

# Ancient forests & the reconstruction of climate variability and climate change

David W. Stahle  
University of Arkansas, Fayetteville

[dendro.uark.edu](http://dendro.uark.edu)

## Outline:

History of old growth forests?

Standard dendroclimatic theory

Moisture signal

Summer temperature signal

NASPA

(temporal & spatial reconstruction of cool & warm season precipitation)

Climate dynamics & climate change

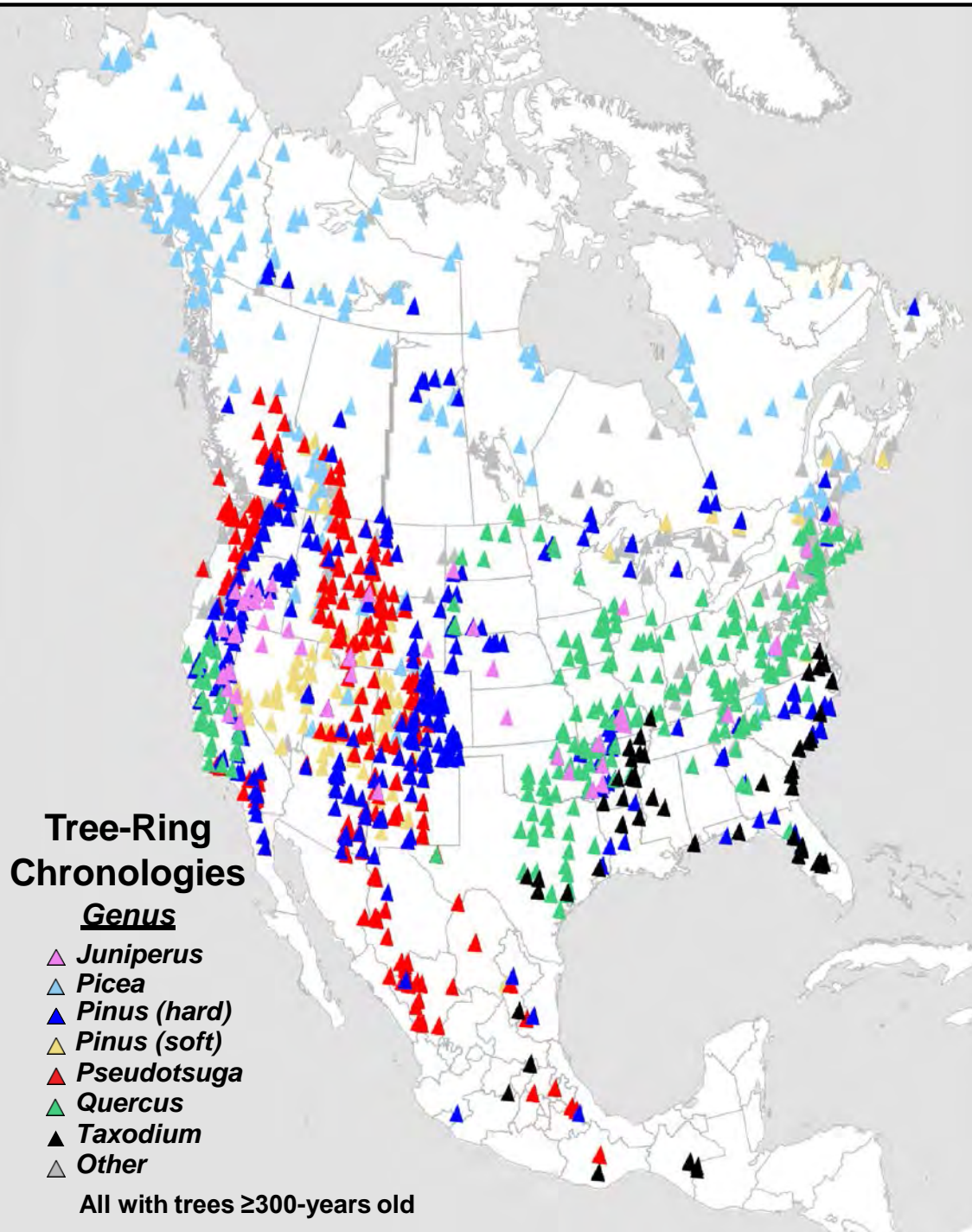
Drought & floods in the Amazon

## Tree-Ring Chronologies

### Genus

- △ *Juniperus*
- △ *Picea*
- ▲ *Pinus (hard)*
- ▲ *Pinus (soft)*
- ▲ *Pseudotsuga*
- ▲ *Quercus*
- ▲ *Taxodium*
- △ *Other*

All with trees  $\geq 300$ -years old



# The Principal of Site Selection in Dendroclimatology:



**Complacent Rings**



**Sensitive Rings**



## The 'Environmental Mediation of the Climate Signal in Tree Growth'

All tree species and forest types are not equally valuable for dendrochronology, so we practice 'site selection' to identify environmental conditions that maximize the climate influence on tree growth, particularly precipitation and temperature.

### Key points illustrated:

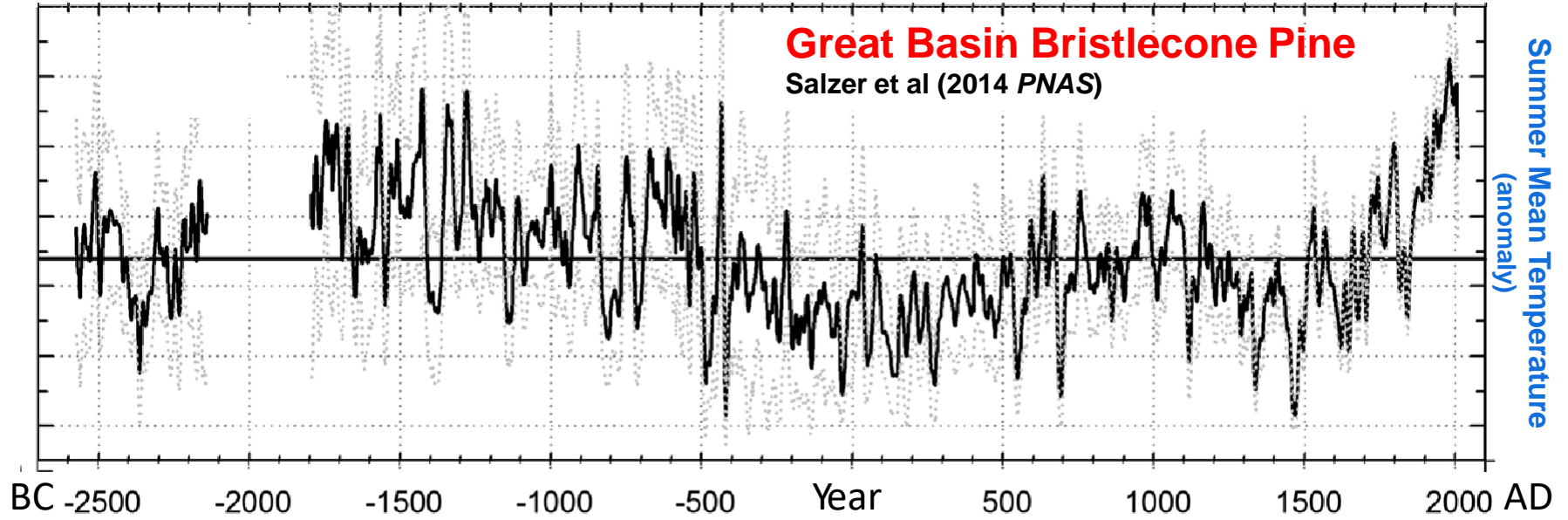
Complacent vs. sensitive sites

Size may not be equal to age

Longevity under adversity

Commercial vs. non-commercial forests



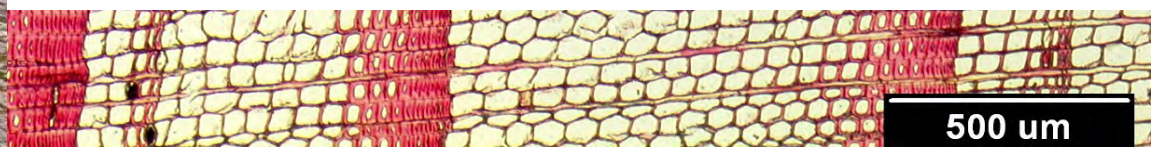
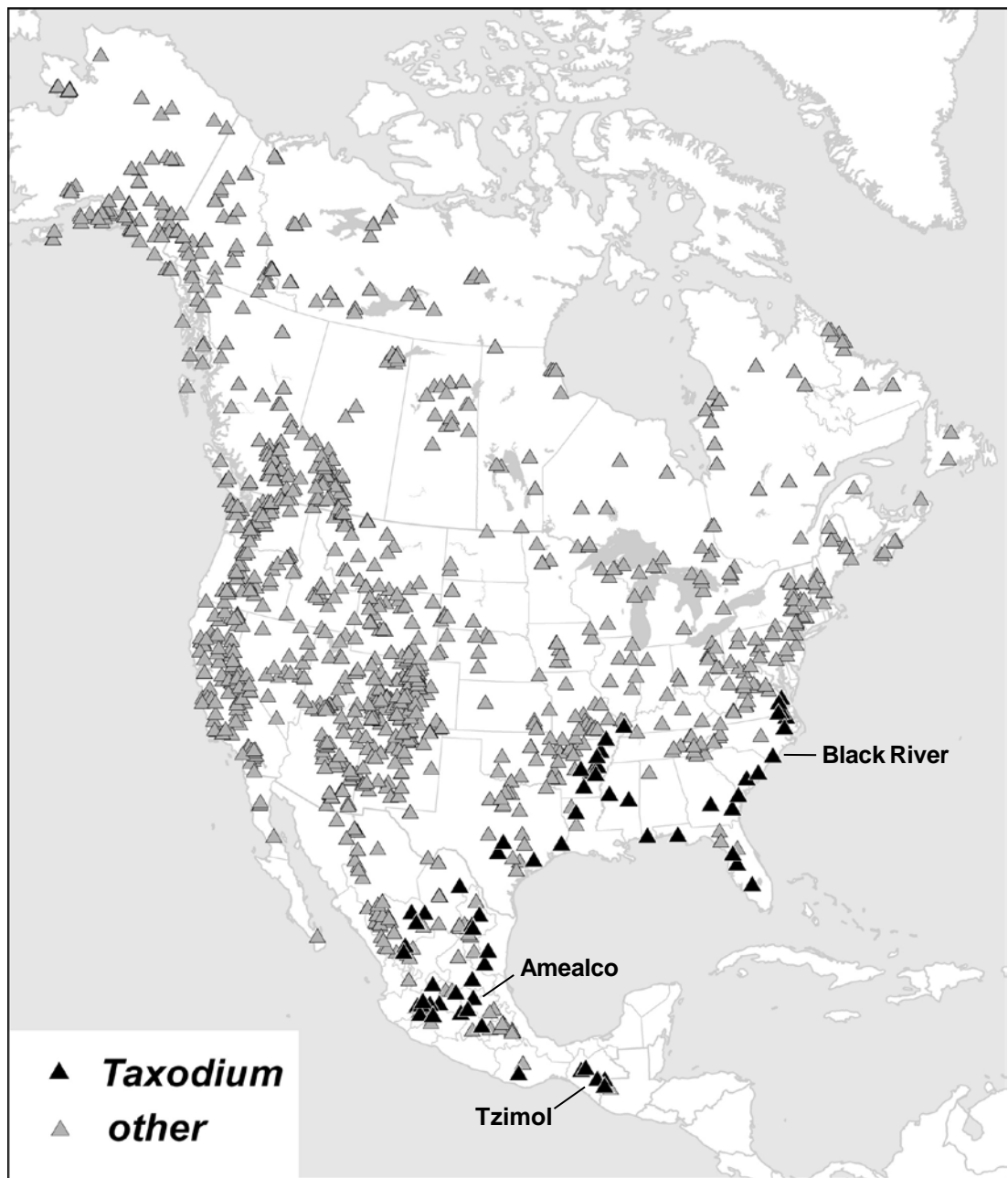


Strong temperature signal at the “absolute tree line”





Ancient bald cypress >2,000-years old  
Black River, NC

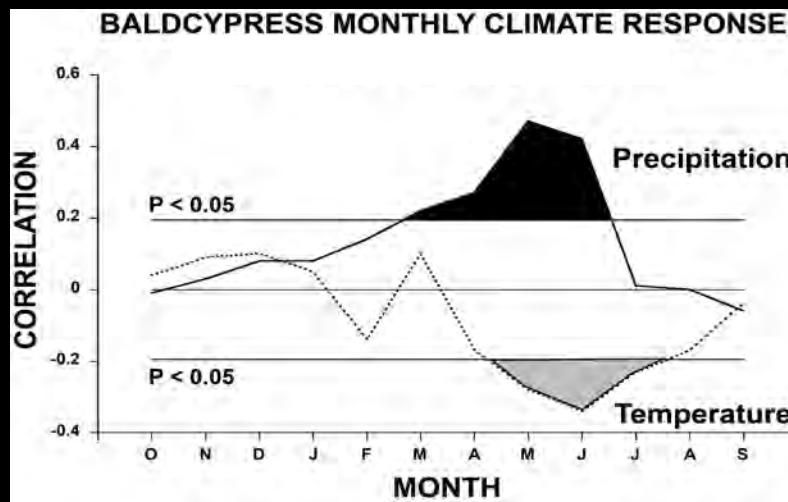


500 um





Mac Stone



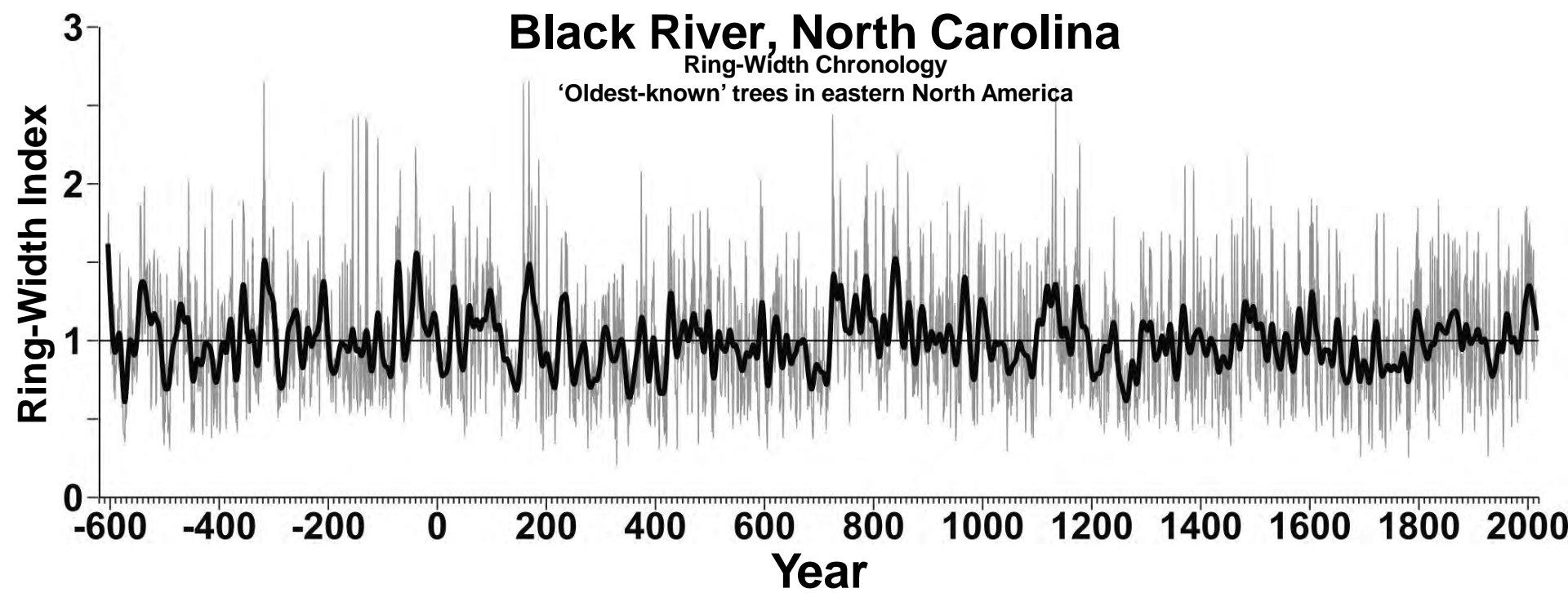
positive correlation with precipitation, negative with temperature, during the growing season!



# Black River, North Carolina

Ring-Width Chronology

'Oldest-known' trees in eastern North America

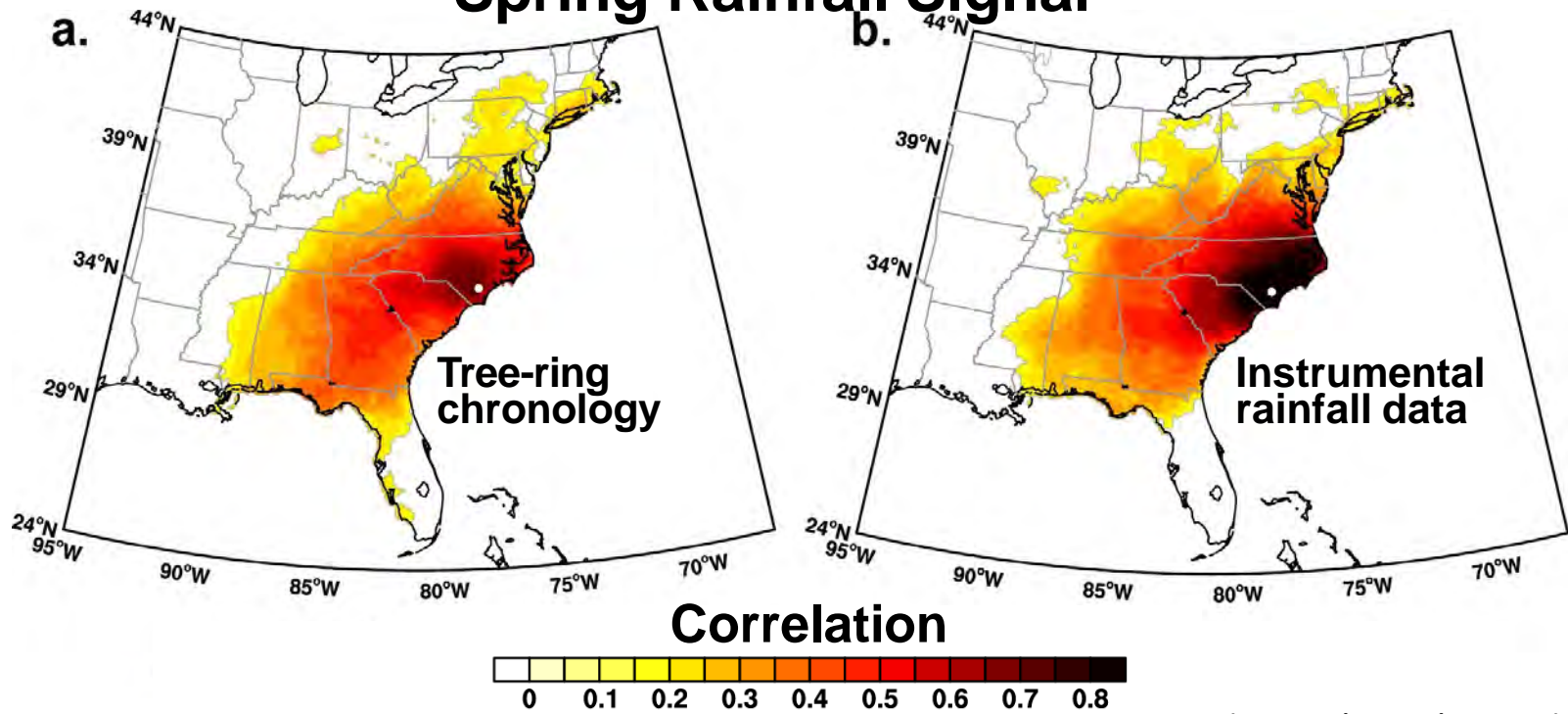


*Environmental Research Comm., 2019*





# Spring Rainfall Signal





# North American Tree-Ring Chronologies

## Eastern species

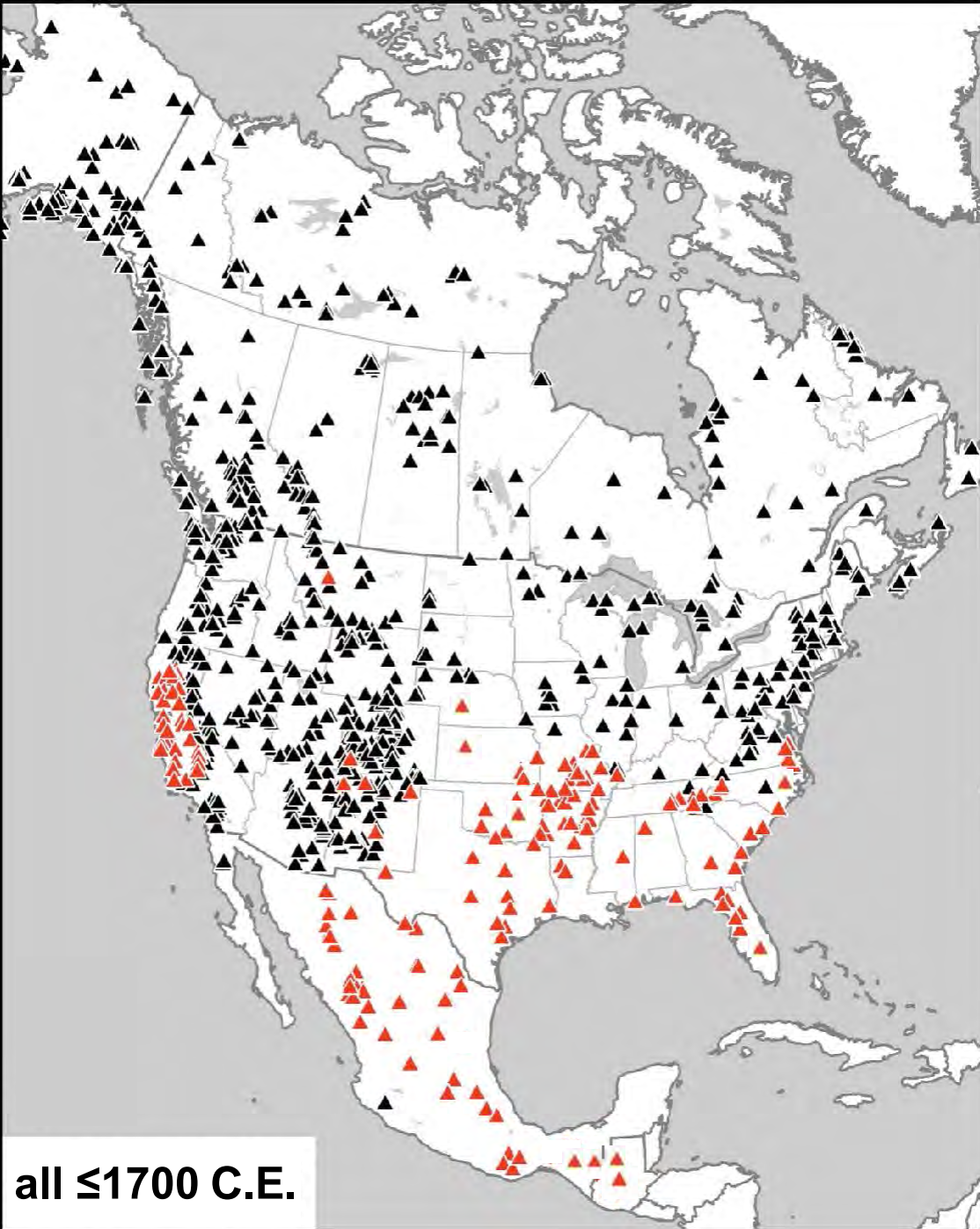
White Oak Group  
Hemlock  
Baldcypress  
Tulip Poplar  
Overcup Oak  
Northern Red Oak  
American Chestnut (relict wood)  
Eastern Red Cedar  
Northern White Cedar  
Red Pine  
Shortleaf Pine  
E. White Pine  
Red Spruce

## Western species

Ponderosa Pine  
Douglas-fir  
Big Cone Douglas-fir  
High Elevation Conifer  
Mountain Hemlock  
Other Conifer  
Pinyon Pine  
Western Juniper  
Blue Oak / Valley Oak

red = University of Arkansas  
Tree-Ring Laboratory

all  $\leq 1700$  C.E.



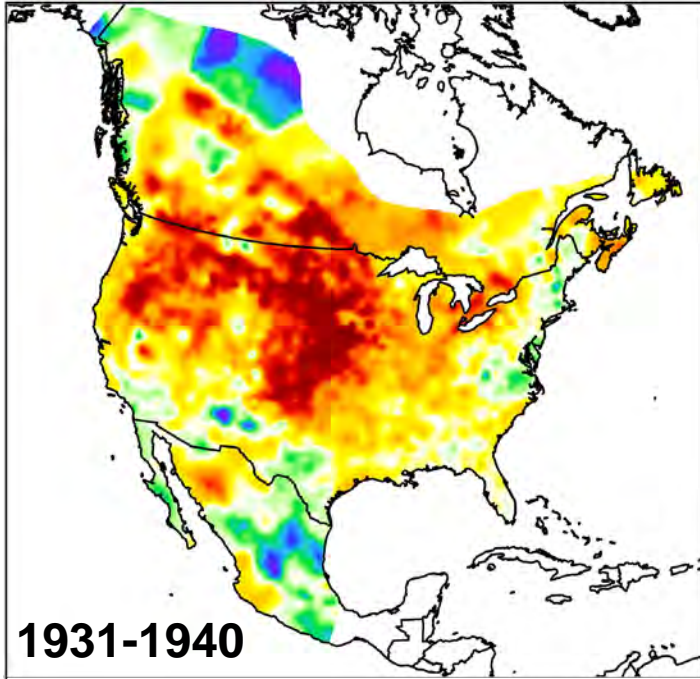


# North American Drought Atlas

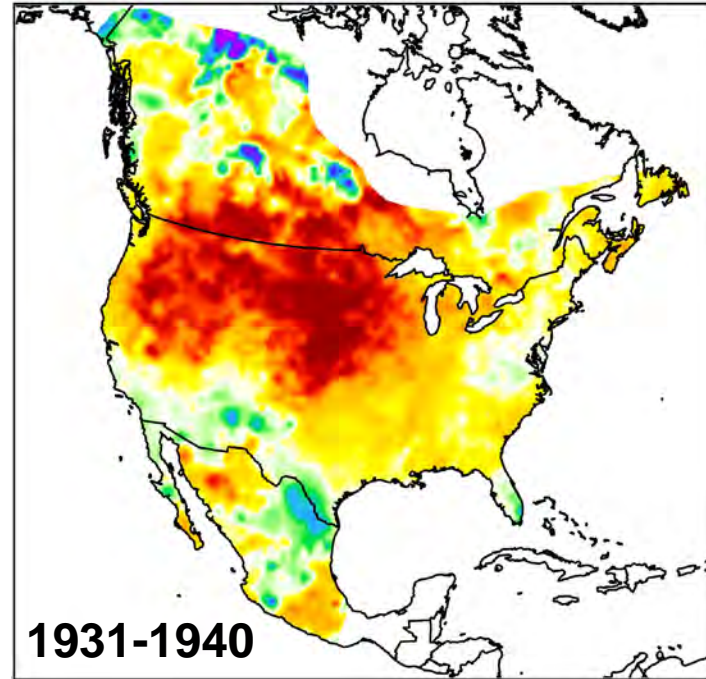
NADA

## Dust Bowl Drought

Instrumental PDSI



Tree-Ring Reconstructed PDSI

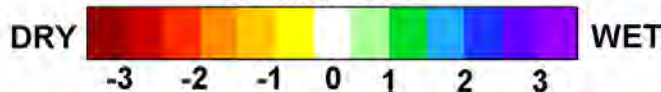


1931-1940

1931-1940

Summer PDSI

<http://drought.memphis.edu/NADA/>



Gridded reconstruction of the Palmer Drought Index using principal components regression (Cook 2004, 2007, 2010; Stahle et al 2007)

Spatial fidelity, coast-to-coast dryness, worst drought in 350 years

Impact & drought itself aggravated by poor land use. **First anthropogenic megadrought?**



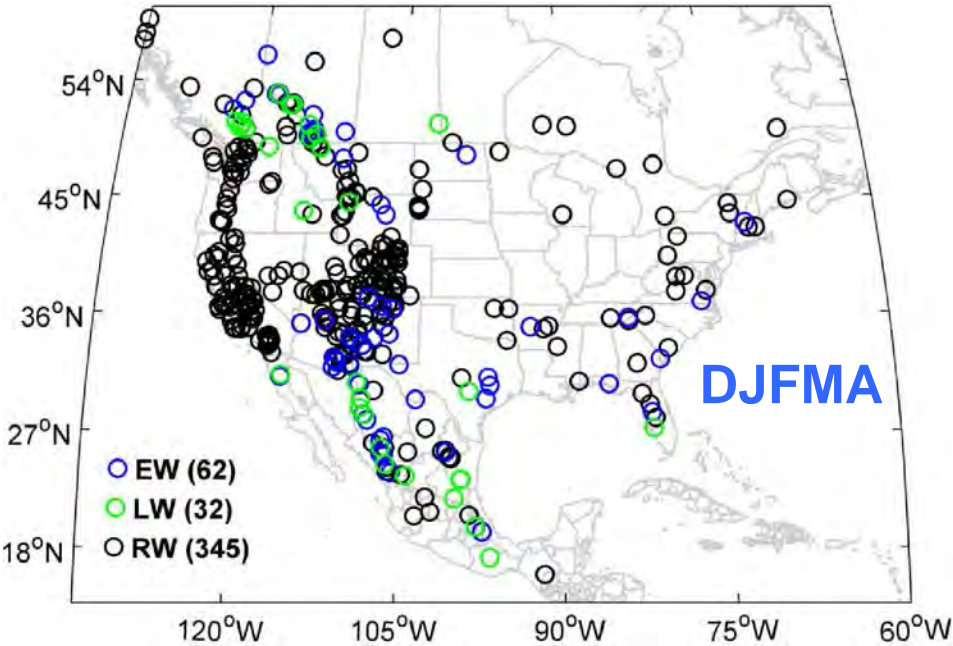
Dalhart, Texas, 1938  
(Dorothea Lange)



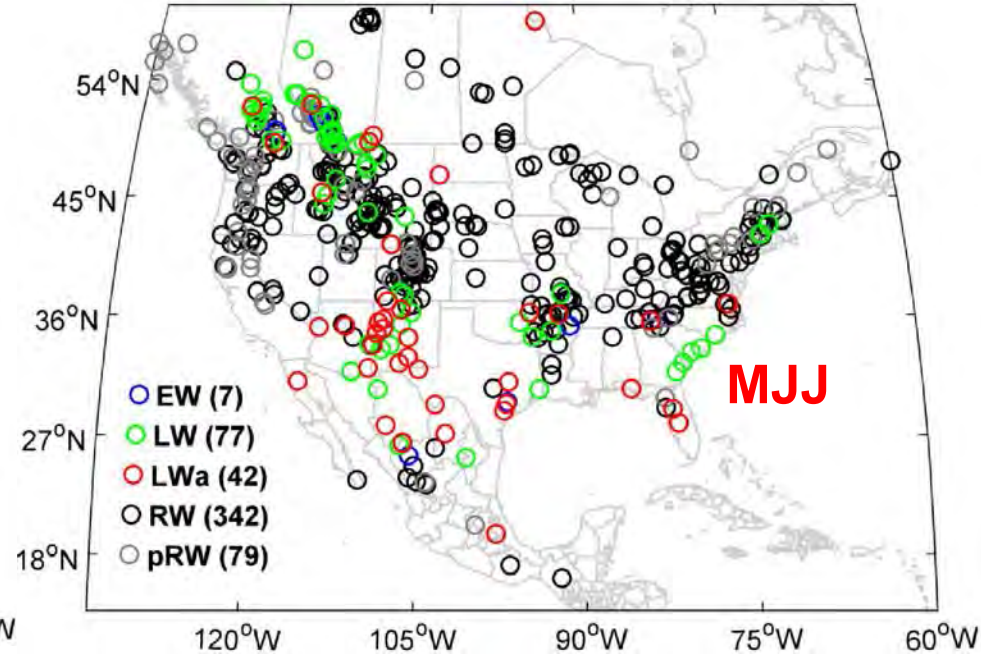
# North American Seasonal Precipitation Atlas

NASPA (Stahle et al 2020)

## 439 Discrete Cool Season Chronologies

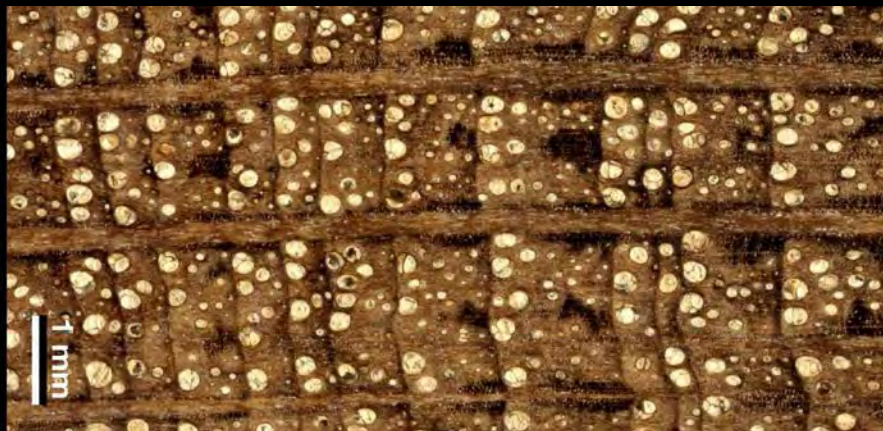


## 547 Discrete Warm Season Chronologies



Subsets of annual and sub-annual ring width chronologies with discrete seasonal signal.

“Discrete” = correlated with precipitation in one season but not the other ( $p < 0.05$ ).



Blue oak



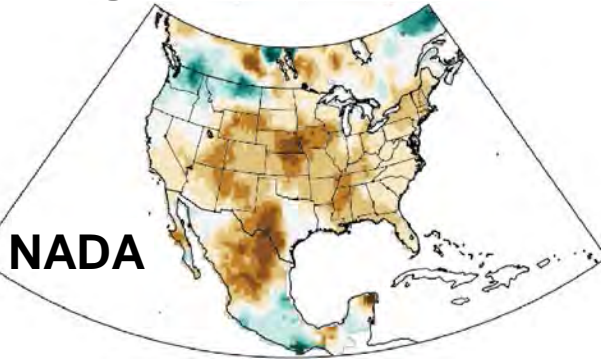
Ponderosa pine



# 16<sup>th</sup> Century Megadrought: 1568-1591

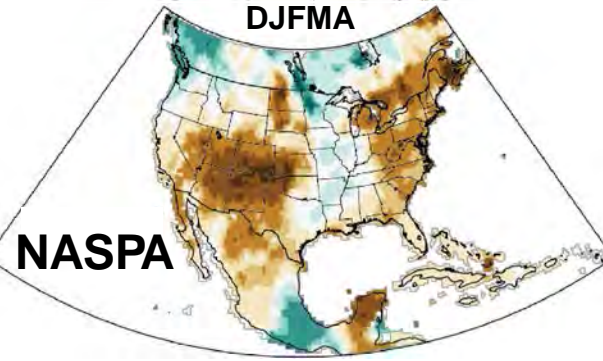
Major Seasonal Differences Sustained for 24-years

### Long-Term Soil Moisture



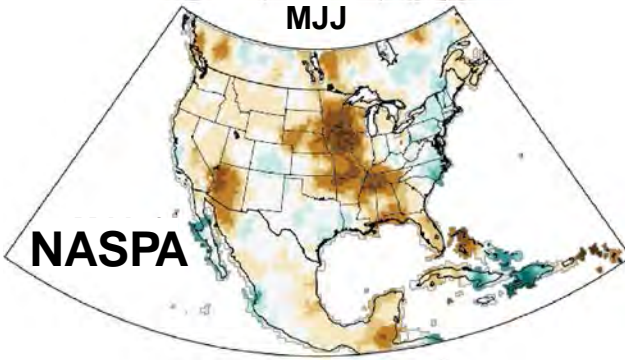
### Cool Season SPI

DJFMA



### Warm Season SPI

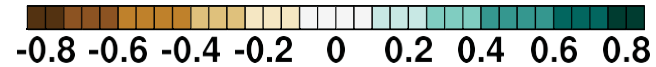
MJJ



### Palmer Drought Severity Index



### Standardized Precipitation Index



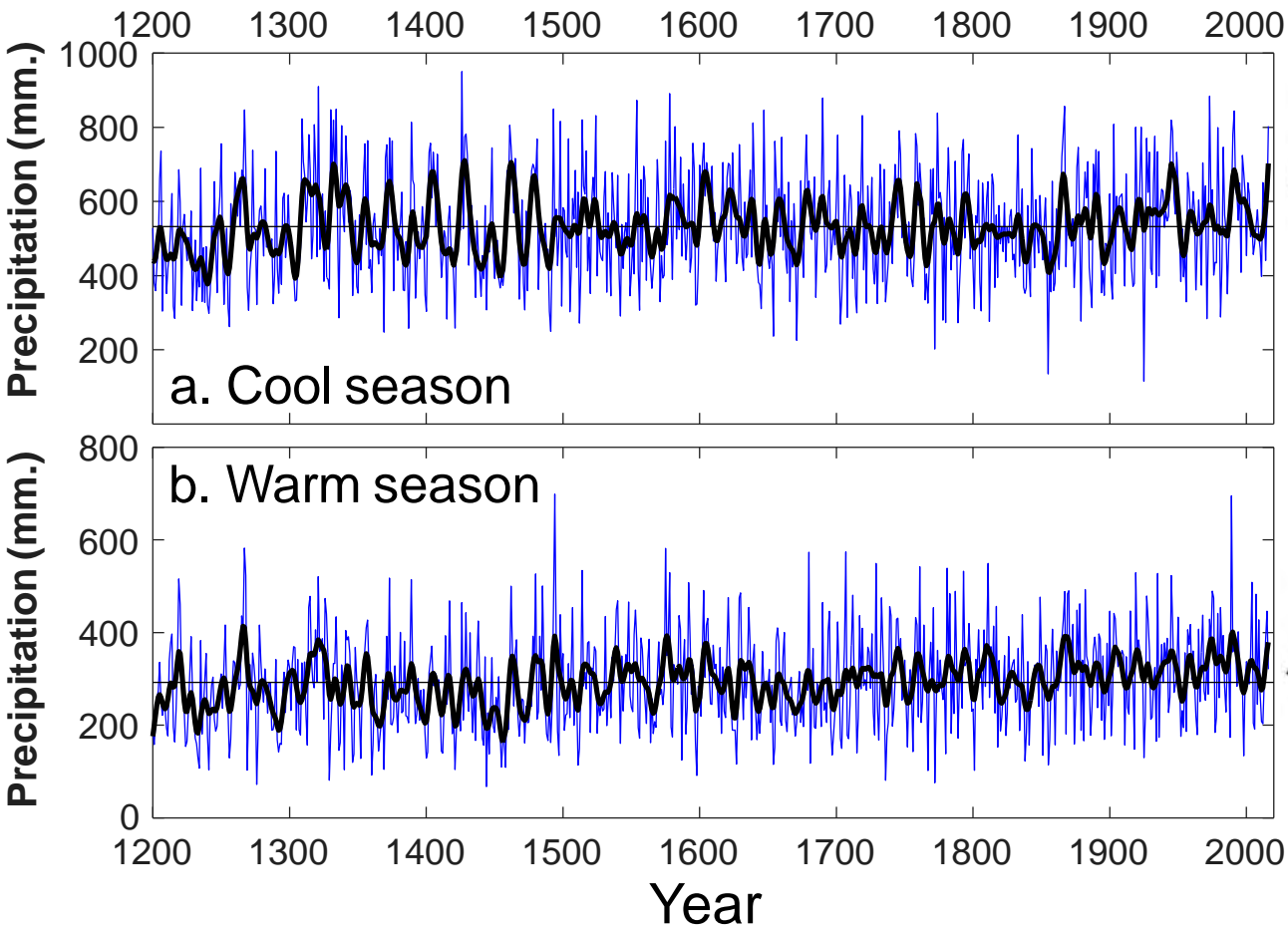
Stahle et al (2020)  
*Journal of Climate*



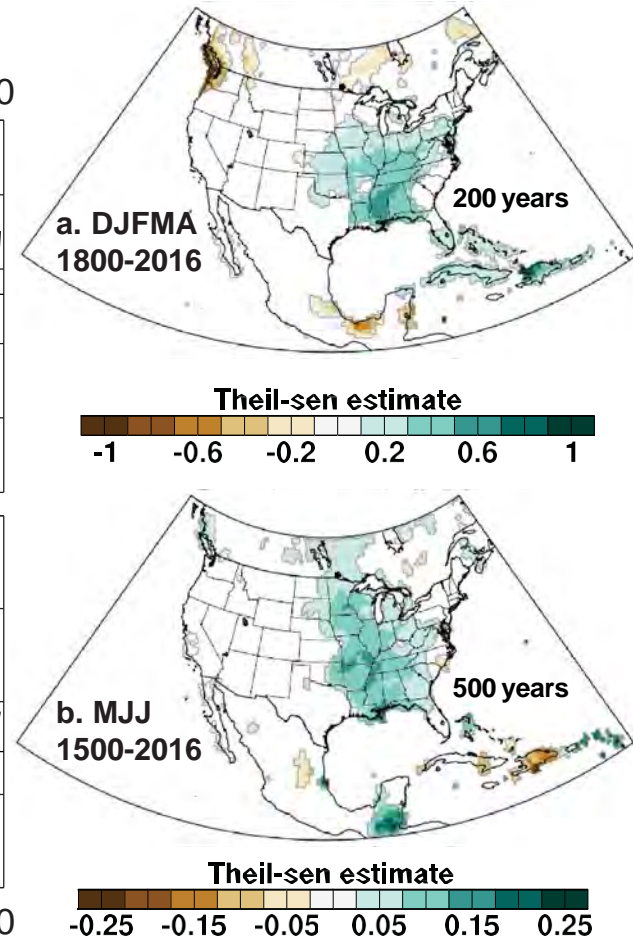
White Canyon, Utah



# Reconstructed Seasonal Precipitation Southcentral United States



# Precipitation Trend

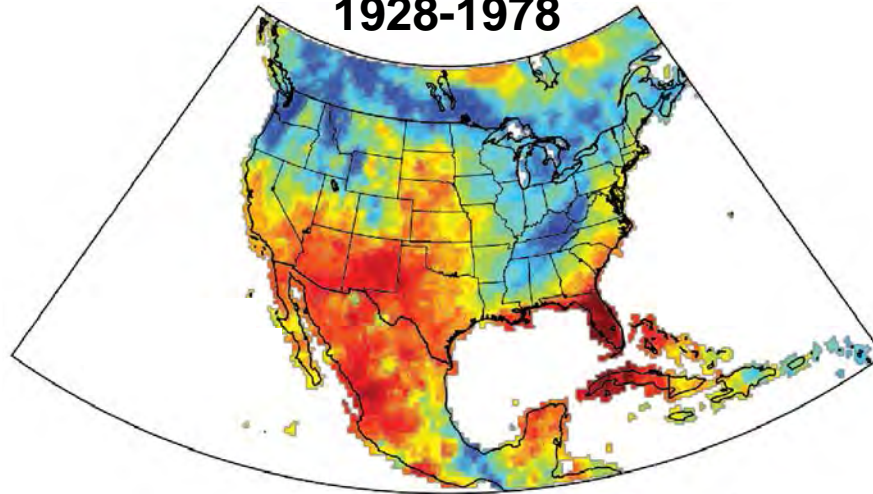




# El Nino/Southern Oscillation correlated with Winter Precipitation over North America

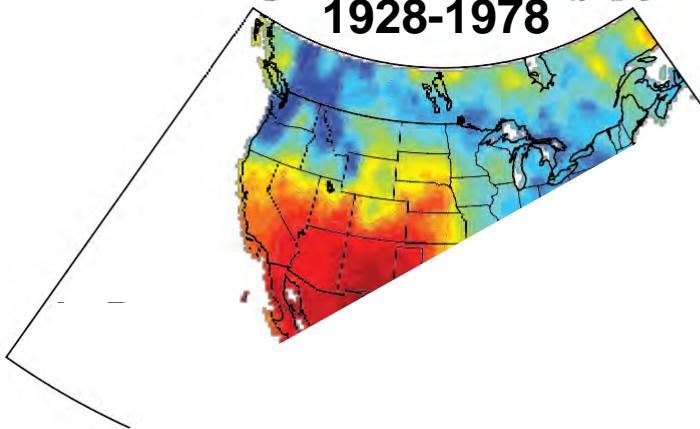
Instrumental DJFMA Precip

1928-1978



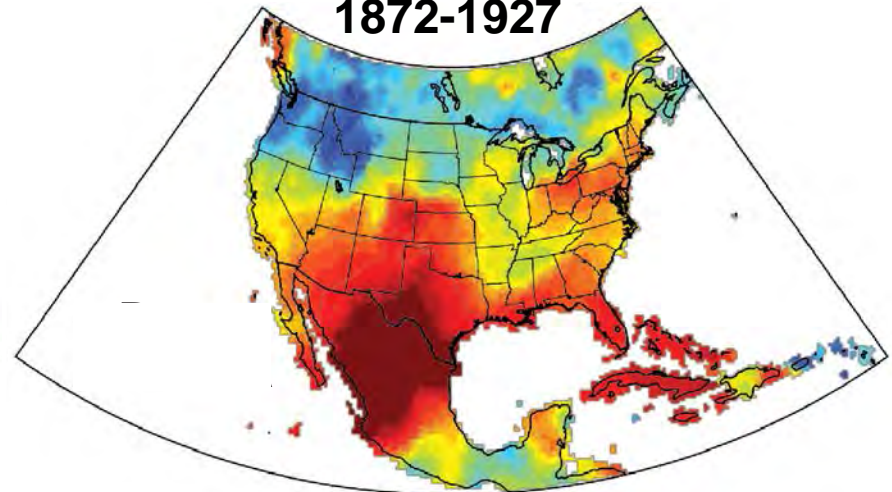
Reconstructed DJFMA Precip

1928-1978

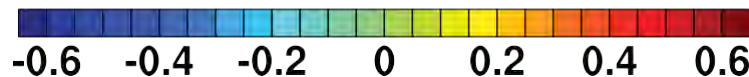


Reconstructed DJFMA Precip

1872-1927



Correlation



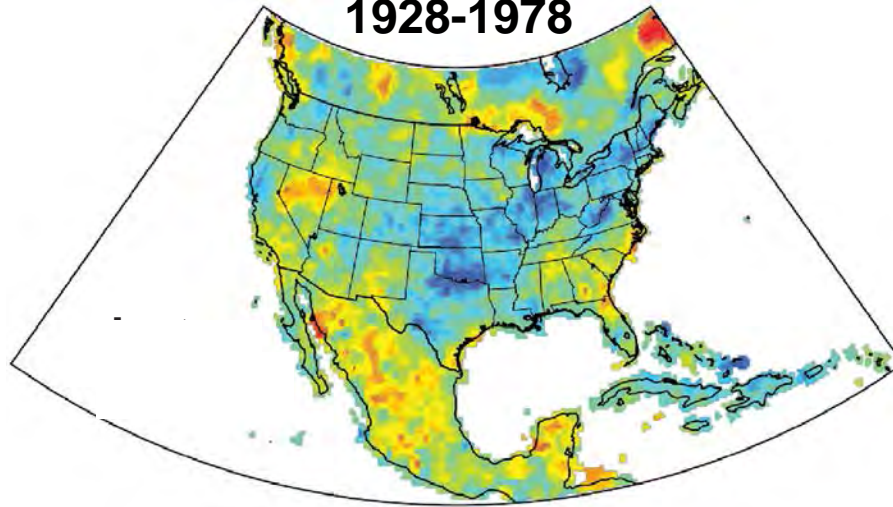


# Arctic Oscillation

correlated with **Summer Precipitation** over North America

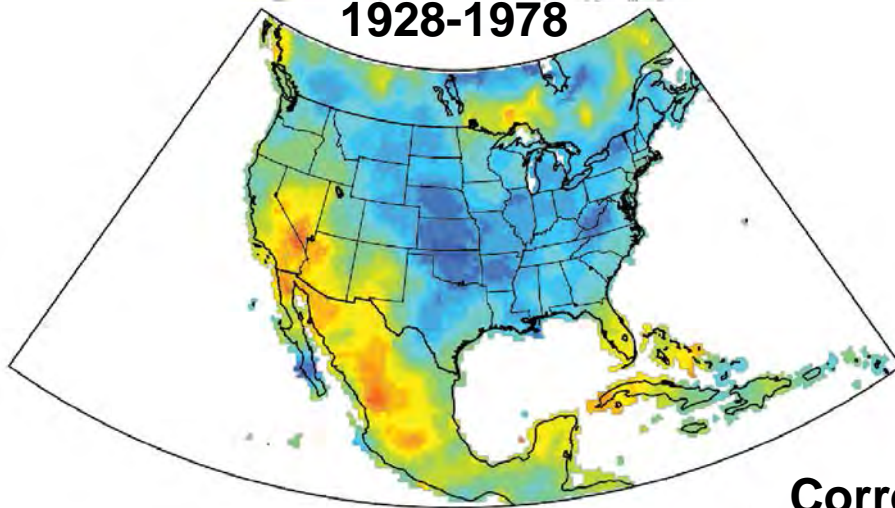
Instrumental MJJ Precip

1928-1978



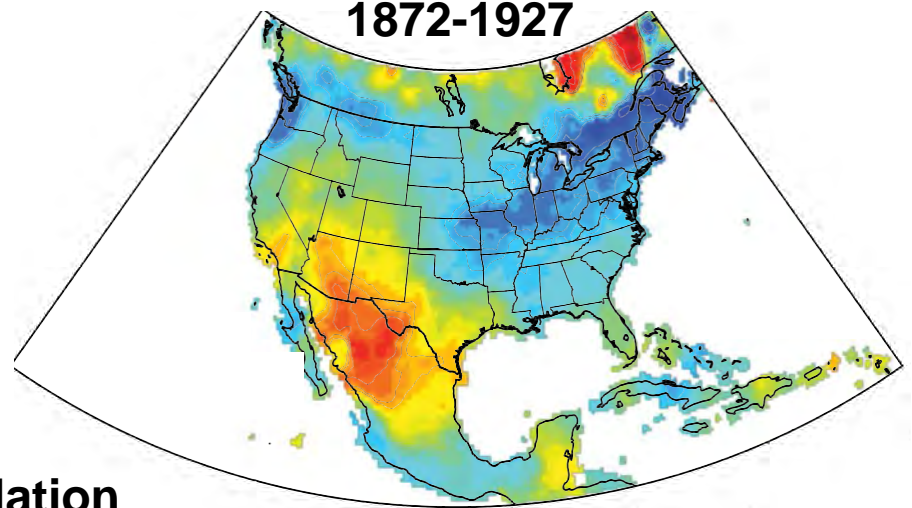
Reconstructed MJJ Precip

1928-1978

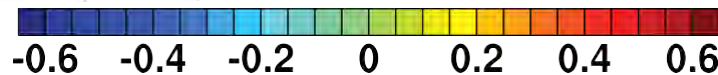


Reconstructed MJJ Precip

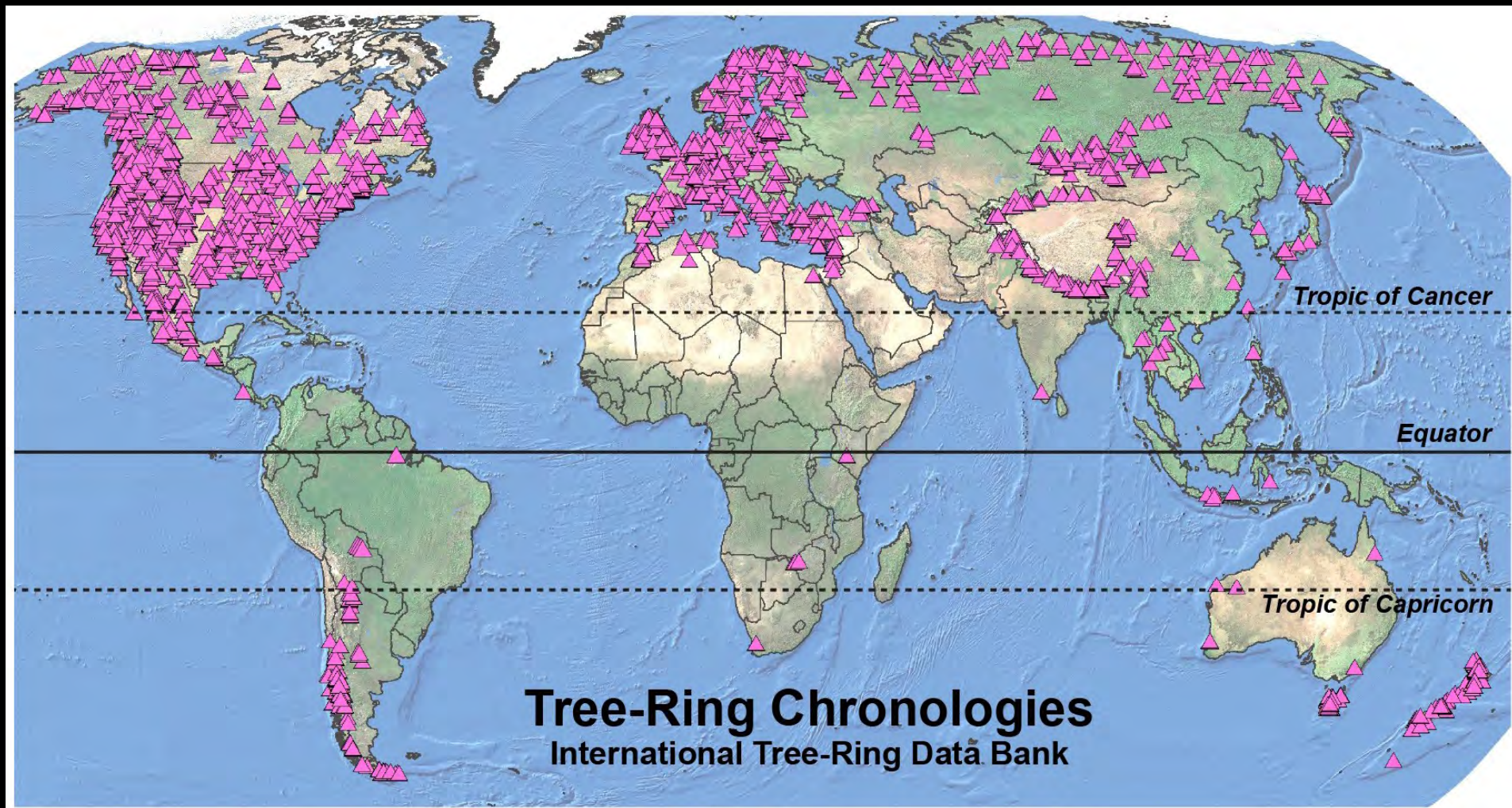
1872-1927



Correlation







Tree ring chronologies (triangles) are very rare in the global tropics ...

6,747 known species of trees in Amazonia, 16,000 likely present ...

Only one species in Amazonia proven to be useful for dendroclimatology: *Cedrela odorata* ...

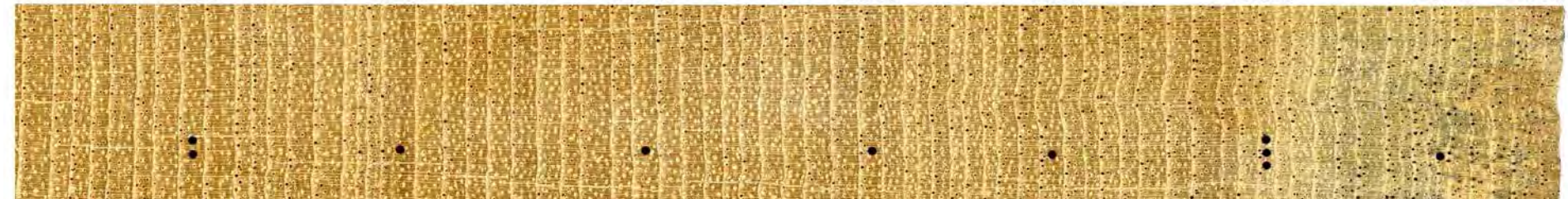


# Drought & Flood Extremes on the Amazon River

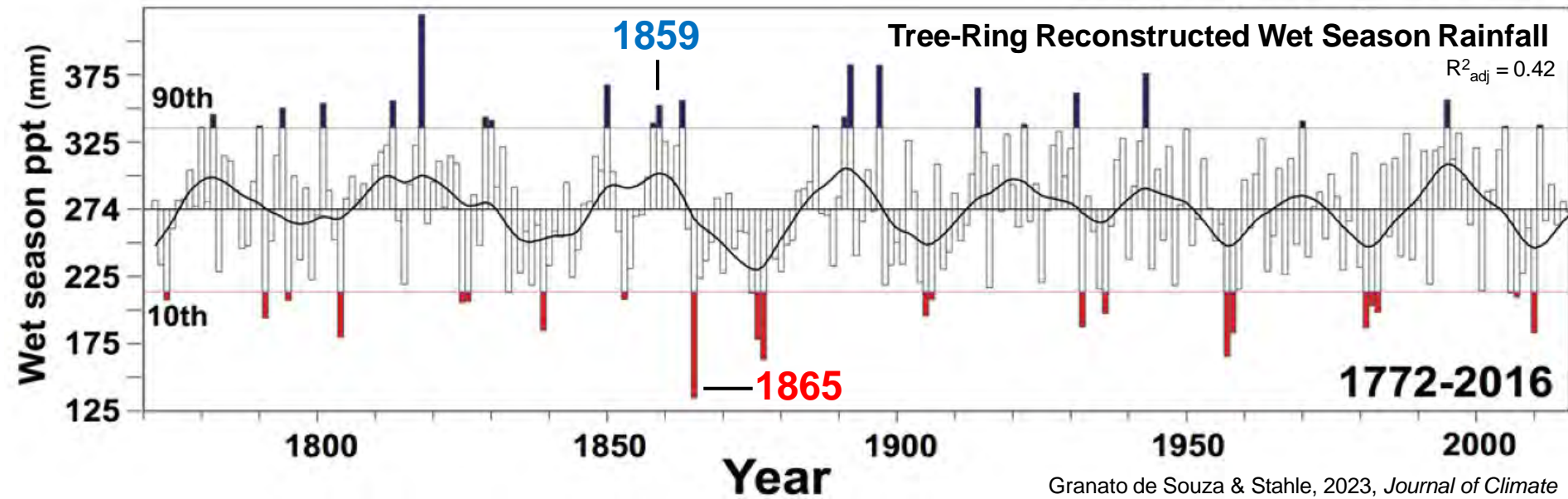
Manaus at the confluence of the Amazon River & Rio Negro, 1867.



1950      1960      1970      1980      1990      2000      2010      2016



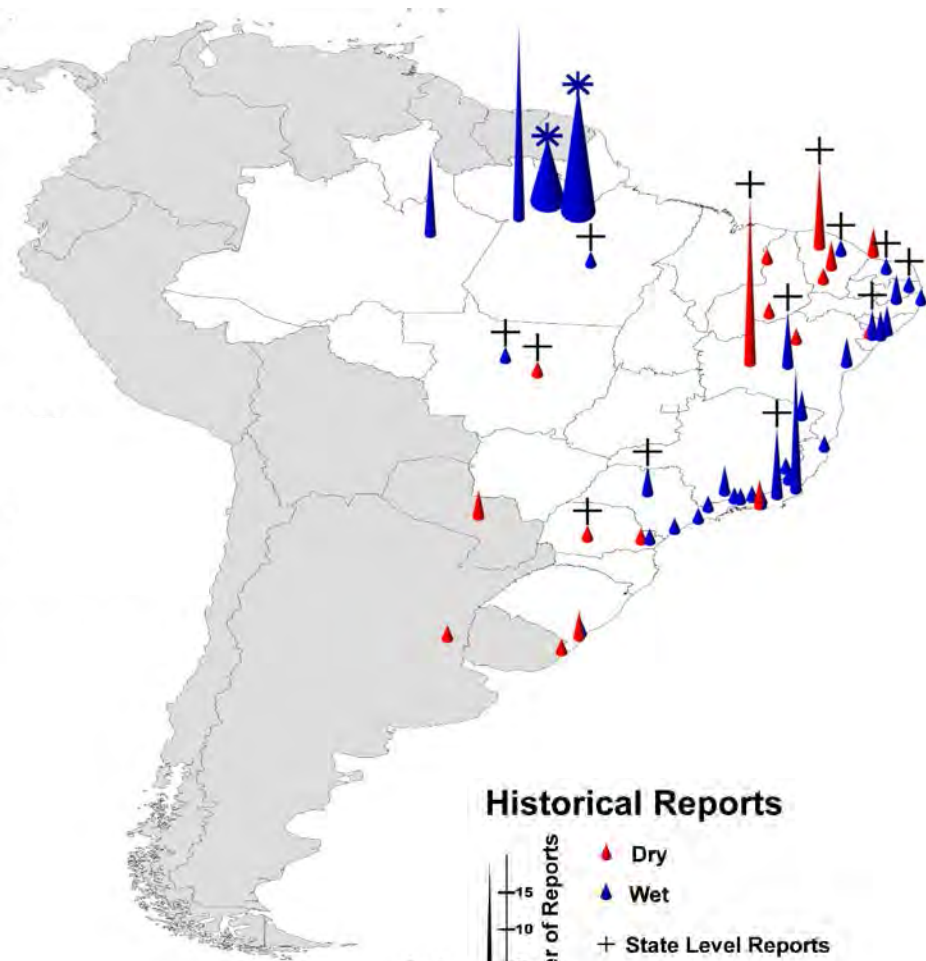
*Cedrela odorata*, Rio Paru, Brazil





# “The Amazon Flood” of 1859

*A Epocha* (1859)



***A Epocha: Folha Politica, Commercial e Noticiosa*** June 7, 1859:

“Santarem.... The Amazon Flood.... covered all the lands, and even was to harm some establishments built in lands of the mainland and very high; and its invasion even went to towns like Santarem and Alemquer, where **First Street was completely impassable, and now traffic can be made by canoe...**”

Lowest elevation of First Street = 10.20m

Record flood of 2009 = 10.22m

Likely flood level for 1859 (+ canoe) = 10.70m

## The Amazon floods of 1859 and 1892,

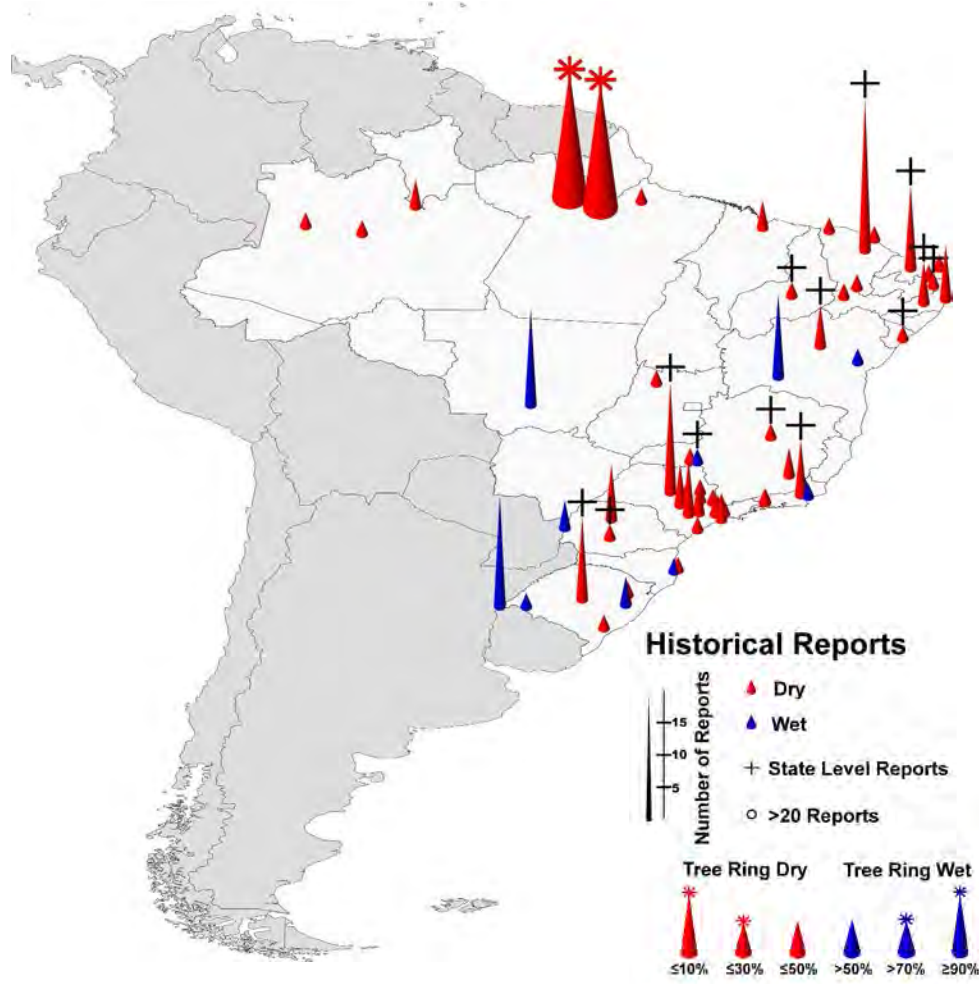
May have been the most extreme in the recorded history of the Amazon, exceeding even recent extremes?

## Candidates for the ‘largest known’ meteorological floods in world history?

**Why?** Amazon River mean discharge = 216,000cms



# The “Forgotten Drought” of 1865



## **Louis Agassiz & Silva Coutinho**

Thayer Expedition, Central Amazon, 1865:

“**maximum ebb**, here near Tabatinga. Large banks of sand & mud are discovered on the headlands of the islands, and even in the middle of the river, where the inhabitants of villages are camped out to fish ...”

**Discovered 800 new species of freshwater fish in 1865**



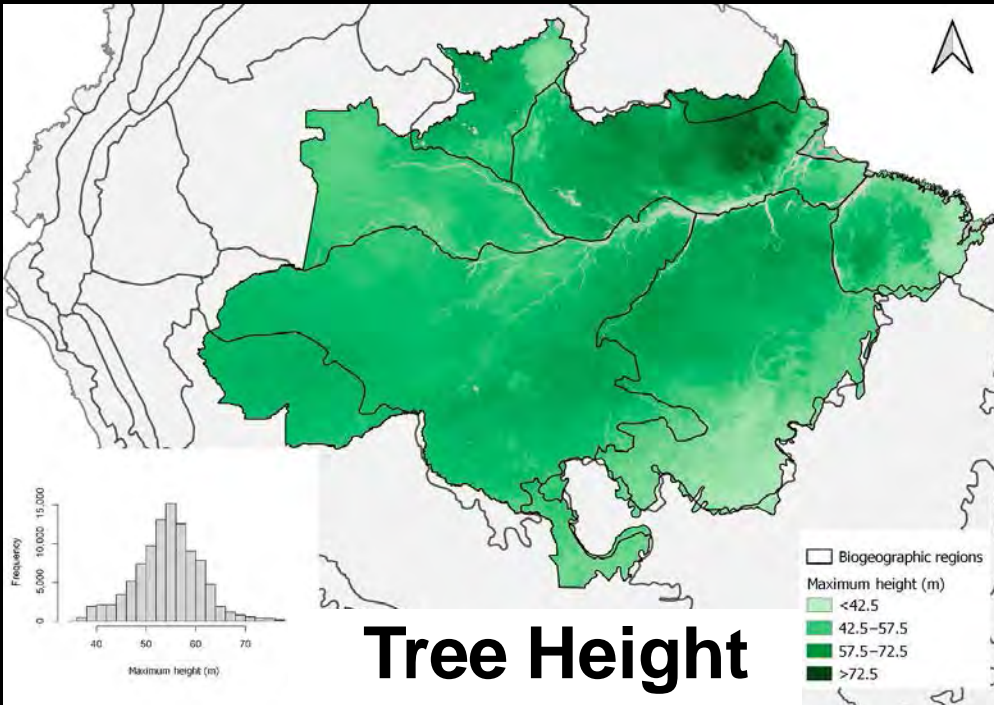
**Louis Agassiz (LA) and Silva Coutinho (SC).**  
Peabody Museum collection, Harvard University.

*Diario de Pernambuco*, Jan 24, 1865:  
**Vazante** (low stand) of 1864-1865, the lowest ever witnessed on the Rio Negro.

*Diario do Rio de Janeiro*, Sept. 1865:  
The **steamship Ycamiaba** “grounded twice on the September trip ...”



# Giant Trees of the Eastern Amazon



*Denezia excelsa*

*Denezia excelsa* >70 meters tall have been discovered in the Rio Paru & Rio Jari drainage basins. Large, old *Cedrela odorata* also present.

Gorgens et al. (2020) *Global Change Biology*.