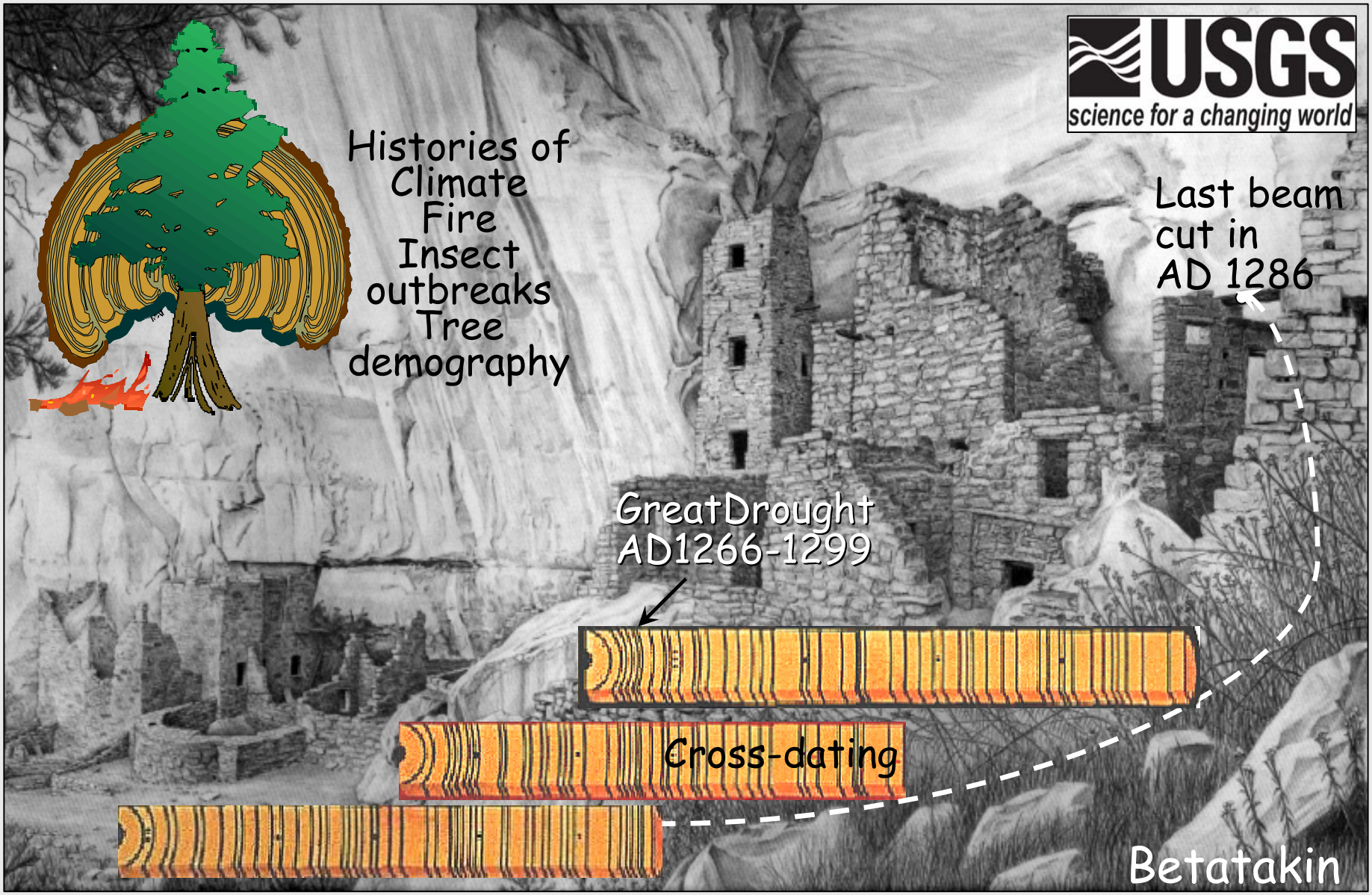
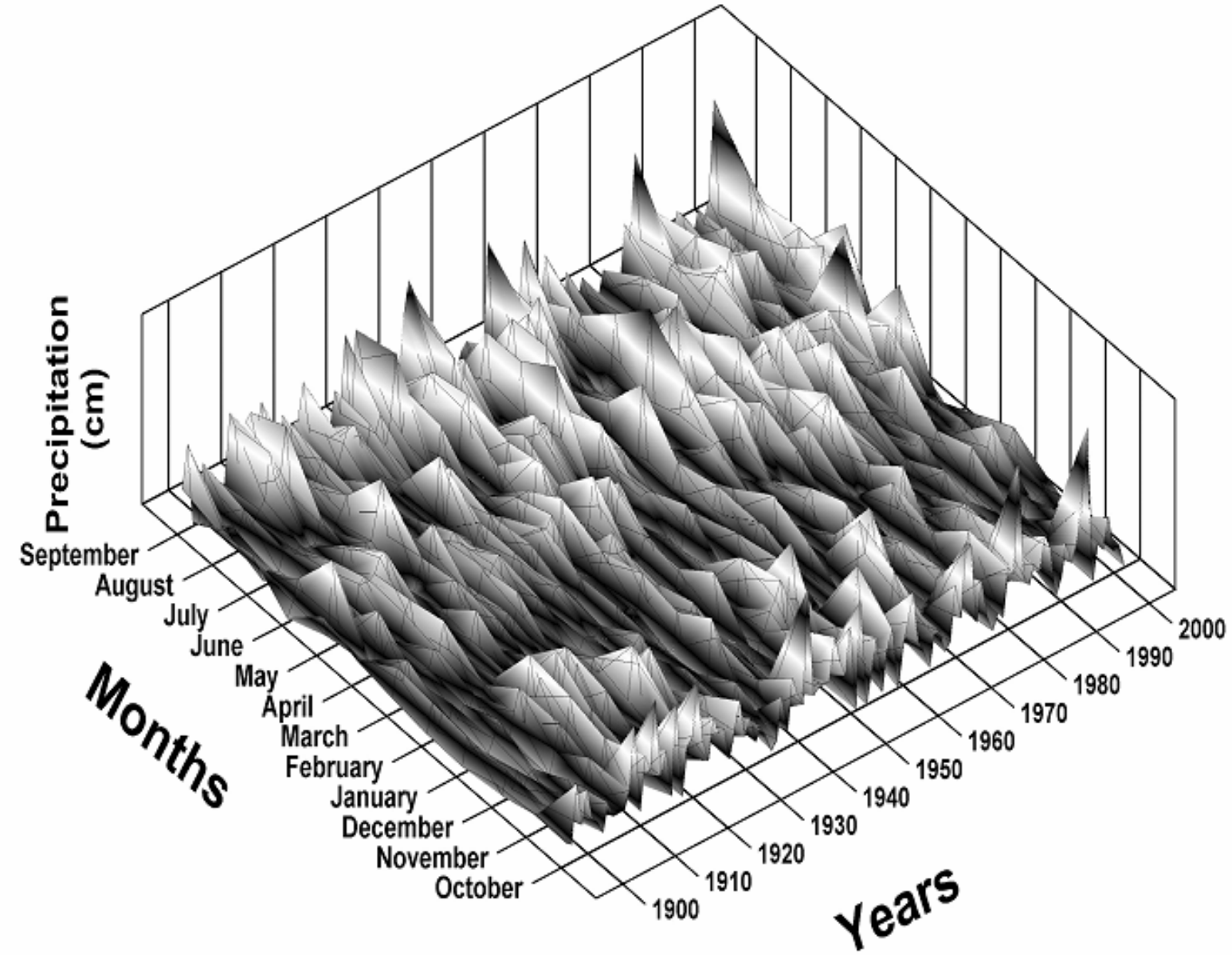
Prehistoric Context for Western Drought

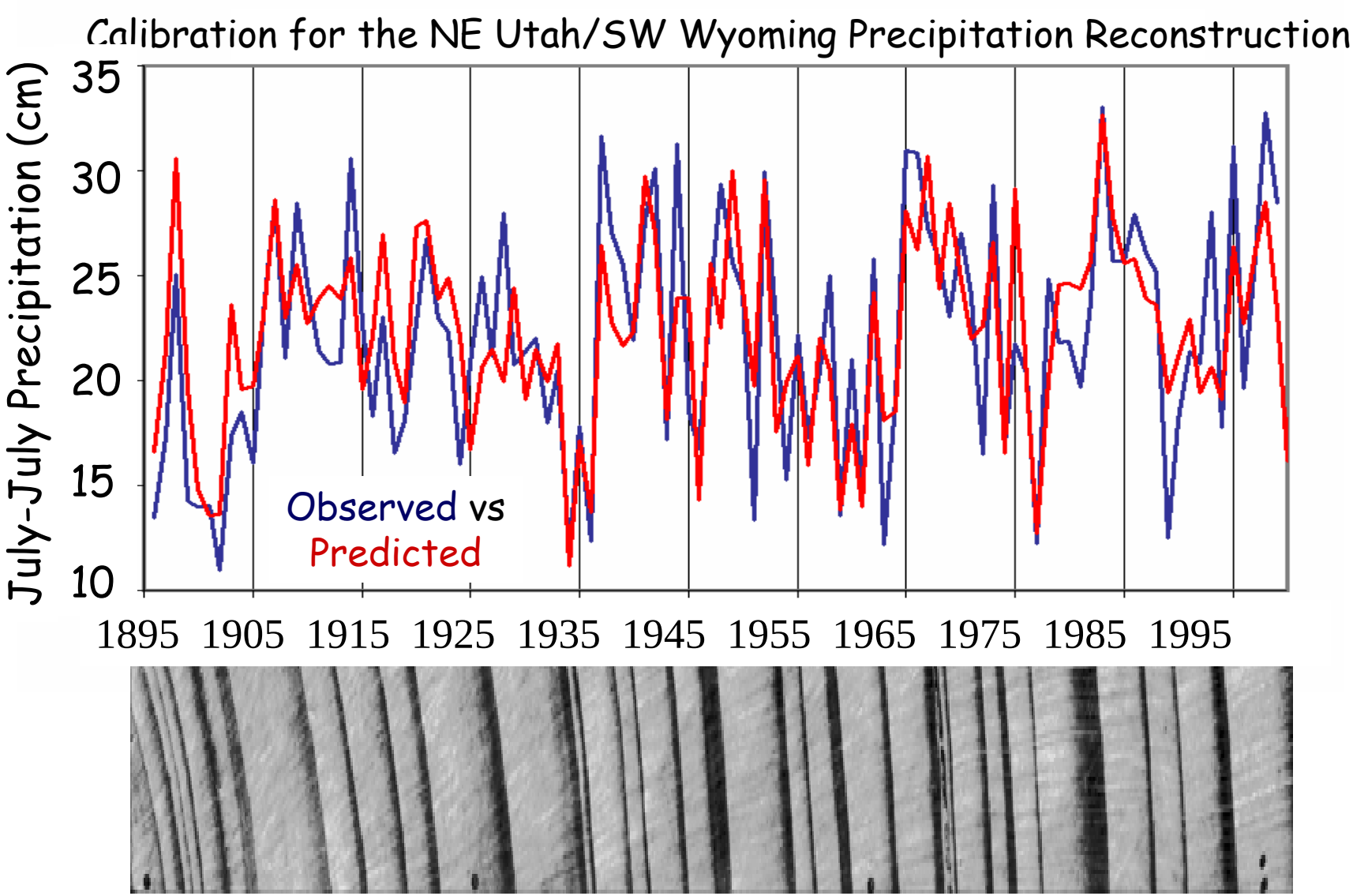
Julio Betancourt, Steve Gray
Greg McCabe, Hugo Hidalgo

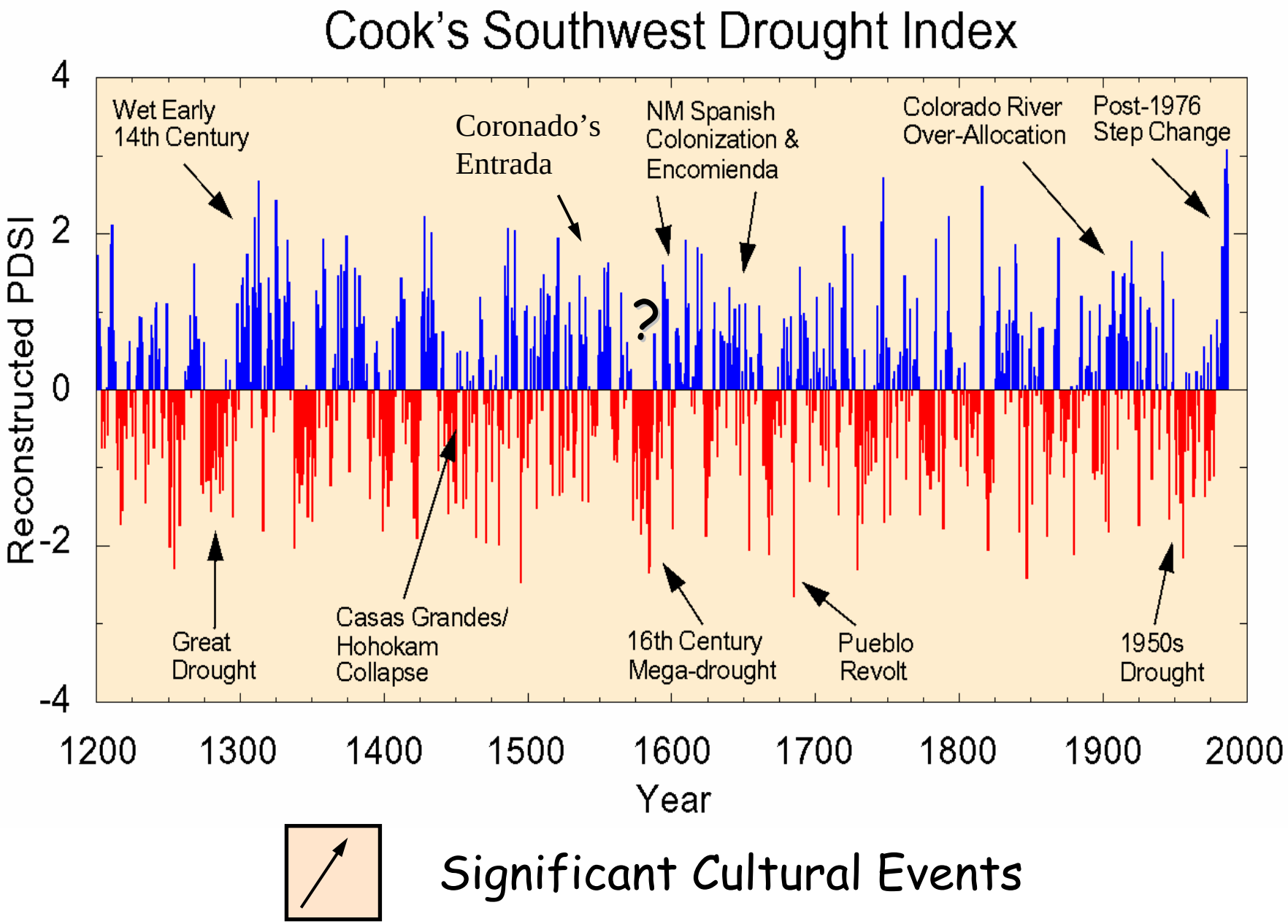


NE Utah Monthly Precipitation 1895-2002



Tree-Ring width series capture both interannual and interdecadal variations in climate



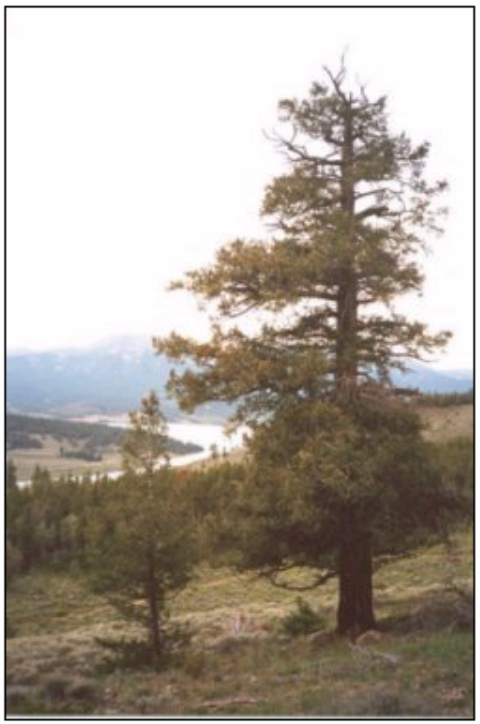

Cook's Southwest Drought Index
Reconstructed PDSI
4
2
0
-2
-4
Wet Early
14th Century
Coronado's
Entrada
NM Spanish
Colonization &
Encomienda
?
Colorado River
Over-Allocation
Post-1976
Step Change
Great
Drought
Casas Grandes/
Hohokam
Collapse
16th Century
Mega-drought
Pueblo
Revolt
1950s
Drought
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year
Significant Cultural Events

TreeFlow

Tree-ring reconstructions of streamflow for Colorado

Connie Woodhouse

www.ncdc.noaa.gov/paleo/streamflow

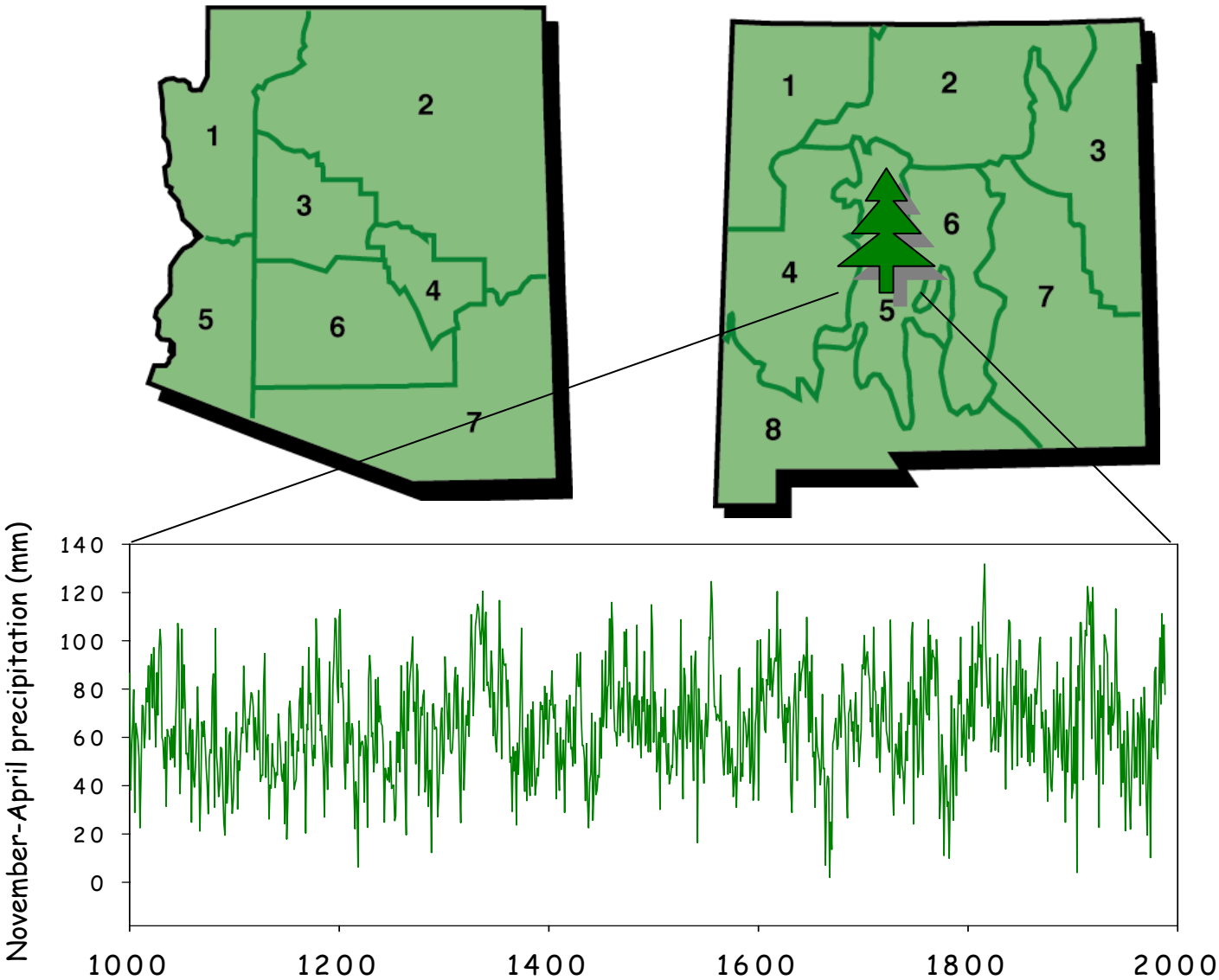


A 660 year old Douglas fir stands just east

Annual tree growth at lower elevations in Colorado is closely correlated with variations in precipitation, snowpack, streamflow, and drought indices. Thus, tree rings can be used to reconstruct records of these hydroclimatic variables for the past 300 to 750 years, or longer. With the *TreeFlow* project, we seek to develop new hydroclimatic

Ni, Cavazos, Hughes, Comrie & Funkhouser (2002)

http://www.ngdc.noaa.gov/paleo/



The North American Drought Atlas

A 2,005 Year History of Drought, Reconstructed from Long Annual Tree-Ring Chronologies

Contains:

1. 2,005 Annual Maps
2. 286 Grid-Point Plots
3. 2,005 Year Animation
4. Data and Images
5. Methodology
6. Browser Setup

Acknowledgement:
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Conditions for use:
All figures and data within are available for responsible reproduction and use.

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Version 1.0

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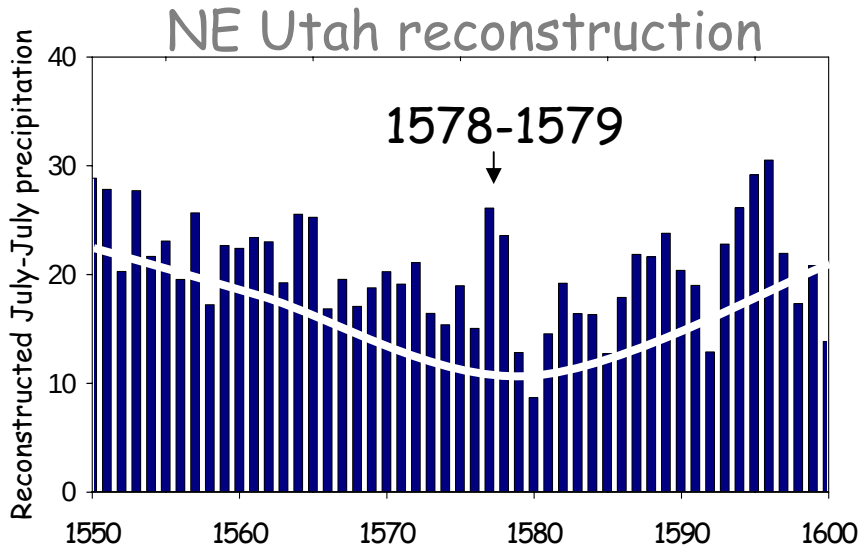
http://www.ngdc.noaa.gov/paleo/

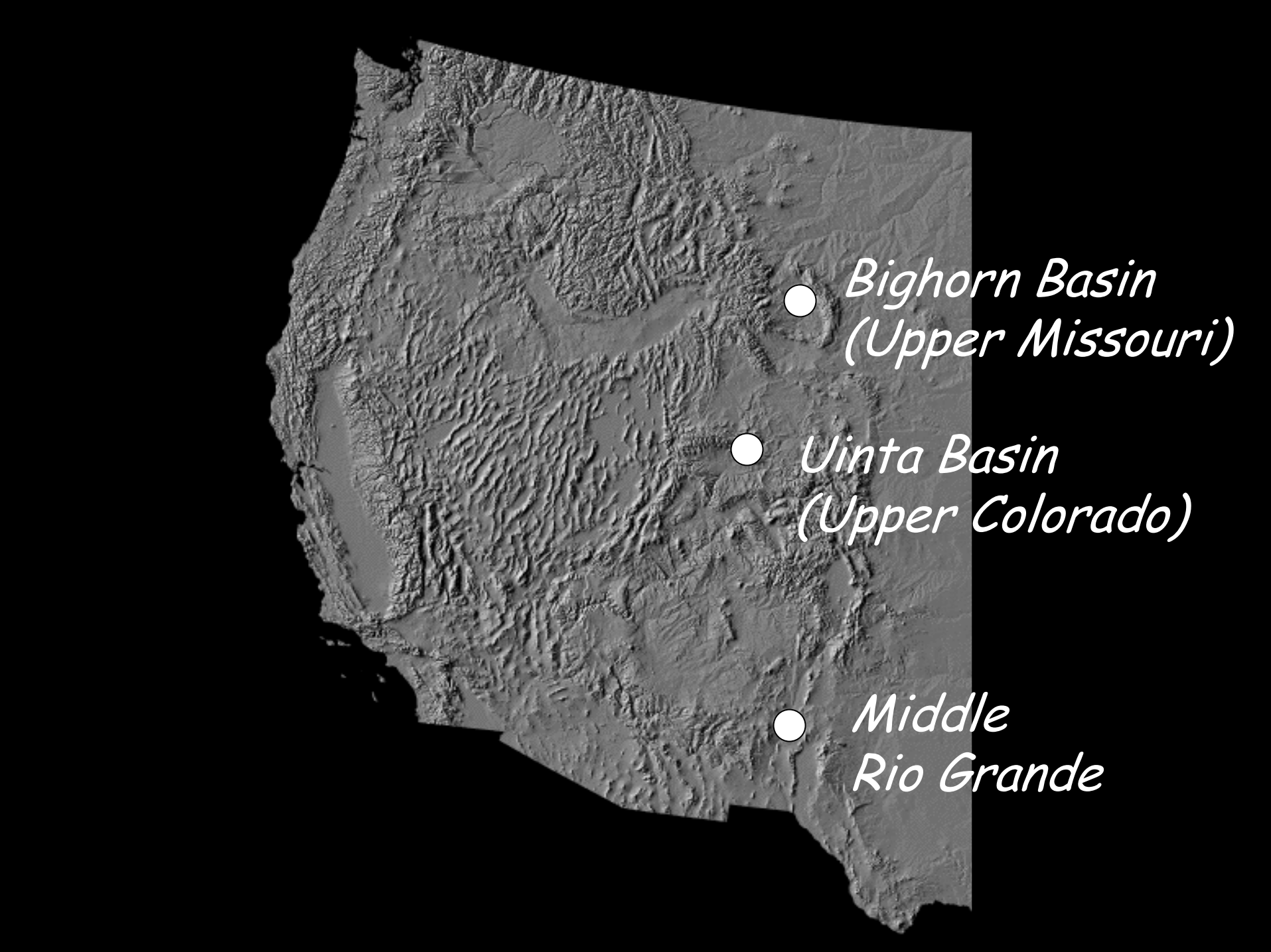
Some applications of tree-ring data towards understanding drought

- structure of droughts
- how representative is instrumental record?
- worst and best-case scenarios for management
- geography of drought
- patterns and sources of synchroneity of decadal to centennial oscillations at regional to subcontinental scales
- temperature reconstructions from upper treeline
- ecological impacts of drought

Use of the tree-ring record to understand structure of droughts

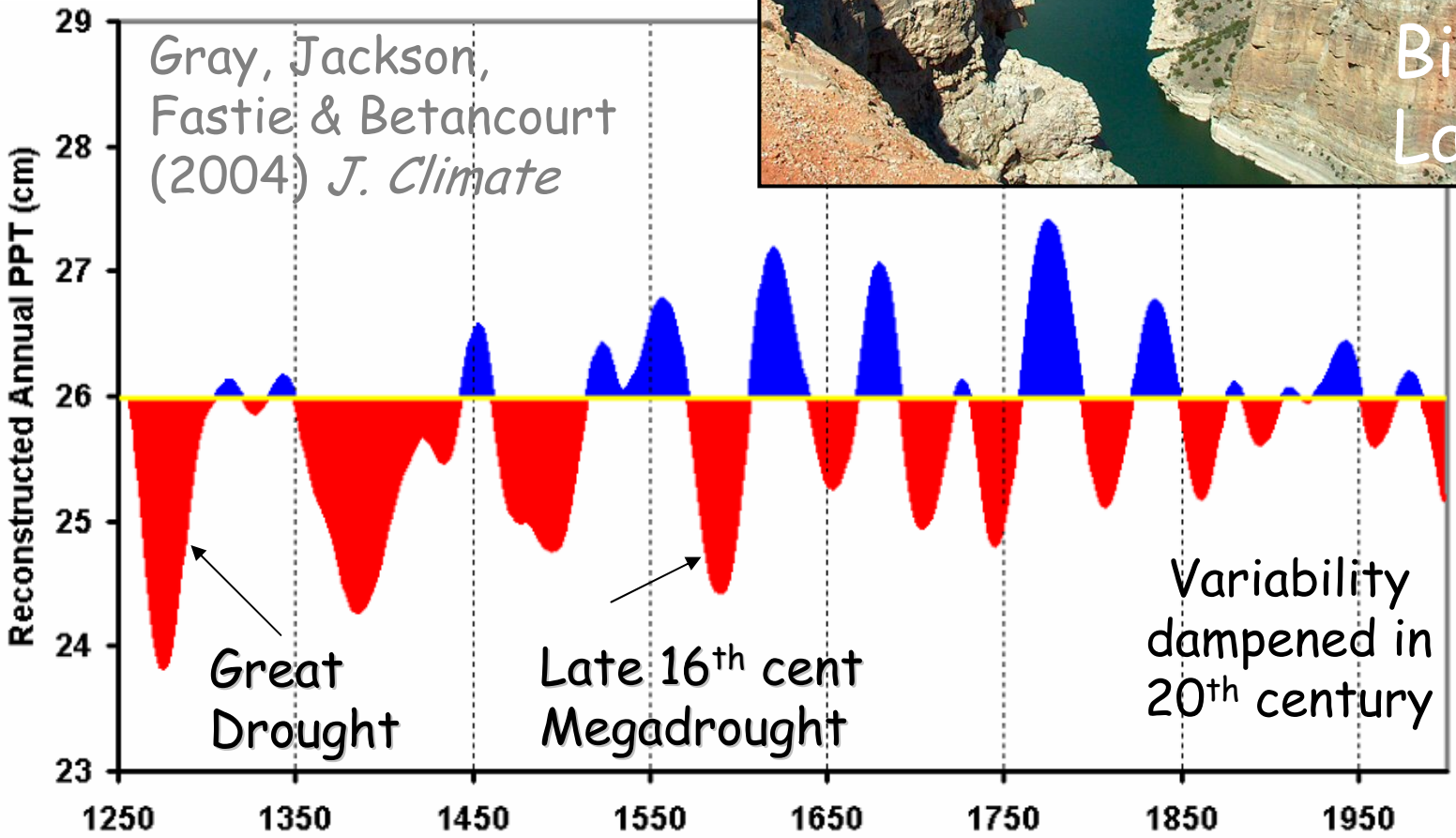


We tend to celebrate too early, and let a little rain spoil our resolve


Bighorn Basin
(Upper Missouri)
Uinta Basin
(Upper Colorado)
Middle
Rio Grande

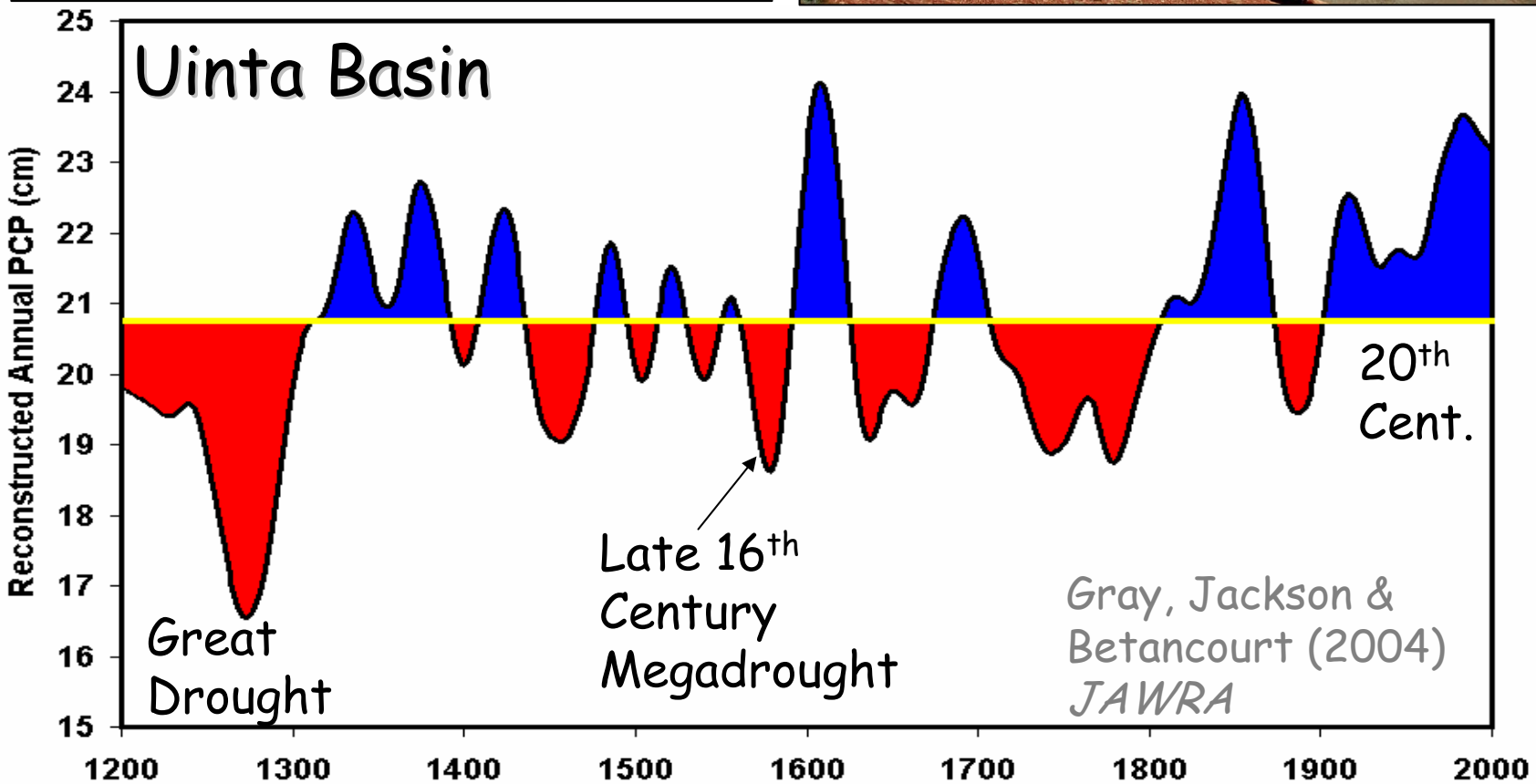
Bighorn River Basin

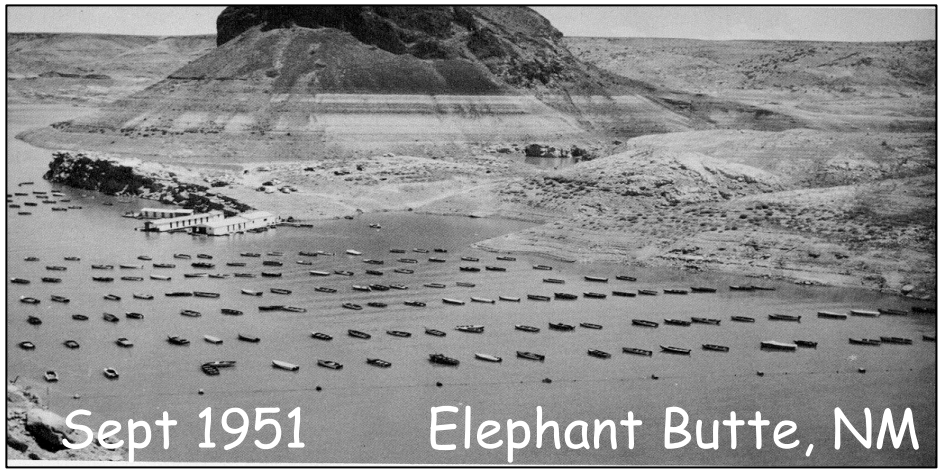
30% of Yellowstone R. contribution to Upper Missouri River




Lake Powell Delta
June 02

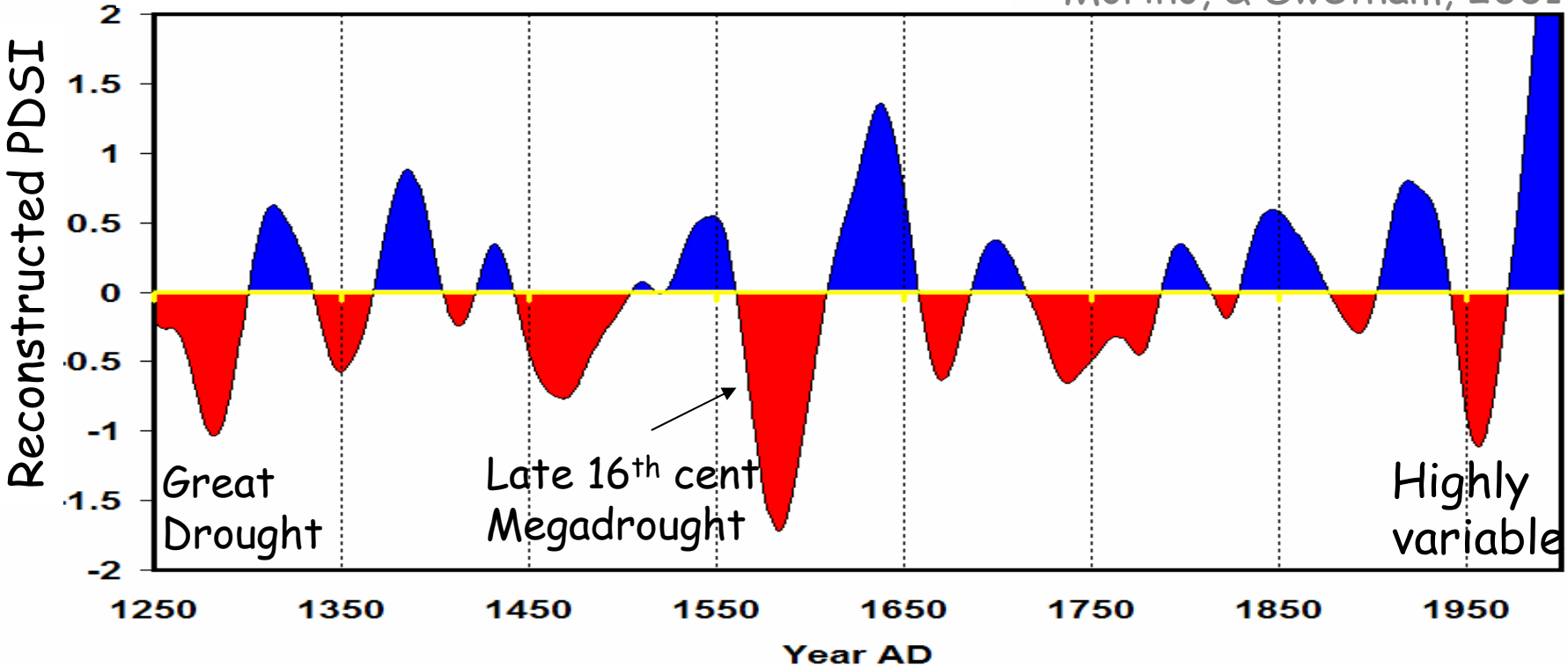

March 03


Uinta Basin
Reconstructed Annual PCP (cm)
25
24
23
22
21
20
19
18
17
16
15
1200
1300
1400
1500
1600
1700
1800
1900
2000
20th Cent.
Late 16th Century Megadrought
Great Drought
Gray, Jackson & Betancourt (2004) JAWRA



Middle Rio Grande Basin, NM AD

Grissino-Mayer, Baisan, Morino, & Swetnam, 2001



Worst Case Scenarios for Water & Land Managers

Uinta Basin
(Upper Colorado)
AD 1226-2001

Gray, Jackson, &
Betancourt (2004)

(1) 1250-1288
(2) 1437-1477
(3) 1772-1786
(4) 1566-1593
(5) 1625-1640

Central Rio
Grande Basin
AD 622-1992

Grissino-Mayer,Baisan
& Swetnam (2001)

(1) 1571-1593
(2) 1272-1297
(3) 1945-1963
(4) 701-712
(5) 1131-1151

Best Case Scenarios for Water & Land Managers

Uinta Basin
(Upper Colorado)
AD 1226-2001

Gray, Jackson, Betancourt & Eddy (2004)

(1) 1594-1624
(2) 1837-1868
(3) 1965-1987
(4) 1478-1492
(5) 1330-1346

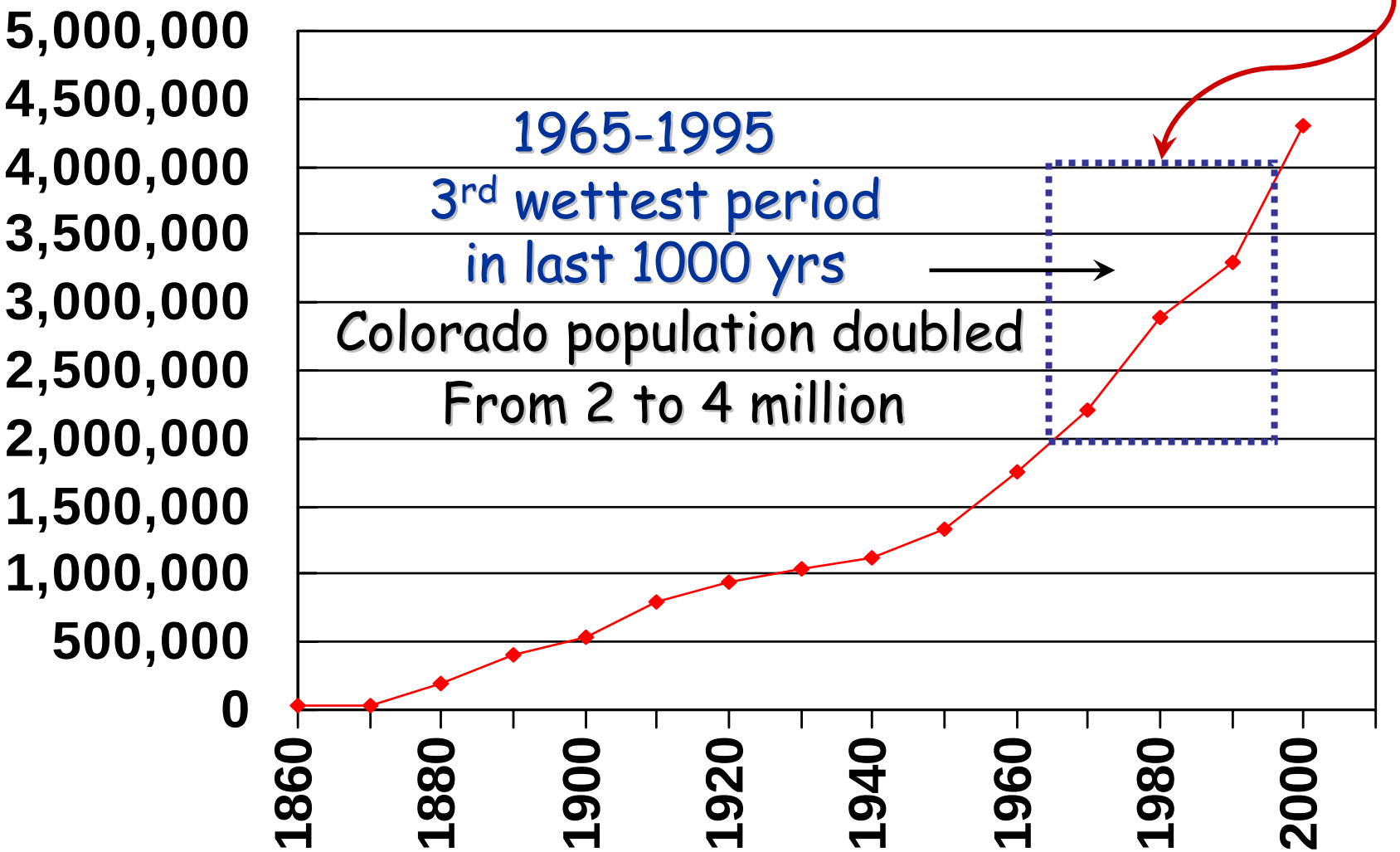
Central Rio Grande Basin
AD 622-1992

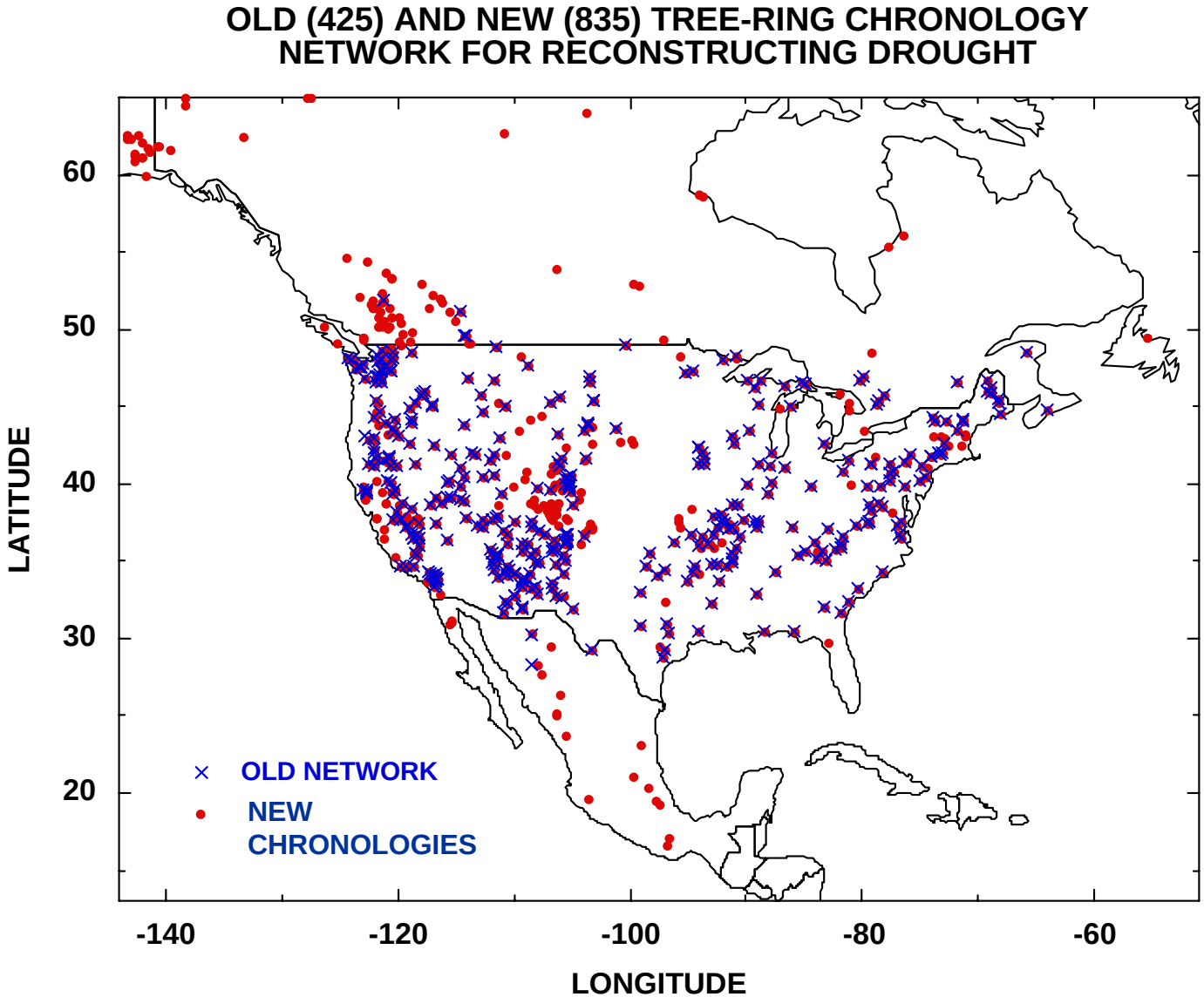
Grissino-Mayer,Baisan & Swetnam (2001)

(1) 1553-1557
(2) 1627-1653
(3) 1978-1992
(4) 724-733
(5) 1377-1396

Population Growth in Colorado

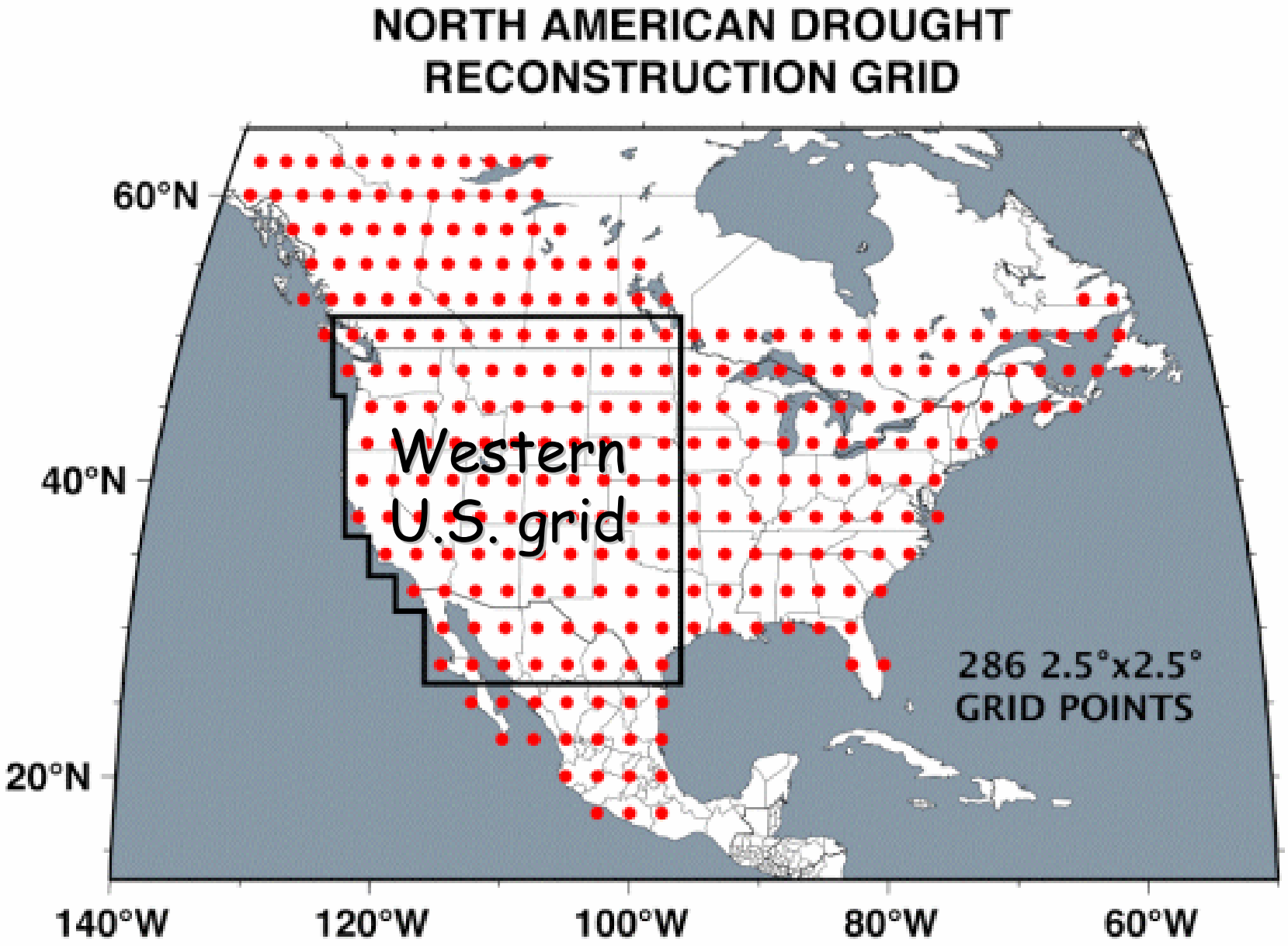
(Should this really be our reference period?)



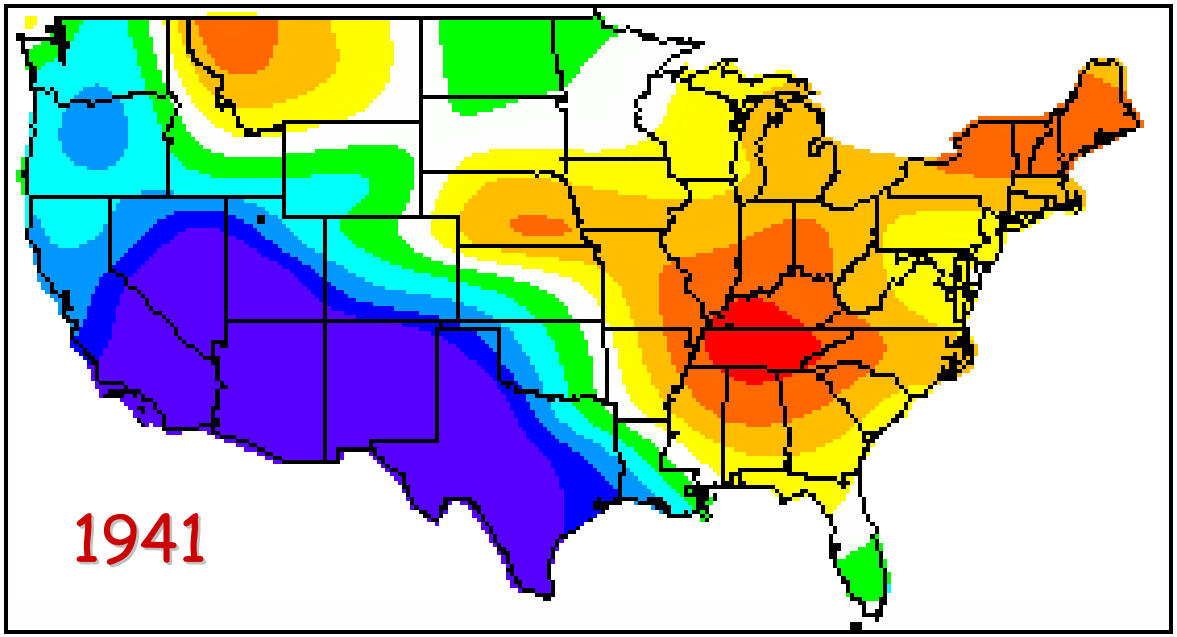


Cook, Meko, Stahle, & Cleaveland (1999) *J. Climate* 1700-2000, http://www.ngdc.noaa.gov/paleo/

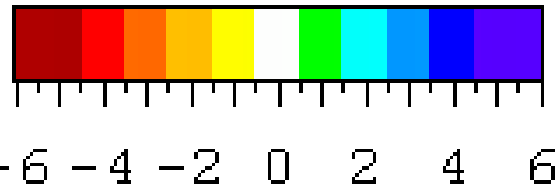
Krusik & Cook (2004) North American Drought Atlas; last 2005 years

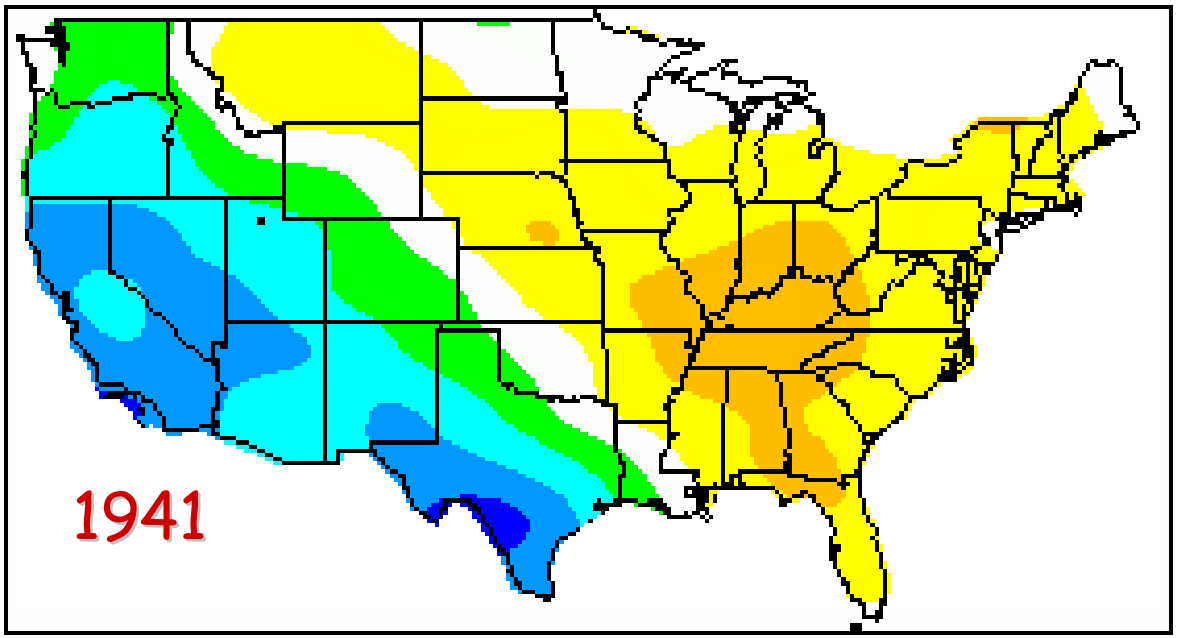


Krusik & Cook (2004) North American Drought Atlas; last 2005 years

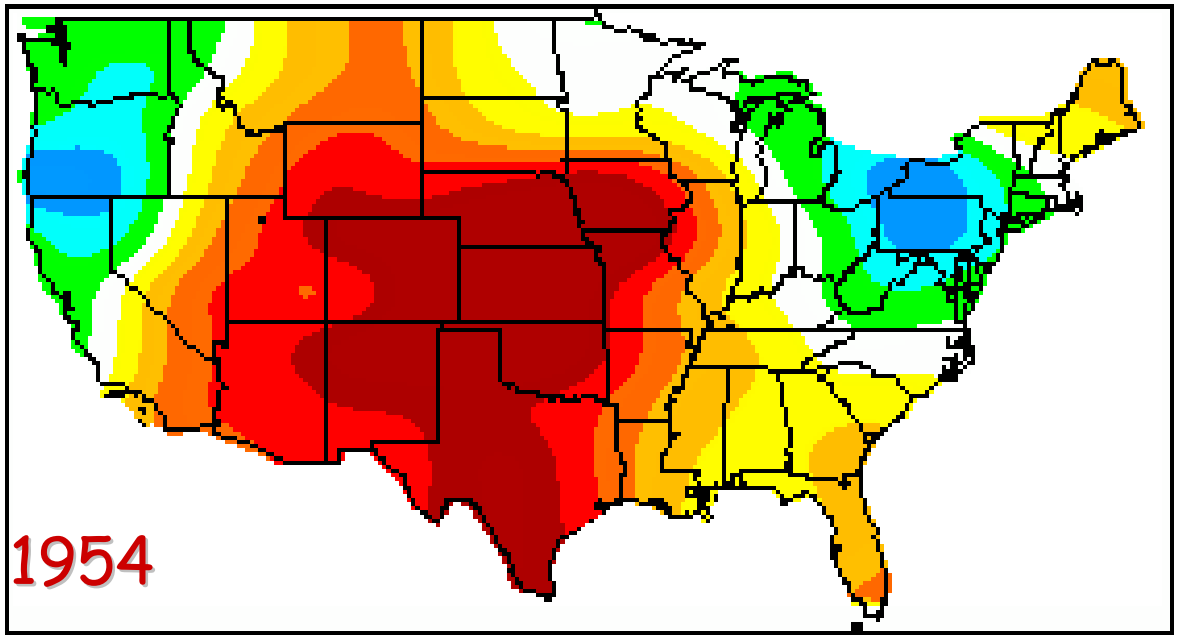


Instrumental

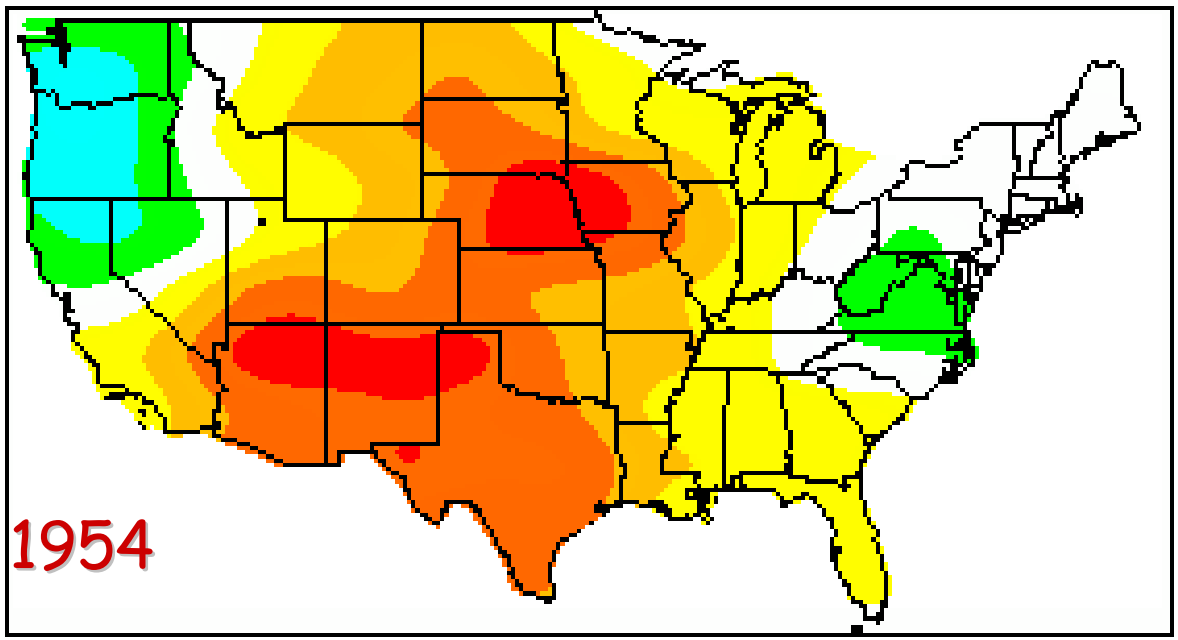


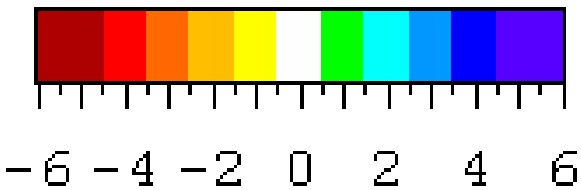


Tree-Ring



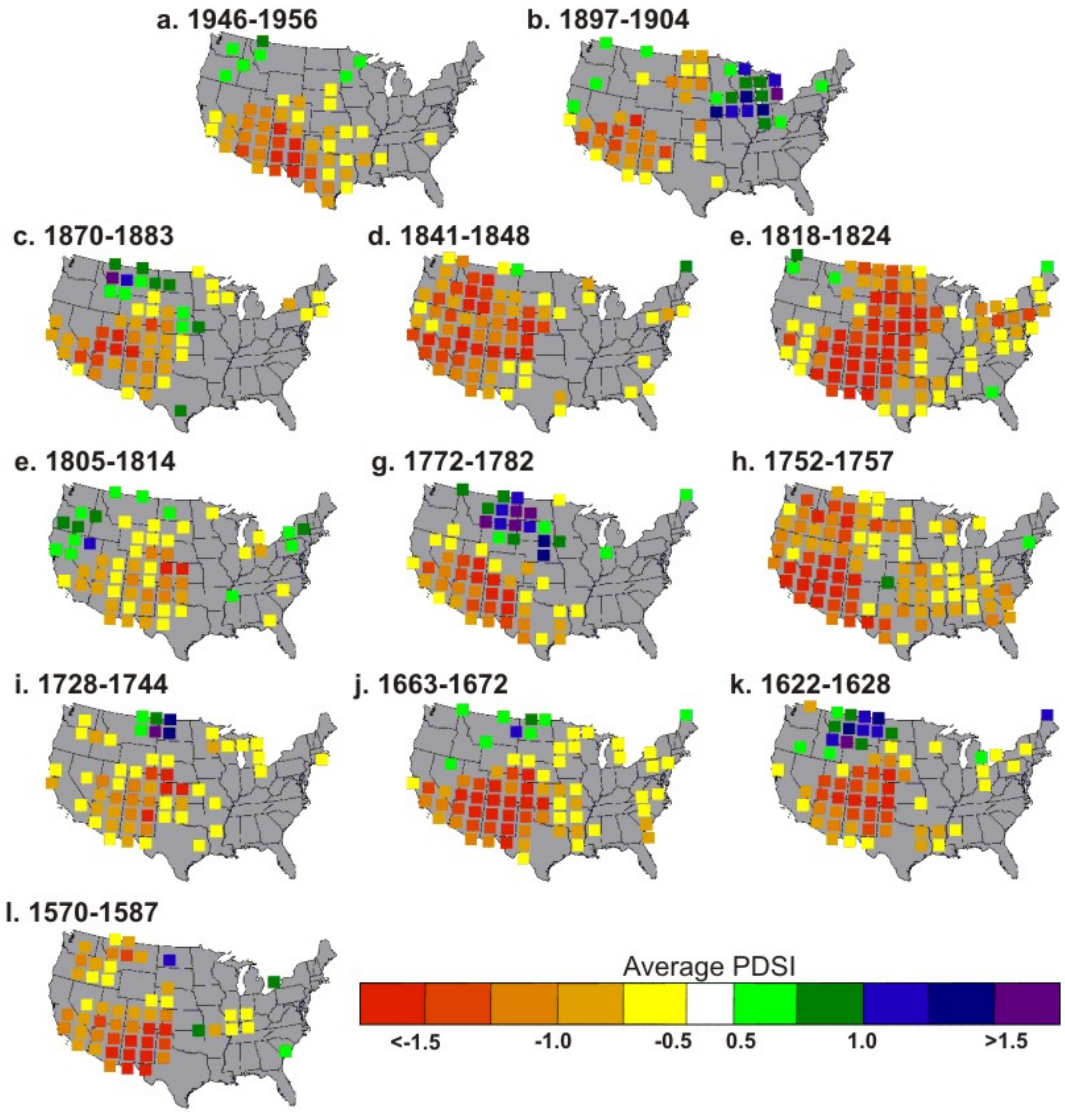
Instrumental



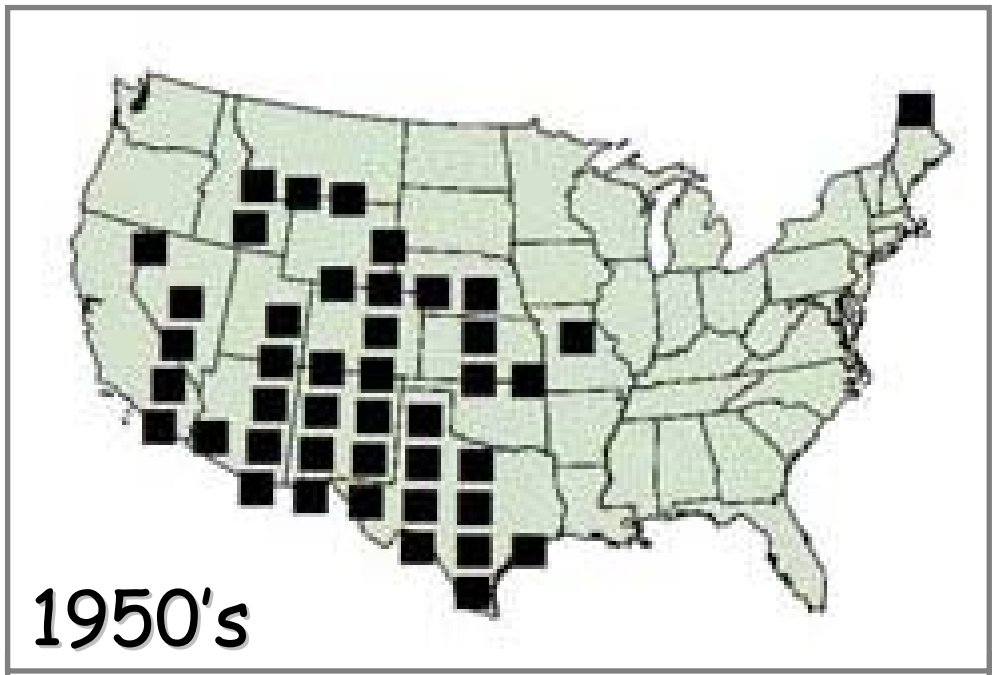


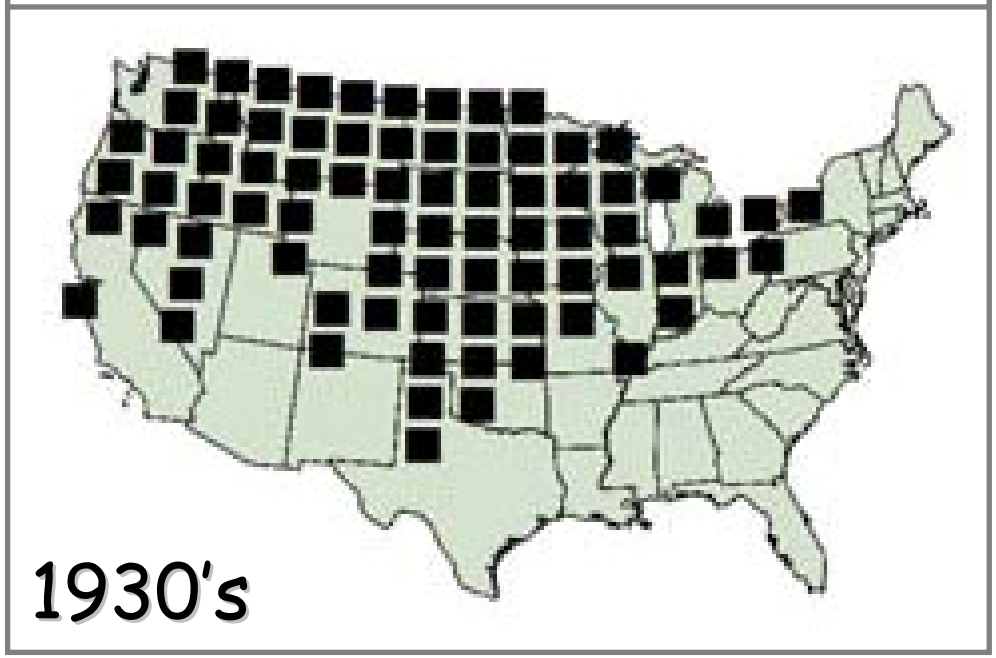
Tree-Ring

Severe Droughts = Widespread Droughts



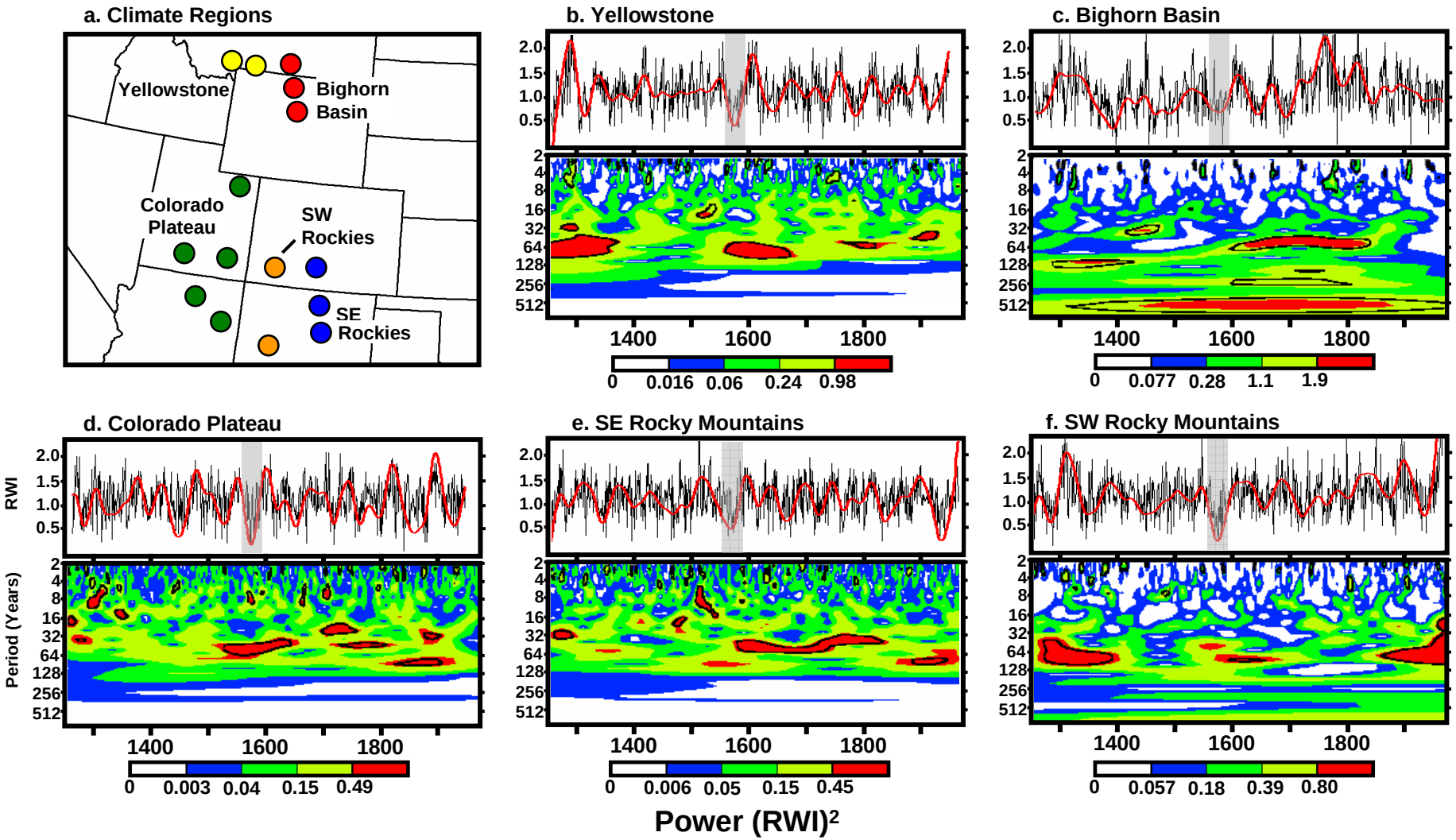
Cook, Meko, Stahle, & Cleaveland (1999)





In Cook *et al.* gridded PDSI reconstructions 1950's-type droughts **6X** more common than 1930's-type droughts

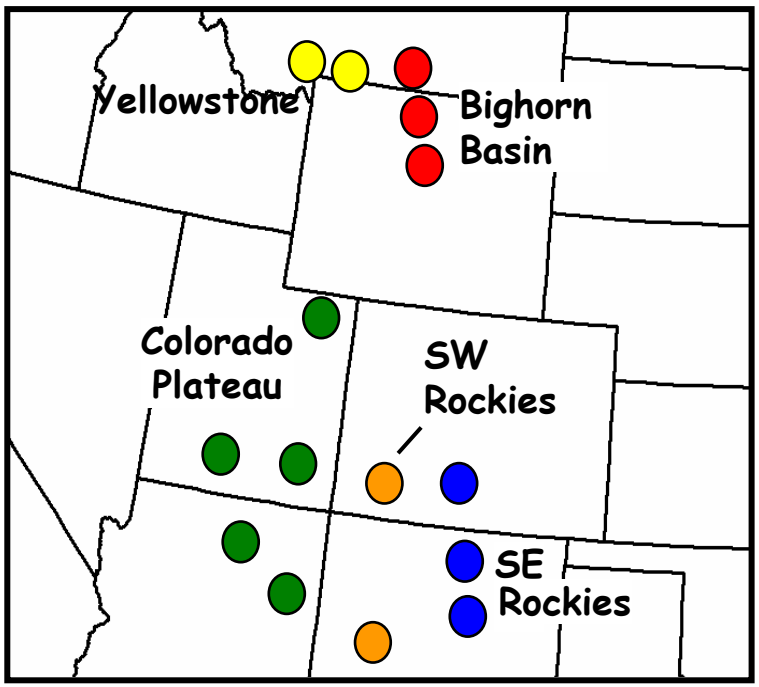
Strong evidence for multidecadal (30-70 yr) persistence and cross-regional synchrony



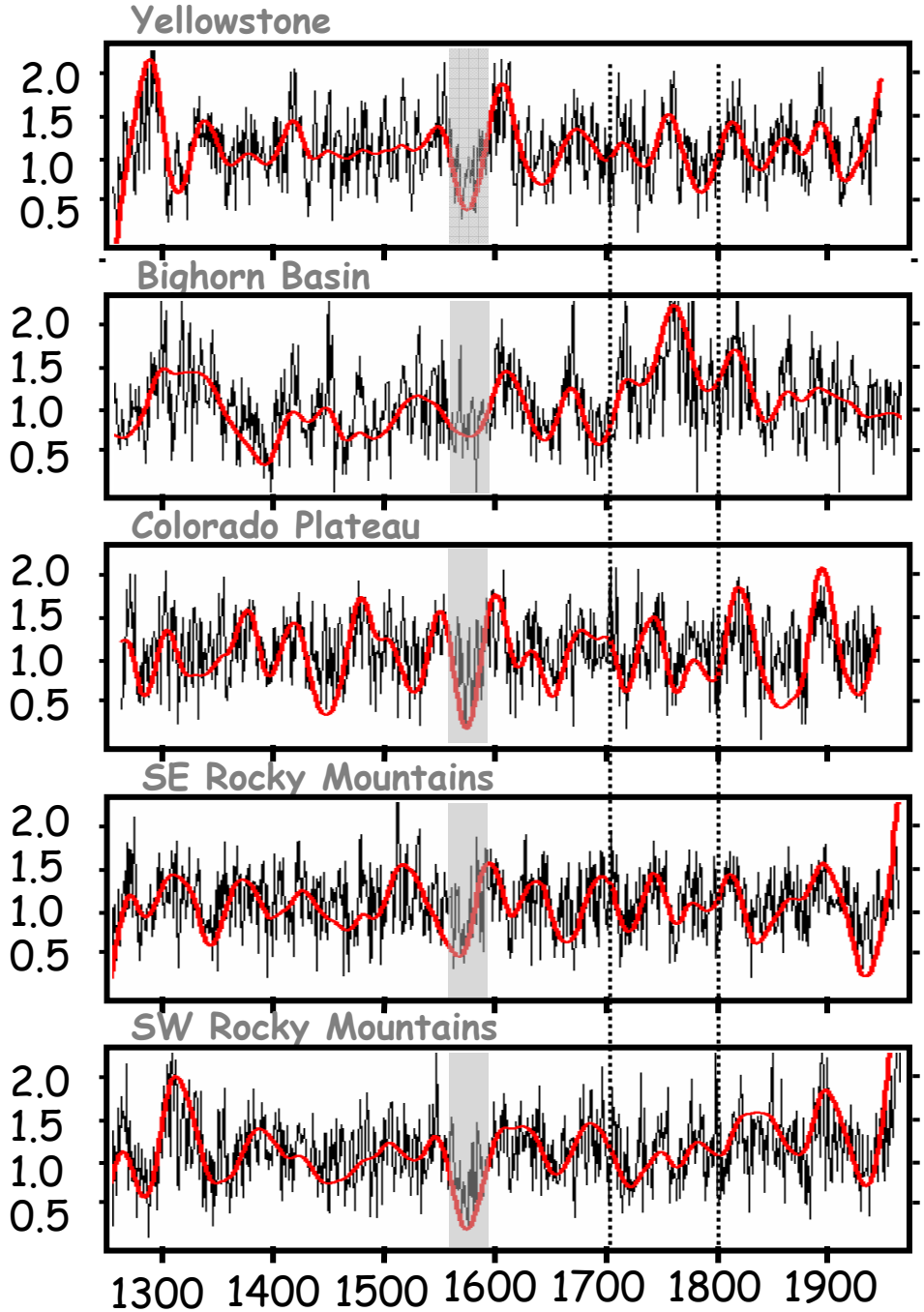
Gray, Betancourt, Fastie, & Jackson (2003) GRL

What causes multidecadal precip variability?

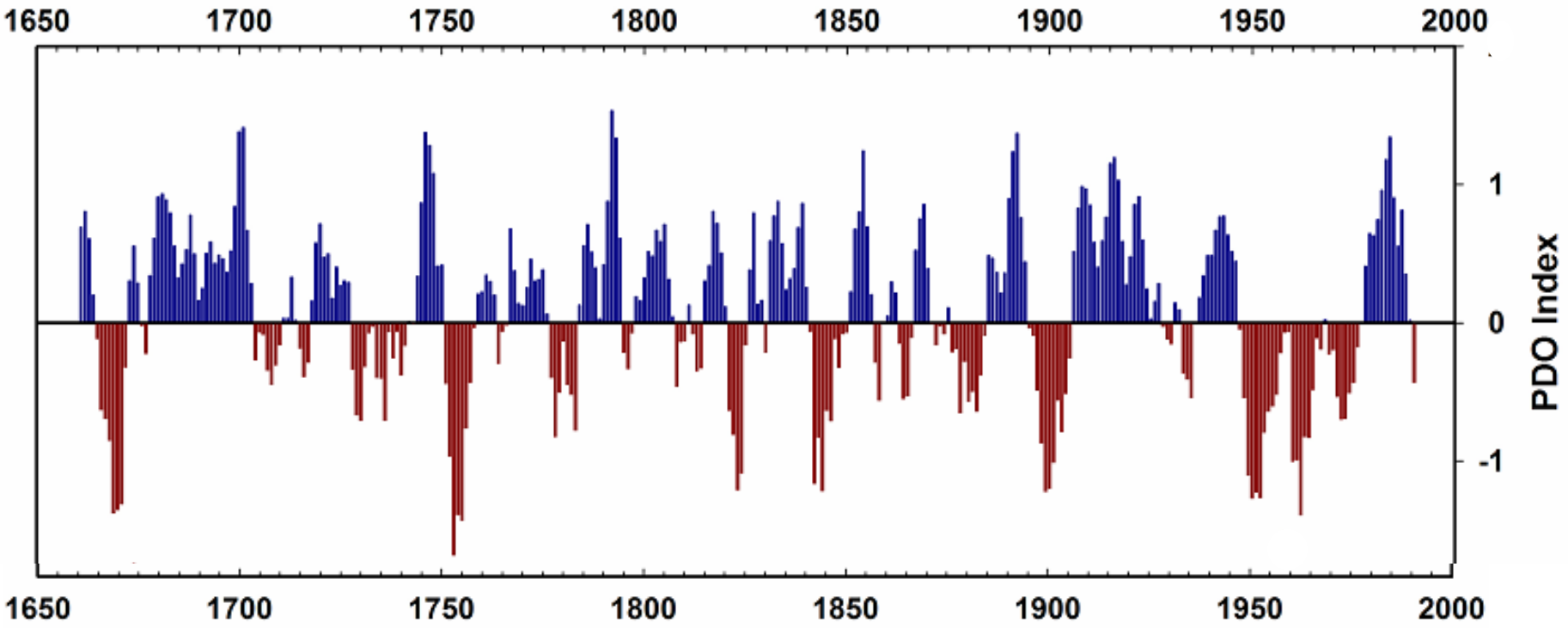
What controls the synchrony across large basins?



Gray, Betancourt, Fastie, & Jackson (2003) *GRL*

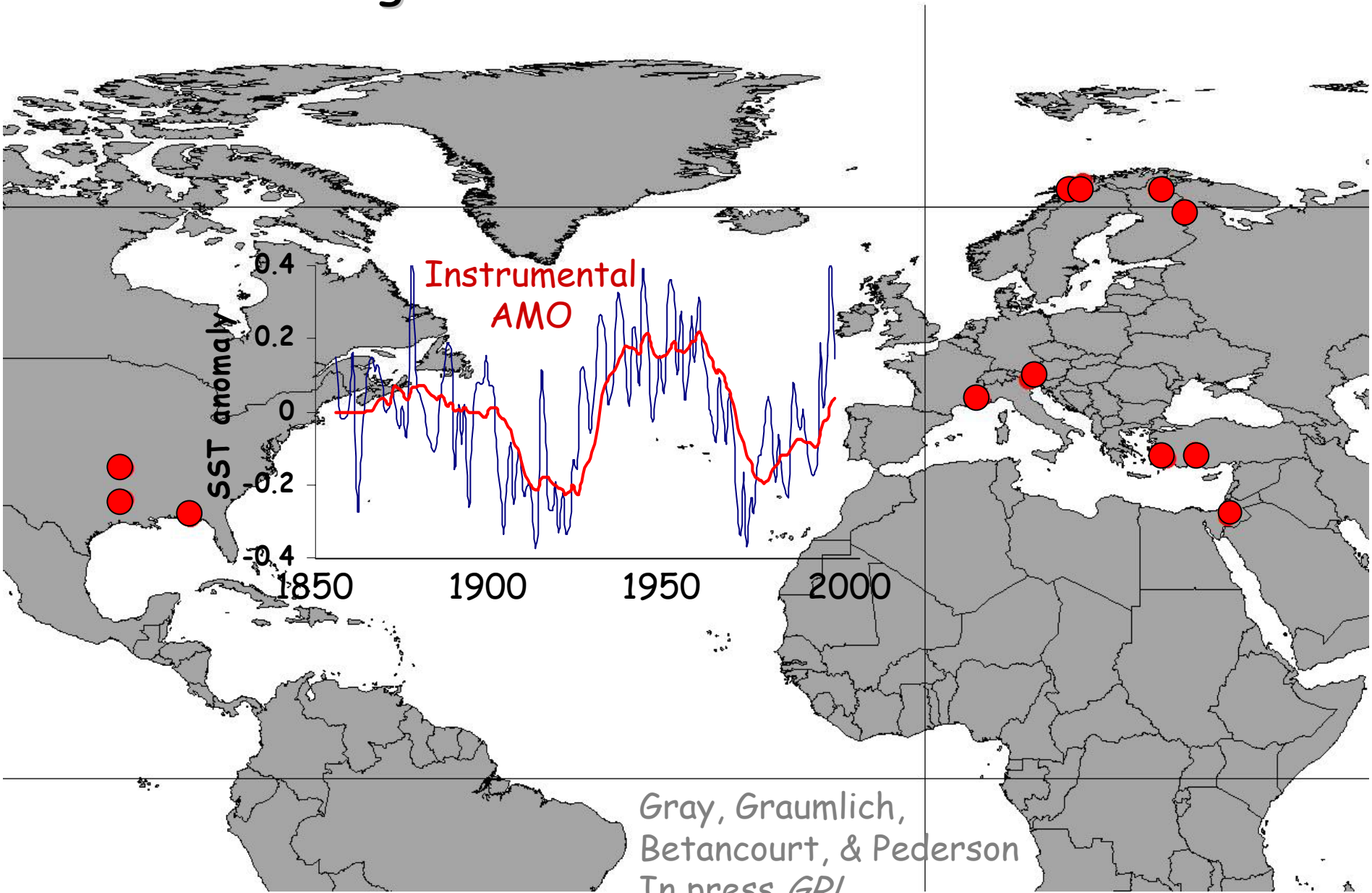


PDO reconstruction from SW USA/N Mexico tree rings

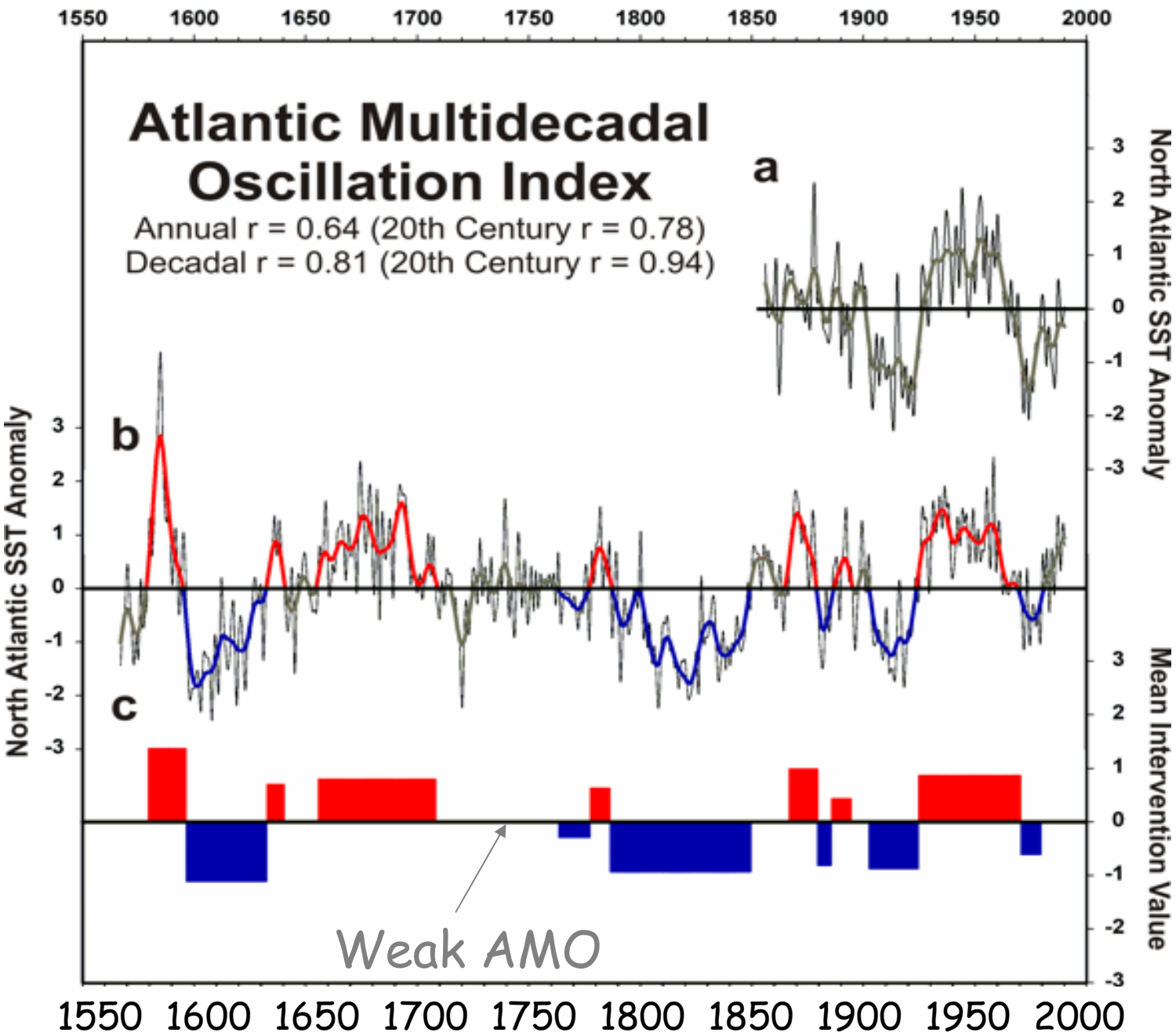


Biondi, Gershunov & Cayan (2001)

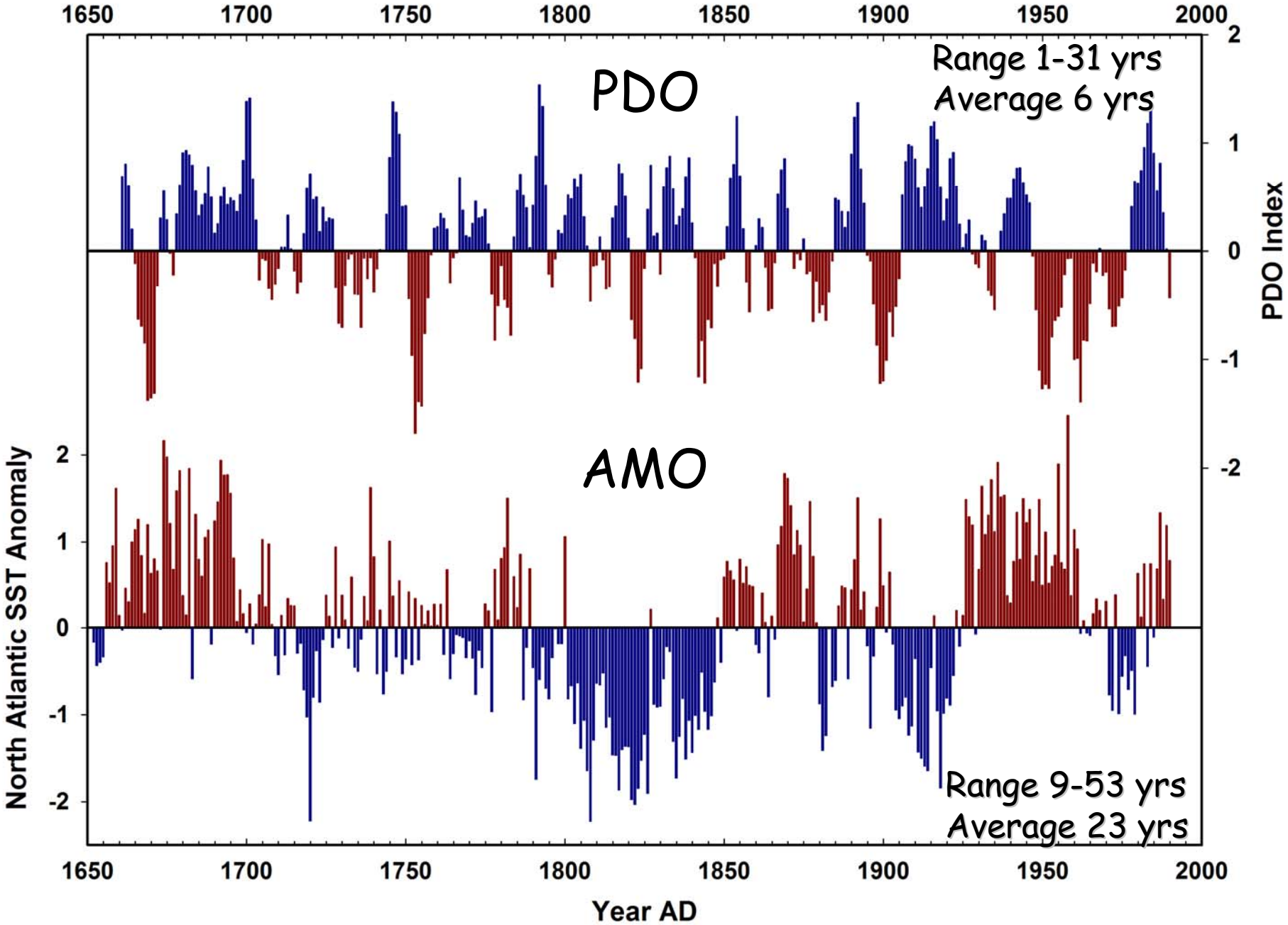
Tree-Ring Sites for AMO Reconstruction



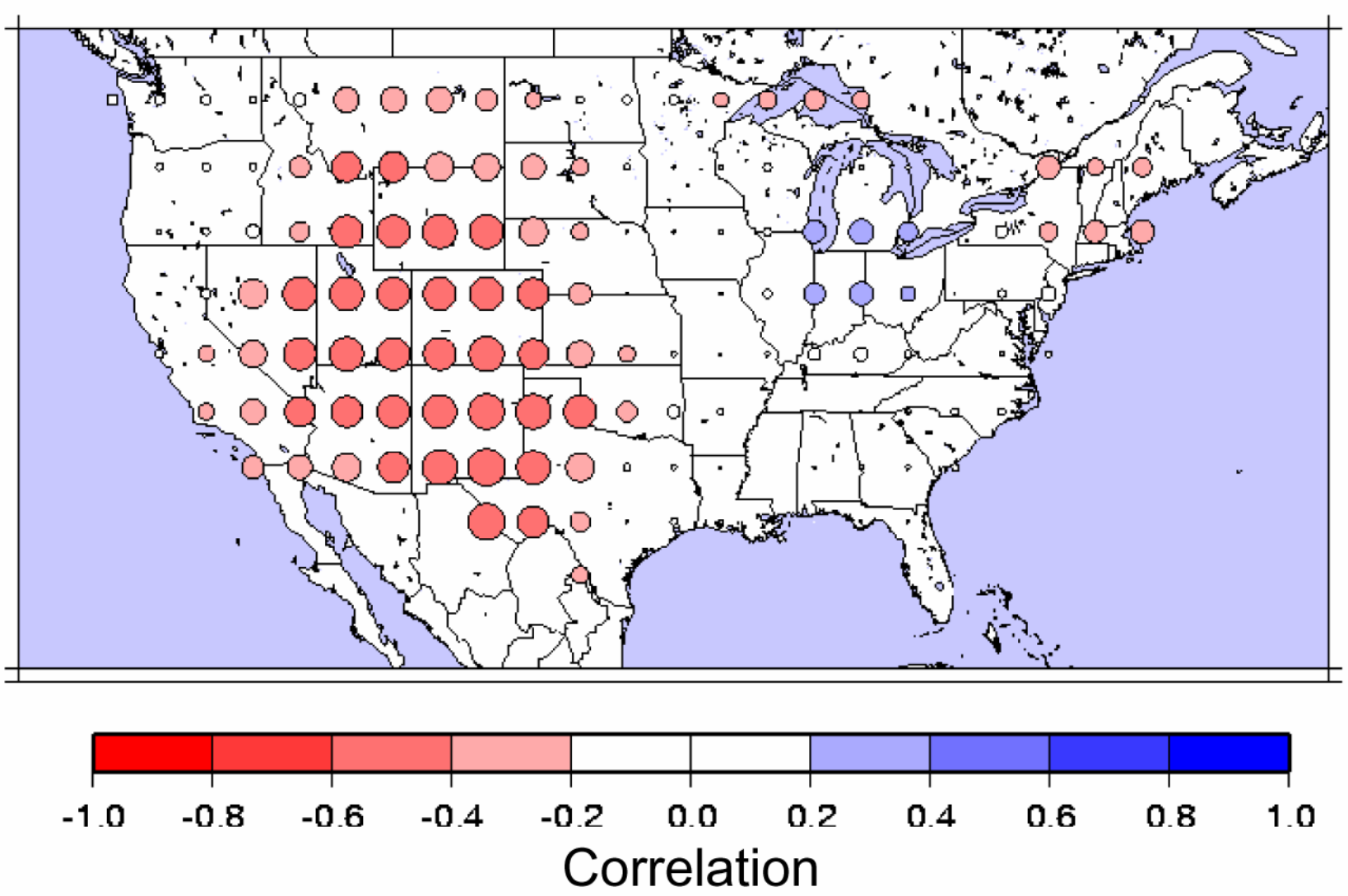
Gray, Graumlich,
Betancourt, & Pederson
In press *GRL*



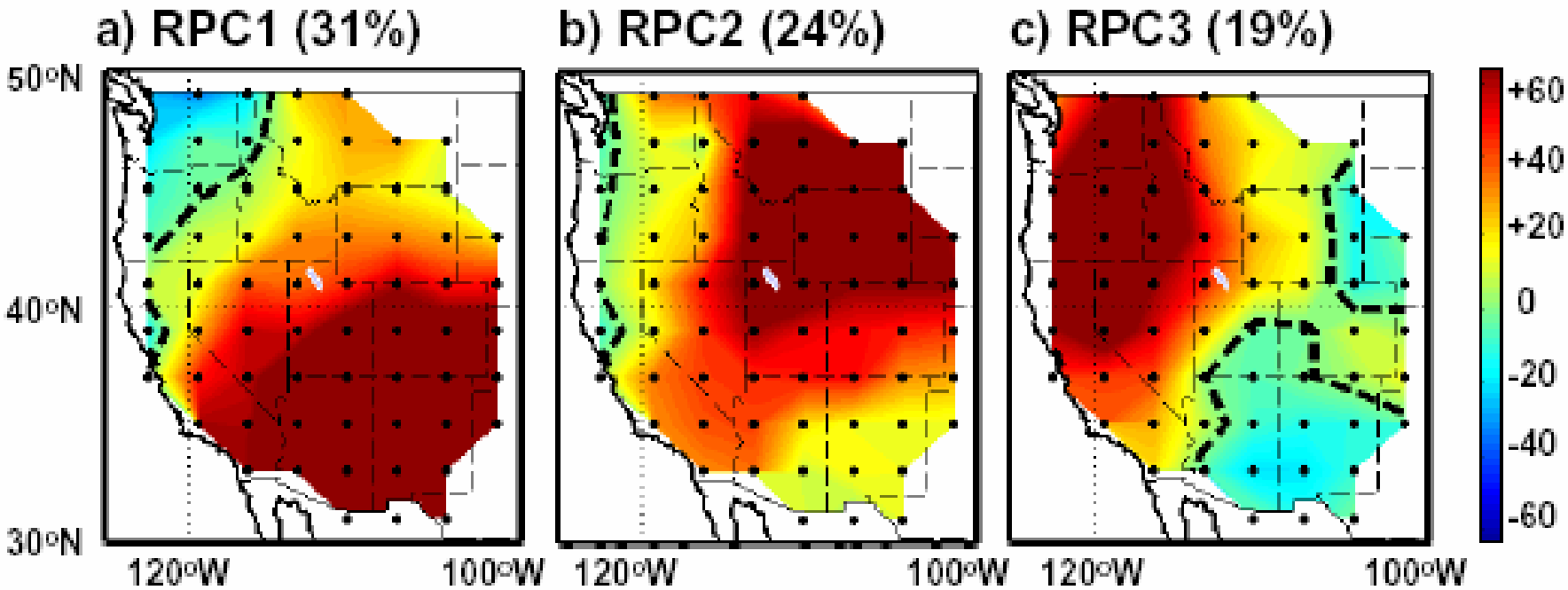
Gray, Graumlich, Betancourt & Pederson, in press *GRL*


PDO
Range 1-31 yrs
Average 6 yrs
AMO
Range 9-53 yrs
Average 23 yrs
PDO Index
North Atlantic SST Anomaly
Year AD
1650
1700
1750
1800
1850
1900
1950
2000
2
1
0
-1
-2

20-yr moving average of PDSI reconstructions Vs. 20-yr moving average of AMO 1567-1900



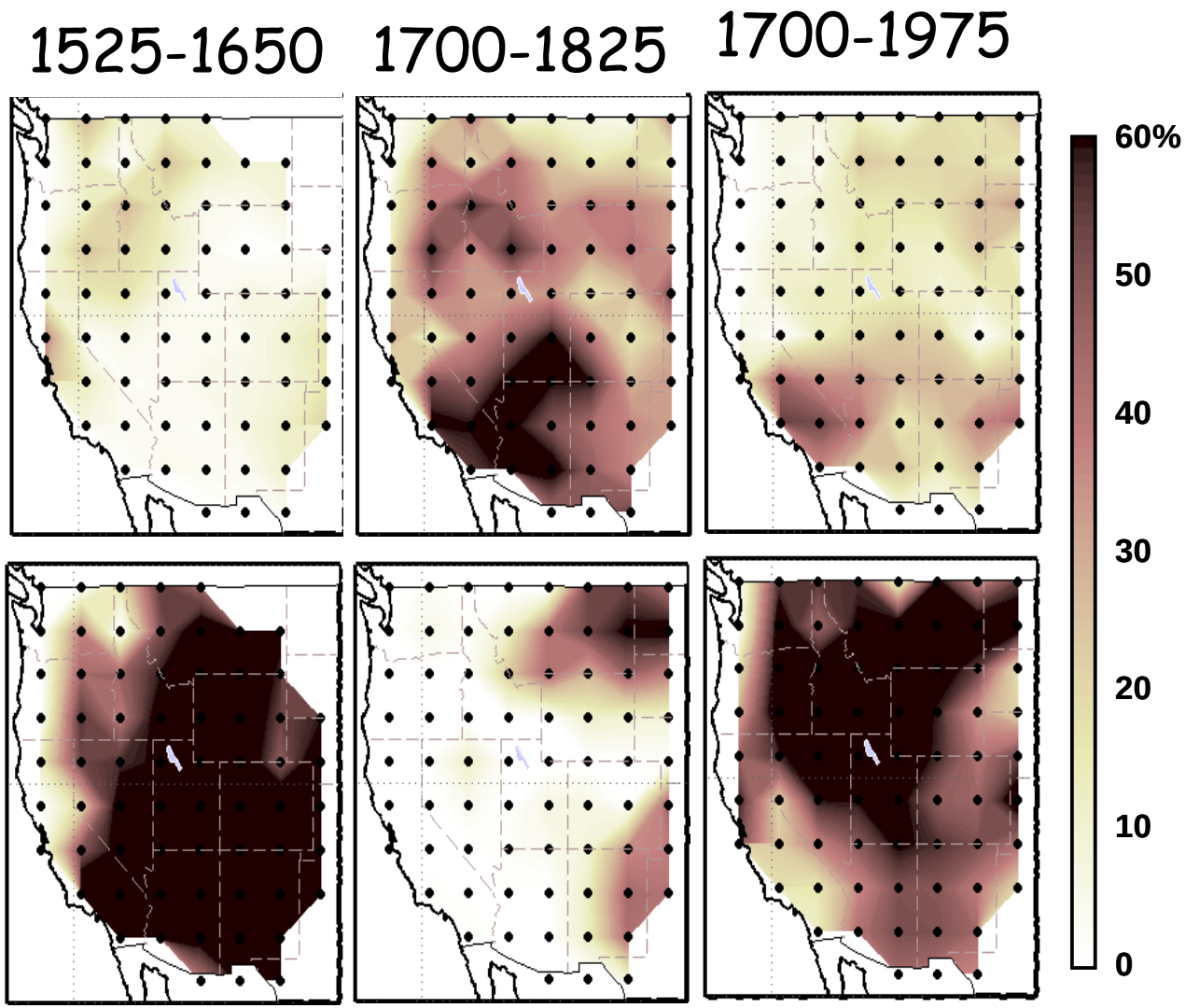
PCA of 20-yr smoothed, reconstructed PDSI 1536-1967



=PDO =AMO =ENSO

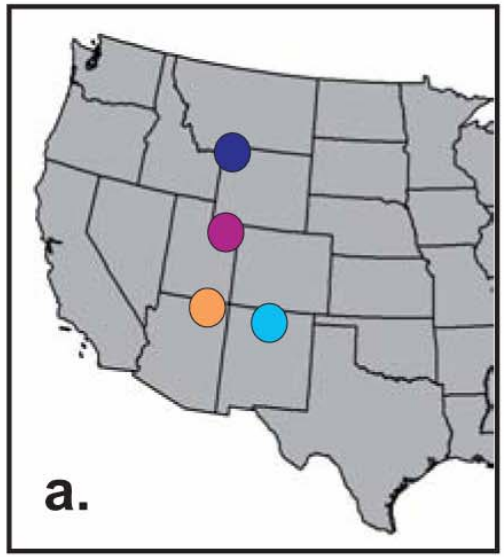
Hidalgo (2004) *WRR*

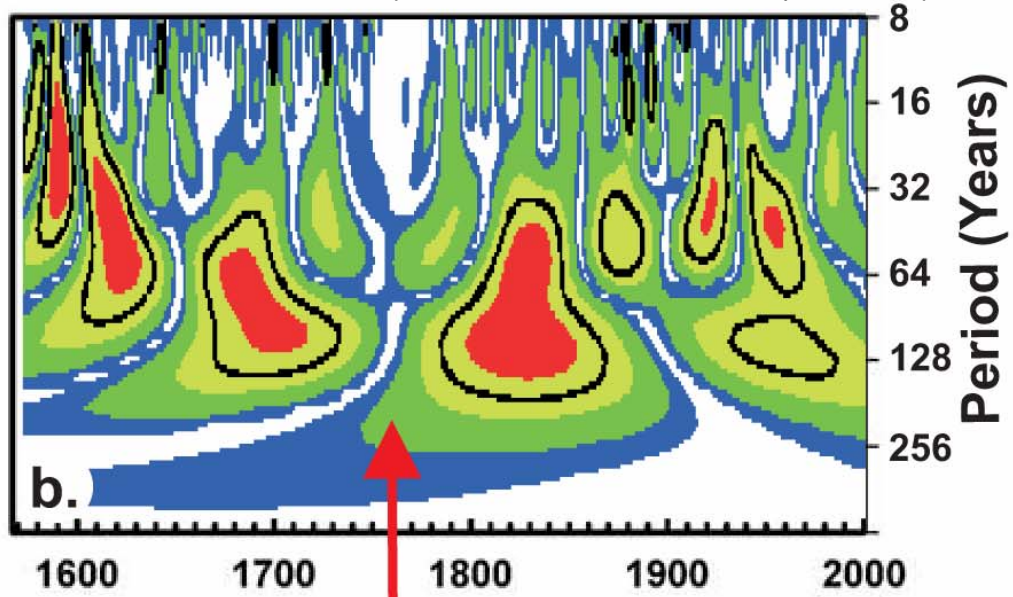
Percentage of total power present at bidecadal and multidecadal bands in gridded PDSI tree-ring reconstructions

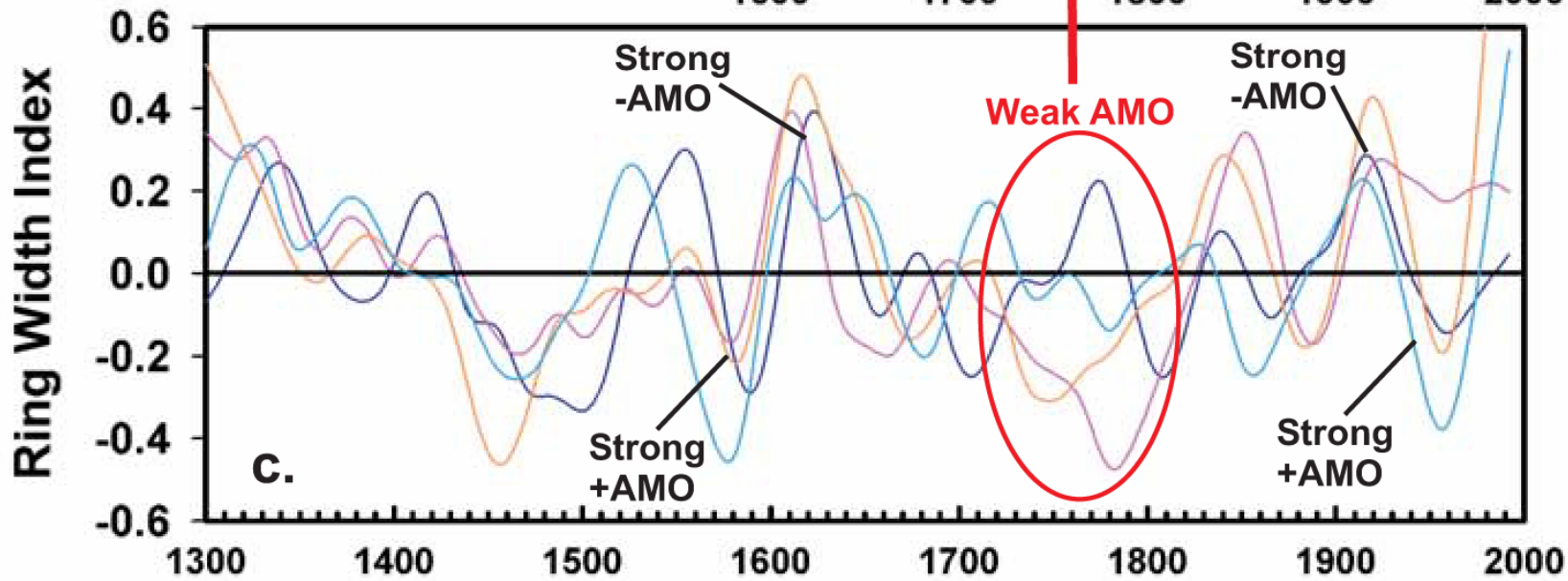


Hidalgo 2004
WRR

Tree-ring regions Wavelet analysis of AMO proxy

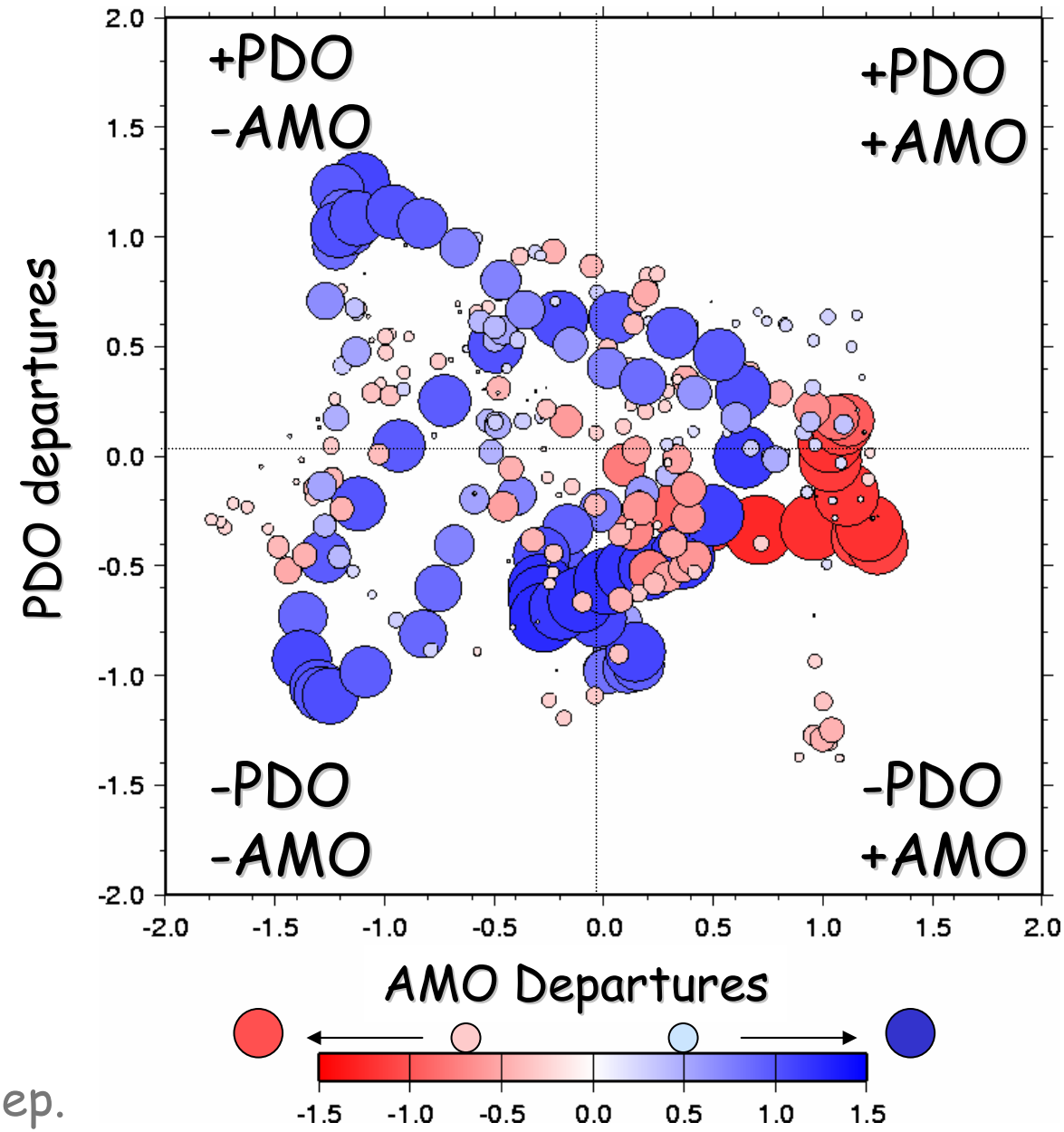




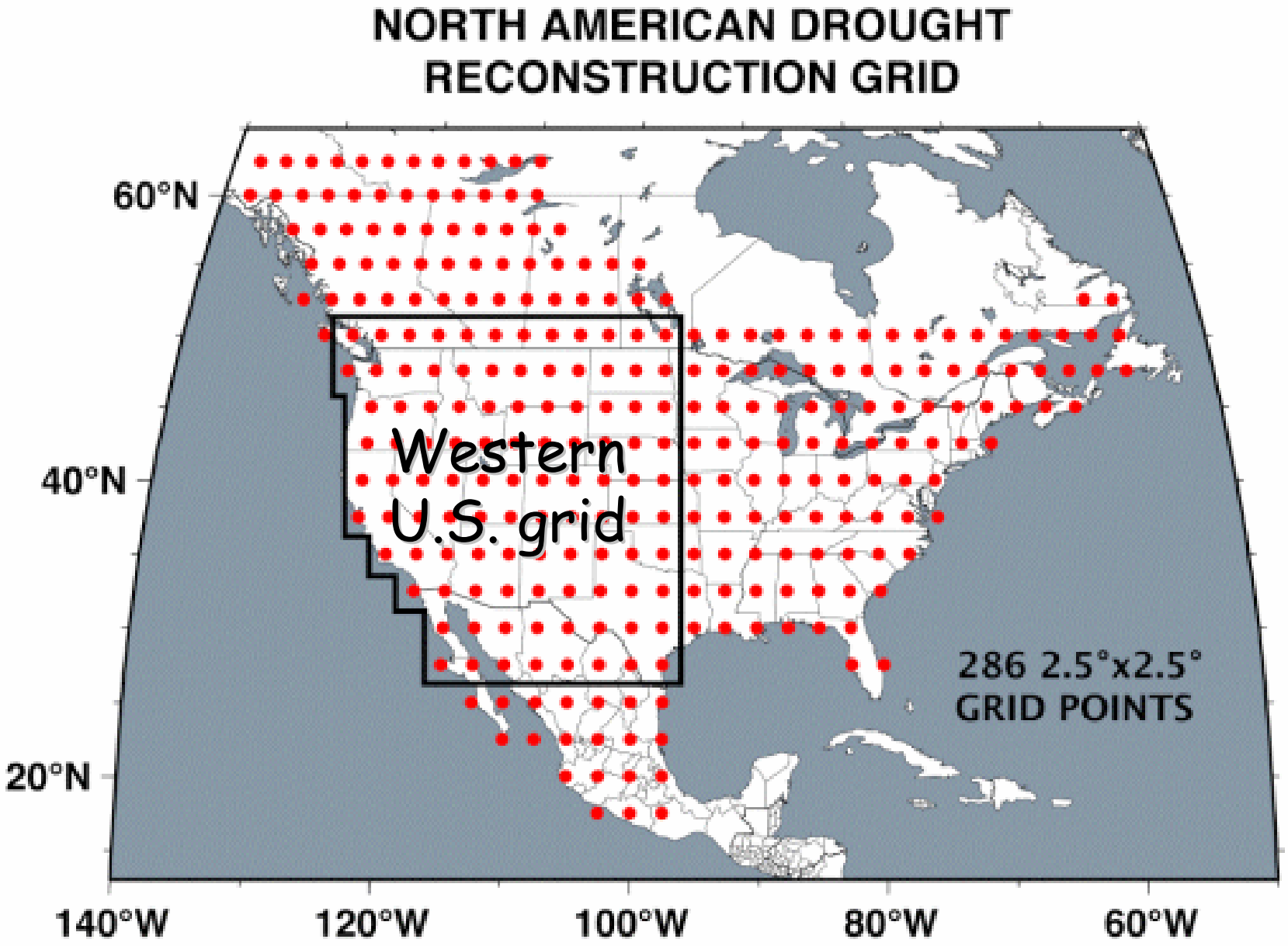


Gray, Graumlich, Betancourt & Pederson, in prep

11-yr moving departures of annual PDO, AMO & Colorado River streamflow at Lee's Ferry 1661-1961

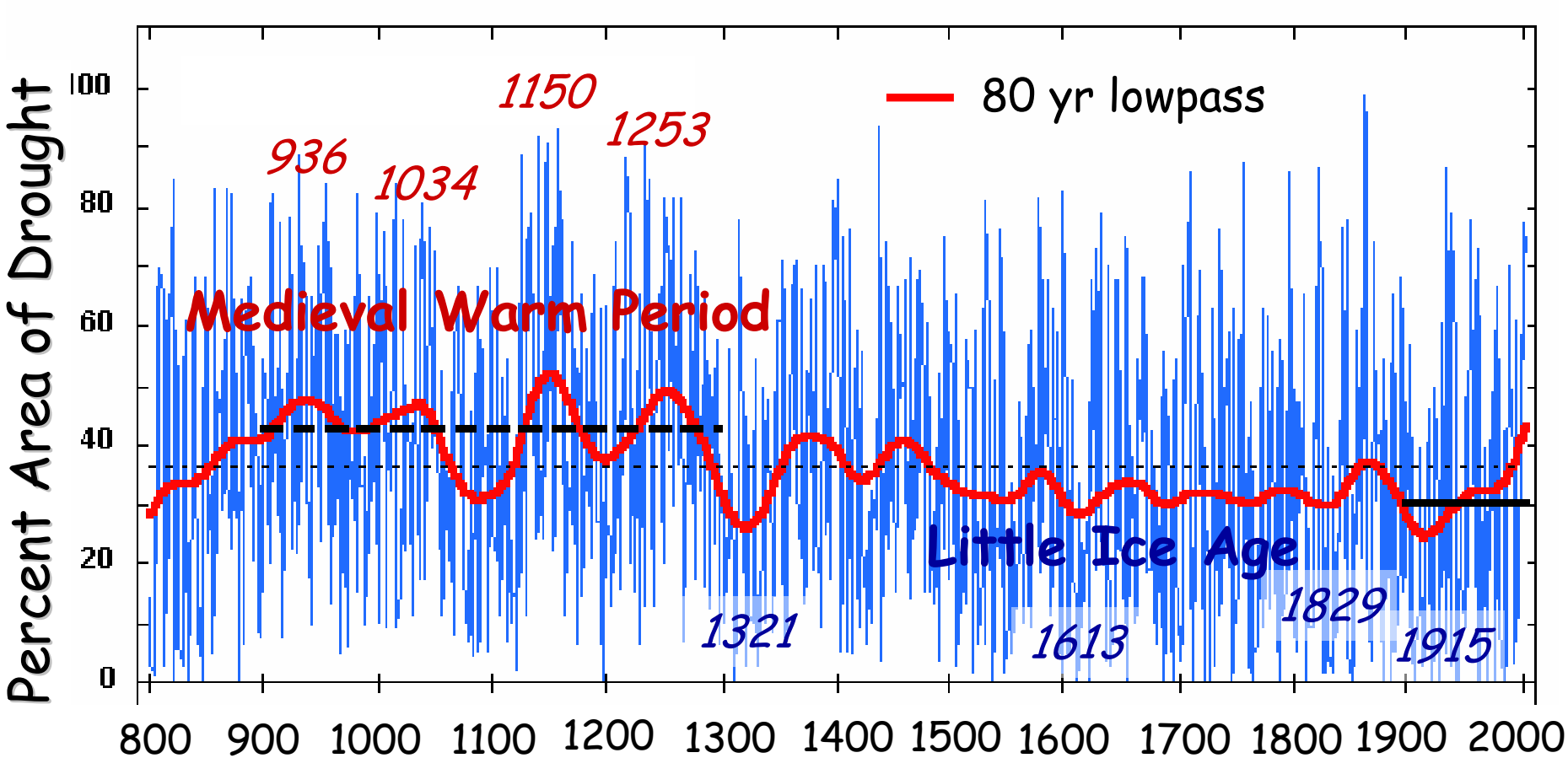


McCabe, Hidalgo, Gray & Betancourt in prep.

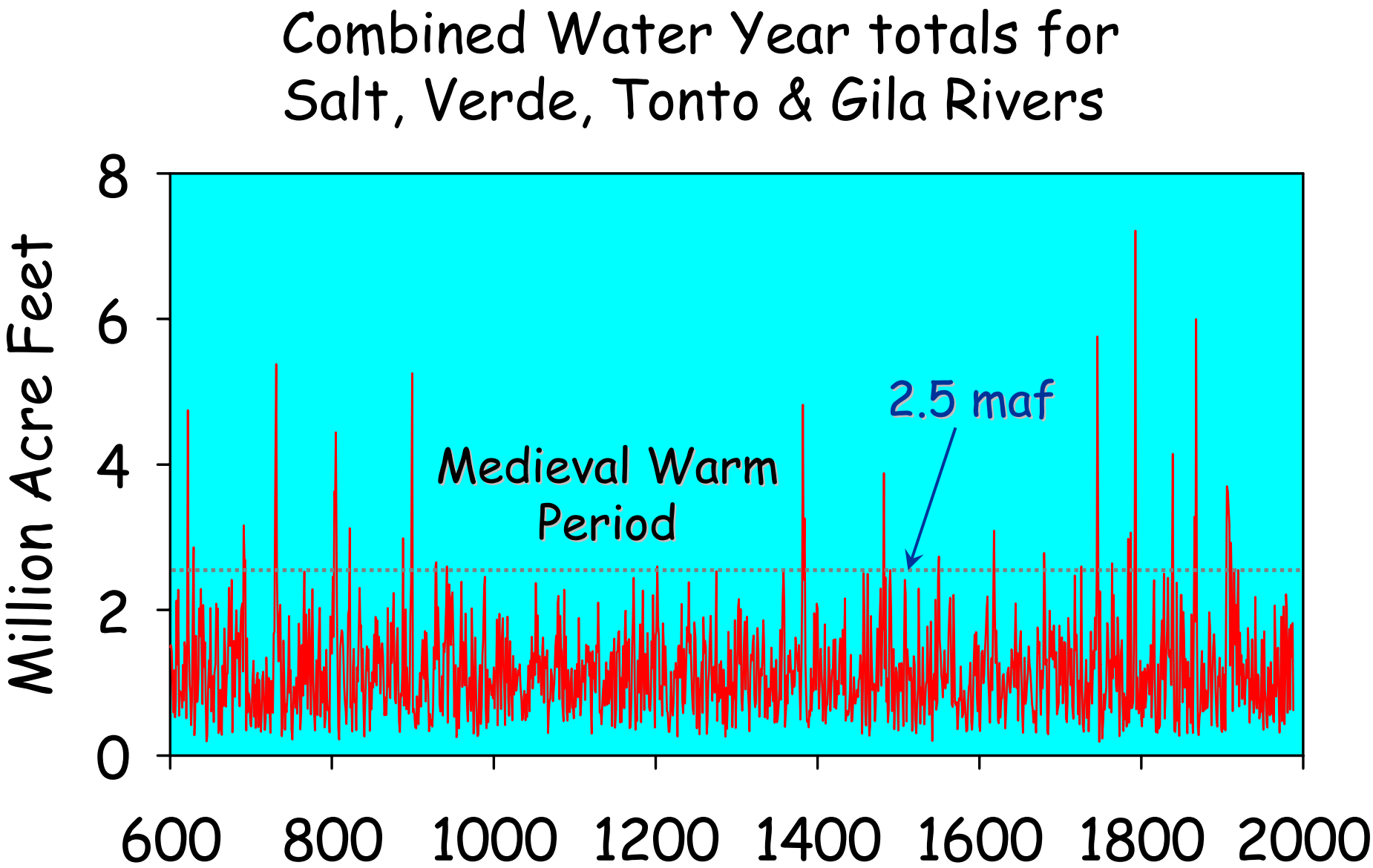


Krusik & Cook (2004) North American Drought Atlas; last 2005 years

Western US Drought Area Index (-1 PDSI)



Cook, Woodhouse, Eakin, Meko & Stahle (2004) Long-term aridity changes in the Western United States. *Science*

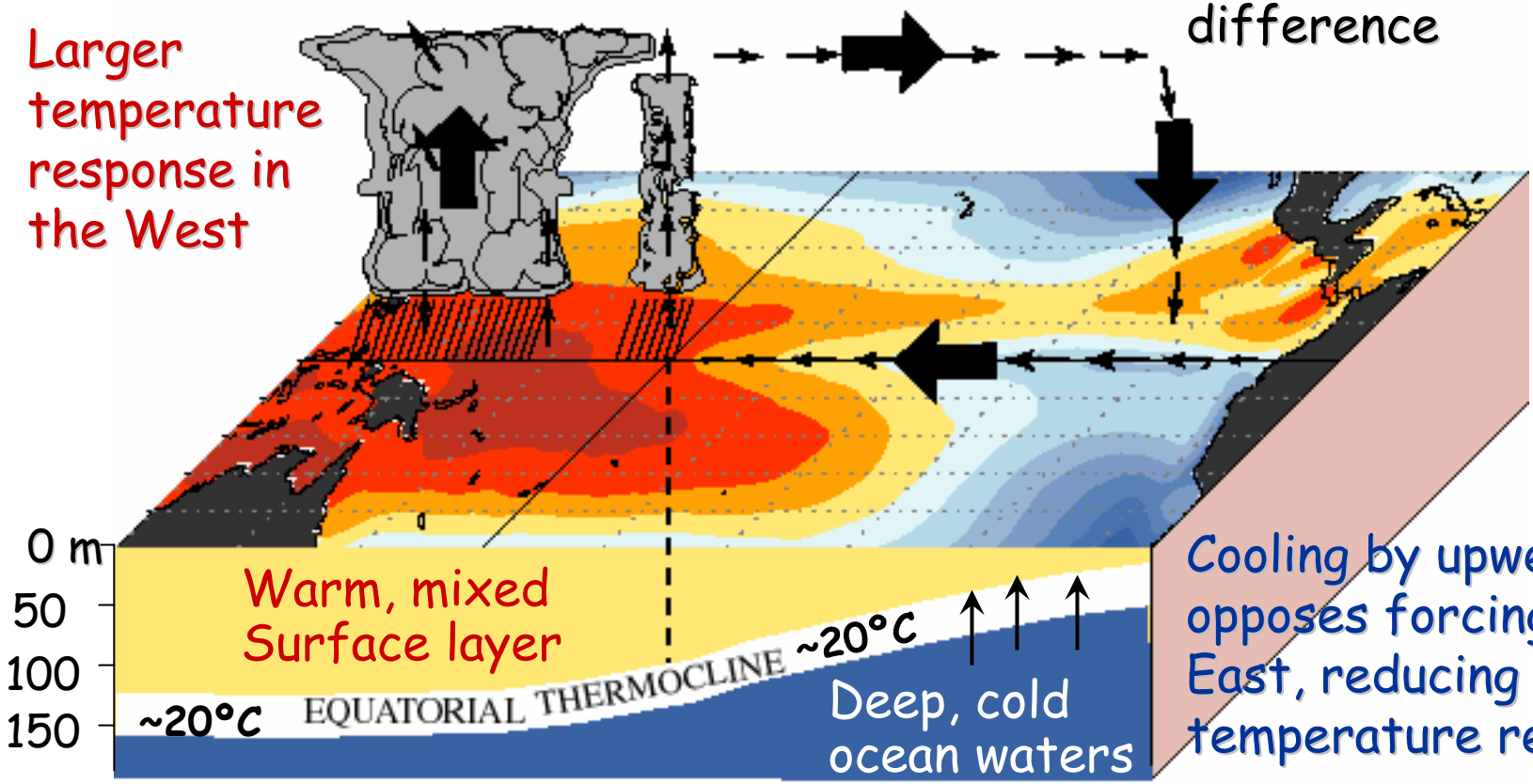


Graybill, Gregory, Funkhouser & Nials F. L. (in press)

Uniform heating

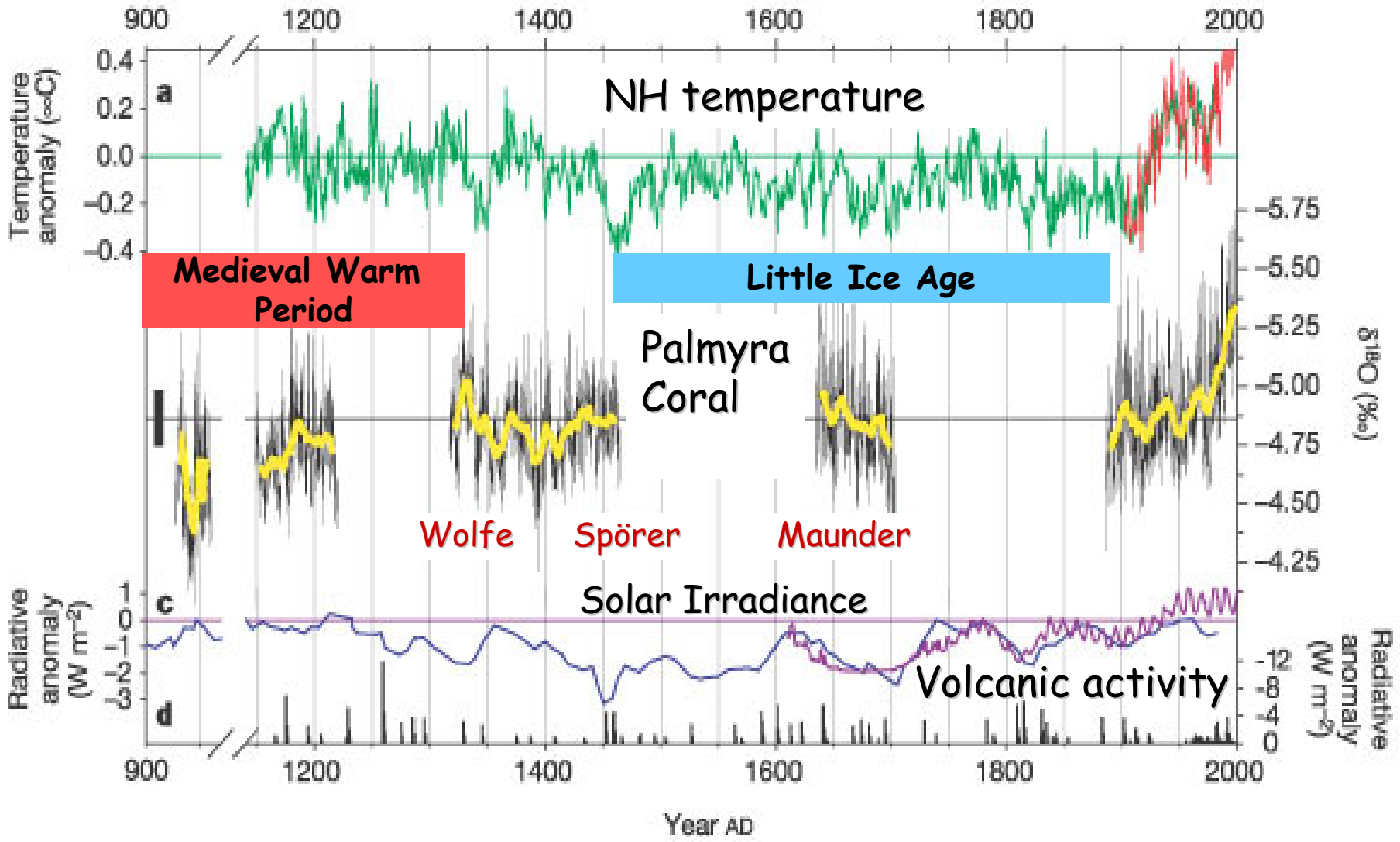
Coupled interactions (*i.e. the Bjerknes feedback*) amplify the East/west temperature difference

Larger temperature response in the West



Cooling by upwelling opposes forcing in the East, reducing temperature response

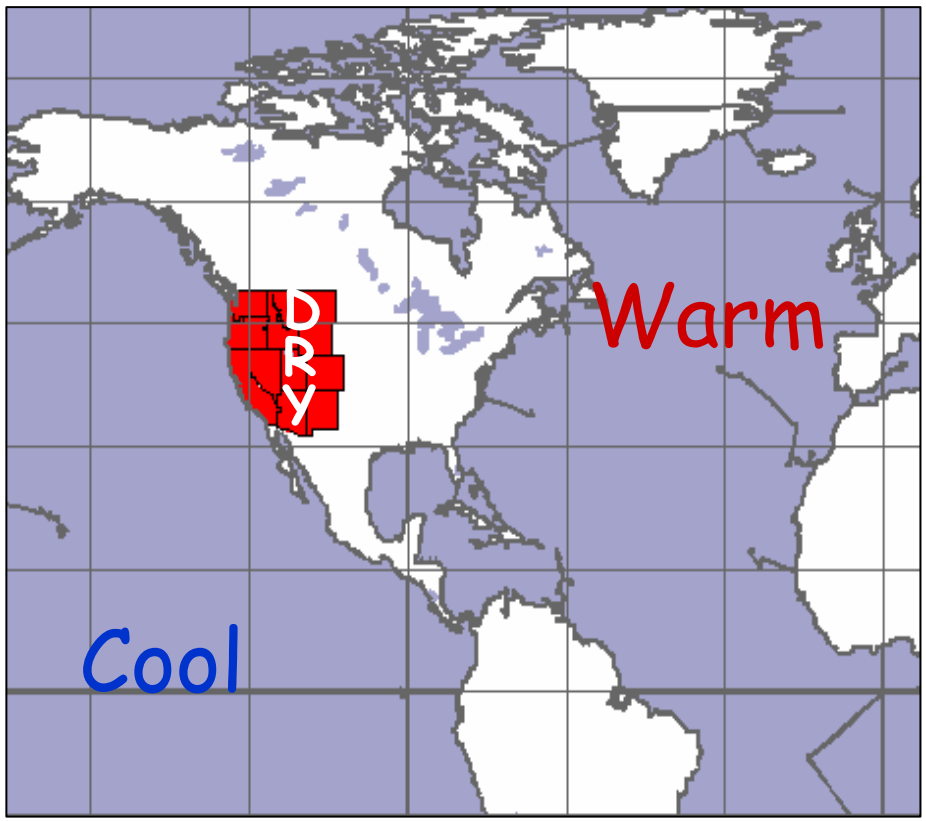
Ocean dynamical 'thermostat' (Clement et al. 1996)



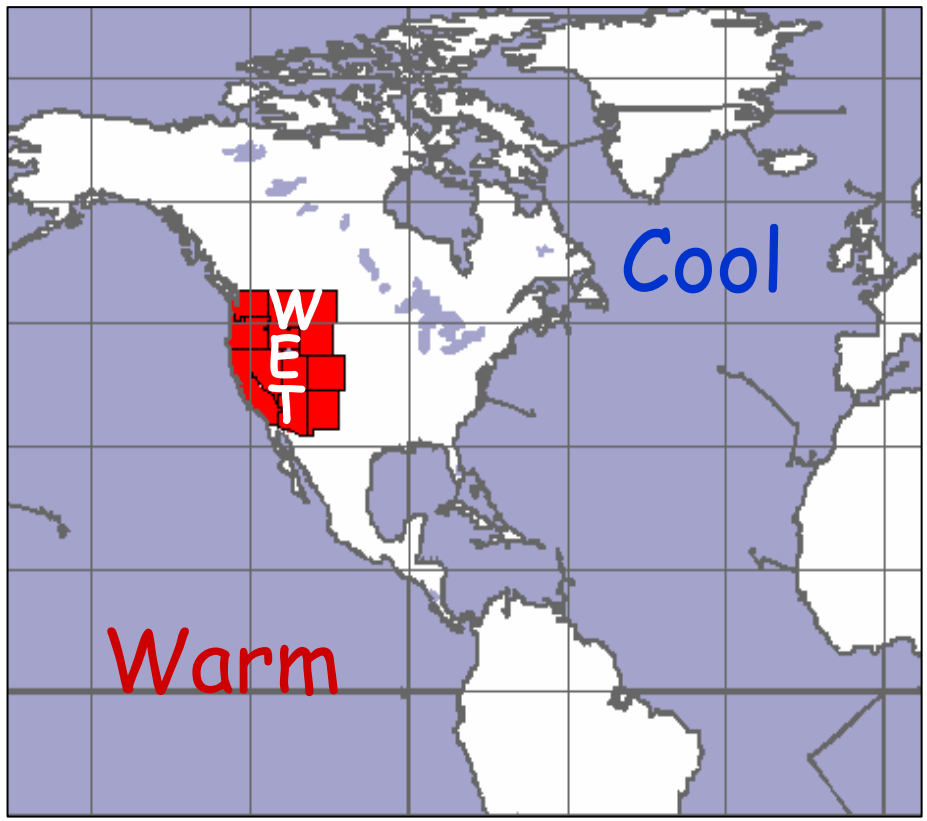
Cobb et al. (2003) *Nature*

Hypothesis: Atlantic & Pacific SST variations also govern centennial-scale trends in western U.S. drought

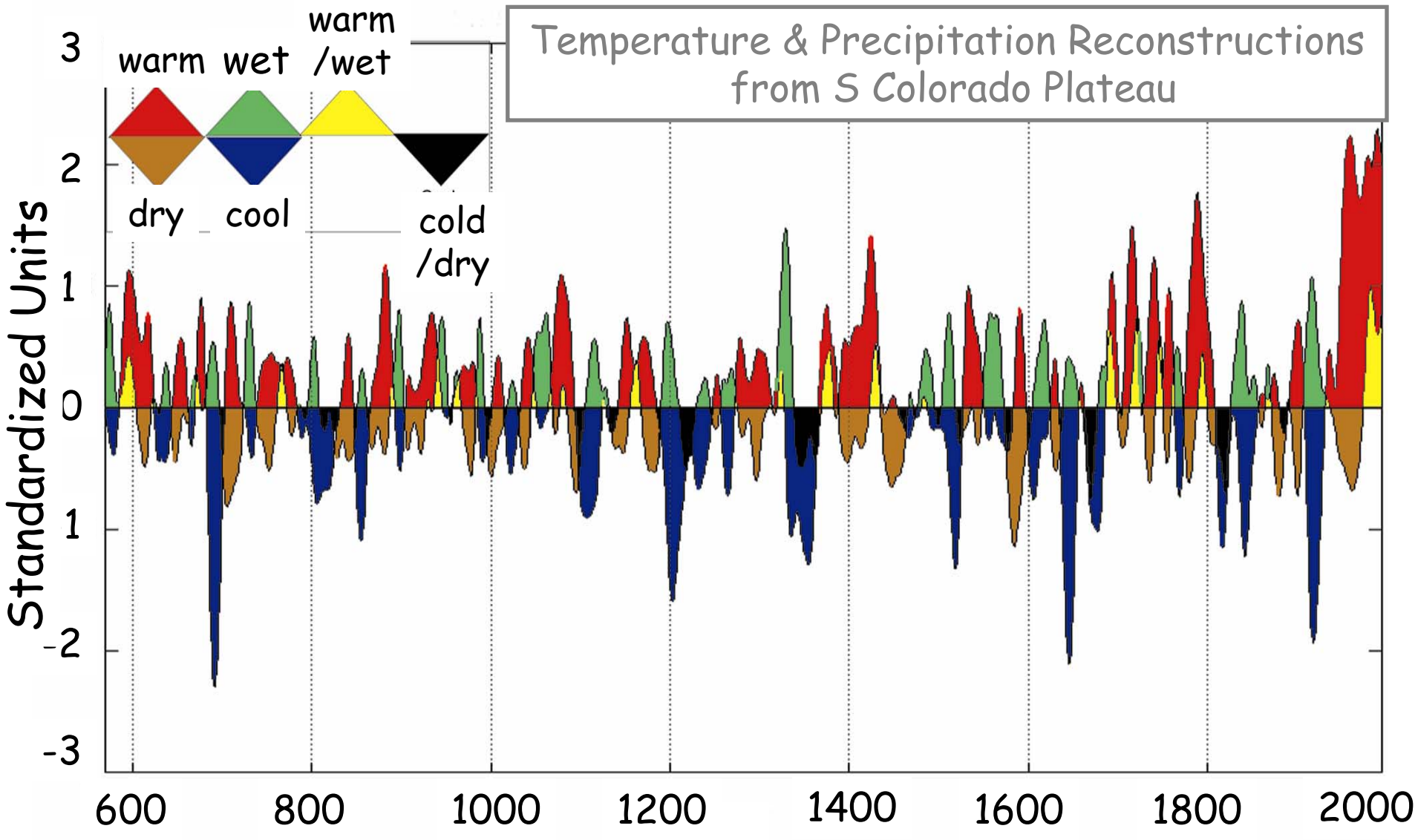
Medieval Warm Period
AD 900-1300



Little Ice Age
AD 1400-1850

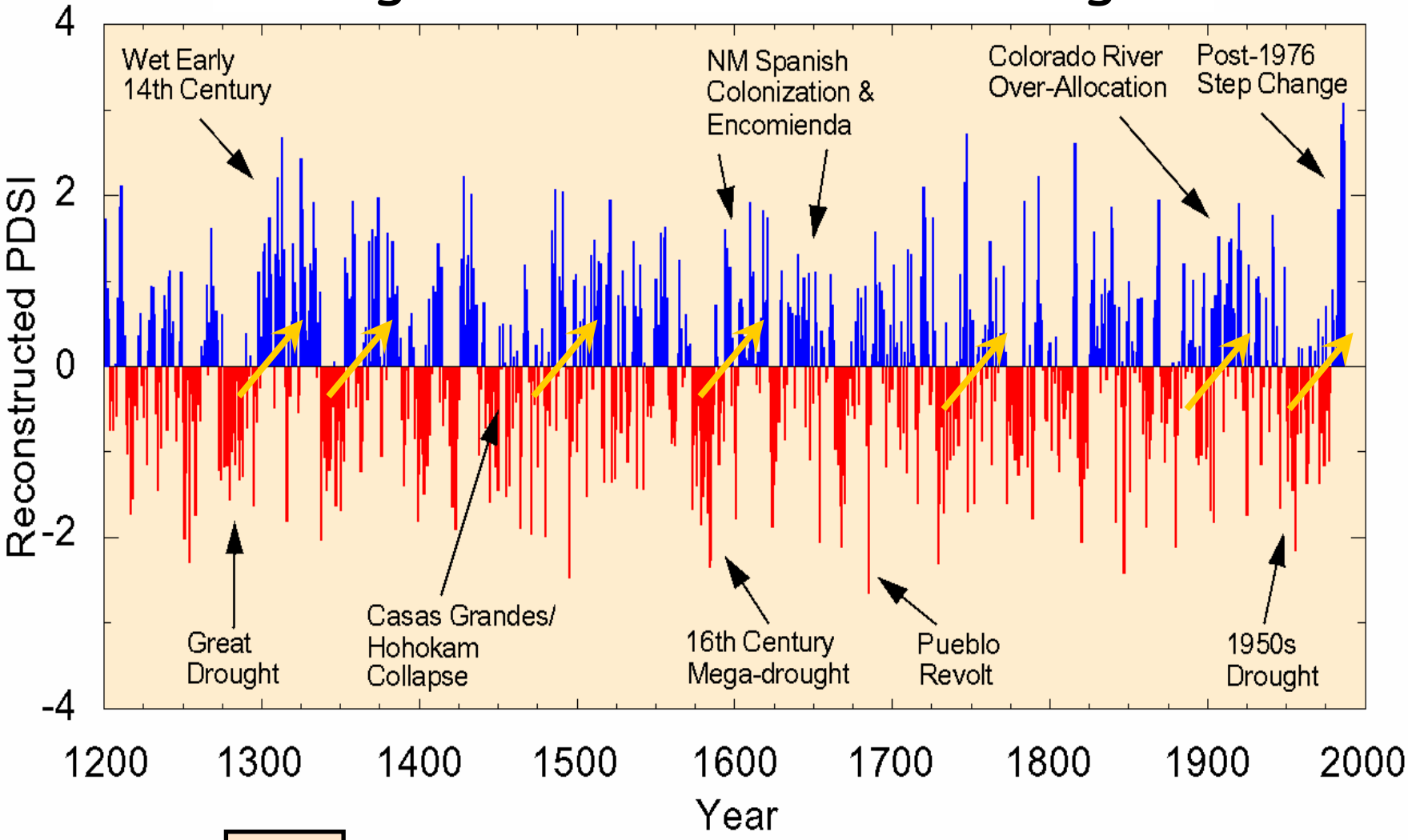


Natural precip. variability will modulate warming impacts



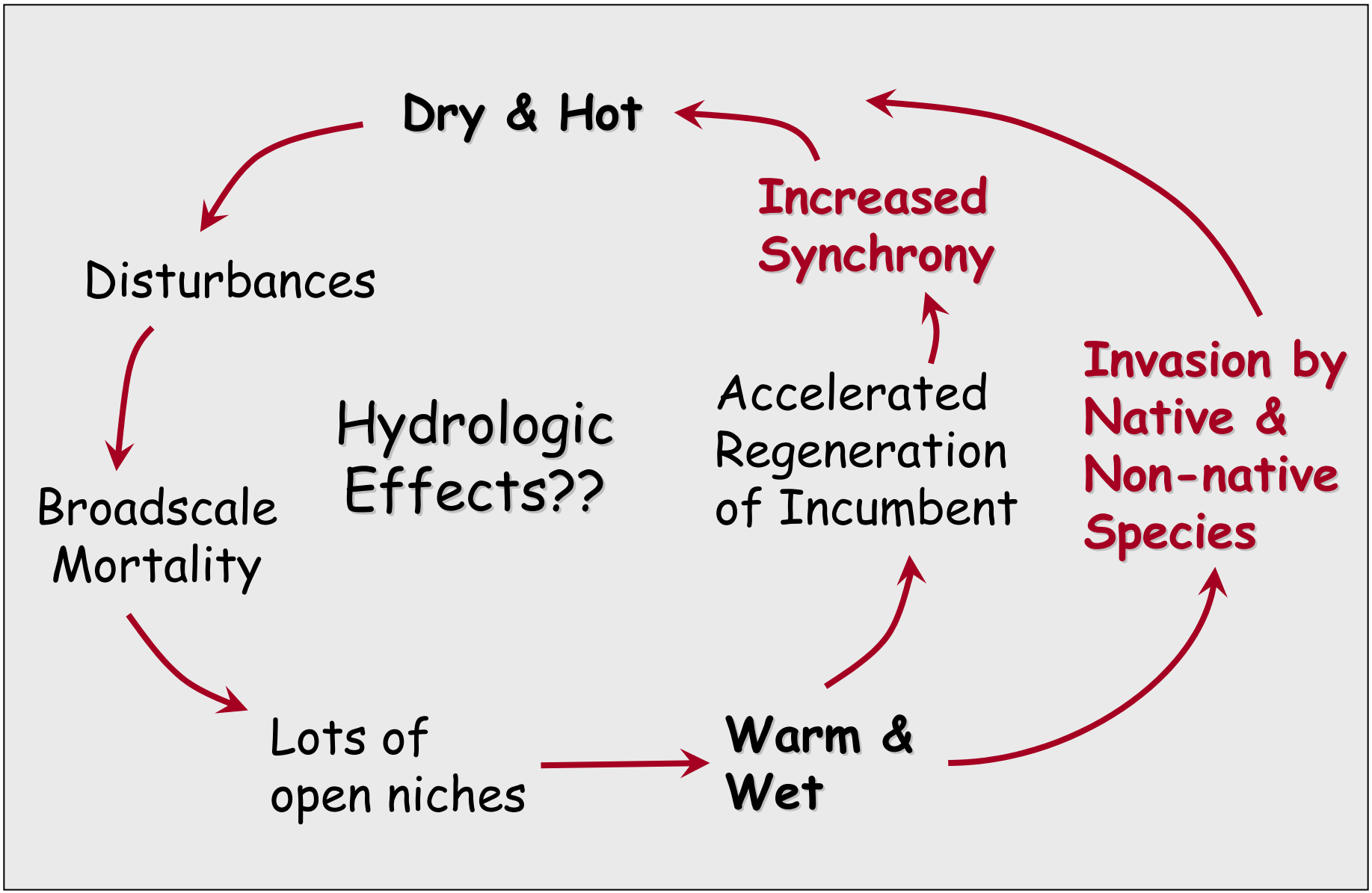
Salzer & Kipfmueller, in press

Ecological Role of Severe Drought



Significant Ecological Resetting Events

Longer, hotter growing seasons accelerate disturbance/ succession cycles and produce greater ecological synchrony



Demographic clocks are being reset by wildfires & dieoffs

Can we predict the outcomes of succession?

Courtesy of Neil Cobb

- El Niños impose short-lived breaks in even the most severe droughts, testing the resolve of drought planners
- Climate variability is a spatially moving target; we should generalize only from regionally integrated tree-ring records
- There appear to be inherent statistical relationships between drought location, extent, duration & severity
- 1950's and 1999-2004 were 6X more common than 1930's-type droughts in last 500 years
- 1965-1995 one of wettest periods in last 1000 years
- AMO influenced frequency, persistence, extent & multi-basin synchrony of drought & fire in last millennium
- AMO/PDO induces D2M fluctuations in water availability & Ecosystems; complicated by warming trends
- Risk increases with time that extraction leases authorized in periods of surplus will carry over into deficit periods