Historical & Climatic Context for Multiseasonal, Multiyear, & Multibasin Droughts

Julio Betancourt
Desert Laboratory

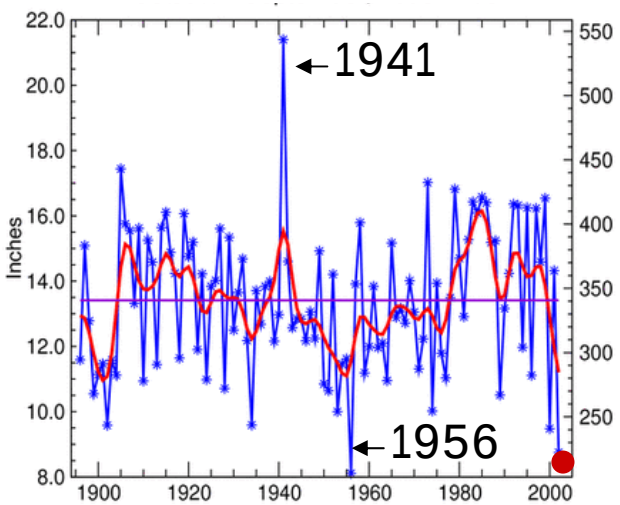
Coauthors

Greg McCabe, USGS, WRD, Denver
Mike Palecki, Illinois State Water Survey
Steve Gray & Lisa Graumlich, Greg Pederson,
Montana State University

Forest Health Monitoring Working Group
Sedona, Arizona
February 10, 2004

Water Year Precipitation

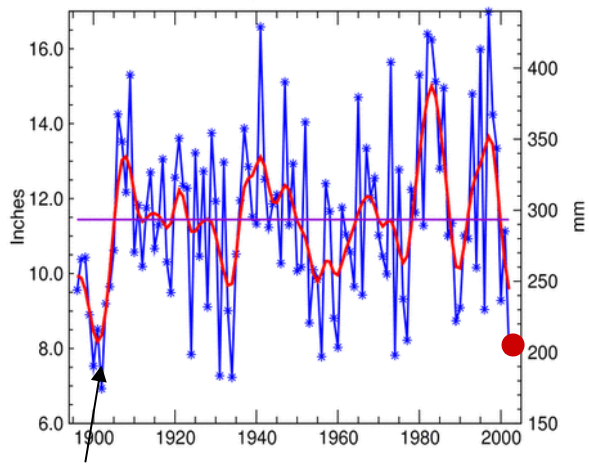
Southwest Average



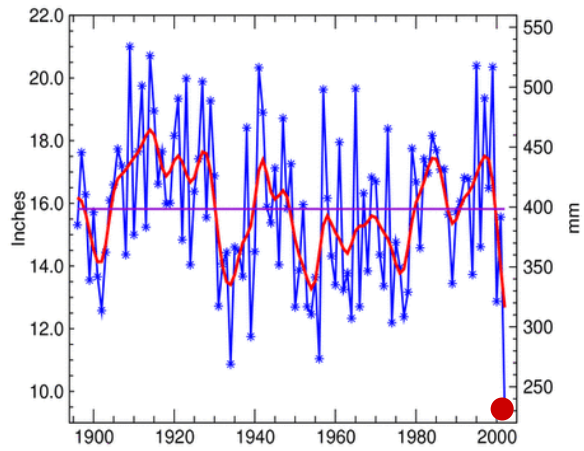
1895-2002

2002 ●

Utah

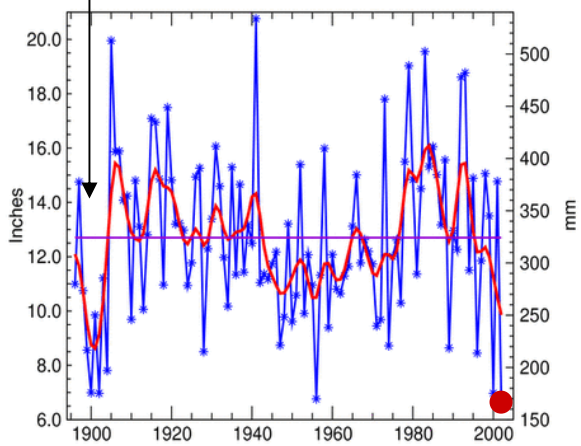


Colorado

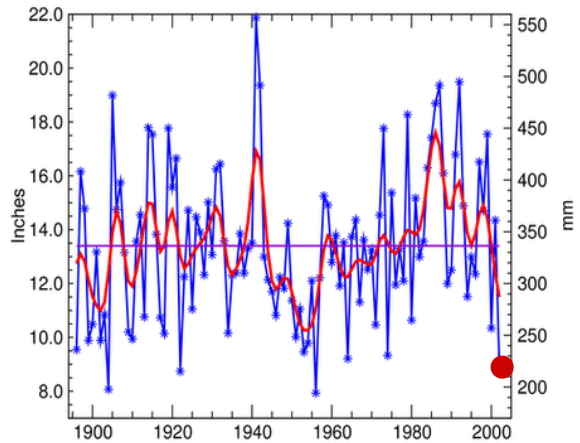


UT CO

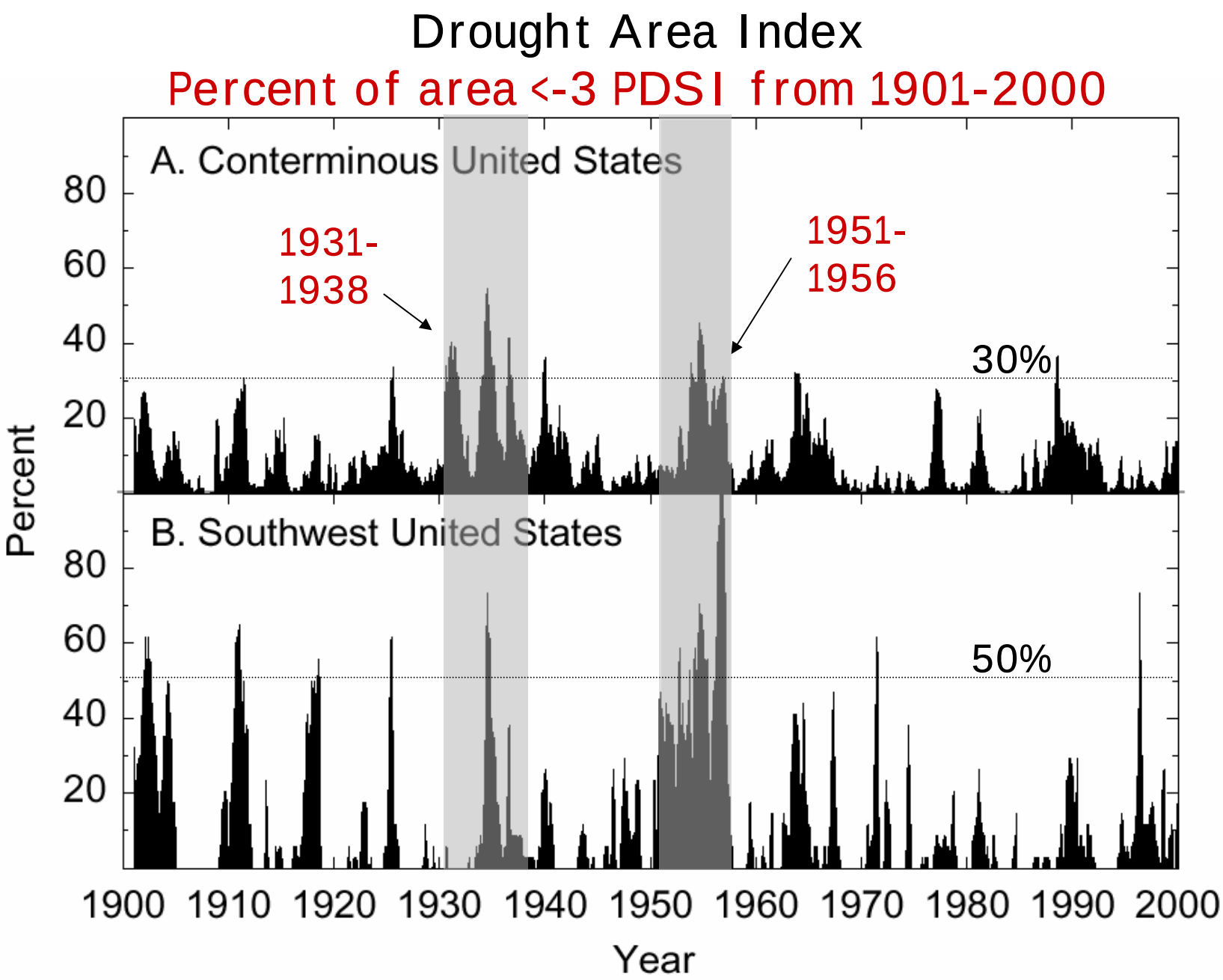
AZ NM



Arizona

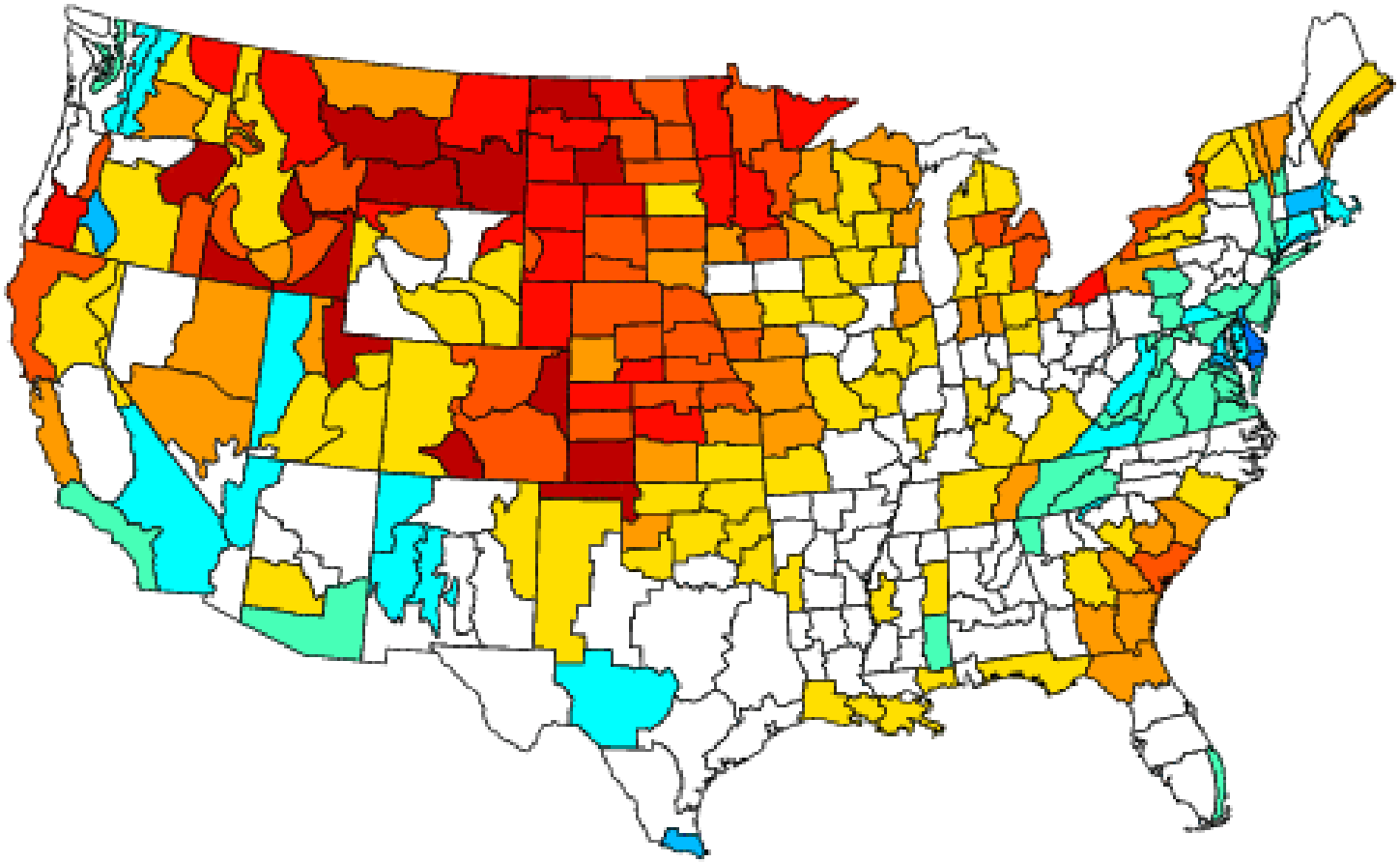


New Mexico


Drought Area Index
Percent of area <-3 PDSI from 1901-2000
A. Conterminous United States
1931-
1938
1951-
1956
30%
B. Southwest United States
50%
Percent
80
60
40
20
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year

Composite Standardized Precipitation Anomalies

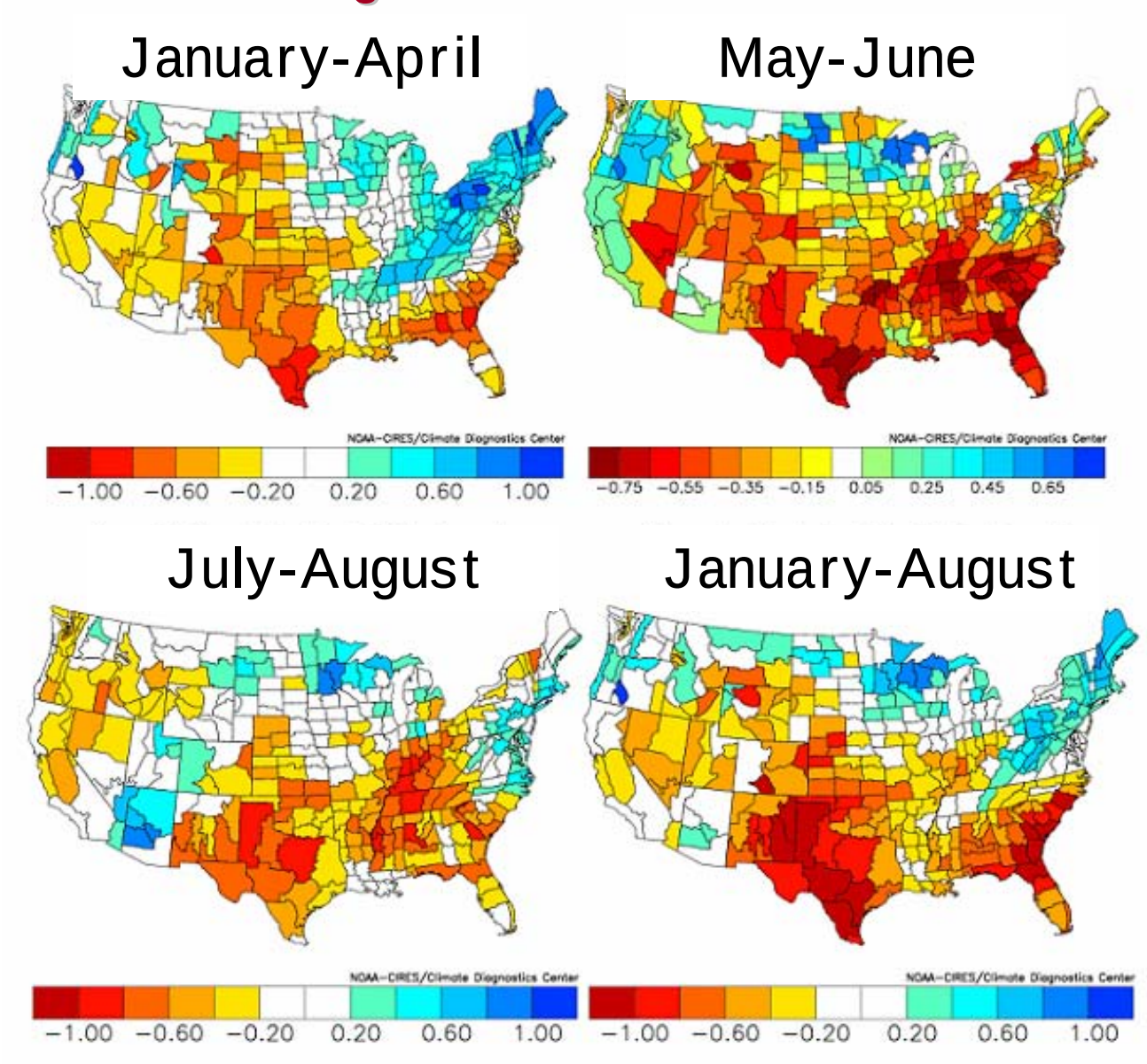
Water Year 1931-1938 vs. 1896-2000 Long-Term Average



NOAA–CIRES/Climate Diagnostics Center

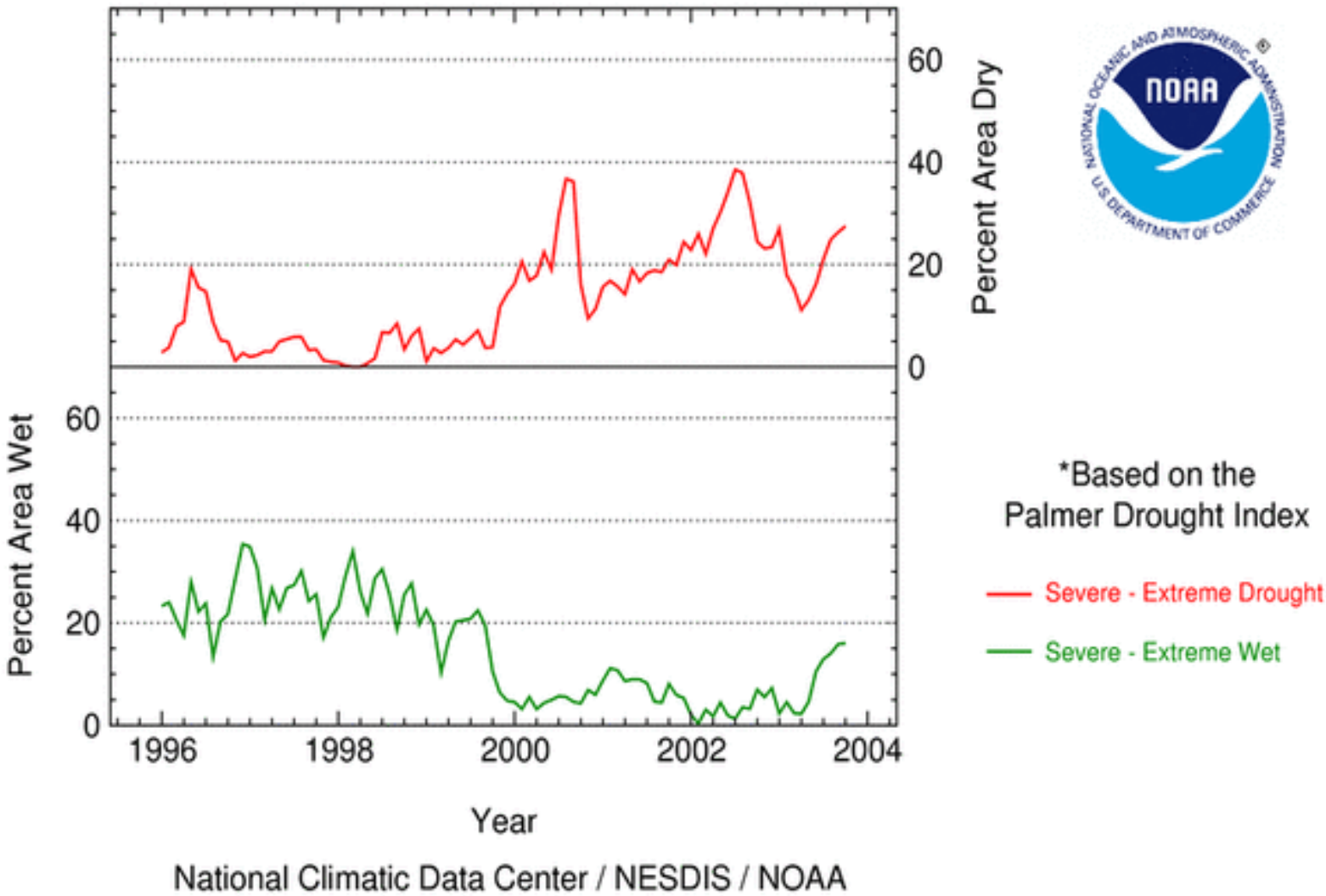
−1.00 −0.60 −0.20 0.20 0.60 1.00

1951-56 Precipitation anomalies relative to long-term normal 1950-95



U.S. Percentage Area Wet or Dry

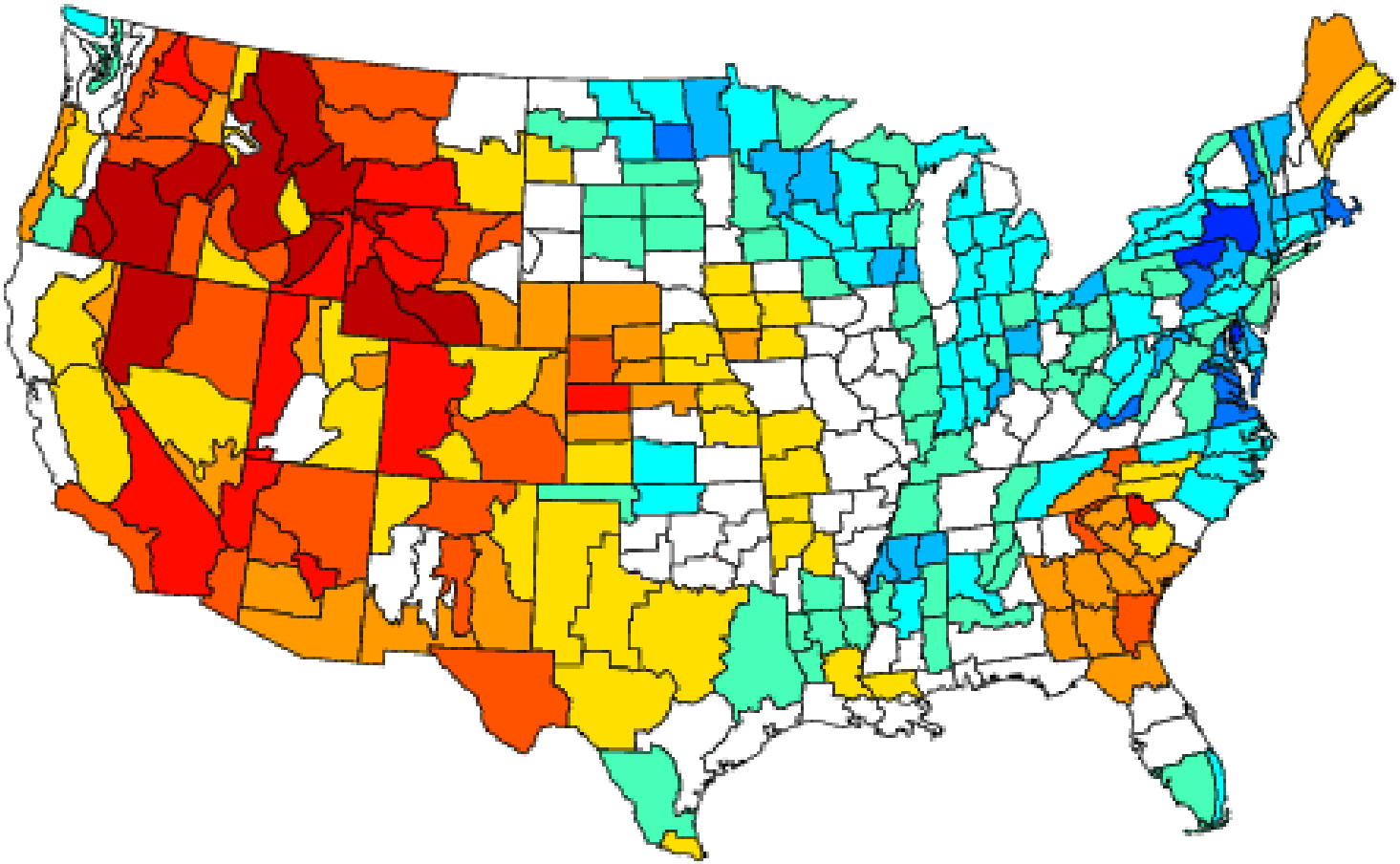
January 1996 - October 2003



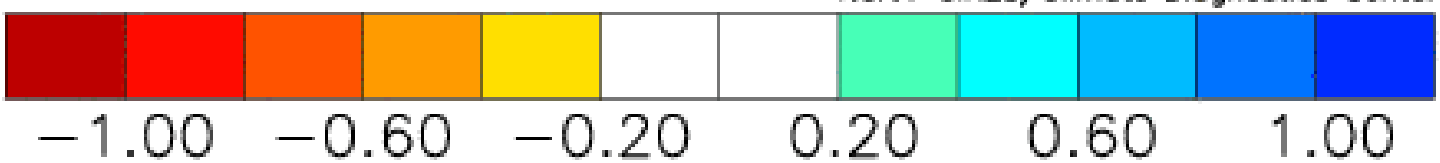
National Climatic Data Center / NESDIS / NOAA

Composite Standardized Precipitation Anomalies

1999-1903 vs. 1896-2000 Long-Term Average



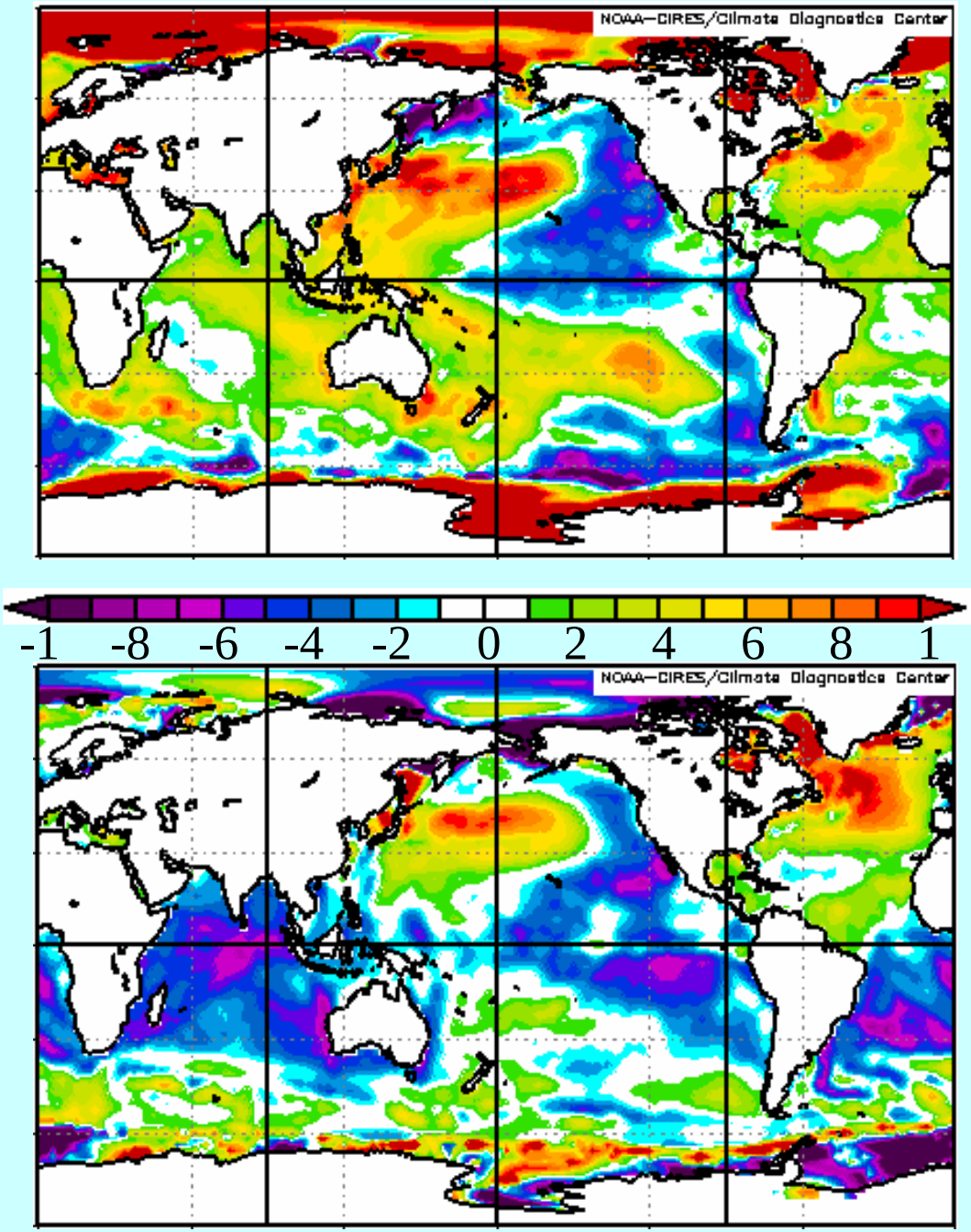
NOAA–CIRES/Climate Diagnostics Center



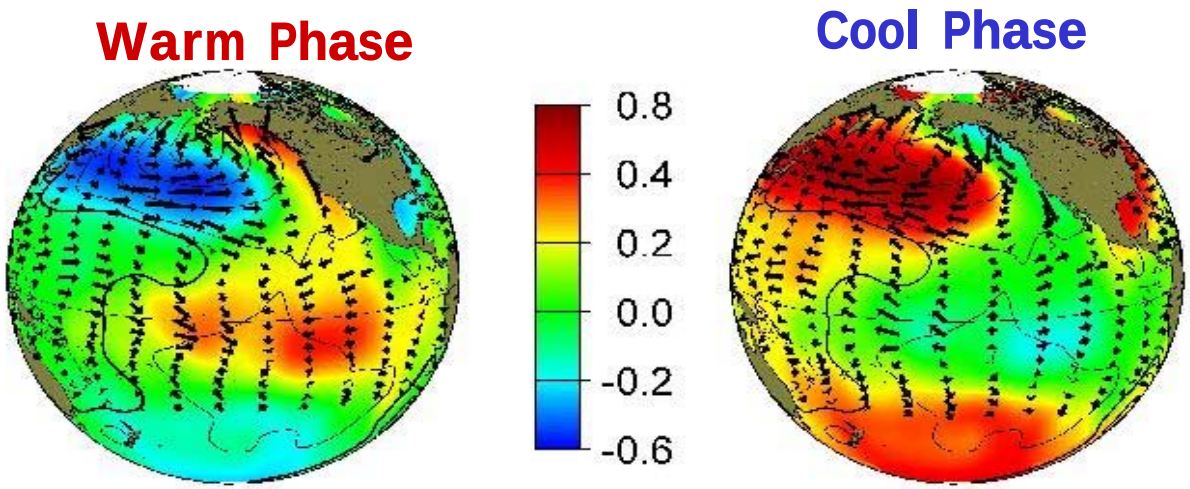
1999-2003

NCEP-NCAR
Reanalysis
SST Anomalies
1968-1996

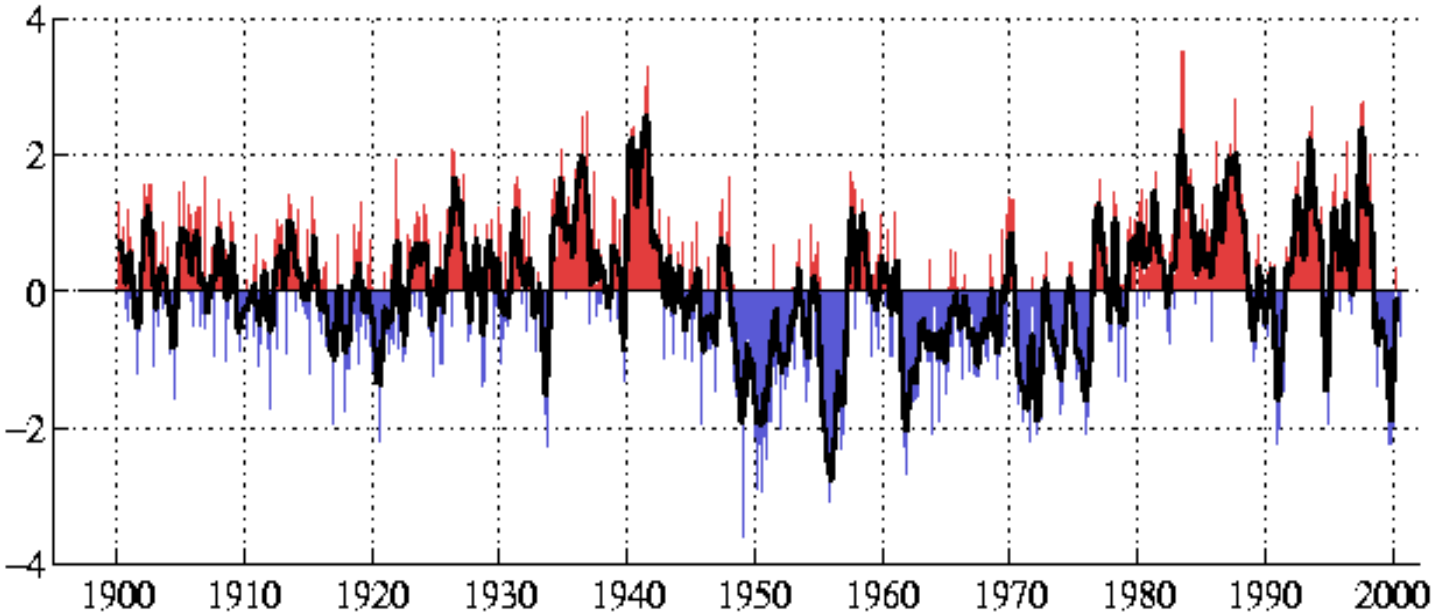
1951-1956

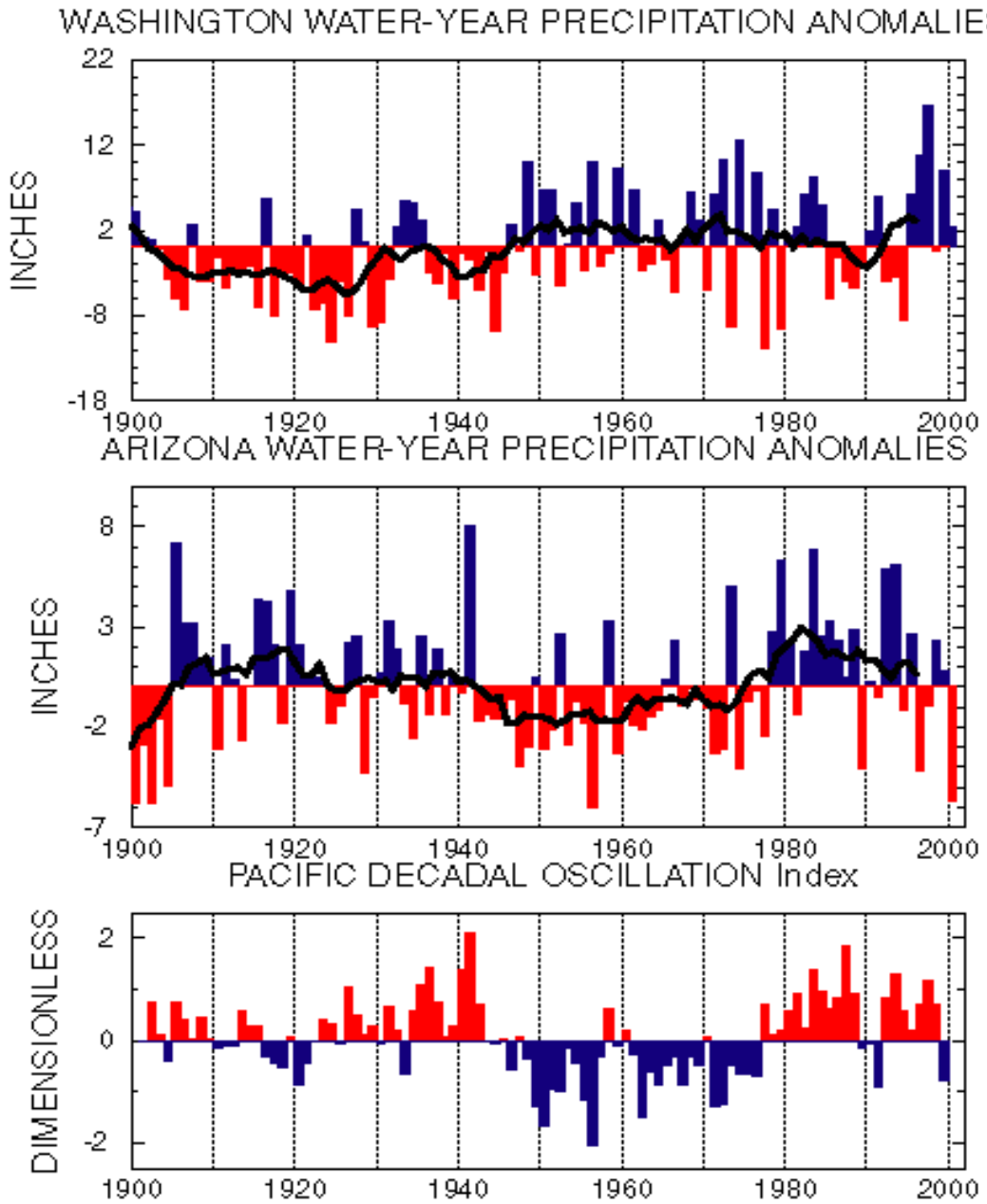


Pacific Decadal Oscillation



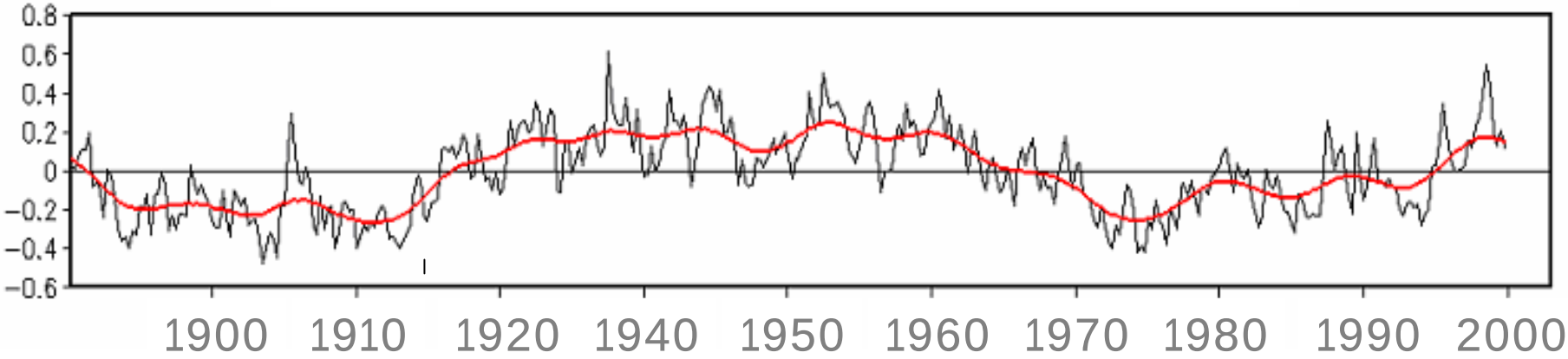
Monthly Values for the PDO Index, 1900-2000





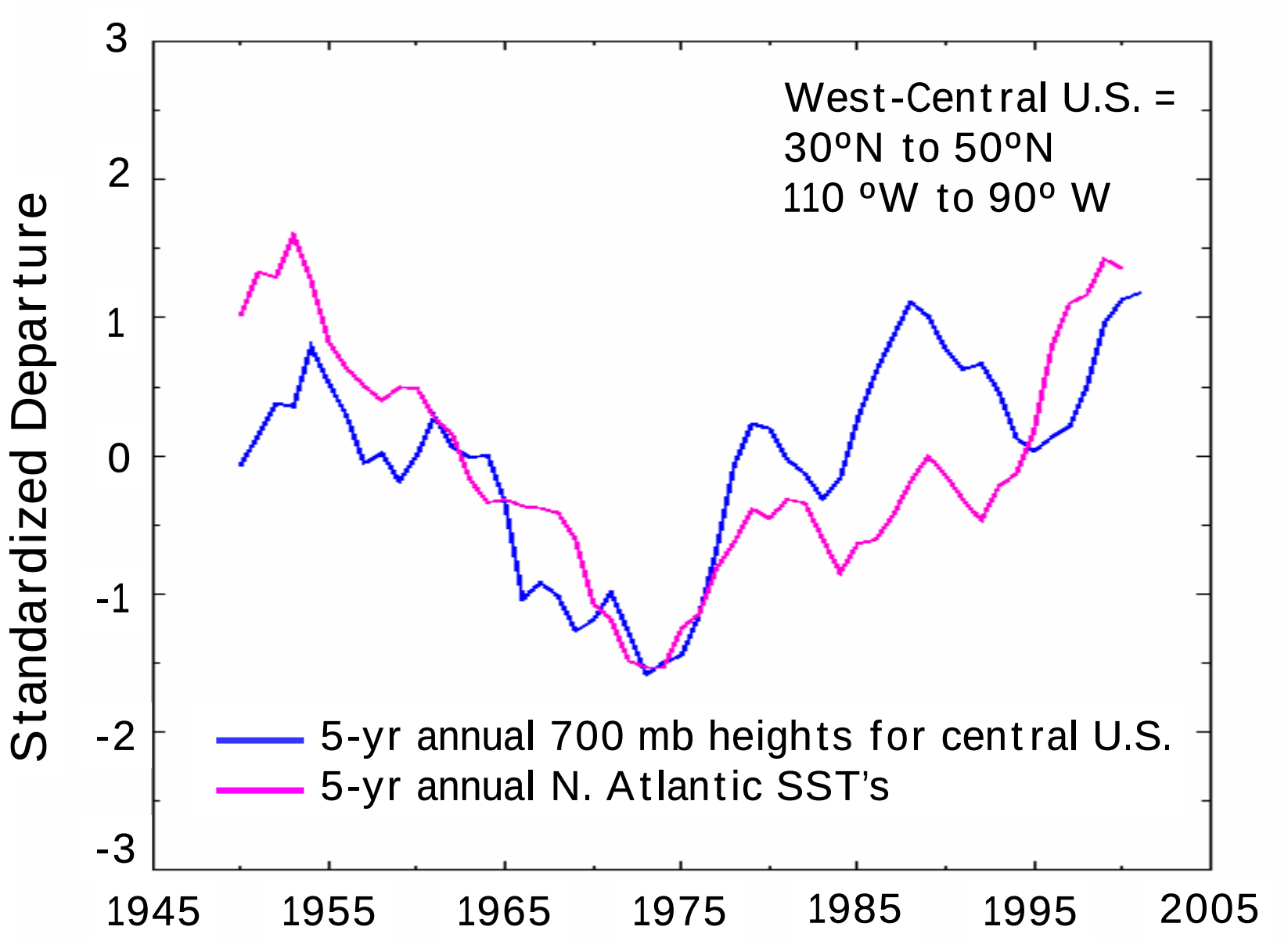
Schmidt & Webb (2001)

Atlantic Multidecadal Oscillation

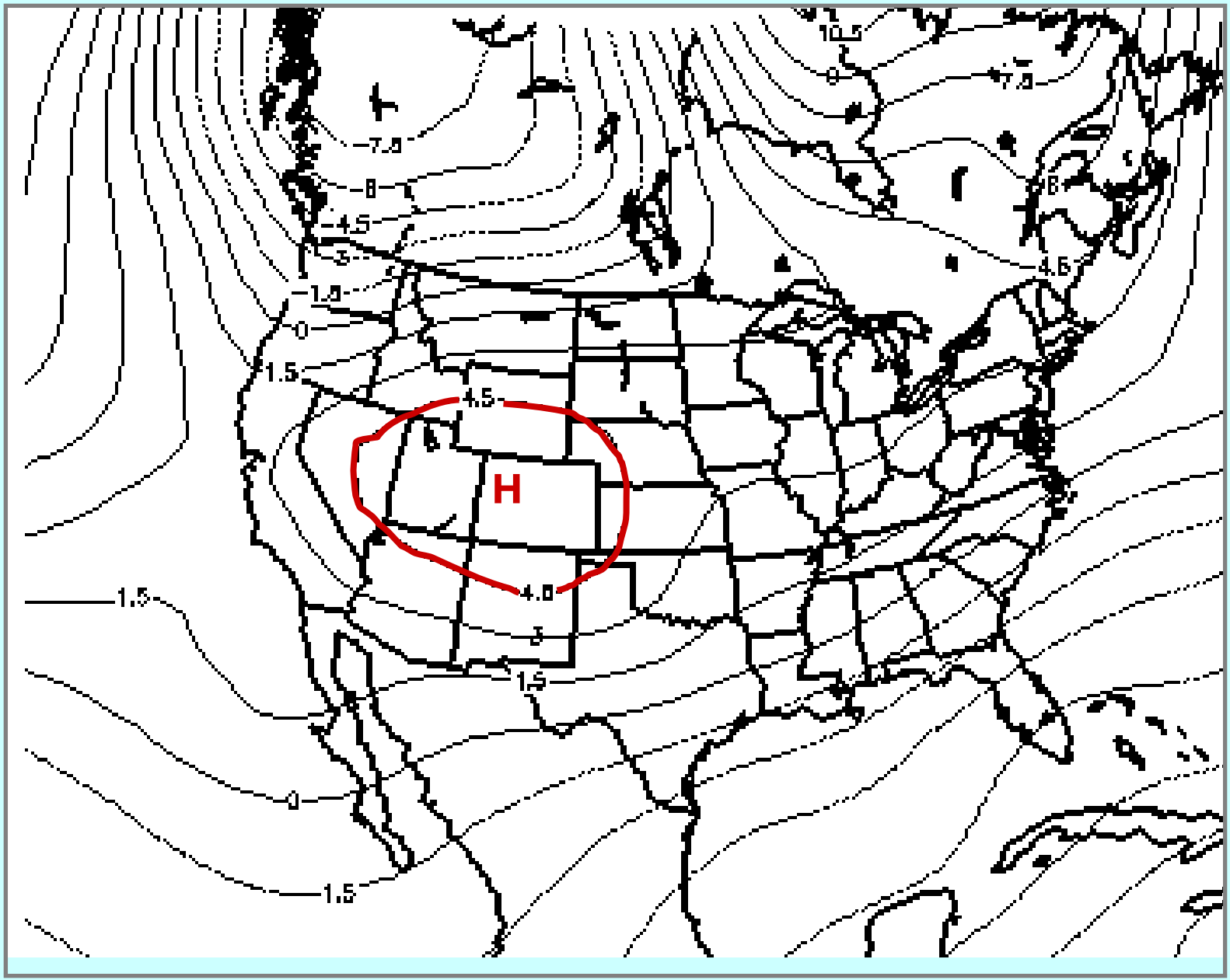


- 10-yr running mean of detrended SST anomalies averaged over N Atlantic from 0-70ºN with an amplitude of 0.4ºC
- Warm phases 1860-1880, 1930-1960, 1995-present
  Cold phases 1905-1925 and 1970-1990
- Probable cause is natural, internal variations in THC & associated meridional heat transport
- Inverse relation with ppn in central & western U.S. & modulates ENSO teleconnection.

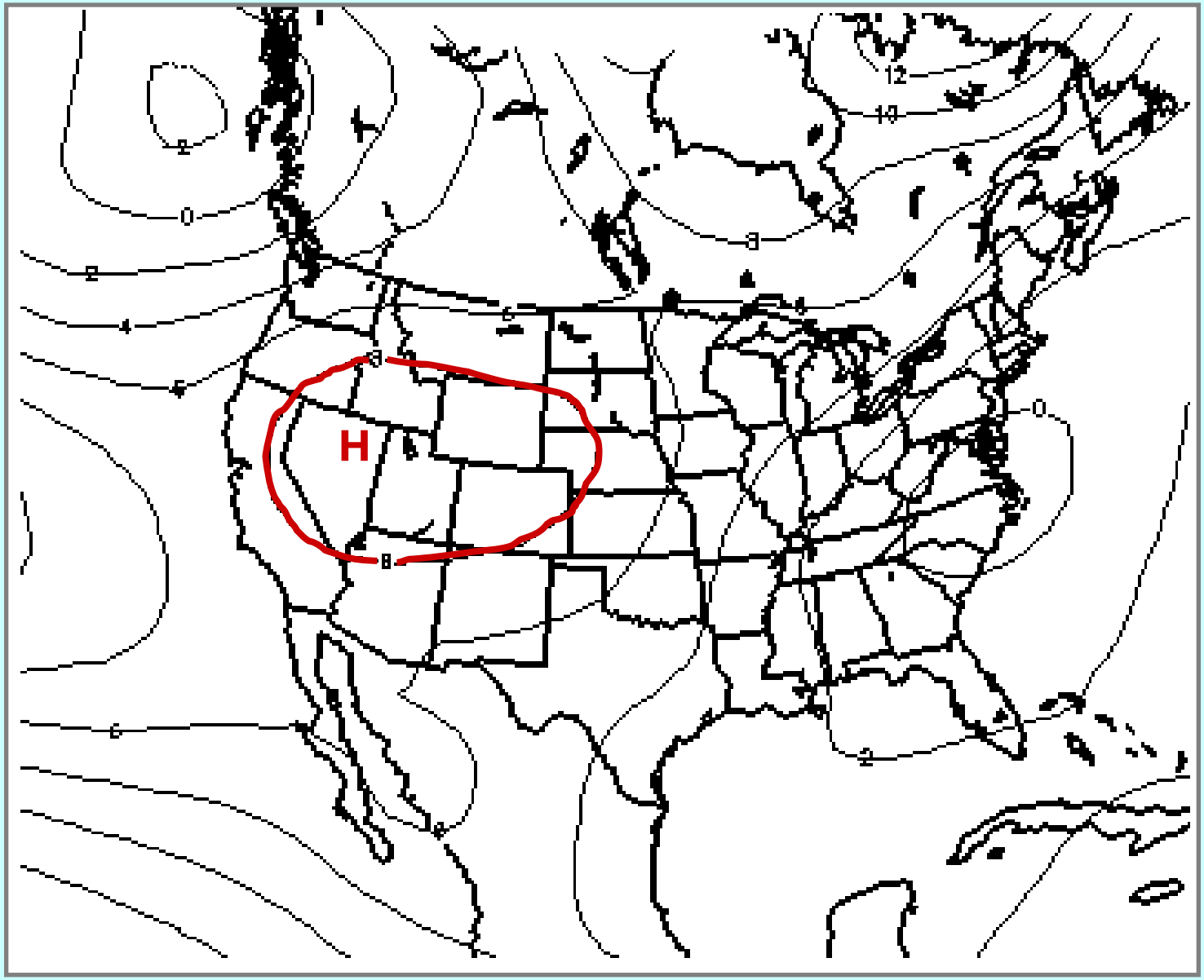
Enfield, Mestas-Nuñez & Trimble (2001)


West-Central U.S. =
30ºN to 50ºN
110 ºW to 90º W
Standardized Departure
3
2
1
0
-1
-2
-3
1945
1955
1965
1975
1985
1995
2005
5-yr annual 700 mb heights for central U.S.
5-yr annual N. Atlantic SST's

700 mb Geopotential Heights (m) Anomalies 1948-1960 vs. 1968-1996

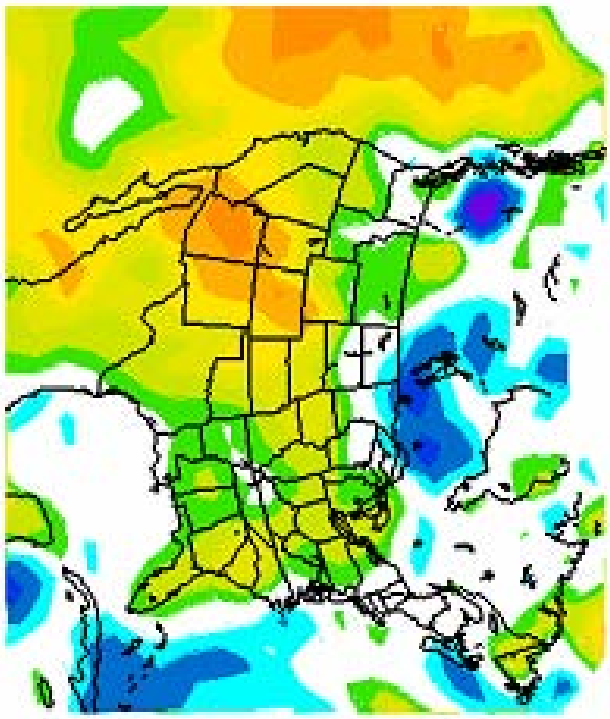


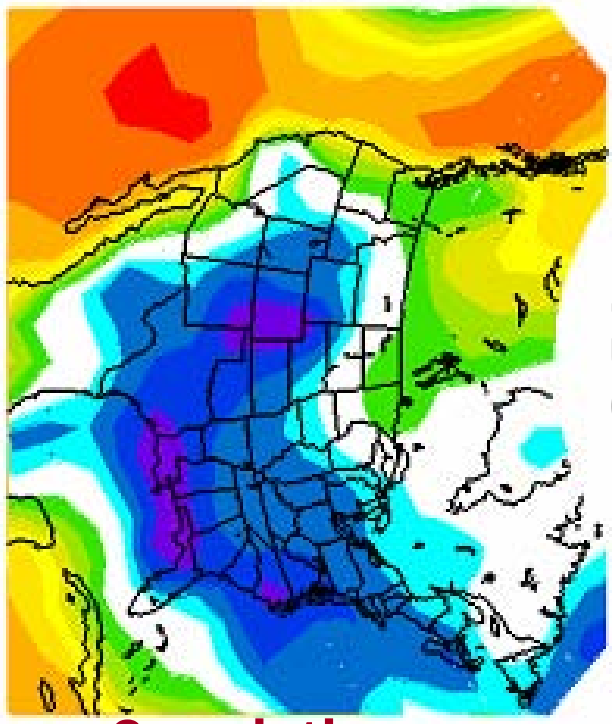
700 mb Geopotential Heights (m) Anomalies 1998-2003 vs. 1968-1996



Precipitation

Temperature





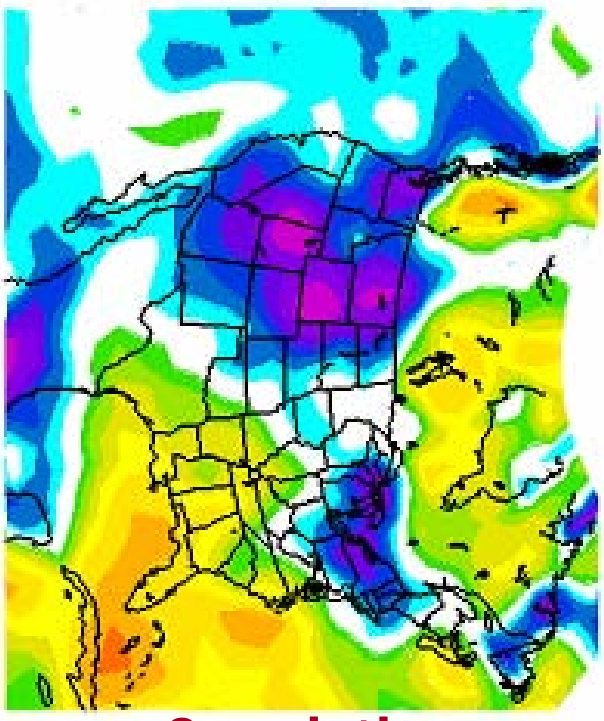
PDO

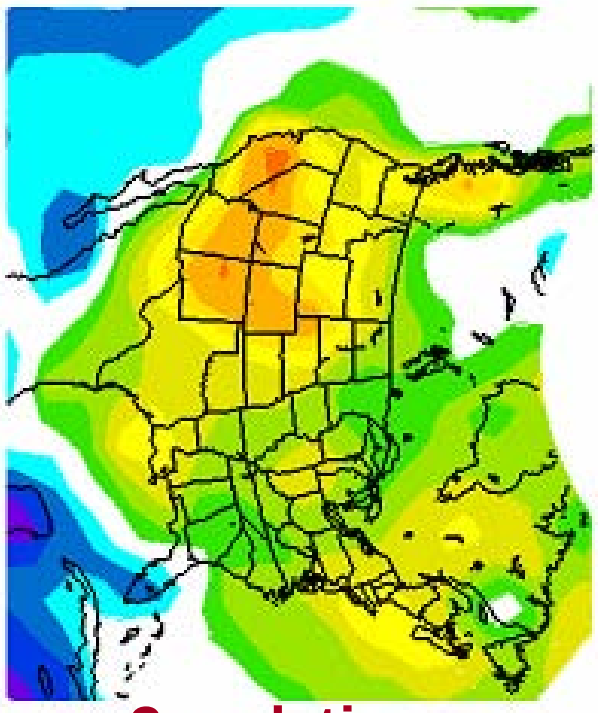
Correlation

-0.9 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.9

Correlation

-0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9





AMO

Correlation

-0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9

Correlation

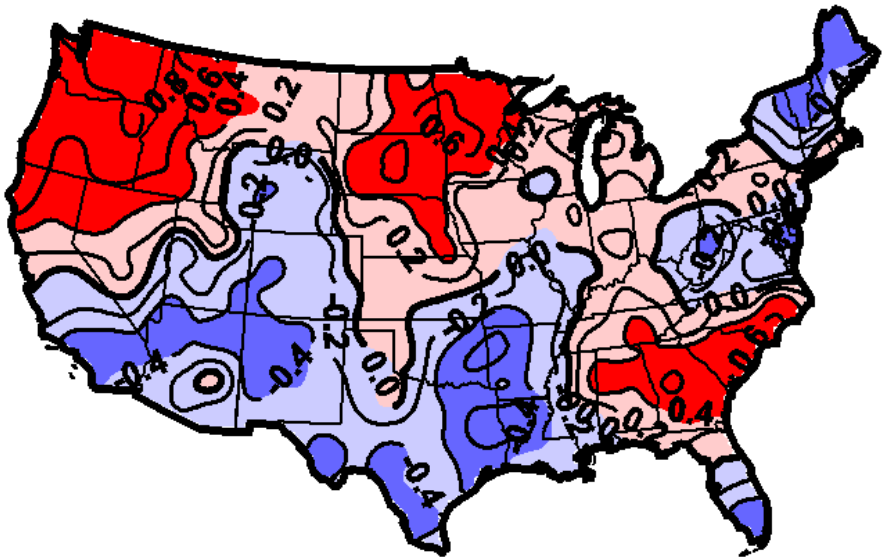
-0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9

Principal Components Analysis of Drought Frequency in the Conterminous U.S.

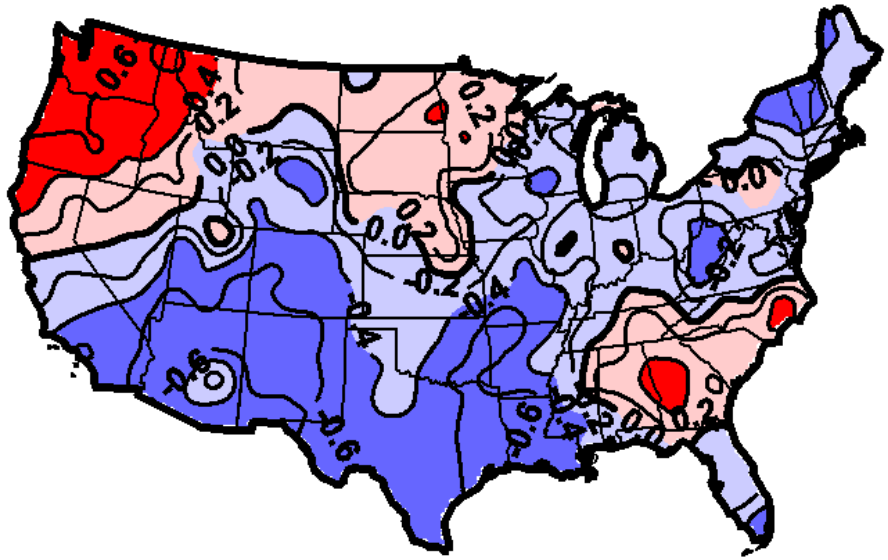
- Decompose drought frequency into its primary modes of spatial & temporal variability
- Drought conditions assumed if annual precipitation in lowest quartile (25%) of 100-yr record
- Drought frequency for 20-yr moving periods calculated for each of 344 climate divisions (results same for 10 and 30-yr moving periods)
- 20-yr moving drought frequencies subjected to rotated PC analysis w/ varimax rotation to identify primary modes
- No *a priori* consideration of climate forcing factors
- Scores and loadings of the PC analysis compared with 20-yr moving averages of PDO, AMO & NH temp. trend

McCabe, Palecki & Betancourt (2004)

PC #1 (r^2= 0.24)
20yr drought frequencies

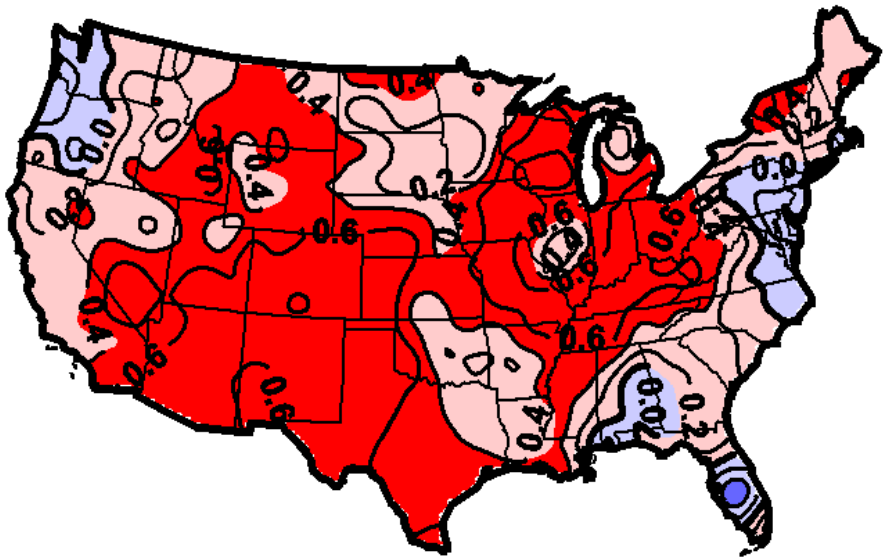


20yr moving PDO vs.
20yr drought frequencies

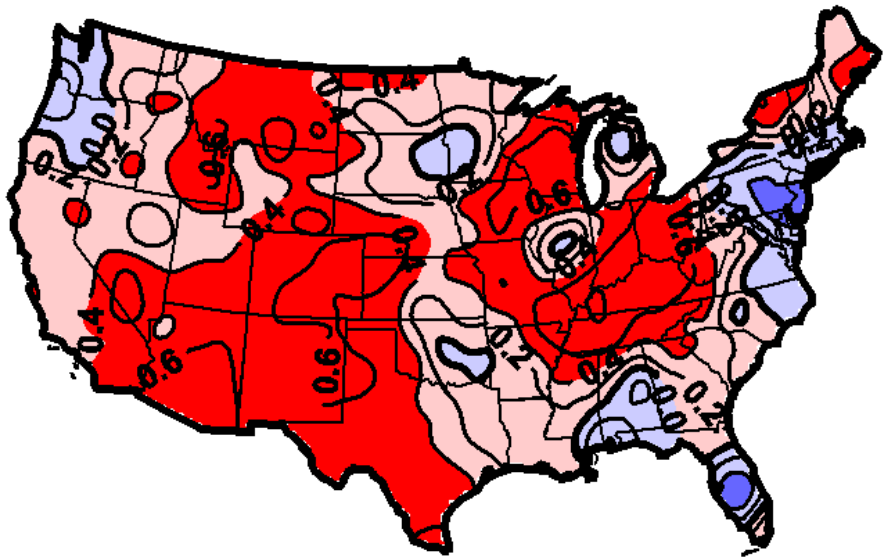


McCabe, Palecki & Betancourt (2004)

PC #2 (r^2= 0.28)
20yr drought frequencies

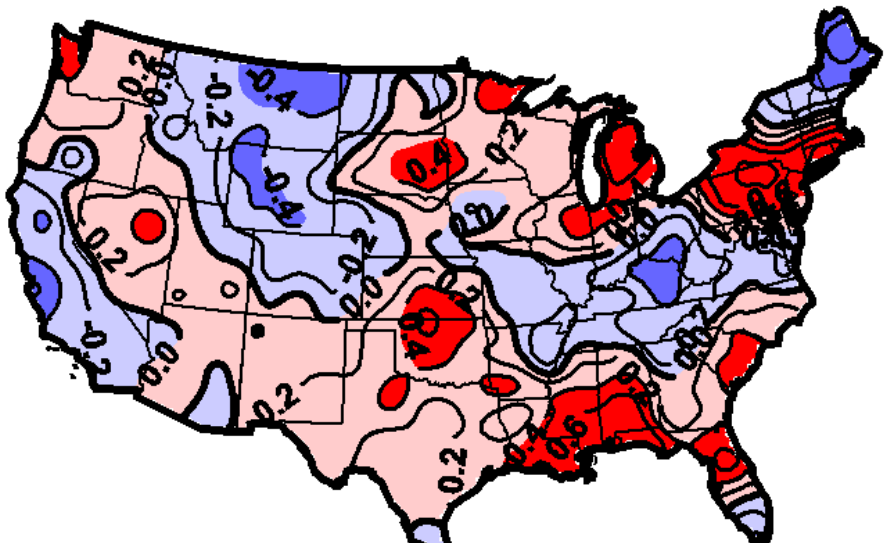


20yr moving AMO vs.
20yr drought frequencies

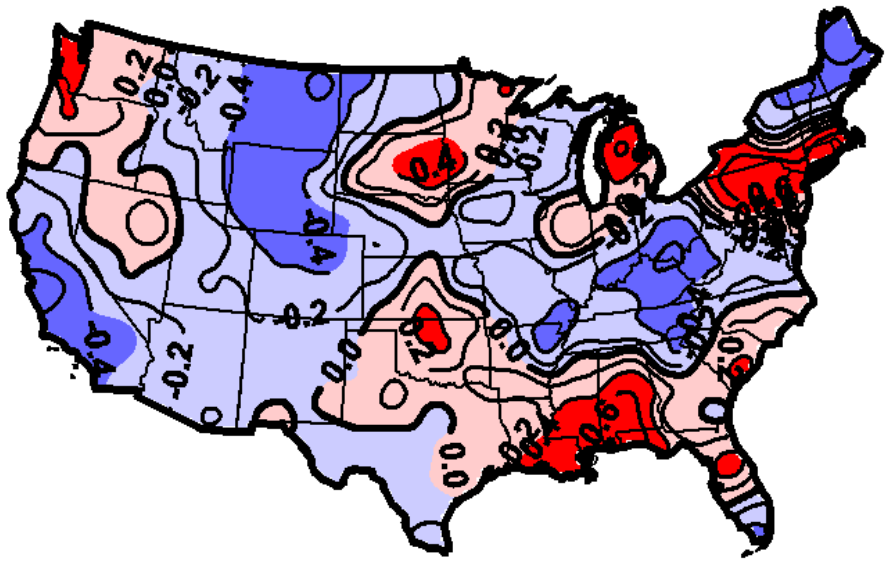


McCabe, Palecki & Betancourt (2004)

PC #3 (r^2= 0.22)
20yr drought frequencies

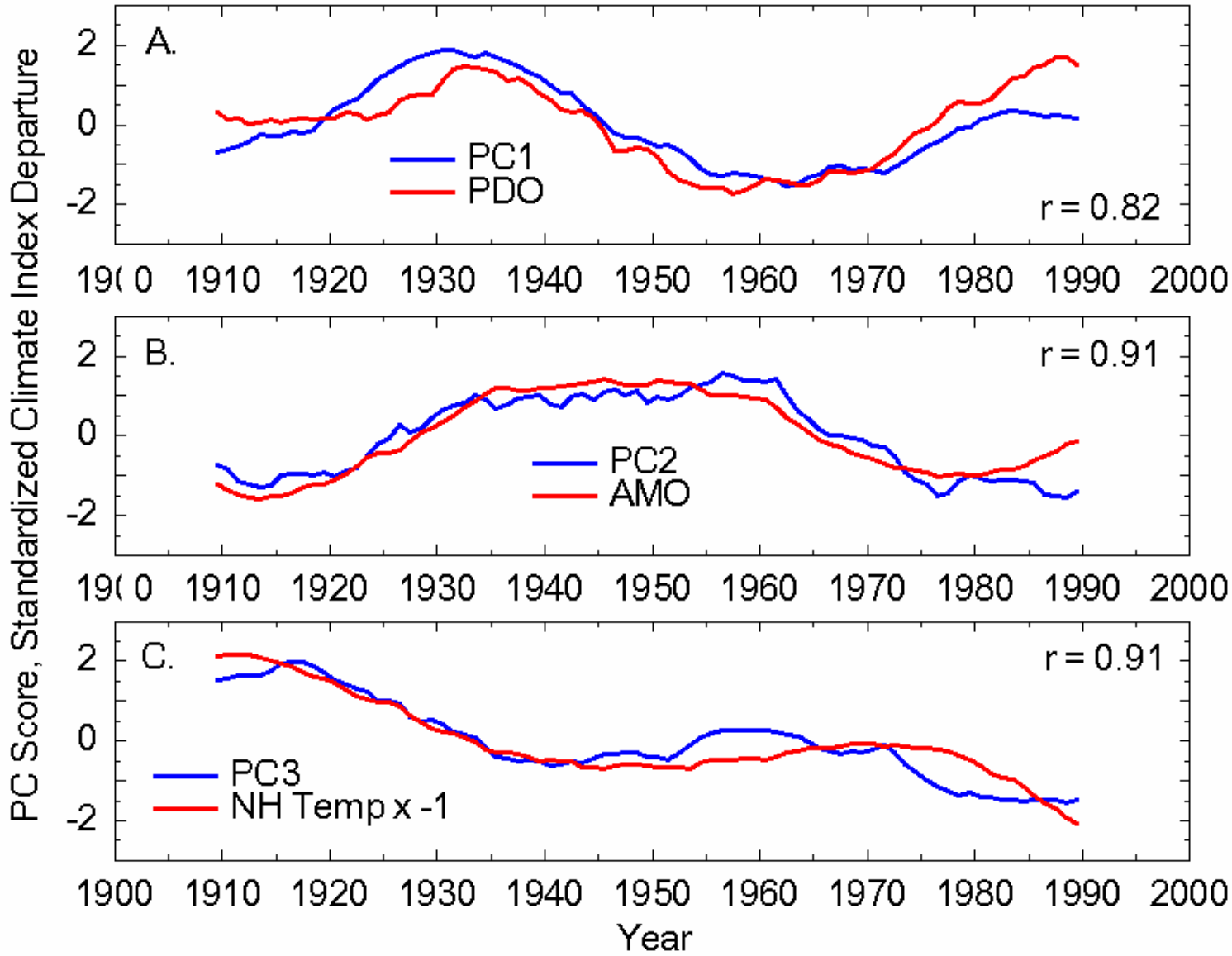


20yr moving NH temp vs.
20yr drought frequencies



Red -> less droughts
Blue -> more droughts

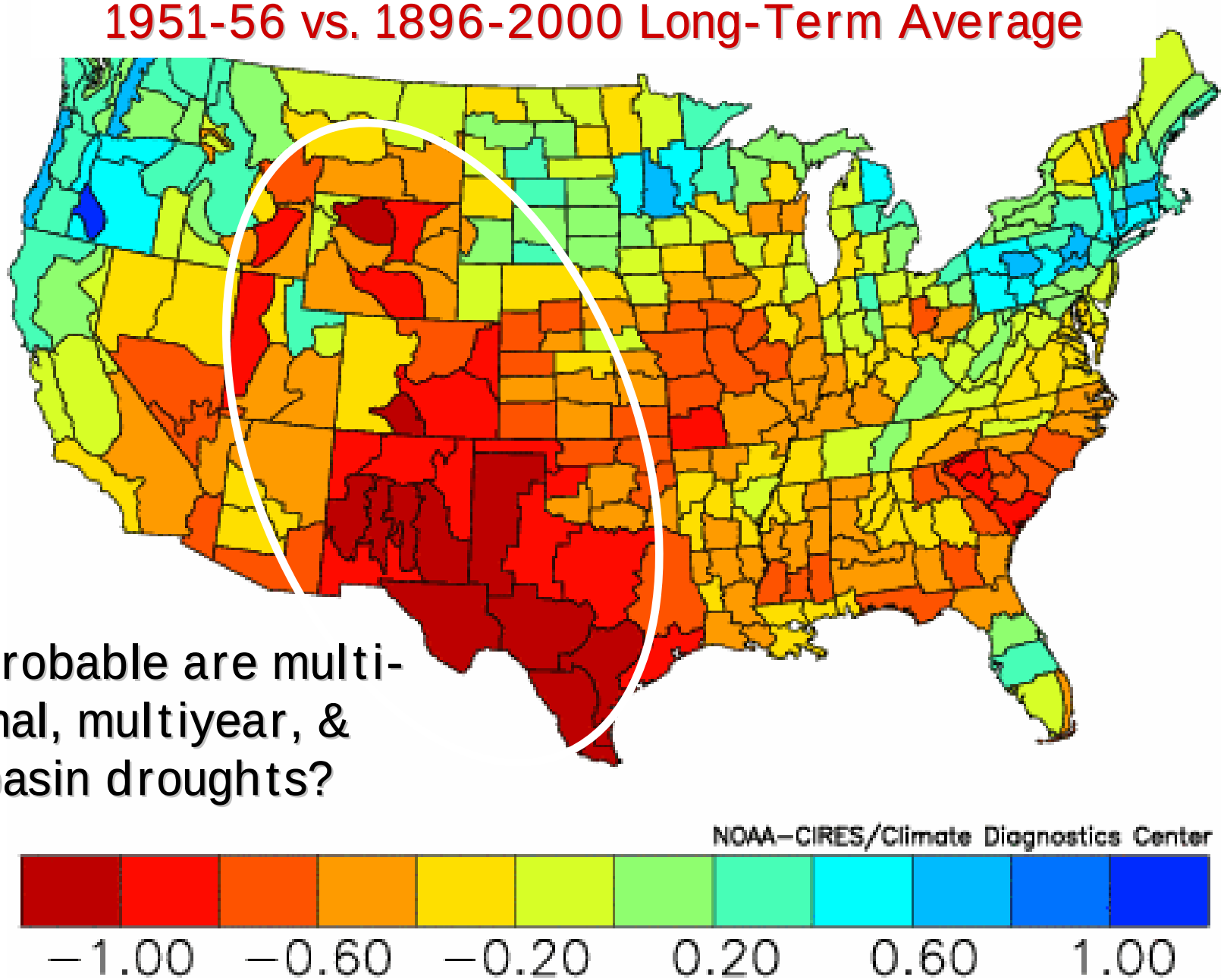
McCabe, Palecki & Betancourt (2004)



McCabe, Palecki & Betancourt (2004)

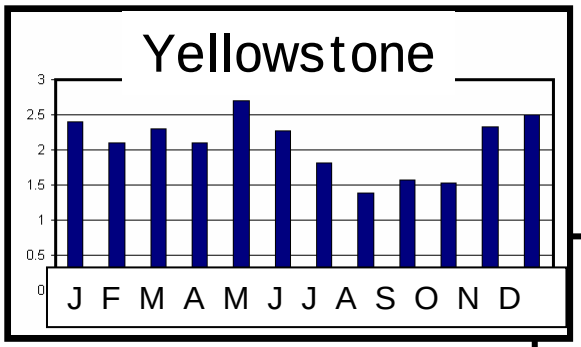
Composite Standardized Precipitation Anomalies

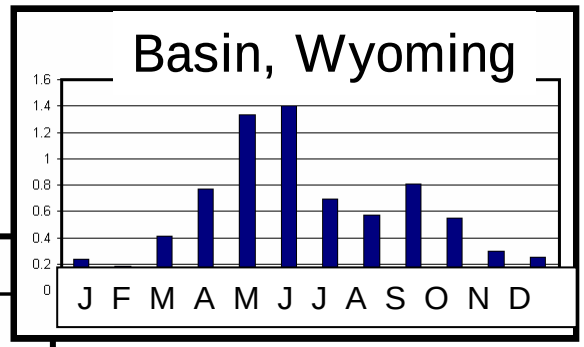
1951-56 vs. 1896-2000 Long-Term Average

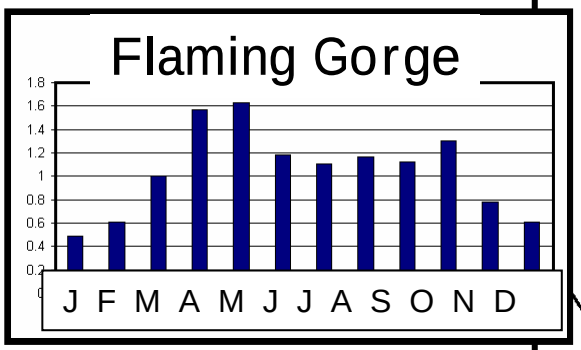


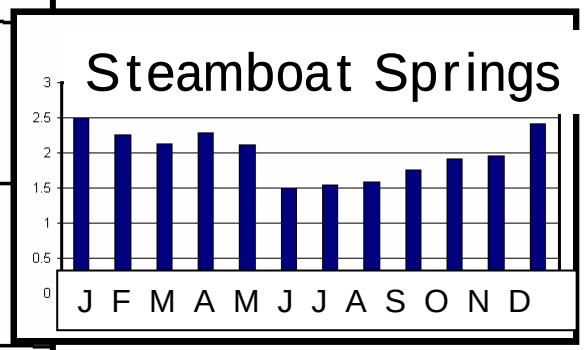
How probable are multi-seasonal, multiyear, & multibasin droughts?

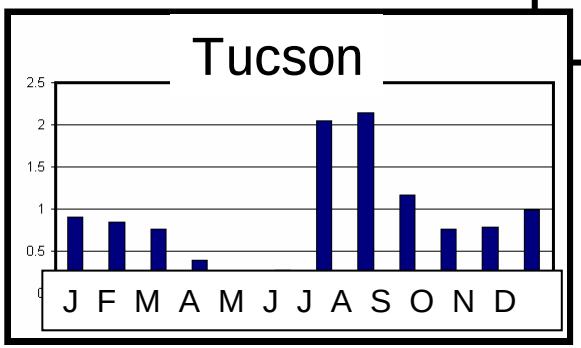
Seasonality of Precipitation

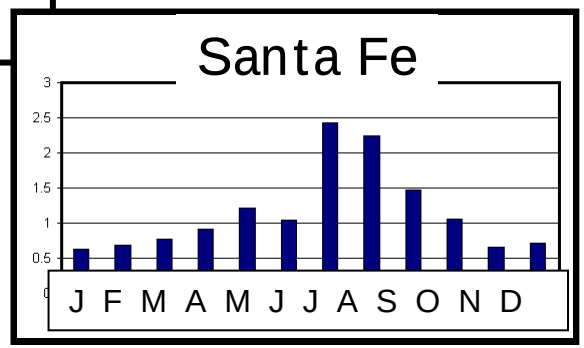


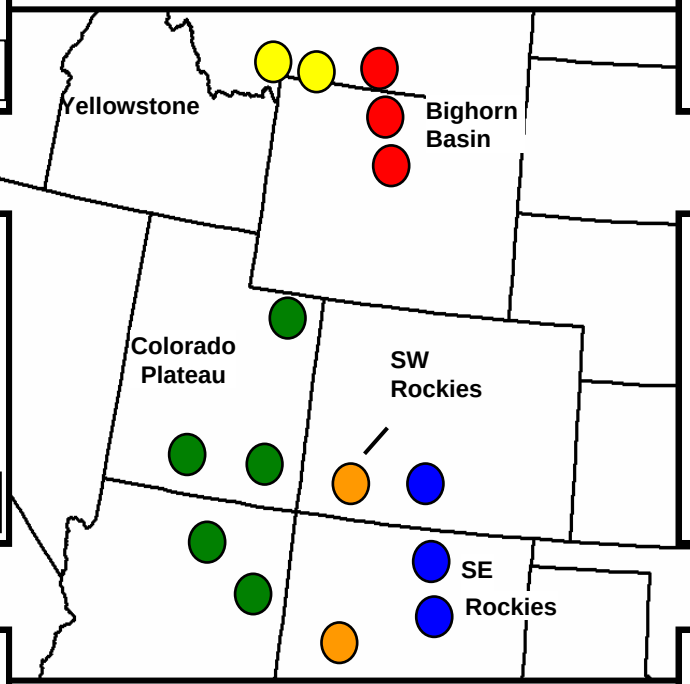






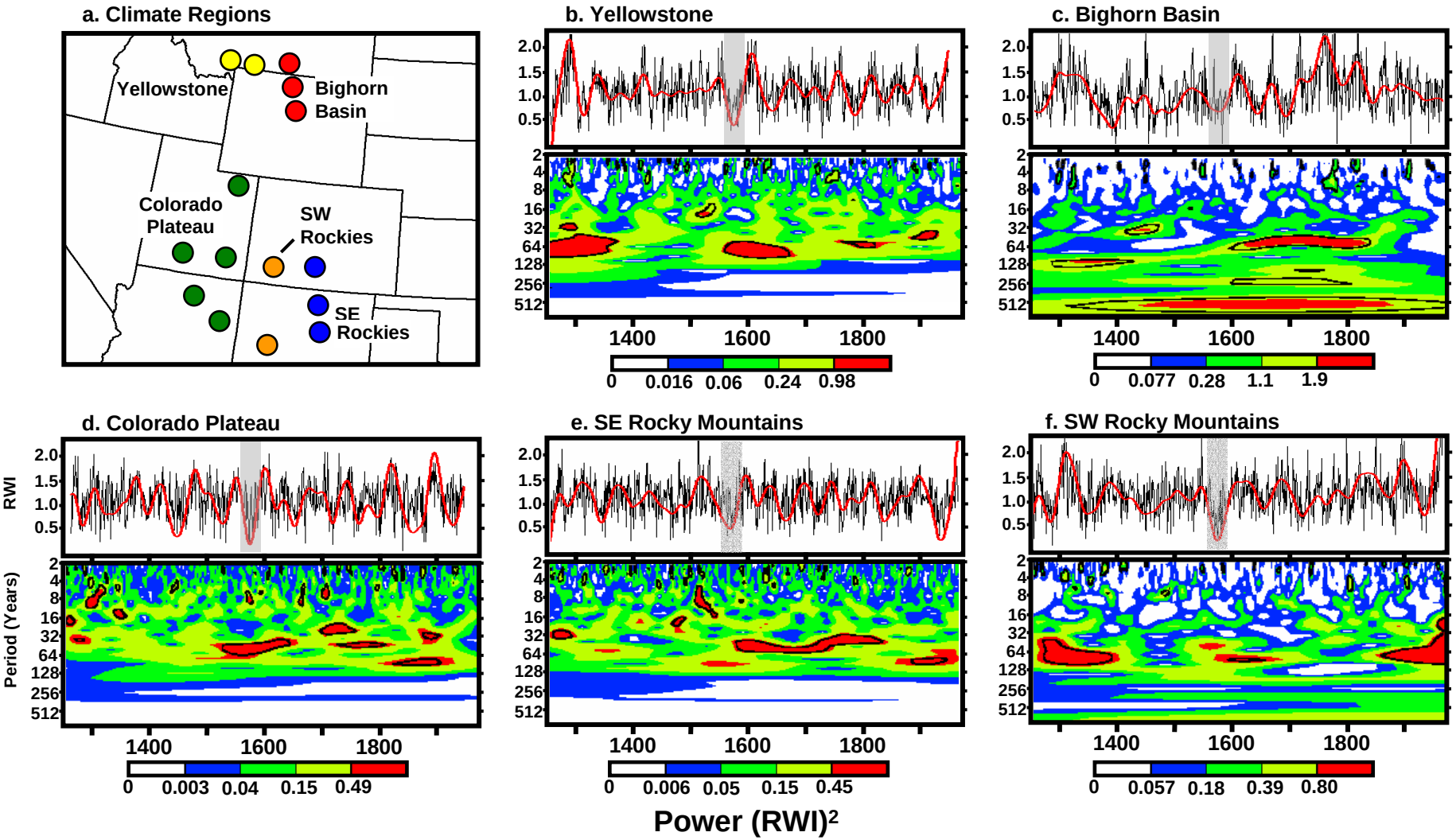






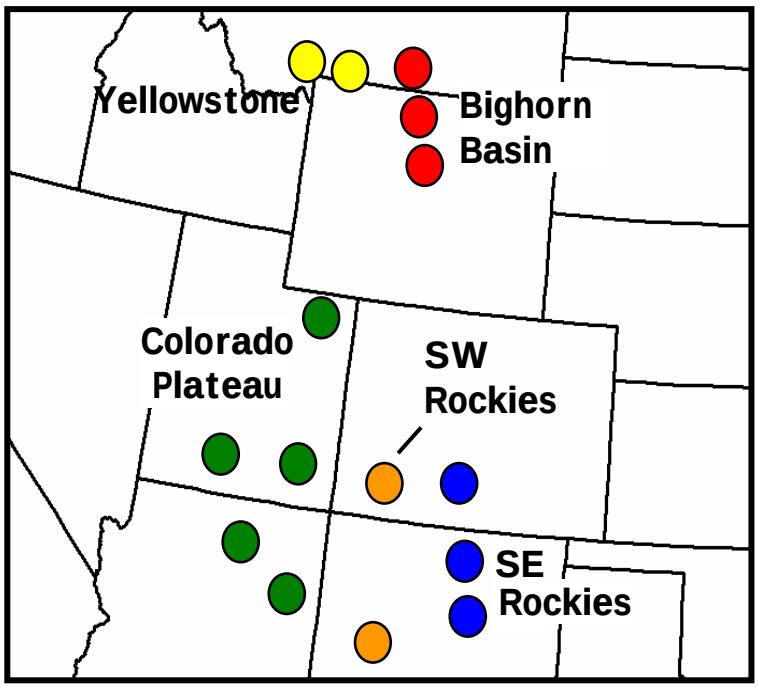
Tree-Ring Sites In Central & Southern Rockies

What is the source of regionally coherent, multidecadal precipitation oscillations in the central & southern Rockies & adjacent regions?

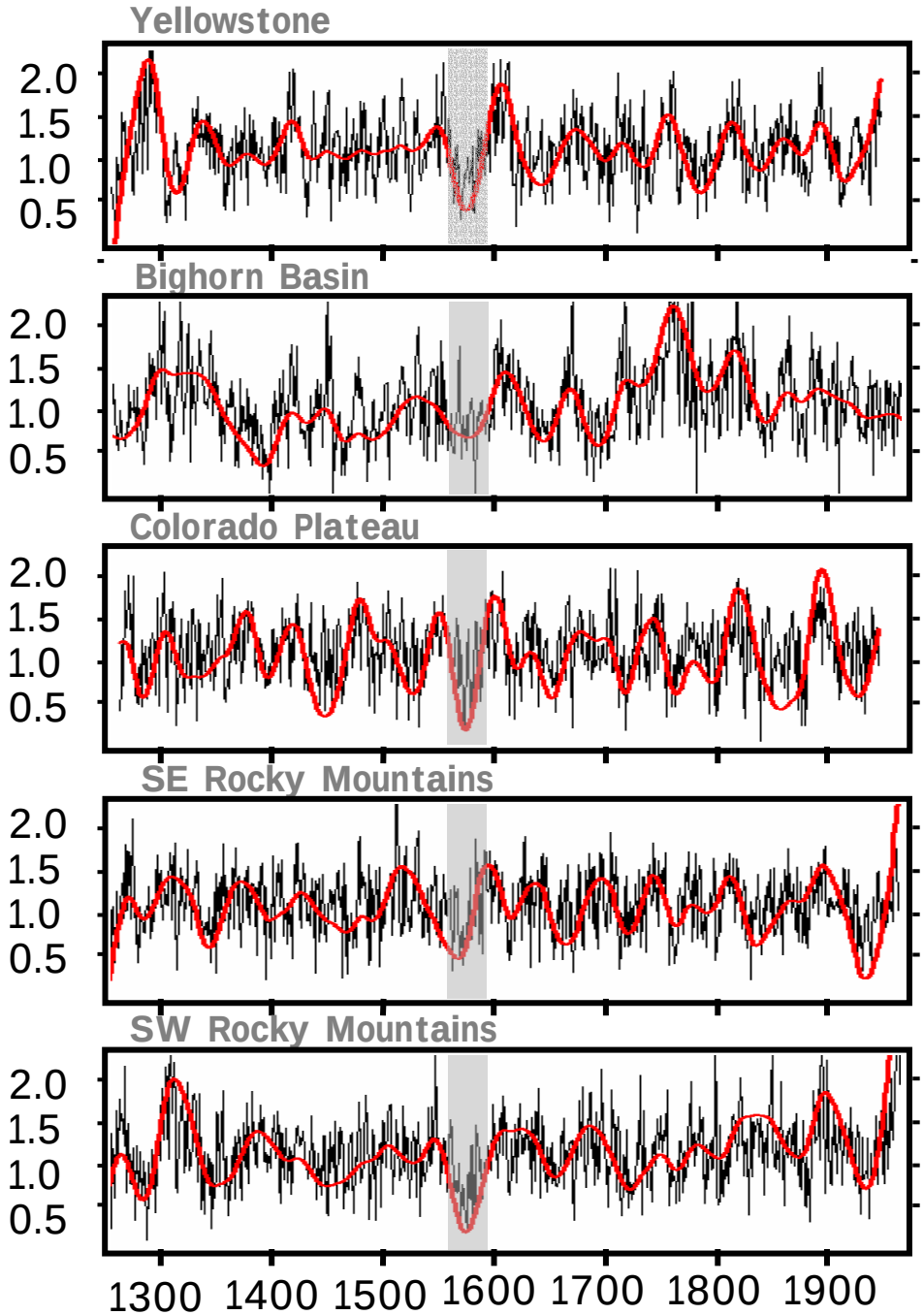


Gray, Betancourt, Fastie,& Jackson 2003

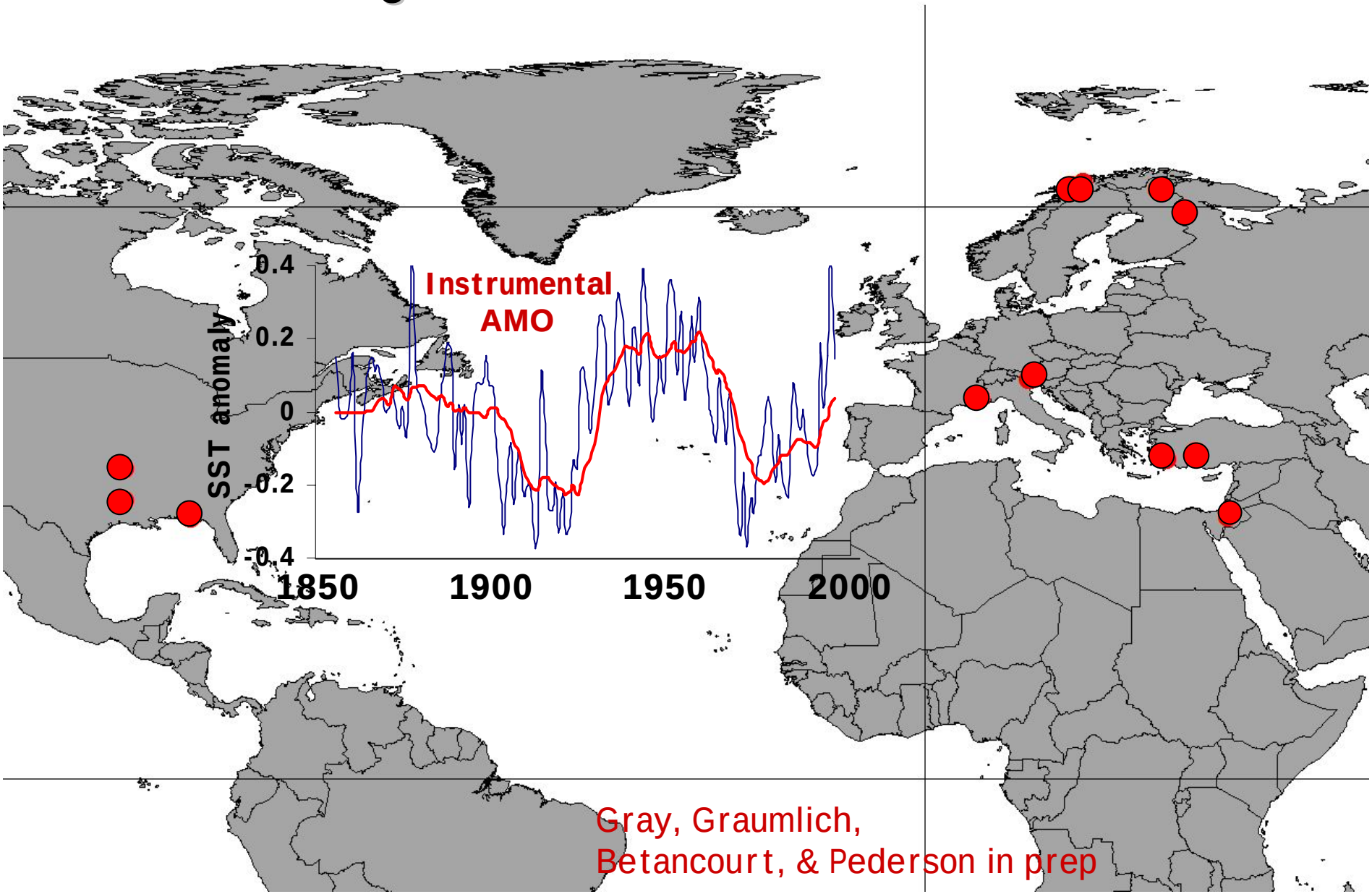
Multidecadal Variability & Evidence for Multi-basin, Multi-seasonal wet & dry spells



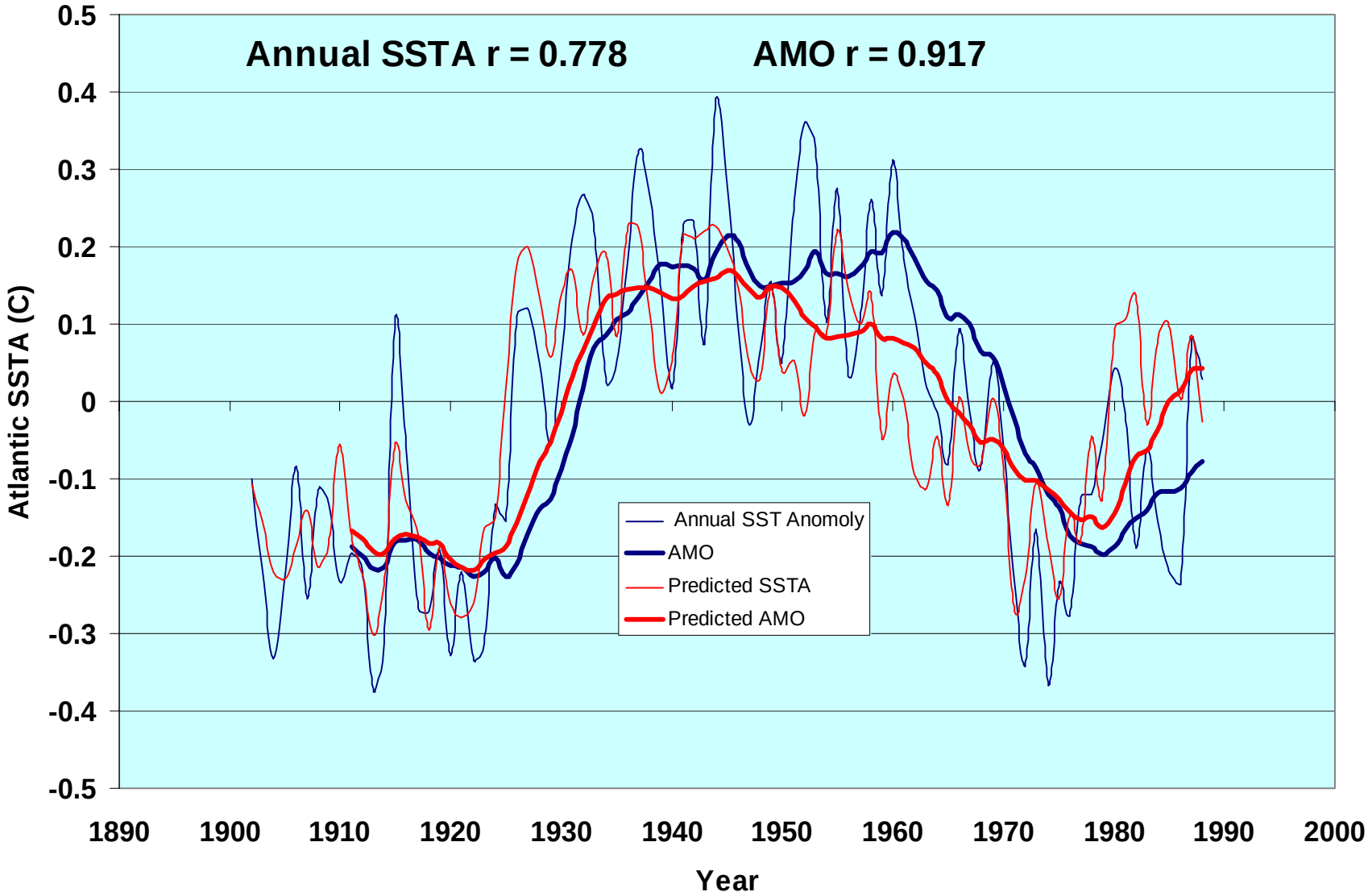
Gray, Betancourt, Fastie, & Jackson 2003



Tree-Ring Sites for AMO Reconstruction

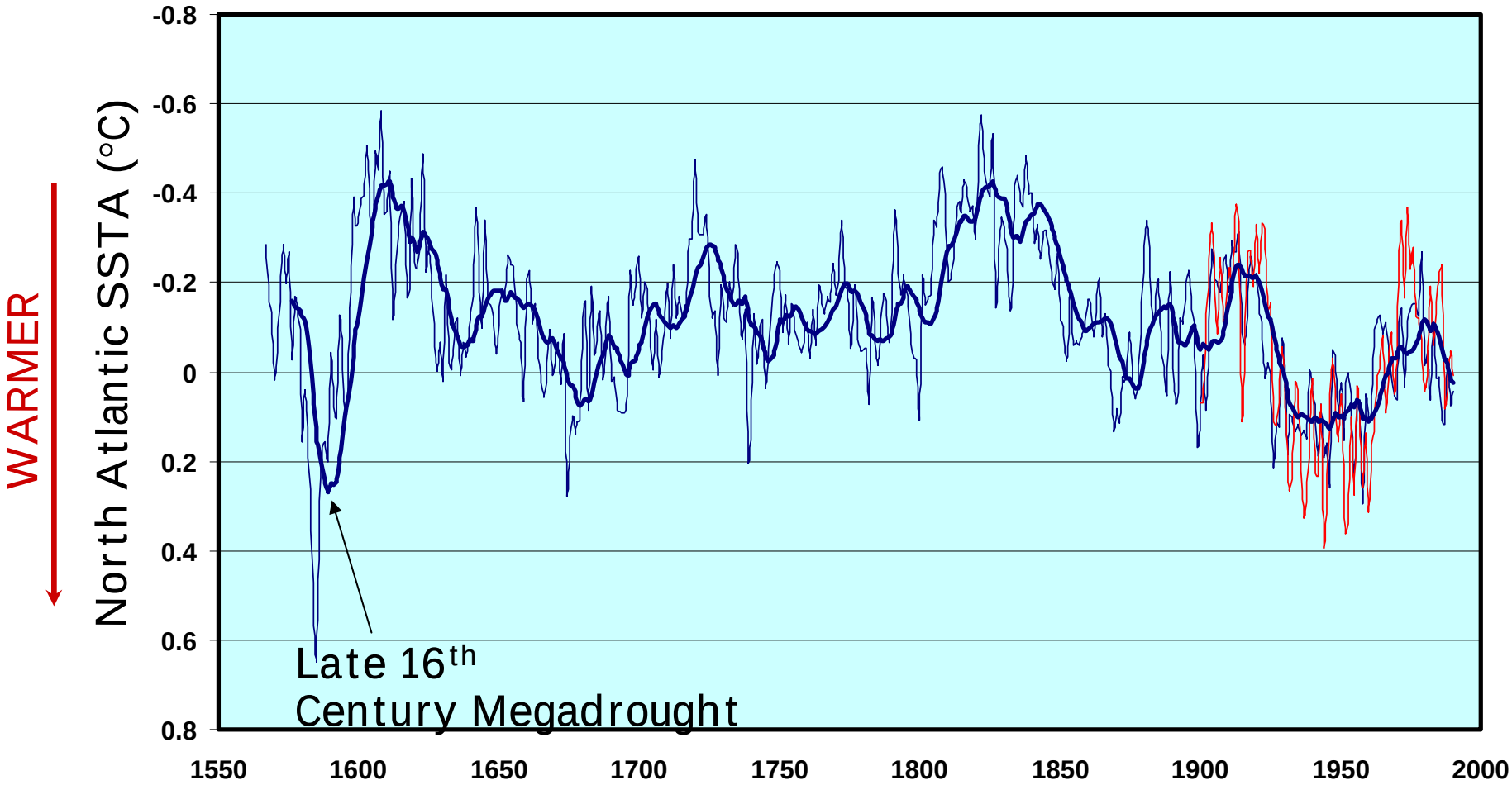


Tree-Ring Reconstruction of AMO: Calibration

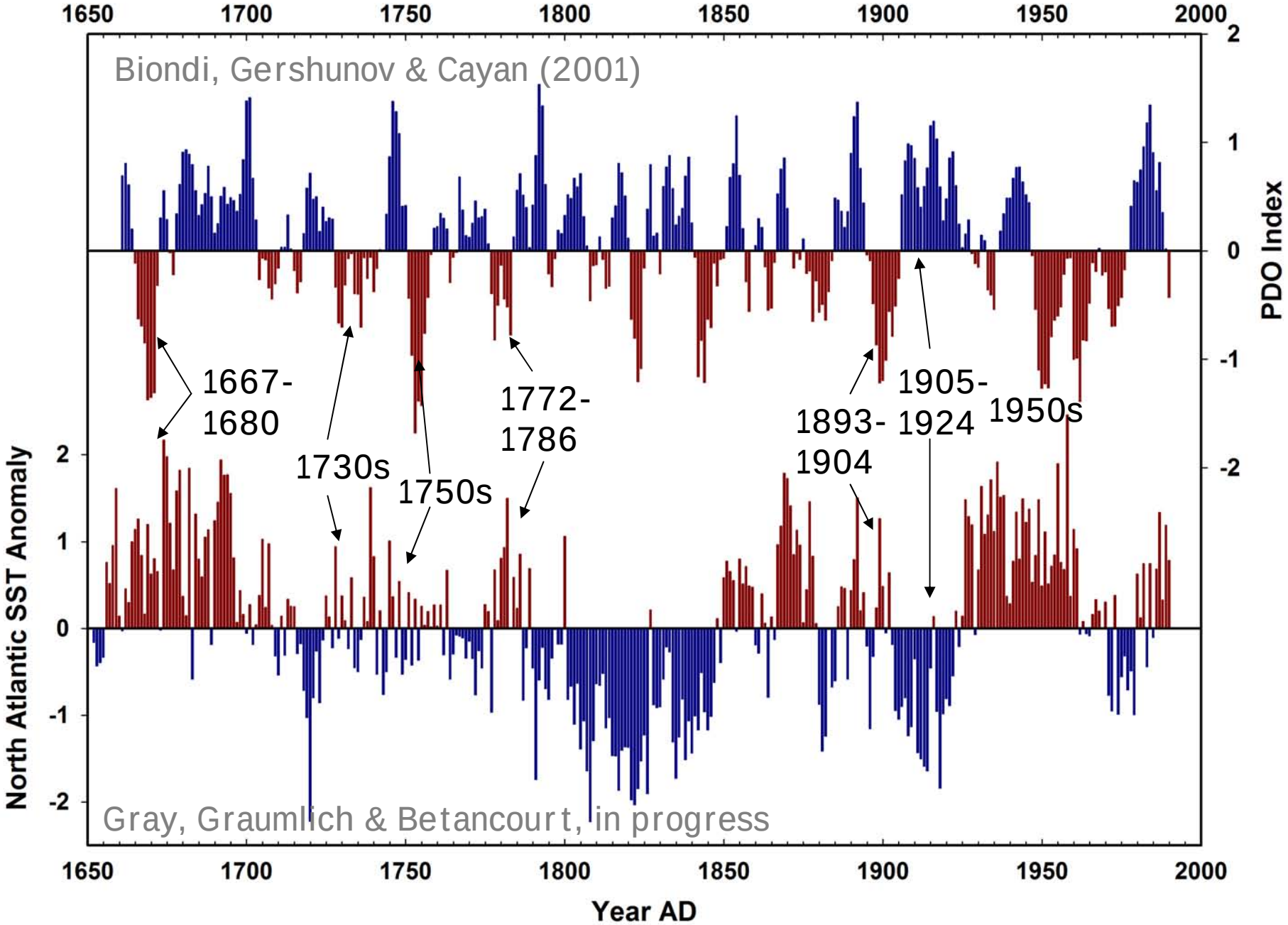


Gray, Graumlich, Betancourt & Pederson in progress

Tree-Ring Reconstruction of AMO



Gray, Graumlich, Betancourt & Pederson, in progress

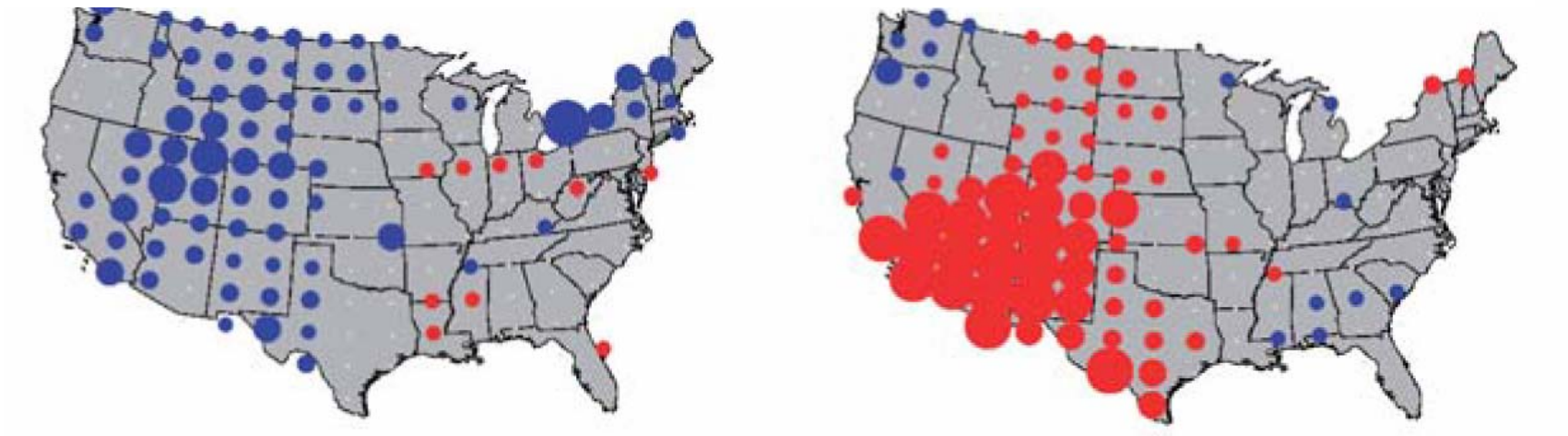

Biondi, Gershunov & Cayan (2001)
Gray, Graumlich & Betancourt, in progress
1667-
1680
1730s
1750s
1772-
1786
1893-
1904
1905-
1924
1950s
1650
1700
1750
1800
1850
1900
1950
2000
Year AD
North Atlantic SST Anomaly
PDO Index
2
1
0
-1
-2

Relationship of 20-yr Smoothed AMO & PDO with Reconstructed PDSI

AD 1660-2000

AMO vs. PDSI

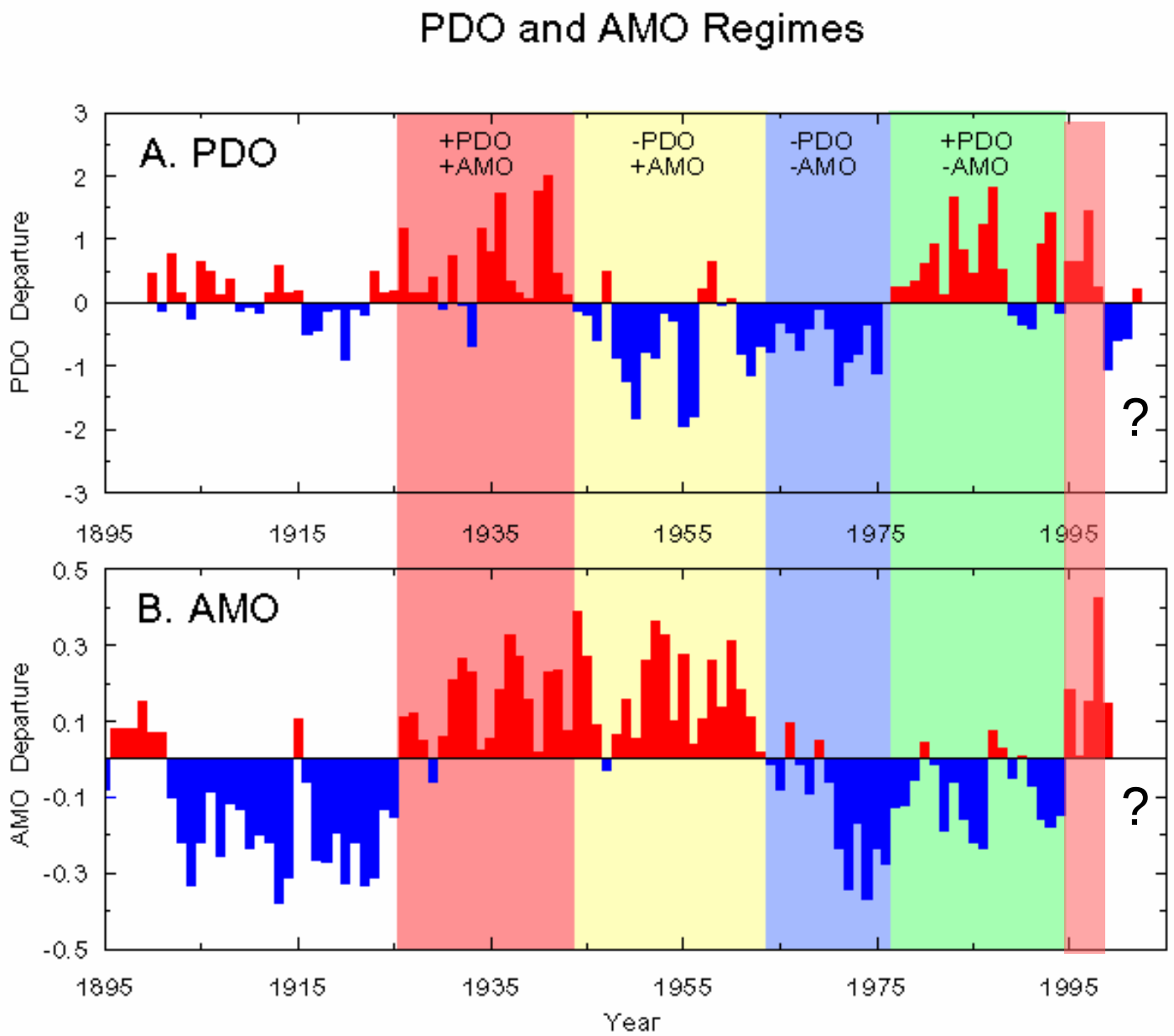
PDO vs. PDSI



AMO- Atlantic Multidecadal Index (Gray, Graumlich & Betancourt, In prep)

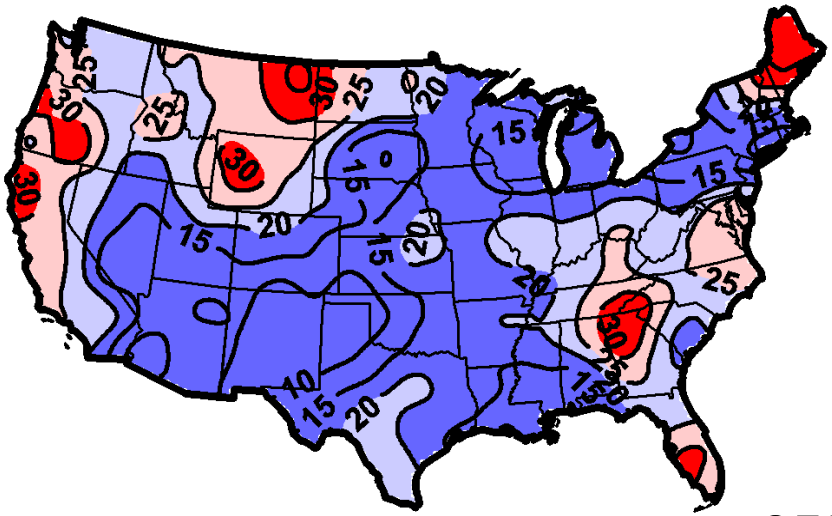
PDSI- Palmer Drought Severity Index (Cook, Meko, Stahle, & Cleavland 1999)

PDO- Pacific Decadal Oscillation (Biondi, Gershunov, & Cayan 2001)

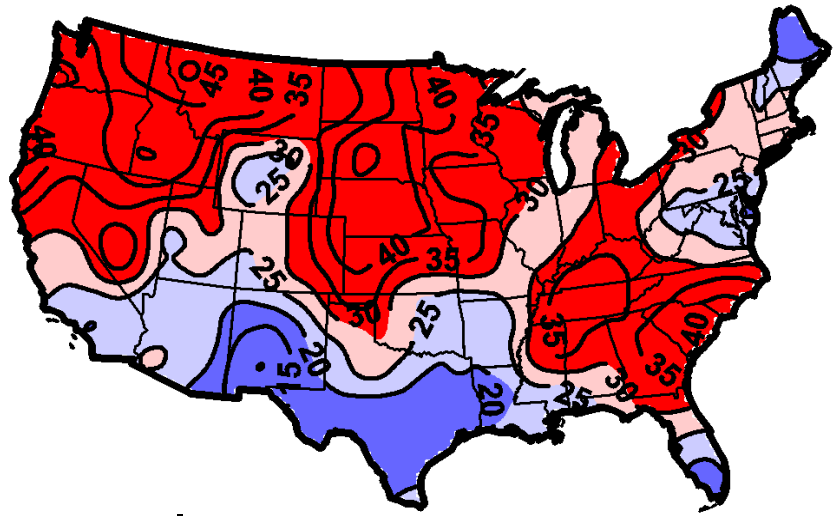


McCabe, Palecki & Betancourt (2003)

+PDO -AMO

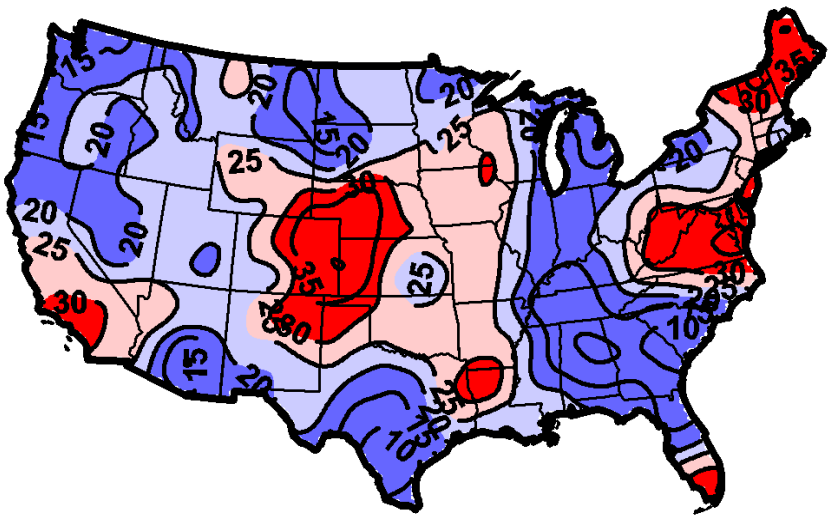


+PDO +AMO

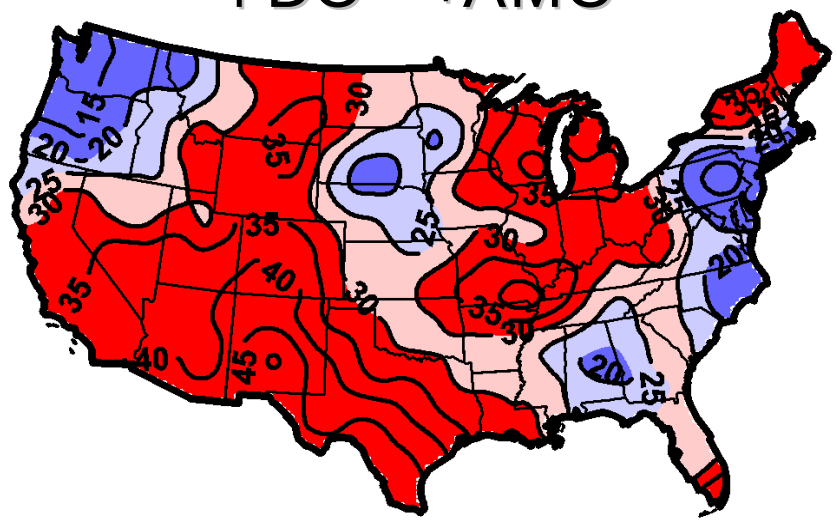


25% = normal

-PDO -AMO

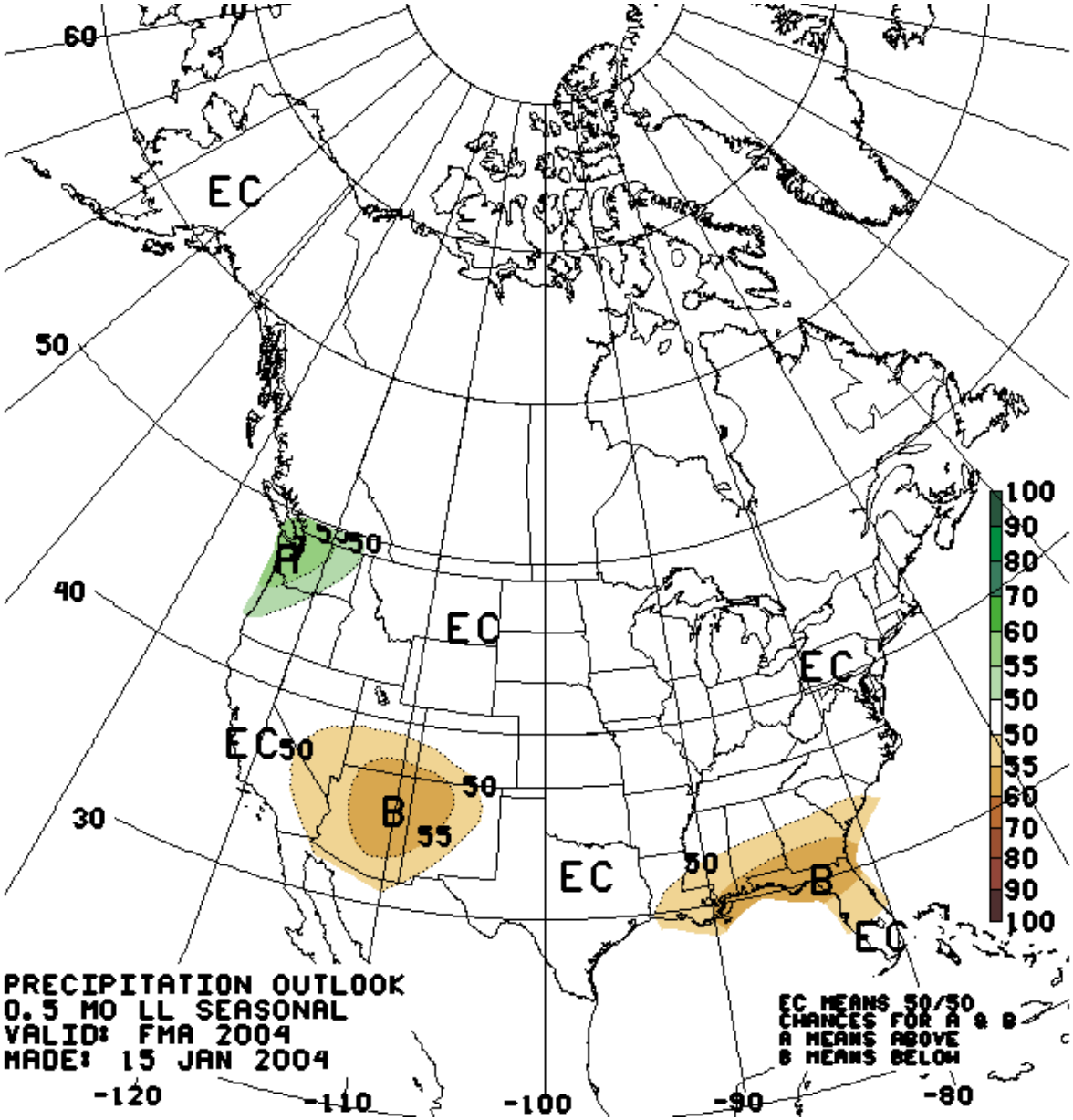


-PDO +AMO



McCabe, Palecki & Betancourt (2003)

Experimental Unofficial Two-class Monthly & Seasonal Climate Outlooks February-March-April 2004



NOAA
CPC

Conclusions

- Spatiotemporal patterns in U.S. drought frequencies are associated with AMO & PDO in both the instrumental & tree-ring record of the last 500 years.
- AMO primarily influences summertime precipitation, but it may also modulate the average latitude & sinuosity of the westerlies (+AMO = H pressure over western states)
- Multiseasonal, large-scale droughts result from complementary modes of the AMO (+) and PDO (-)
- Current ocean configuration foretells continuing drought
- Severe, multiyear and subcontinental droughts play key roles in natural landscape responses to climate variability and could accelerate the impacts of climate change

Stay tuned!

<< FHM Working Group Agenda