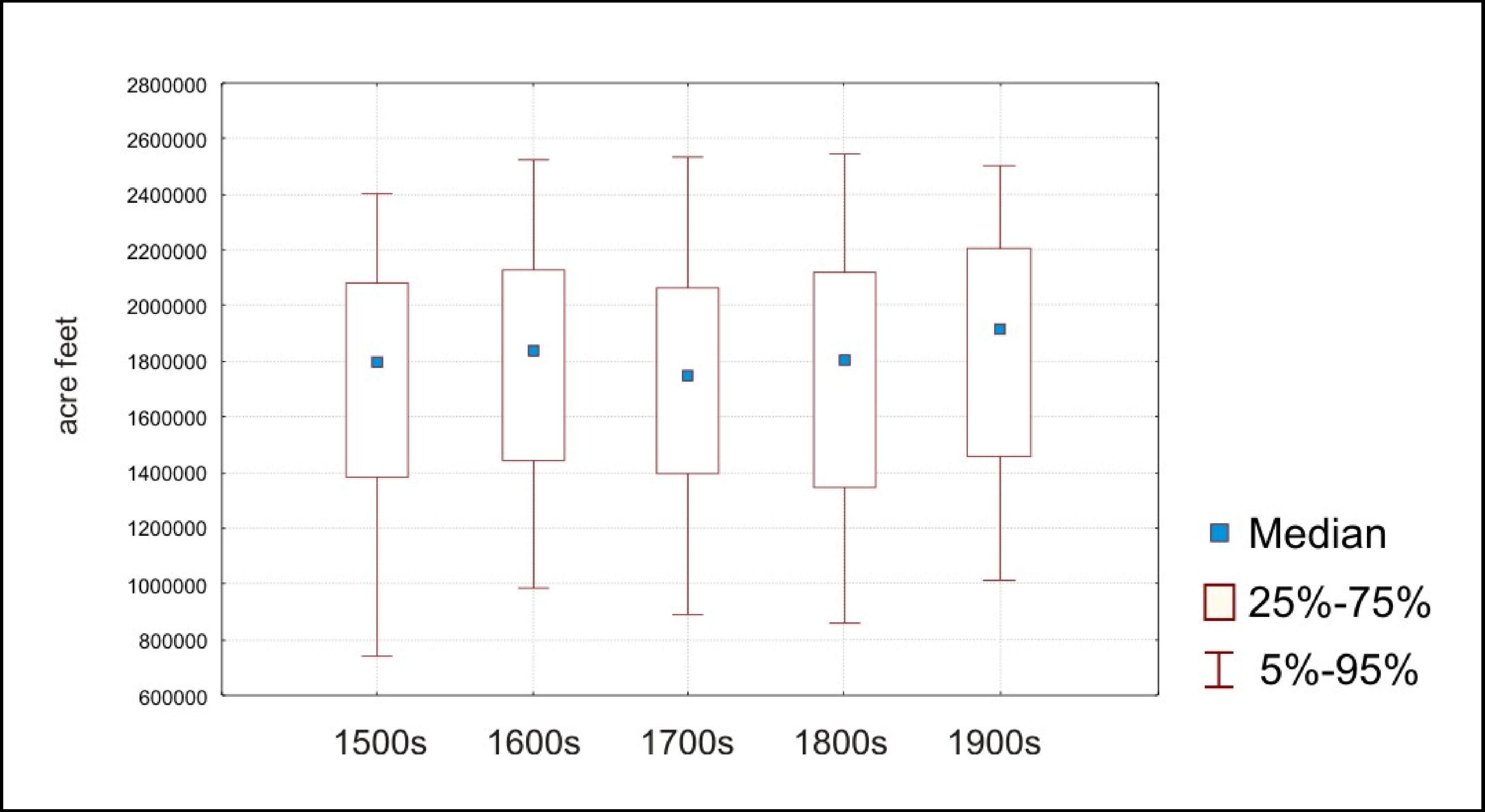
The reconstruction model was calibrating using the average of 17 tree-ring chronologies (green triangles)





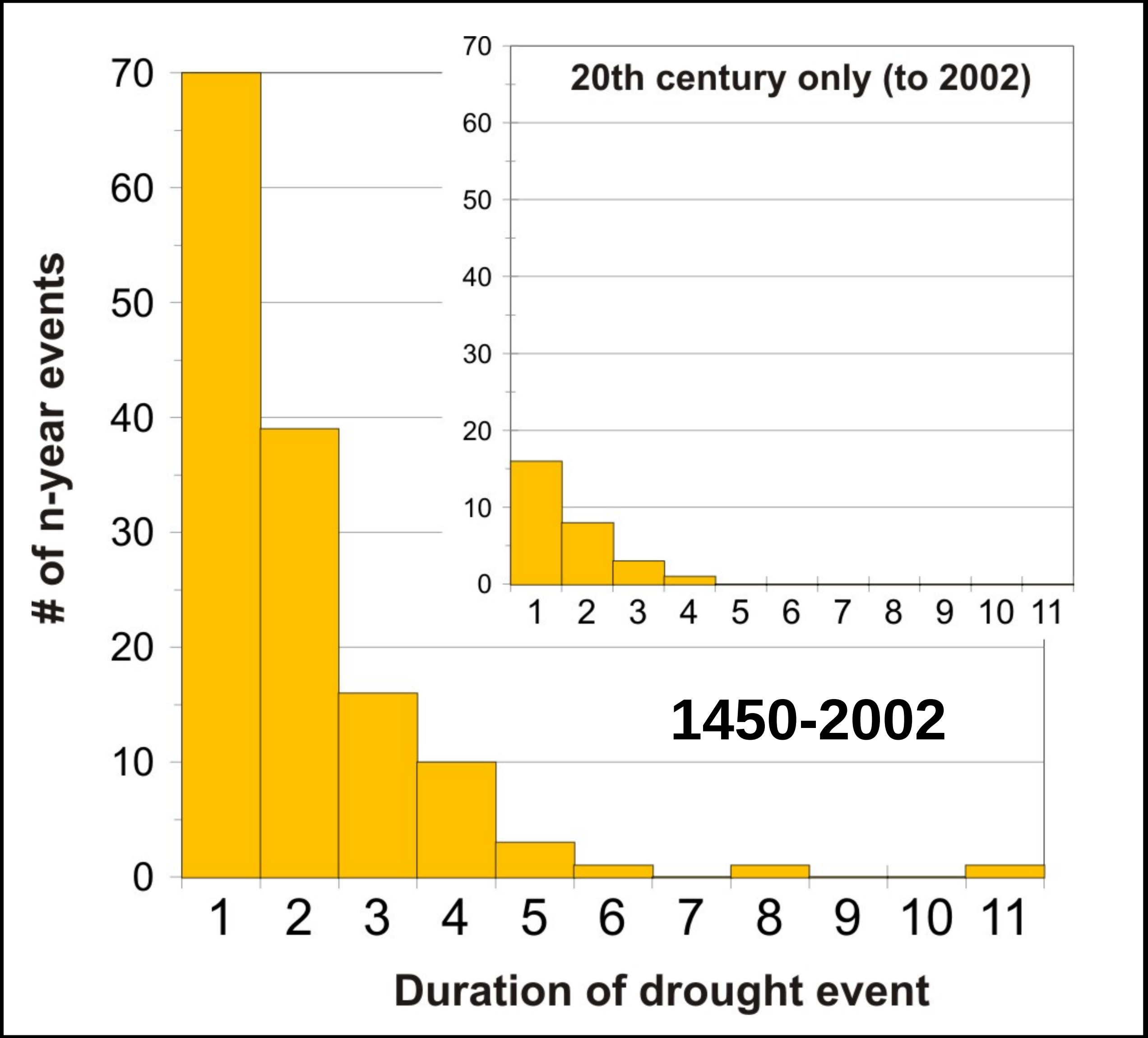
5 Driest Decades	5 Wettest Decades
1576-1585	1978-1987
1772-1781	1482-1491
1623-1632	1610-1619
1874-1883	1912-1921
1893-1902	1831-1840
1950-1959	

Rio Grande, Otowi Reconstruction, Statistical Characteristics by Century



Drought Duration and Frequency, Otowi

Drought is defined as a single year or set of consecutive years below the long-term median



Part 3.

Latewood widths and monsoon reconstruction

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

North American Monsoon Project

Principal Investigators

Connie Woodhouse
David Meko
Ramzi Touchan
Christopher Castro
Steve Leavitt

Graduate Students

Dan Griffin
Carlos Carillo
Holly Faulstich

Research Associate/Post Doc

Kiyomi Morino
Hsin-I Chang

Funding

- National Science Foundation
- EPA STAR Fellowship

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NSF
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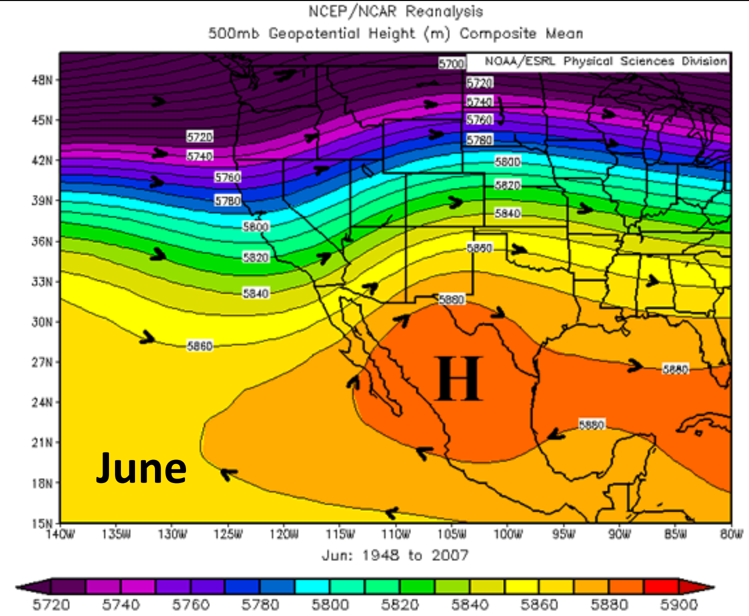
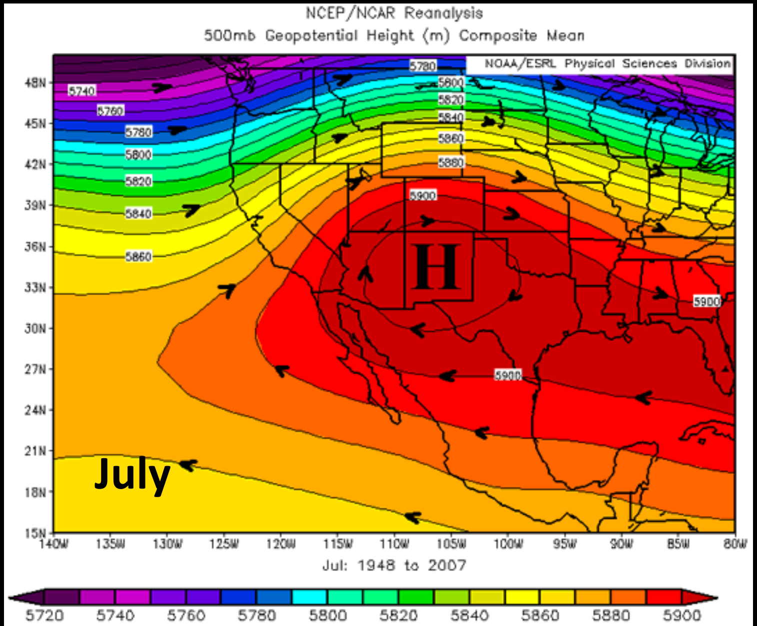
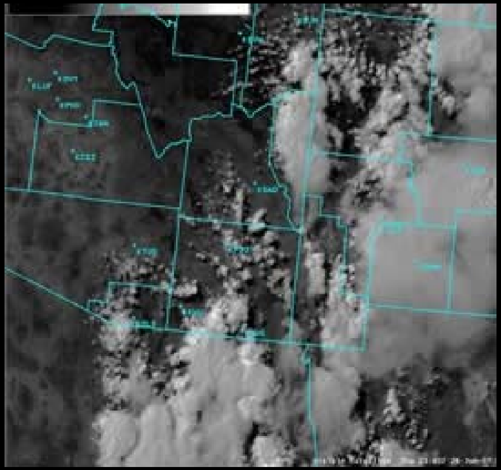
North American Monsoon

Circulation shifts between June and July result a ridge of high pressure over the southwestern U.S., and advection of moisture into the region.

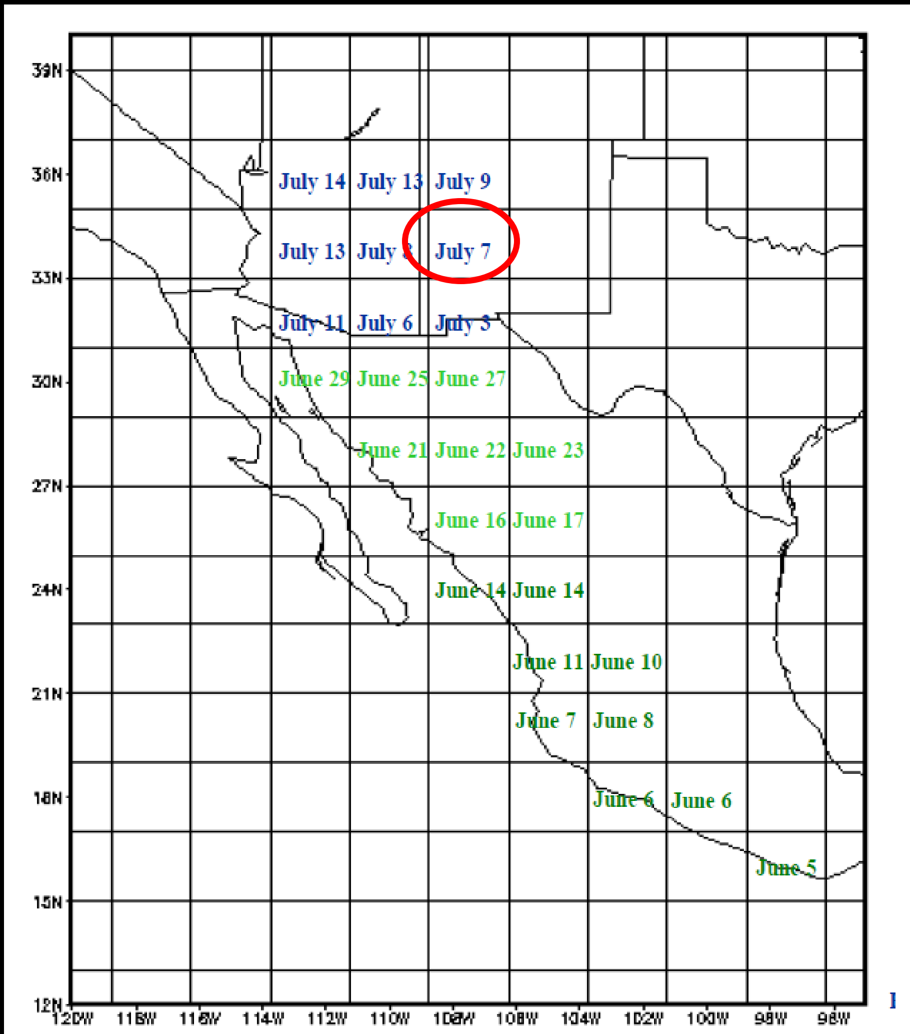




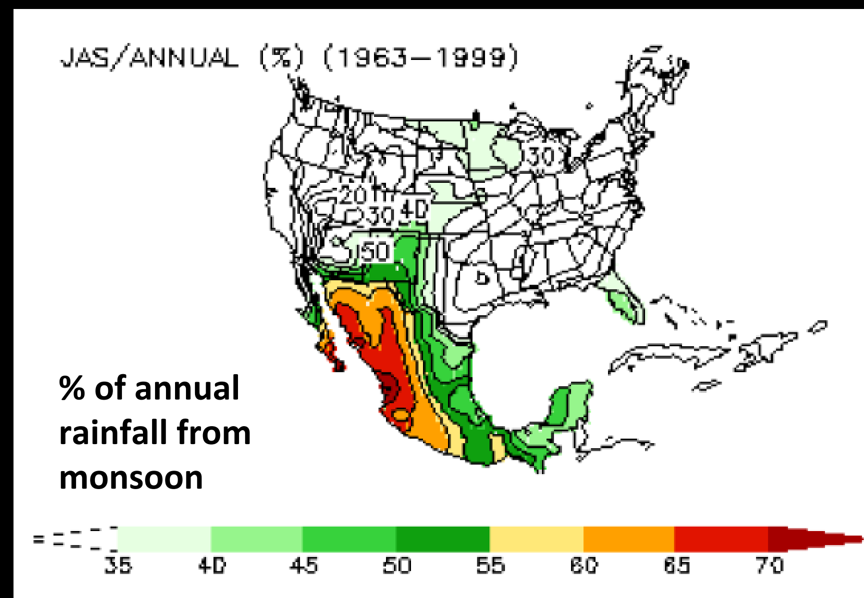


Visible satellite image of isolated thunderstorms during monsoon onset, June 28, 2007

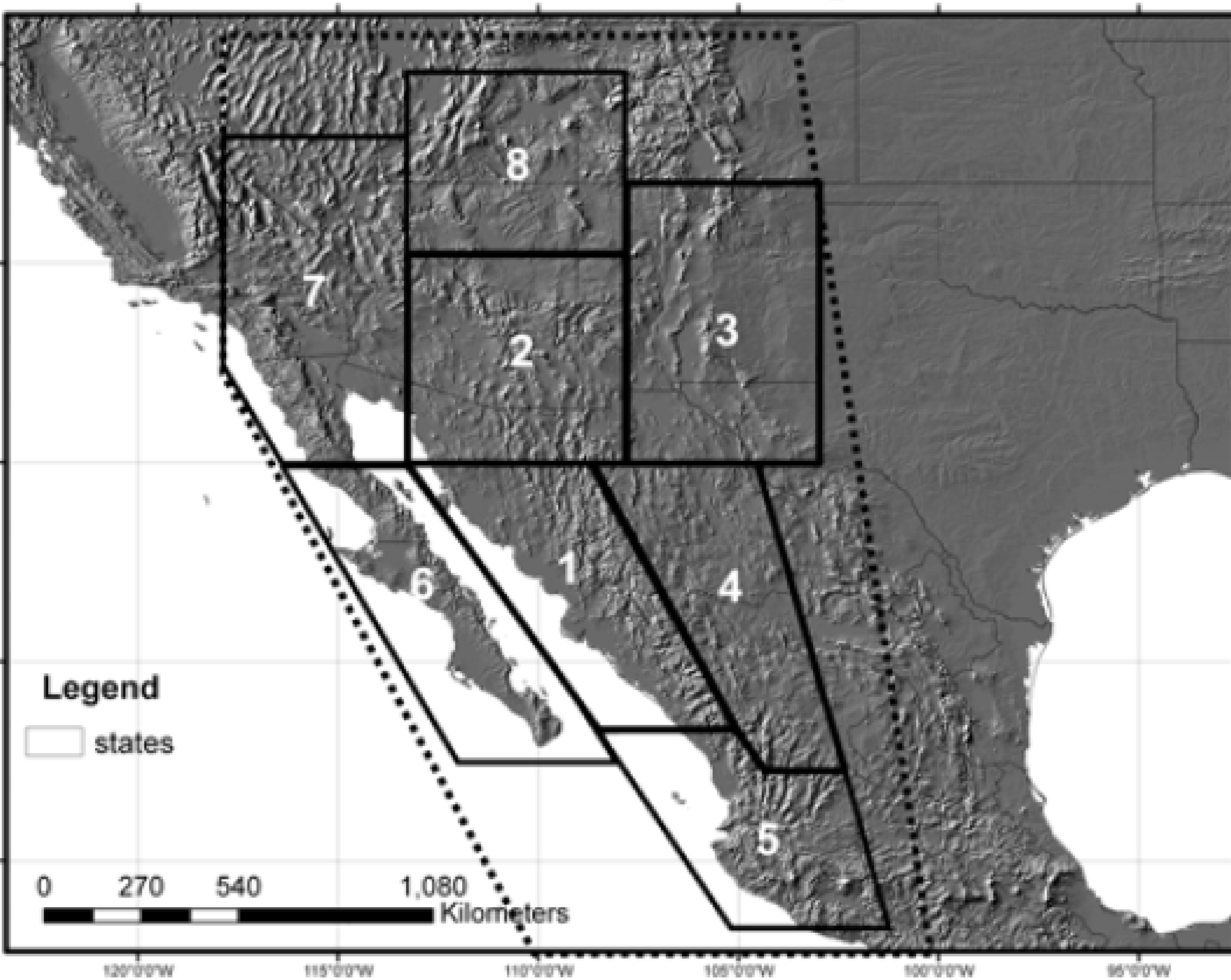
Mean calendar dates of monsoon onset



The Monsoon accounts for more than 70% of total annual precipitation in some parts of Mexico, and for over 50% in parts of Arizona and New Mexico



North American Monsoon sub-regional domains



Earlywood & Latewood

Earlywood

- Lighter color
- Less Dense

  (Larger cells/thinner walls)

- Conducts water & nutrients

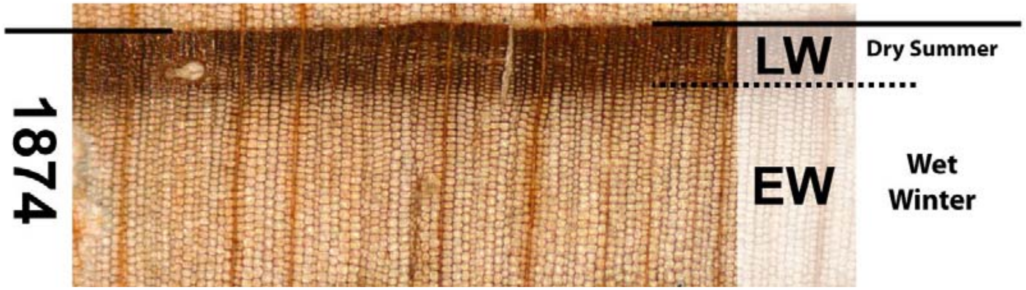
Latewood

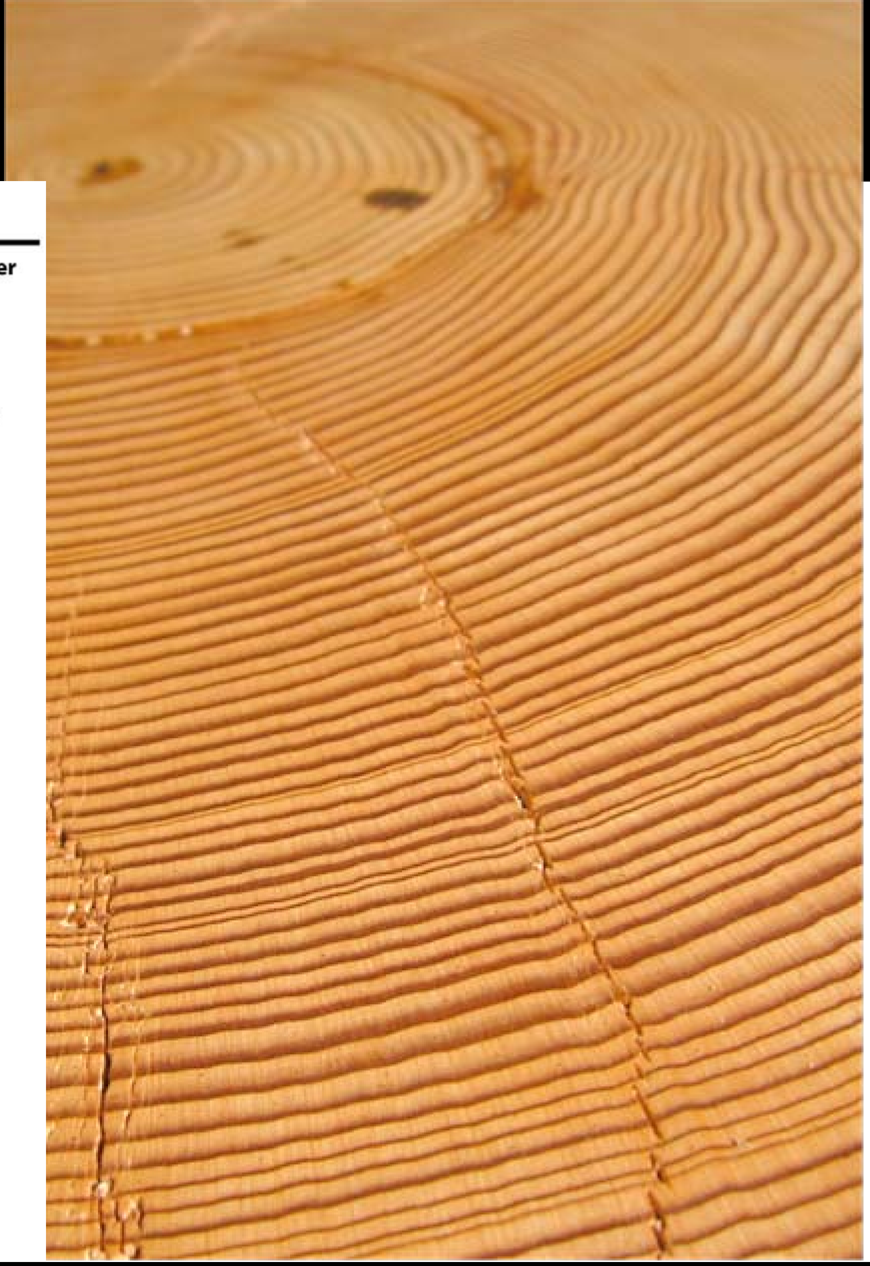
- Darker color
- More Dense

  (Smaller cells/thicker walls)

- Provides structural stability

Earlywood & Latewood





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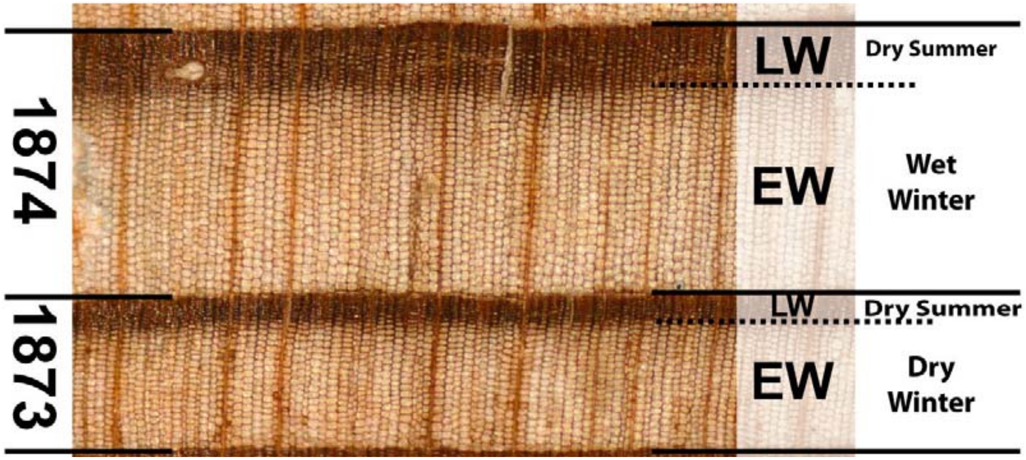

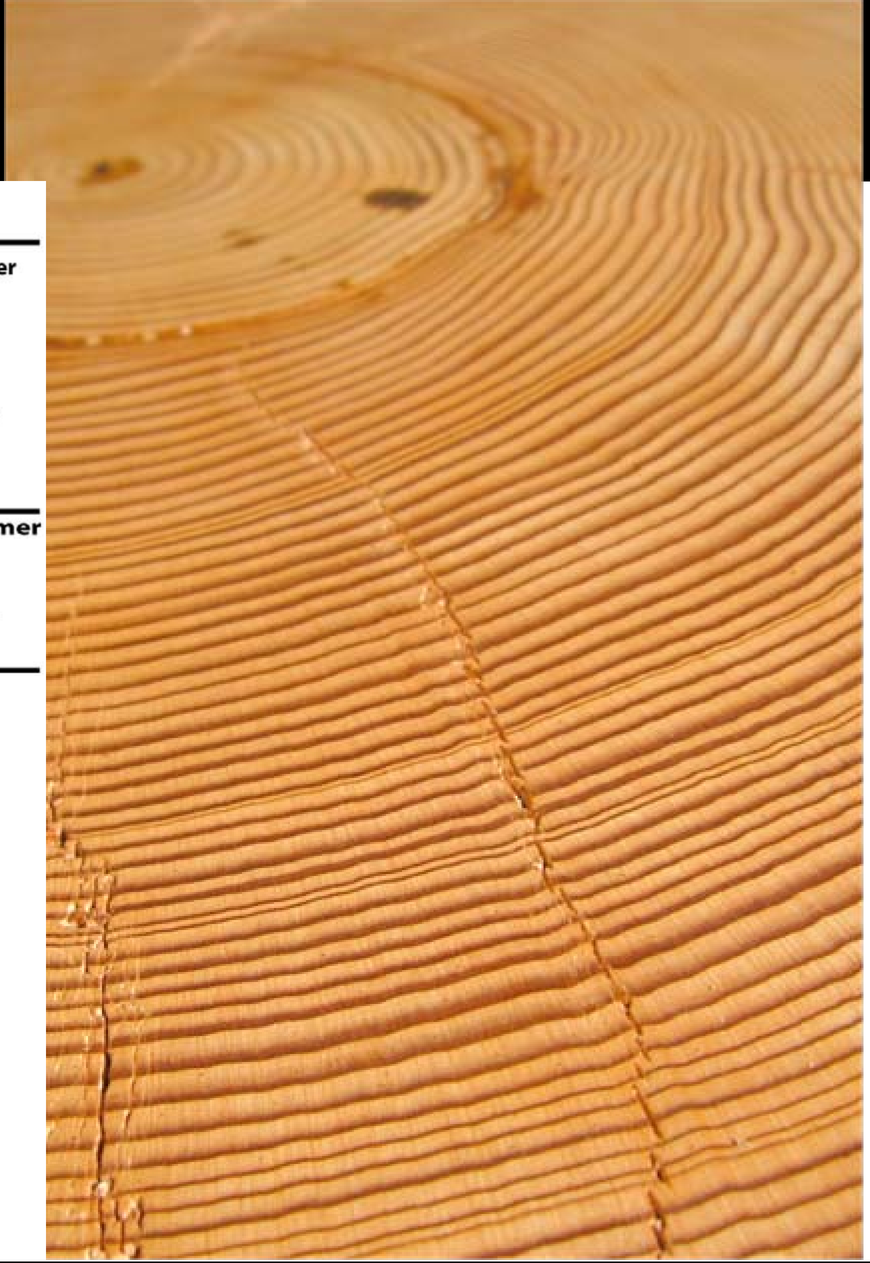

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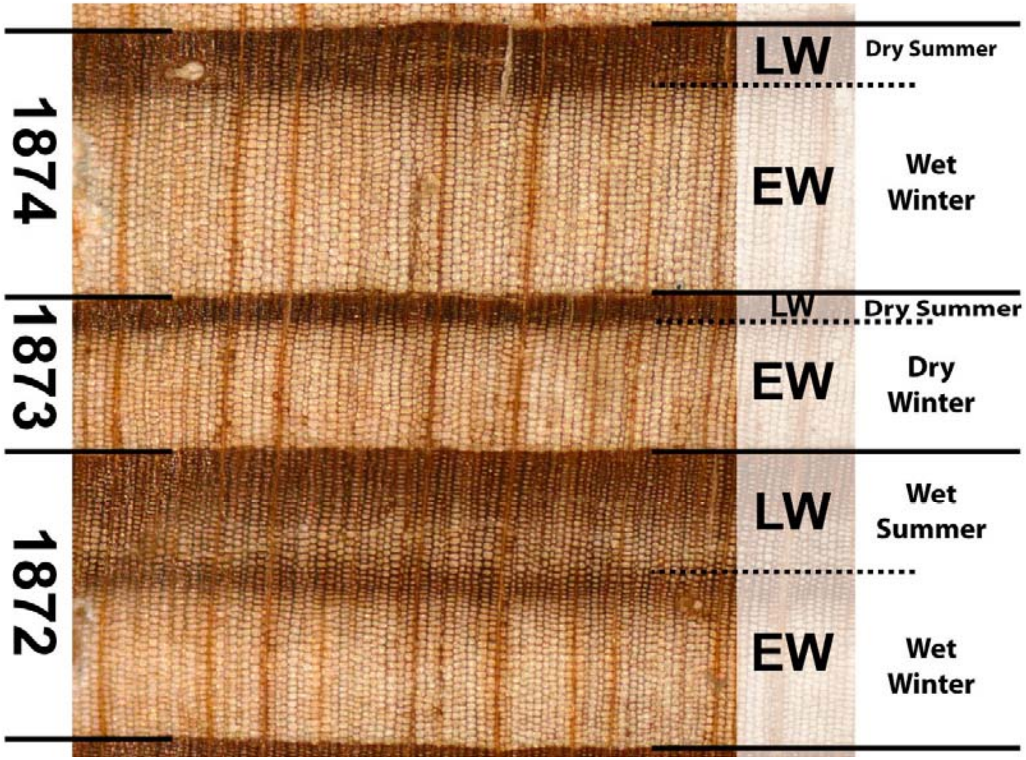

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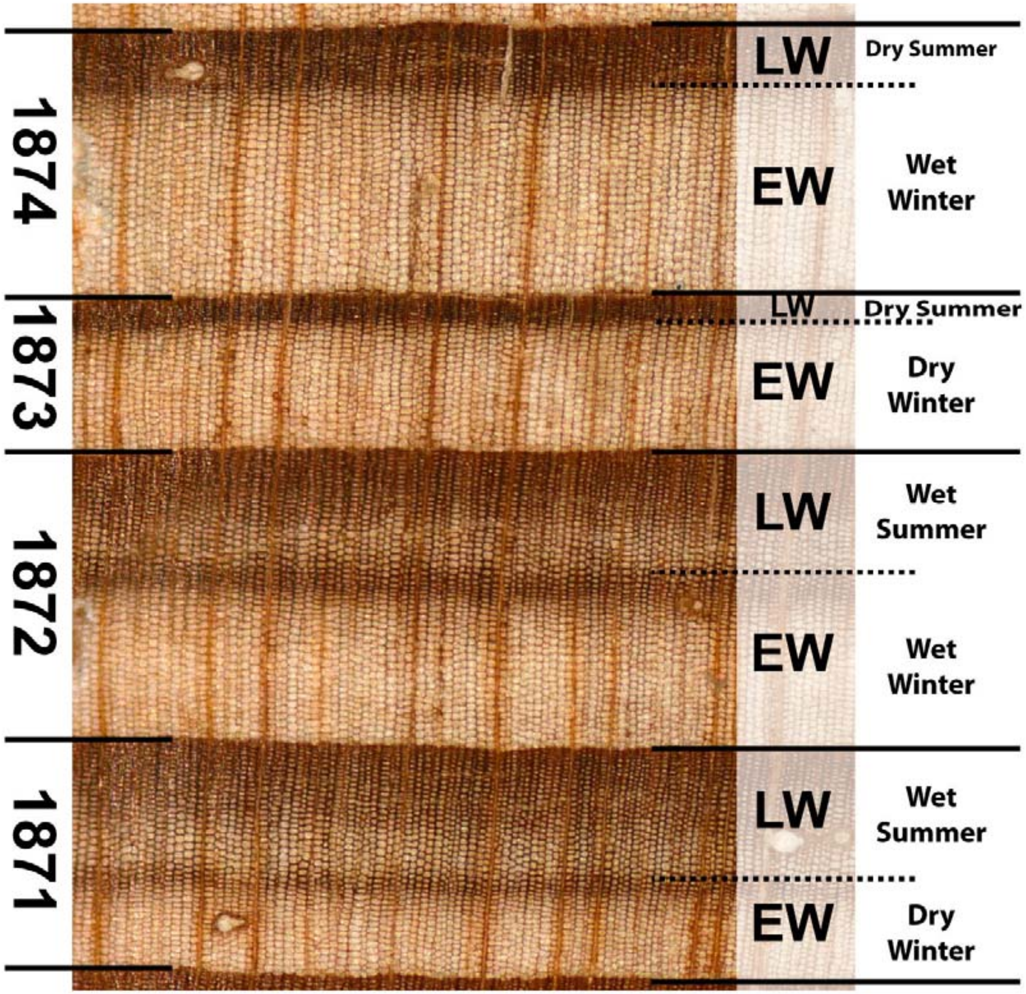

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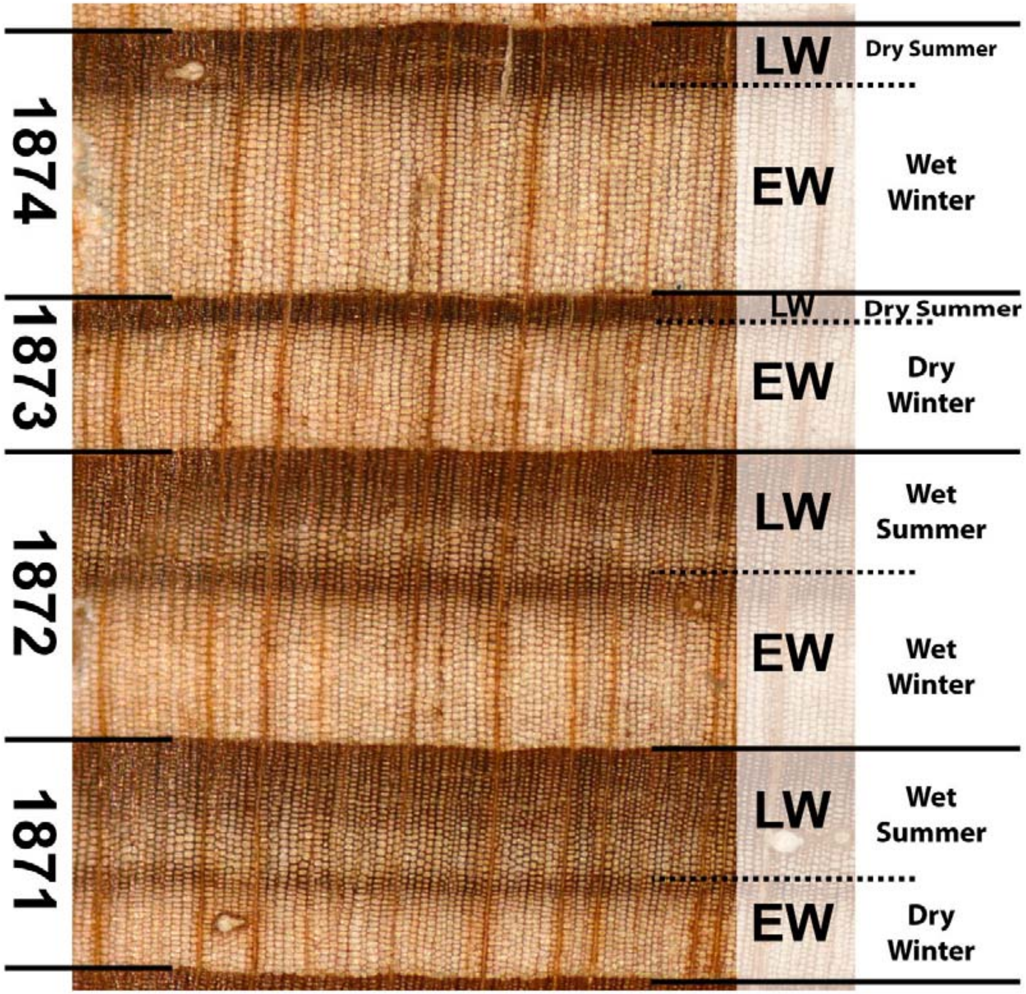

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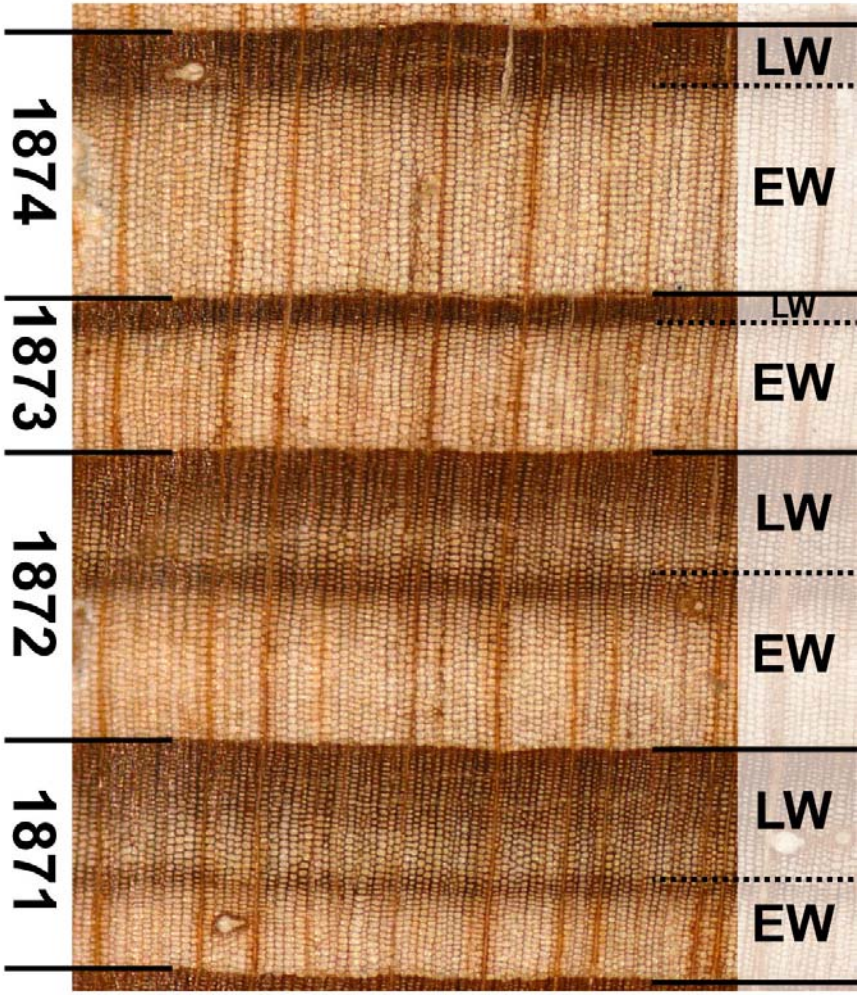
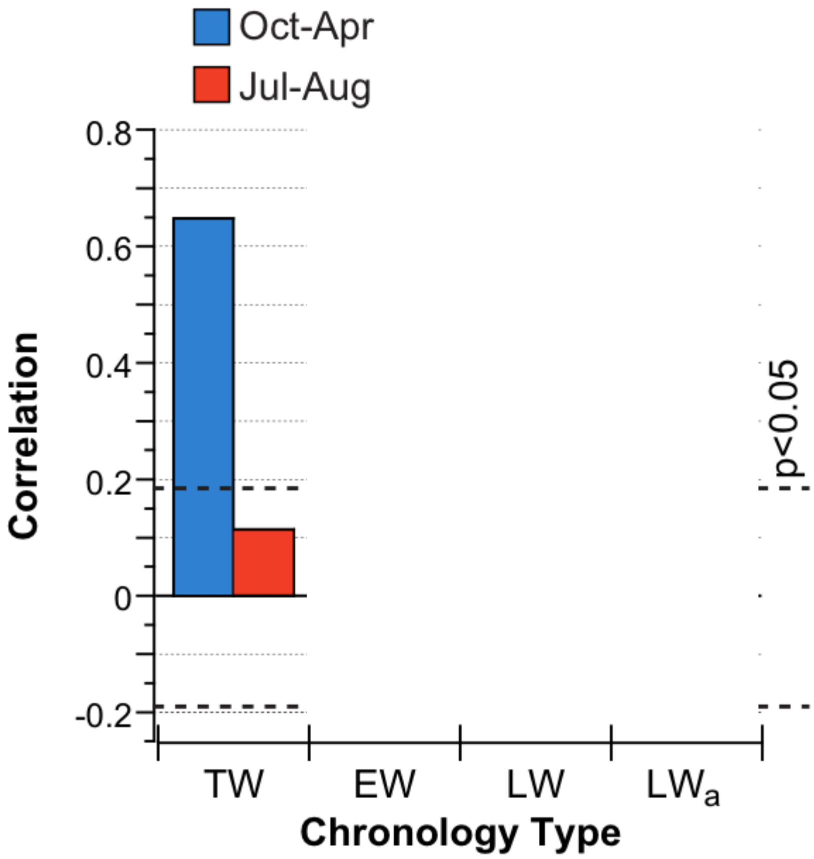
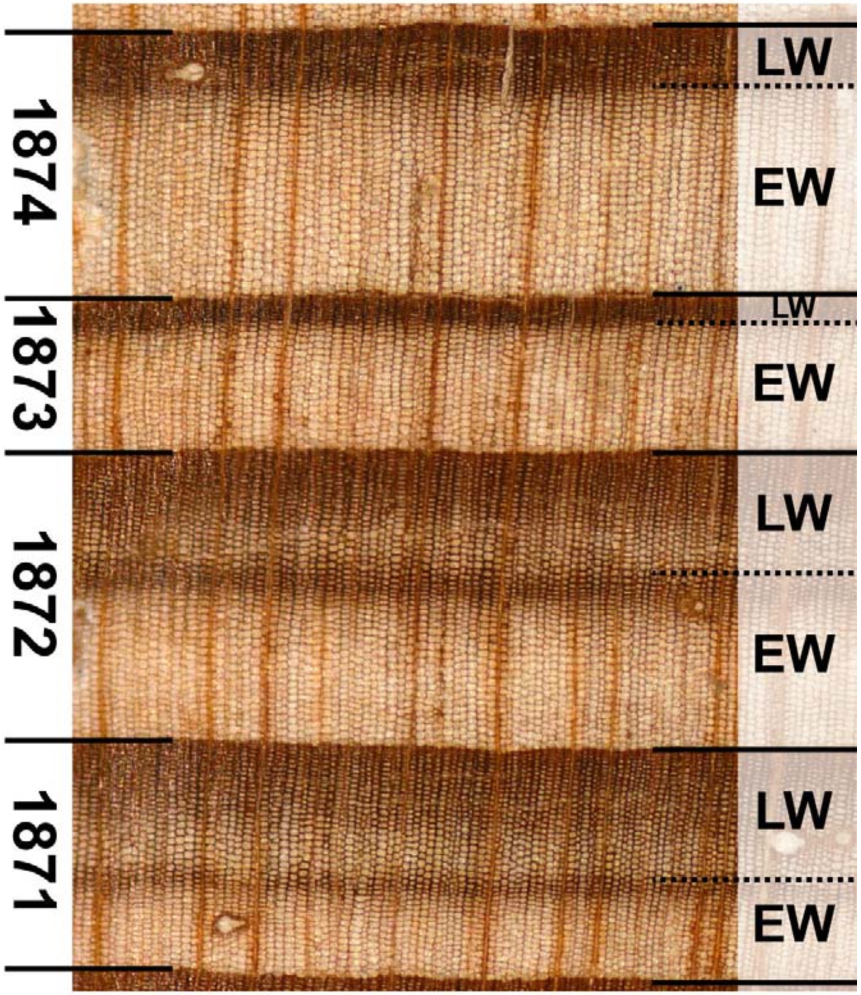
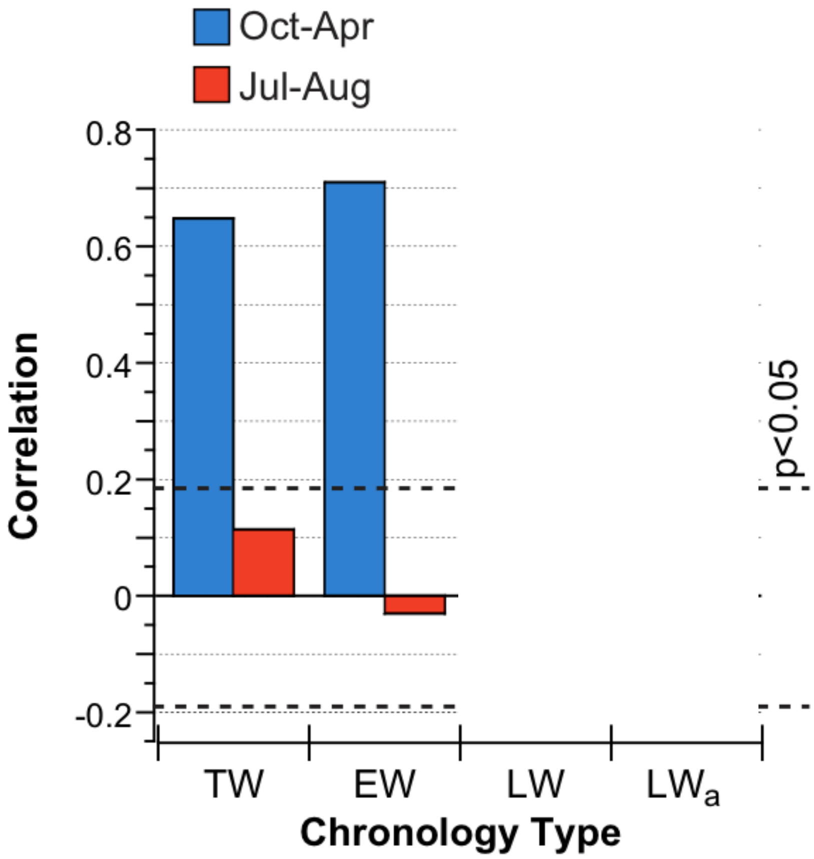




(Griffin et al. 2011 *Tree-Ring Research*)

Earlywood & Latewood





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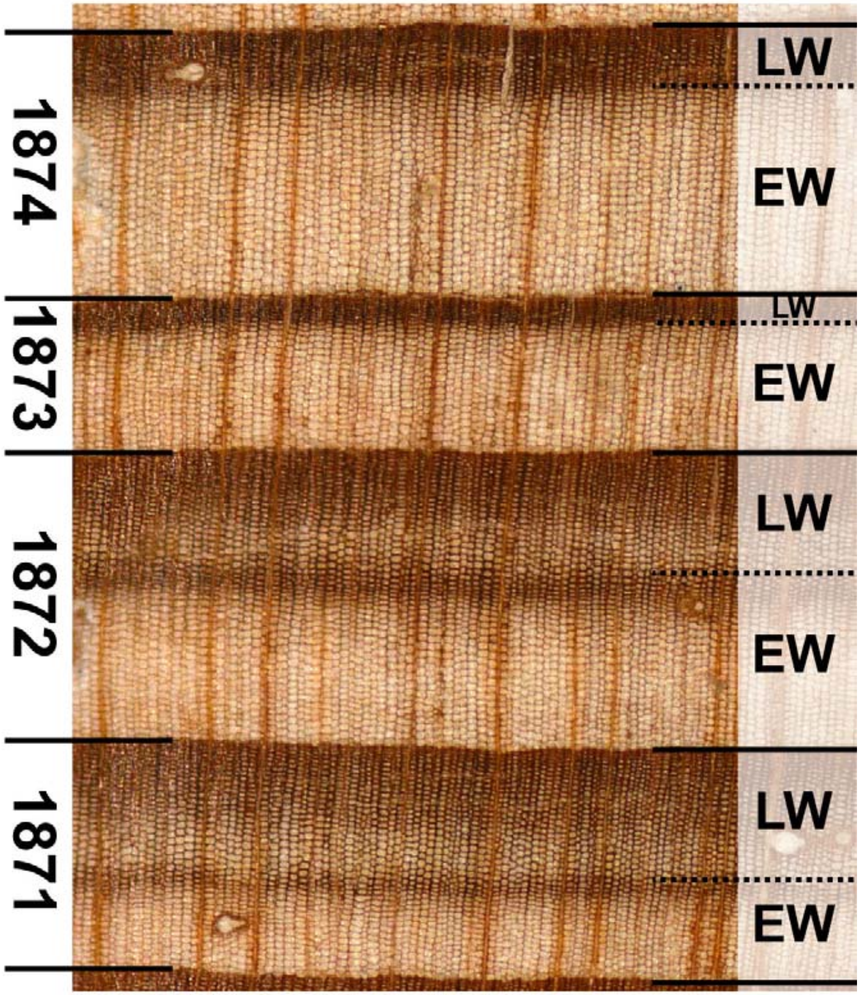

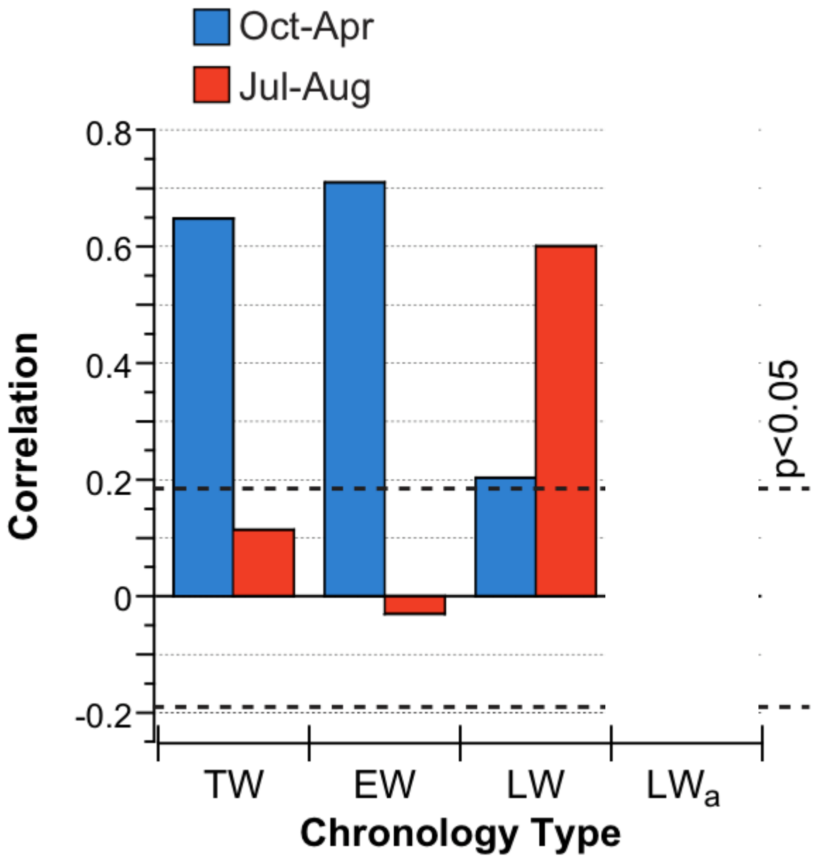

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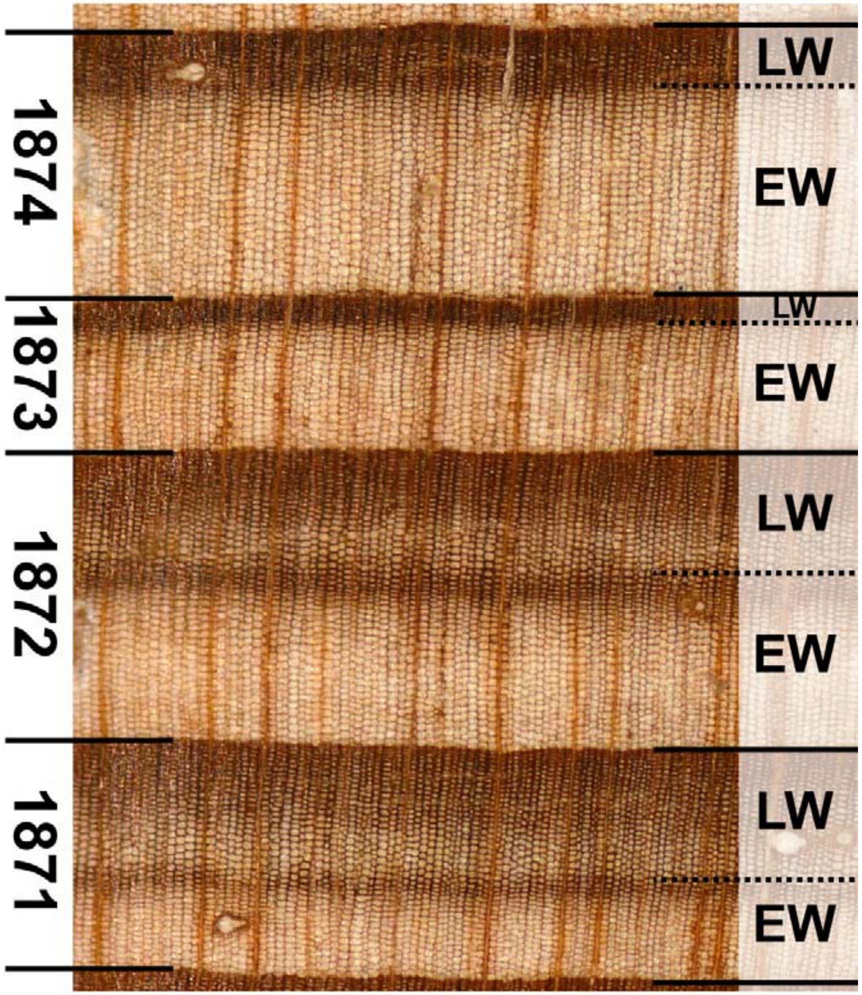
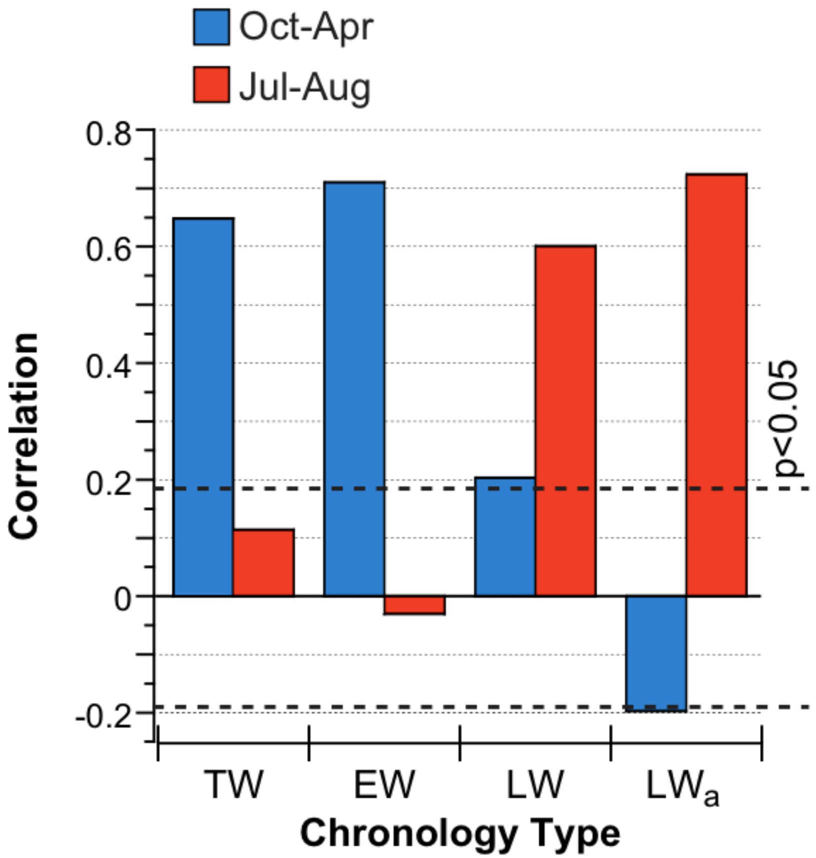


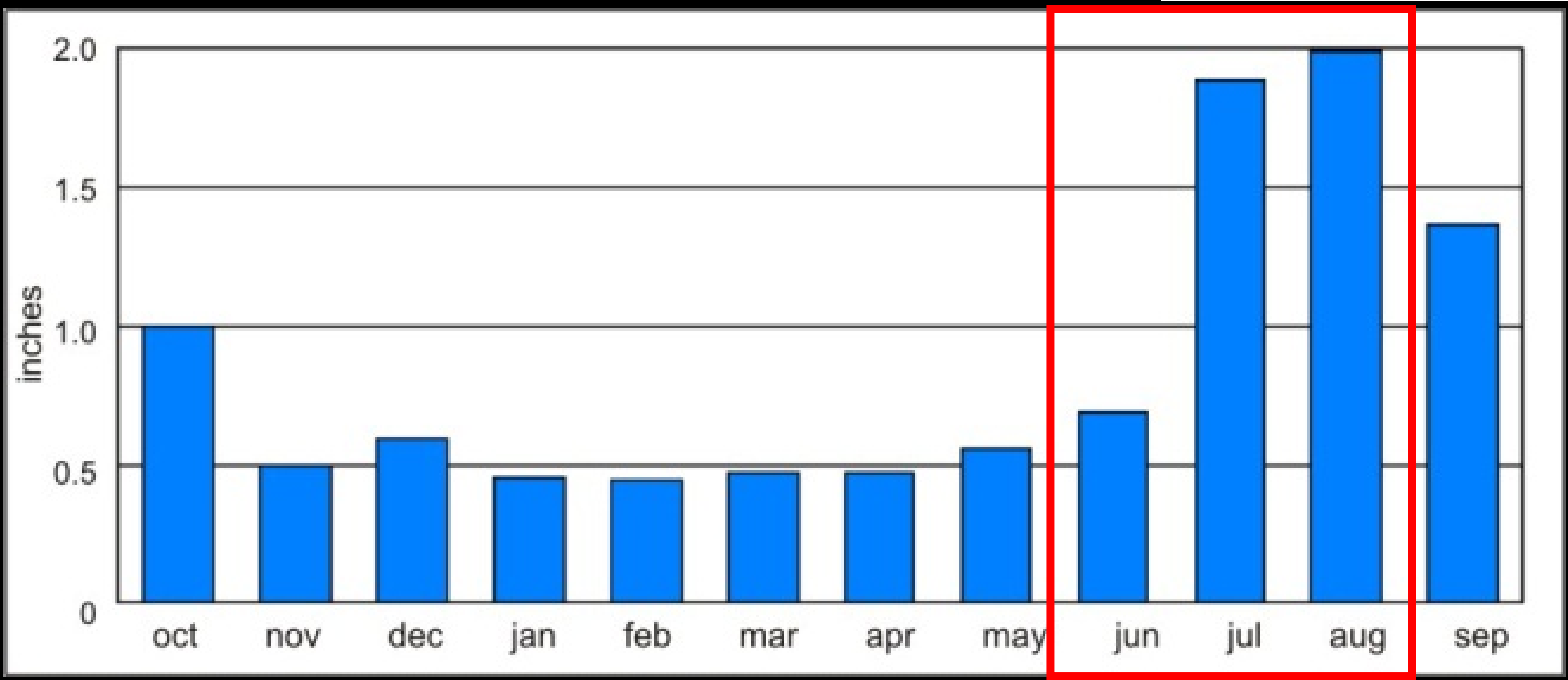


(Griffin et al. 2011 *Tree-Ring Research*)

Monsoon Project Chronology Network

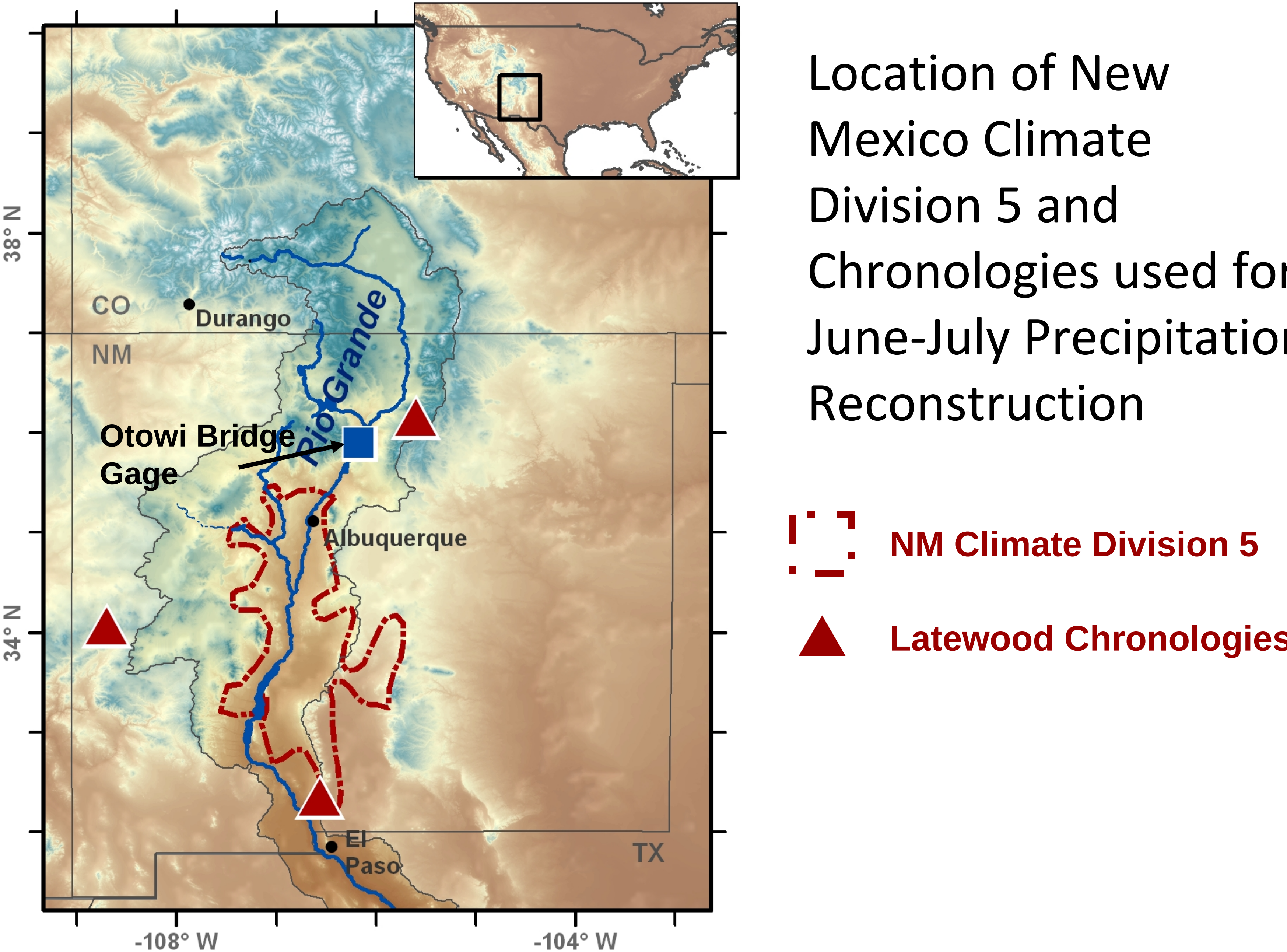
Target Region for Rio Grande Monsoon Reconstruction: New Mexico Climate Division 5

Average monthly precipitation, October – September, 1896-2011

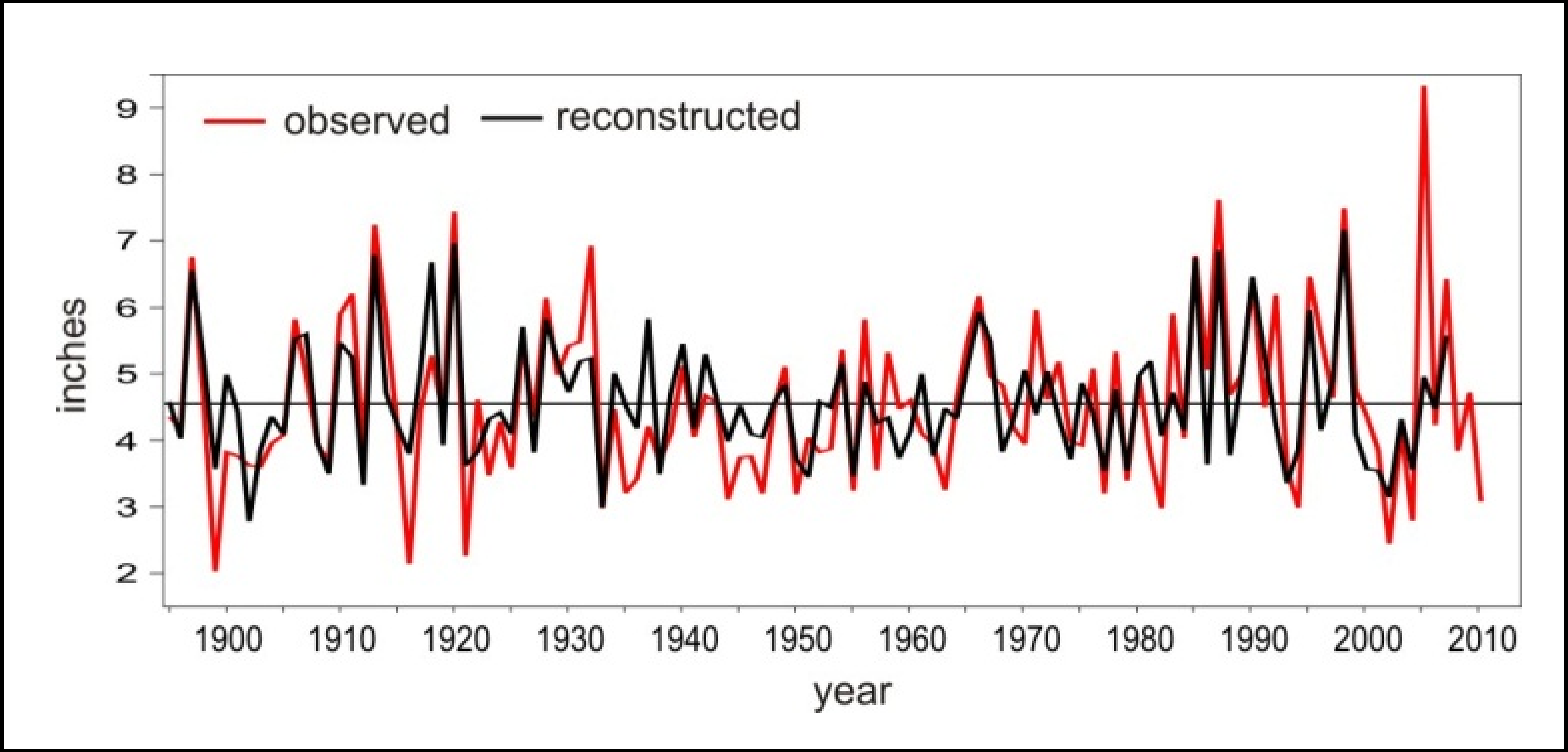


*The monsoon reconstruction is based on June-August total, ~ 77% of JJAS total

Location of New Mexico Climate Division 5 and Chronologies used for June-July Precipitation Reconstruction



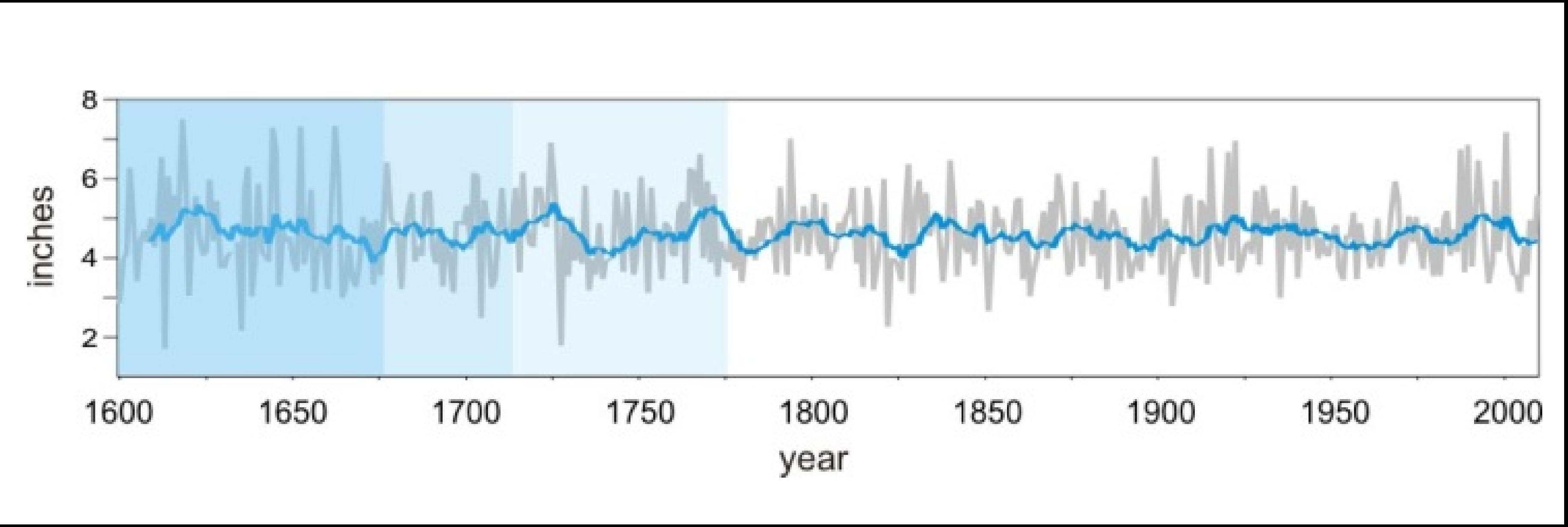
Monsoon Reconstruction (June-July-August) for the Middle Rio Grande Region, 1896-2008



Reconstruction model explains 53% of the variance in the precipitation record.

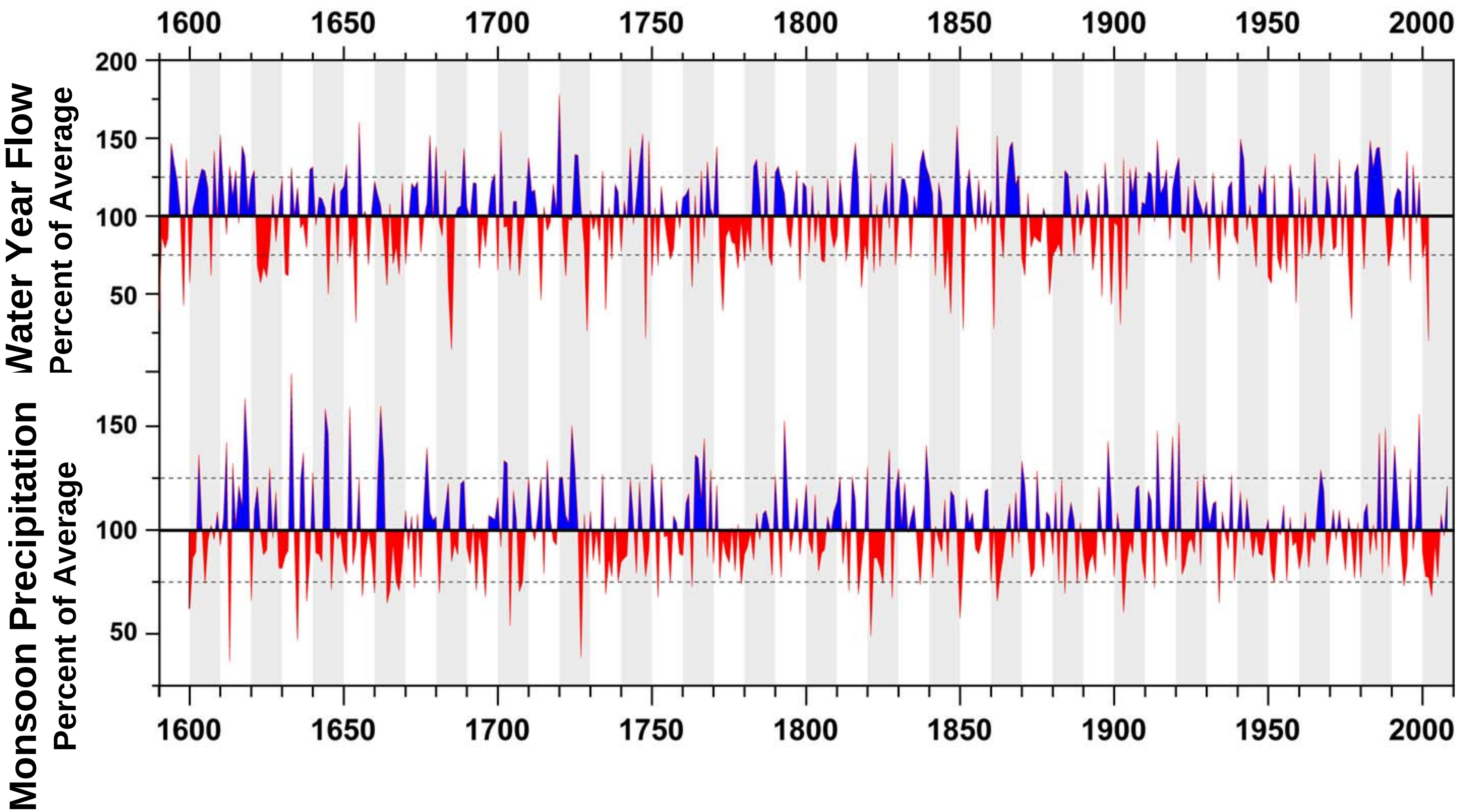
Full Monsoon Reconstruction (June-July-August) for the Middle Rio Grande Region

Annual values (gray line) and 10-year running average (blue line)

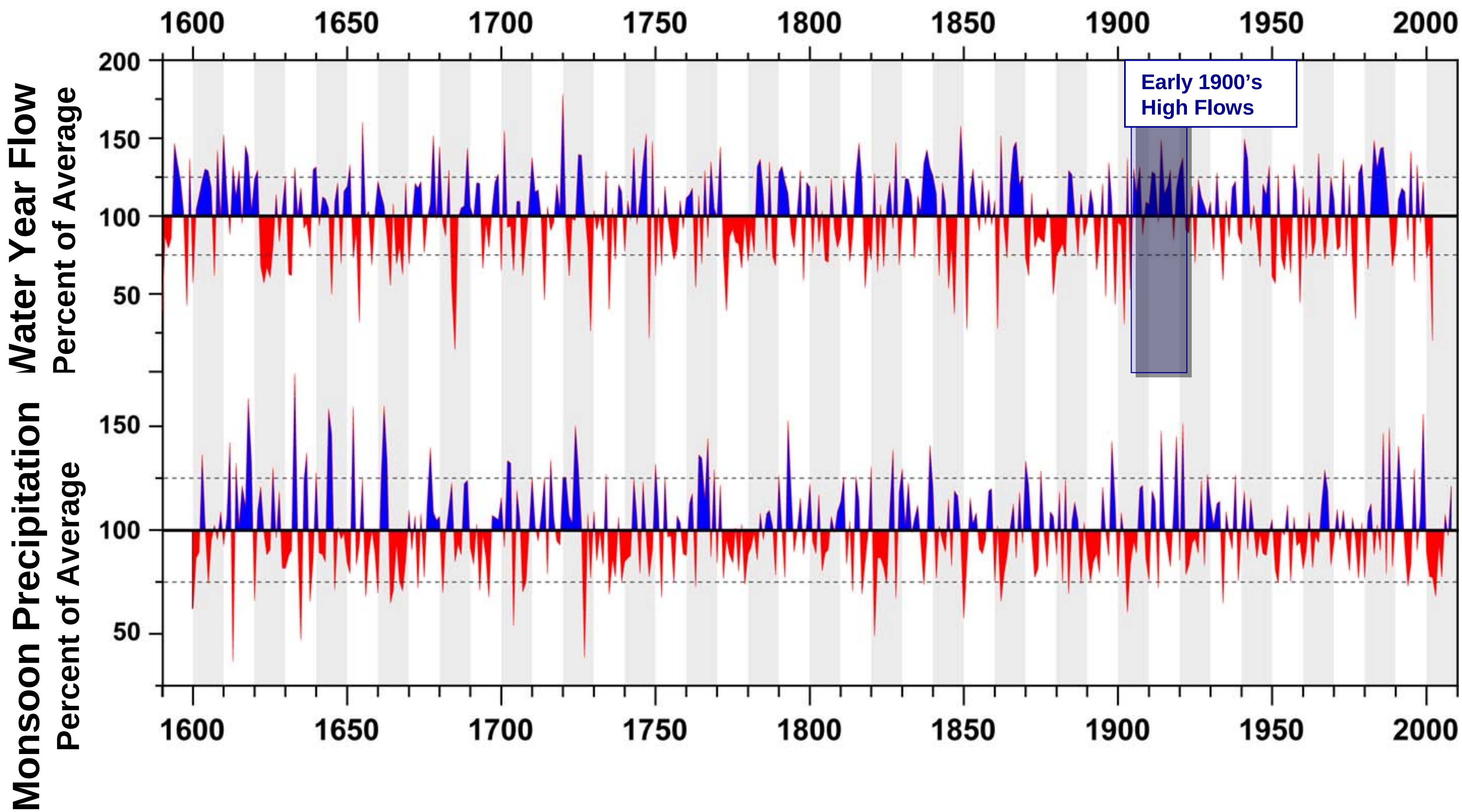


The number of samples that go into the reconstruction decrease back in time, thus there is less confidence in the reconstruction going back in time, especially before 1677.

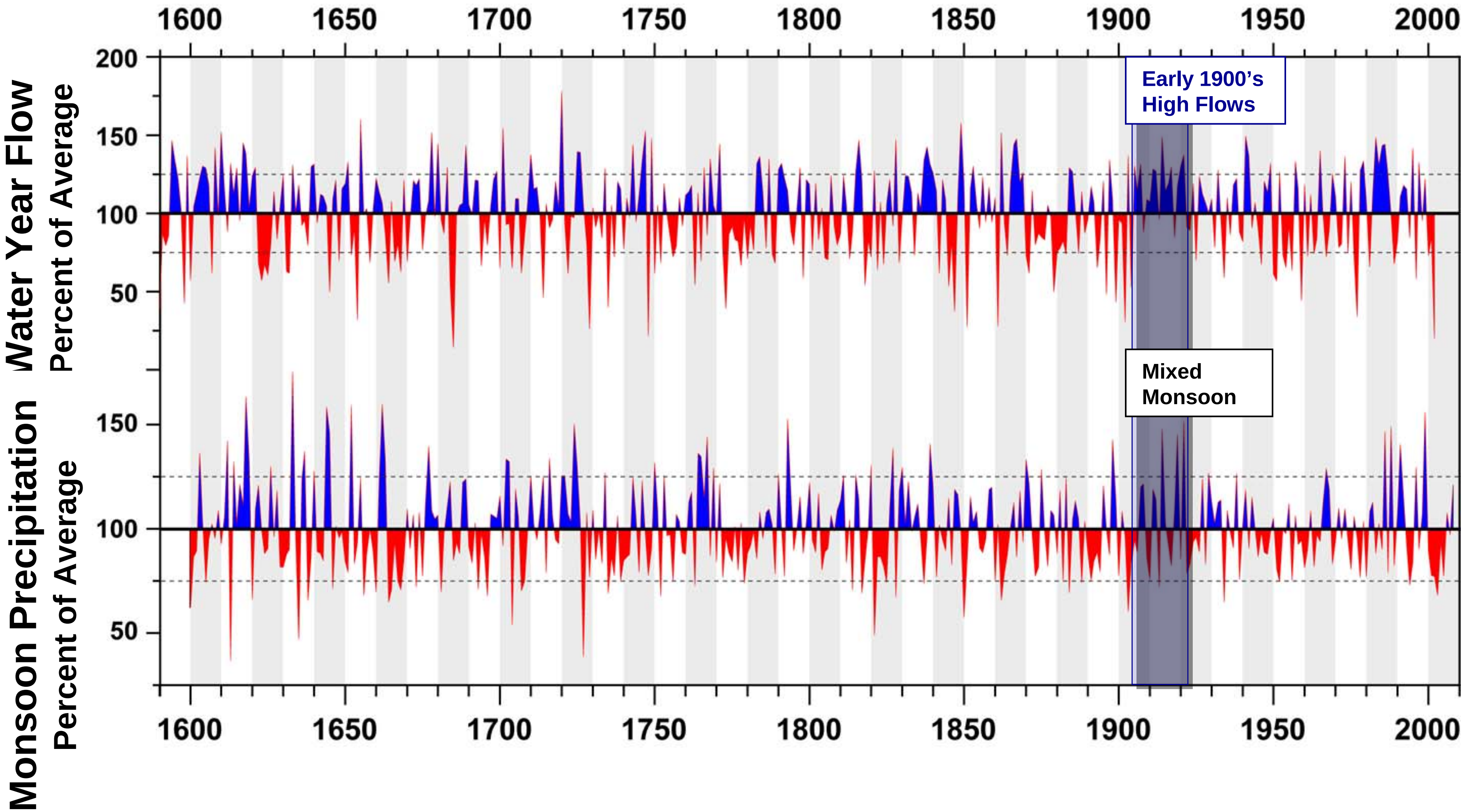
Middle Rio Grande Reconstructions



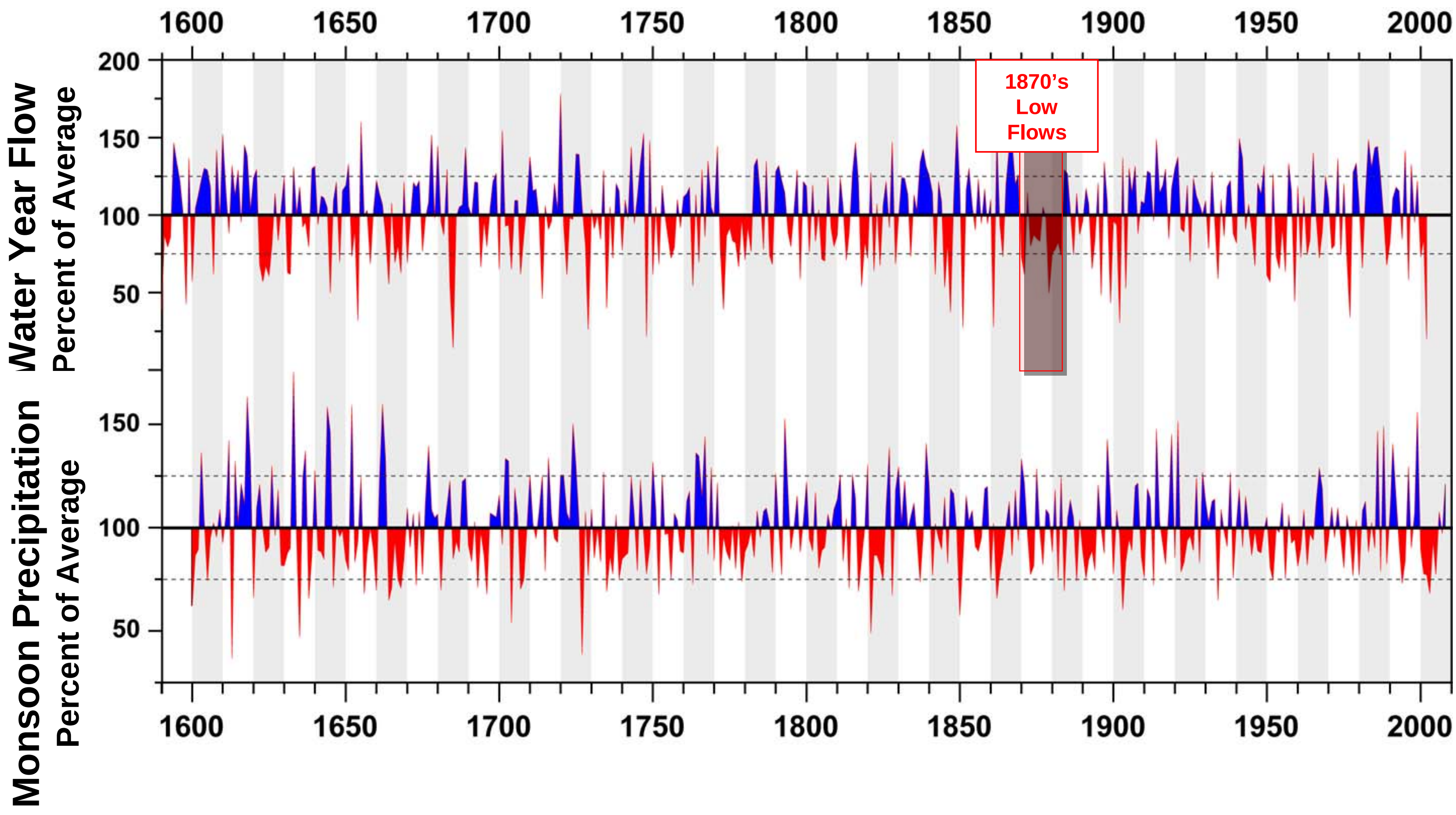
Middle Rio Grande Reconstructions



Middle Rio Grande Reconstructions



Middle Rio Grande Reconstructions



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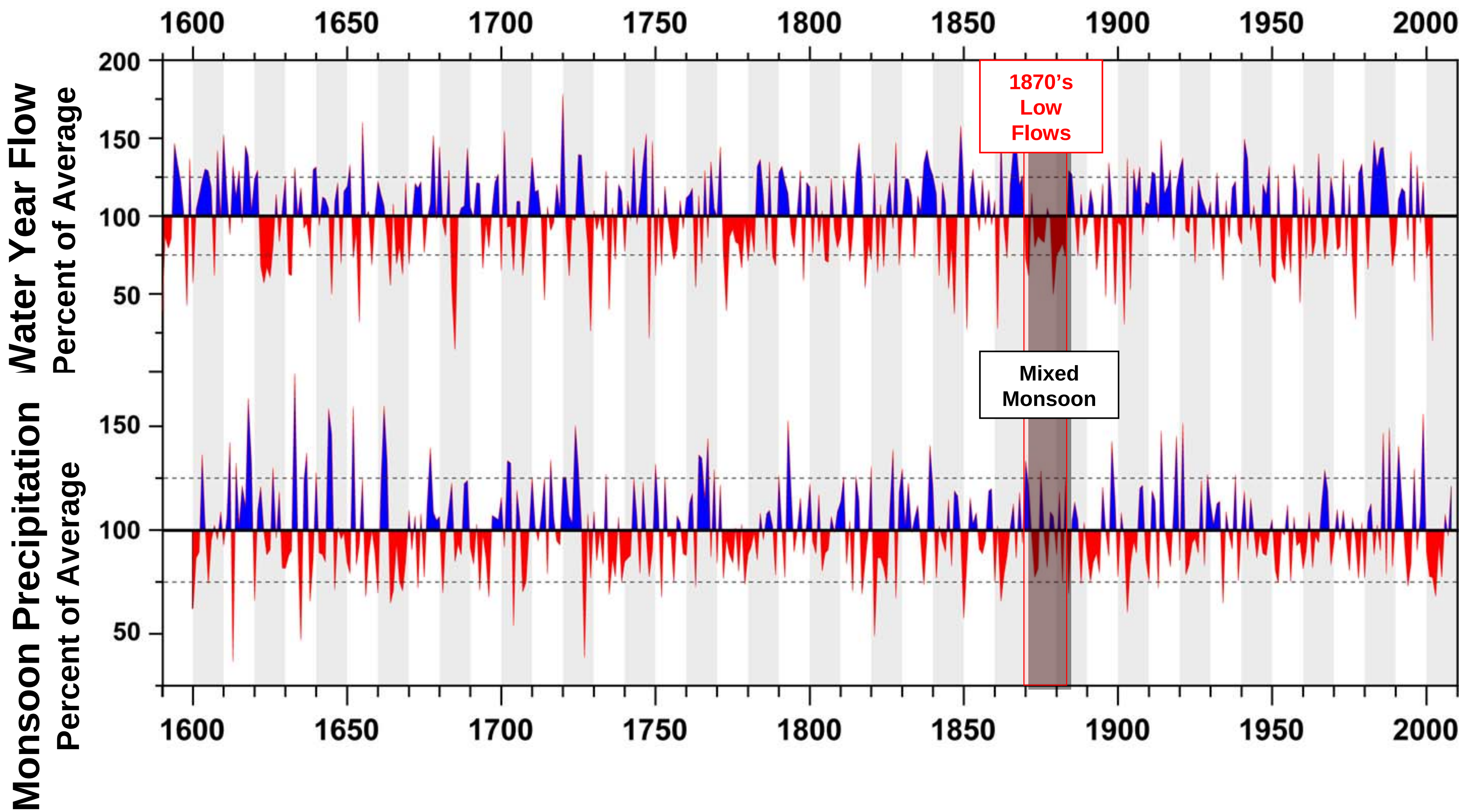

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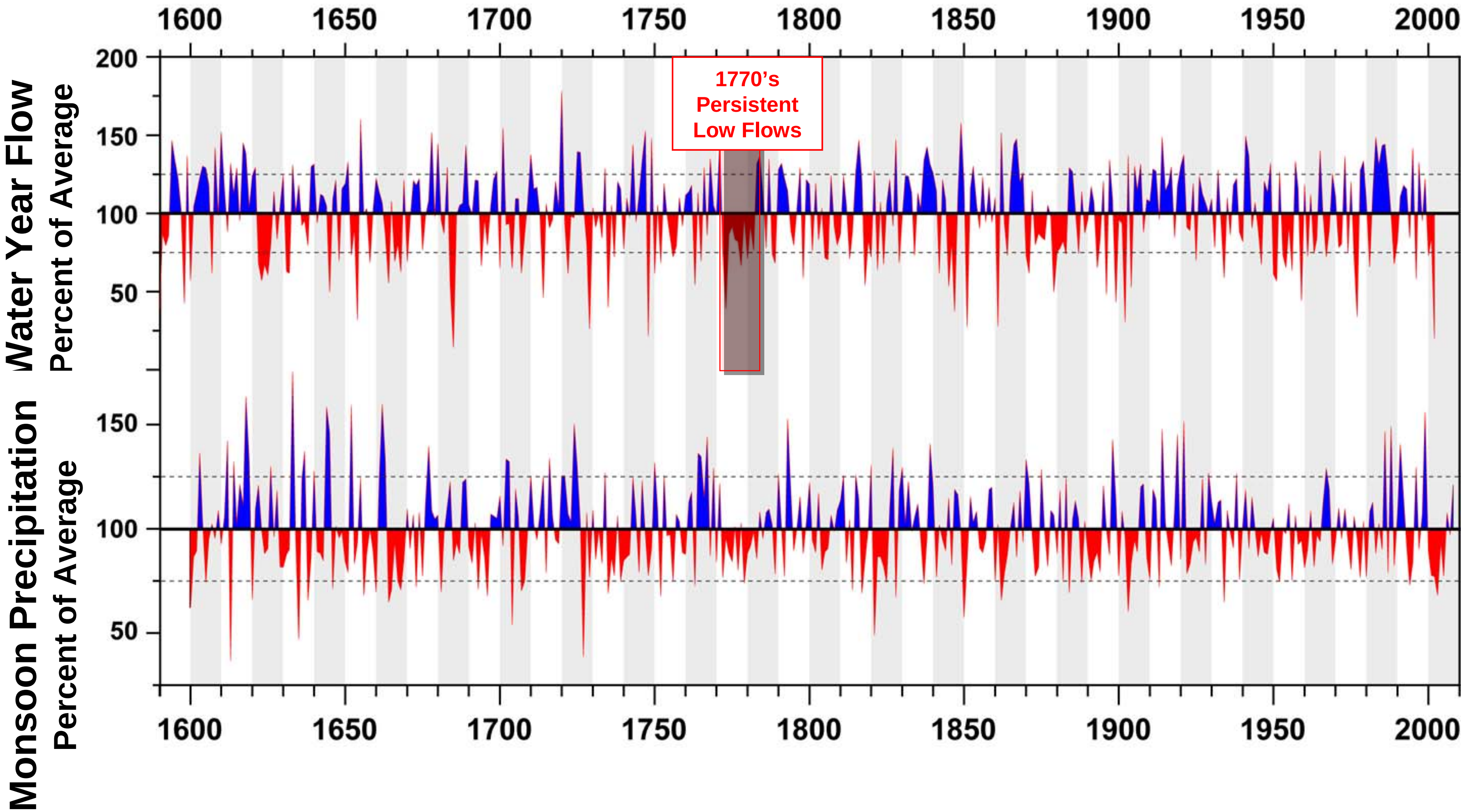

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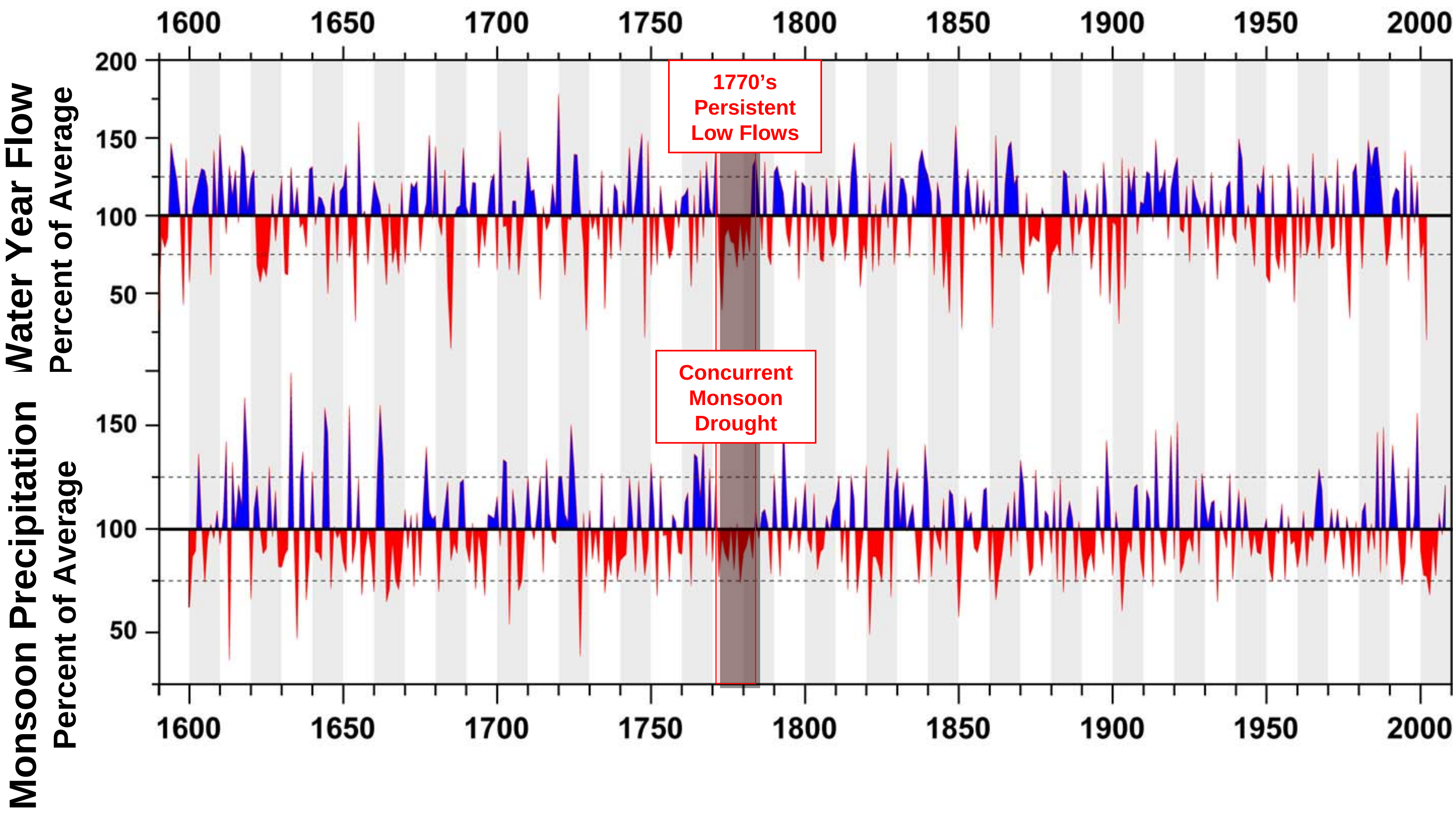

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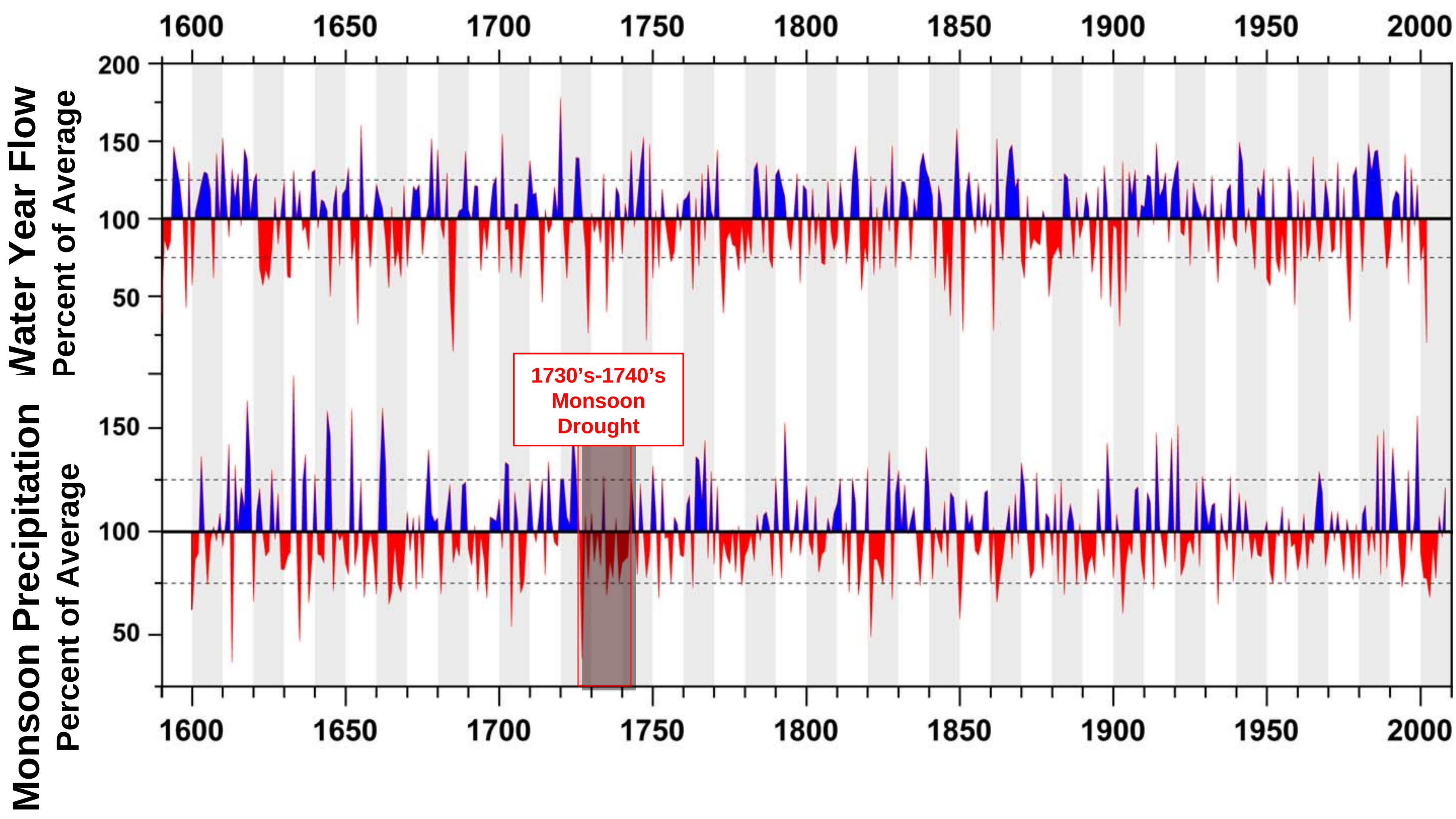

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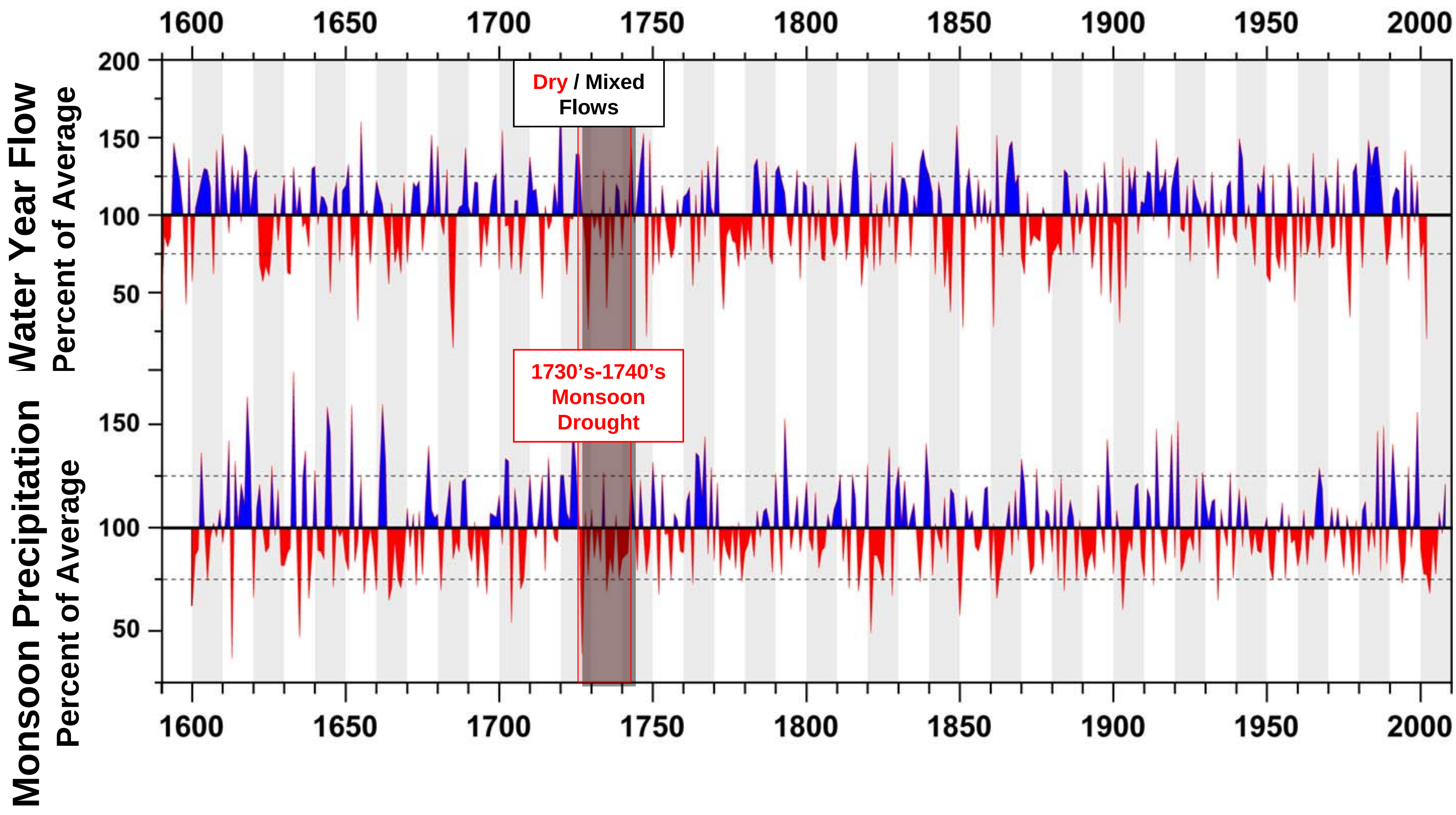

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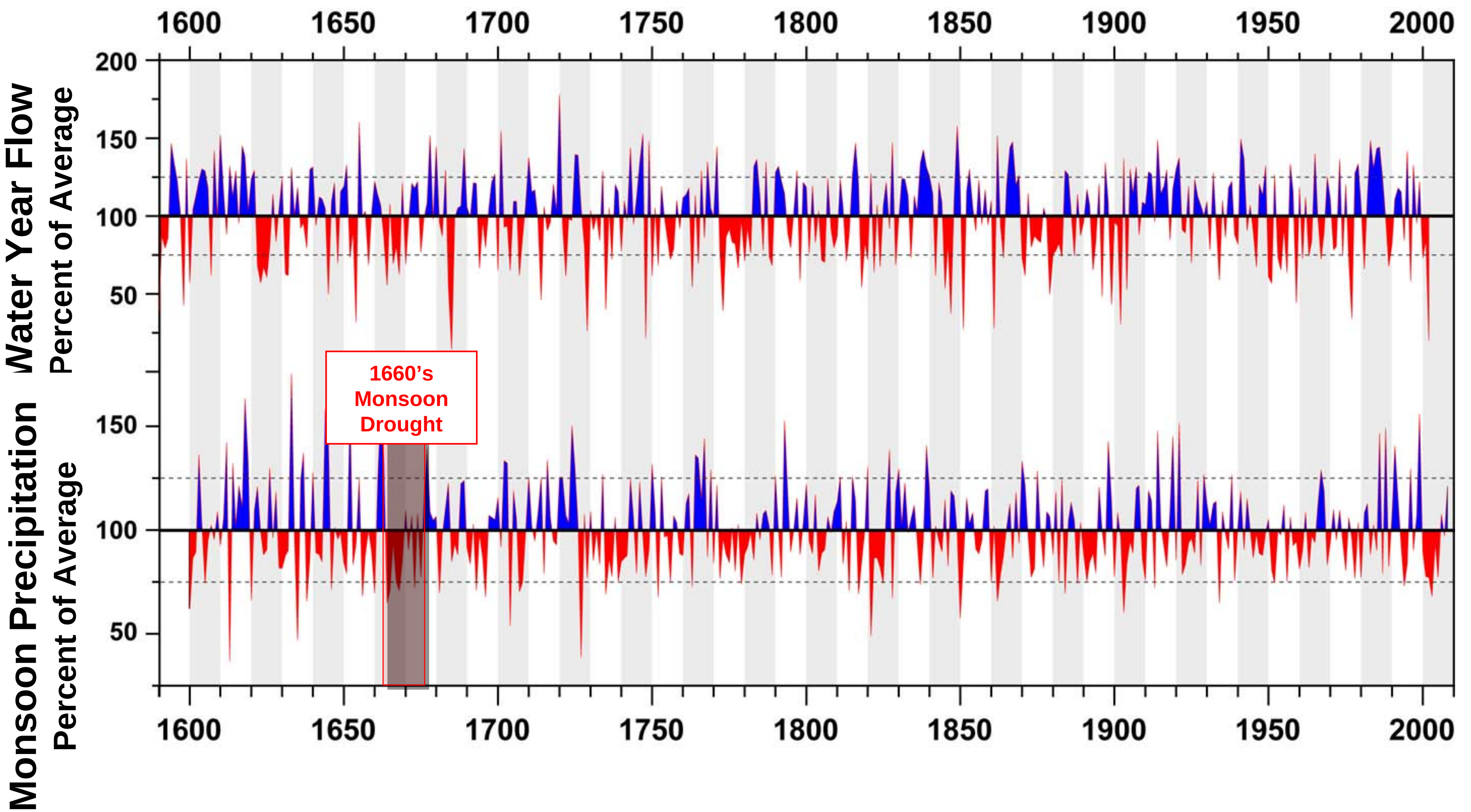

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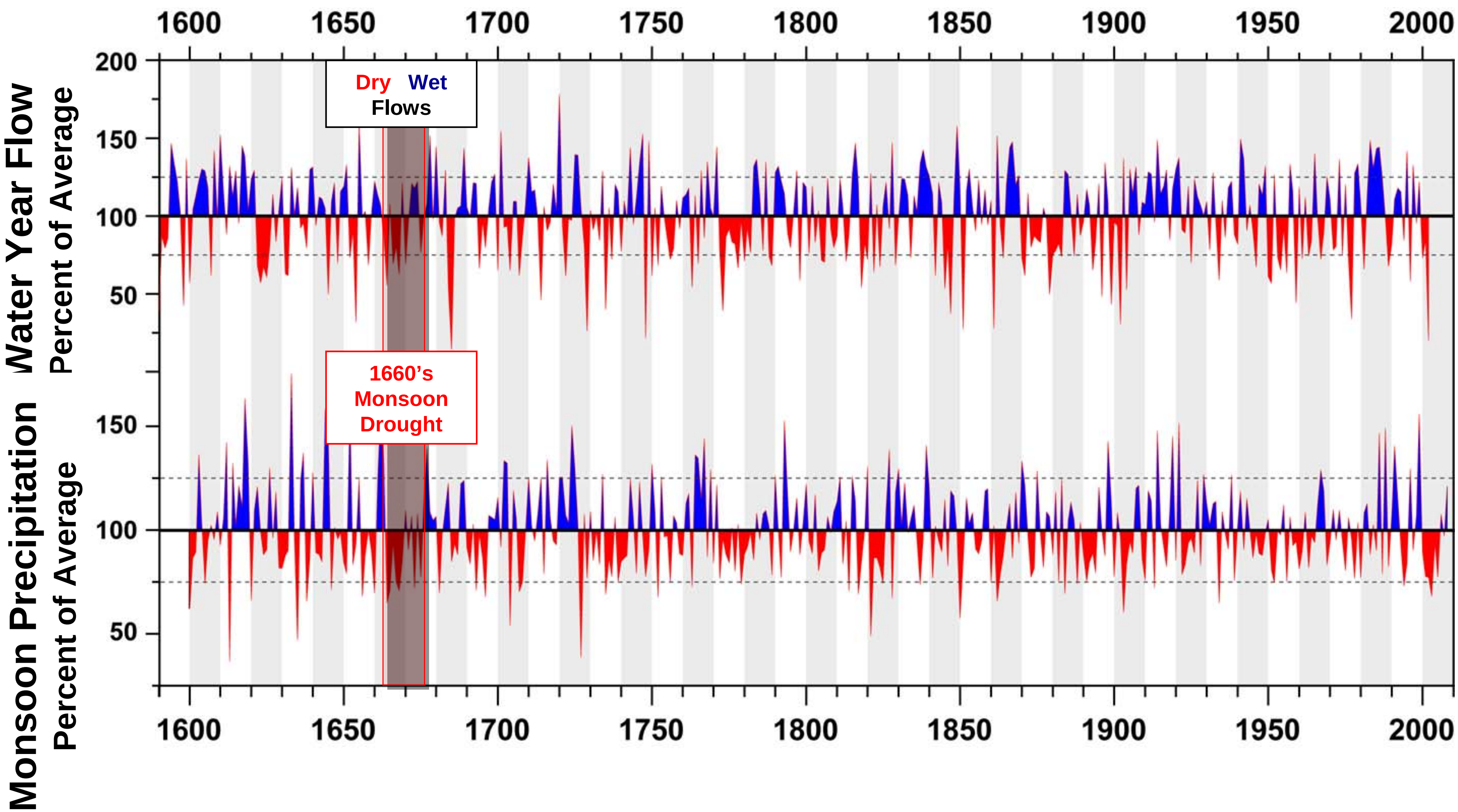

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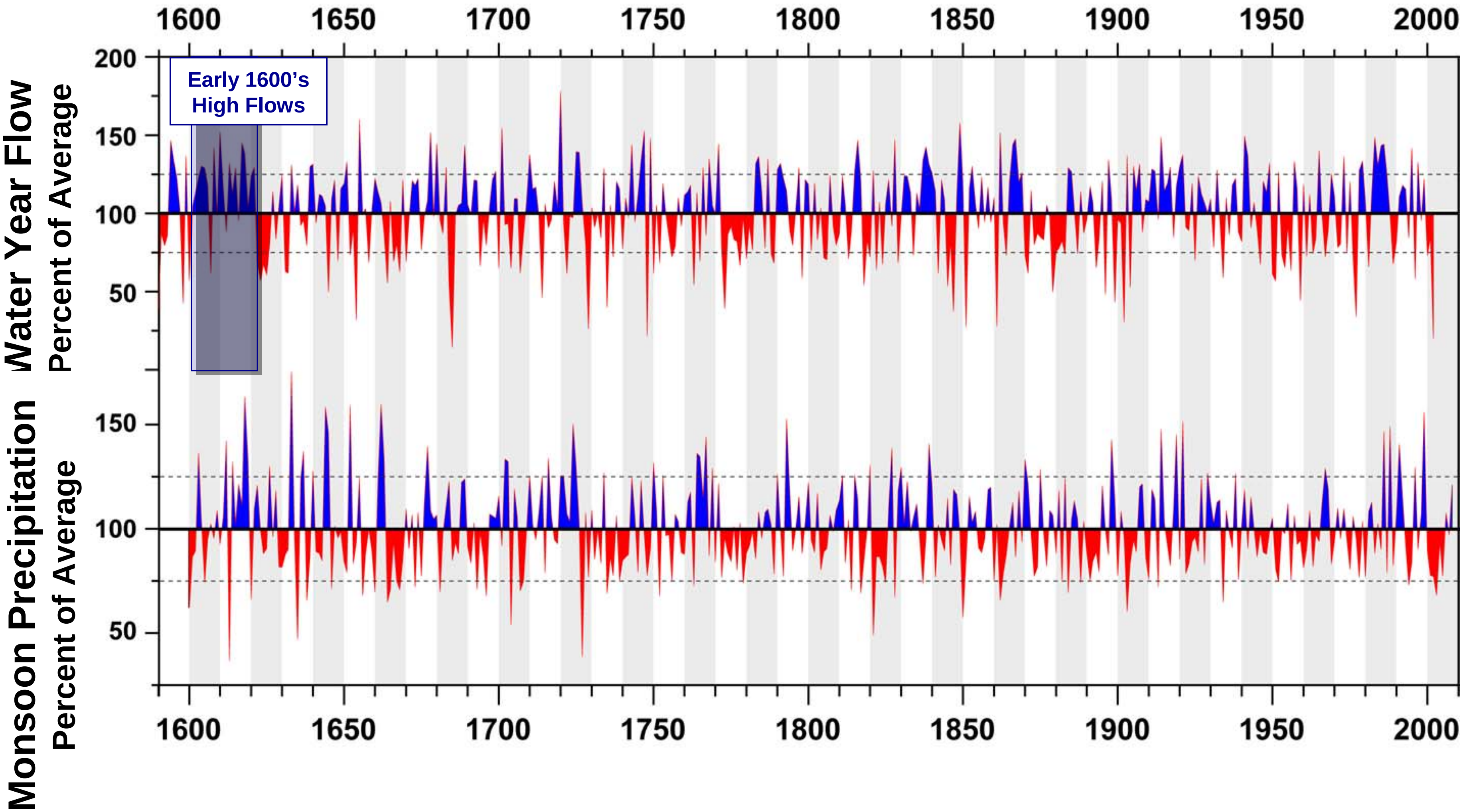
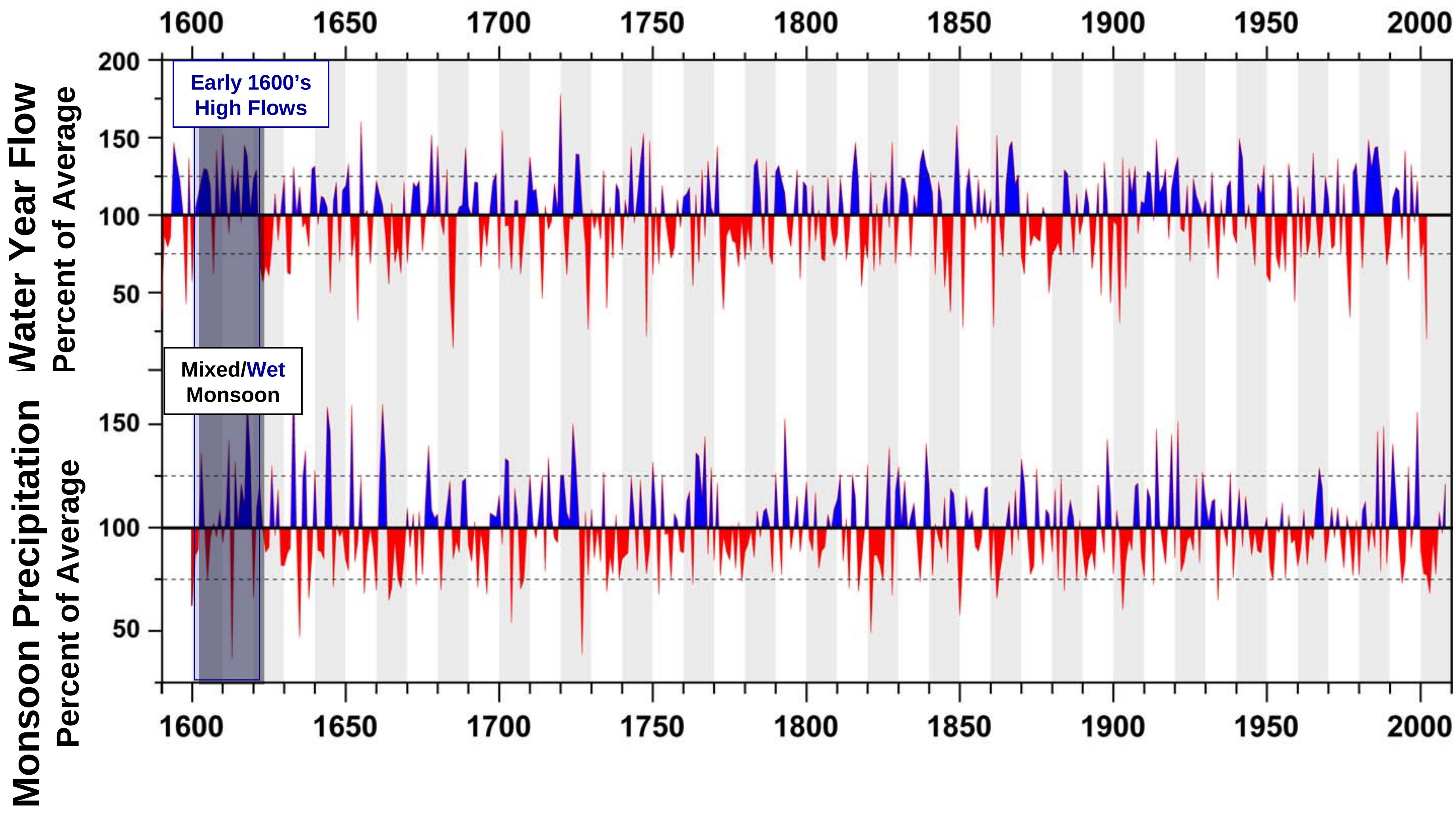


Middle Rio Grande Reconstructions



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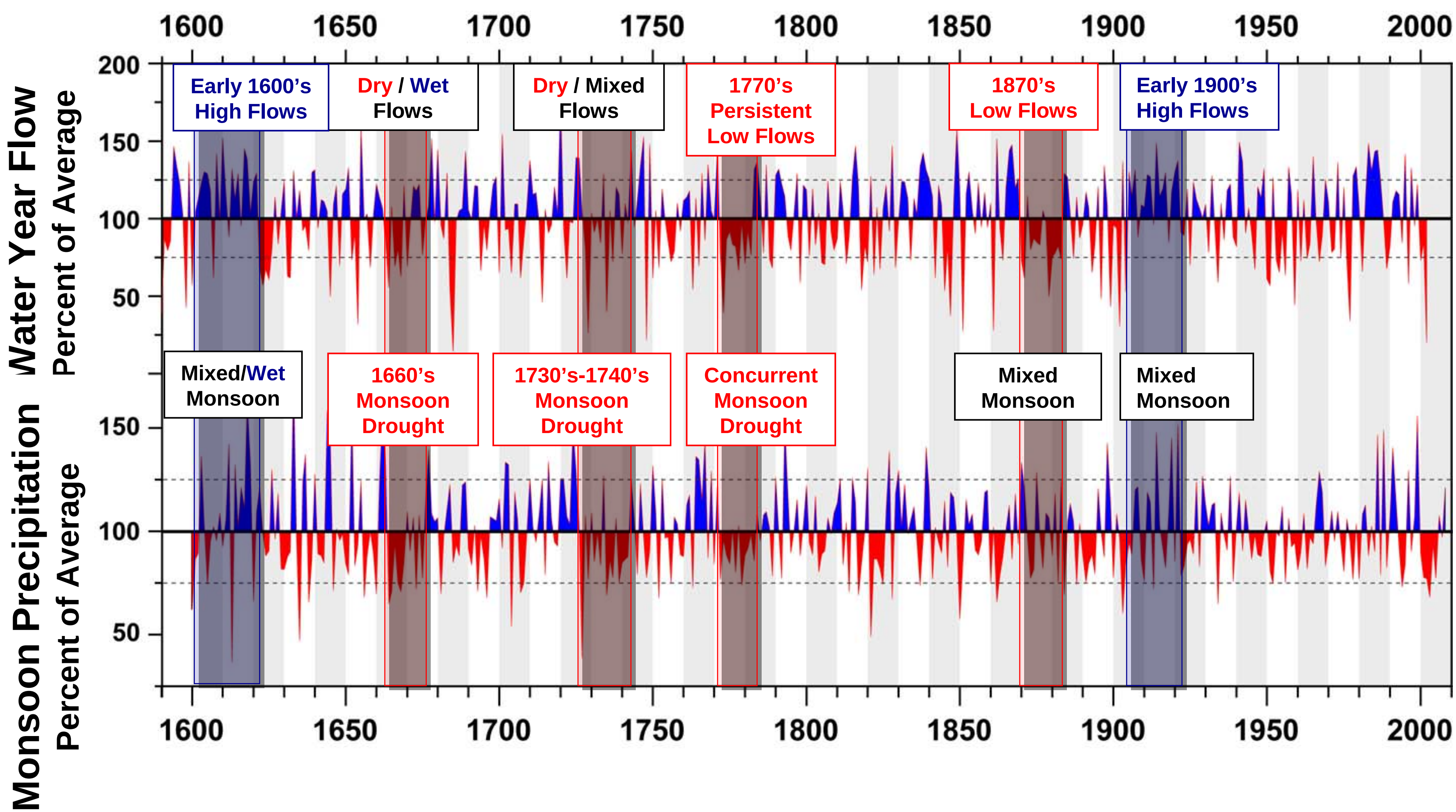
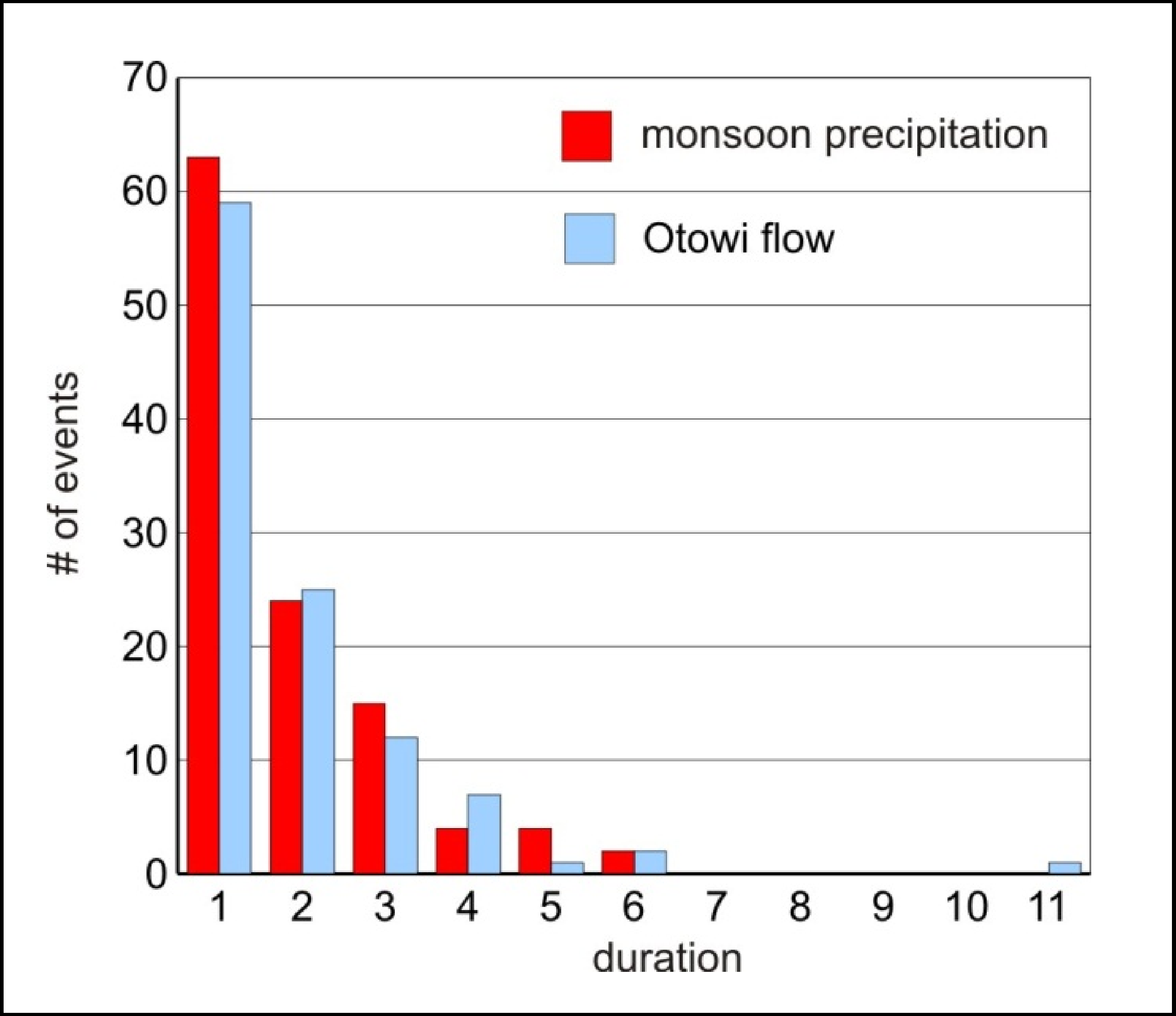


Part 4.

Analysis of Monsoon and Rio Grande Streamflow Reconstructions

- Are summer droughts longer than winter (i.e., from streamflow) droughts?
- How closely are Rio Grande water year streamflow and monsoon precipitation related?
- How often do low flows and dry monsoons occur in the same year?
- How does the recent sequence of wet and dry years compare to sequences of years over the past centuries?

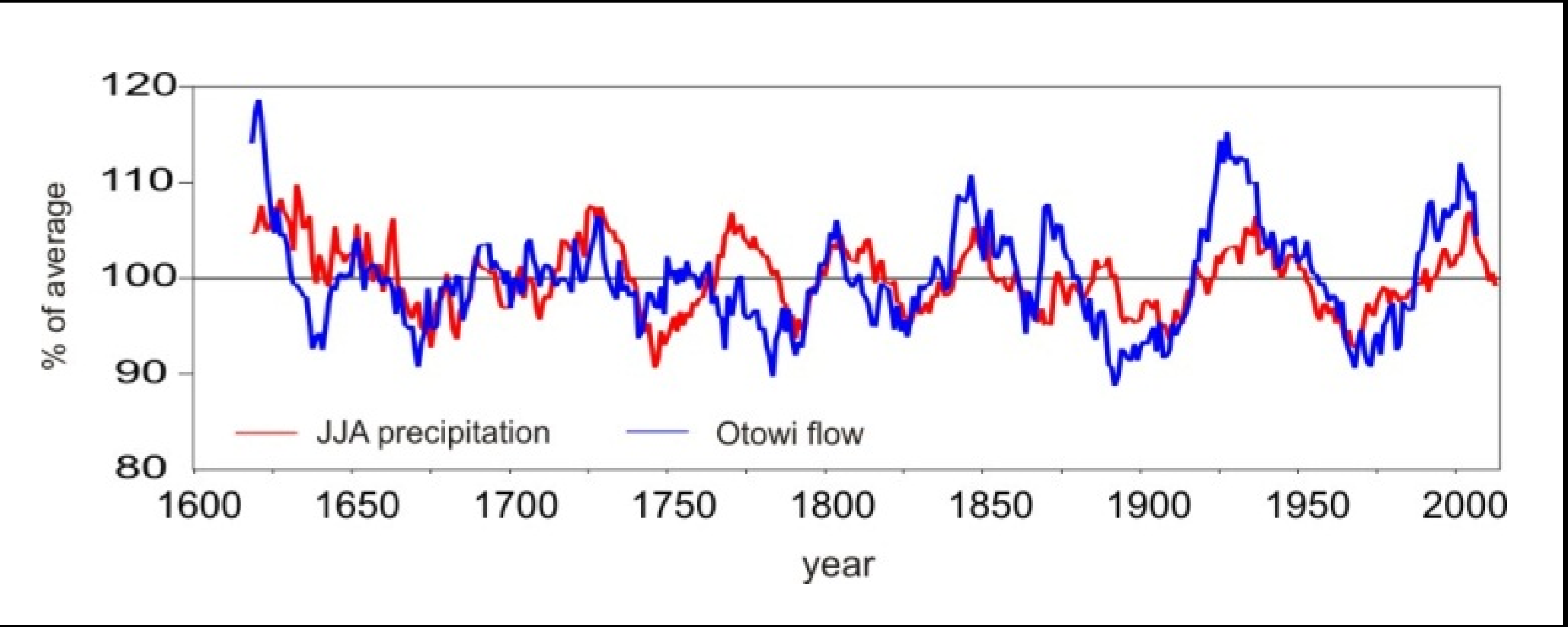
Drought Duration and Frequency, Otowi Flow and Monsoon Precipitation, 1600-2002



Drought is defined as a single year or set of consecutive years below the long-term median

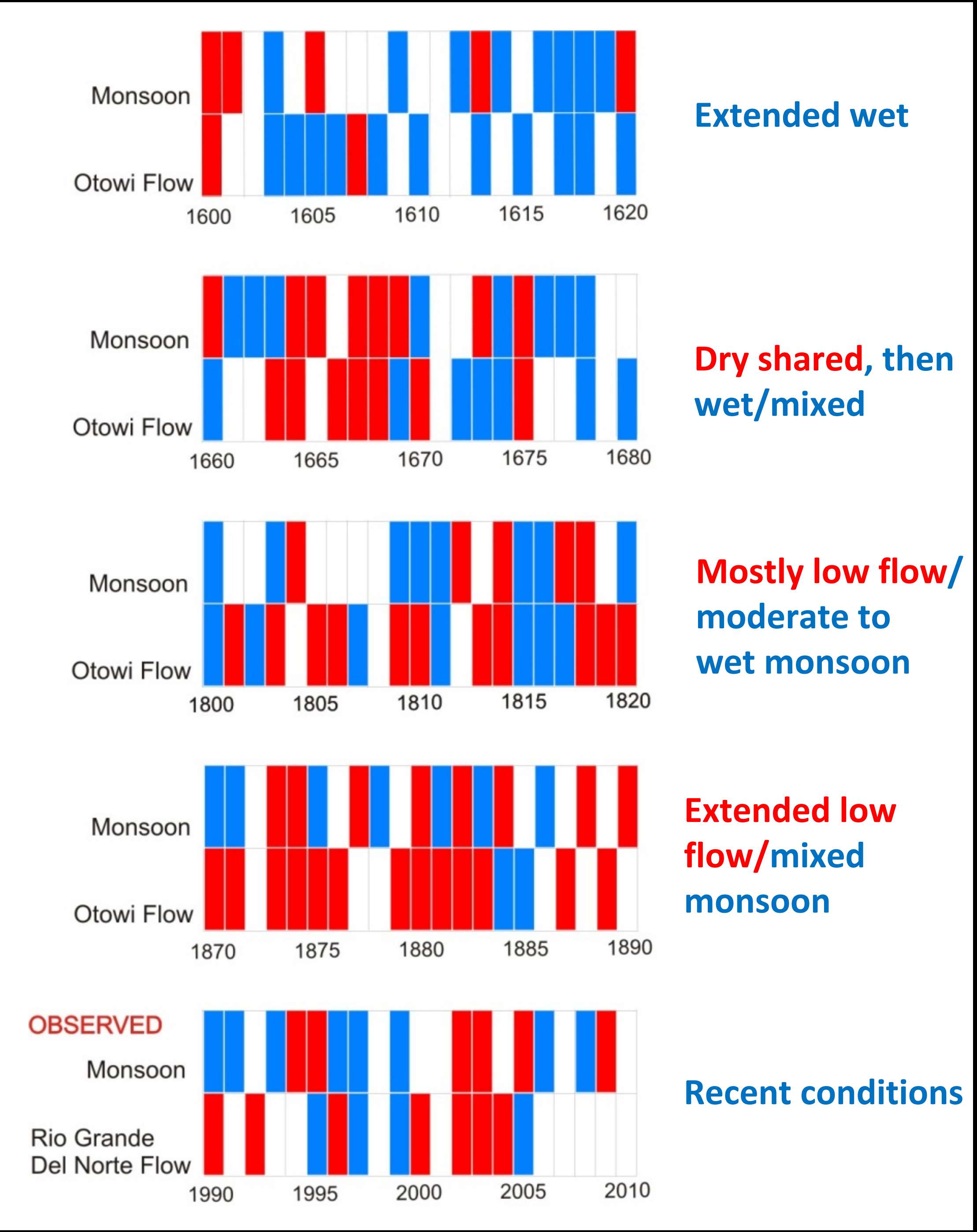
Comparison of Rio Grande Otowi Water Year Flow and Monsoon Precipitation

1600-2002 (monsoon to 2008)
smoothed with a 20-year moving average

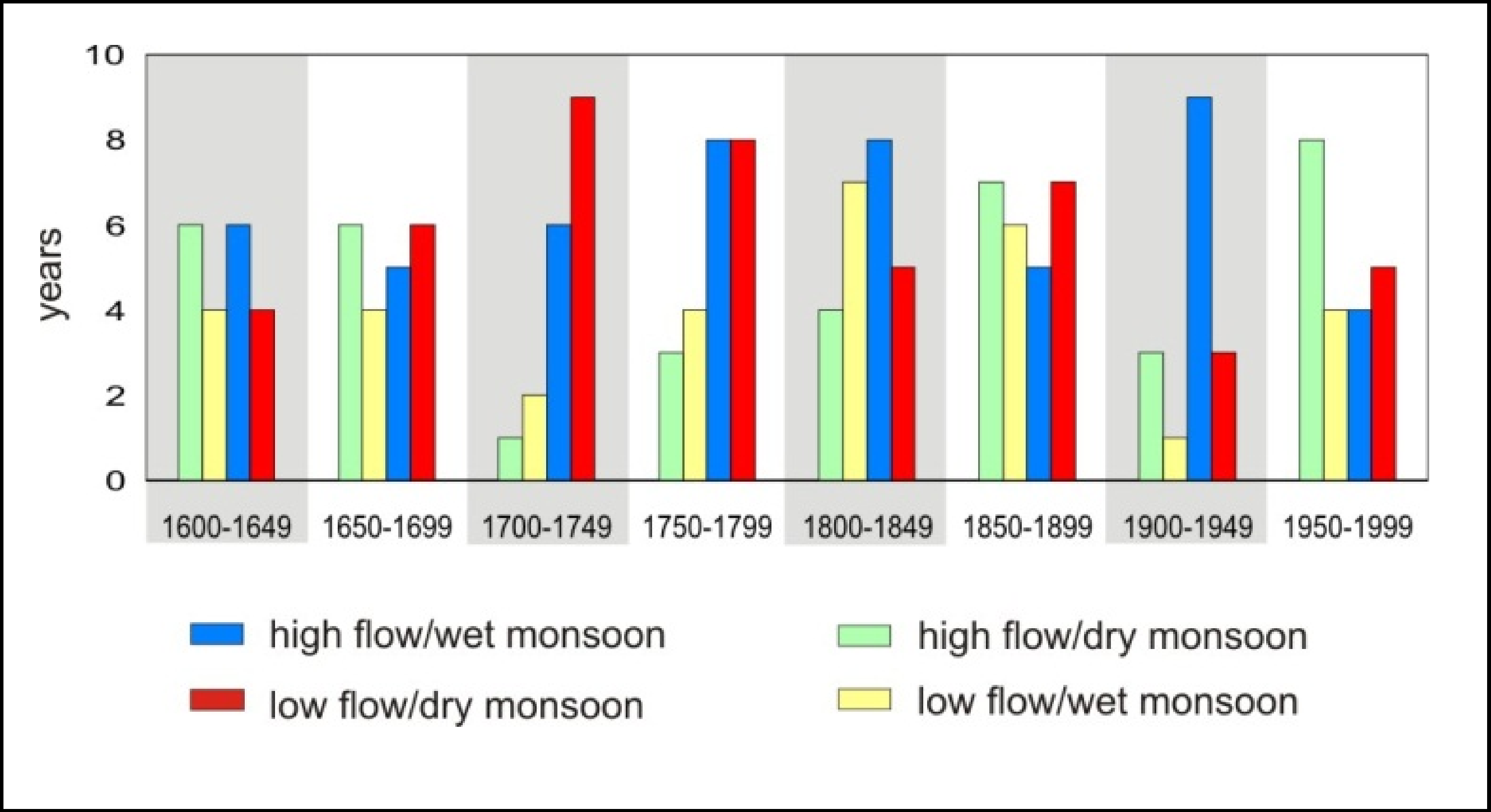


Note: On an annual basis, Otowi flow and JJA precipitation are uncorrelated (observed record, $r = -0.07$; reconstruction, $r = 0.06$, and in the full reconstruction, $r = 0.11$, $p < 0.01$)

Sequences of wet/dry/moderate monsoon precipitation and Rio Grande flow years



Numbers of years with shared and opposite wet and dry conditions by 50-year periods



Wet and dry years are those in the highest and lowest third of values

Numbers of years with shared and opposite wet and dry conditions by 50-year periods

	low flow dry monsoon	high flow wet monsoon	SHARED SUM	flow low monsoon wet	high flow monsoon dry	OPPOSITE SUM
1600-1649	4	6	**10**	4	6	**10**
1650-1699	6	5	**11**	4	6	**10**
1700-1749	9	6	**15**	2	1	**3**
1750-1799	8	8	**16**	4	3	**7**
1800-1849	5	8	**13**	7	4	**11**
1850-1899	7	5	**12**	6	7	**13**
1900-1949	3	9	**12**	1	3	**4**
1950-1999	5	4	**9**	4	8	**12**
SUM	**47**	**51**	**98**	**32**	**38**	**70**

Overall, the number of shared wet or dry years exceeds years with opposite conditions, although this varies somewhat over time

Summary

•By analyzing latewood widths from tree rings, it is possible to reconstruct monsoon precipitation, at least for a portion of the monsoon season.

•When Rio Grande streamflow and monsoon observed data and reconstructions are compared, there is no correlation between the two on year-to-year time scales.

•Over decadal time scales, it looks like there is some coherence during some intervals of time

•The occurrence of years with shared flow/monsoon conditions and opposite conditions is variable over time.

•Generally speaking, years with shared conditions are more typical than opposite conditions

Questions?

Some of ours:

- How important is the monsoon in the Rio Grande basin?

- What management issues/questions does it impact?

- Is an understanding of variability on the seasonal scale helpful?

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How well do the reconstructions replicate the distribution of shared/opposite wet/dry conditions when compared to the observed record?