Rio Grande Tree-Ring Monsoon Workshop

New Mexico State University
Las Cruces, NM

September 19, 2013

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Welcome and Introductions

New Mexico State University

Laboratory of Tree-Ring Research
The University of Arizona

Climate Assessment for the Southwest

The University of Arizona

The information and research presented here are the result of the efforts of many people and a variety of funding sources (I'll get back to this)

Today's Agenda

- Tree-ring workshops background
- Tree Rings 101 in brief: using tree rings to reconstruct past climate, applications
- Reconstruction of the Rio Grande/Otowi, lower Rio Grande monsoon precipitation
- Comparison of records of past streamflow and monsoon precipitation over past centuries; current conditions in context
- Some words on the Rio Conchos watershed reconstruction
- Discussion, questions, comments, and suggestions for next steps

THIS IS INFORMAL!
PLEASE FEEL FREE TO ASK QUESTIONS AND MAKE COMMENTS

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

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

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

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

The purpose of this workshop was to provide information about how tree-rings document not only past streamflow but monsoon precipitation in the Middle Rio Grande region

National Science Foundation WHERE DISCOVERIES BEGIN · CLIMAS · Western Water Assessment · NOAA · USGS science for a changing world · NM STATE

Workshop #4: Tree-Ring Reconstructions of Streamflow, Precipitation, and Monsoon Variability in the Rio Grande Basin, NM, Sept 19, 2013

Purpose of this workshop

- Provide you with information about tree-ring reconstructions for Rio Grande flow, lower Rio Grande monsoon, and Rio Conchos precipitation

- Learn from you how this information could be made more useful for planning and management

THE UNIVERSITY OF ARIZONA

National Science Foundation
WHERE DISCOVERIES BEGIN

CLIMAS

NM STATE

Rio Grande water year streamflow (Otowi gage, Del Norte gage)

Lowe Rio Grande June-July total precipitation

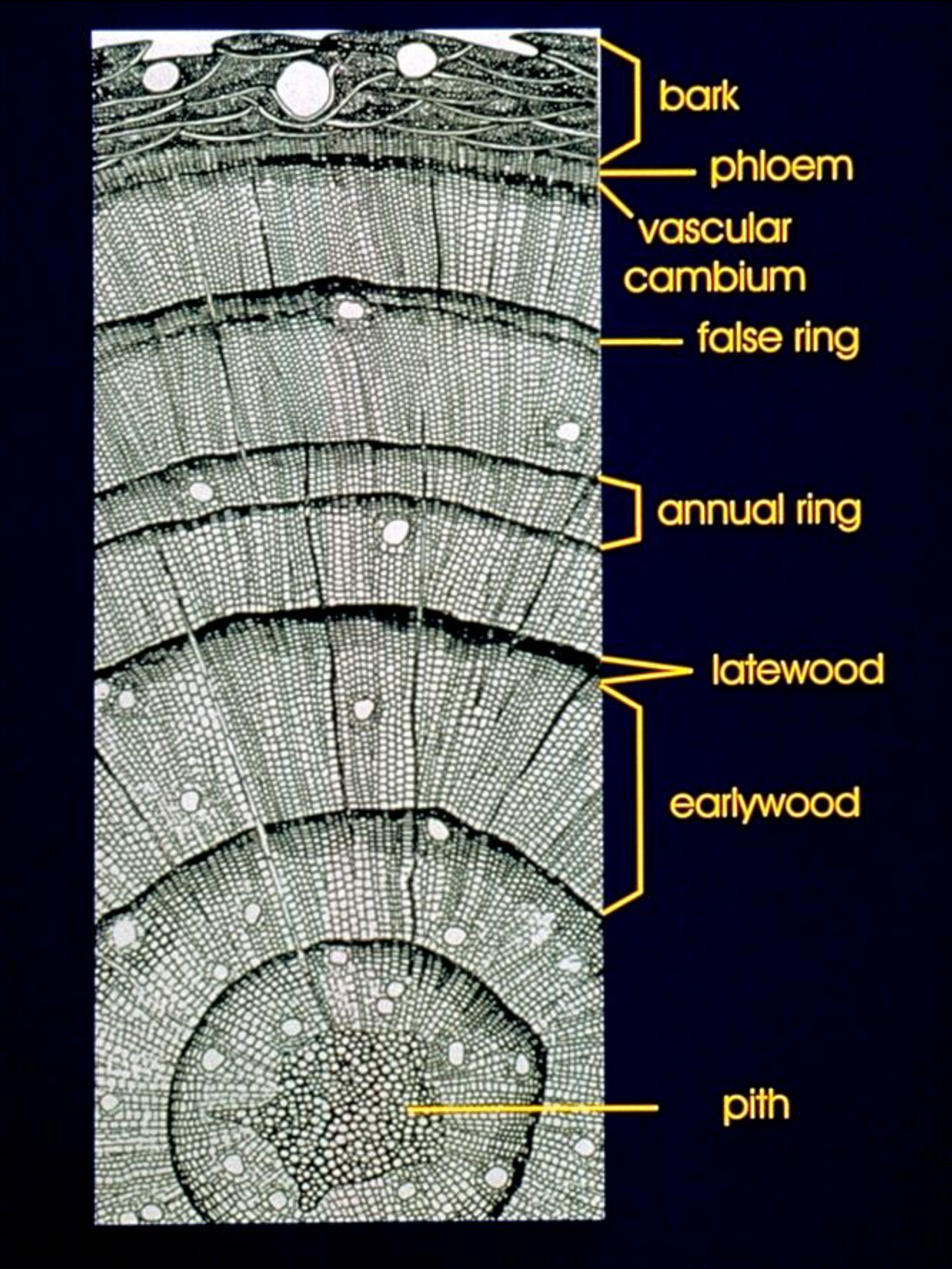
Rio Conchos basin October-July total precipitation

Part 1.

Overview of Tree Rings and Climate Reconstruction

- how trees record climate
- how reconstructions past climate and hydrology 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 widths 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?

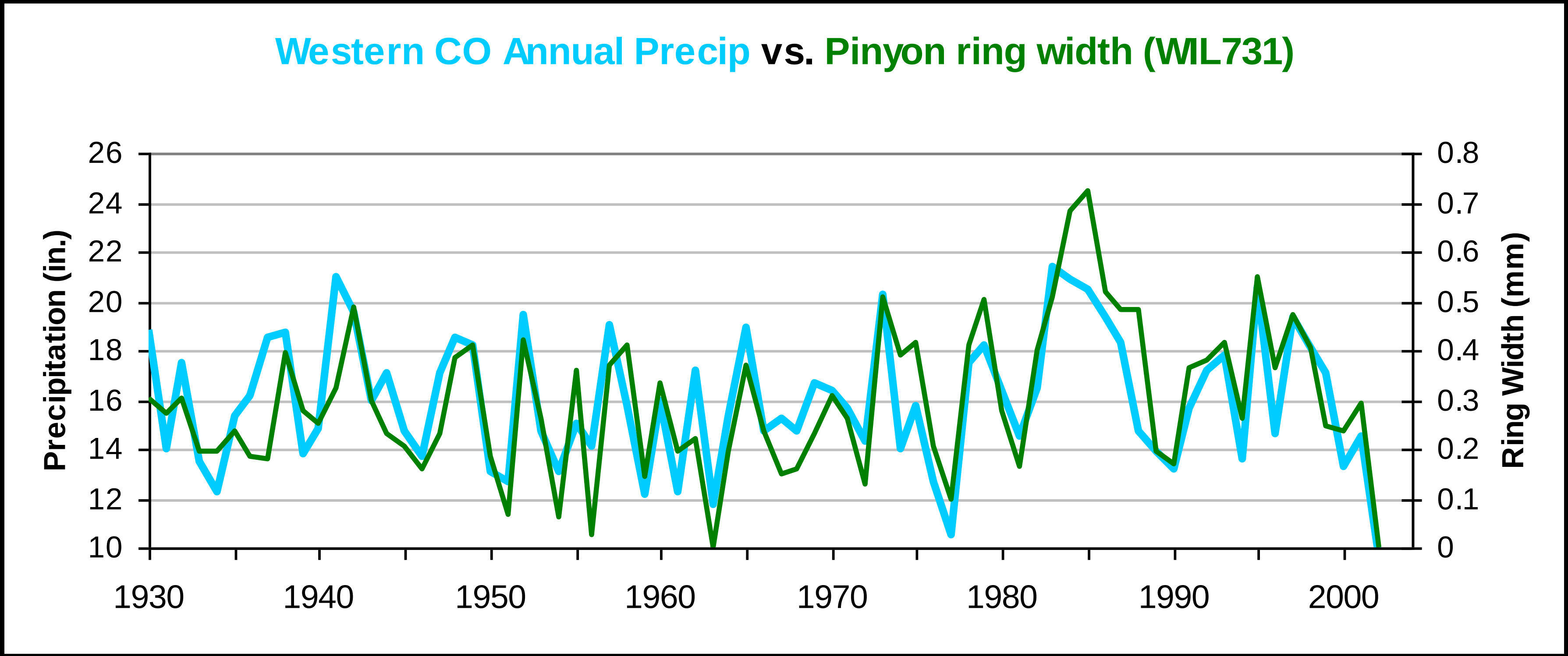
Typically (but not always), trees that are limited by moisture, growing on open, well-drained sites, with thin soils

Douglas-fir

Pinyon pine

Ponderosa pine

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



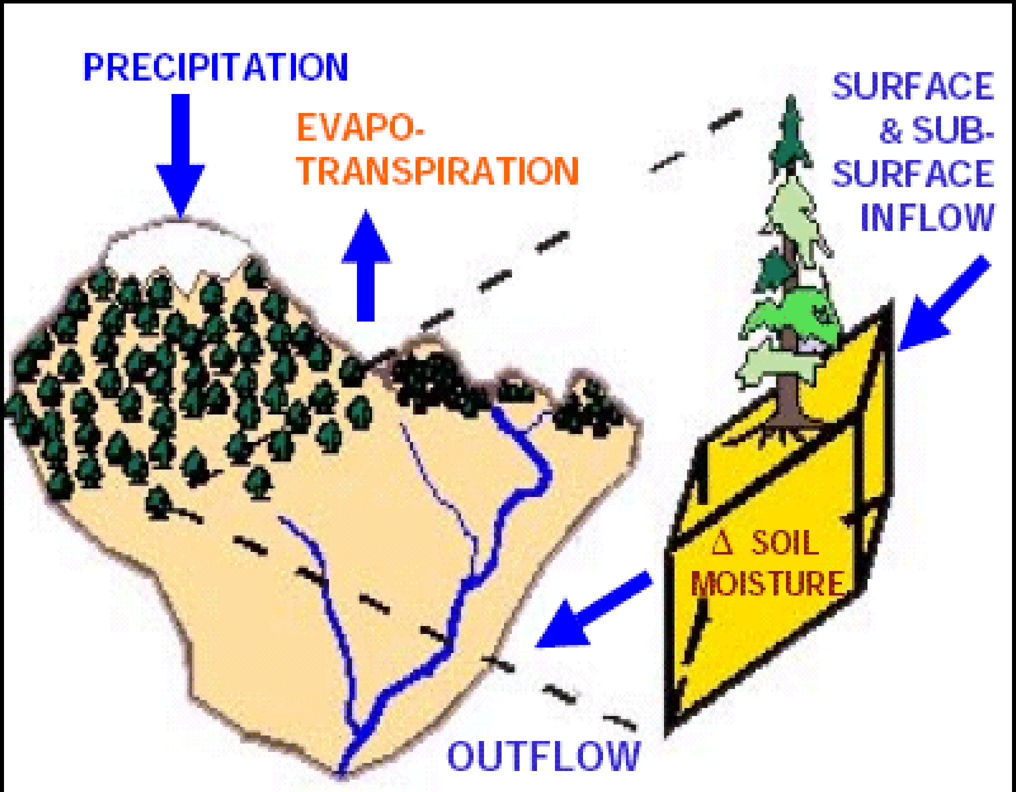
Here, the ring widths from *one* tree are closely correlated to the western Colorado precipitation ($r = 0.78$) from 1930-2002

Annual tree growth of some tree species is associated with winter snowpack in Colorado and New Mexico

Since snow is the major source of water for the Rio Grande headwaters, it is possible to use tree rings to reconstruct past streamflow

How does this work?

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



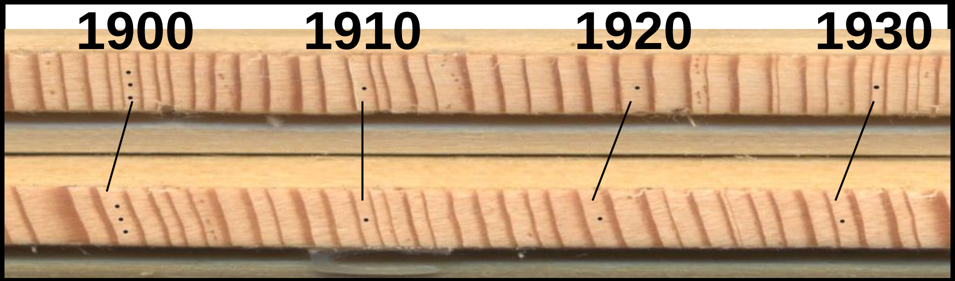
How climate reconstructions are developed : field work to statistical model

1. Field Collections

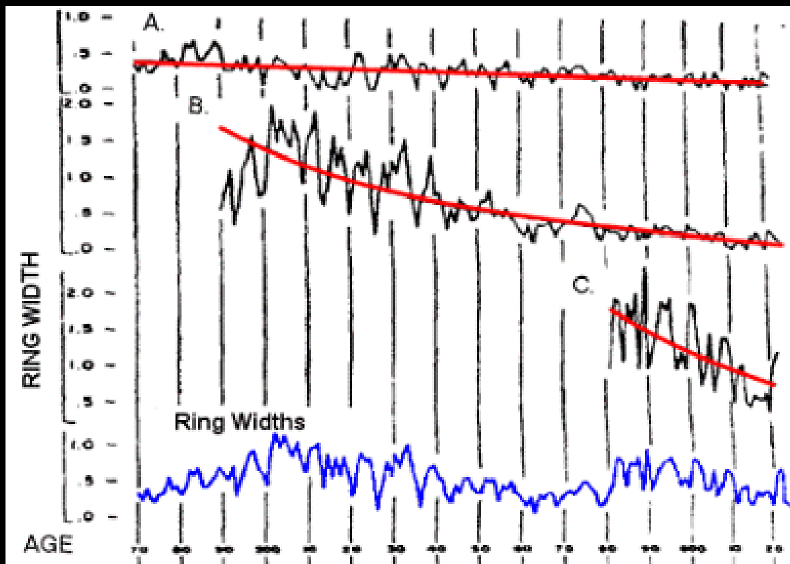
An increment borer is used to sample cores from about 20 trees at a site

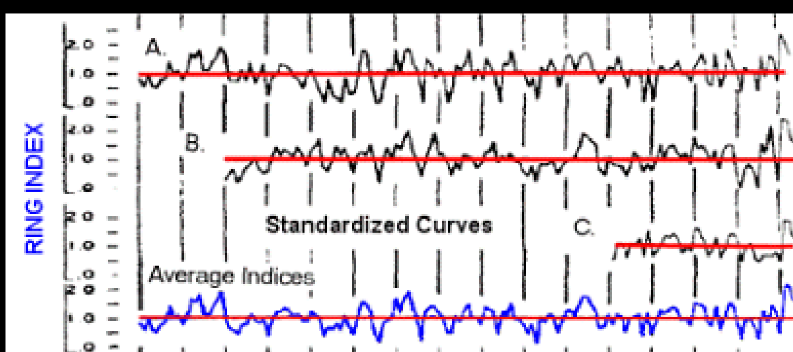
2. Sample Preparation

Cores are mounted and sanded, then dated, and measured



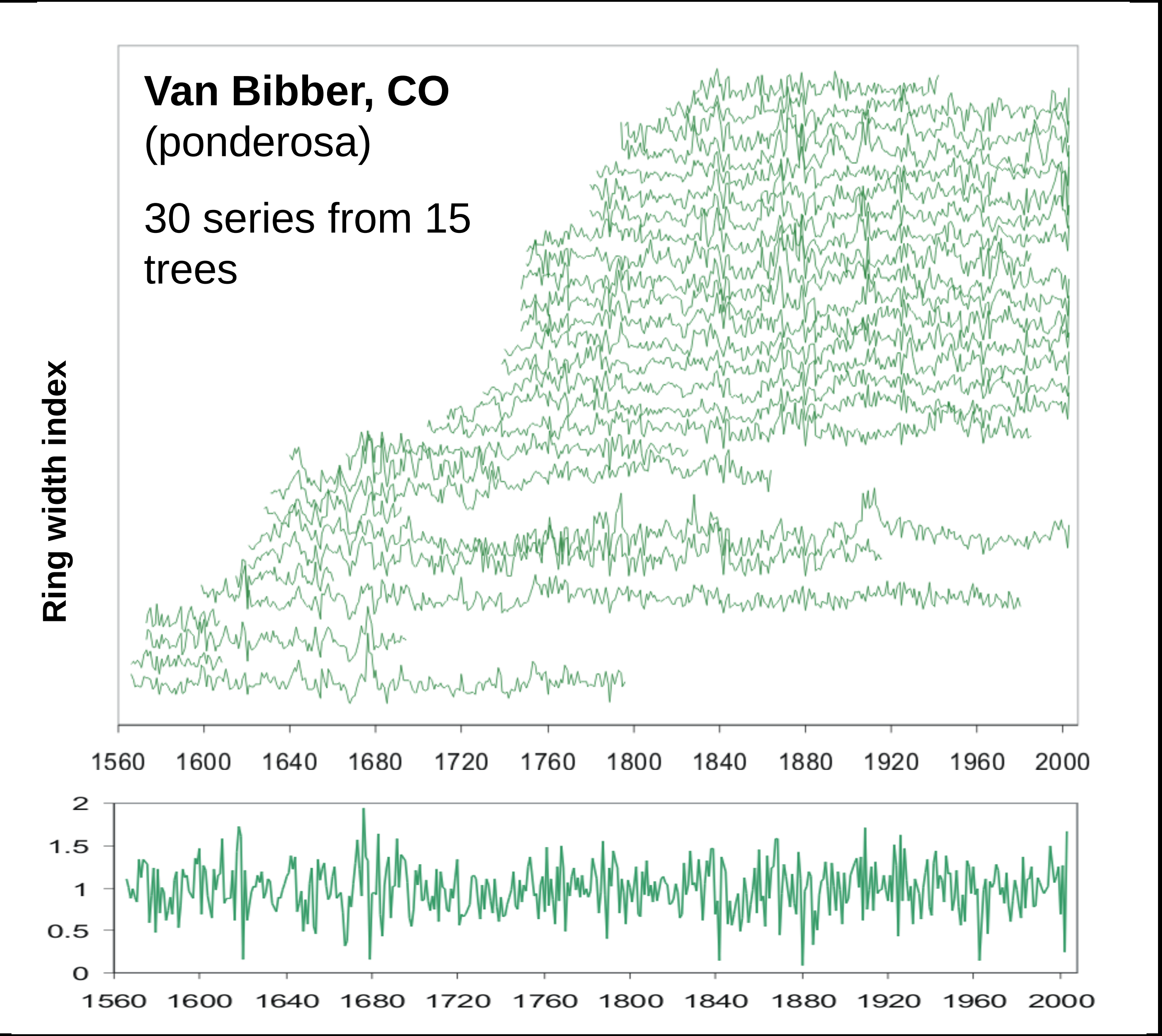
3. Detrending the measured series





- 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

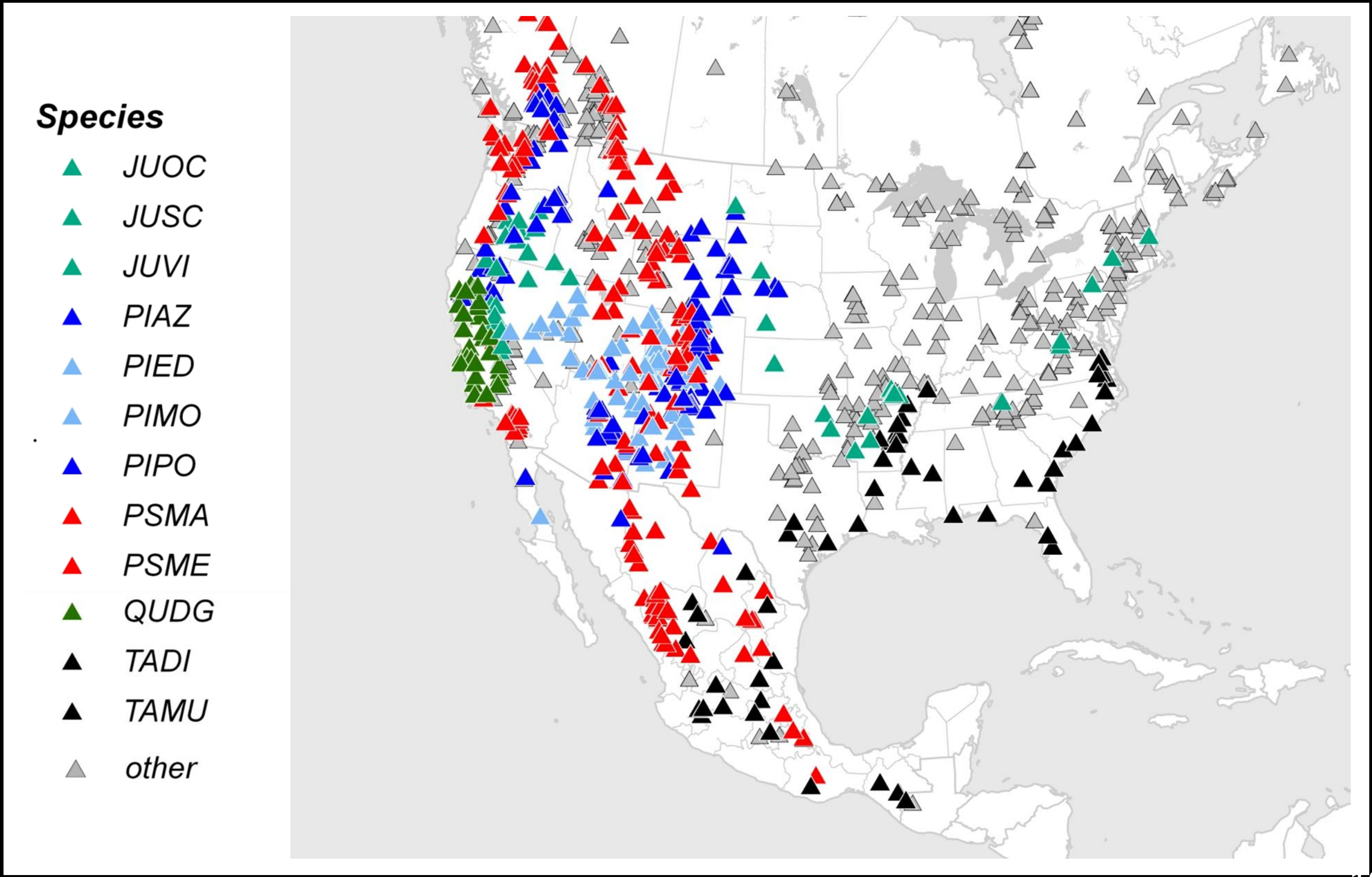
4. Compiling the Tree-Ring Chronology from the measurements from many trees



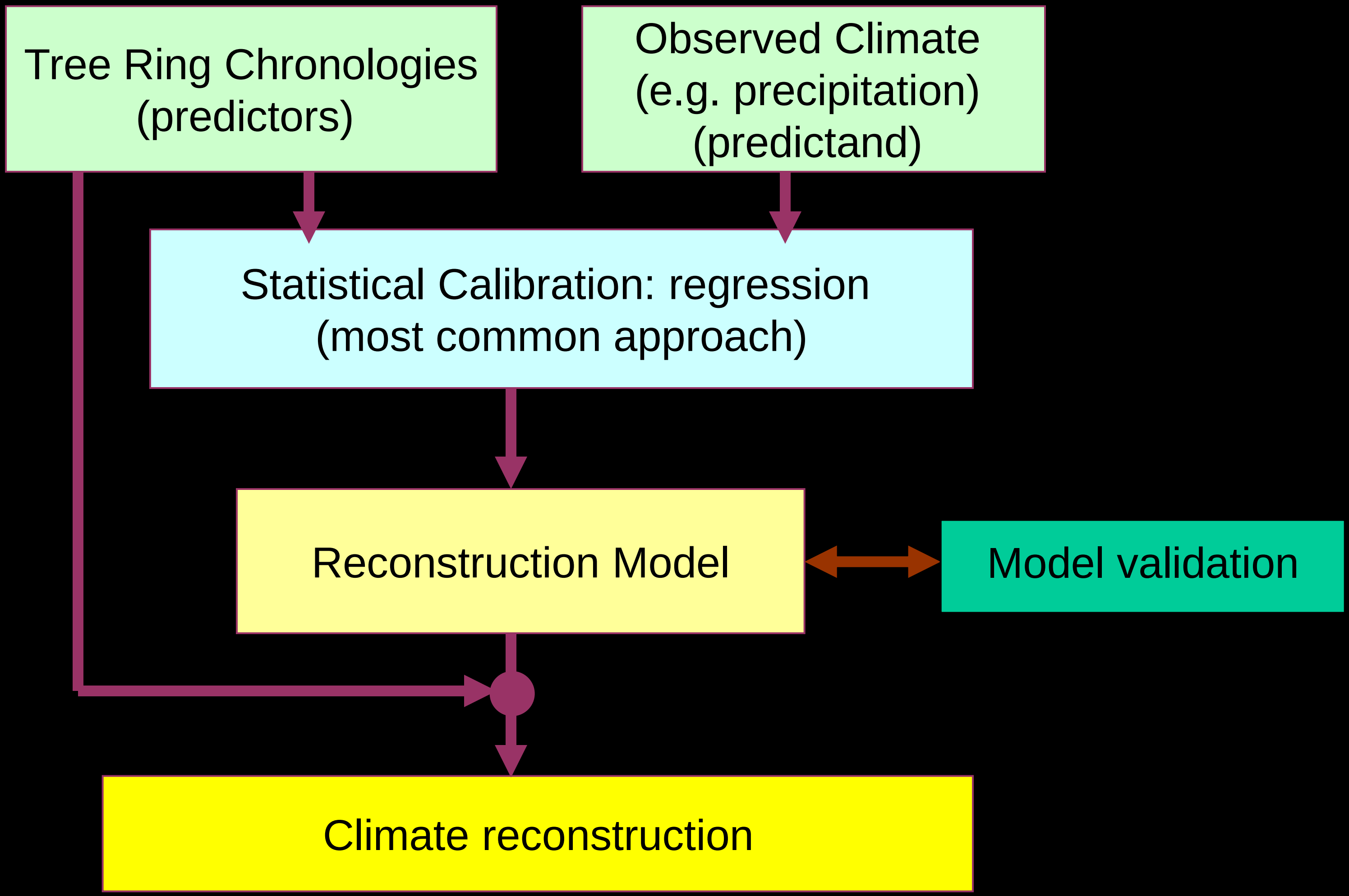
Chronology = basic unit of tree-ring data, "building block" for the climate reconstruction

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 or hydrology records

- **Length** – minimum 40 years for robust calibration with tree-ring data
- **Quality –** screened for station moves, changes in instrumentation, natural or estimated natural flows.
  - Gridded climate data are now commonly used

Requirements for tree-ring chronologies

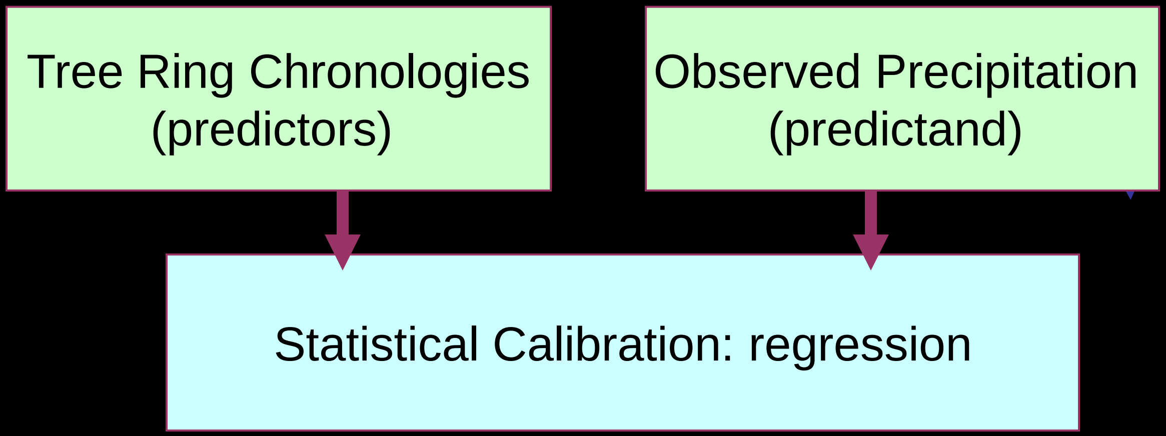
- **Moisture sensitive species** – primarily Douglas-fir, ponderosa pine, pinyon pine
- **Location** – from a region that is climatically linked to the region of interest
- Length tradeoff: fewer chronologies available further back in time (and in recent years, to some extent)

Douglas-fir

Pinyon pine

Ponderosa pine

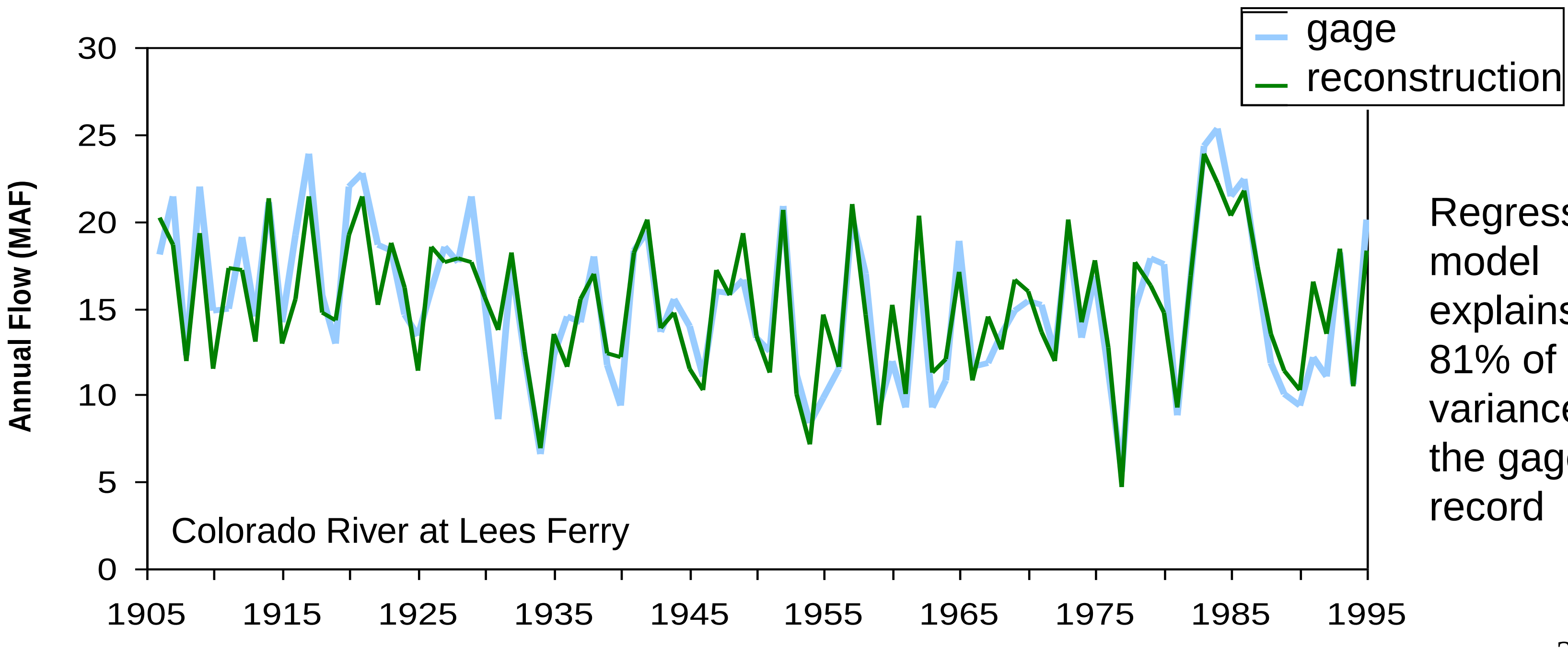
Reconstruction modeling strategies



- 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)

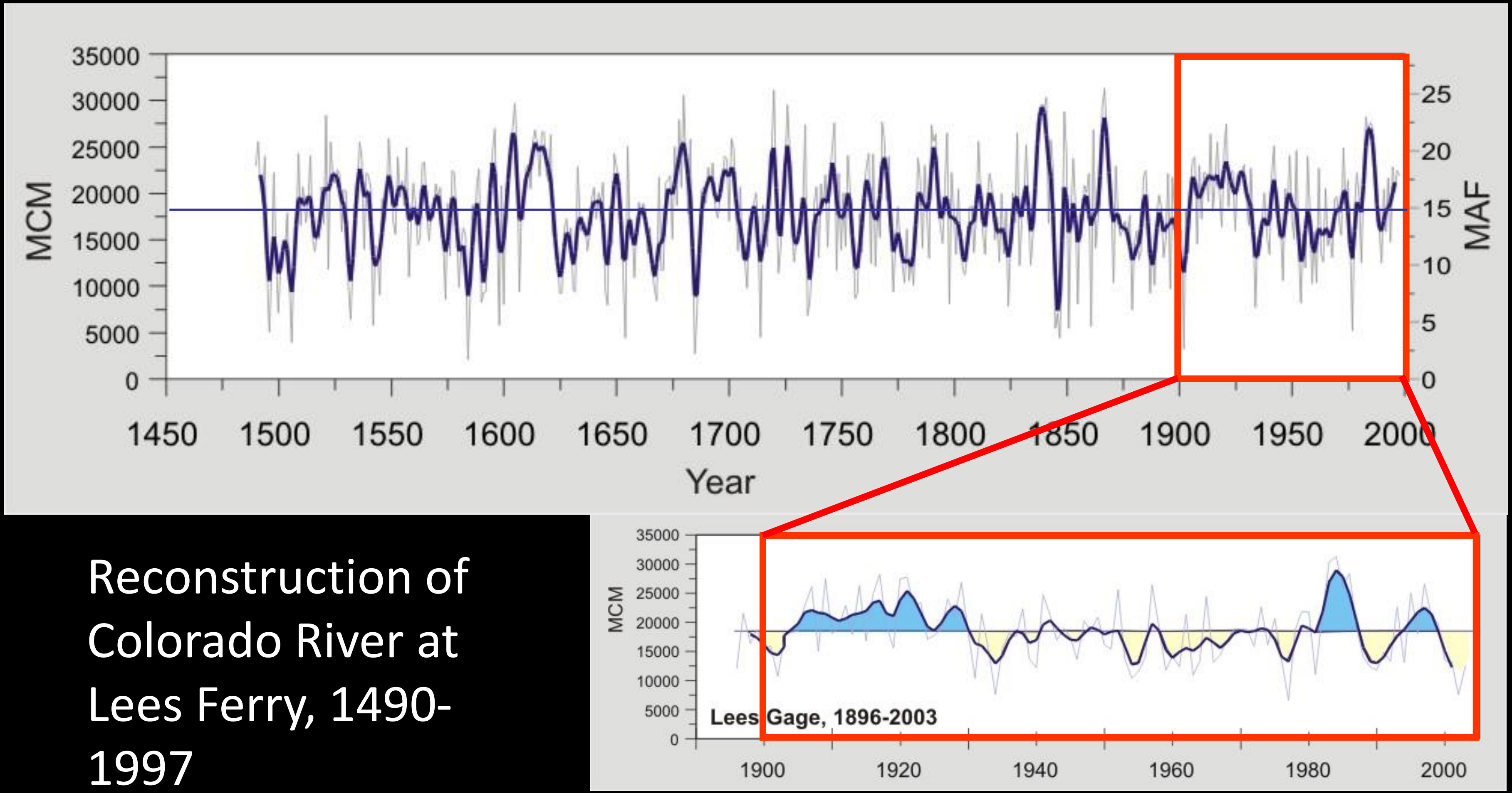
6. Model validation and skill assessment

- 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.

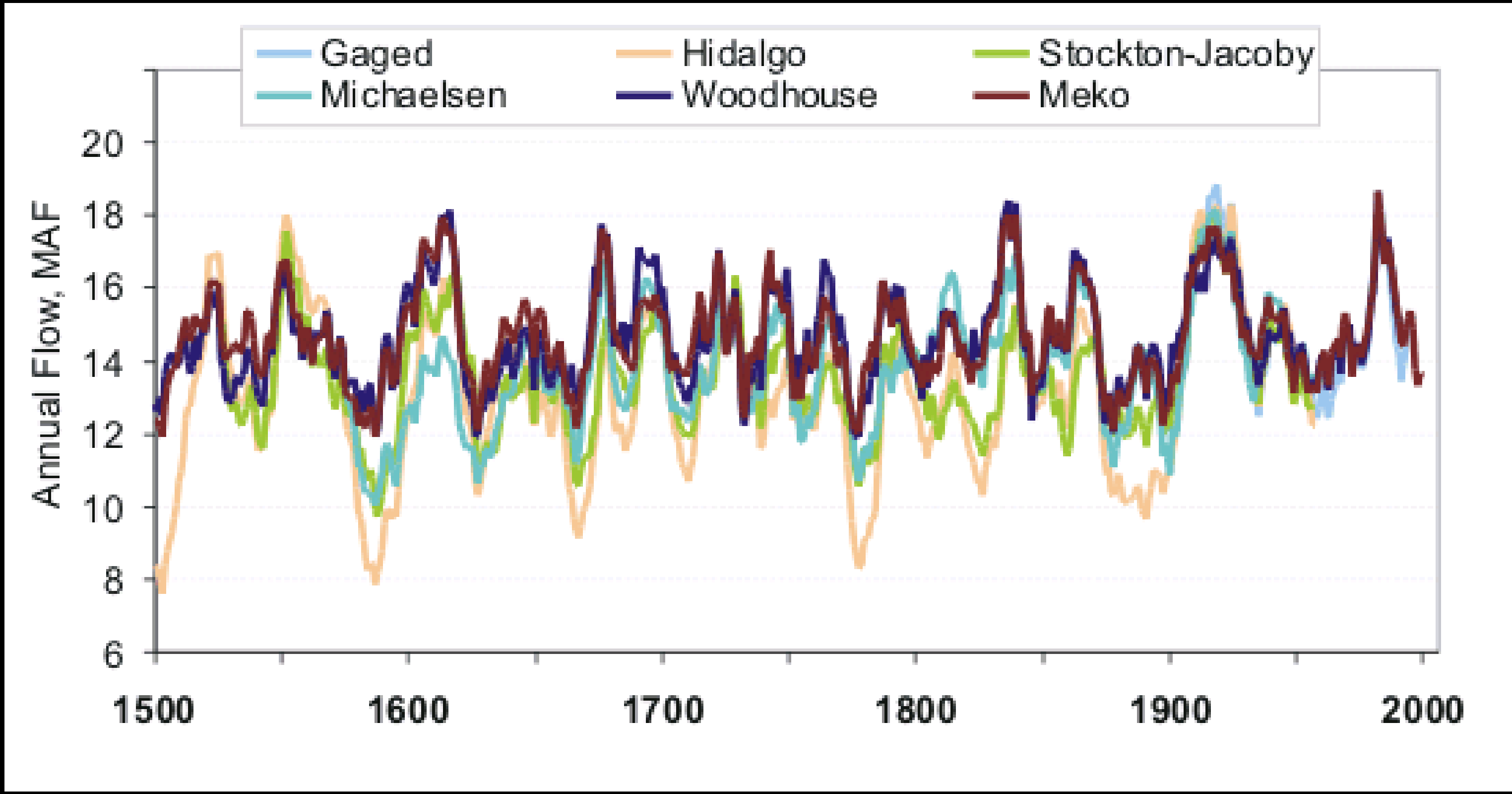
- The reconstruction model never explains 100% of the variance in the observed record.

- Climate or hydrology 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.

- BOTTOM LINE: 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 or gage record over a longer time frame

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

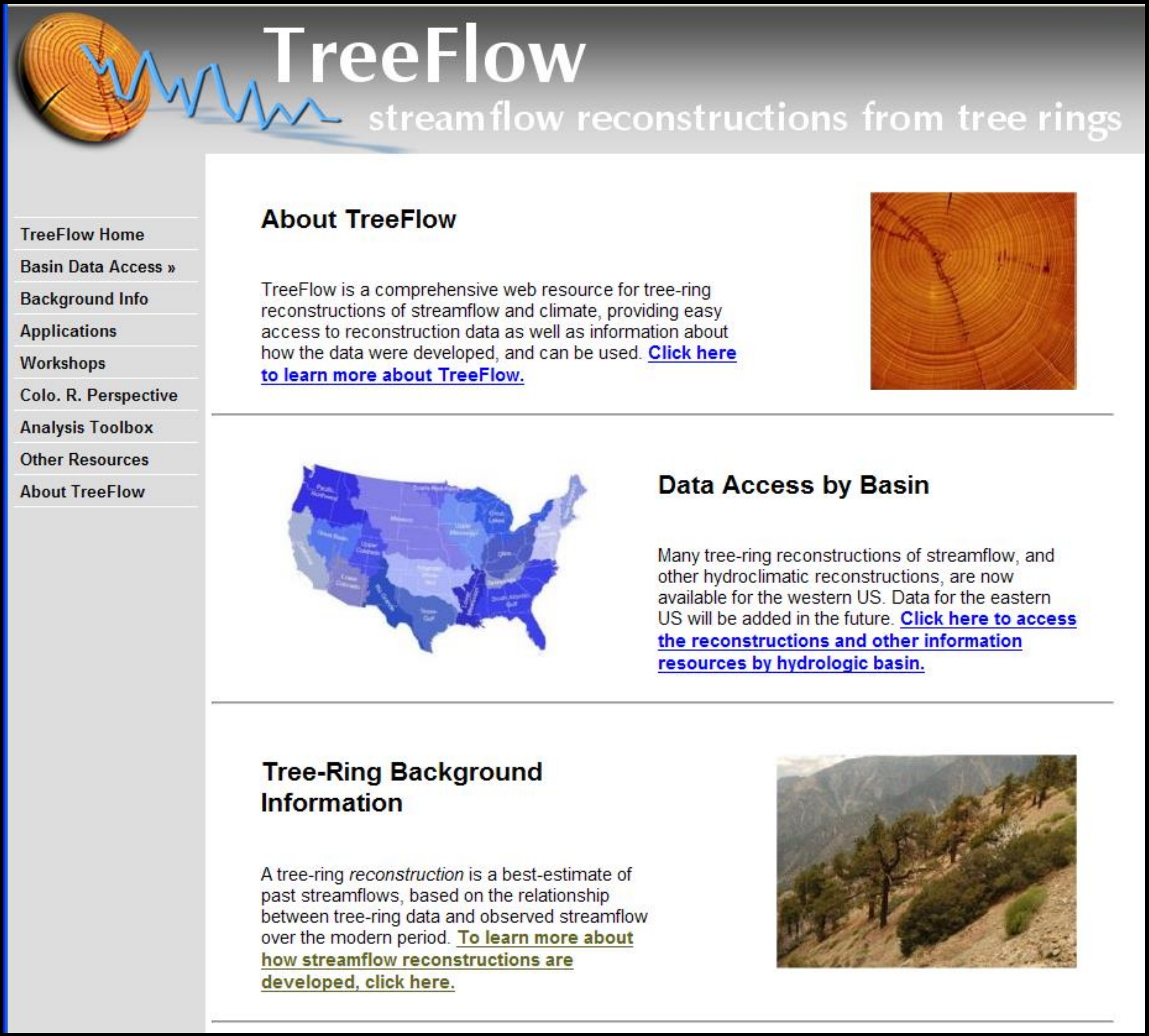
• a framework for understanding the range of drought characteristics (intensity, duration, magnitude) that has occurred

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

• an understanding of the rich 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



http://treeflow.info/

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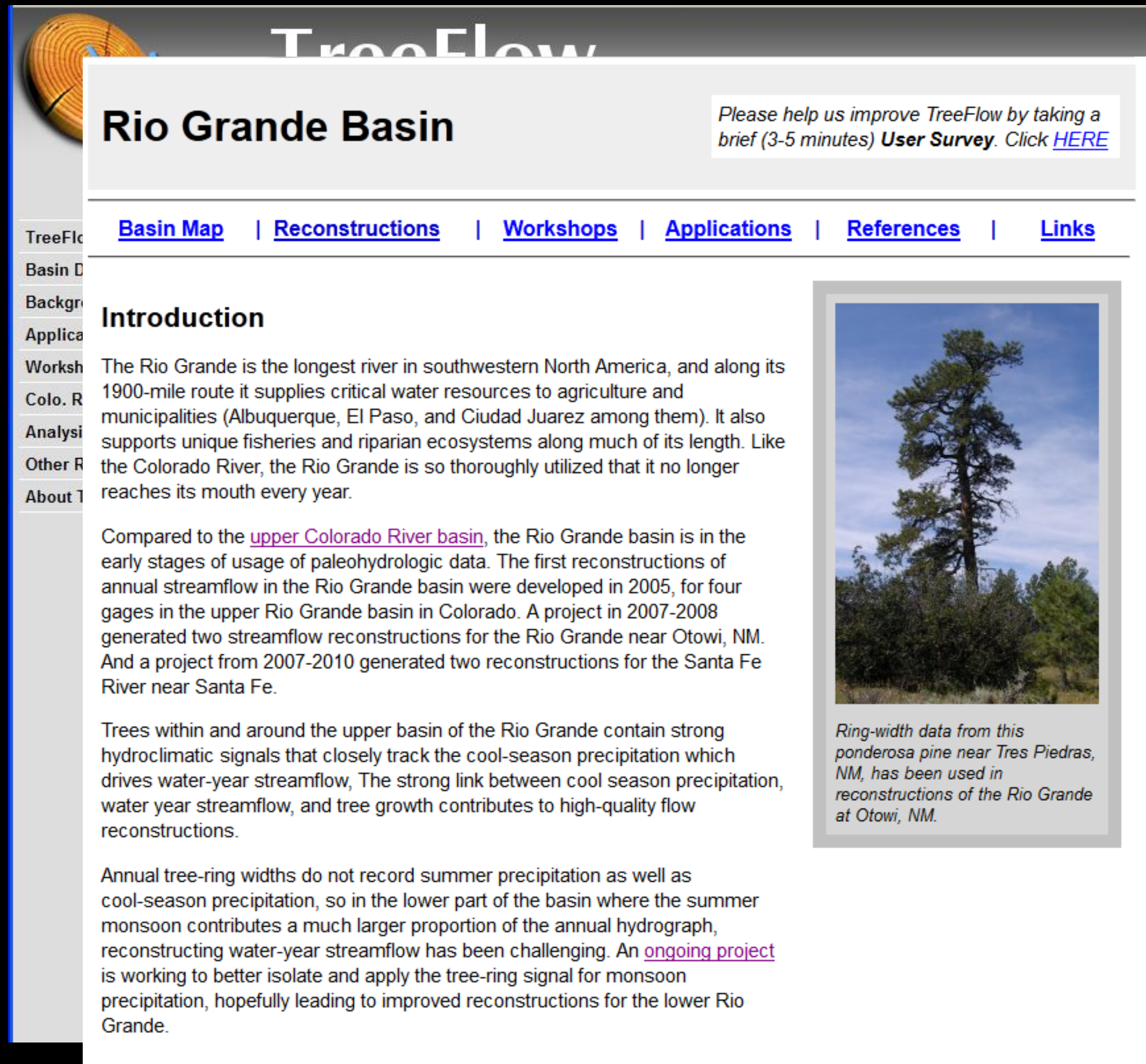

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Rio Grande Basin

Please help us improve TreeFlow by taking a brief (3-5 minutes) ***User Survey****. Click HERE*

Basin Map | Reconstructions | Workshops | Applications | References | Links

Introduction

The Rio Grande is the longest river in southwestern North America, and along its 1900-mile route it supplies critical water resources to agriculture and municipalities (Albuquerque, El Paso, and Ciudad Juarez among them). It also supports unique fisheries and riparian ecosystems along much of its length. Like the Colorado River, the Rio Grande is so thoroughly utilized that it no longer reaches its mouth every year.

Compared to the upper Colorado River basin, the Rio Grande basin is in the early stages of usage of paleohydrologic data. The first reconstructions of annual streamflow in the Rio Grande basin were developed in 2005, for four gages in the upper Rio Grande basin in Colorado. A project in 2007-2008 generated two streamflow reconstructions for the Rio Grande near Otowi, NM. And a project from 2007-2010 generated two reconstructions for the Santa Fe River near Santa Fe.

Trees within and around the upper basin of the Rio Grande contain strong hydroclimatic signals that closely track the cool-season precipitation which drives water-year streamflow, The strong link between cool season precipitation, water year streamflow, and tree growth contributes to high-quality flow reconstructions.

Annual tree-ring widths do not record summer precipitation as well as cool-season precipitation, so in the lower part of the basin where the summer monsoon contributes a much larger proportion of the annual hydrograph, reconstructing water-year streamflow has been challenging. An ongoing project is working to better isolate and apply the tree-ring signal for monsoon precipitation, hopefully leading to improved reconstructions for the lower Rio Grande.

Ring-width data from this ponderosa pine near Tres Piedras, NM, has been used in reconstructions of the Rio Grande at Otowi, NM.

TreeFlow we

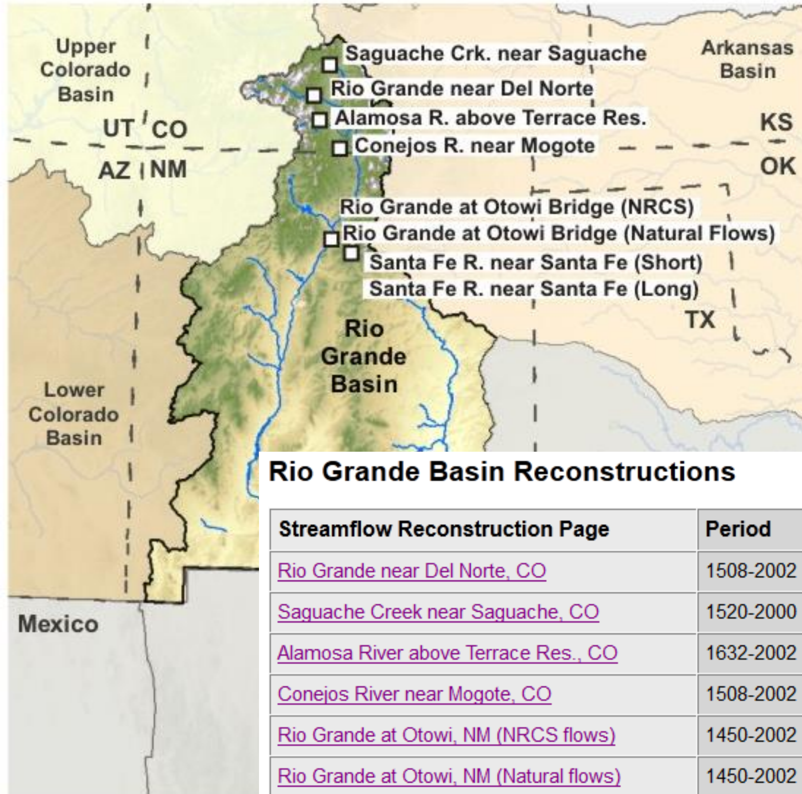
managers

- tree-ring basics
- reconstruction and gage data
- workshop presentations
- applications examples
- references

http://treeflow.info/

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

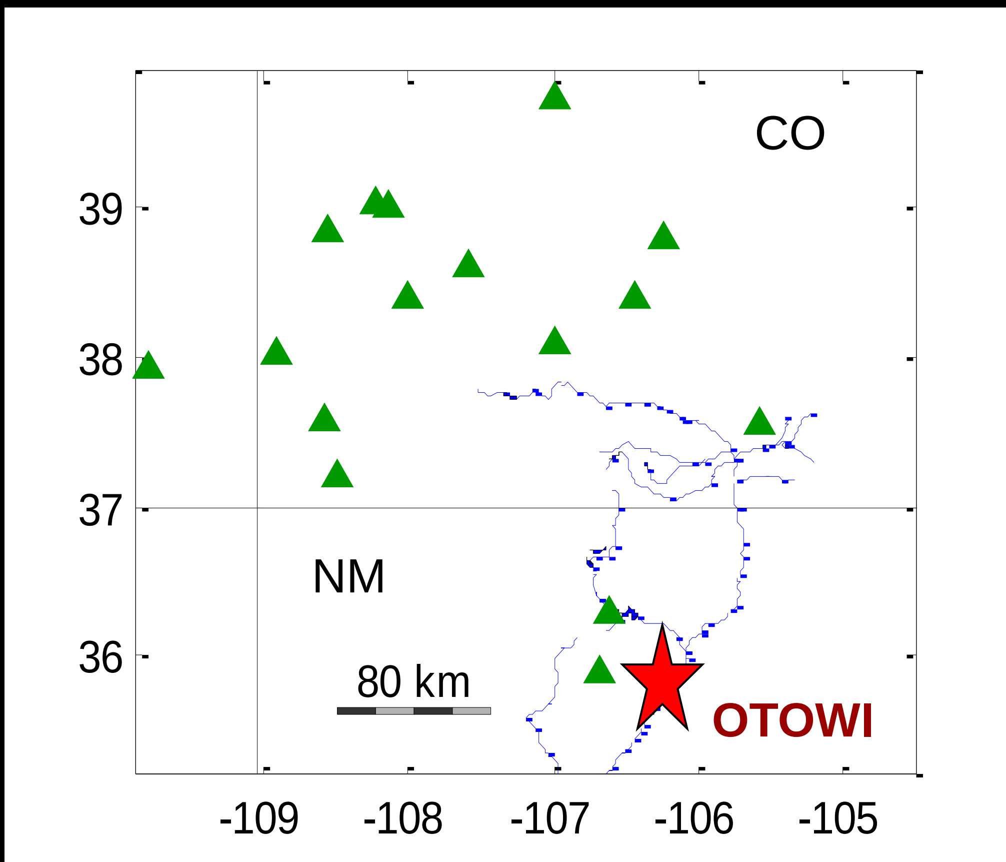
Cool season (Nov-Mar) precipitation for each climate division in New Mexico and Arizona, extending back 1000 years (Ni et al. 2002)

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

Part 2.

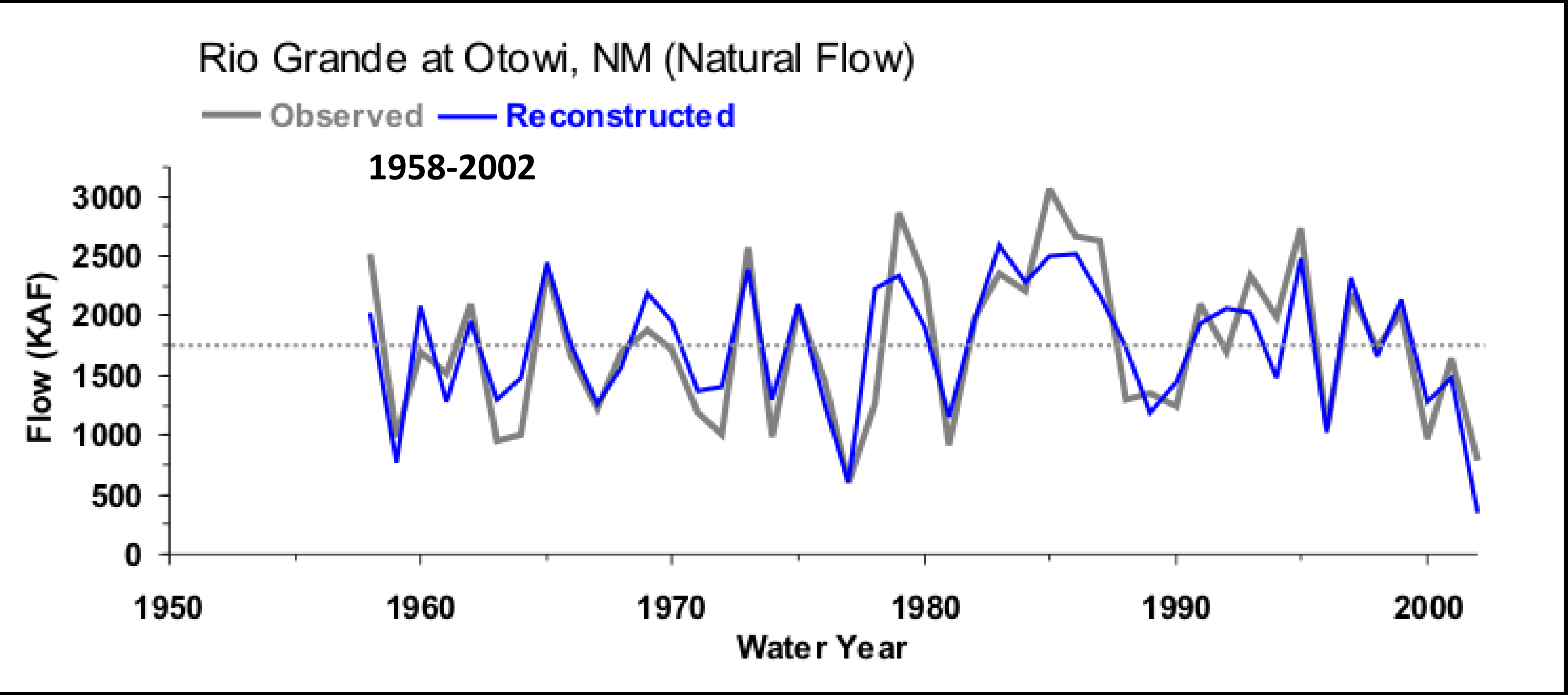
Streamflow Reconstruction for the Rio Grande at Otowi

Streamflow Reconstruction for Rio Grande at Otowi, NM

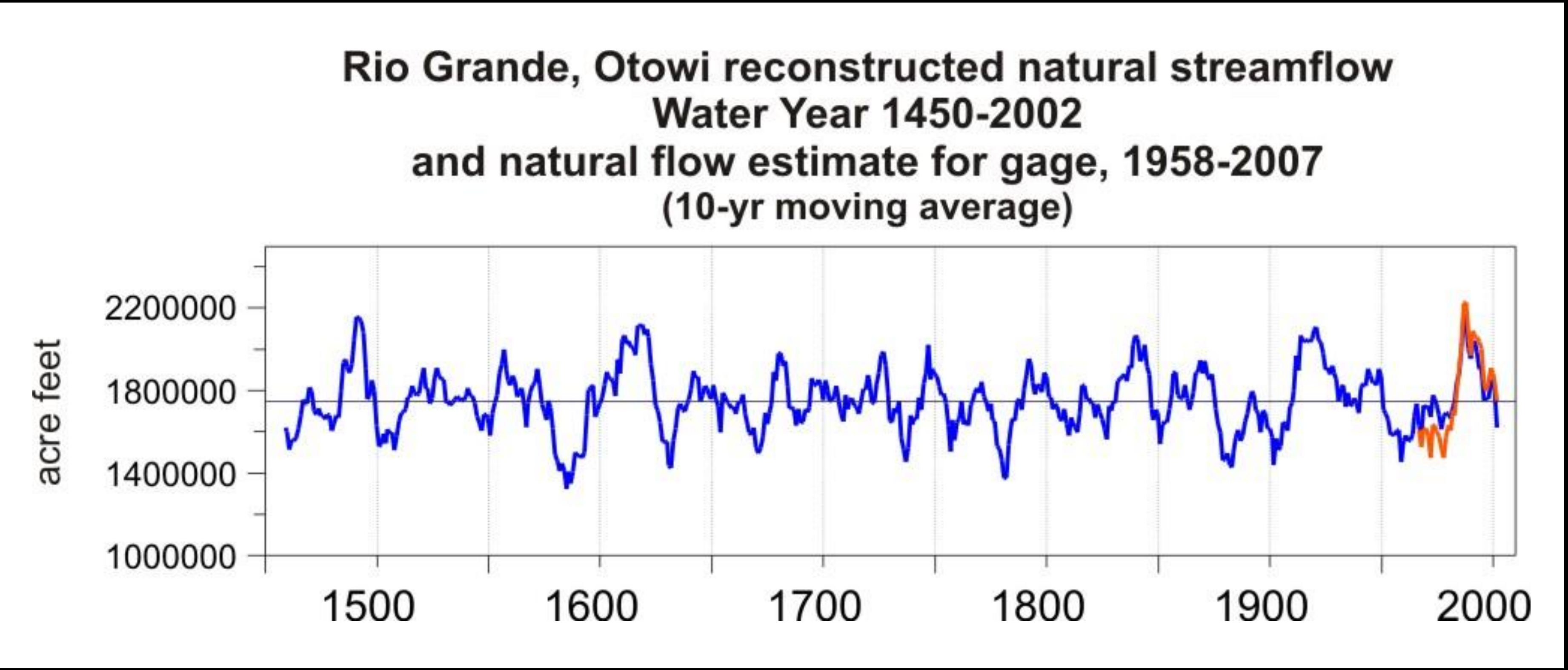


The reconstruction model was calibrating using the average of 17 tree-ring chronologies (GREEN TRIANGLES)

Streamflow Reconstruction for Rio Grande at Otowi, NM

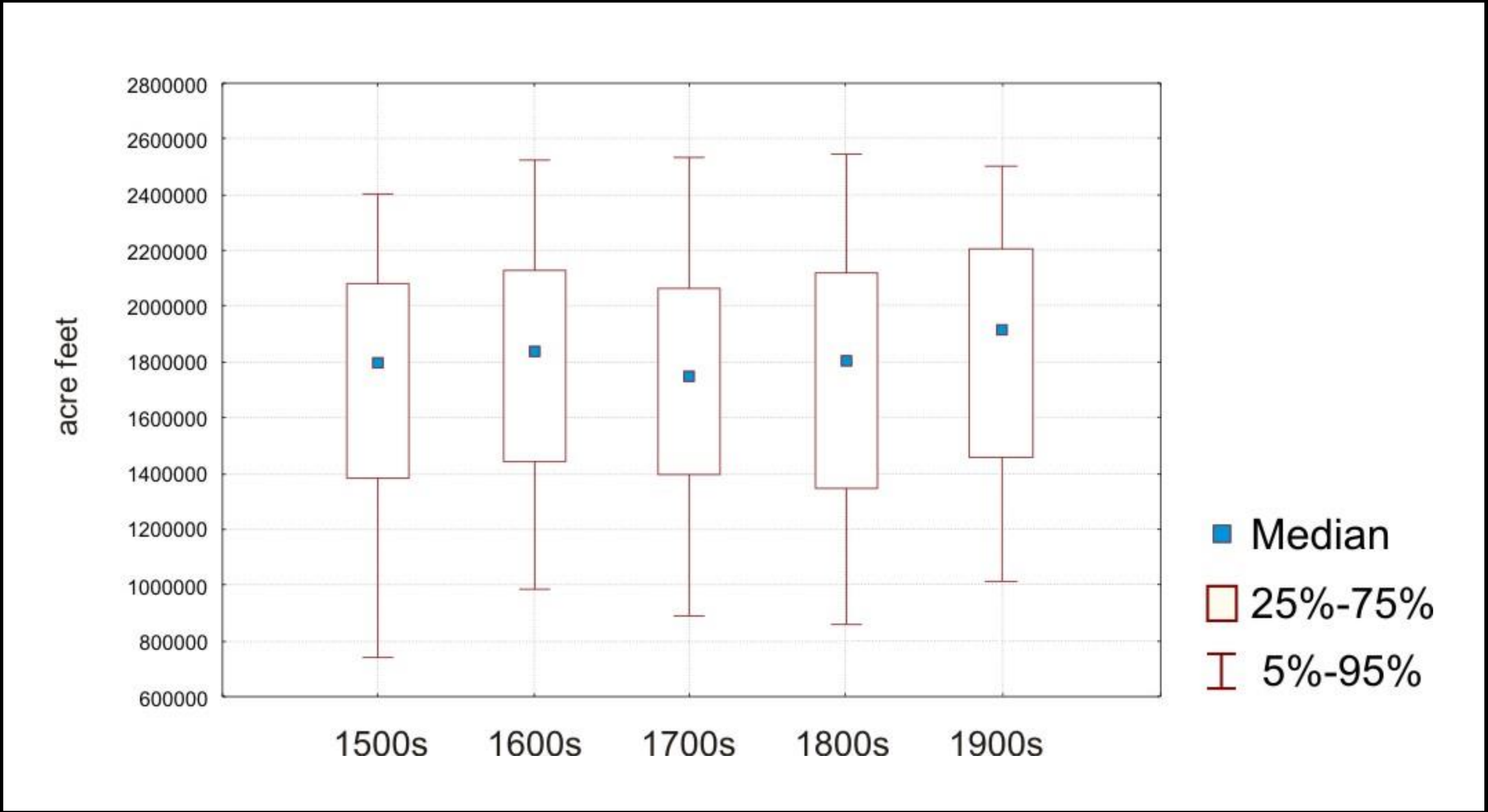


Reconstruction explains 74% of the variance in the gage record.



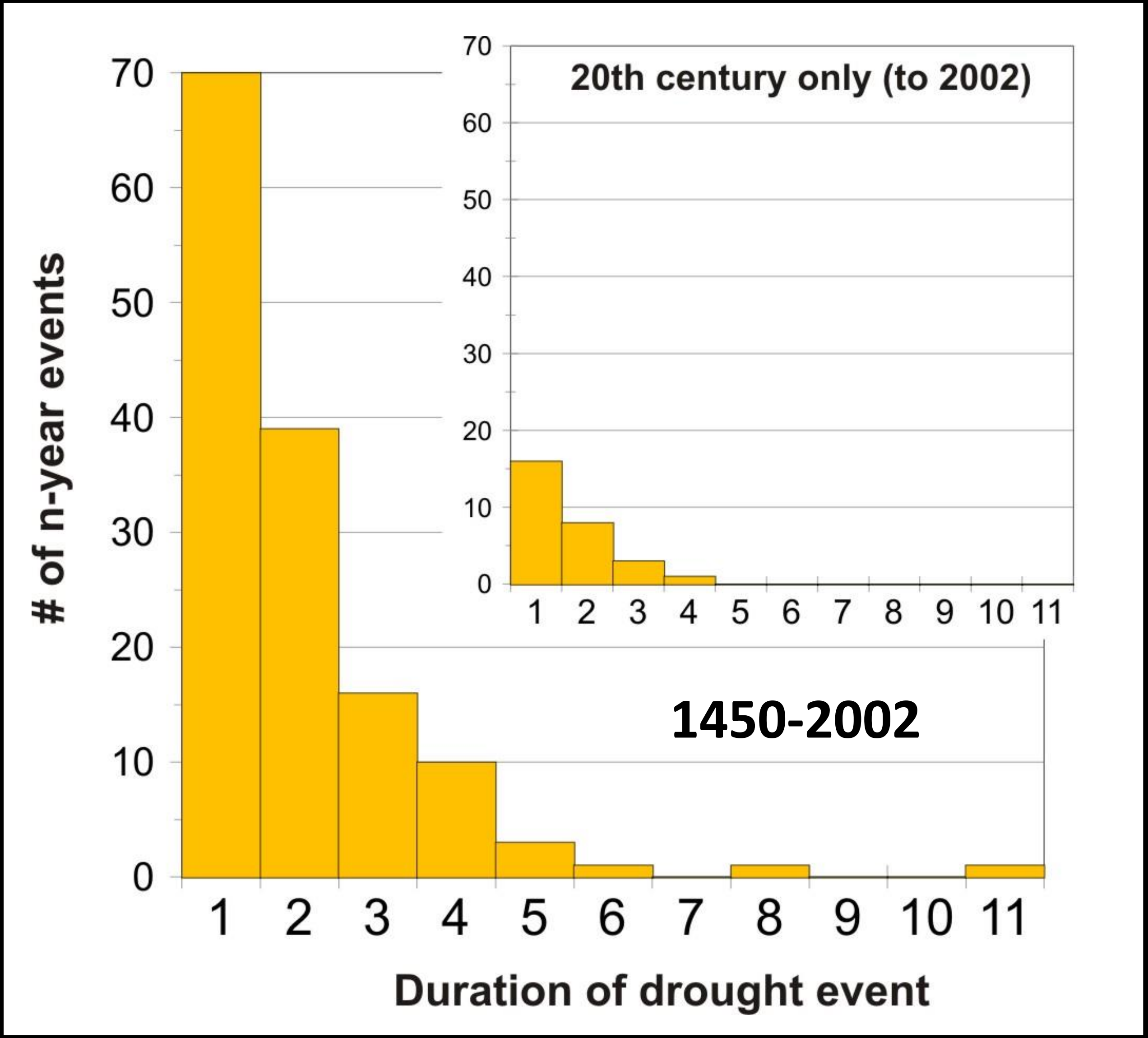
5 Driest Decades	5 Wettest Decades
1576-1585	1978-1987
1772-1781	1482-1491
1623-1632	1610-1619
1874-1883	1912-1921
1893-1902	1831-1840
1950-1959	

Rio Grande, Otowi Reconstruction, Statistical Characteristics by Century



Drought Duration and Frequency, Otowi

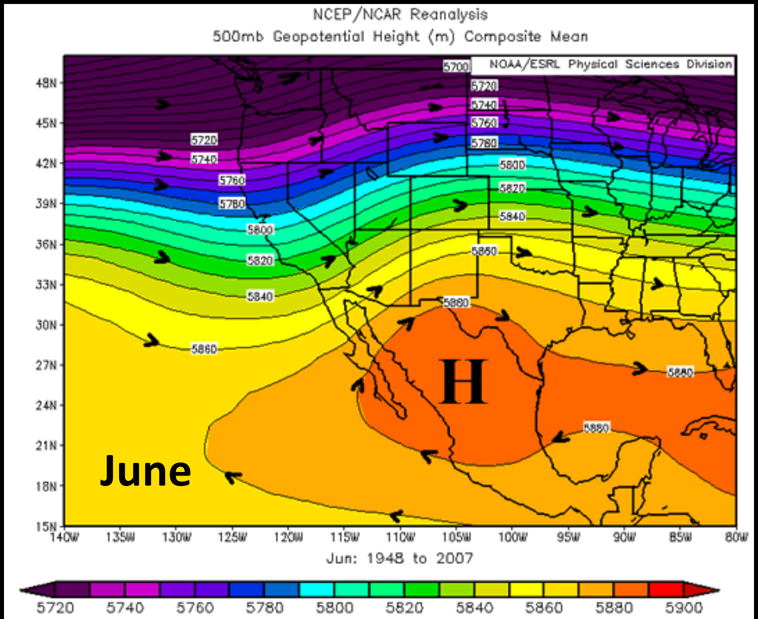
Drought is defined as a single year or set of consecutive years below the long-term median

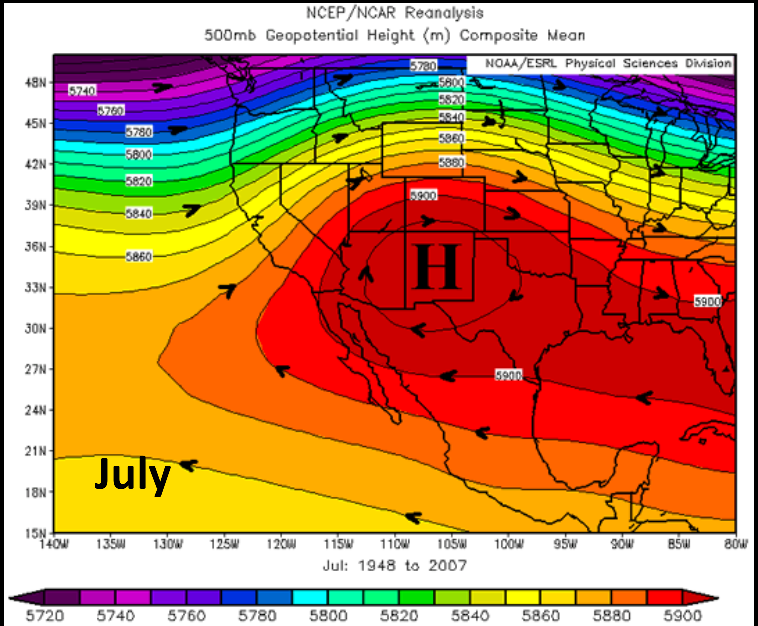


Part 3.

Lower Rio Grande monsoon reconstruction: a slightly different approach

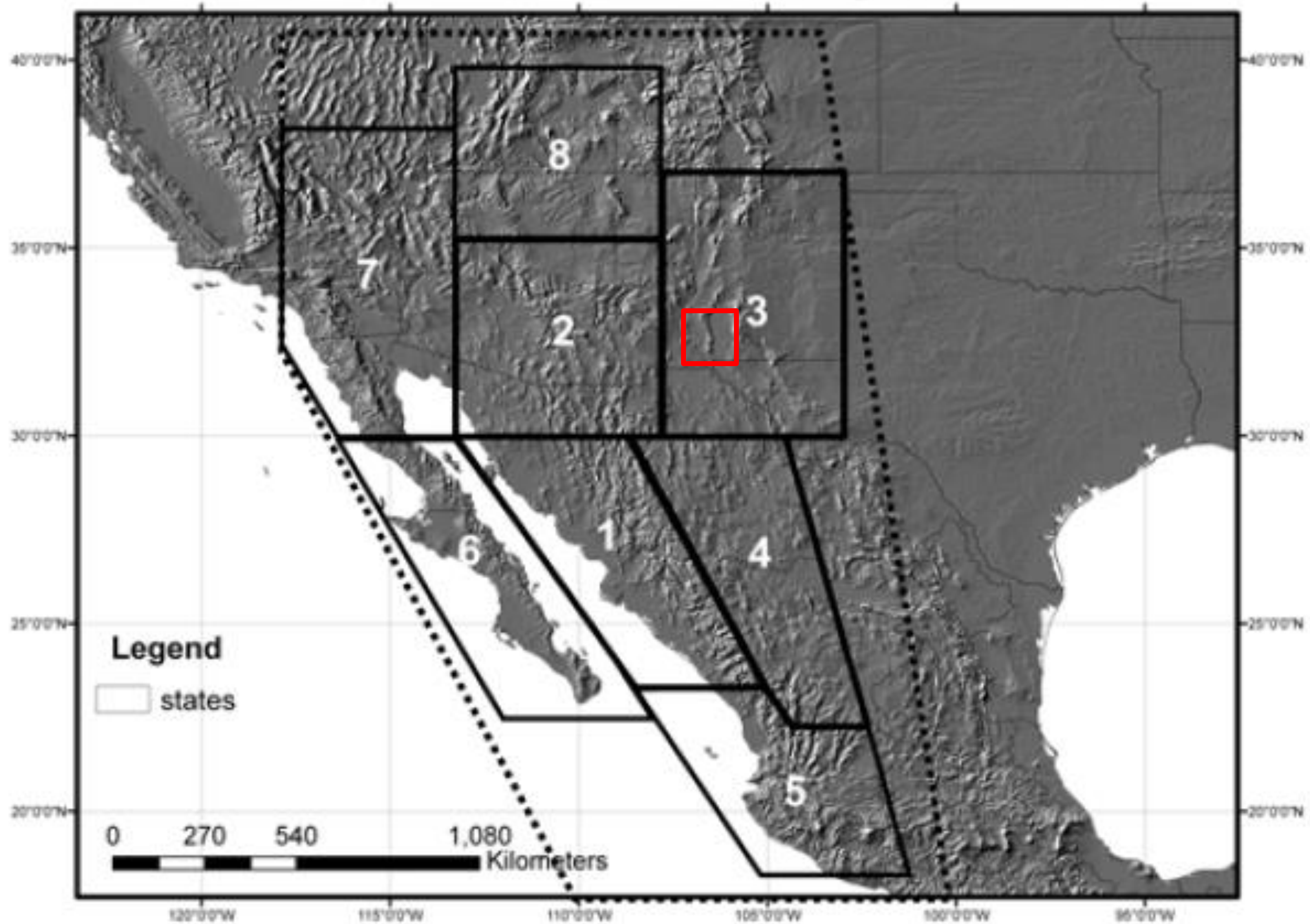
North American Monsoon



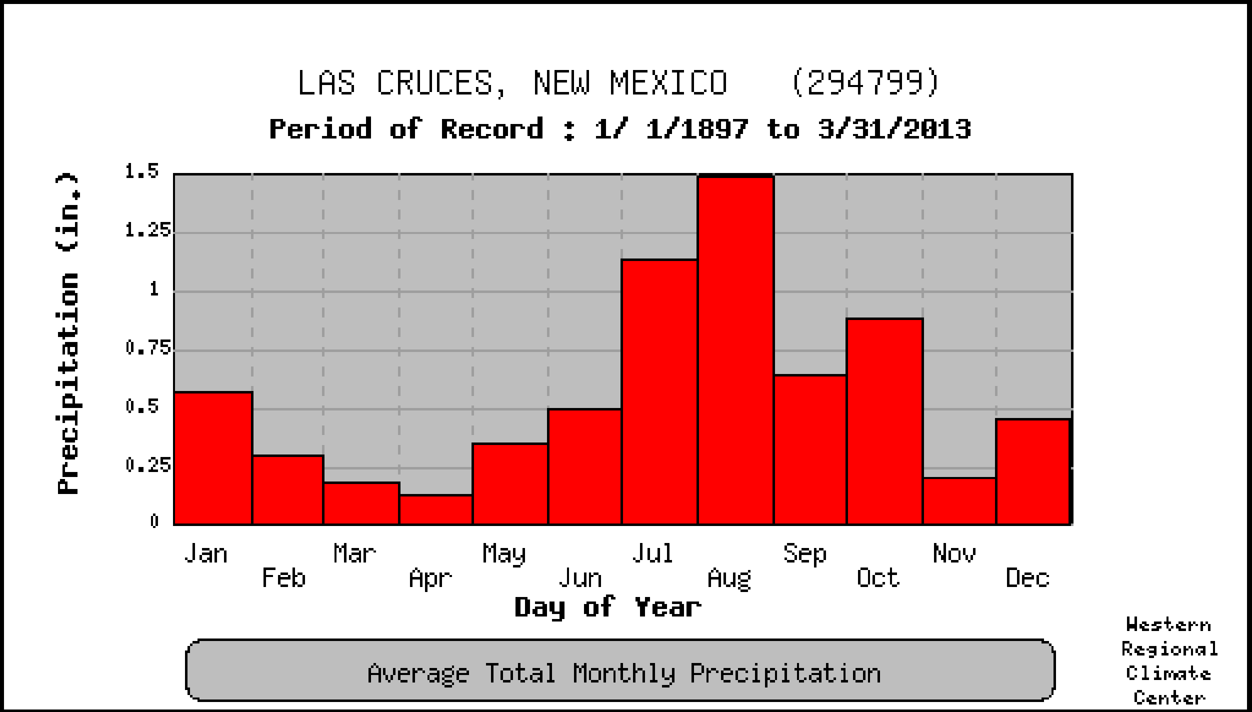


Circulation shifts between June and July result a ridge of high pressure over the southwestern U.S., and advection of moisture into the region.

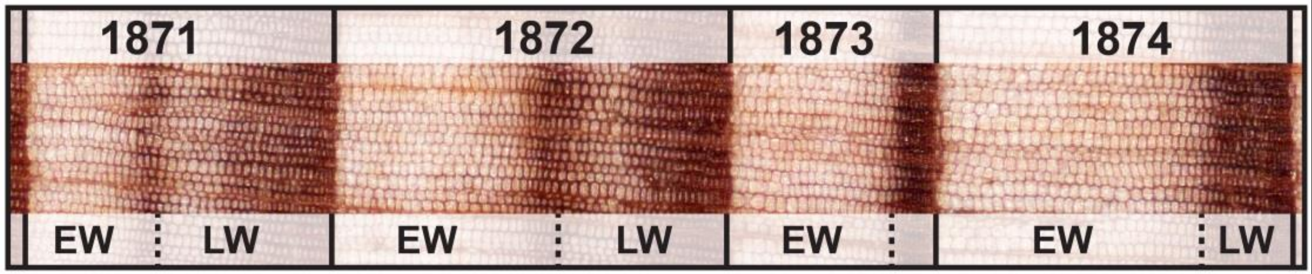
North American Monsoon sub-regional domains



The US Southwest has a bimodal precipitation regime: winter rain/snow and summer monsoon



This precipitation regime is reflected in the sub-annual ring widths increments, called earlywood (EW) and latewood (LW) in several southwestern tree species



Earlywood & Latewood

Earlywood

- Lighter color
- Less Dense

(Larger cells/thinner walls)

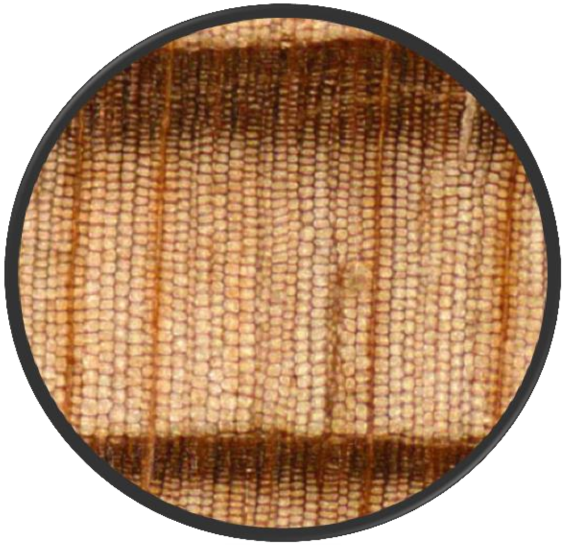
- Conducts water & nutrients

Latewood

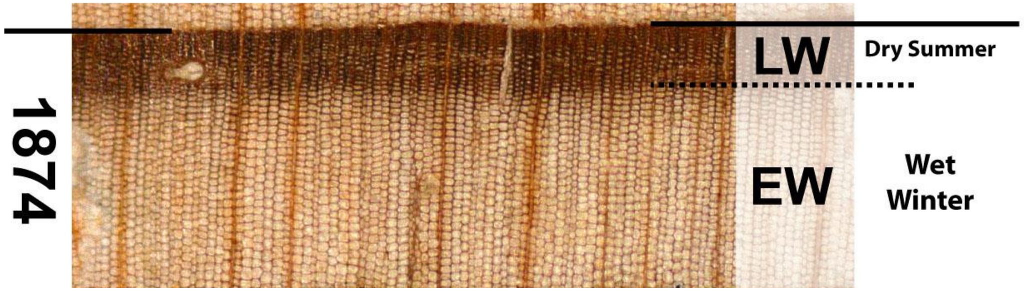
- Darker color
- More Dense

(Smaller cells/thicker walls)

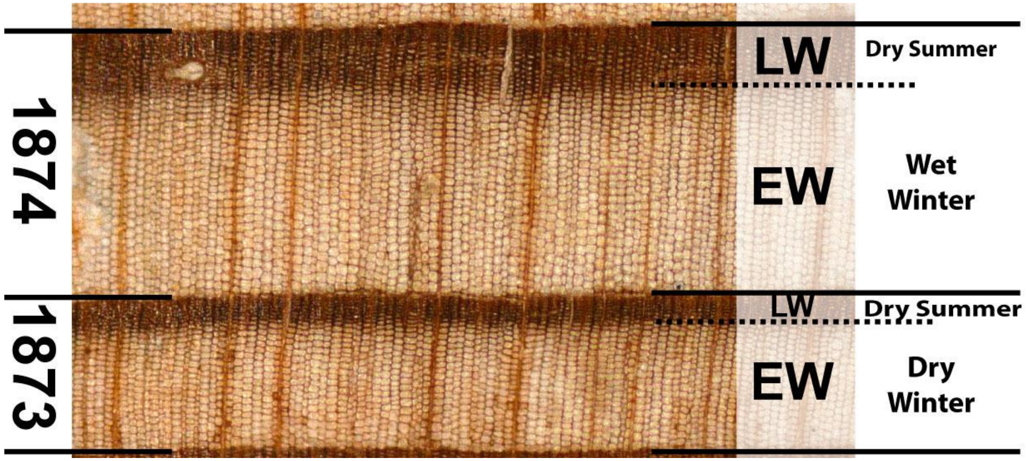
- Provides structural stability



Earlywood & Latewood



Earlywood & Latewood



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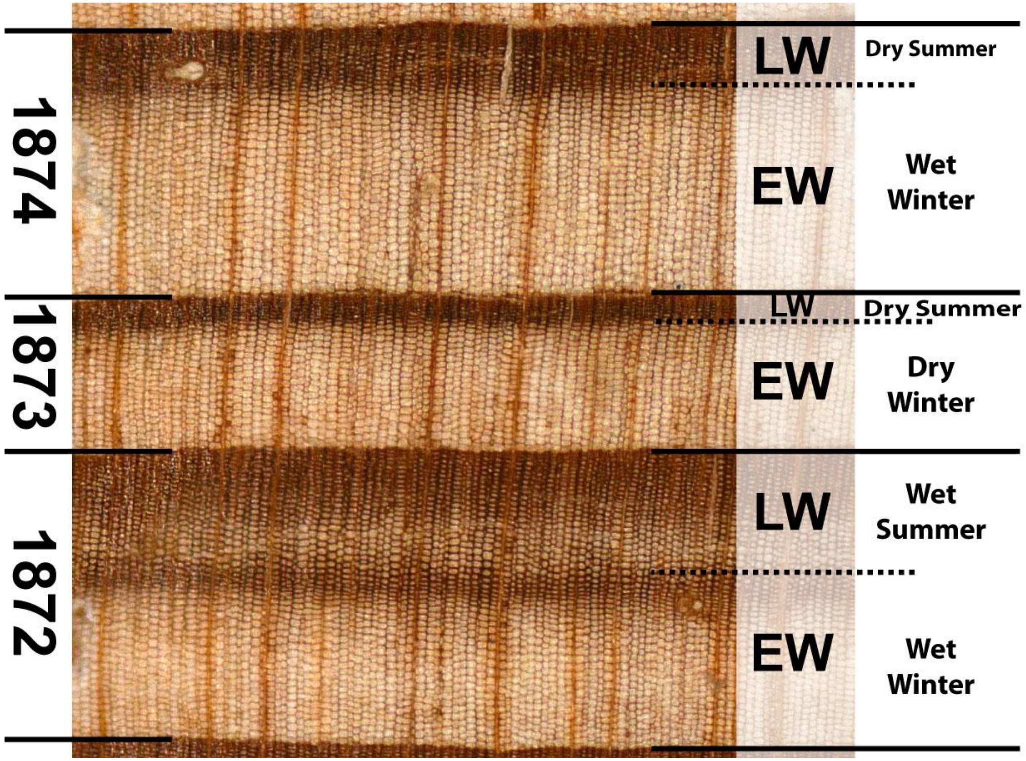

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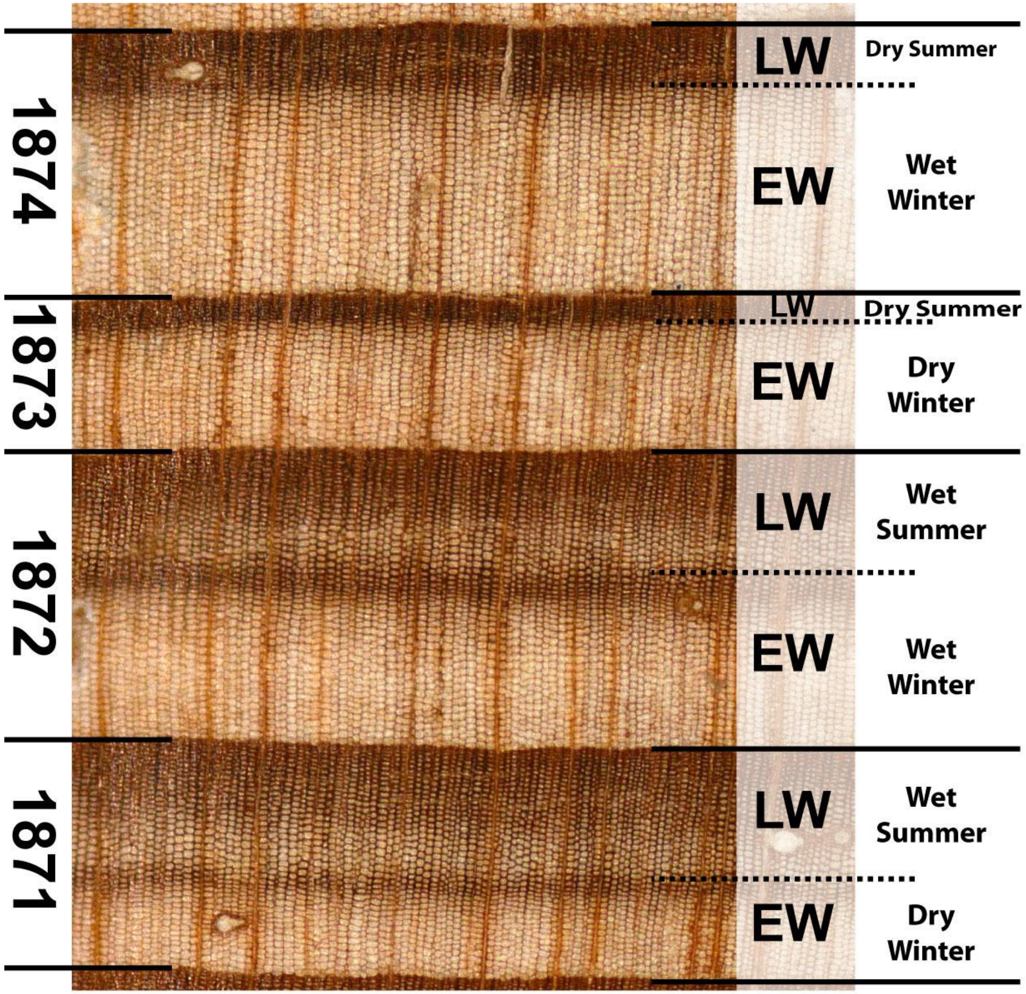

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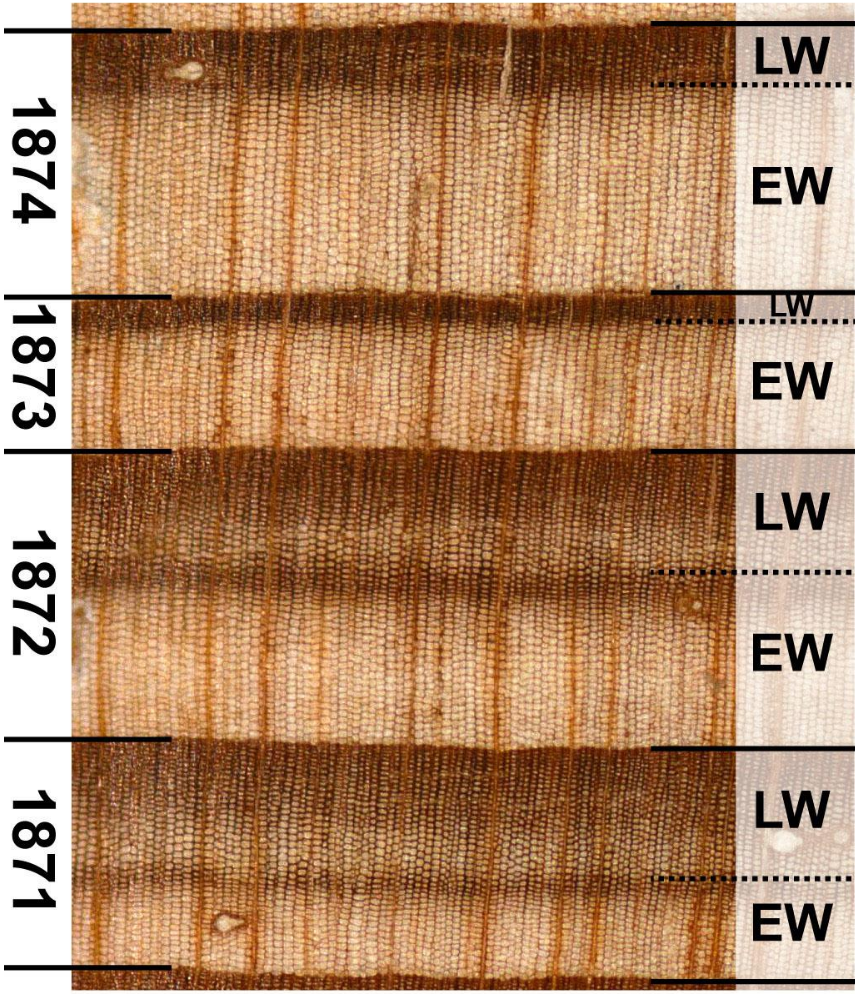
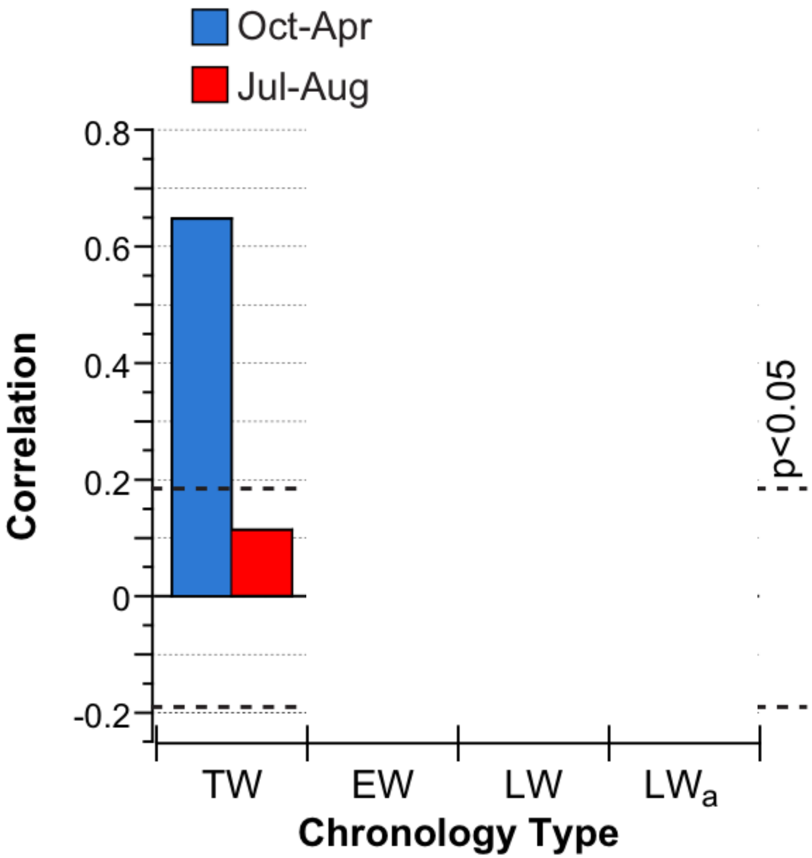
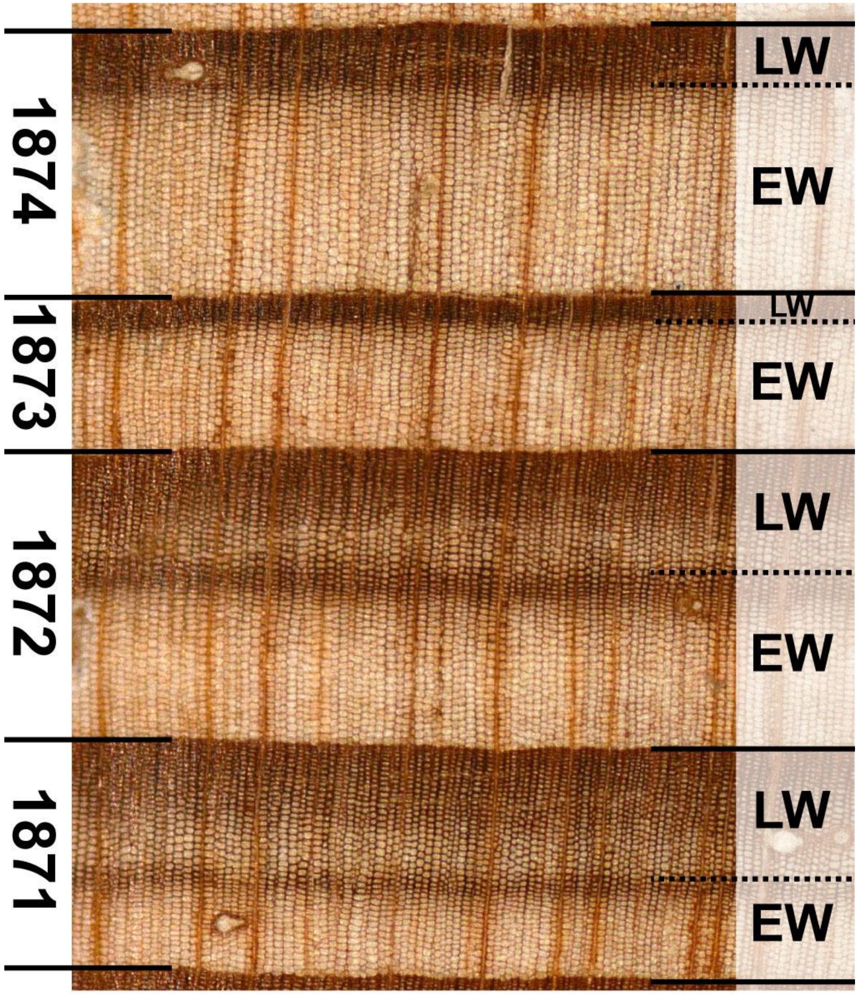
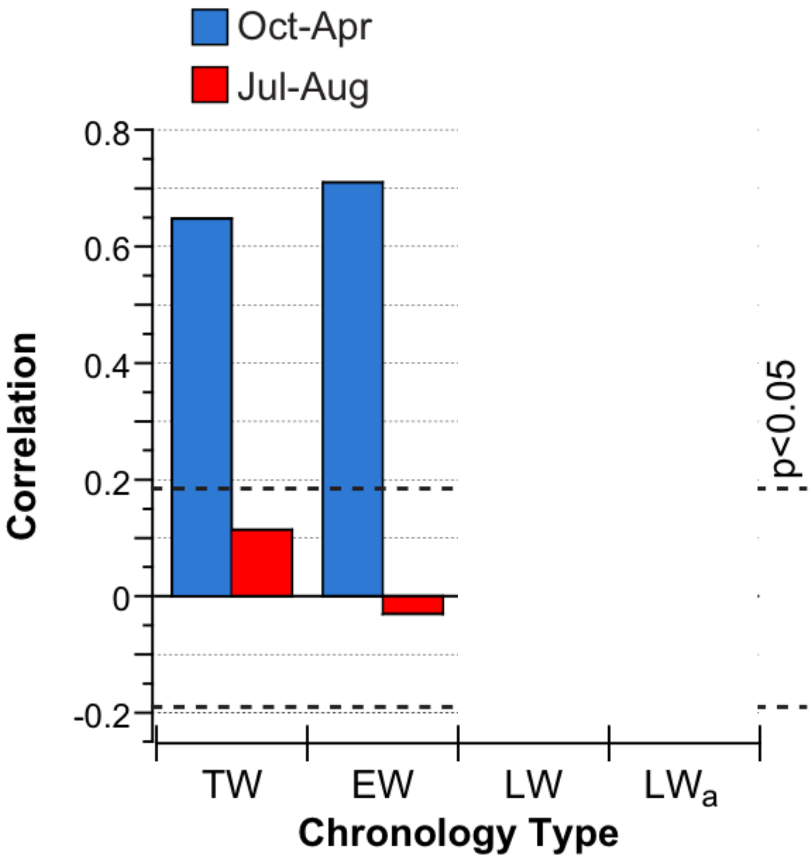




(Griffin et al. 2011 *Tree-Ring Research*)

Earlywood & Latewood





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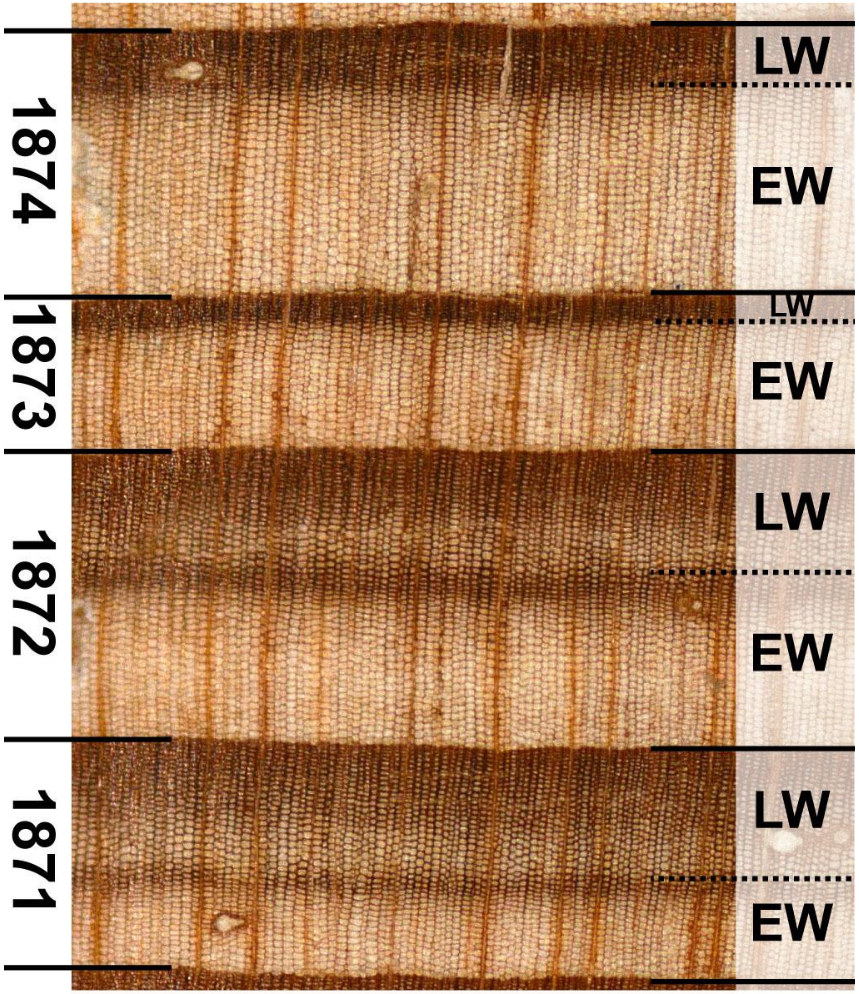

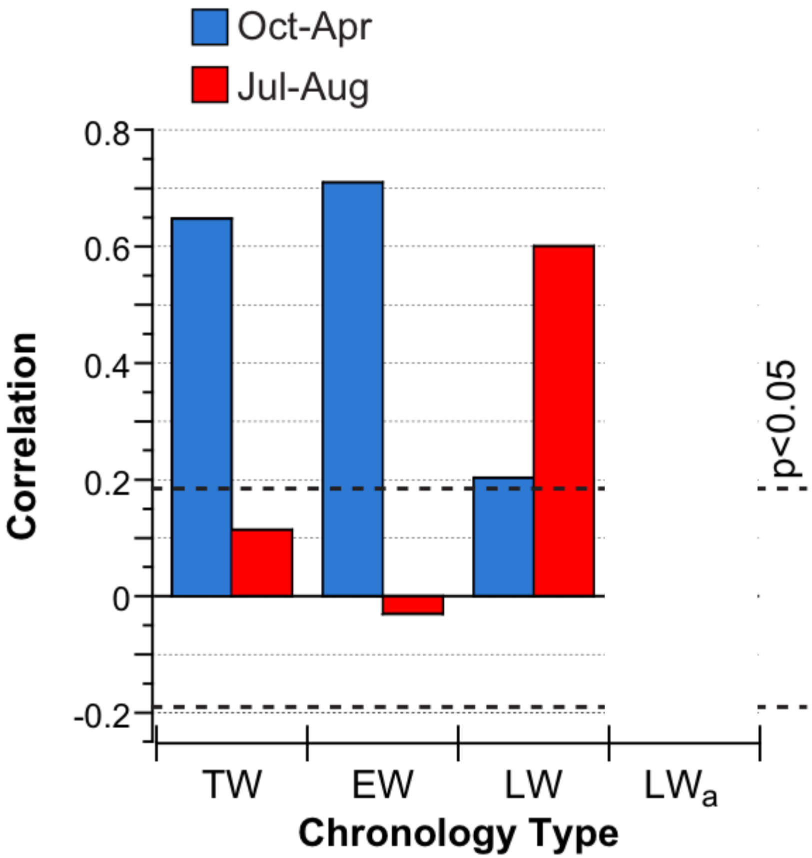

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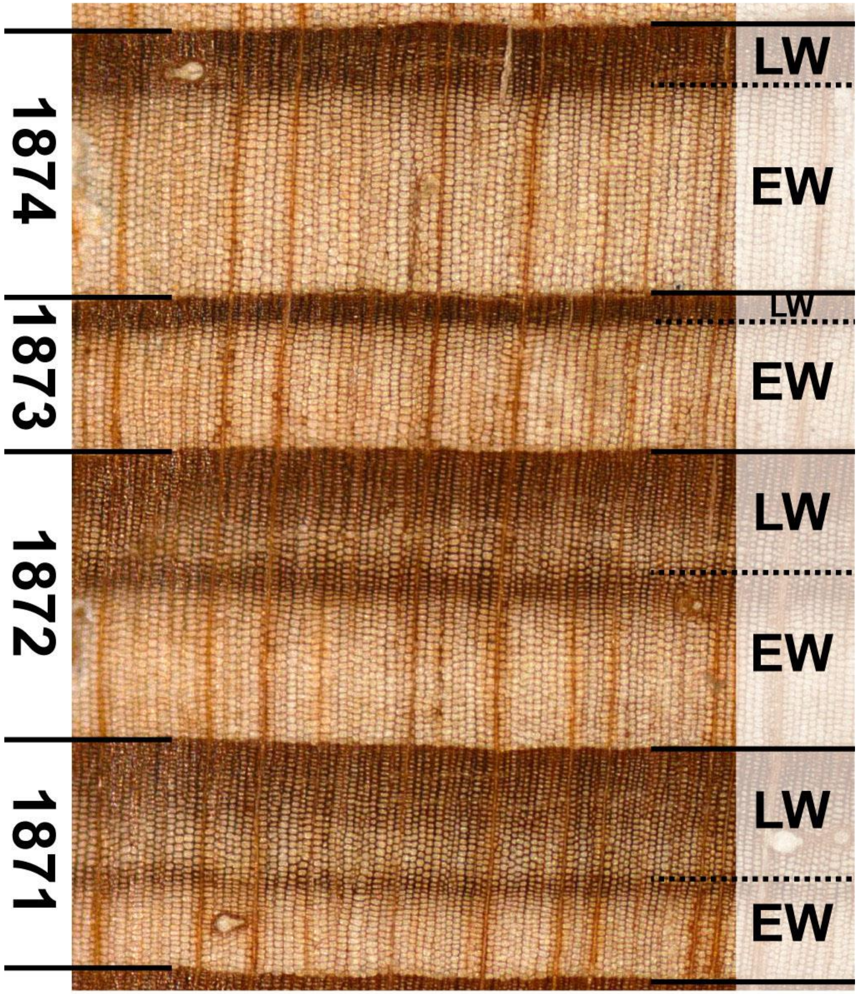
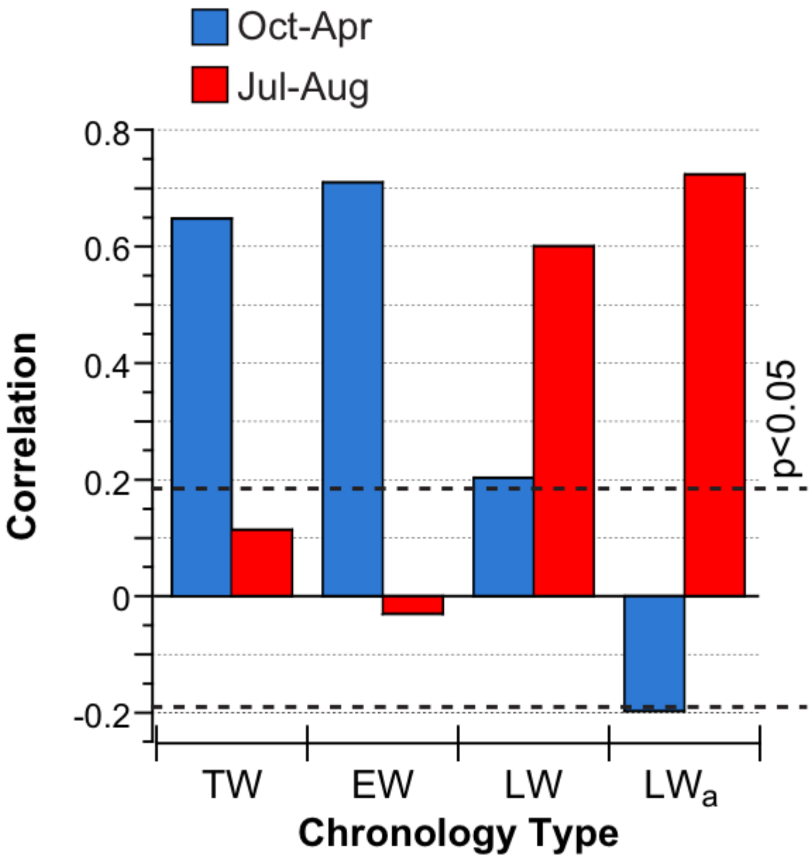
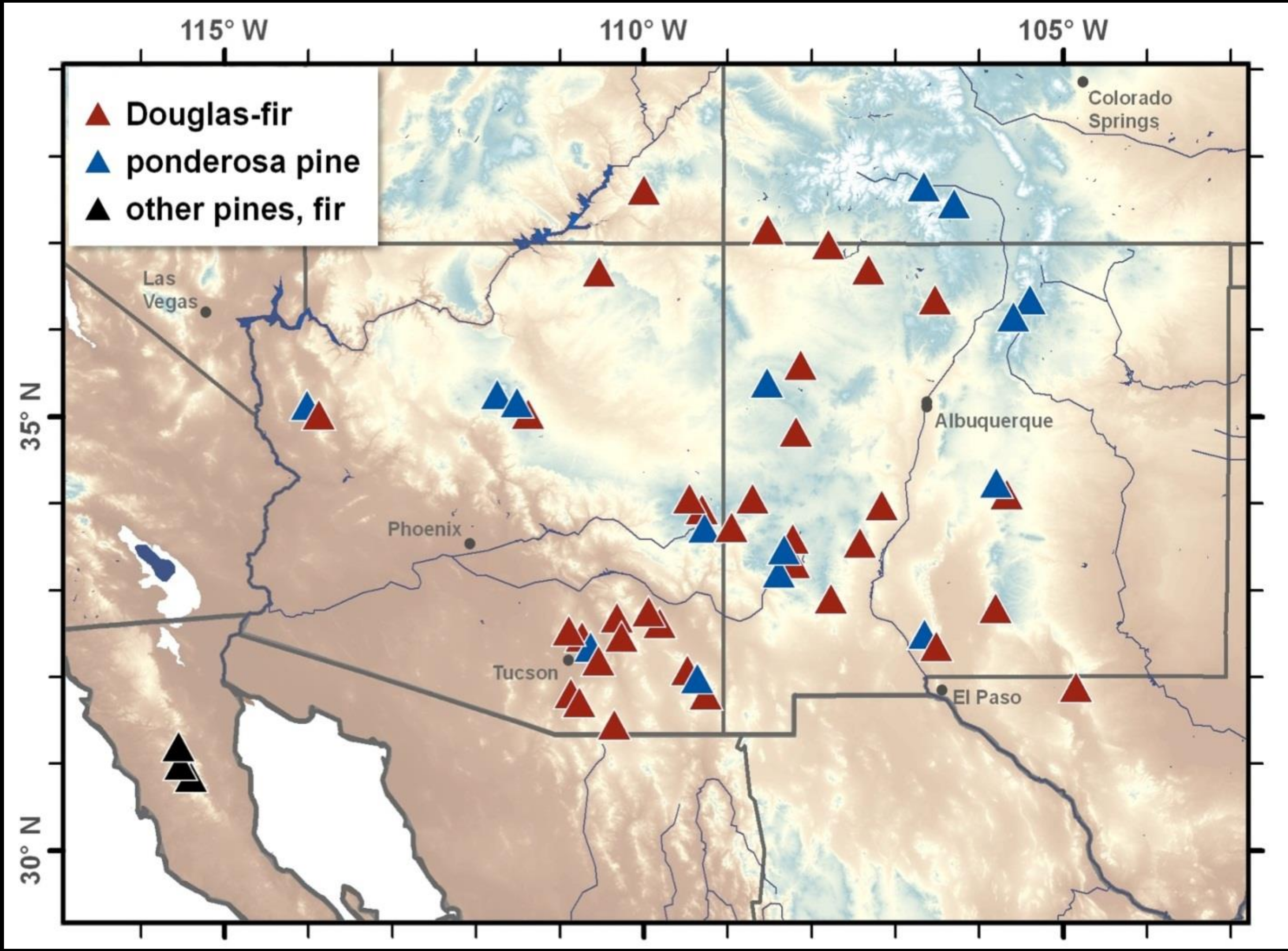


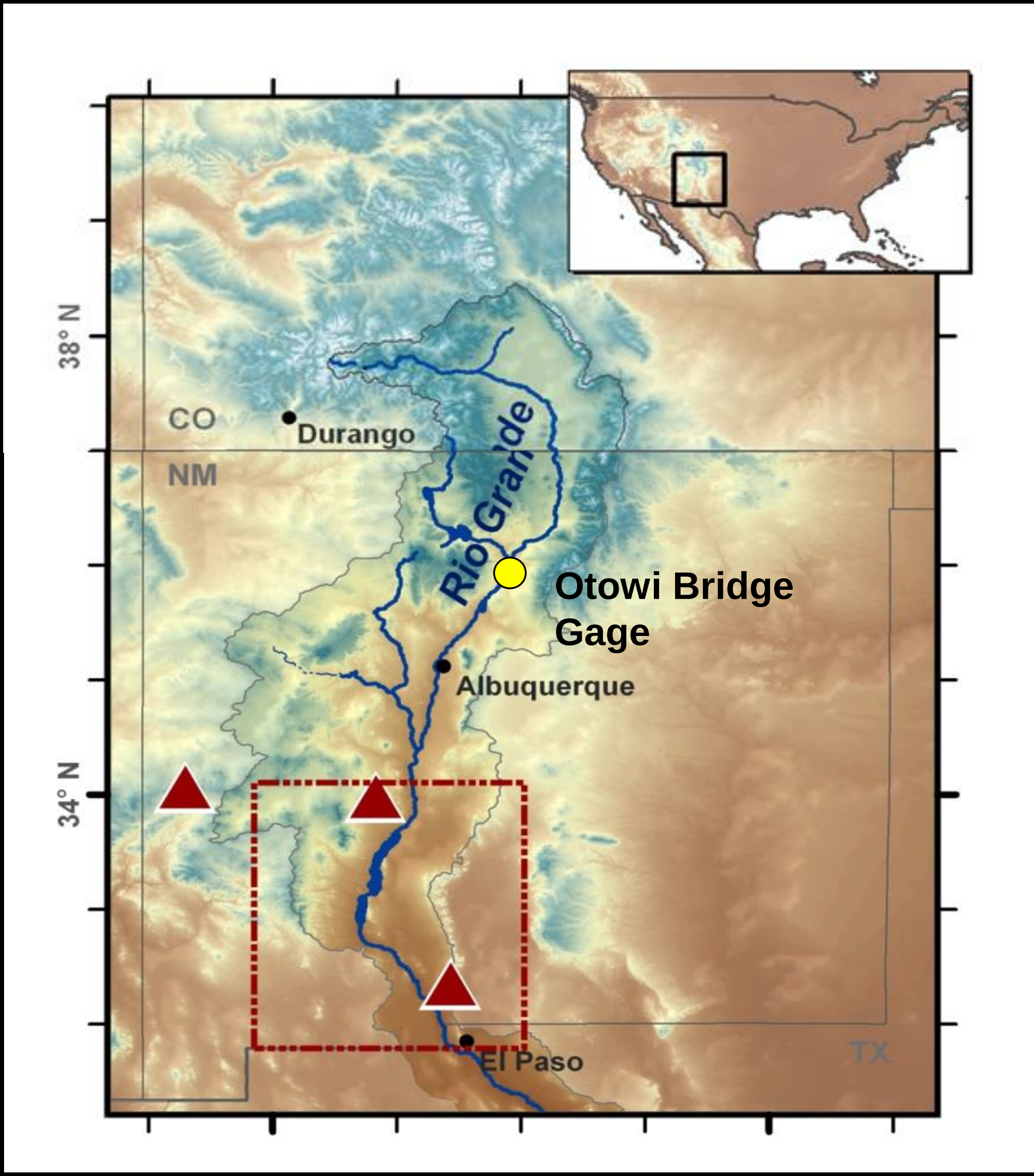


(Griffin et al. 2011 *Tree-Ring Research*)

Monsoon Project* Chronology Network



*A National Science Foundation-funded project just completed. For more information, see: http://monsoon.ltrr.arizona.edu/

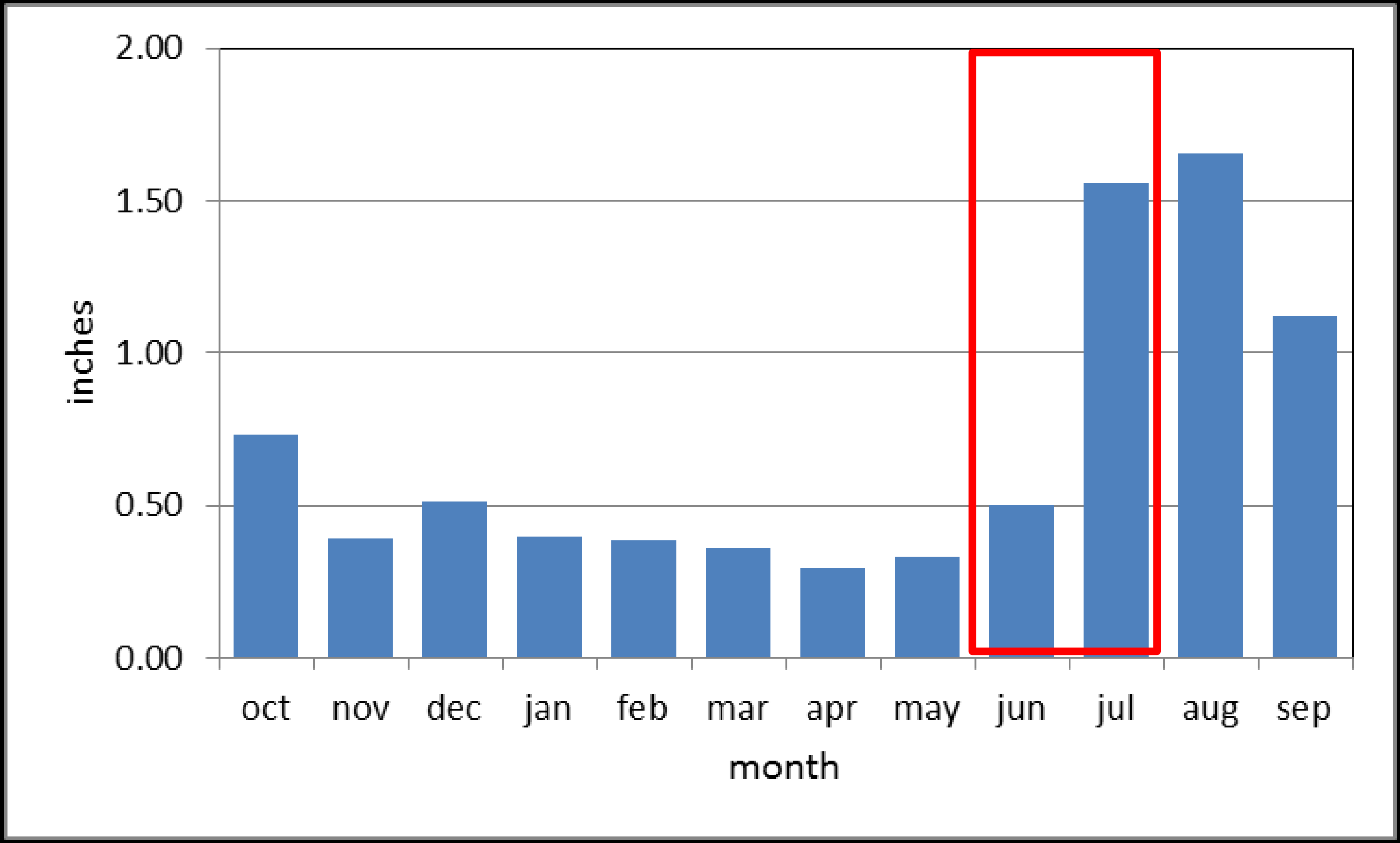


Location of Lower Rio Grande Monsoon Region and Chronologies used for June-July Precipitation Reconstruction

Monsoon region

Latewood Chronologies

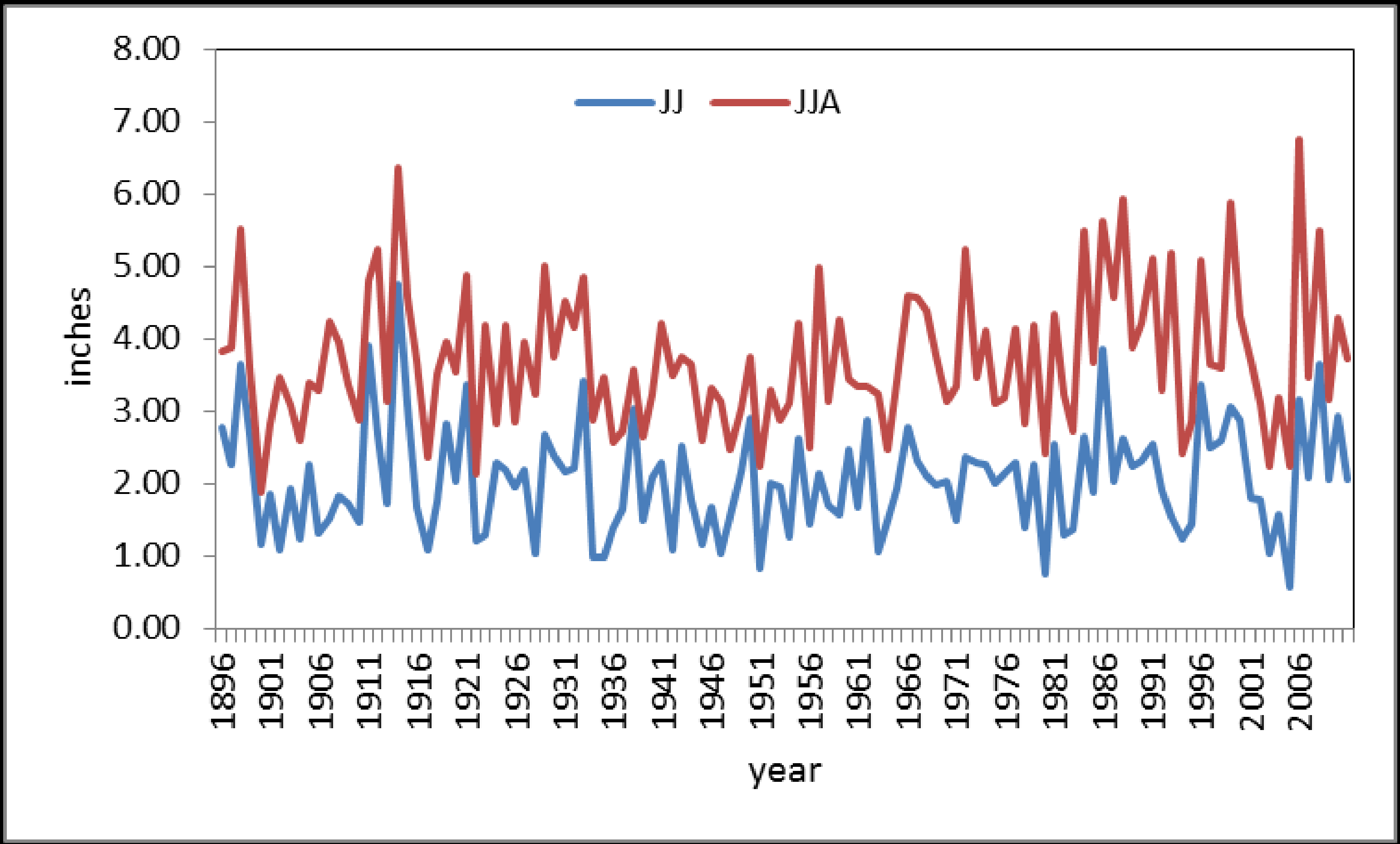
Lower Rio Grande Region average monthly precipitation (based on 1896-2010)



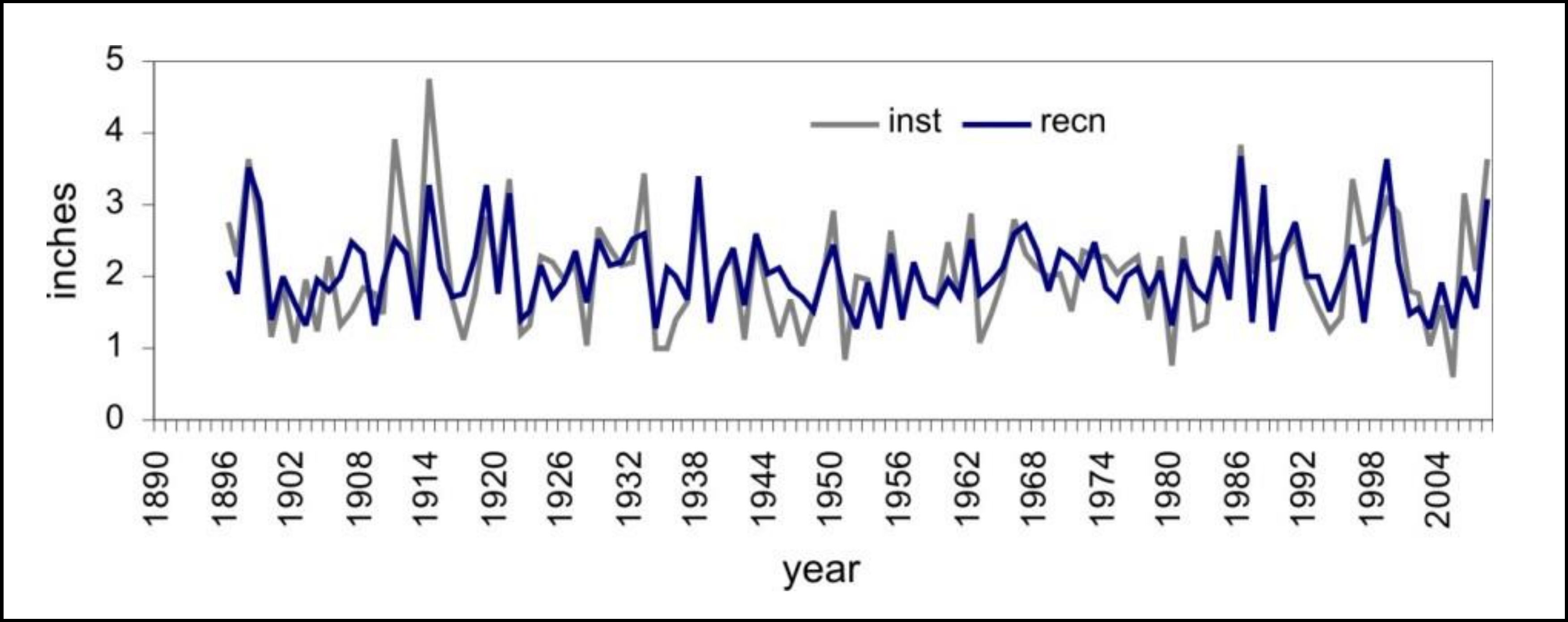
The monsoon reconstruction is based on June-July total, ~ 55% of the June-August total

With this reconstruction, we are getting early and mid-monsoon precipitation -- not the entire season.

However, June +July is fairly representative of June-August precipitation (correlation between JJ and JJA = 0.76)



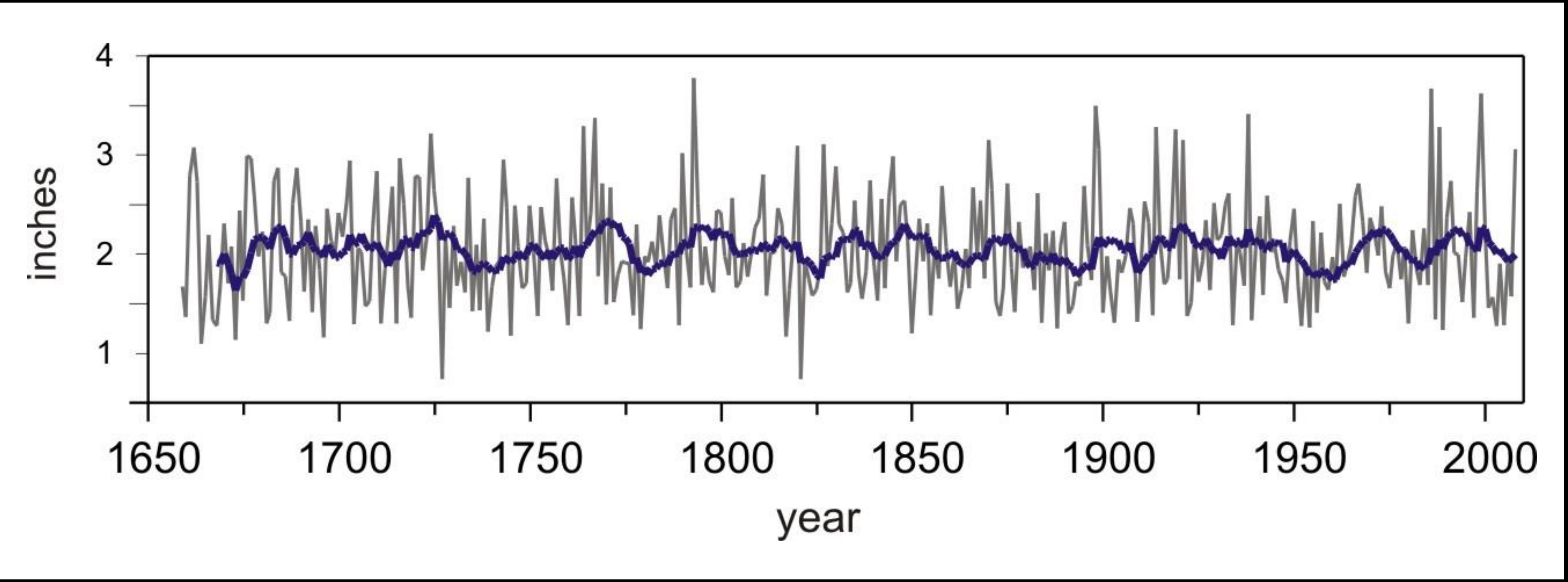
Monsoon Reconstruction (June-July) for the Lower Rio Grande Region, 1896-2008



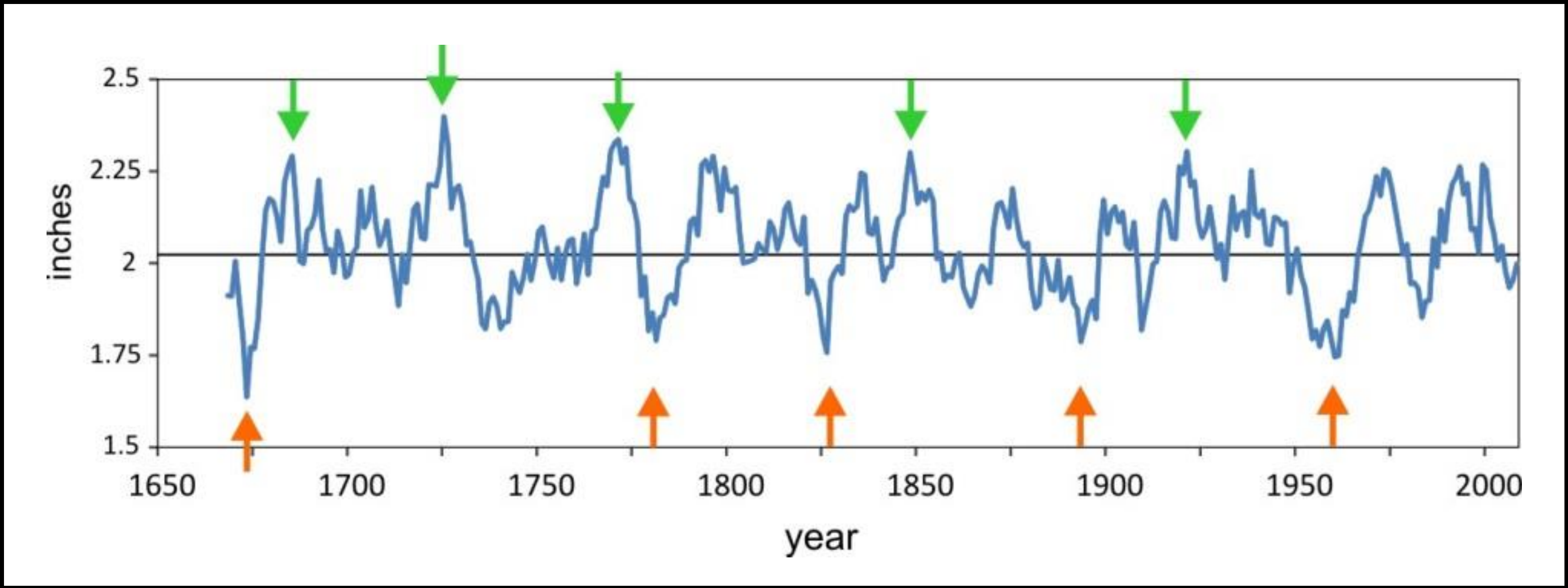
Reconstruction model explains 53% of the variance in the precipitation record.

Monsoon Reconstruction (June-July) for the Lower Rio Grande Region, 1659-2008

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



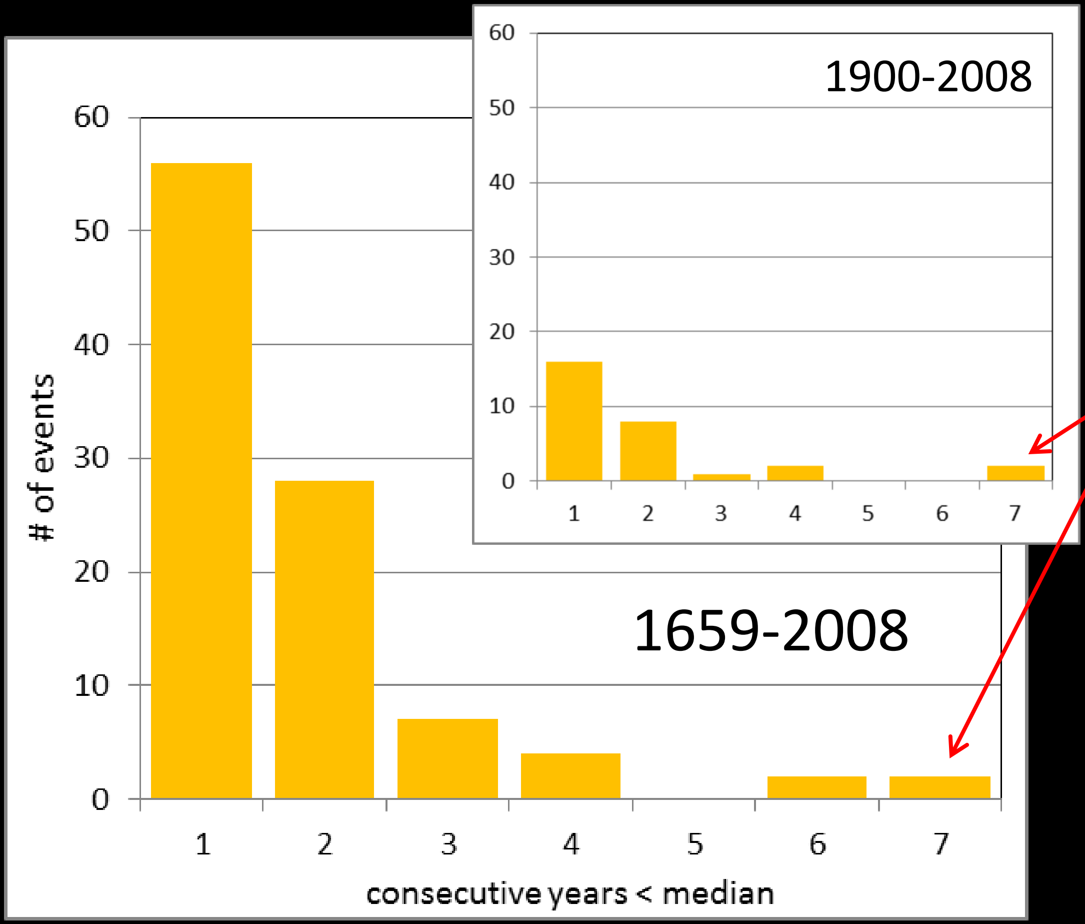
Monsoon Reconstruction (June-July, 10yr moving average)
Wettest and Driest Decades (non-overlapping)



5 Driest Decades	5 Wettest Decades
1664-1673	1716-1725
1951-1960	1762-1771
1817-1826	1912-1921
1884-1893	1839-1848
1772-1781	1676-1685

Lower Rio Grande June-July Drought Duration and Frequency

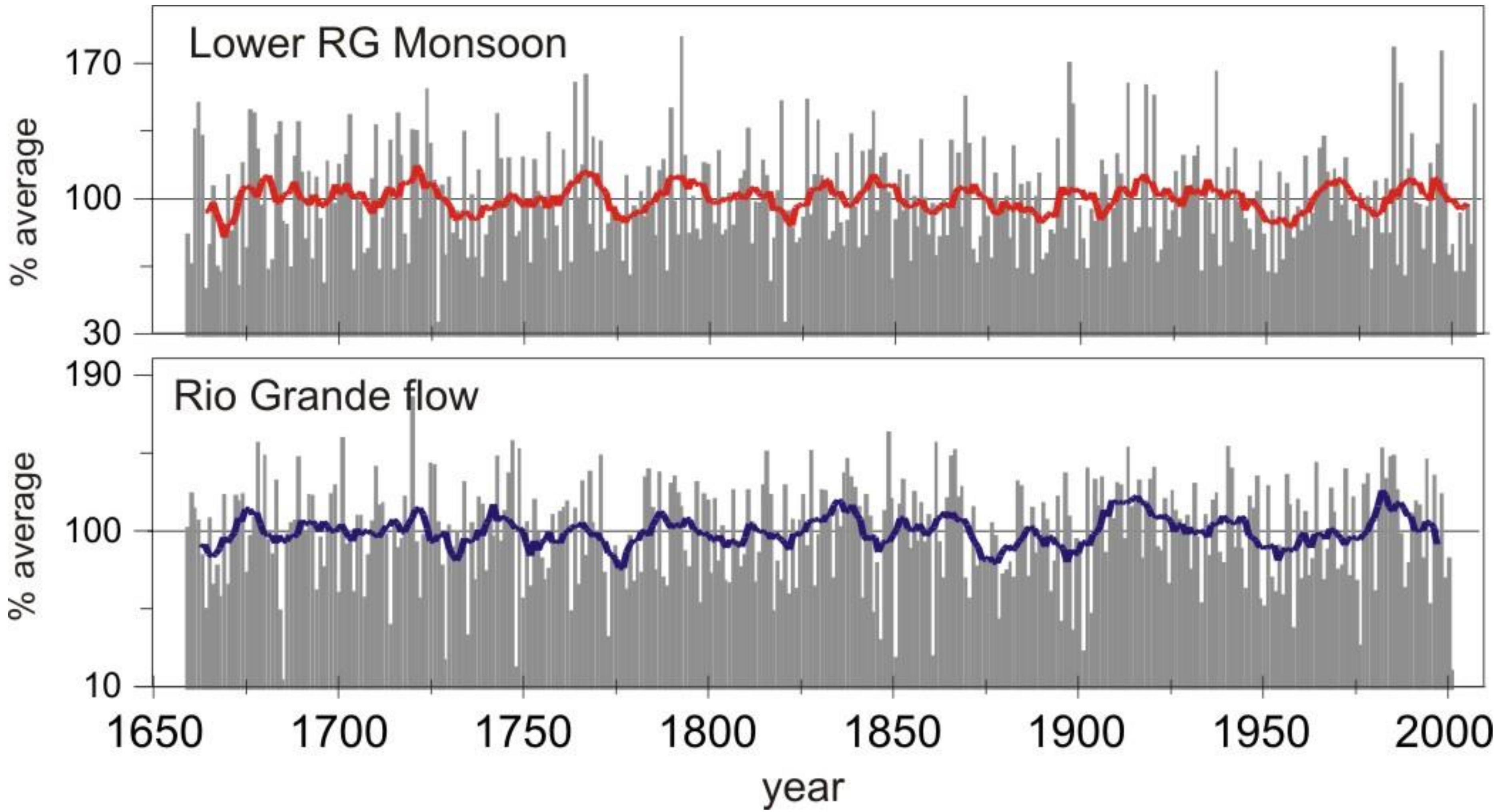
Drought is defined as a single year or set of consecutive years below the long-term median



2 events:
1900-1906
2001-2007
But 2006 only 0.001"
Below the median

Rio Grande Reconstructions

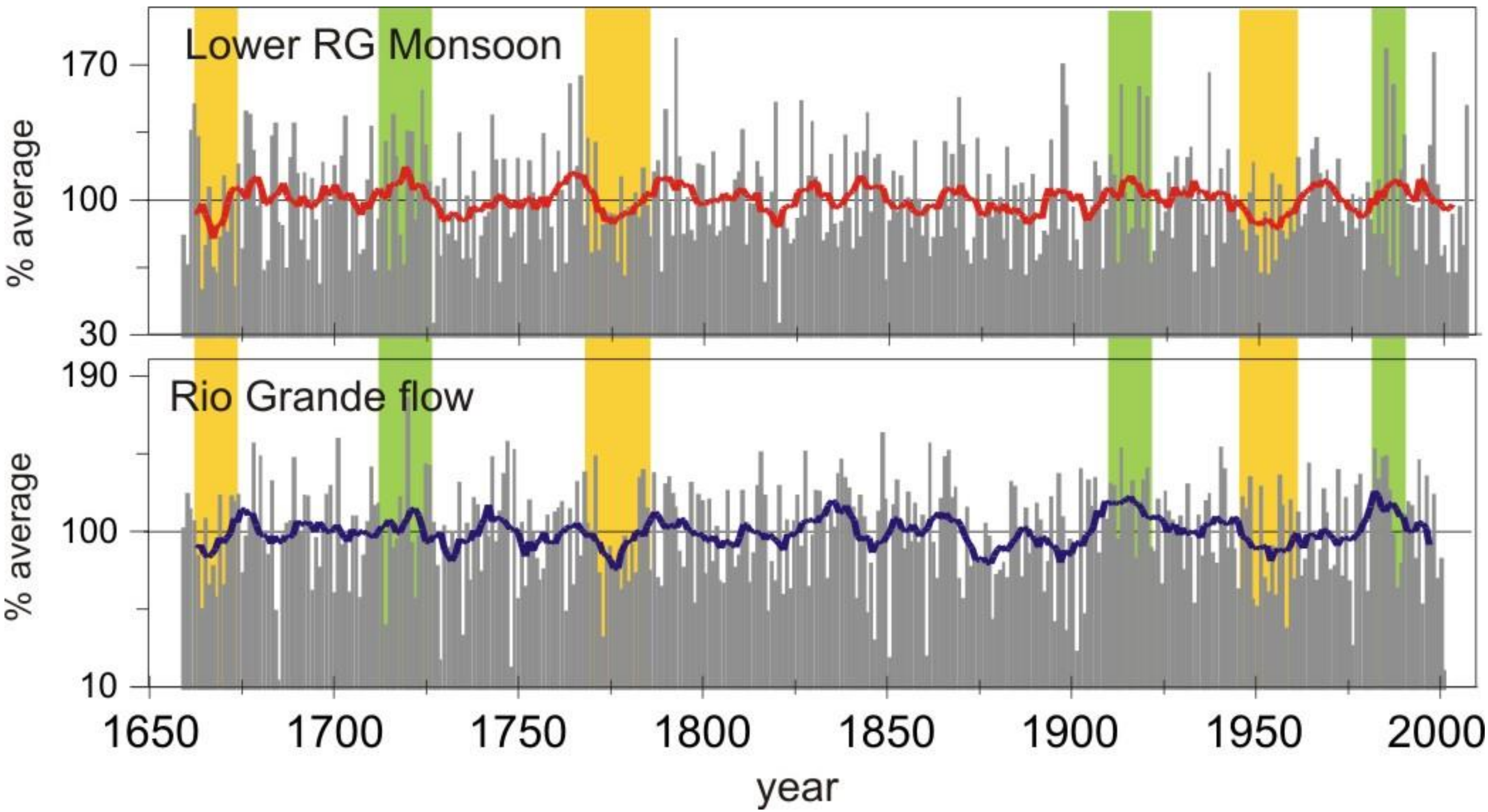
Annual values (gray line) and 10-year running average (red or blue line)



Rio Grande Reconstructions

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

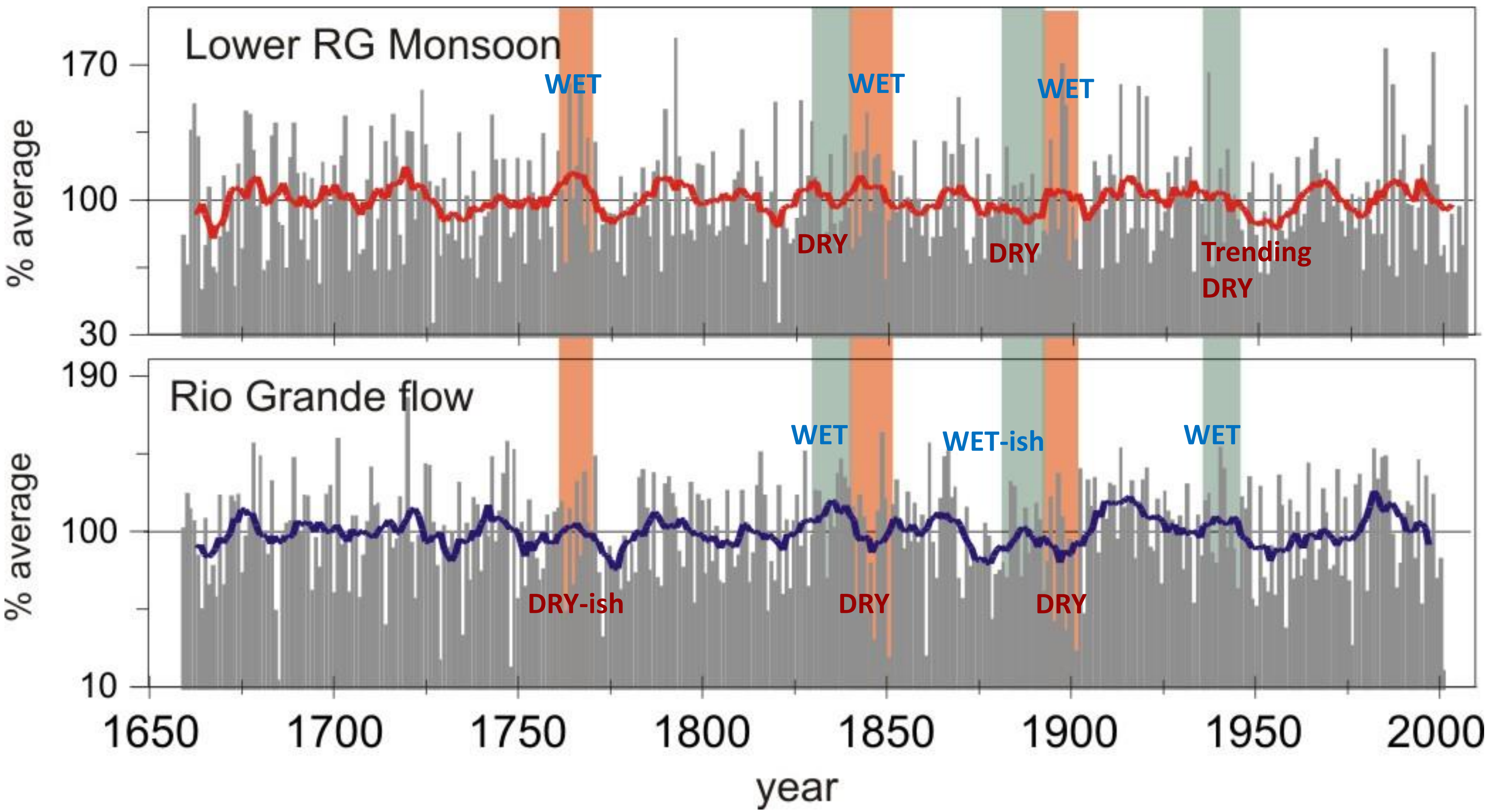
EXAMPLES of PERIODS with WET AND DRY CONDITIONS in both seasons



Rio Grande Reconstructions

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

EXAMPLES of PERIODS with OPPOSITE CONDITIONS in the 2 seasons

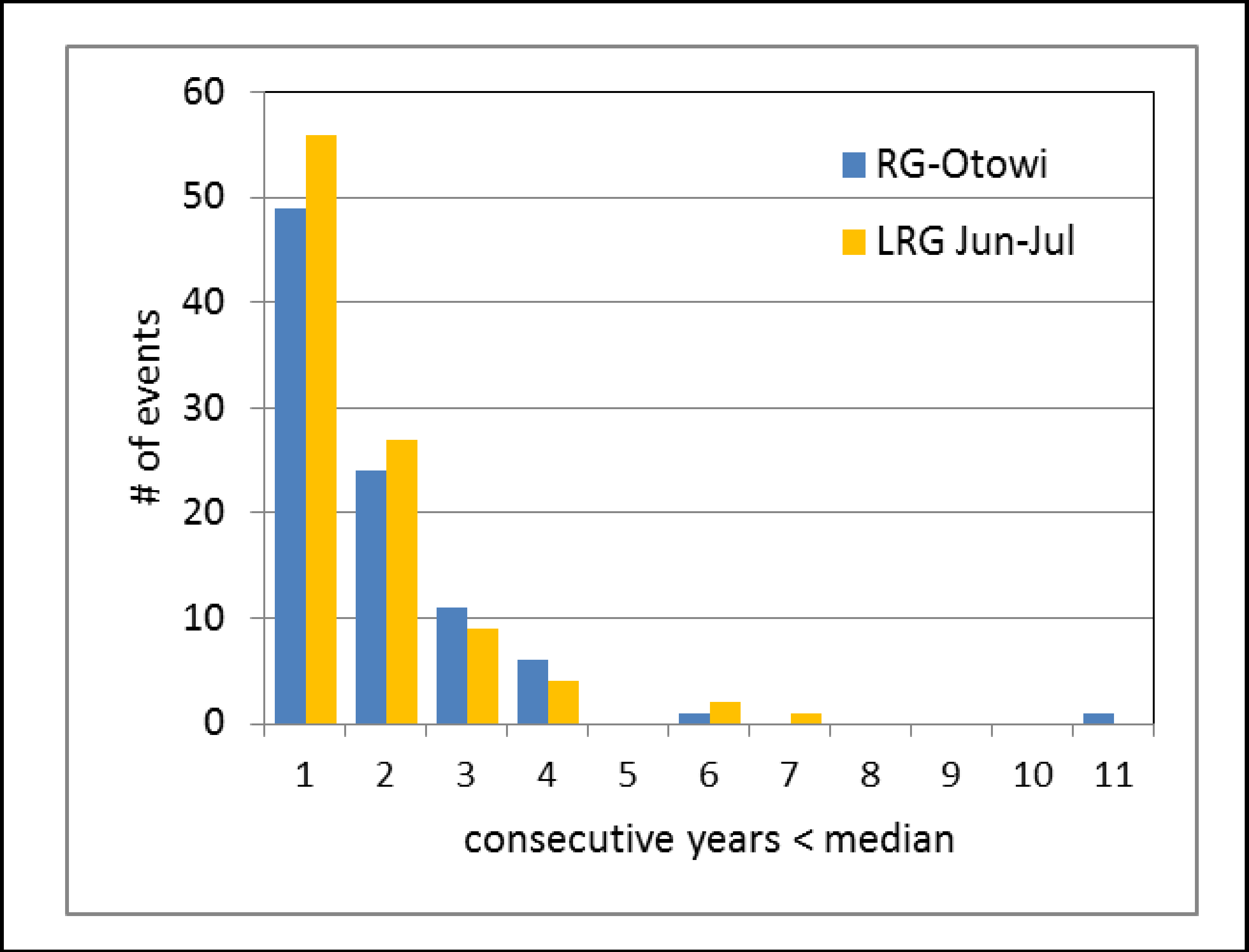


Part 4.

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, 1659-2002

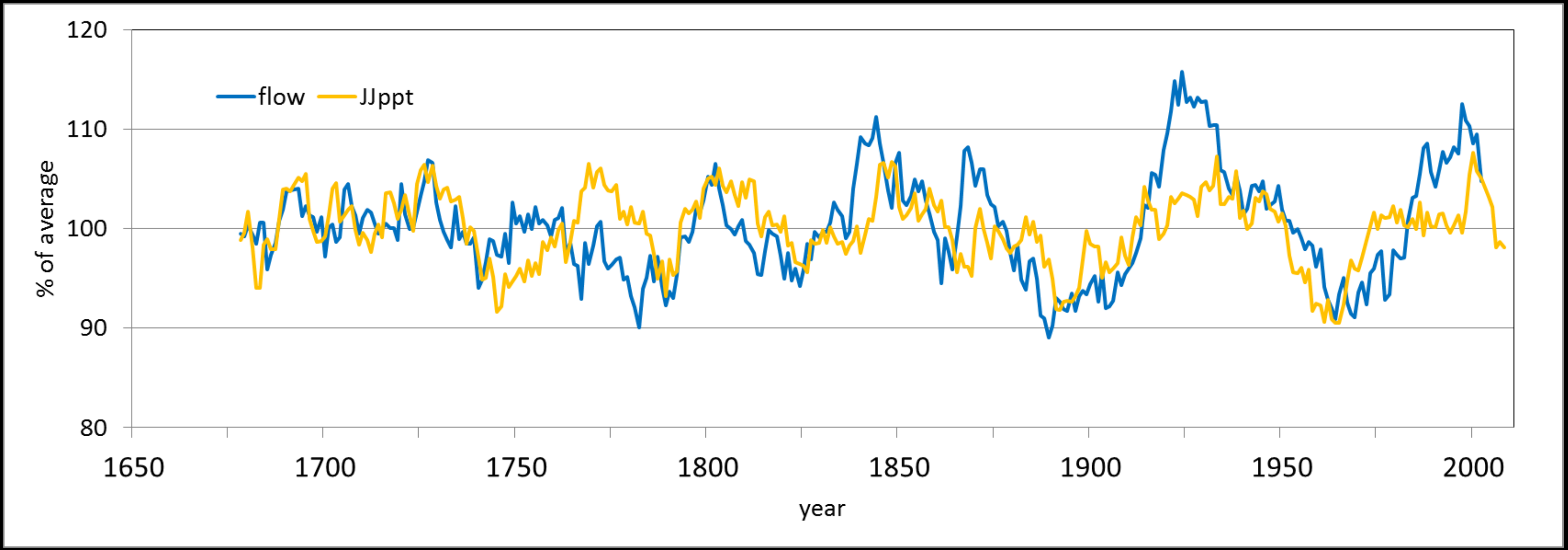


Drought is defined as a single year or set of consecutive years below the long-term median

Comparison of Rio Grande Otowi Water Year Flow and June-July Precipitation

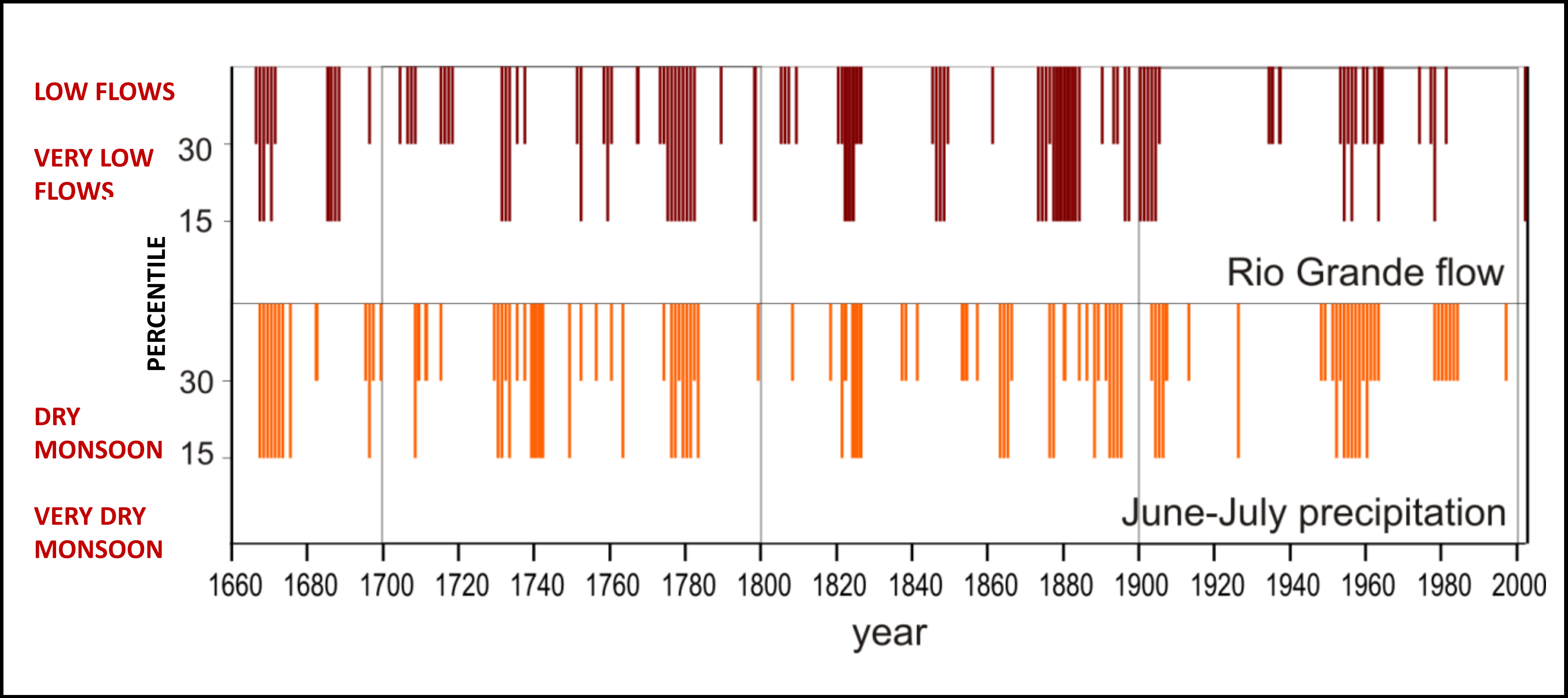
1659-2002 (monsoon to 2008)

smoothed with a 20-year moving average



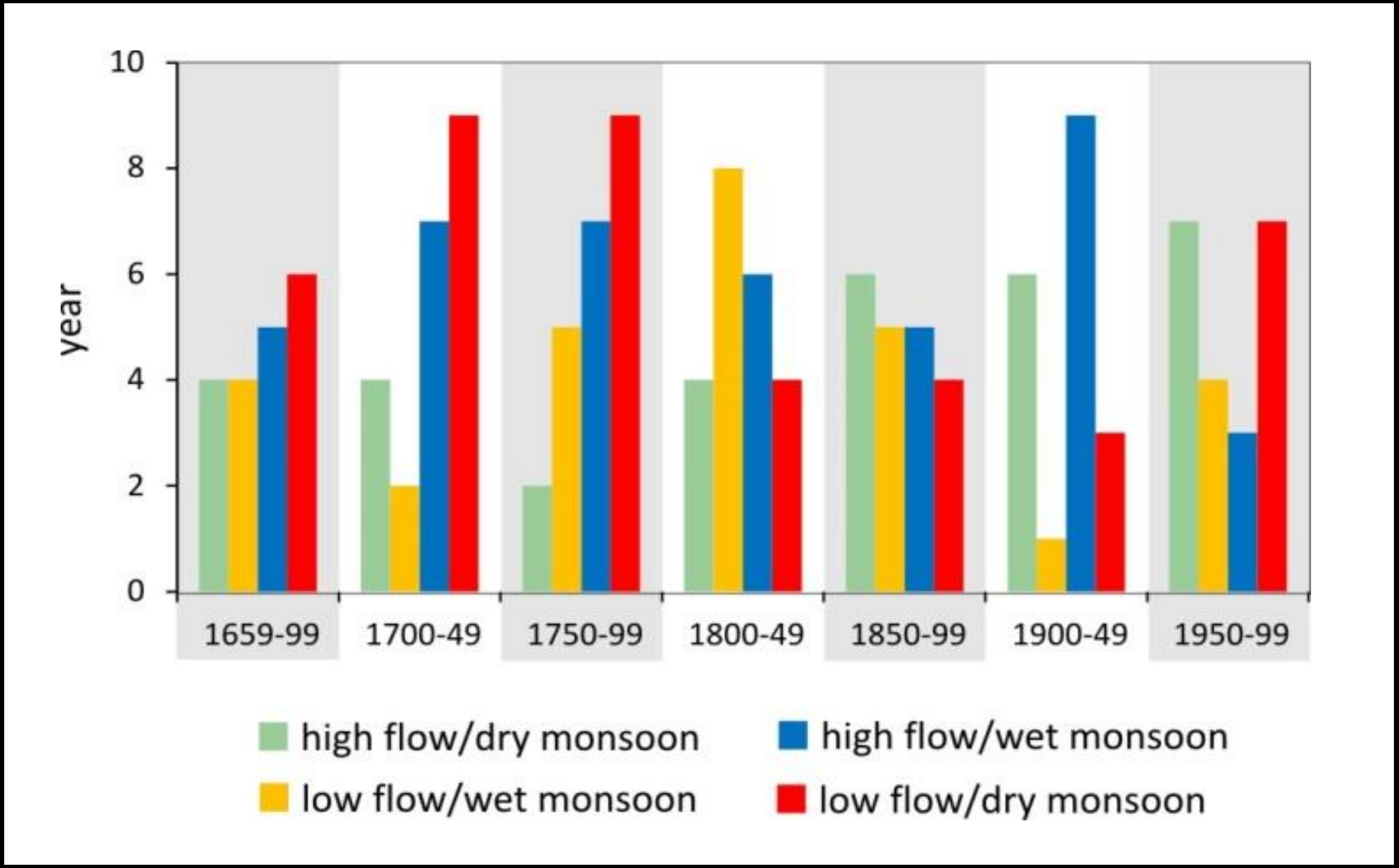
Note: On an annual basis, Otowi flow and June-July precipitation are uncorrelated (observed record, r = -0.03; reconstruction, r = 0.13, 1958-2002), and just barely significant for the full reconstruction, r = 0.14 (p < 0.01)

Concurrence of dry periods* in Rio Grande headwaters flow and Monsoon precipitation



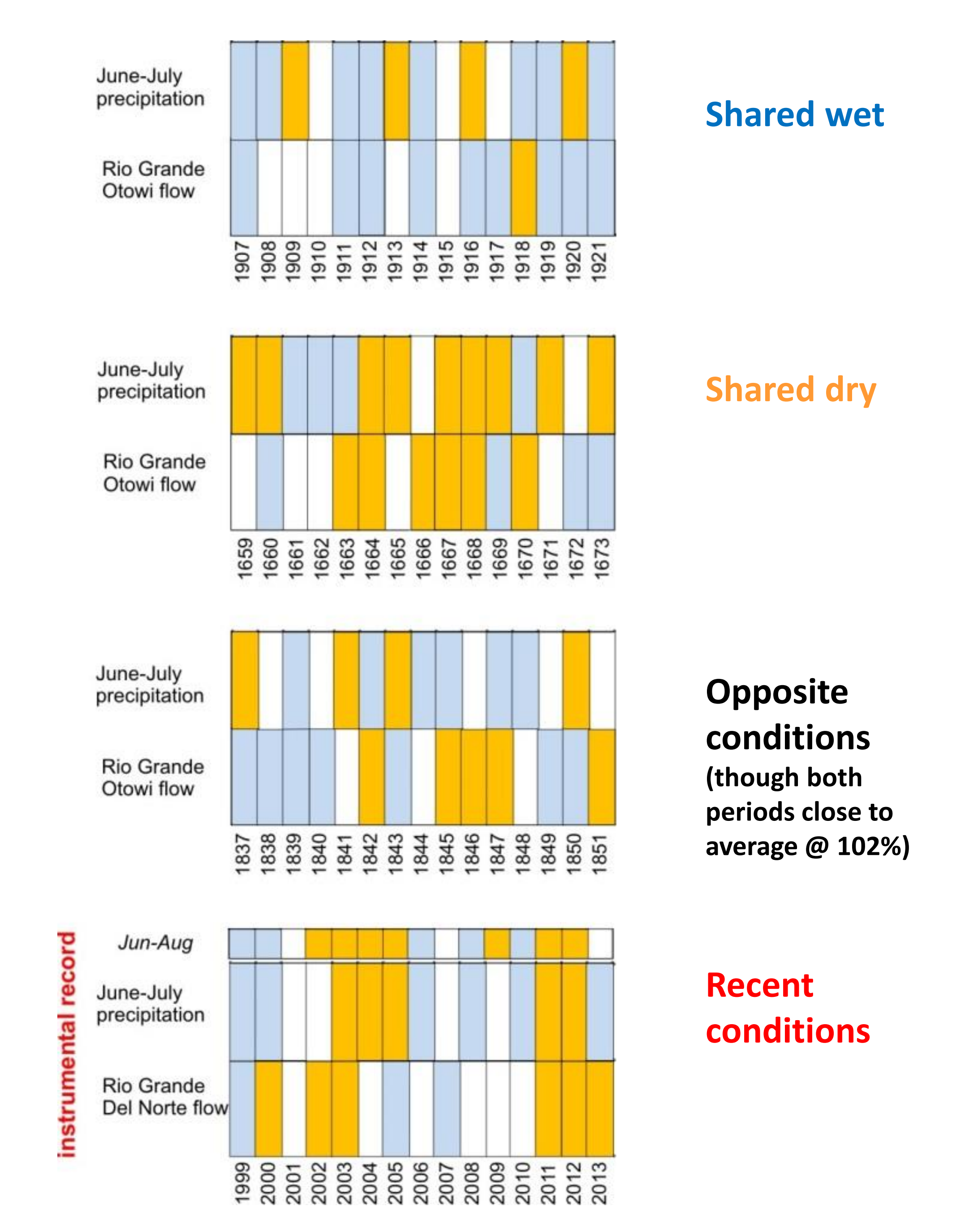
Series were filtered with a 5-year running mean. Only periods with values in the 30th and 15th percentiles are shown. The percentiles are inverted to emphasize drought severity.

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, respectively

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

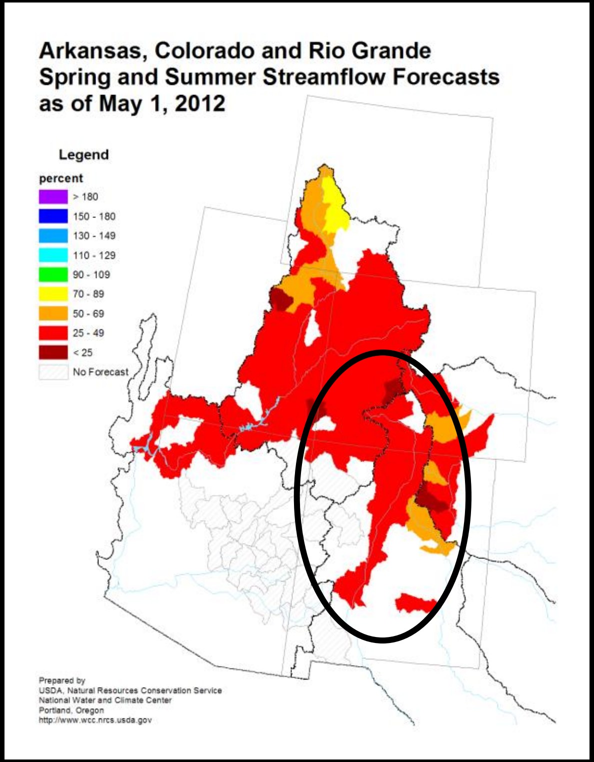


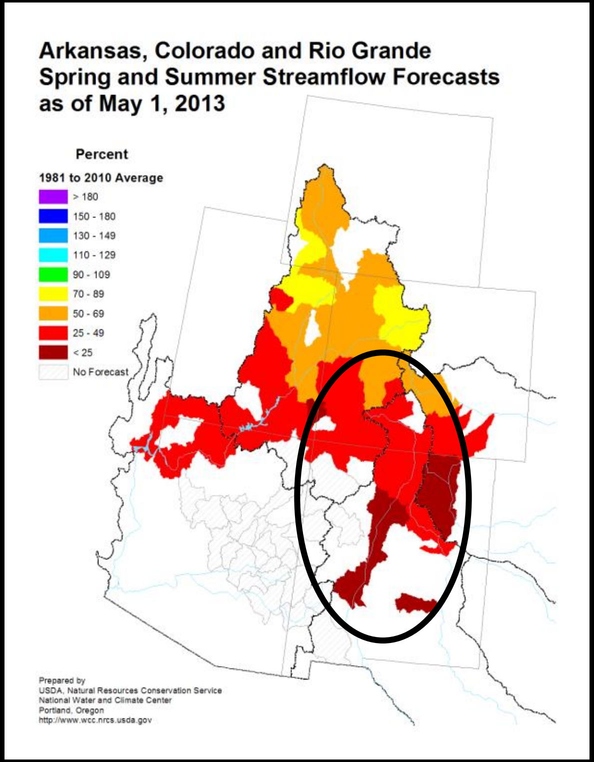
ORANGE = DRIEST 1/3
BLUE - WETTEST 1/3
WHITE = MIDDLE 1/3

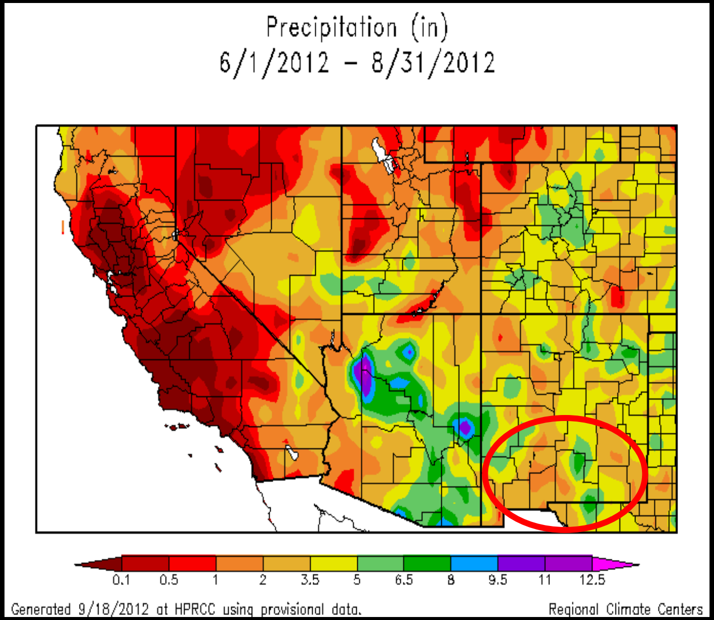
Current conditions in a long-term context

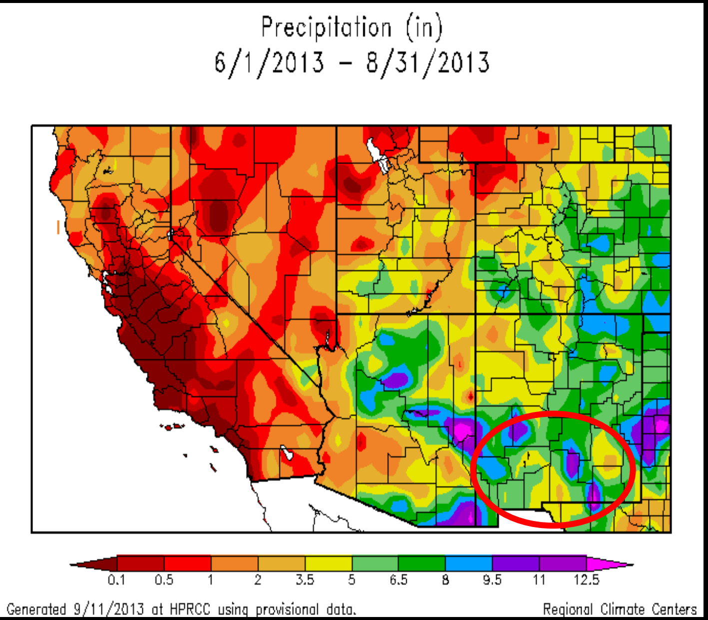
2012 and 2013 Streamflow and Monsoon Conditions

Streamflow forecasts for spring and summer



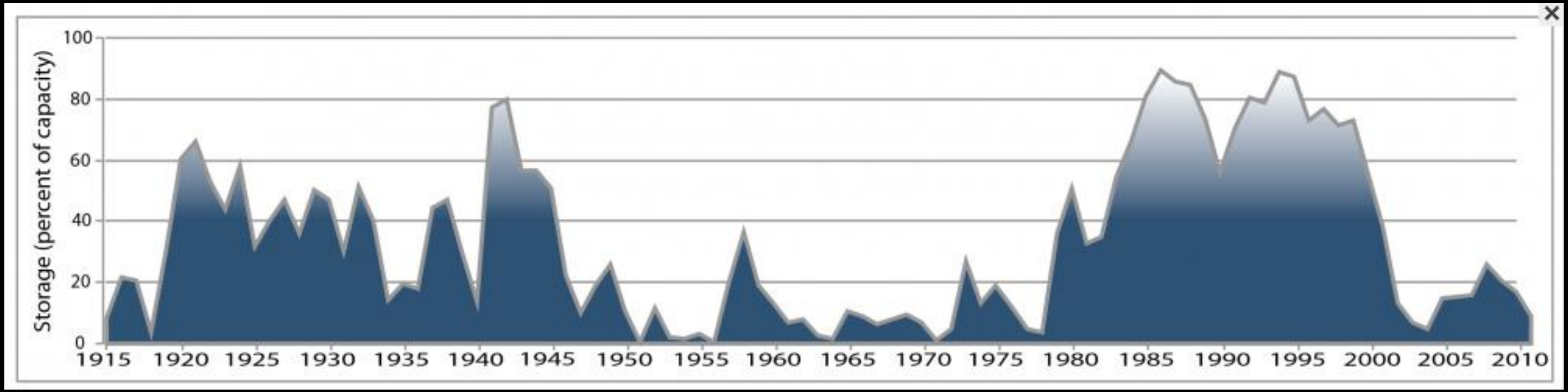






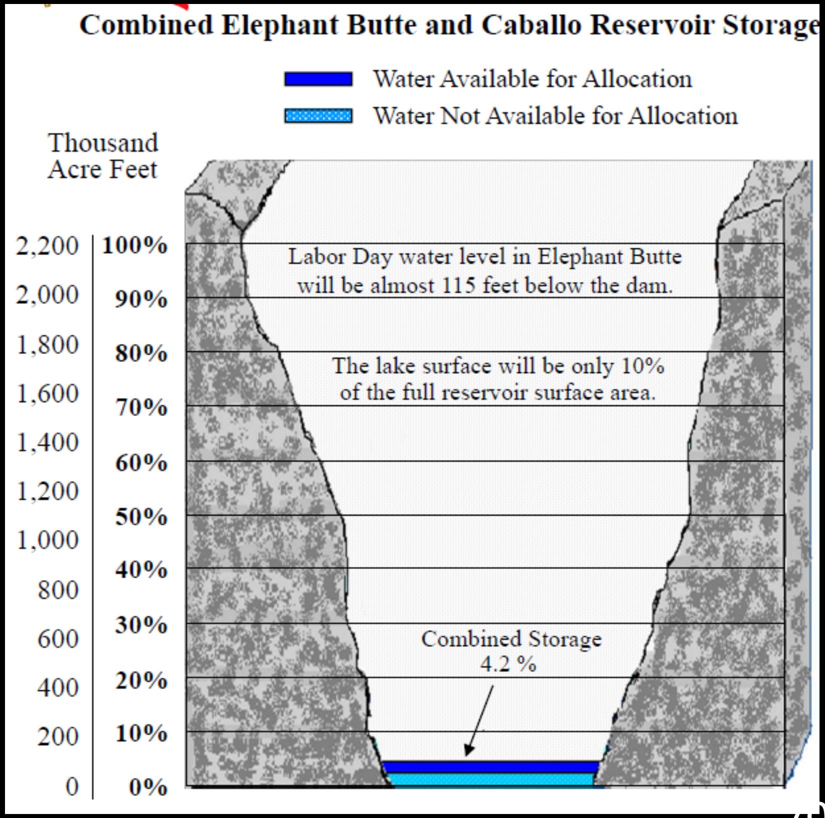
Precipitation totals for June-July-August

Not news to anyone here…



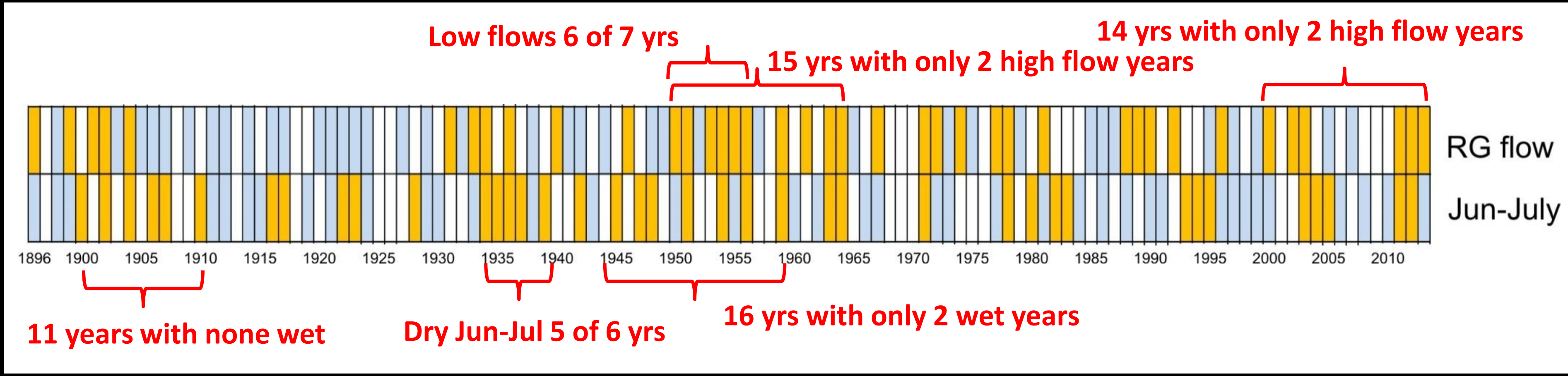
Water stored in Elephant Butte Reservoir (1915-2010) as a percent of its full capacity of 2.195 million acre-feet at the beginning of the water year on October 1.

Elephant Butte and Caballo Storage, August 28, 2013



Rio Grande (del Norte) Streamflow and Lower Rio Grande June-July precipitation, 1896-2013 – Instrumental Data

ORANGE = DRIEST 1/3
BLUE - WETTEST 1/3
WHITE = MIDDLE 1/3



Looking at averages over 10-15 year periods: While never the lowest, 21st century Rio Grande flow ranks in 2nd or 3rd lowest of 13-14 yr periods (period ending 1963 and/or 1964 has lower flow)

In terms of driest 10 to 15 year periods, the 21st century trails periods in the 1900s, late 1930s-40s, and 1950s, coming in at the 37th driest of all 11-yr periods (other length periods rank wetter)

*Very similar results for June-July-August

While we cannot make direct comparisons of conditions beyond the reconstruction (2008 for monsoon, 2002 for flow), an assessment of the instrumental records allow us to compare the driest/lowest flows in the 20th century with the reconstructions

Rio Grande/Otowi Flow, 1450-2002

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	

In the gaged Rio Grande flows, the decade of 2002-2011 ranks 7th behind the 1950s (for Del Norte gage)

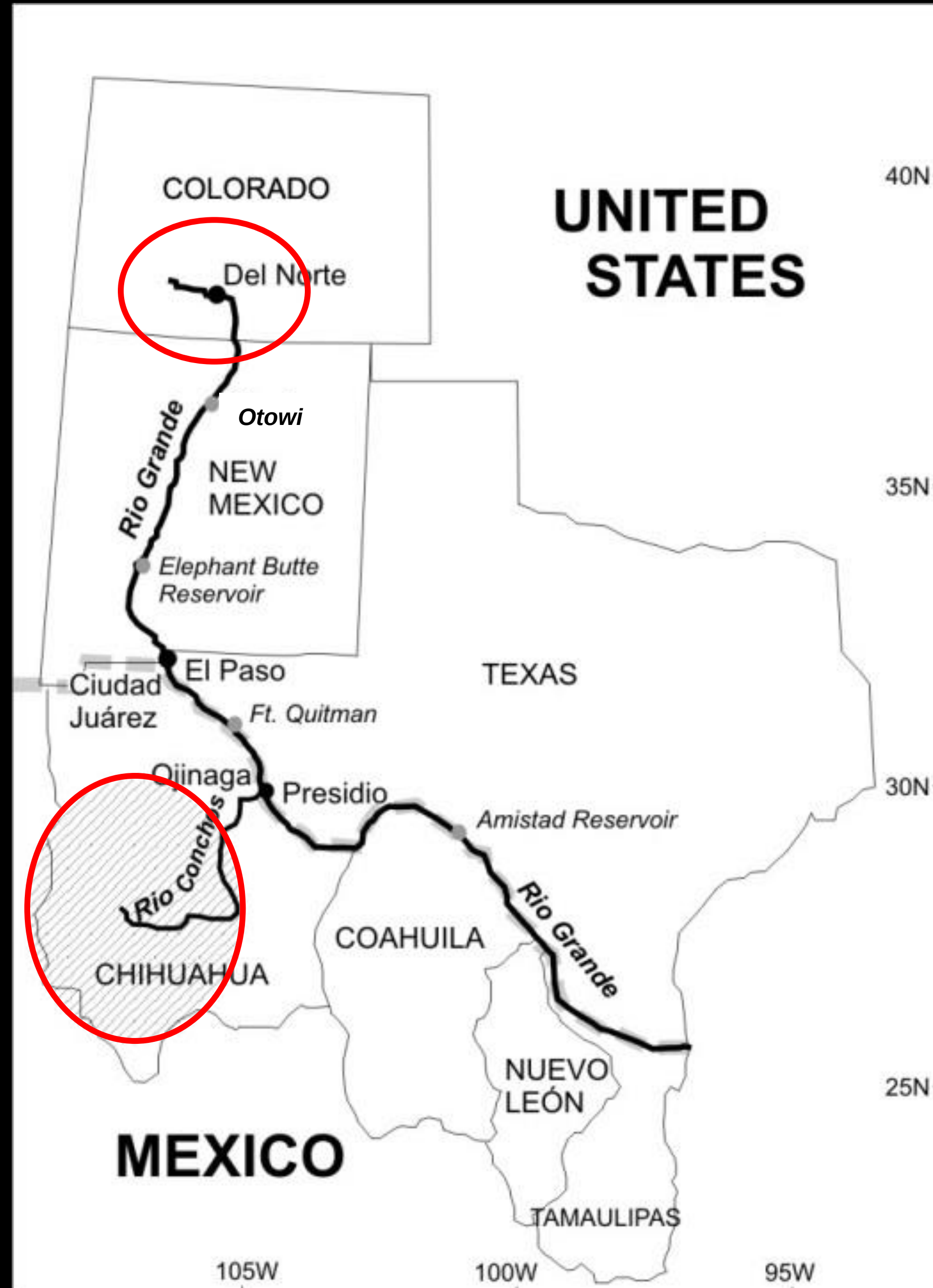
*note: June-July reconstruction is shorter than flow reconstruction; does not get the late 16th century, which is a a dry monsoon in AZ

Lower Rio Grande June-July precipitation, 1659-2008*

5 Driest Decades	5 Wettest Decades
1664-1673	1716-1725
1951-1960	1762-1771
1817-1826	1912-1921
1884-1893	1839-1848
1772-1781	1676-1685

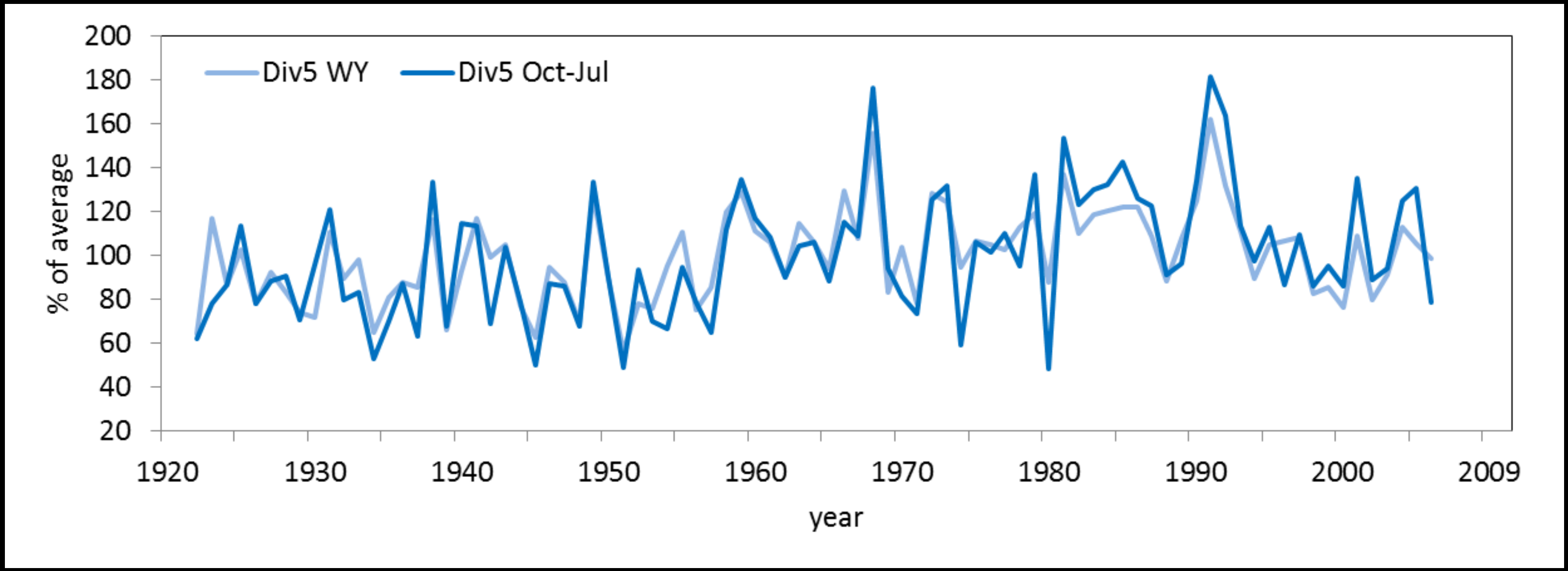
In the instrumental record, the 21st century decades trails decades in the early 1900s, late 1930s-40s, and 1950s, coming in at the 45th driest of all 10-yr periods

Rio Grande Flow and Rio Conchos Precipitation Reconstructions



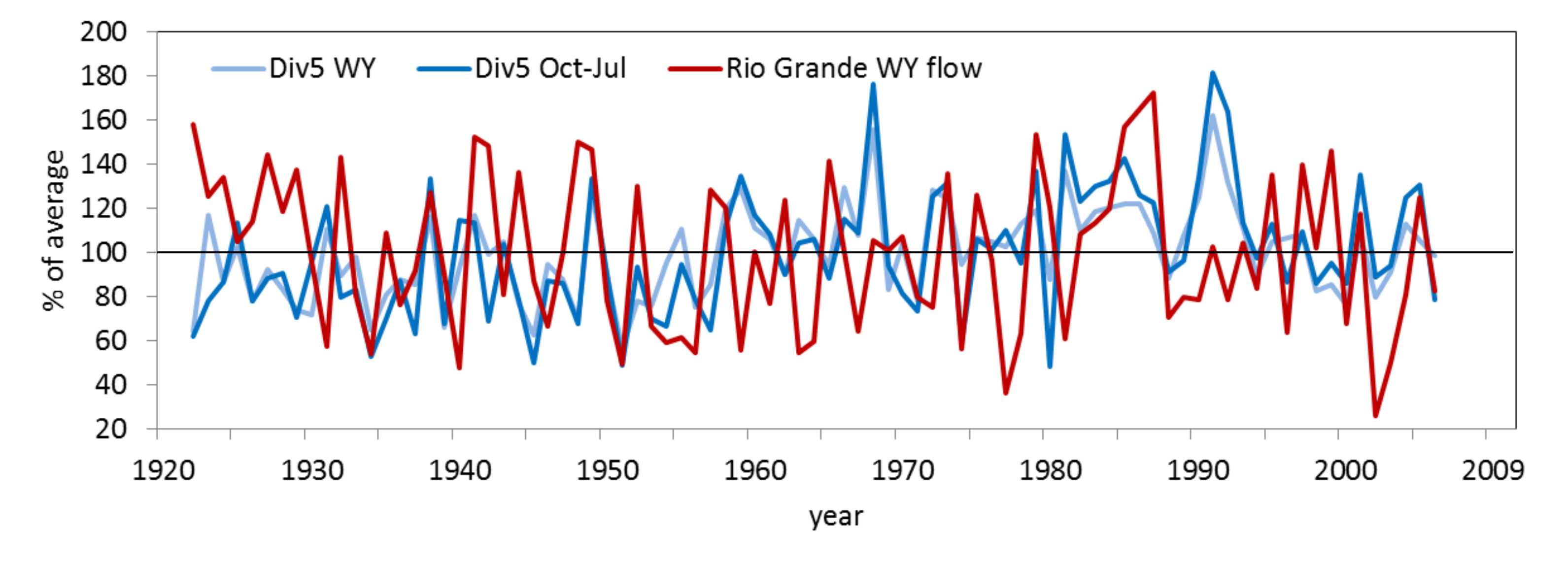
Woodhouse et al. 2012, *Climate Research*

Comparison of total water year precipitation and Oct-July precipitation*, Mexico Division 5, Rio Conchos basin



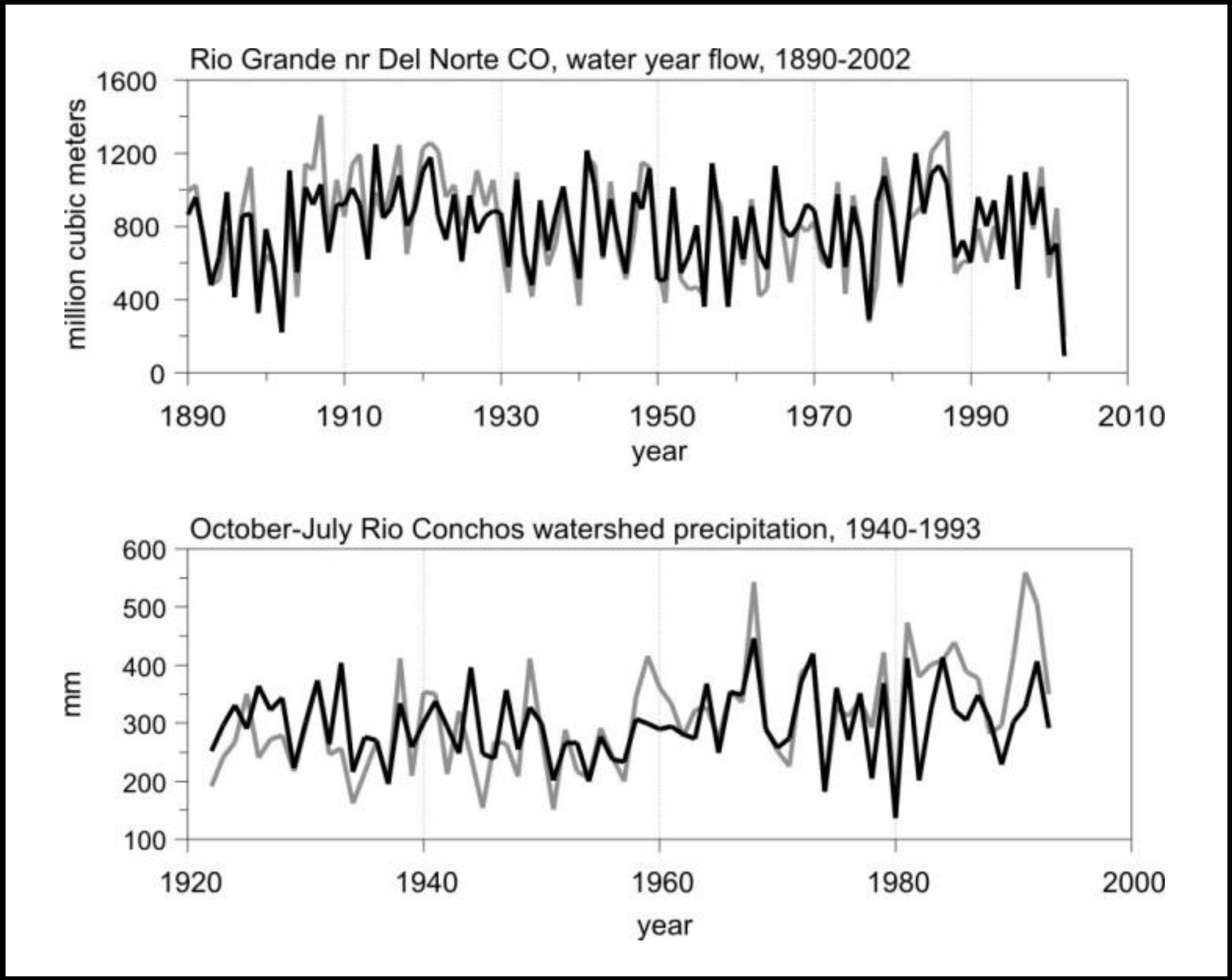
*Because of the information we could extract from the tree-ring data available, we could only reconstruct Oct-July total precipitation.

Comparison of total water year precipitation, Oct-July precipitation, and Rio Grande headwaters water year flow



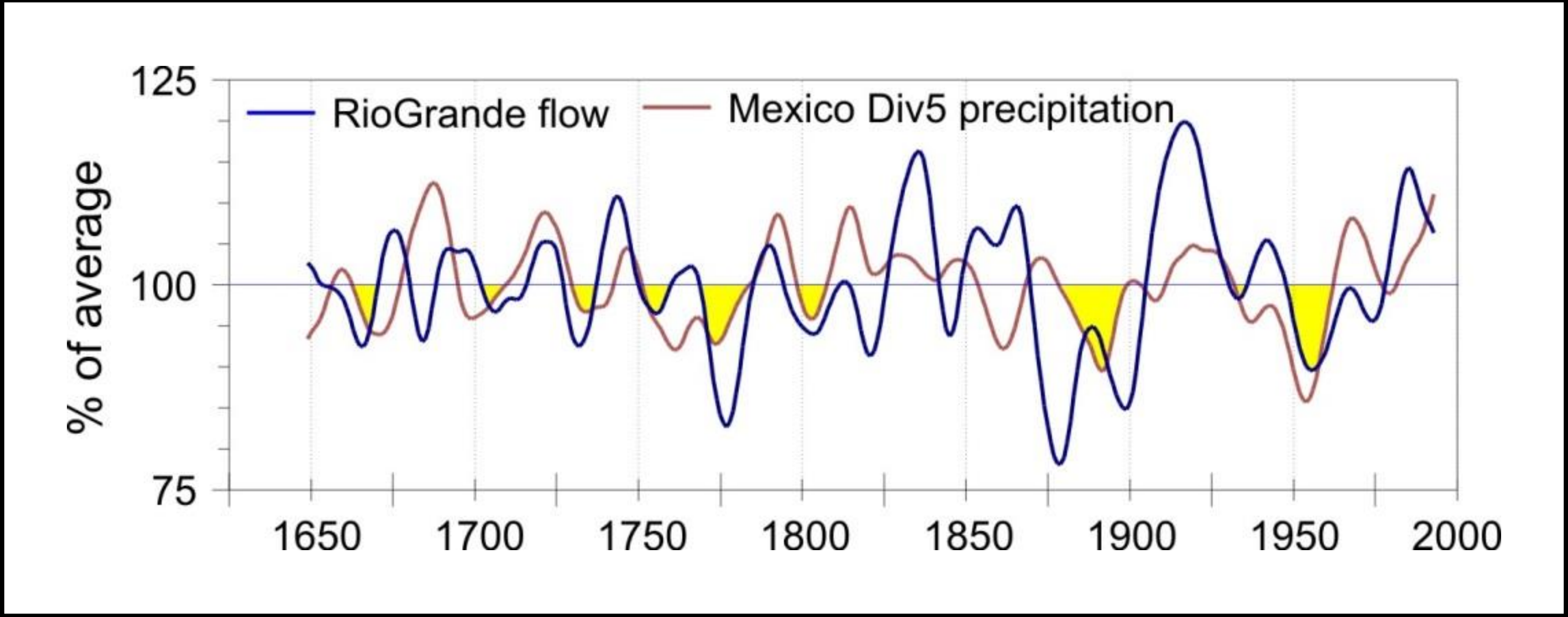
Correlations:
Water year precipitation and RG water year flow, r = 0.080
Oct-July precipitation and RG water year flow, r = 0.111

Comparison of observed (light line) and reconstructed (dark line) Rio Grande streamflow and Rio Conchos precipitation



Reconstructed Rio Grande streamflow and Rio Conchos watershed October-July total precipitation, 1649-1993

(smoothed with a 20-year filter)



Yellow shading indicates periods when values in both reconstructions are below average.

Summary

•By analyzing total, earlywood and latewood widths from tree rings, it is possible to reconstruct streamflow, cool season, and monsoon (at least for a portion of the season) precipitation.

•When Rio Grande streamflow and monsoon are compared, there is no relationship between the two on year-to-year time scales (both in observed and reconstruction data), but perhaps some coherence at longer times scales

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

• Recent conditions in Rio Grande flow and lower Rio Grande monsoon precipitation have yet exceeded the severity of the 20th century; reconstructions suggest longer, more severe droughts are possible*

• Conditions in the Rio Conchos and the Rio Grande headwaters are largely uncorrelated, but drought have been synchronize in both regions in the past.

Publications (in folder)

WATER RESOURCES RESEARCH, VOL. 49, 1–7, doi:10.1002/wrcr.20098, 2013

Tree rings and multiseason drought variability in the lower Rio Grande Basin, USA

C. A. Woodhouse,[1,2] D. M. Meko,[2] D. Griffin,[1,2] and C. L. Castro[3]

Received 28 May 2012; revised 7 January 2013; accepted 9 January 2013.

[1] Agriculture and ranching in semiarid regions often rely on local precipitation during the growing season as well as streamflow from runoff in distant headwaters. Where snowpack and reservoir storage are important, this pattern of reliance leads to vulnerability to multiseason drought. The lower Rio Grande basin in New Mexico, used as a case study here, has experienced drought conditions over the past 12 years characterized both by low local summer monsoon precipitation and by reduced availability of surface water supplies from the upper Rio Grande. To place this drought in a long-term context, we evaluate the covariability of local warm-season and remote cool-season hydroclimate over both the modern period and past centuries. We draw on a recently developed network of tree-ring data that allows an assessment of preinstrumental warm-season variations in precipitation over the southwest. Both instrumental and paleoclimatic data suggest that low runoff followed by a dry monsoon is not unusual, although over the full reconstruction period (1659–2008), years with wet or dry conditions shared in both seasons do not occur significantly more often than unshared conditions. Low flows followed by dry monsoon conditions were most persistent in the 1770s and 1780s; other notable periods of shared seasonal droughts occurred in the 1660s and 1950s. The recent drought does not yet appear to be unusually severe in either the instrumental or paleoclimatic context.

Citation: Woodhouse, C. A., D. M. Meko, D. Griffin, and C. L. Castro (2013), Tree rings and multiseason drought variability in the lower Rio Grande Basin, USA, *Water Resour. Res.*, *49*, doi:10.1002/wrcr.20098.

1. Upper and Lower Rio Grande Basin Drought

[2] Summer precipitation can impact water demand and be an important source of water for irrigation in areas where streamflow may be largely driven by cool-season precipitation, such as the intermountain and southwestern United States. These semiarid regions often rely on multiple sources of water, including local precipitation during the growing season as well as streamflow derived from runoff in distant headwaters, leading to vulnerability to multiseason drought. Relatively little attention has been paid to the phasing of seasonal drought and the history of past concurrent warm- and cool-season moisture deficits, but these events can compound the effect of droughts, impact natural vegetation and phenological responses, and exacerbate water management challenges [e.g., *Crimmins et al.*, 2008; *Castro et al.*, 2009; *Phillips et al.*, 2009; *Weiss et al.*, 2009]. The lower Rio Grande basin in New Mexico is used as a case study here to examine the covariability of local warm-season and remote (upper Rio Grande basin) cool-season hydroclimate over both the modern period and past centuries, using paleoclimatic data.

[3] In southern New Mexico, summer rains associated with the North American monsoon contribute 50% or more of the annual total precipitation (based on July–September) [*National Weather Service Climate Prediction Center*, 2012b]. While monsoon rainfall may contribute little to reservoir levels, it can be a critical source of water for agriculture and ranching, as is the case in the lower Rio Grande basin. Agriculture in this region typically relies on summer rains to supplement surface water rights to the Rio Grande water and groundwater pumping. The Elephant Butte Irrigation District in southern New Mexico, the state's largest supplier of surface water, provides irrigation from the Rio Grande to over 36,000 ha of crops, including pecans, chilis, and cotton [*Bureau of Reclamation*, 2012; *Elephant Butte Irrigation District*, 2012]. Water year (October–September) streamflow in the headwaters of the upper Rio Grande, which is largely derived from snowmelt [*Dahm et al.*, 2005], has been below average in 8 of 12 years since 2000 (Rio Grande near Del Norte Colorado, data from Colorado Department of Water Resources and U.S. Geological Survey (USGS) gage 08220000, 1895–2010 average). As a consequence, Elephant Butte Reservoir, a major reservoir on the Rio Grande, has dropped to 5% of capacity as of 17 October 2012 [*Natural Resources Conservation Service*, 2012a]. Over the same time period, the lower Rio Grande region has suffered 8 years of below-average summer

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0043-1397/13/10.1002/wrcr.20098

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CLIMATE RESEARCH
Clim Res

Published online March 7

Rio Grande and Rio Conchos water supply variability over the past 500 years

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[2]Department of Geosciences, University of Arkansas, Fayetteville, Arkansas 72701, USA
[3]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Gómez Palacio, Durango, Mexico

ABSTRACT: The Rio Grande is a major source of water for parts of Mexico and the USA. The 2 main source regions for the Rio Grande system are the San Juan Mountains of the southern Rocky Mountains and the Sierra Madre Occidental in Mexico, which is the headwaters for the Rio Conchos, the largest tributary of the Rio Grande. Precipitation and streamflow from these 2 source regions are largely independent of each other; winter snowpack is the dominant contributor to the annual streamflow north of the USA–Mexico border, and the North American monsoon is a key factor in the Rio Conchos basin. Reconstructions of water year (October–September) streamflow for a gauge in the upper Rio Grande, 1508–2002, and of October–July precipitation in the Rio Conchos watershed region, 1649–1993, also indicate a lack of correlation between the 2 basins over century time scales. Despite this lack of correlation, periods of concurrent multiyear drought have occurred over the past 4 centuries, most notably in the 1770s, 1890s and 1950s. These rare concurrent droughts in the upper Rio Grande and Rio Conchos source regions may arise from large-scale forcing out of the Pacific Ocean and will be relevant to the binational planning of these water resources, which serve a large and growing population of users.

KEY WORDS: Rio Grande · Rio Conchos · Water resources · Dendrochronology · Paleoclimate

1. INTRODUCTION

The Rio Grande (Rio Bravo in Mexico) is one of 2 rivers shared by Mexico and the USA. It is a critical source of water for both countries, supplying water to 5 million people, 4 million of whom live along the USA–Mexico border. The Rio Grande is the fifth longest river in North America (2830 km) and has a drainage basin encompassing 870 000 km^2; slightly more than half of this area contributes to flow (Dahm et al. 2005). The Rio Grande is considered one of the most impacted rivers in the world and has multiple issues that are related to water quality and quantity (Dahm et al. 2005).

The headwaters of the Rio Grande lie in the San Juan Mountains of Colorado and the runoff is largely from snowmelt. Peak flows for the portion of the river dominated by snowmelt occur from April to June. The average Rio Grande flow in northern New Mexico is about 43 m^3 s^{-1}. Flows become very limited downstream from the border at El Paso, Texas, and Ciudad Juárez, Mexico. From here, the Rio Grande flow consists mostly of wastewater and irrigation return flows until its confluence with the Rio Conchos (Everitt 1993, Miyamoto et al. 1995, Schmandt et al. 2000). After this point, the main contribution to the Rio Grande comes from the Rio Conchos, which has its headwaters in the Sierra Madre Occidental, a mountain range in northeastern Mexico (Fig. 1). Above the confluence with the Rio Conchos, the Rio Grande average annual flow is about 3 m^3 s^{-1}, while below this confluence the flow averages about 30 m^3 s^{-1} (Dahm et al. 2005).

Unlike the upper part of the Rio Grande, the Rio Conchos watershed is strongly under the influence of the North American monsoon. Over 50% of

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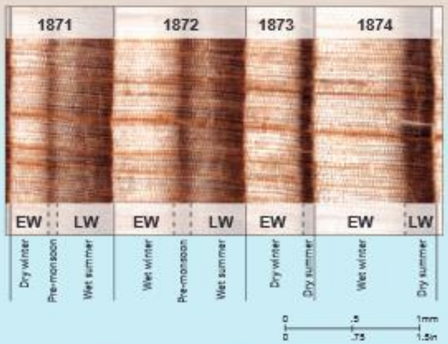
New Mexico EARTH MATTERS

WINTER 2013

Tree-ring Insights on New Mexico's Monsoon and Rio Grande Stream Flow

Recent drought conditions have caught the attention of many people, and a question commonly asked is: How bad is this drought? Is this the driest series of monsoon years, and are these the lowest flows the Rio Grande has ever experienced? Are these drought conditions an indication of climate change, or just part of the natural variability of the climate system? How often are winters with low runoff followed by dry monsoons? Gage record of rainfall and stream flow for this region are little more than 100 years in the best cases. Do these records fully capture the range of conditions that could occur under natural climate variability?



Sequence of four Douglas-fir tree rings from southwestern New Mexico, for the four-year period from 1871 to 1874. Each annual growth ring is composed of light-colored earlywood (EW) and dark-colored latewood (LW). Both 1871 and 1872 contain density variations—"false rings"—which likely result from seasonal drought in the pre-monsoon period.

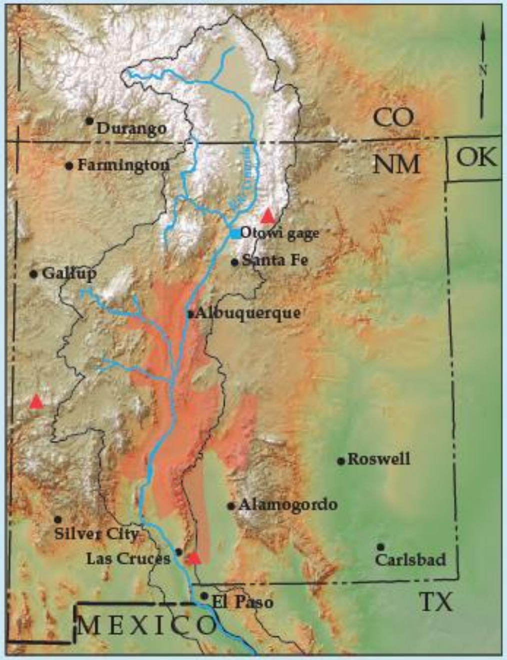
It is possible to extend instrumental records back in time using biologic or geologic evidence from sources such as tree rings, corals, ice cores, and sediments from the bottoms of lakes and oceans, all of which can reflect climate variations in their rings or layers. Data from these sources, called paleoclimatic or proxy data, provide information about past climate, before the time of modern climate measurements. Tree rings have been especially useful for documenting variations in rainfall, drought, and stream flow in New Mexico, because the growth rings in several tree species that grow in this area are limited by moisture. These species include Douglas-fir and ponderosa pine. A small ring in these trees indicates dry conditions and a wide ring indicates wet conditions. Because trees have annual rings, there is a ring-width value for each year, and because the widths correspond to growth-limiting moisture, the series of widths can be used as a proxy for climate extending back the length of the tree's life. Here in the Southwest, it is common to find trees 300–500 years old, and many as old as 600–700 years.

In order to create a tree-ring width record, about 25–35 trees at a single site are sampled with an increment borer, which is used to extract a pencil-width cylinder of wood from the tree. These tree cores are glued into core mounts, sanded to a fine surface, and each ring is assigned a calendar year date. Dating is accomplished using a method called cross- dating, which is anchored by the ring next to the bark—the year the tree was sampled—and matching the ring-width patterns between trees. The patterns are extremely consistent among moisture-sensitive trees across a climatic region, and this pattern-matching technique is used to ensure each and every ring is correctly dated. Dated rings are then measured, the measurements are adjusted to account for difference in ages of trees sampled, and then averaged together to create a tree-ring chronology for that site.

In New Mexico, detailed information about both the summer monsoon rainfall and the cool season precipitation that is largely responsible for Rio Grande peak runoff can be obtained from tree rings. It has long been recognized that annual growth rings have two parts: a light-colored part formed in the first part of the growing season, called the earlywood, and a dark part formed near the end of the growing season, called the latewood. Although it has been customary to measure the entire ring, if two measurements are made, of the earlywood and latewood widths separately, scientists have found that, throughout much of the southwestern U.S., earlywood widths correspond to cool season precipitation and the latewood widths correspond to monsoon season precipitation.

In 2008 the National Science Foundation funded a study to collect tree-ring data from across the Southwest for the purpose of reconstructing the North American monsoon. Previous

Published by the New Mexico Bureau of Geology and Mineral Resources • A Division of New Mexico Tech



Rio Grande, Climate Division 5 (shaded red), Otowi gage (blue square), and tree-ring chronologies used in monsoon reconstruction (red triangles).

http://geoinfo.nmt.edu/publications/periodicals/earthmatters/13/EMv13n1.pdf

Other related documents and data

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

- Home
- Background
- Documents & Data
- Tree-Ring Sites
- Links
- About Us

Documents & Data

This page hosts documents related to the Monsoon Project:

Publications and data from peer-reviewed research.

Articles aimed at non-technical audiences.

Workshop descriptions and presentations.

Posters presented at professional conferences.

http://monsoon.ltrr.arizona.edu/documents.html

Questions?

Some of mine:

- 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?
- Is there anything we can do to make this information/data more useful to you?

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CLIMAS Climate Assessment for the Southwest
NSF
EPA