Drought: Historical Context

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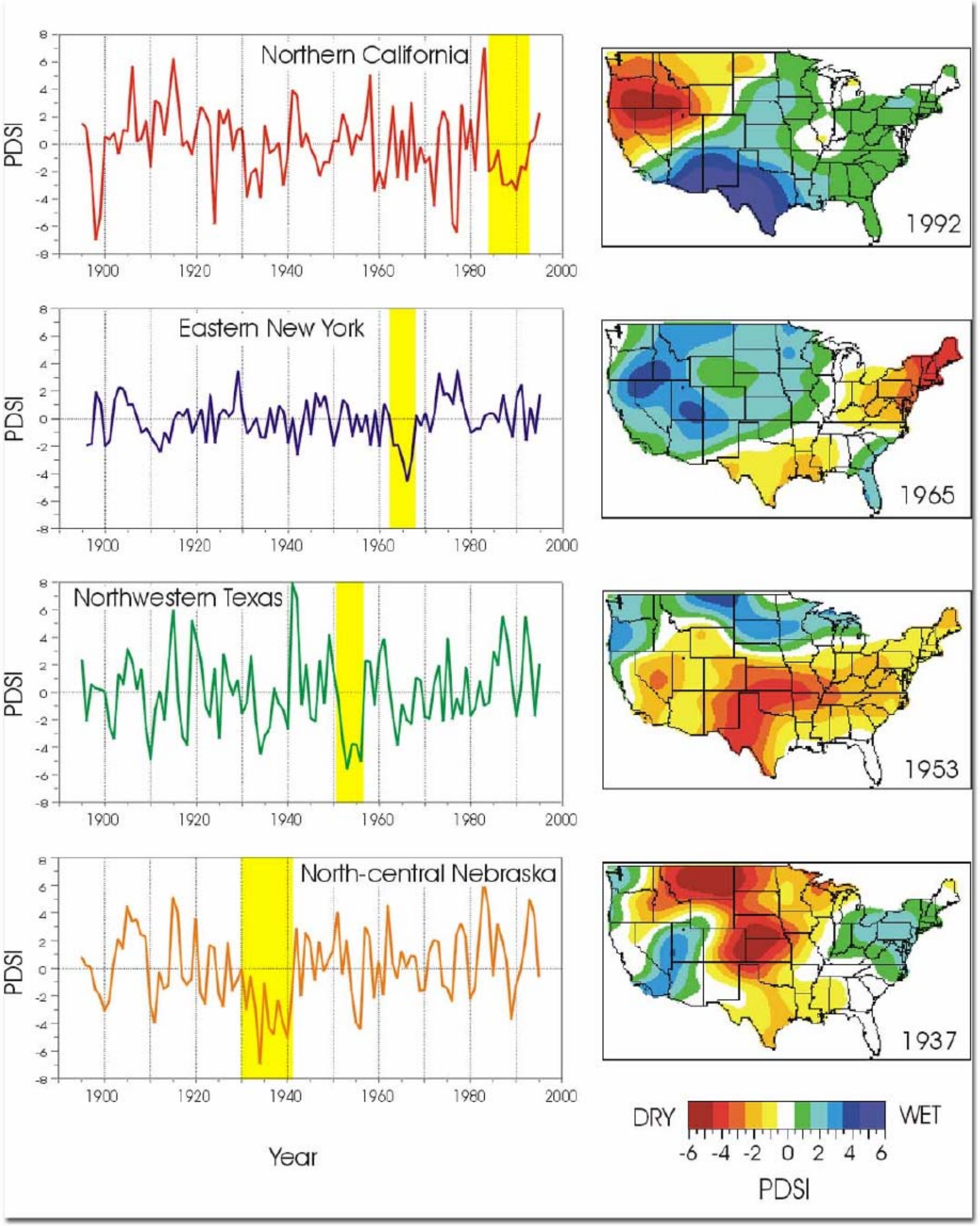
Platte River, near Columbus, Nebraska, October 2004

The spatial and temporal variability of drought is large.

Local droughts are not cyclical (same amplitude at regular intervals).

Predictability of drought is difficult.



Source: NOAA Paleoclimate web page

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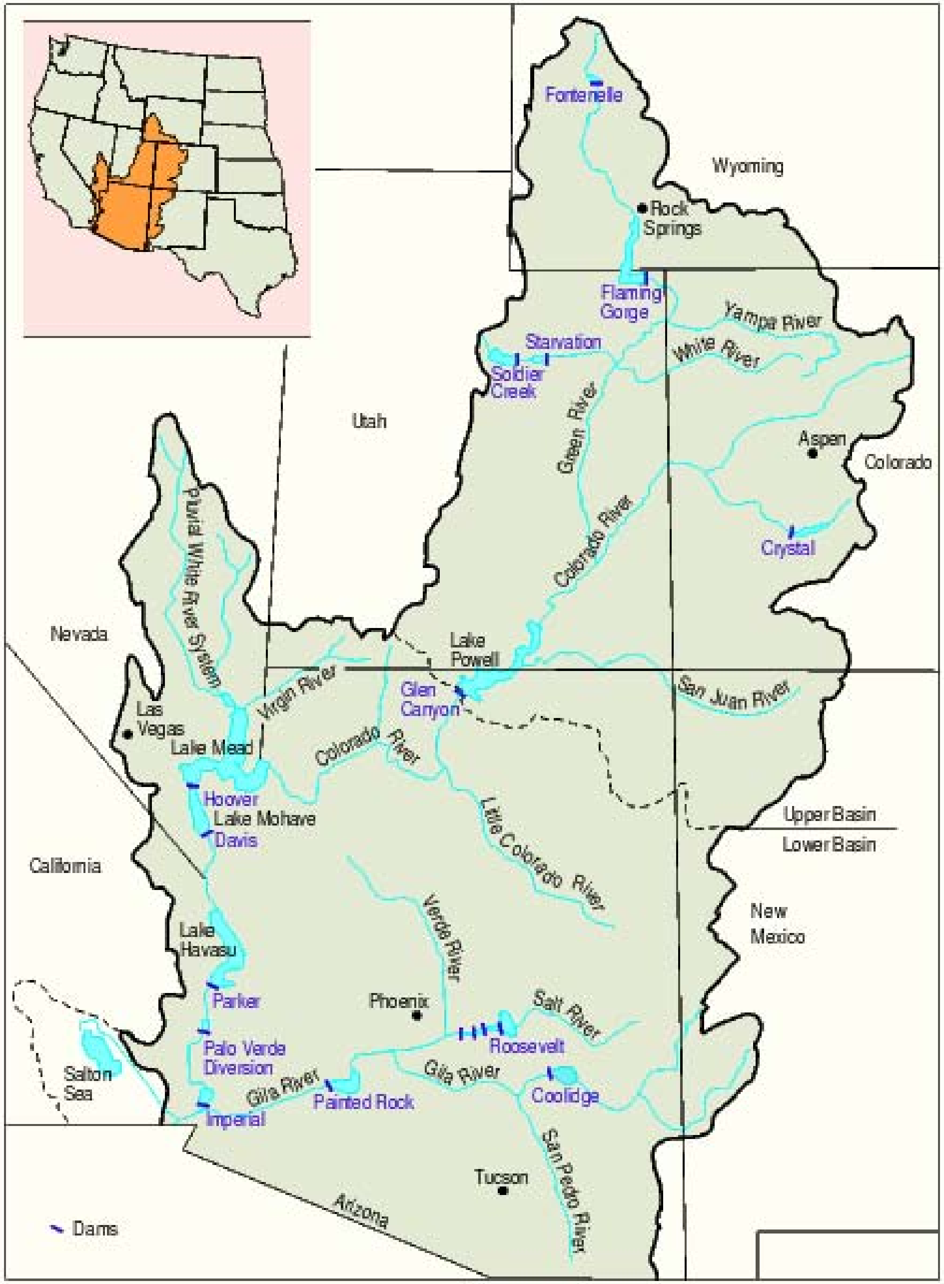
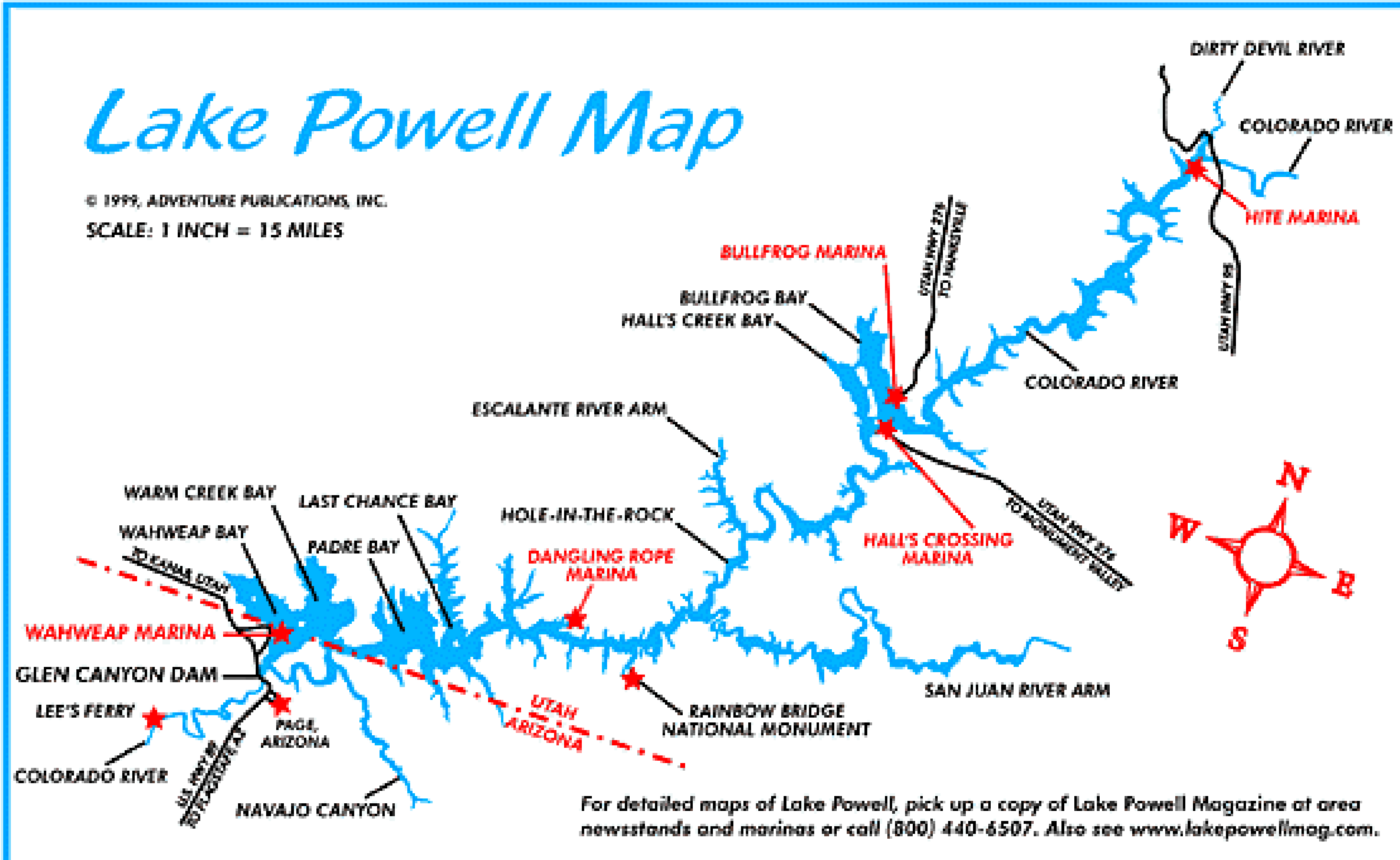
Colorado River Basin



The Colorado River Basin (243,937 mi2 / 631,960 km2)



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Drought has continued in a large part of the western U.S.

These two photos of Lake Powell and the confluence of the Colorado River and the Dirty Devil River show a 17-meter drop in the reservoir pool elevation from June 29, 2002 to December 23, 2003. (photos by John Dohrenwend)

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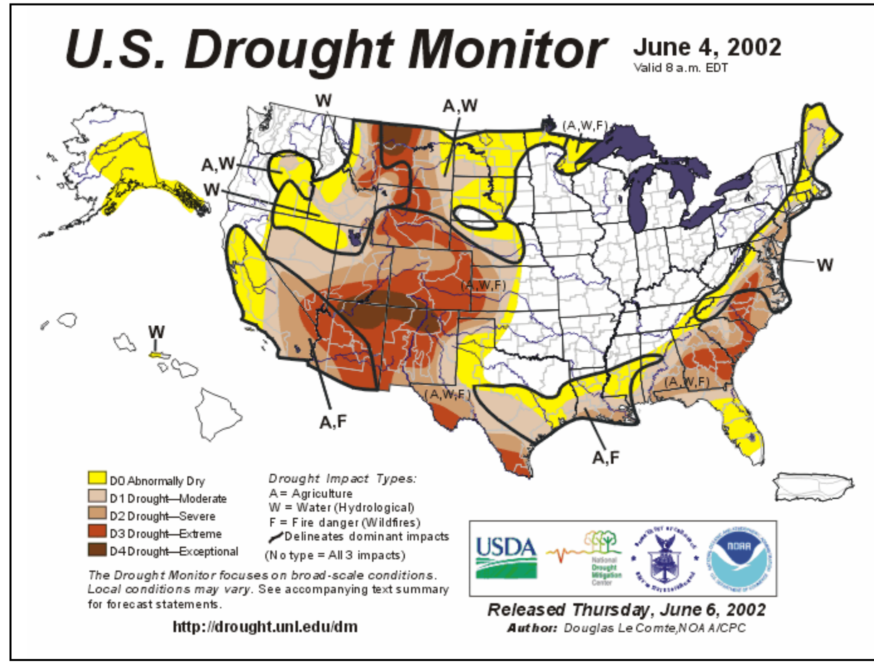

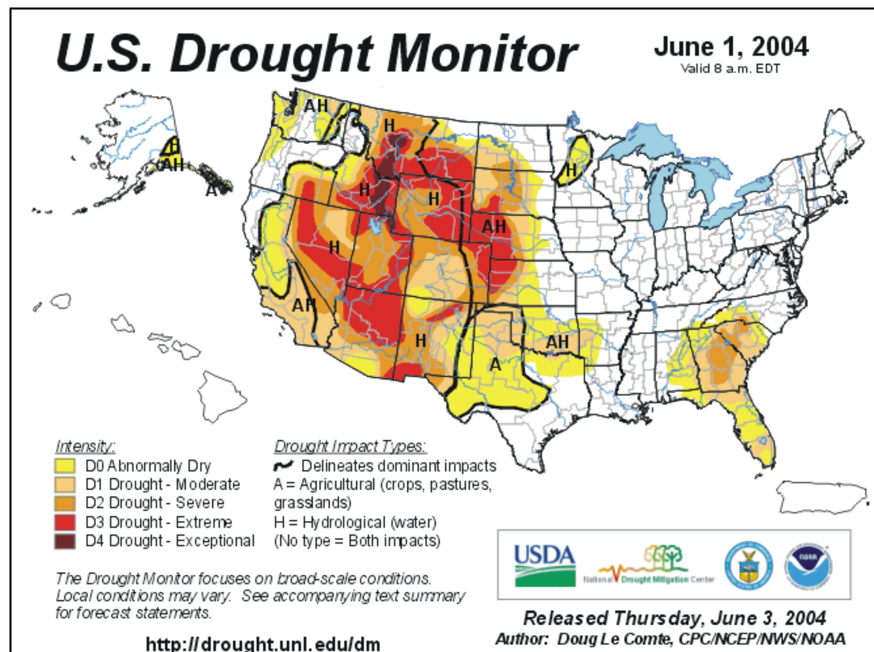

Forgotten Canyon, Lake Powell, 08/2004

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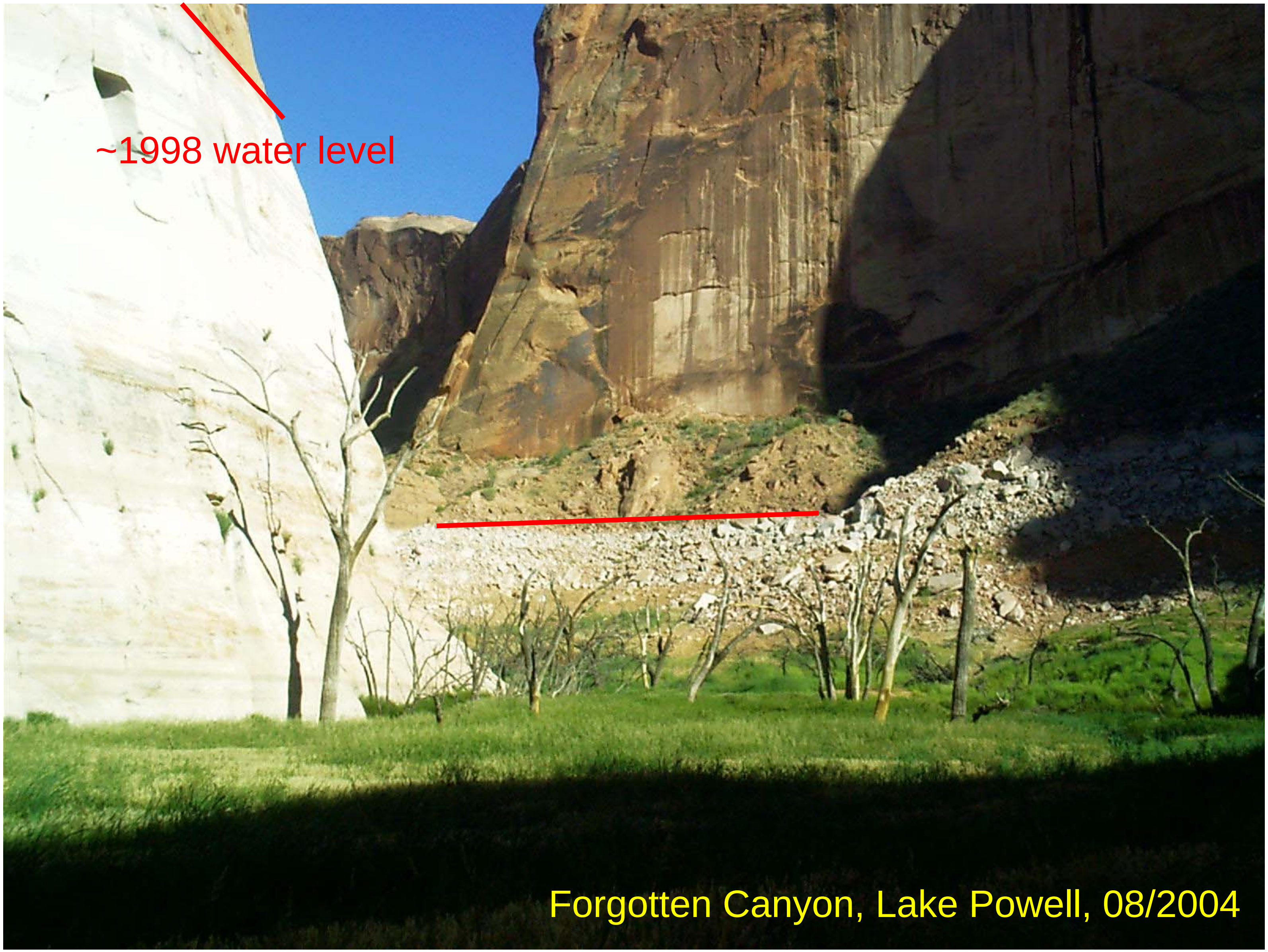
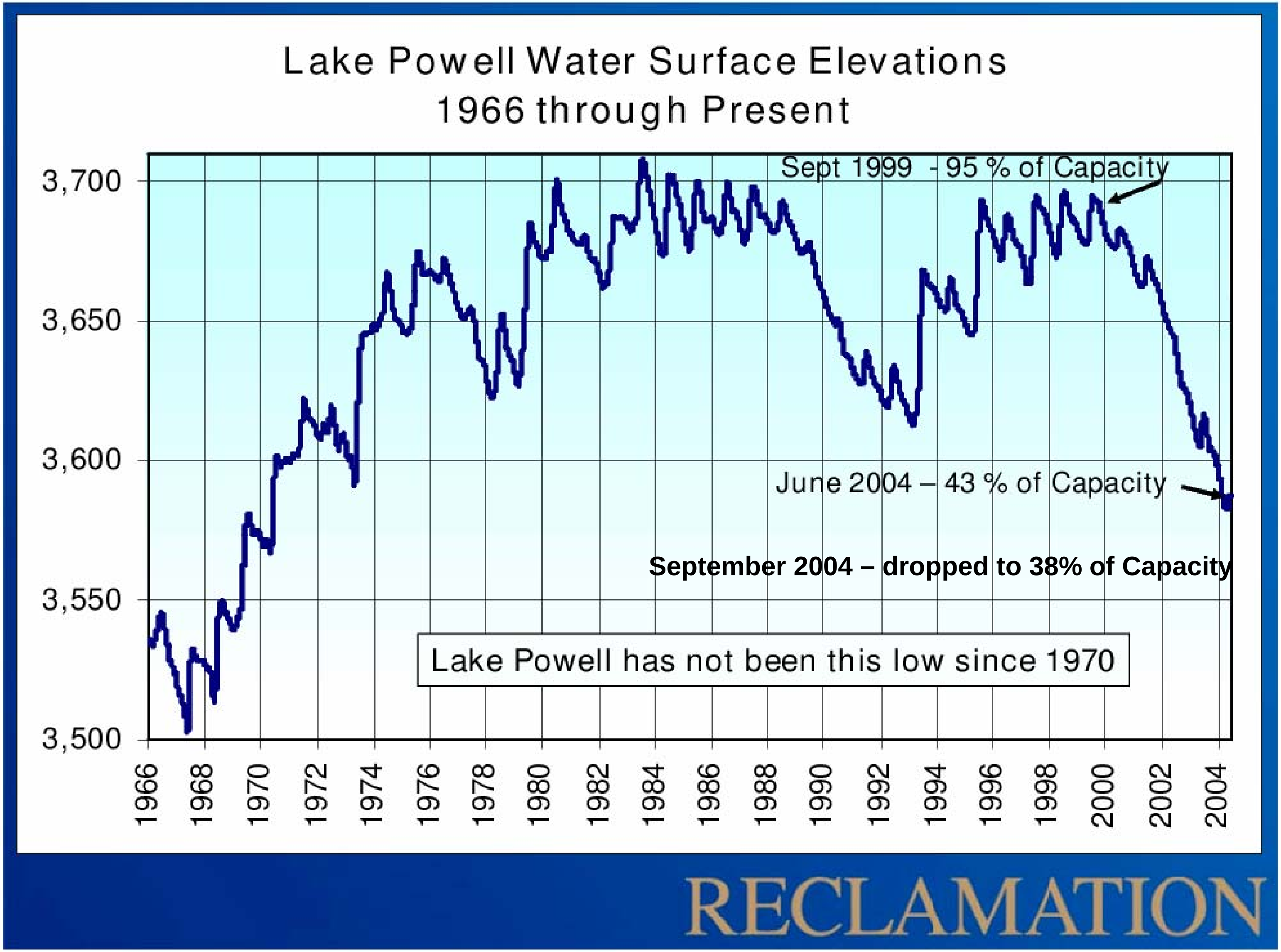

~1998 water level
Forgotten Canyon, Lake Powell, 08/2004



Courtesy Tom Ryan, US Bureau of Reclamation

Natural Flow
Mid-Term Droughts - Colorado River
(Average 100 year natural flow 15.0 maf)

Years	Duration	Average Flow
• 1931-1935	5 years	11.4 maf
• 1953-1956	4 years	10.2 maf
• 1959-1964	6 years	11.4 maf
• 1988-1992	5 years	10.9 maf
• 2000-2004	5 years	9.9 maf *

2000-2004 - Worst Mid-Term Drought in Record Keeping

Data from USBR

* Estimated

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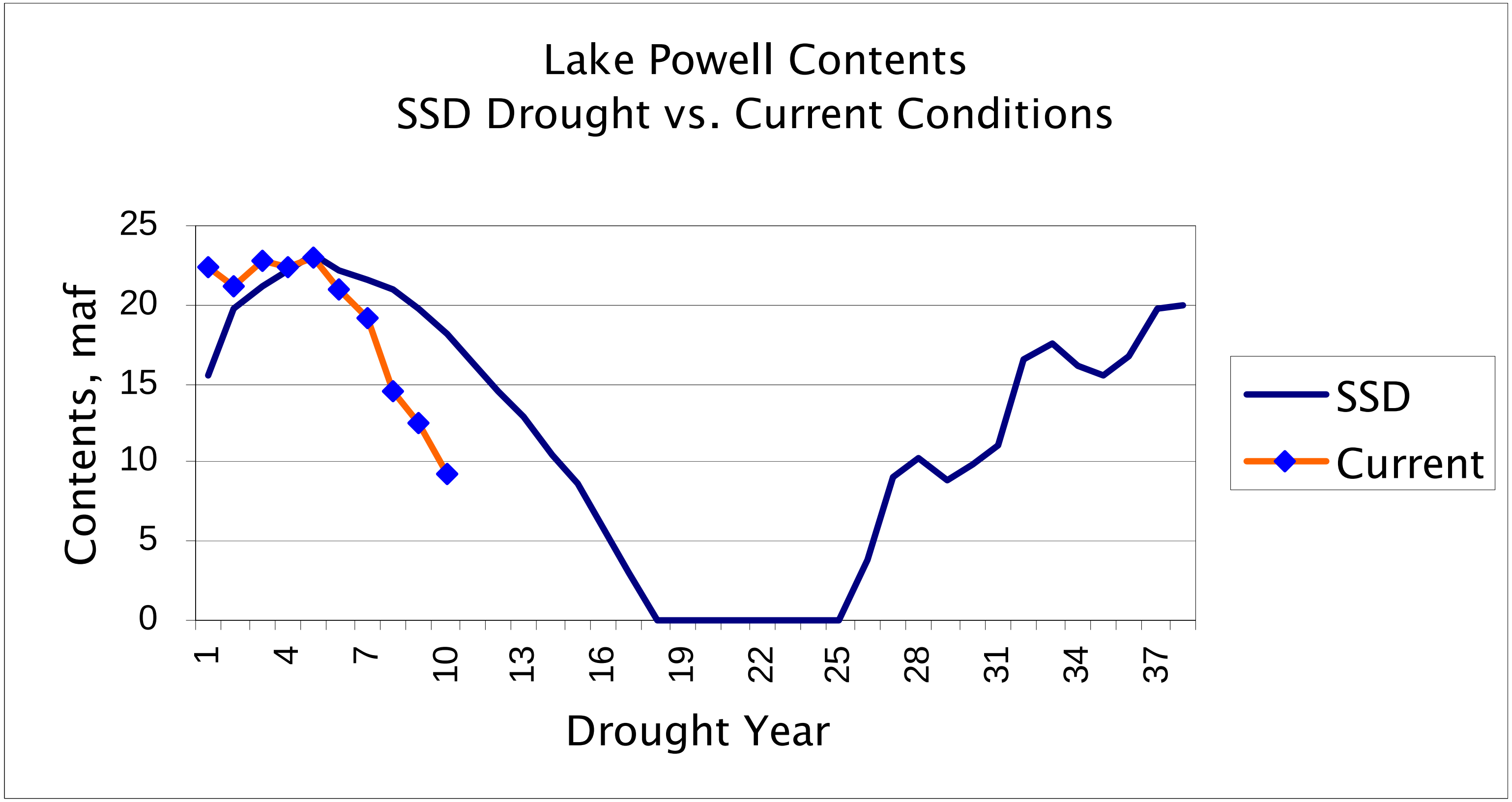
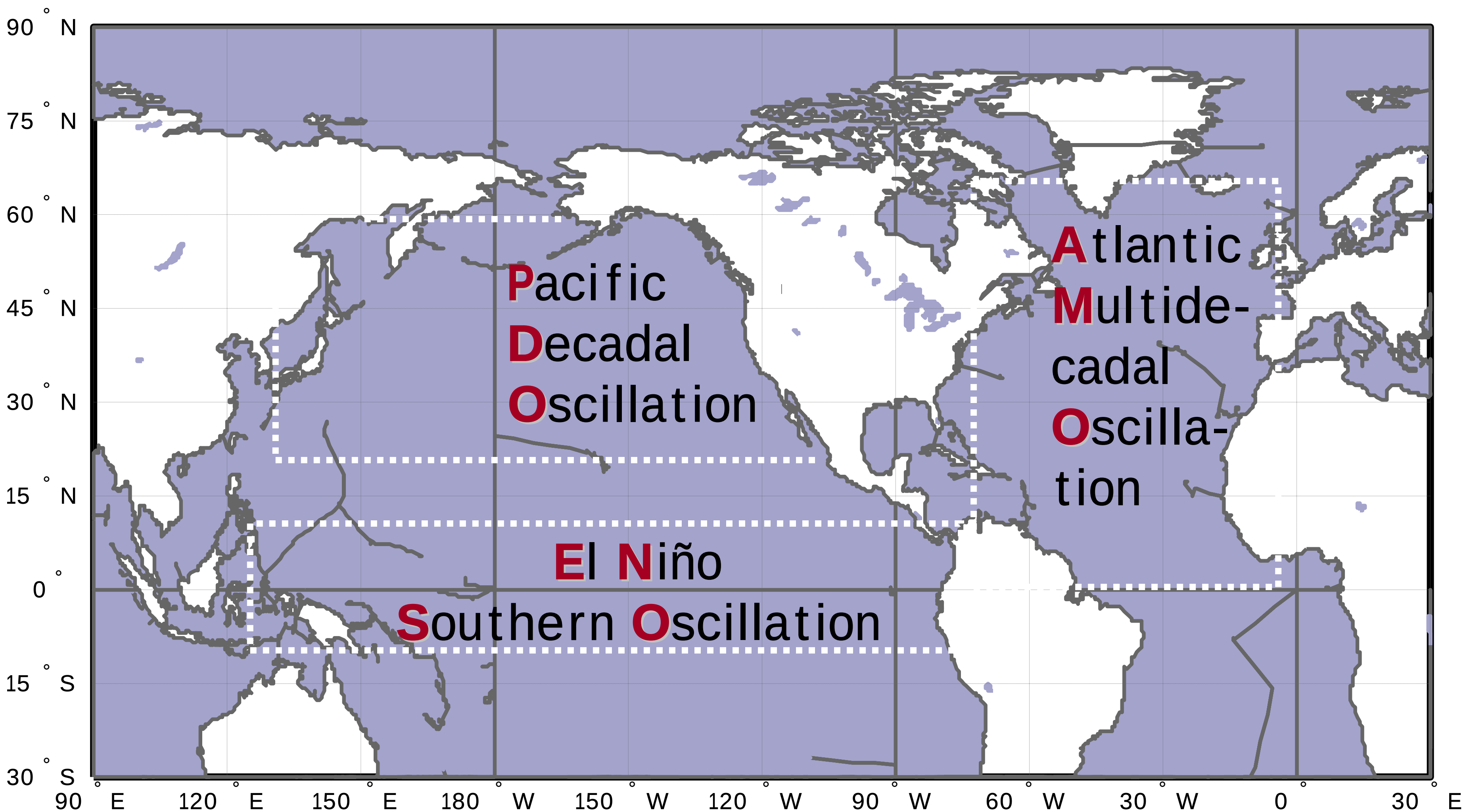
Effects of Severe-Sustained Drought on Lake Powell



Ben Harding, Hydrosphere,
http://www.hydrosphere.com/publications/recent_publications.htm

SST modes that influence US hydroclimatology



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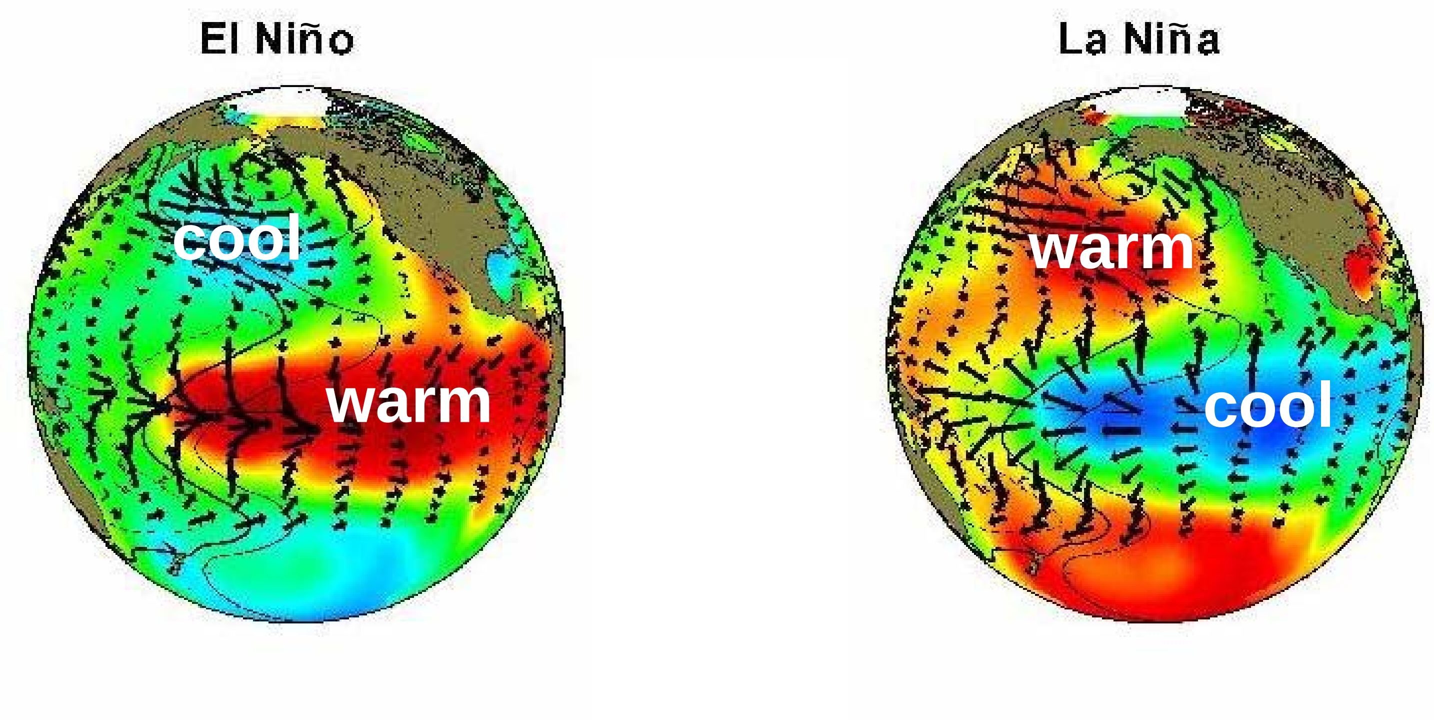
El Niño/Southern Oscillation (ENSO) is a primary mode of Pacific climate variability

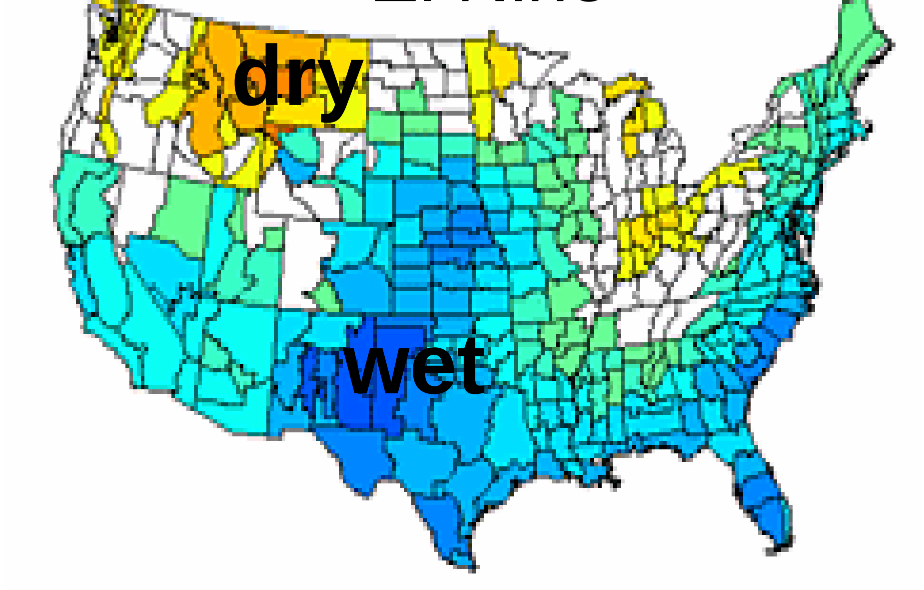
ENSO Sea-Surface Temperatures



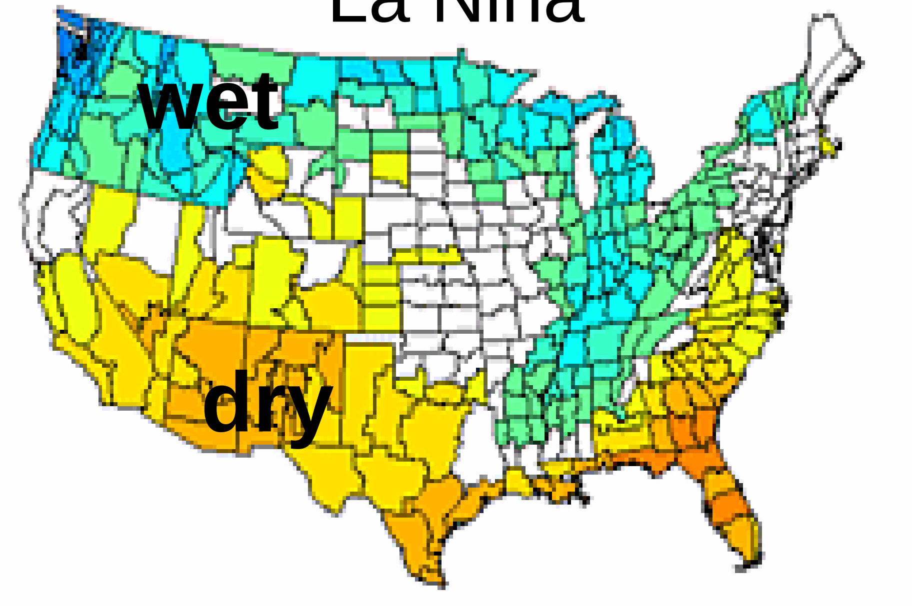
El Nino/La Nina affect climate in the US on short time scales (year-to-year fluctuations).

Winter Precipitation Anomalies for El Niño and La Niña

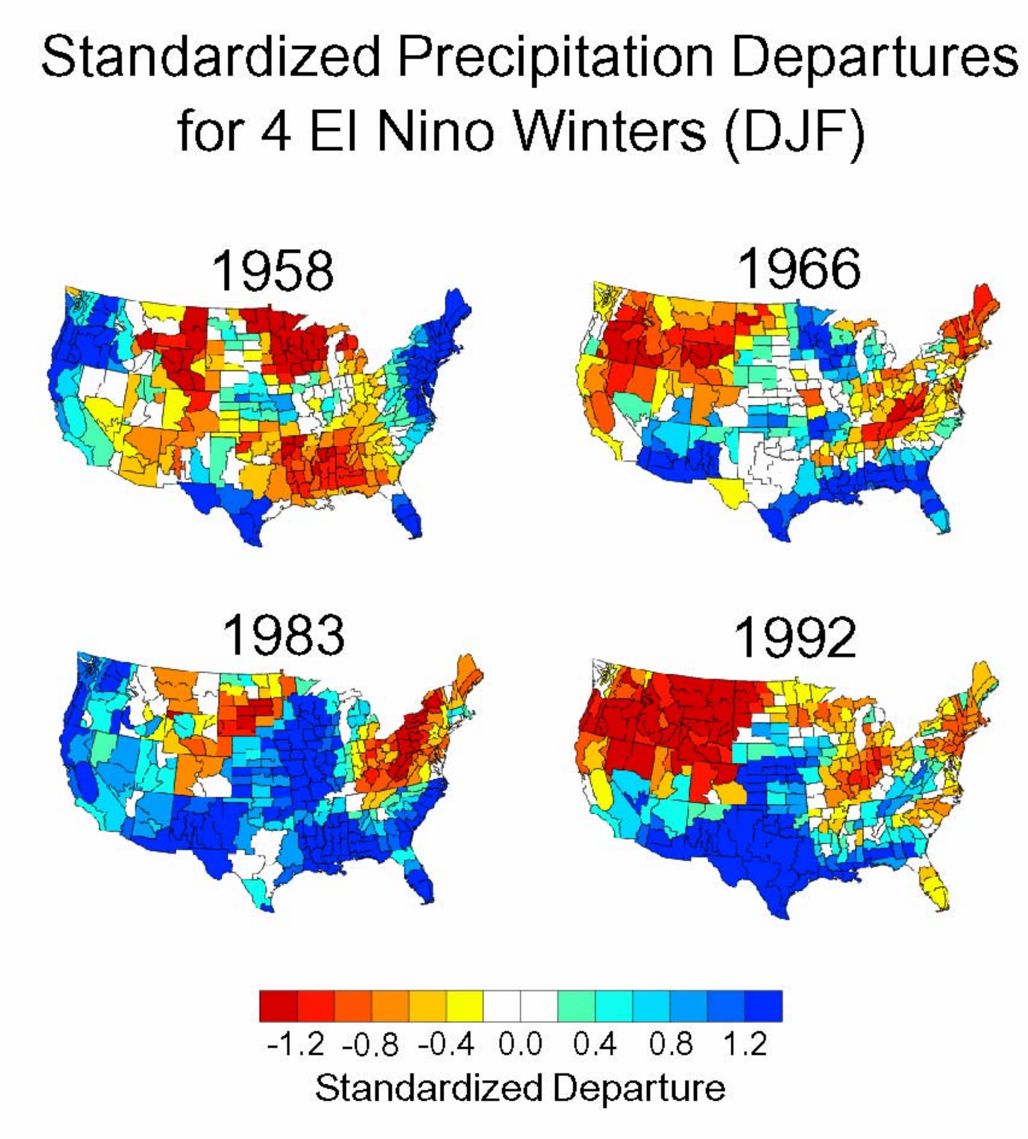
El Niño



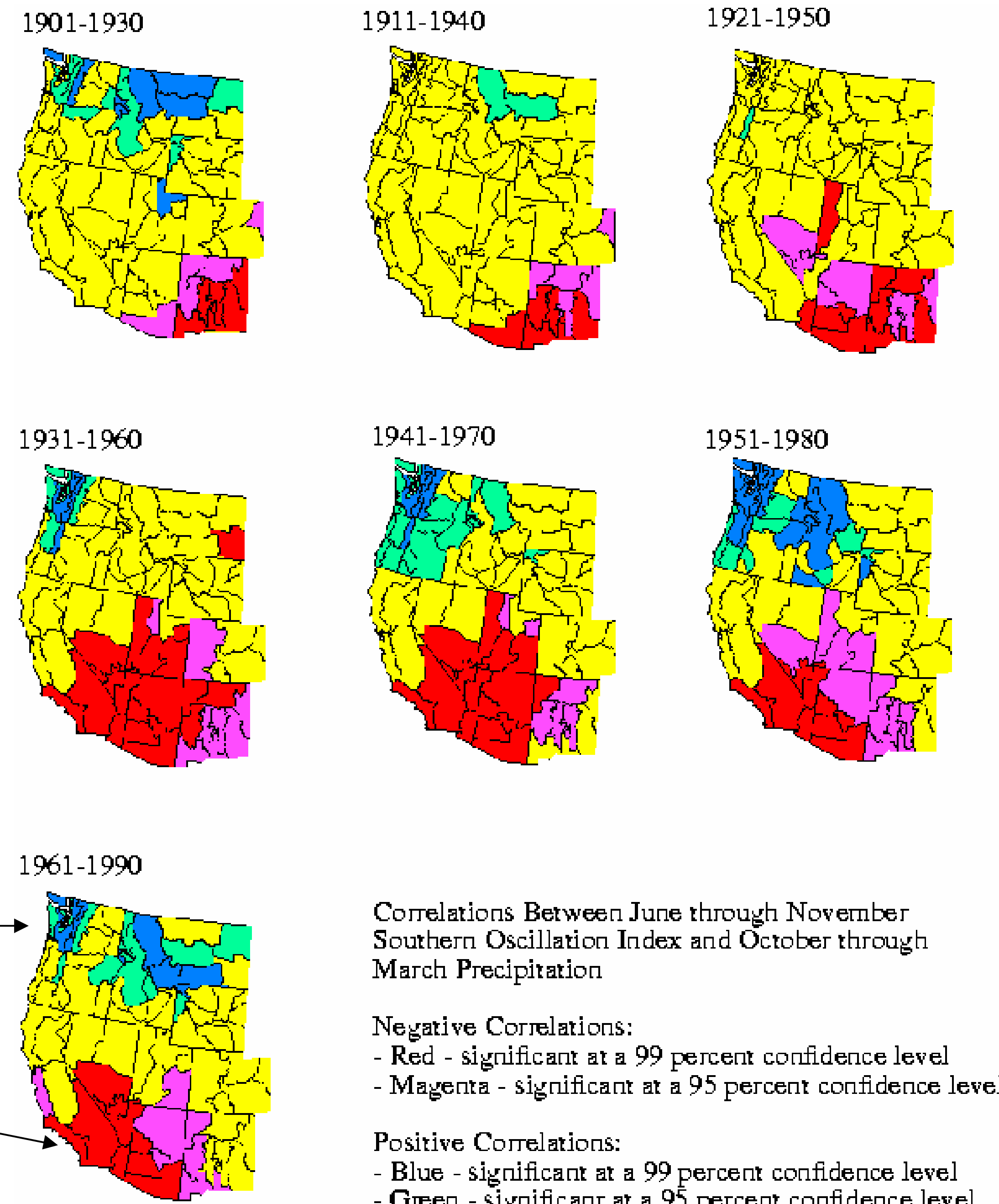
La Niña



The different flavors of El Nino.



The strength of the ENSO signal in western U.S. precipitation has varied through time.



positive correlations →

negative correlations →

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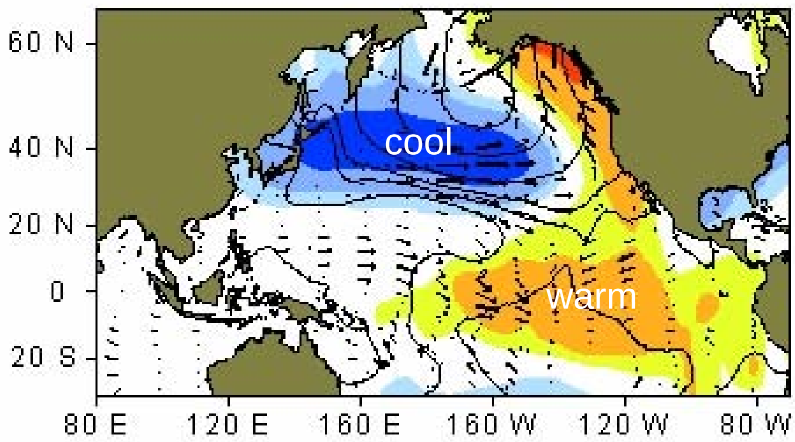
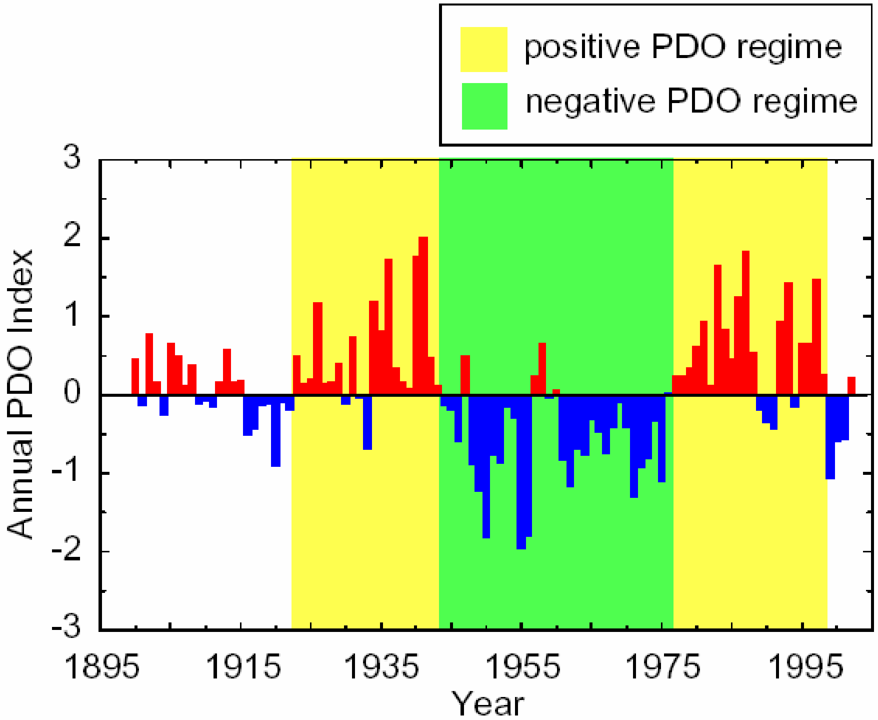
Pacific Decadal Oscillation - PDO

PDO reflects slow decadal variability in the North Pacific Ocean.

Positive PDO Phase

Sea-surface Temperatures





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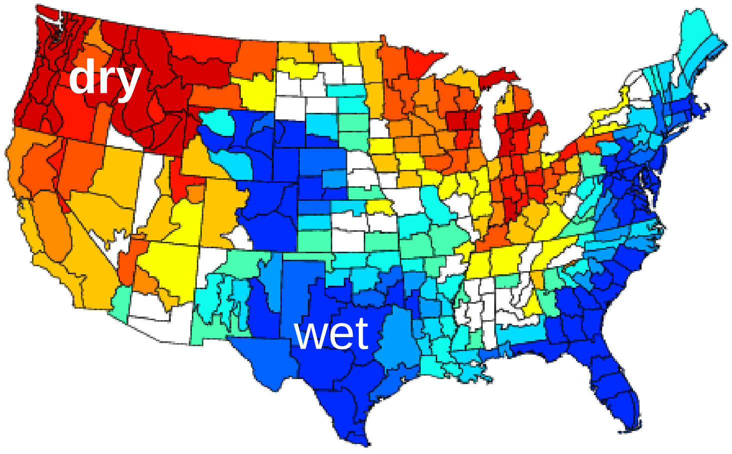
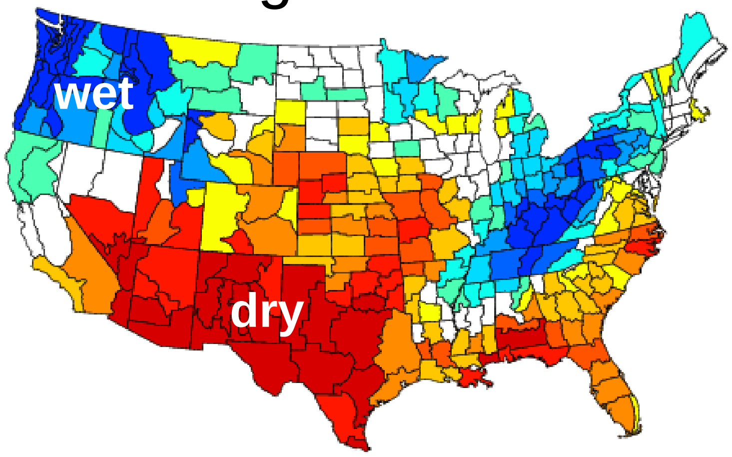
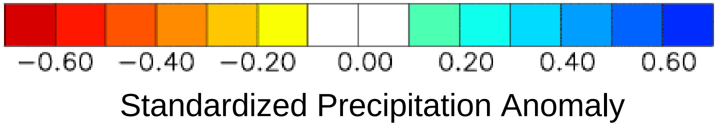
Effects of PDO on Winter Precipitation

Positive PDO



Negative PDO



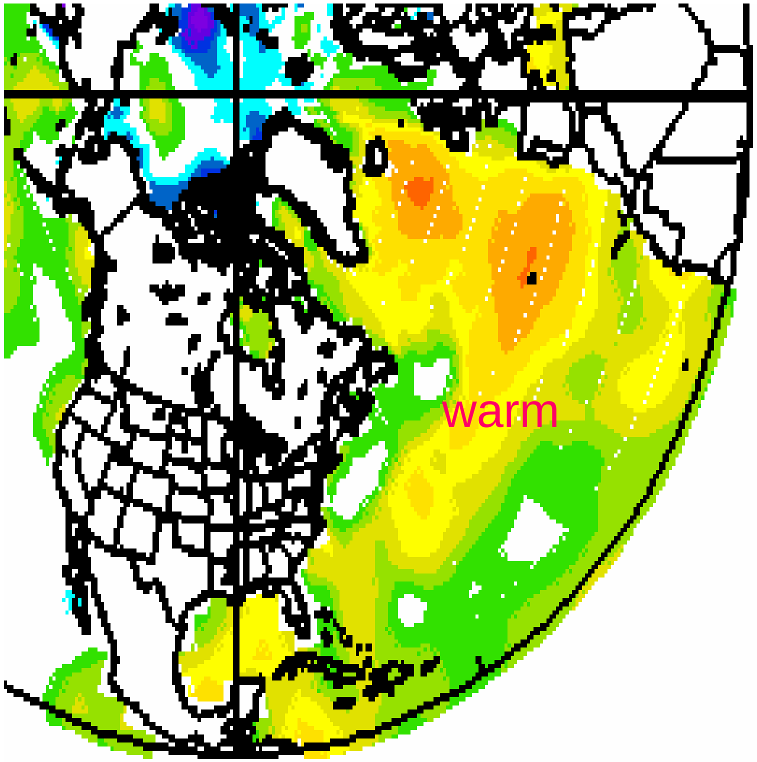


Maps created using the NOAA-CIRES Climate Diagnostics web page

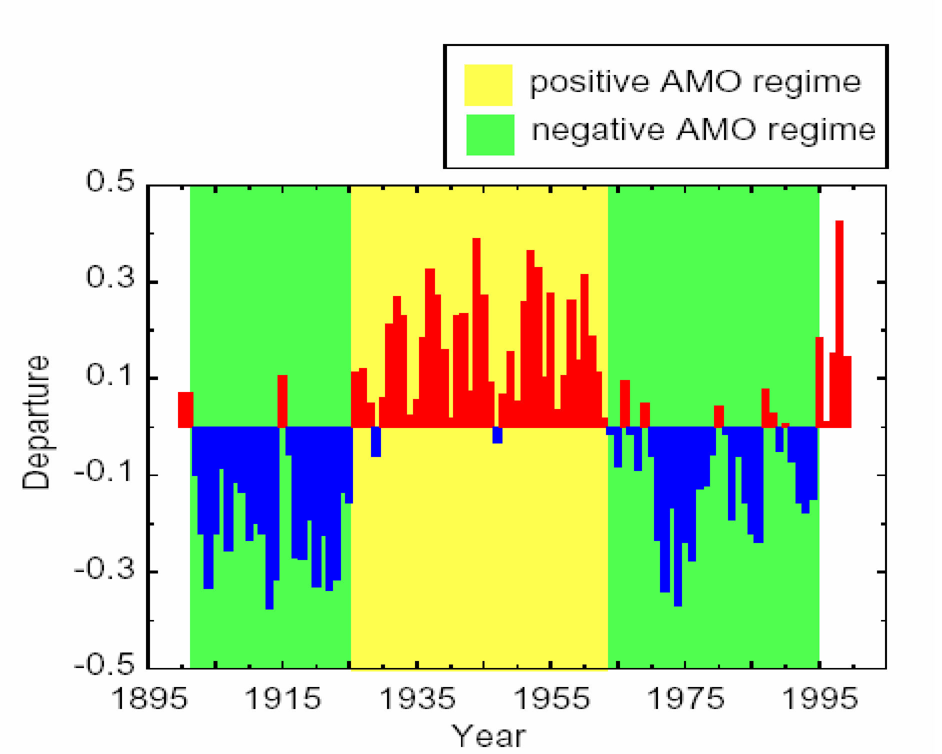
Atlantic Multi-Decadal Oscillation - AMO

Positive AMO Phase

Sea-surface Temperatures



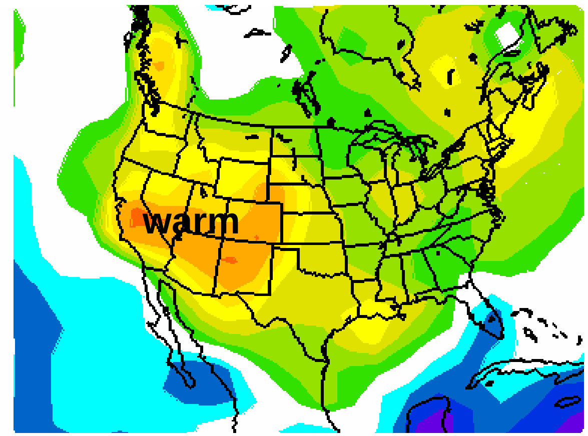
AMO is an index of decadal variability in the North Atlantic Ocean.

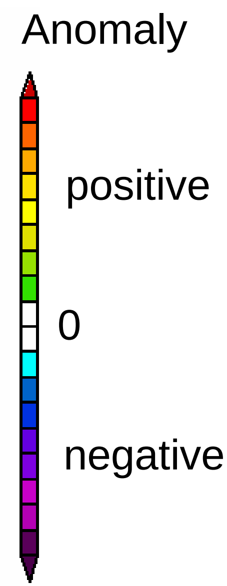


During +AMO a large part of the U.S. is dry and warm

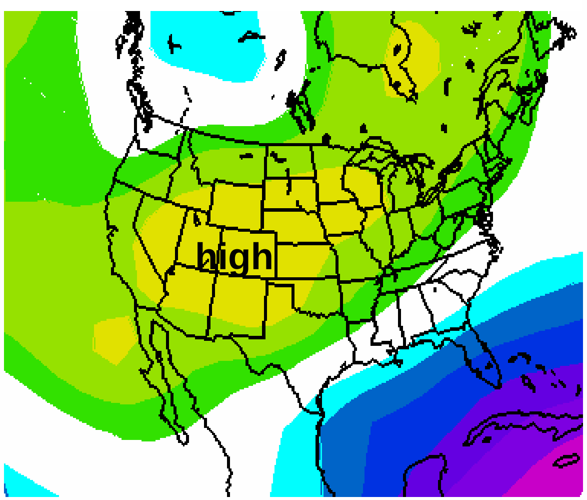
Climate Anomalies for Positive AMO

Annual Temperature

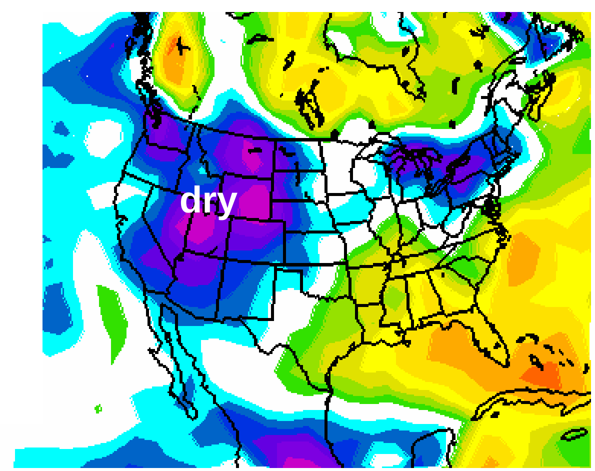




Annual 700hPa Heights



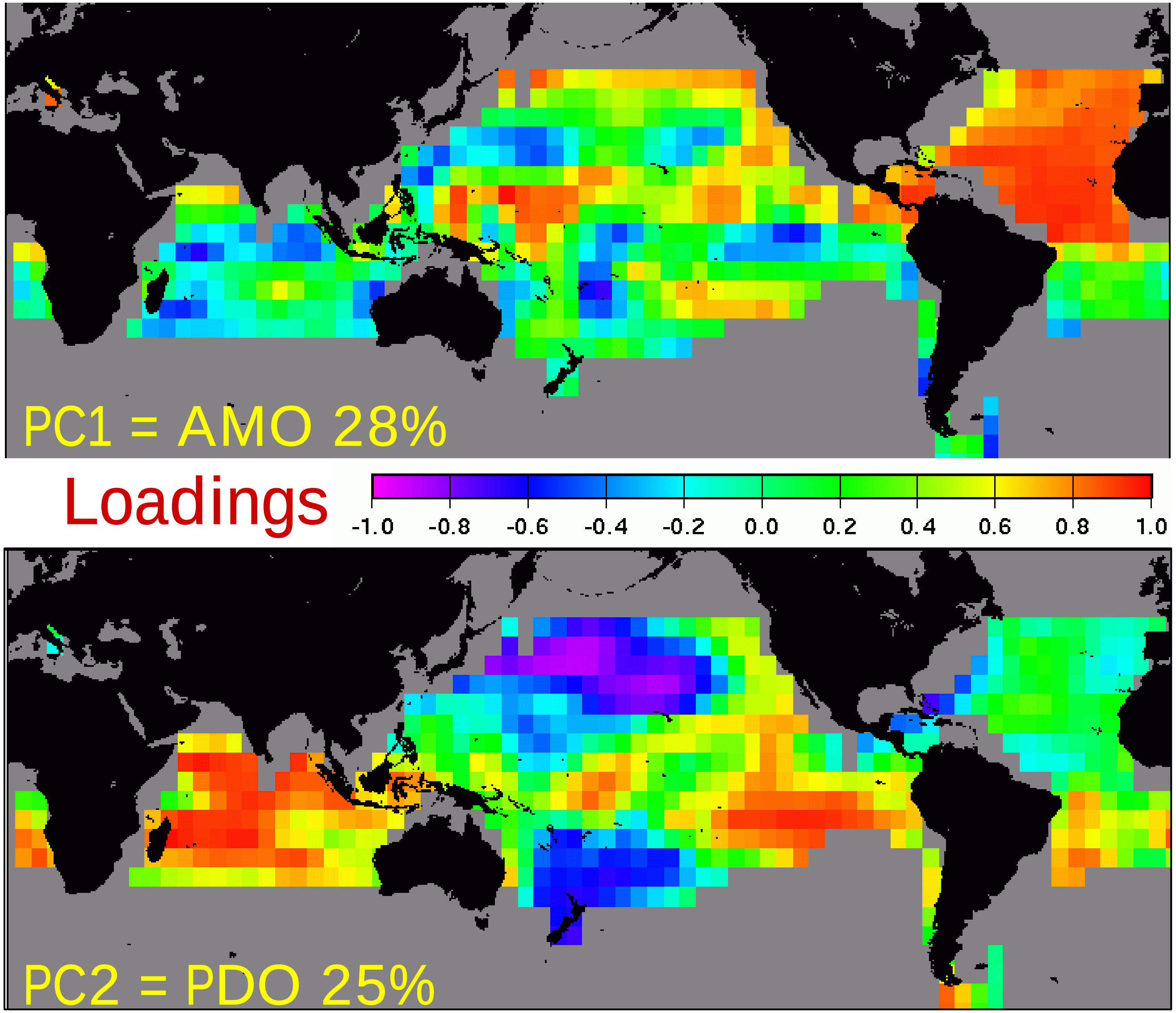
Annual Precipitation



Maps created using the NOAA-CIRES Climate Diagnostics web page

Primary patterns of 10-year smoothed detrended annual global SSTs
(determined using PCA)

The AMO and PDO are dominant modes of decadal global annual SST variability



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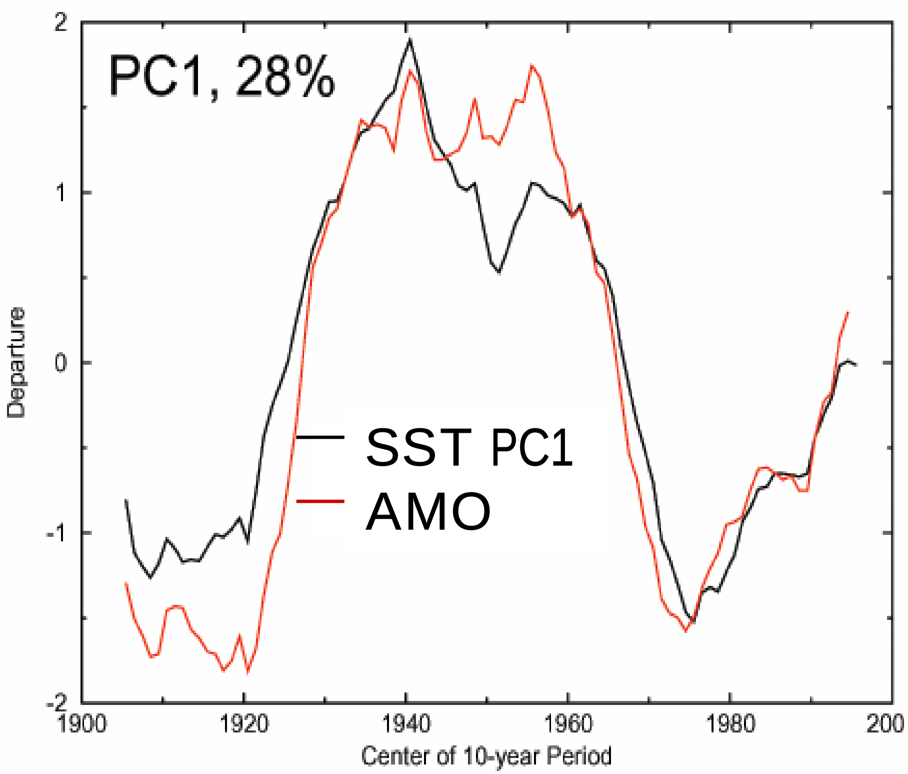
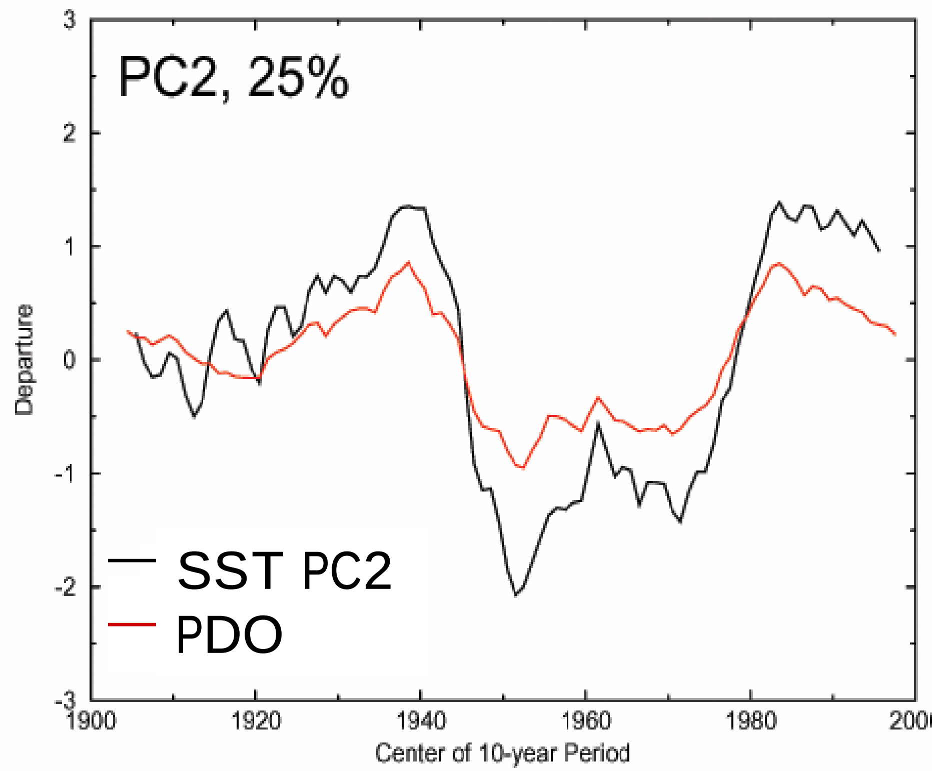
The AMO and PDO are dominant modes of decadal global annual SST variability





PCs from a PCA using data for 1901-2000

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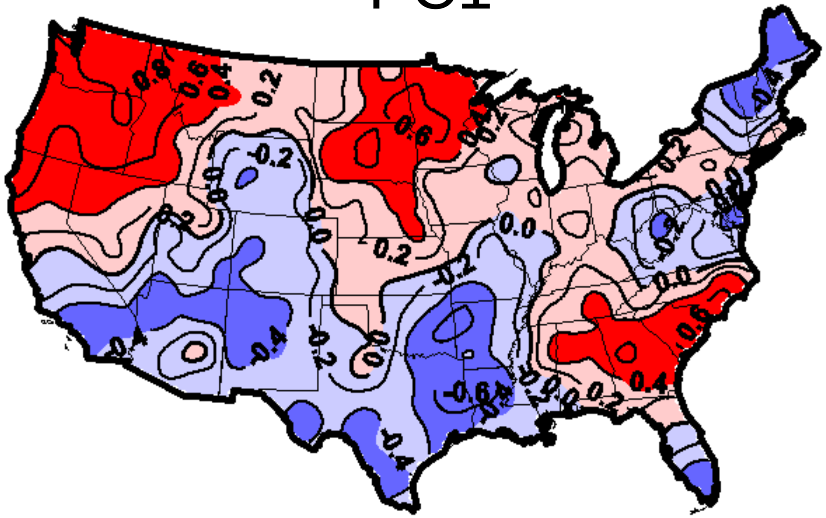
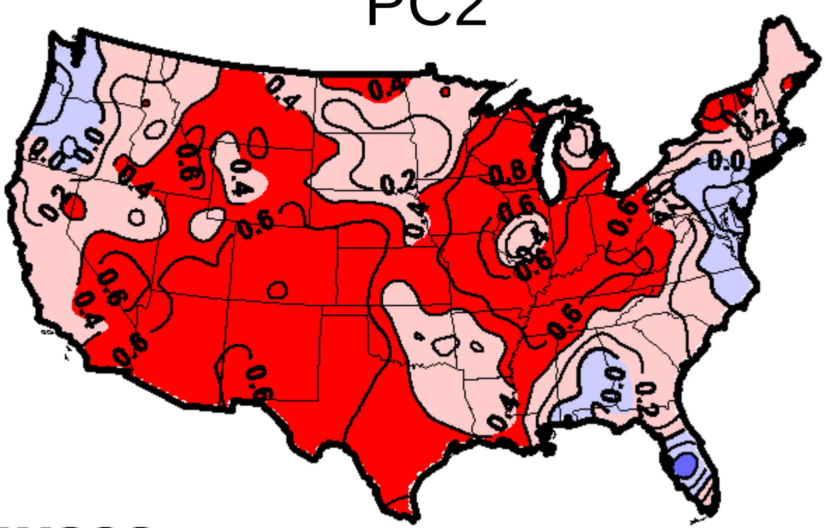
PC1

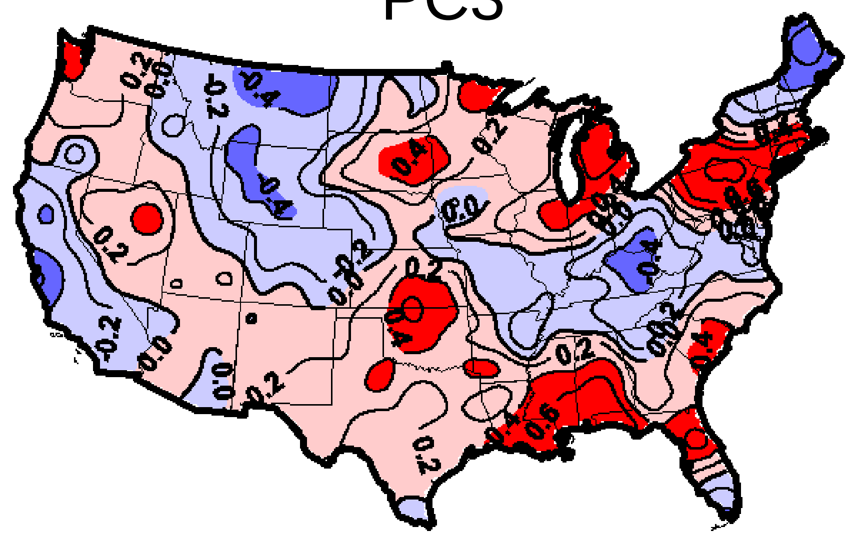


Primary patterns of multi-decadal drought variability

PC2



PC3



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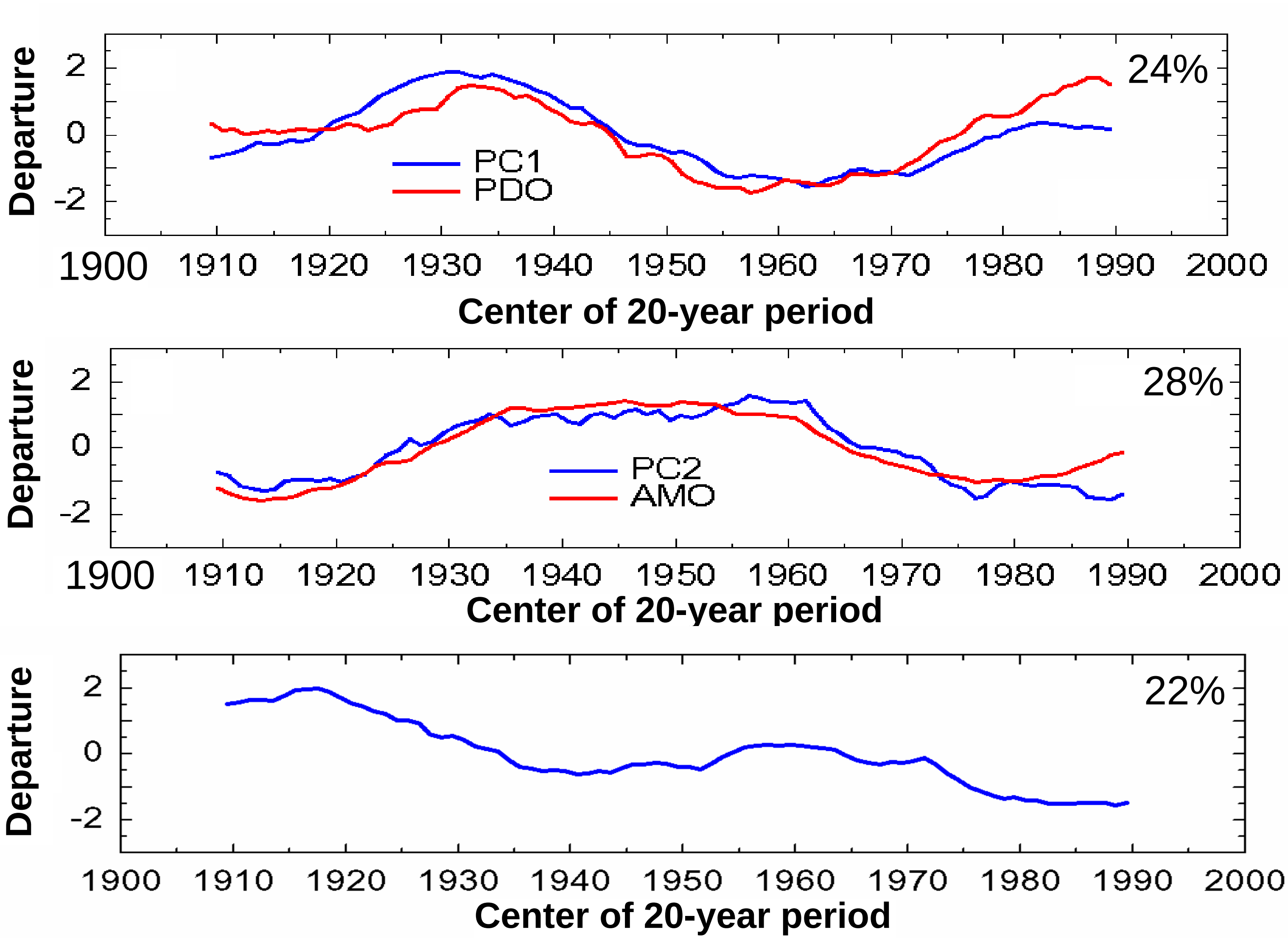
AMO and PDO reflect dominant modes of multi-decadal drought frequency



McCabe, Palecki & Betancourt (2004)

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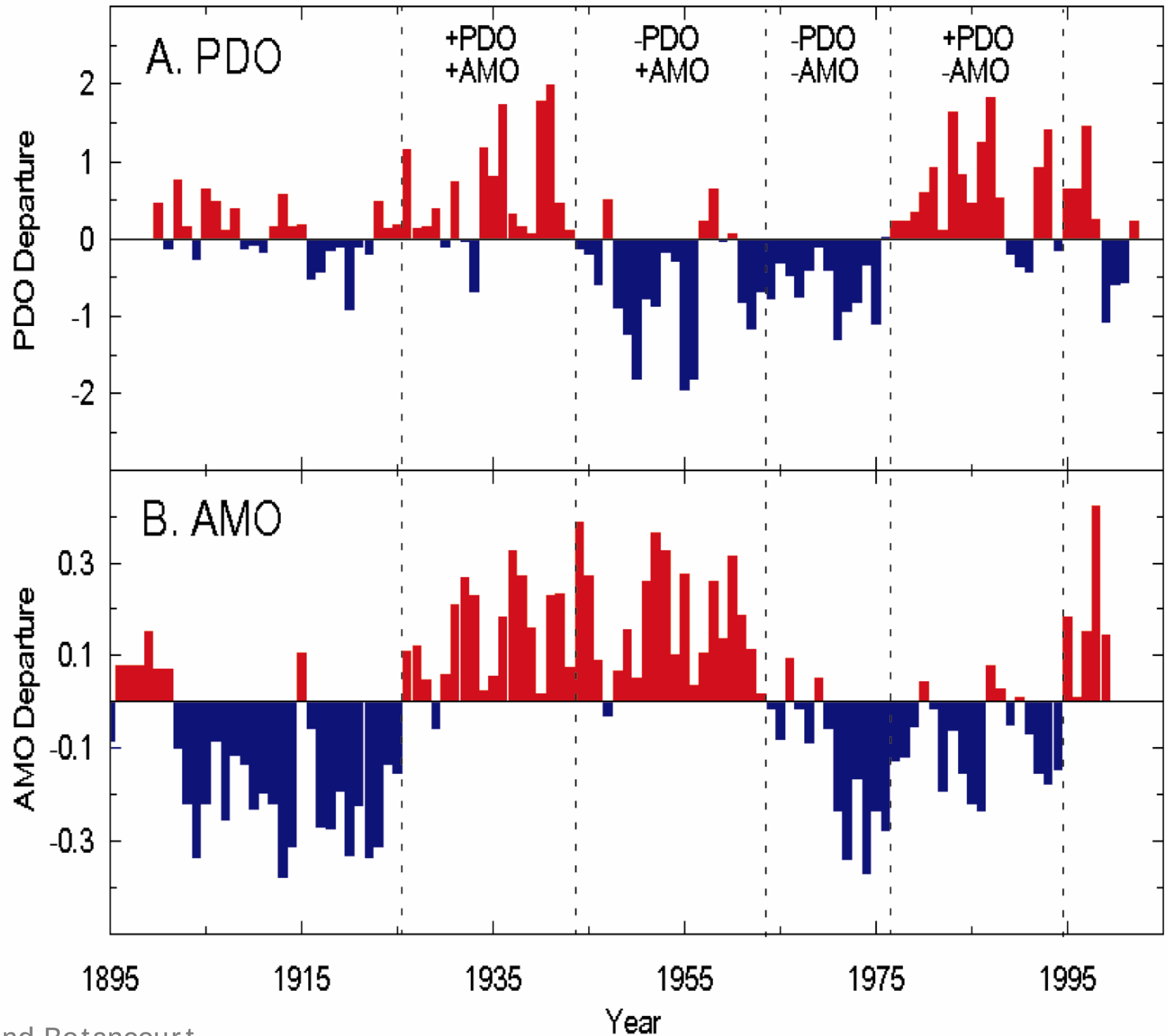
PDO and AMO Regimes



McCabe, Palecki, and Betancourt, PNAS, 2004

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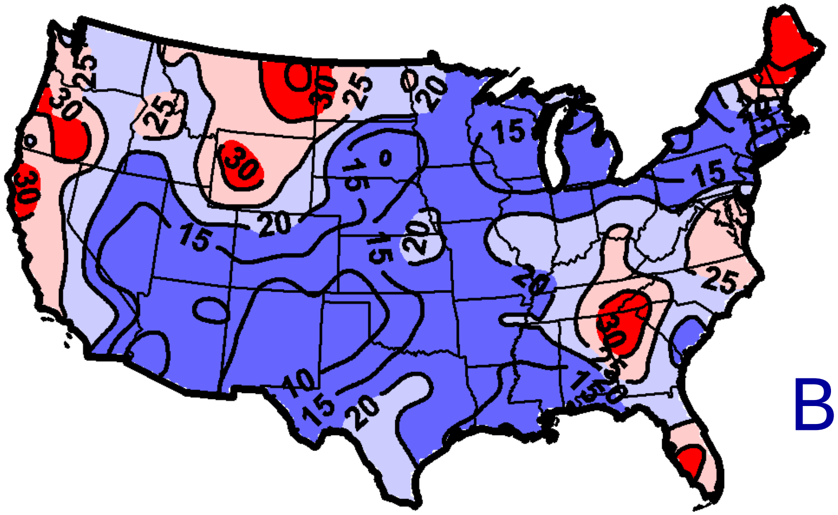
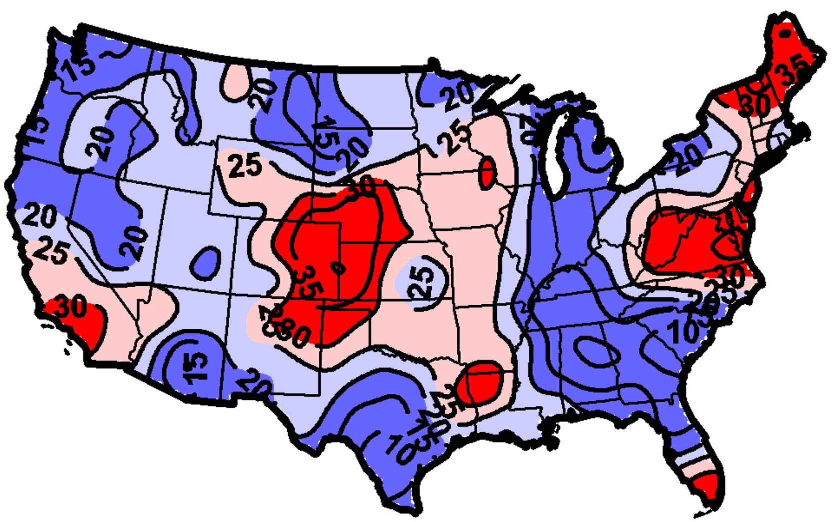
+PDO -AMO



Blue- low drought frequency

Red- high drought frequency

-PDO -AMO



25% = normal drought frequency McCabe, Palecki & Betancourt (2004)

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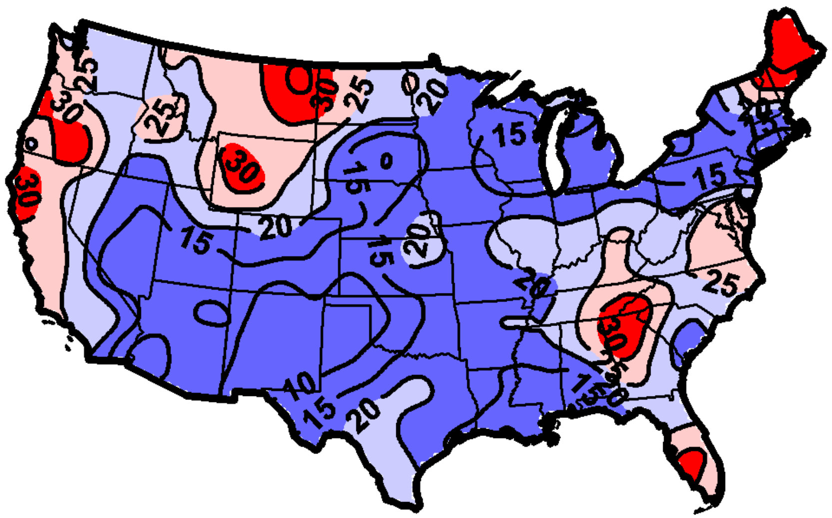
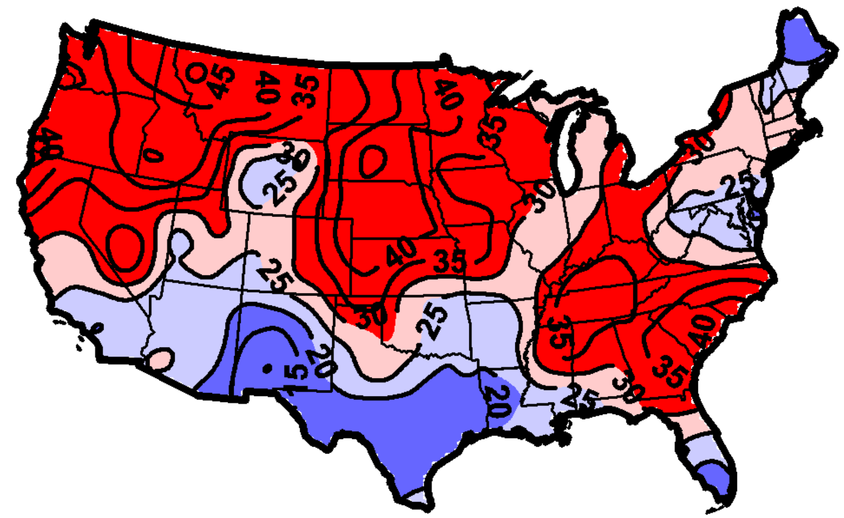
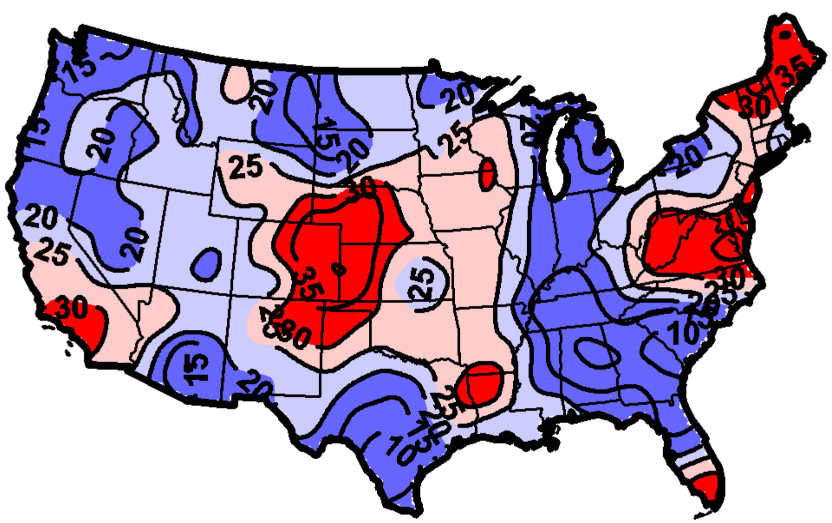
+PDO -AMO



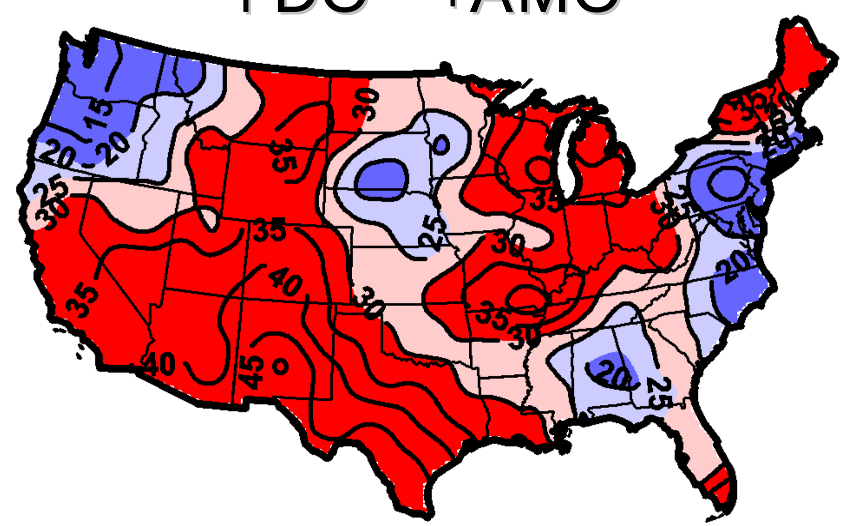
+PDO +AMO



-PDO -AMO



-PDO +AMO

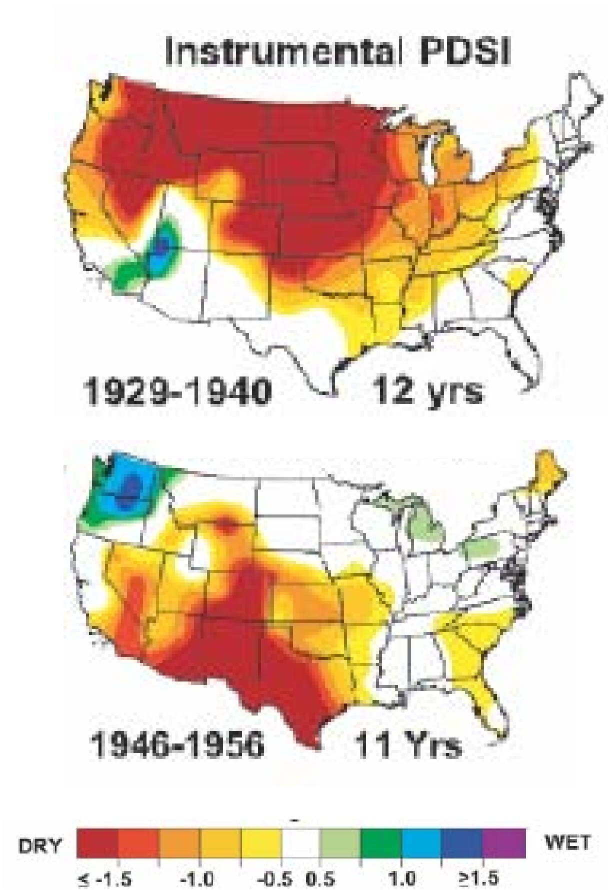


25% = normal drought frequency

McCabe, Palecki & Betancourt (2004)

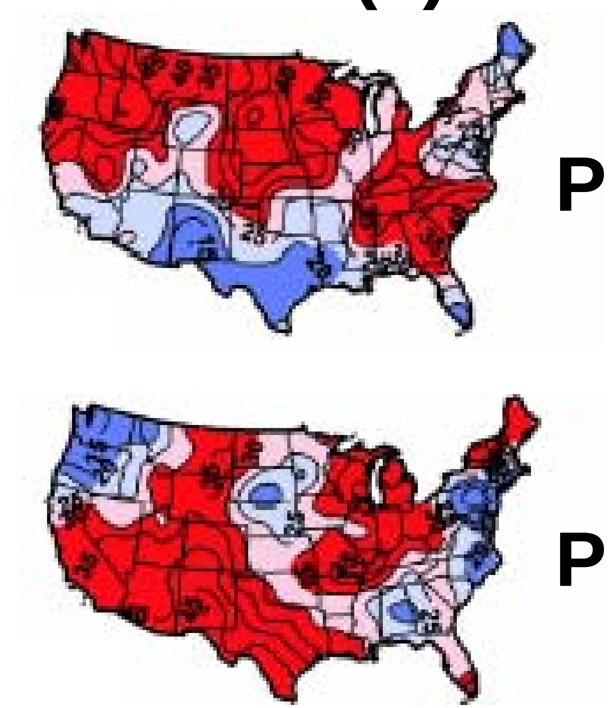
Does the interaction of AMO with PDO produce two families of drought?

Observed PDSI
(Fye et al. 2003)



Drought frequency
(McCabe et al. 2004)

AMO (+)



PDO (+)

PDO (-)

Red: Higher probability of drought
Blue: Lower probability of drought

Courtesy, Hugo Hidalgo

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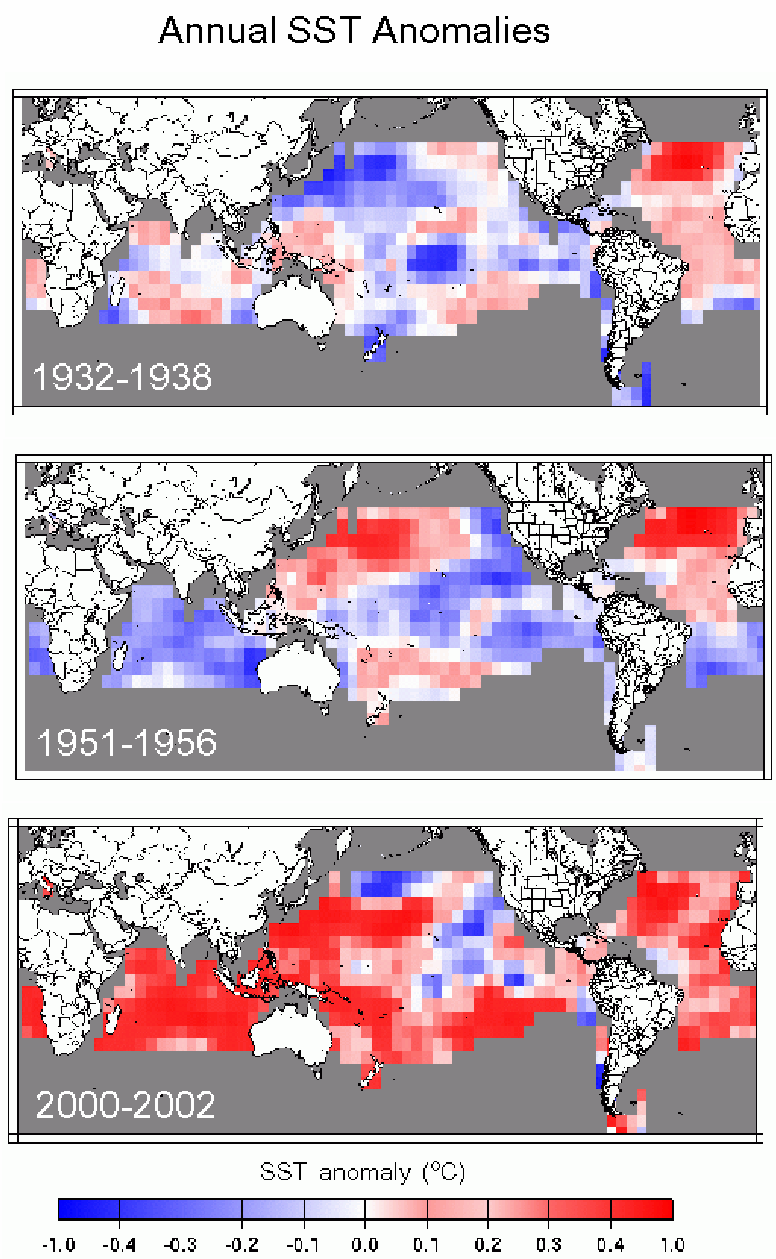
North Atlantic Ocean sea-surface temperature anomalies were above average for each of the major droughts during the last century.



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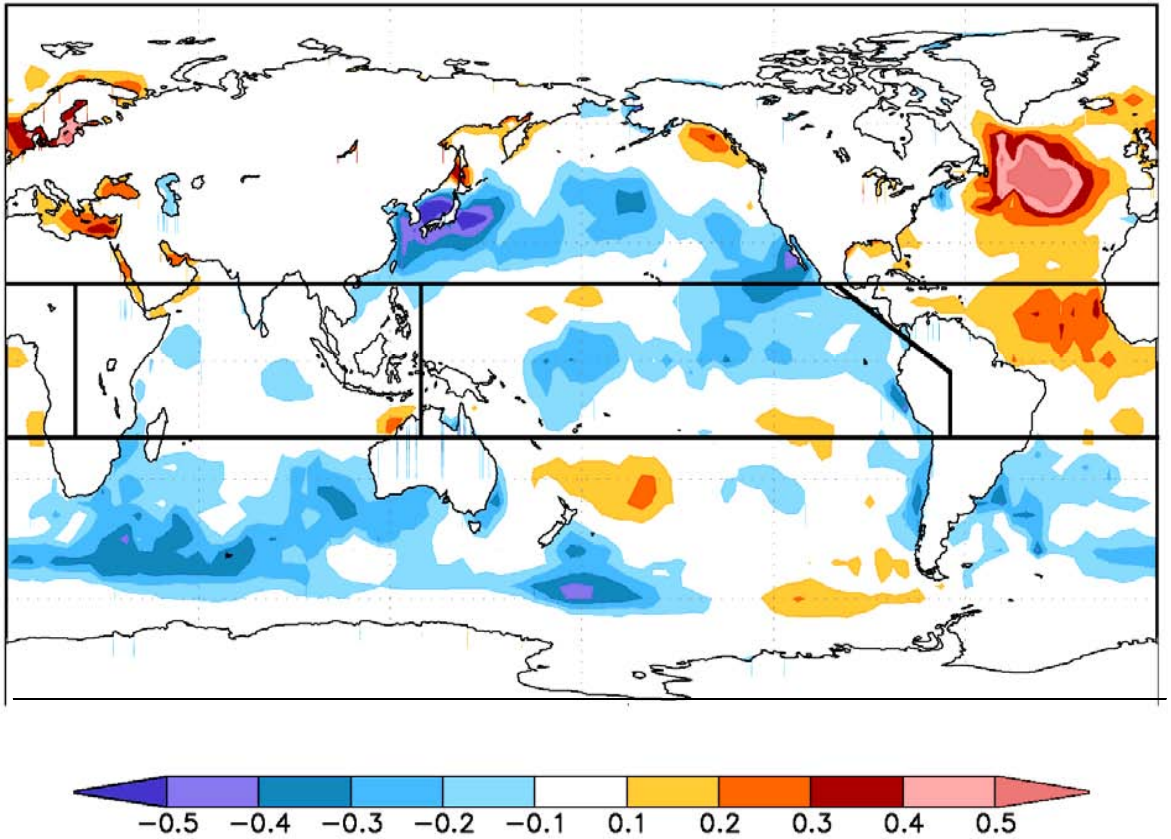
Use of AGCM's to Evaluate Role of SST's, Different Ocean Basins, & Tropics vs. Extratropics in Drought

1932-1938 composite SST



AGCM: NSIPP-1

HadISST and sea ice dataset (1902-1999)

14 ensemble members same SST, different ICs

Schubert, Suarez, Pegion, Koster & Bacmeister (2004) *Science*

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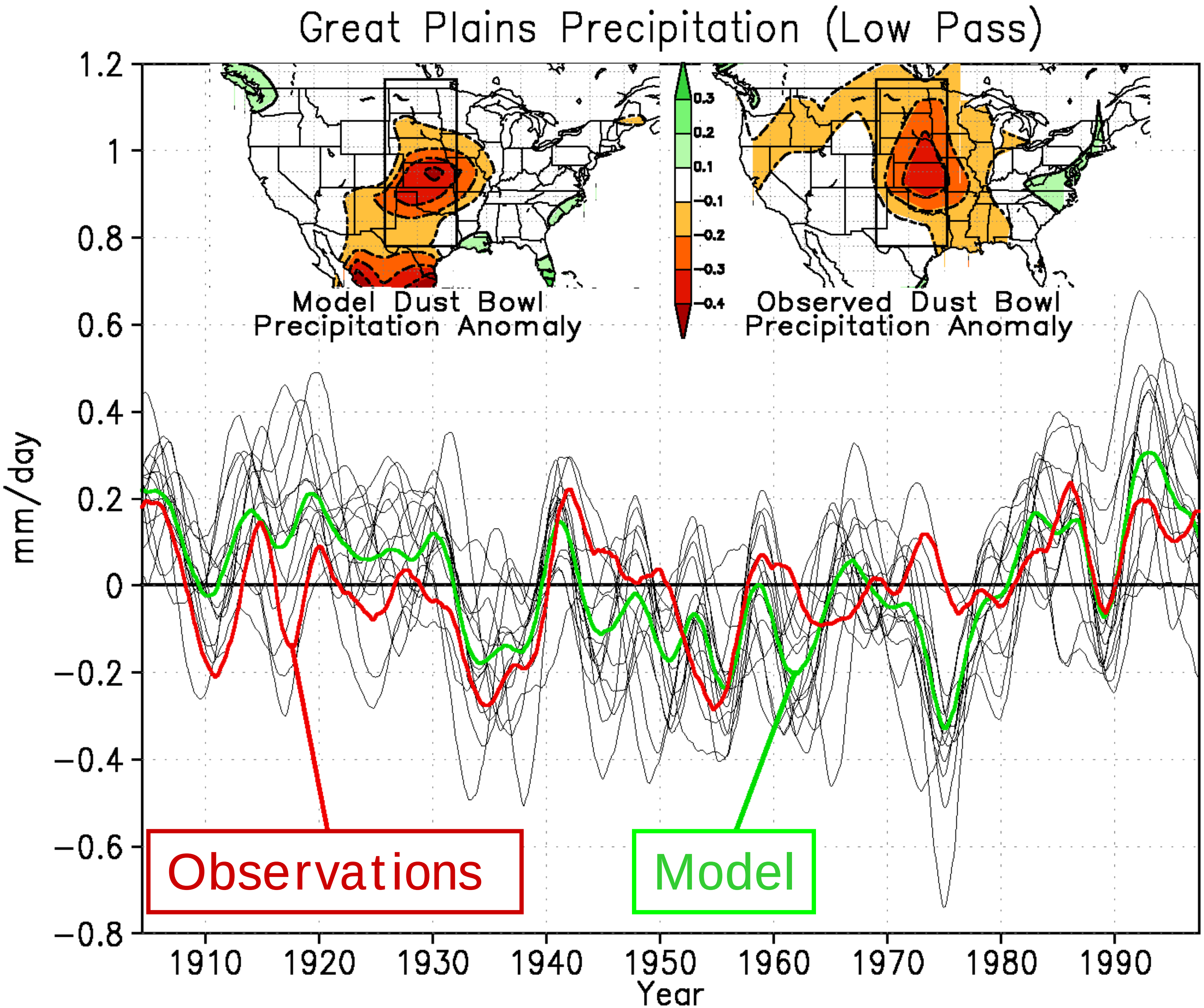

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Schubert, Suarez, Pegion, Koster & Bacmeister (2004) *Science*

On the Cause of the 1930s Dust Bowl

S. D. Schubert et al.

Science vol. 303, p. 1855-1859 (19 March 2004)

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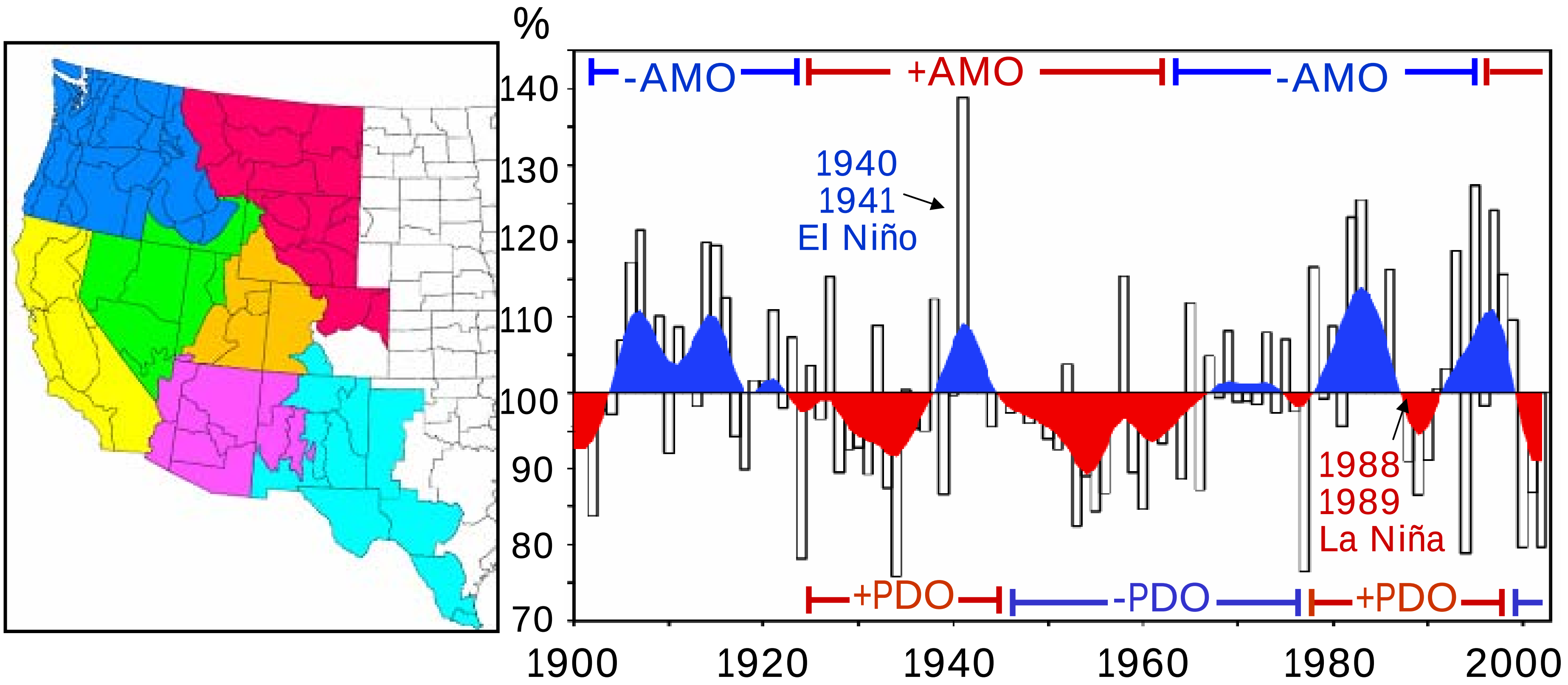
Seven Western Rivers Index
Water Years 1900-2002



Courtesy of Henry Diaz, NOAA

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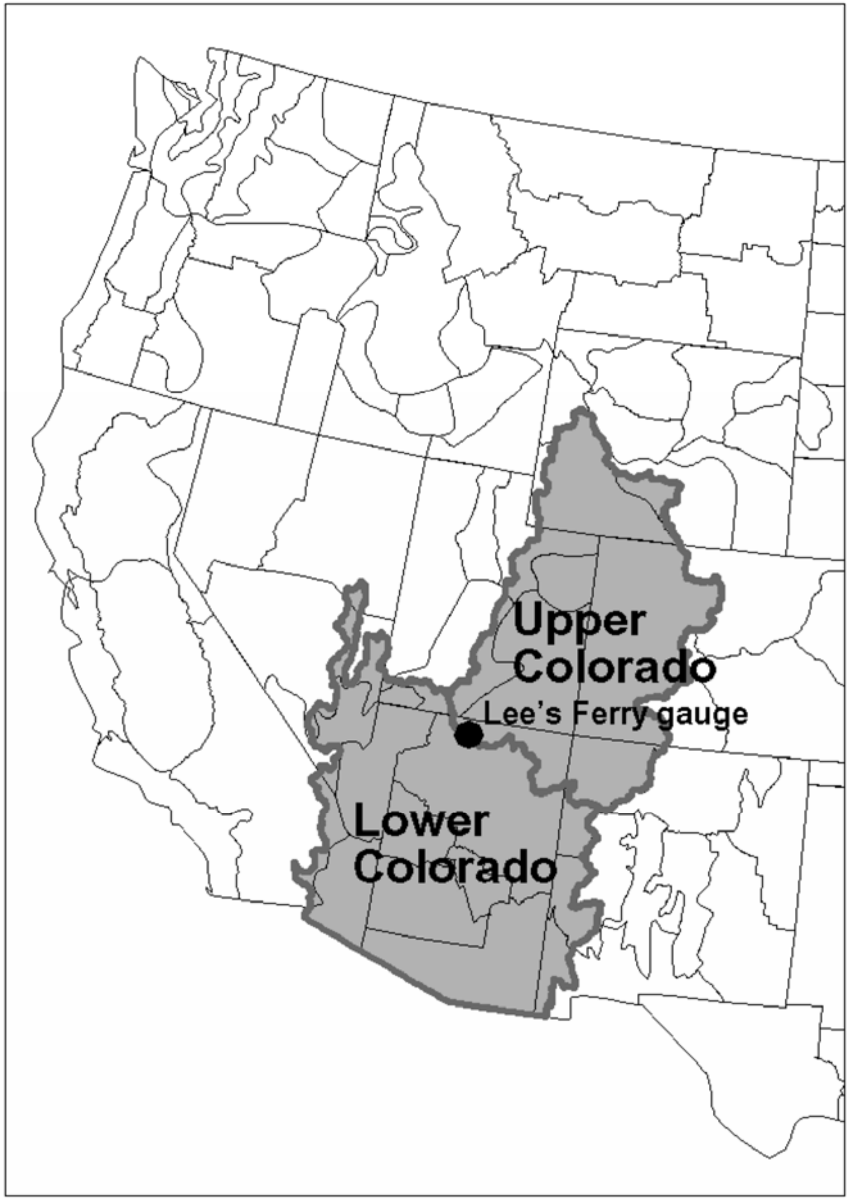
Colorado River Basin and climate divisions in the western United States



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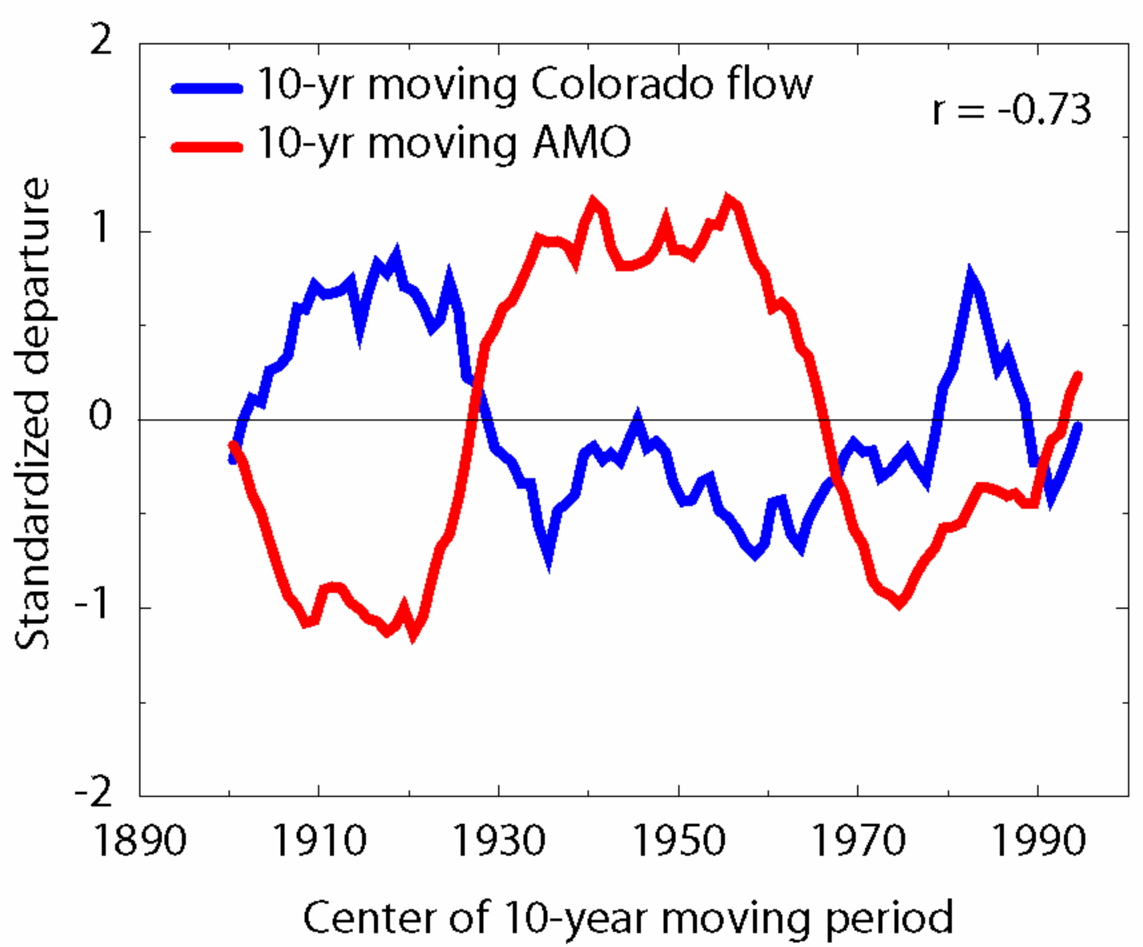
The AMO explains a large amount of the decadal variability in the flow of the Upper Colorado River basin

10-year moving averages of standardized departures of annual Colorado River flow and the Atlantic Multidecadal Oscillation (AMO)



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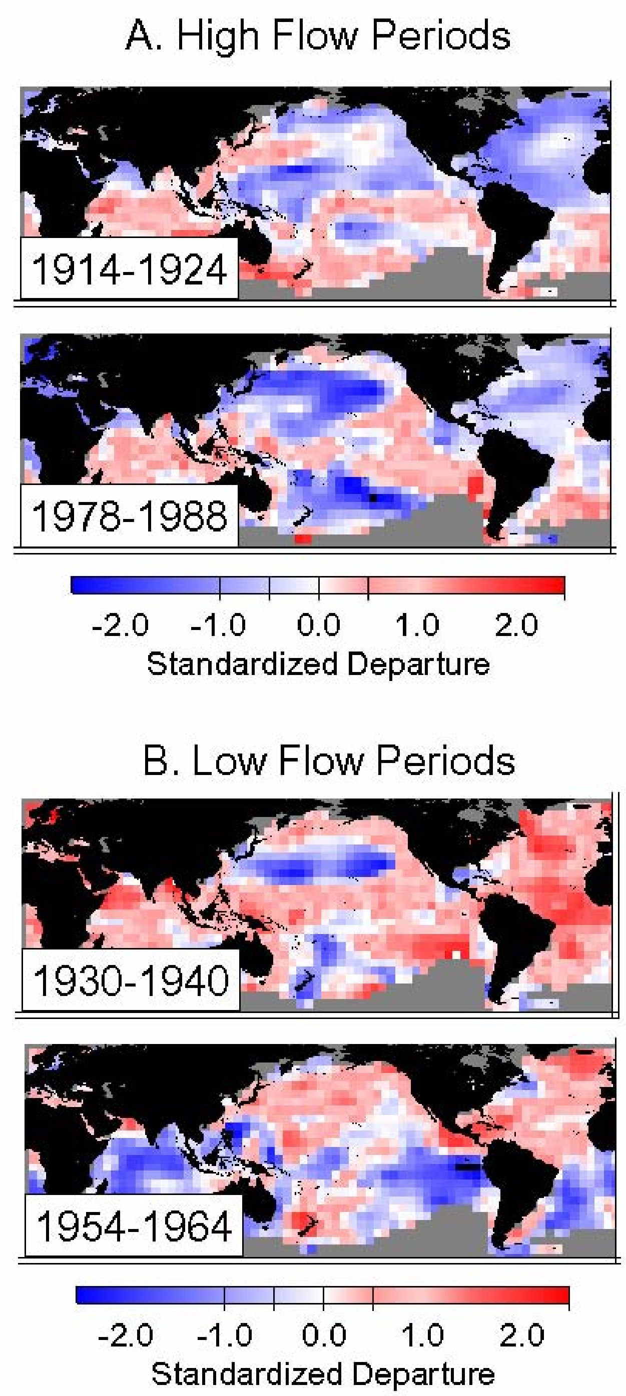
SST composites for high and low flow periods of the Upper Colorado River Basin

High flows are related to negative AMO conditions and low flows are related to positive AMO conditions



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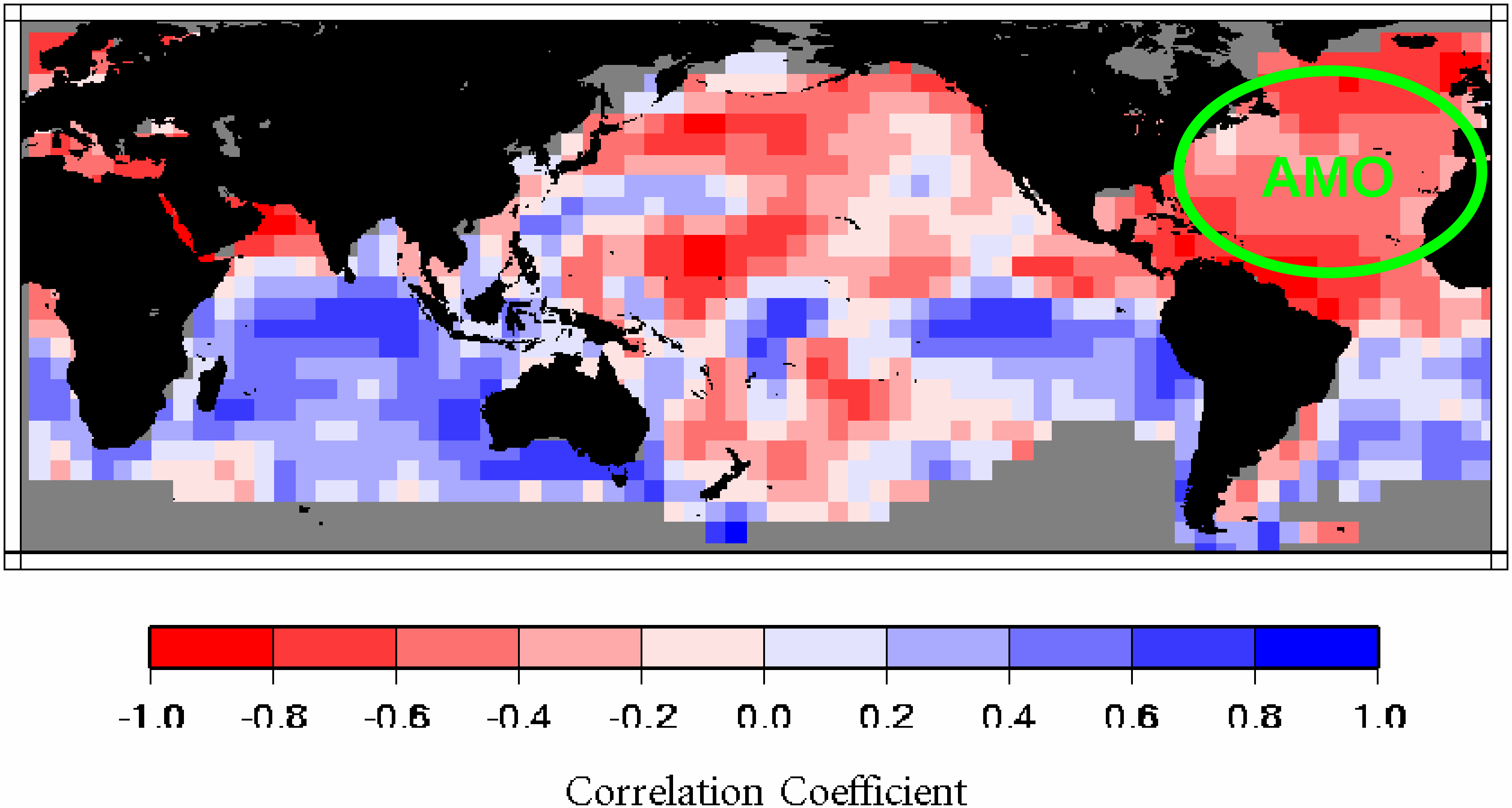
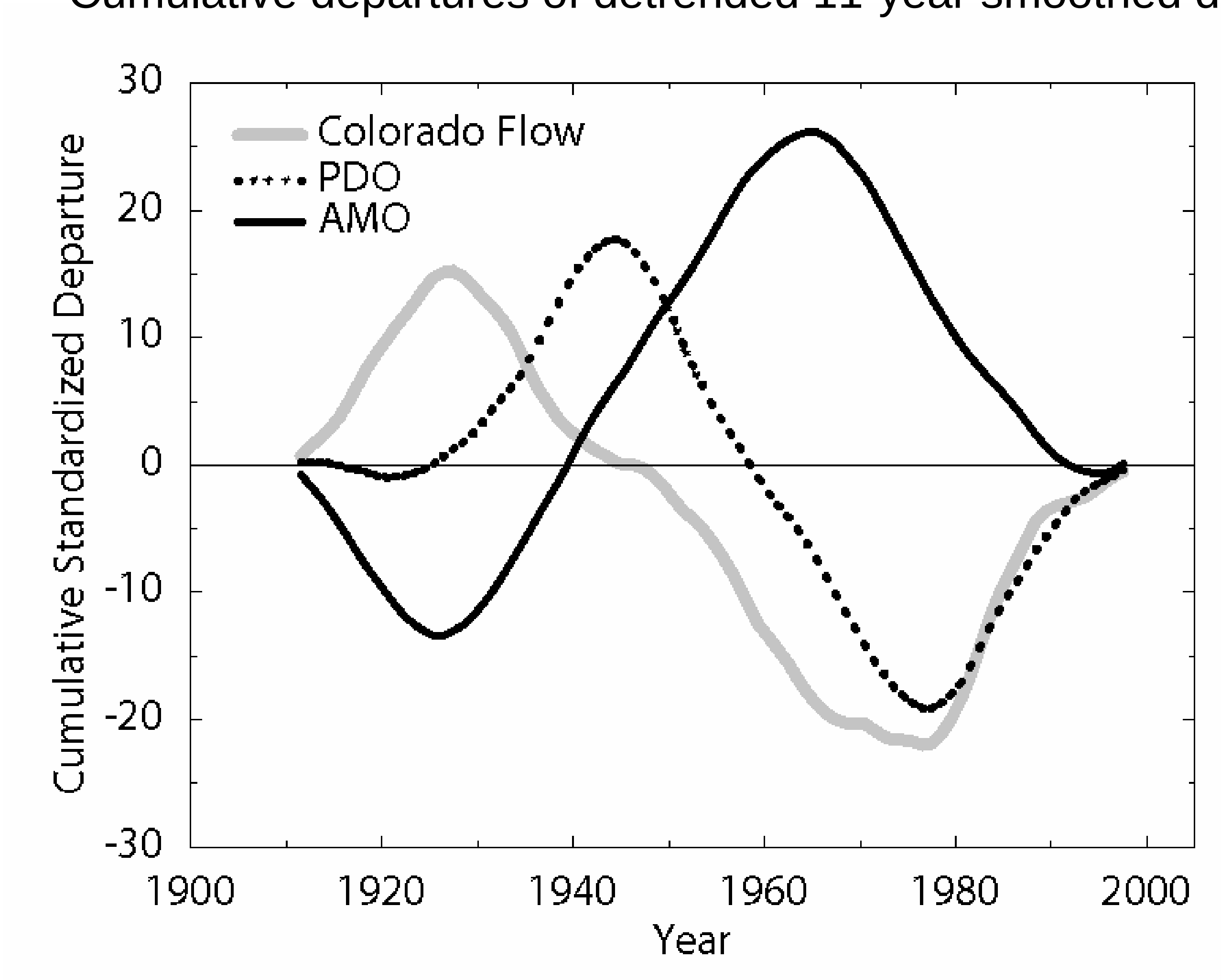
Correlations between detrended 11-year smoothed WY flow of the Upper Colorado River Basin and detrended 11-year smoothed WY SSTs



Low frequency variations of AMO are strongly correlated with low frequency variations of Upper Colorado River flow

Cumulative departures of detrended 11-year smoothed data



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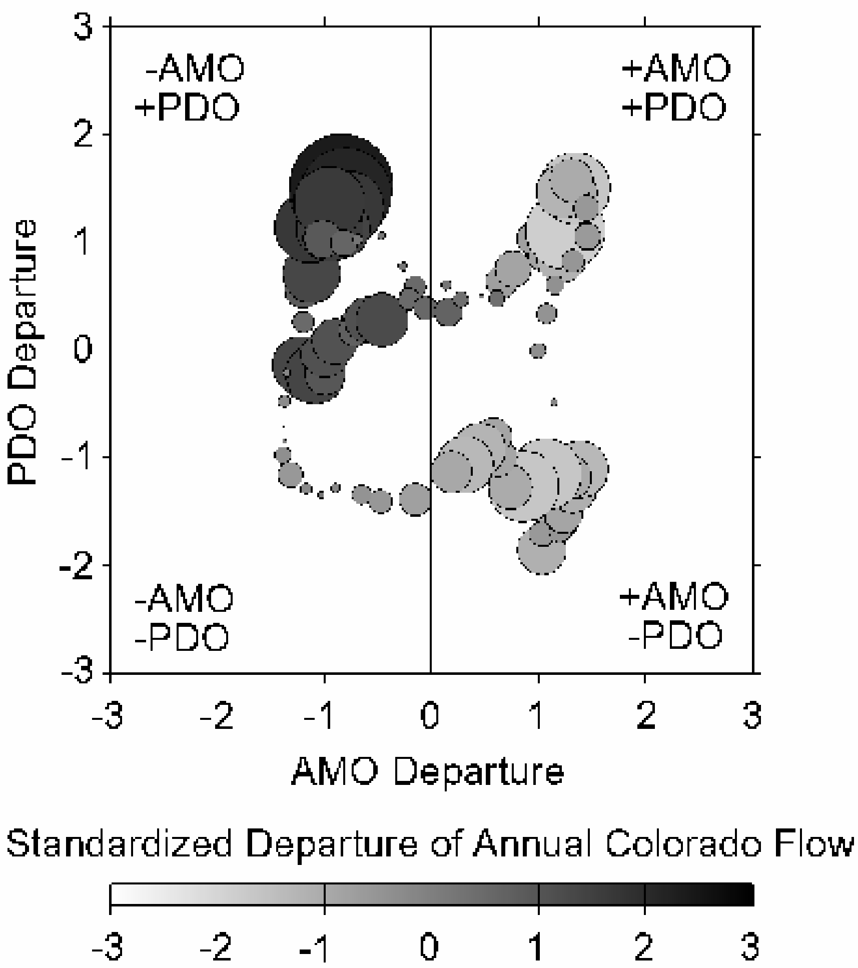
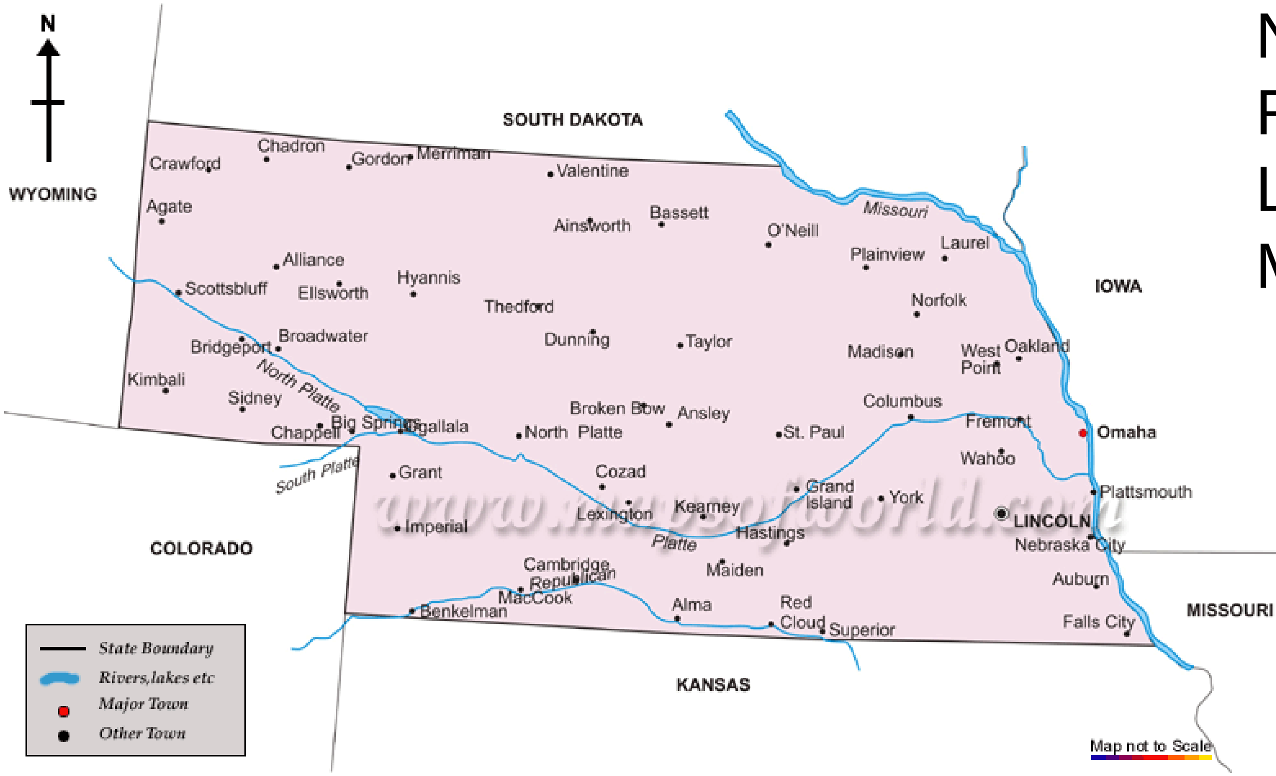
Decadal-scale variations of the North Atlantic Ocean appear to strongly affect decadal variations of Upper Colorado River flow



Nebraska Rivers and Lake McConaughy



Lake McConaughy

Capacity – 1,900,600 acre feet

Length – 22.1 miles

Maximum depth – 142 feet

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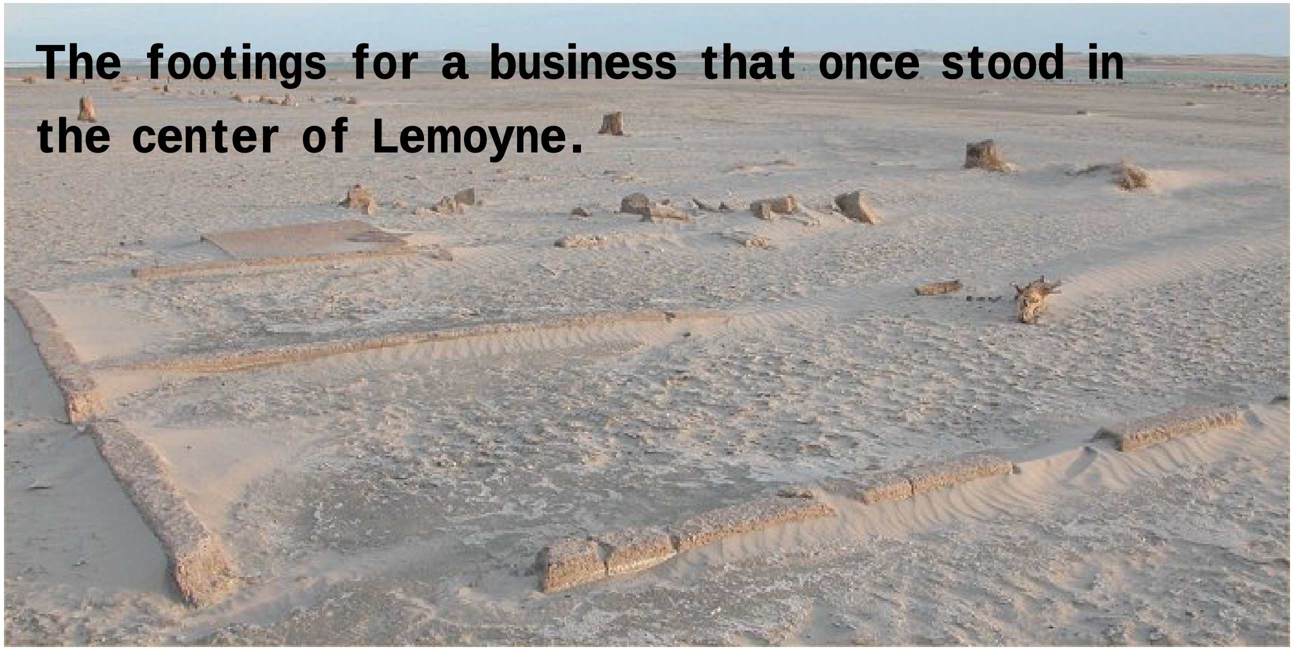
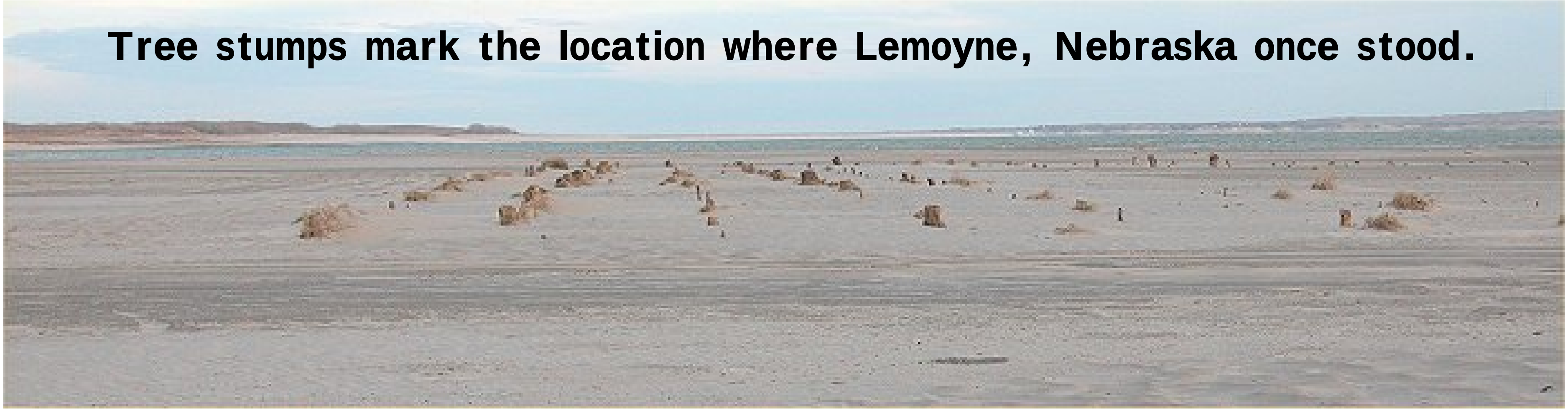
The original Lemoyne, Nebraska was flooded in 1942 when Lake McConaughy began to fill.





Photos courtesy of Ken Dewey, High Plains Regional Climate Center

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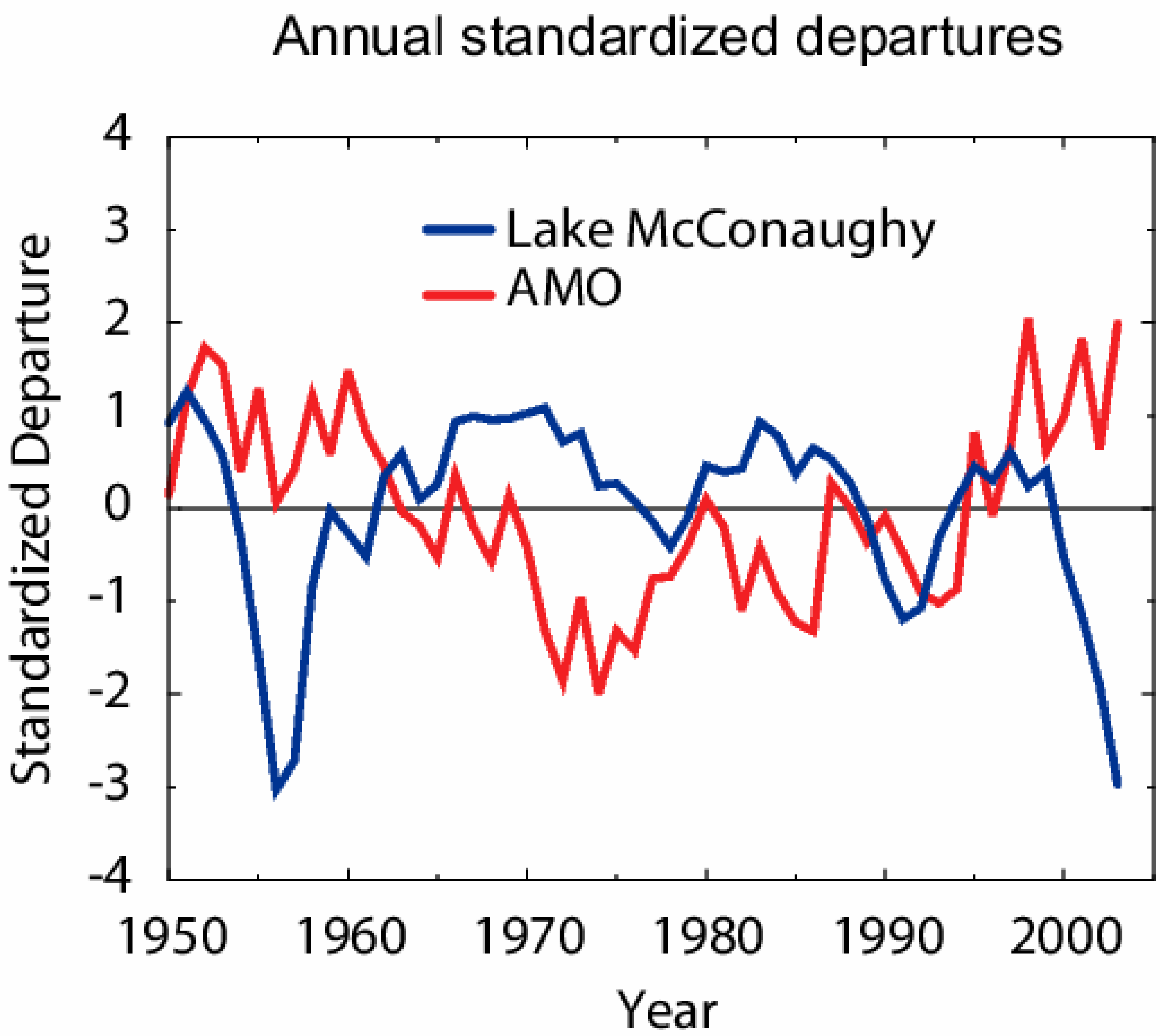
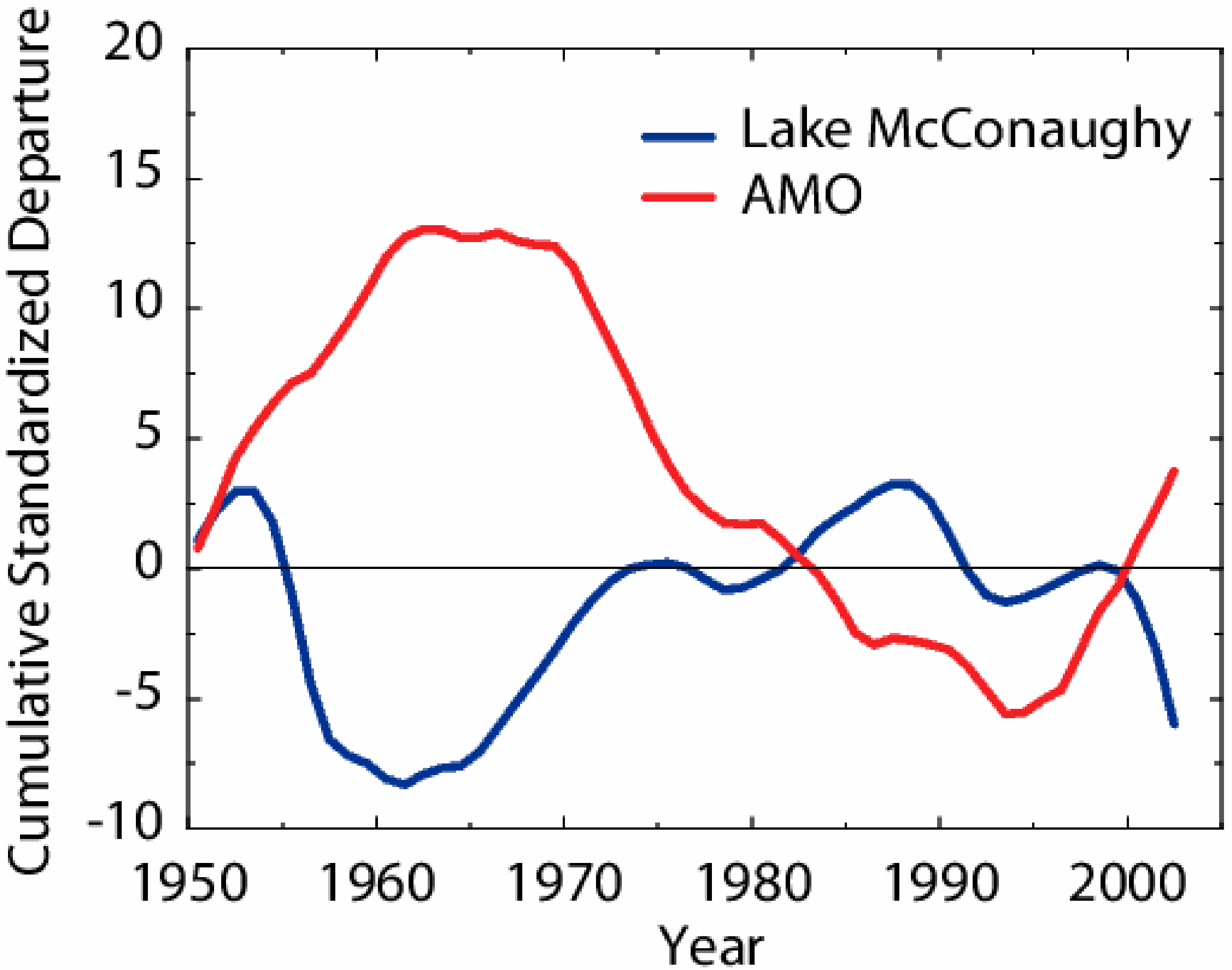


Annual standardized departures
Lake McConaughy
AMO
Standardized Departure
4
3
2
1
0
-1
-2
-3
-4
1950
1960
1970
1980
1990
2000
Year

North Atlantic sea-surface temperatures appear to be inversely related to Lake McConaughy levels



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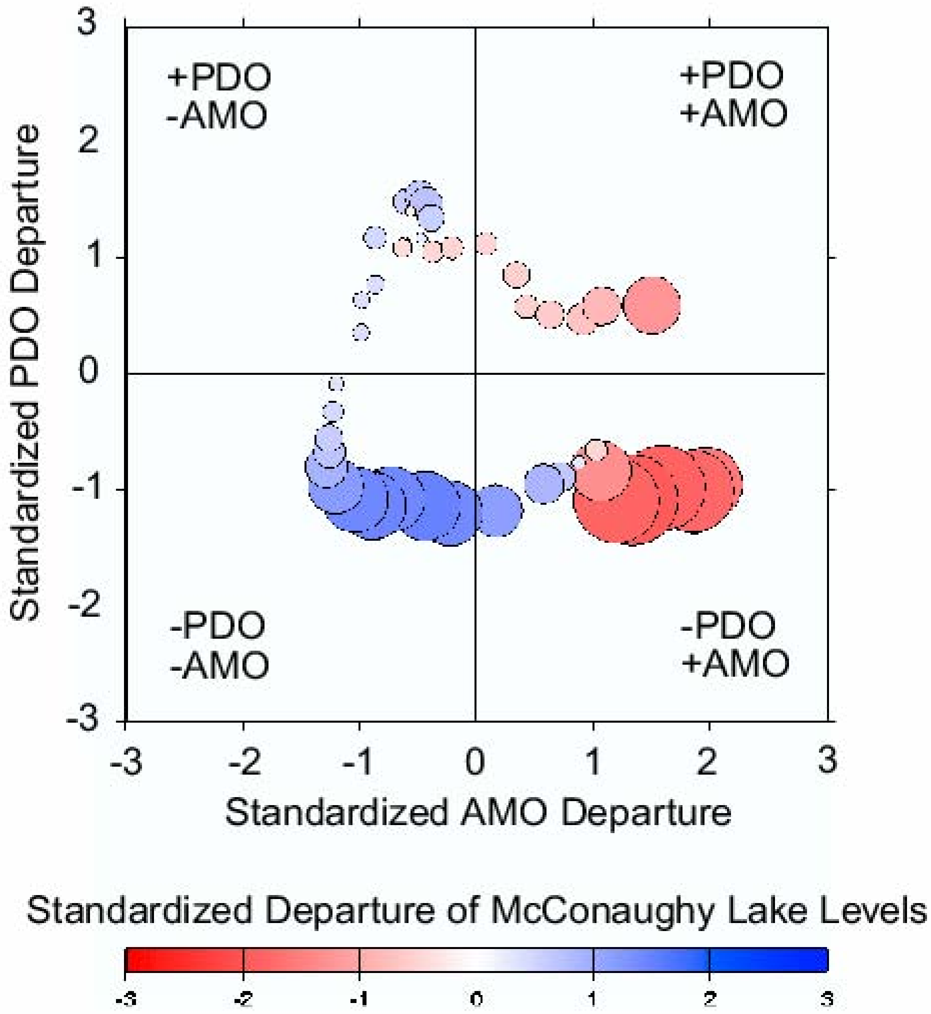
Decadal-scale variations of Lake McConaughy levels appear to be more sensitive to decadal-scale variations of the North Atlantic Ocean than of the Pacific Ocean



All data are 11-year moving averages of annual values, 1950-2003

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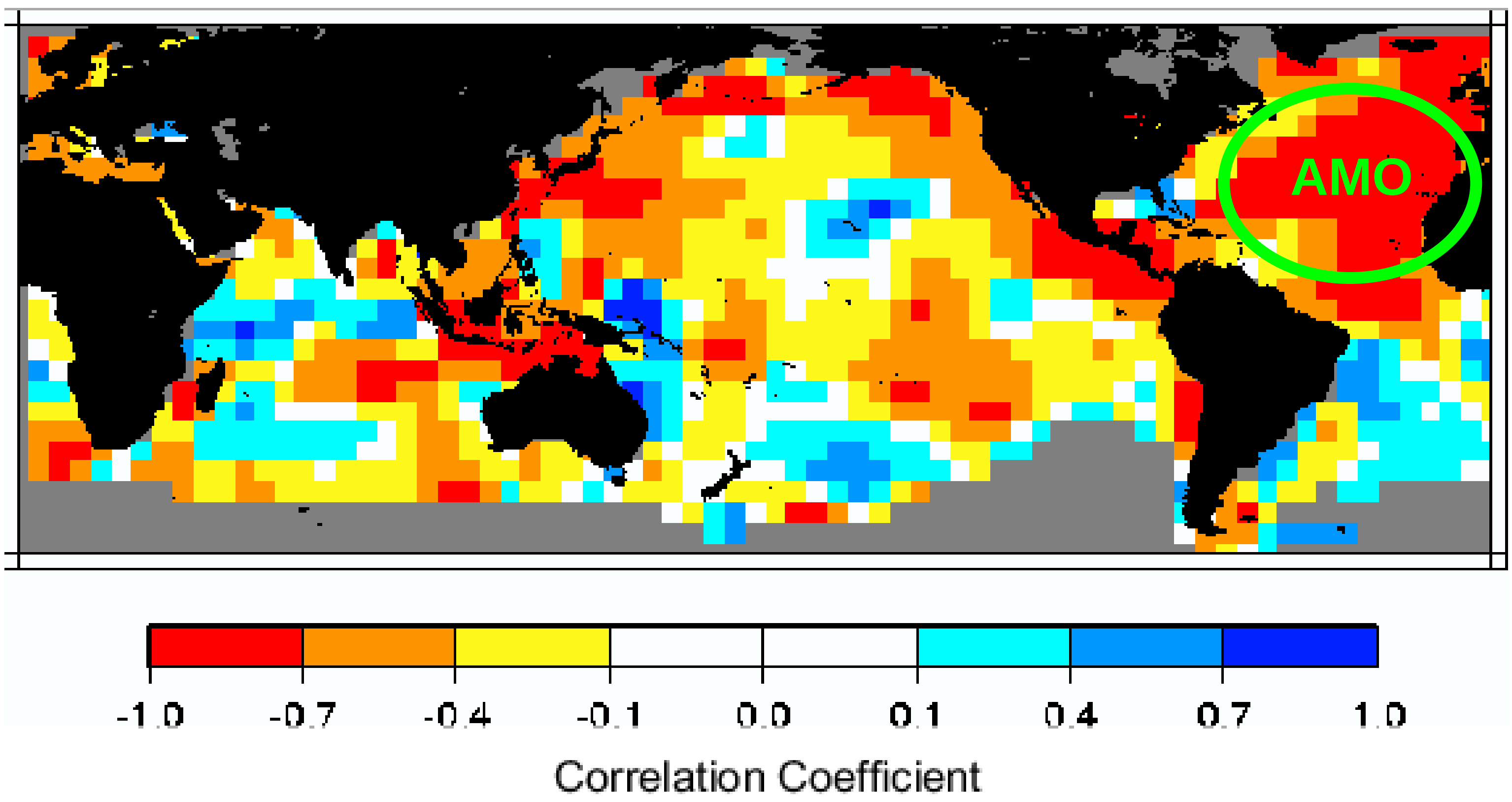
Correlations between detrended 11-year smoothed Lake McConaughy levels and detrended 11-year smoothed annual sea-surface temperatures, 1950-2003



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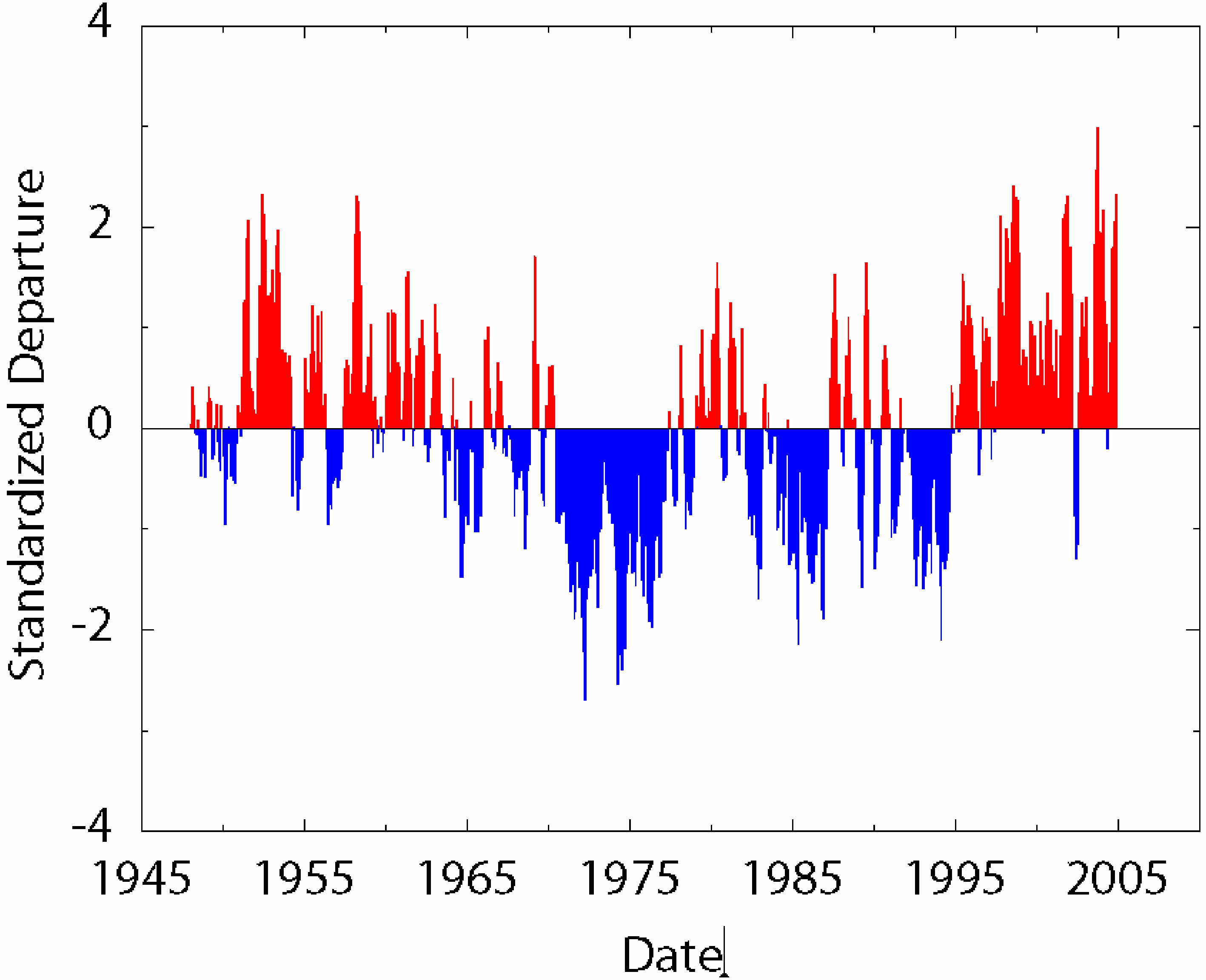
North Atlantic SSTs continue to be warm (+AMO)



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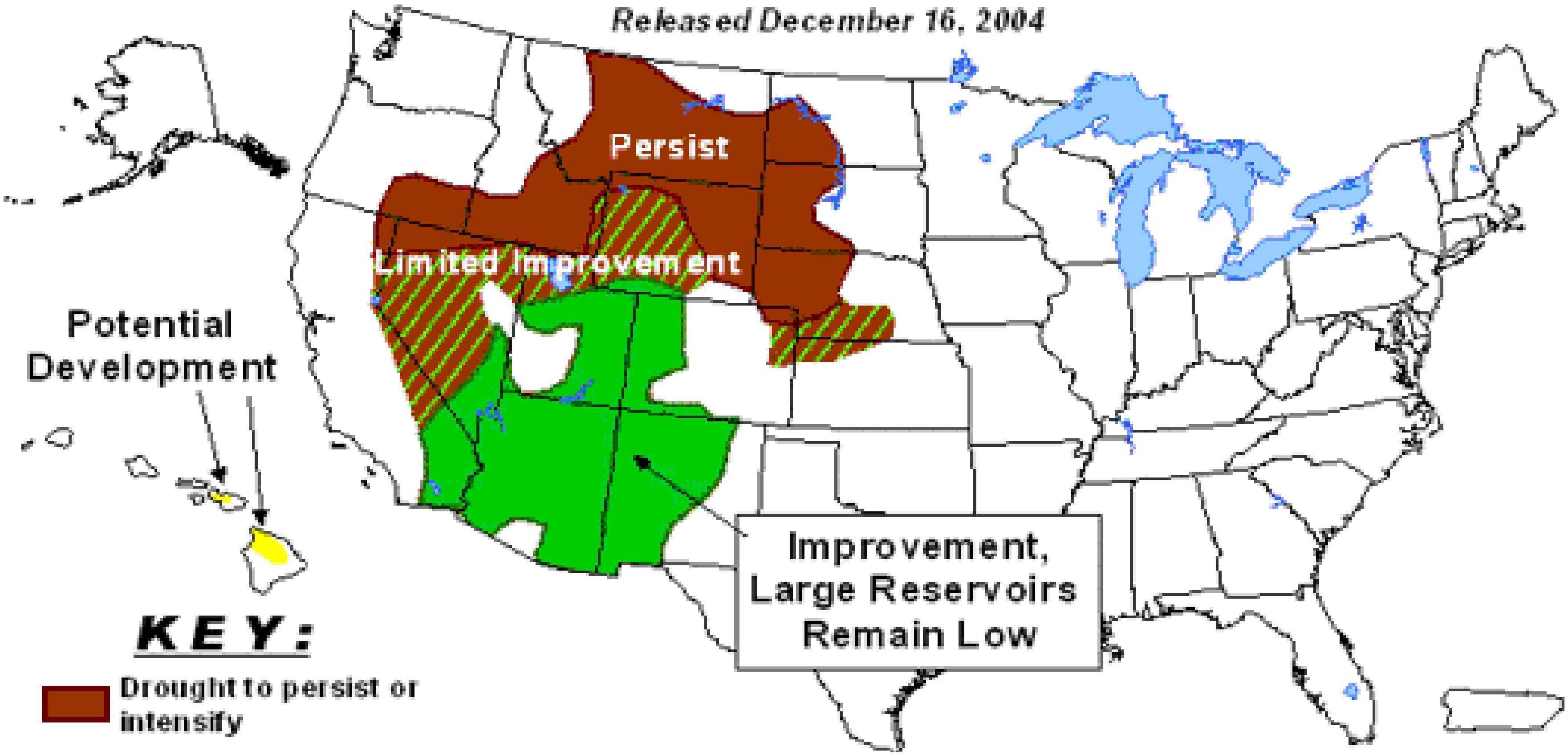
U.S. Seasonal Drought Outlook

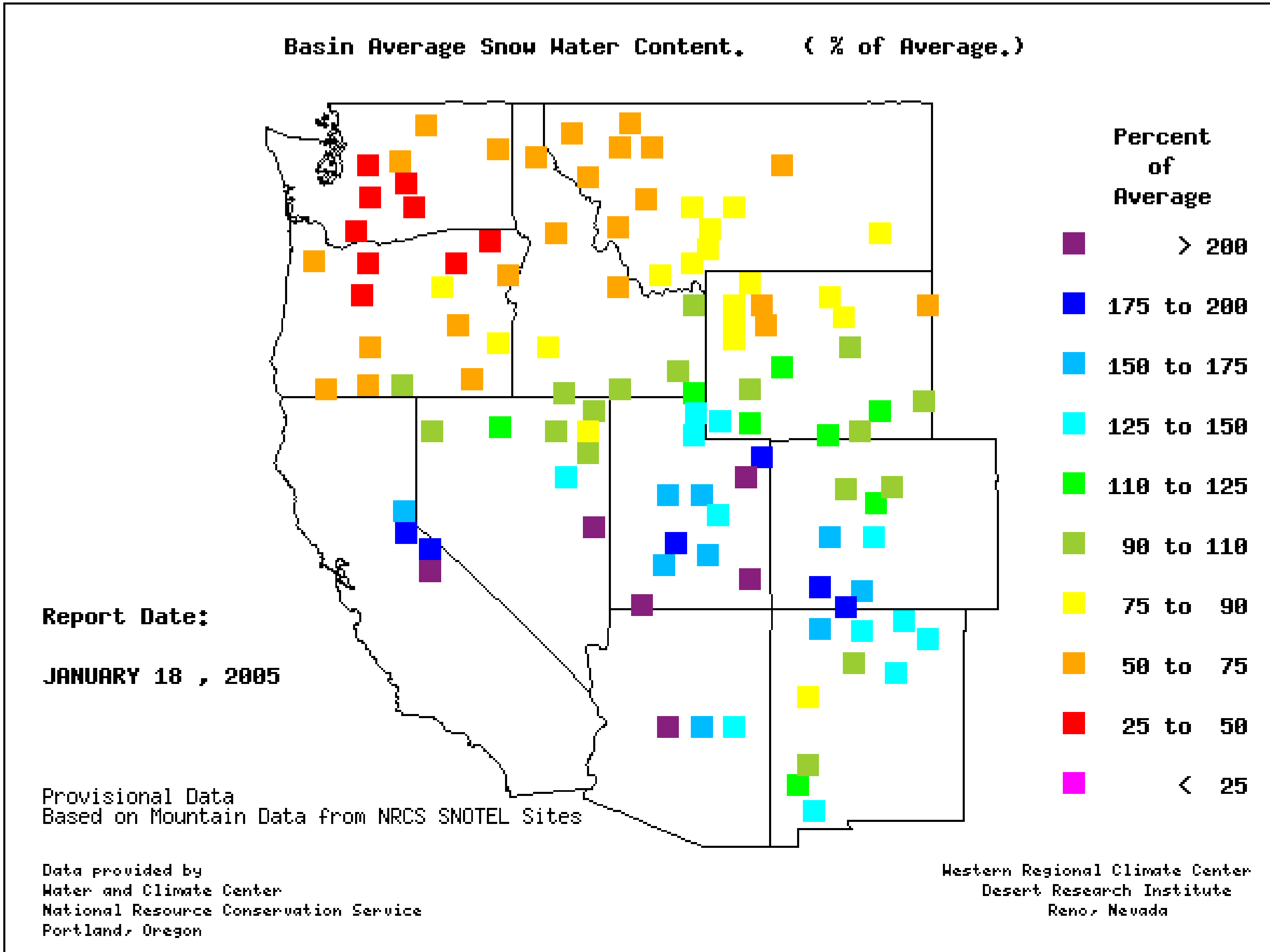
Through March 2005

Released December 16, 2004



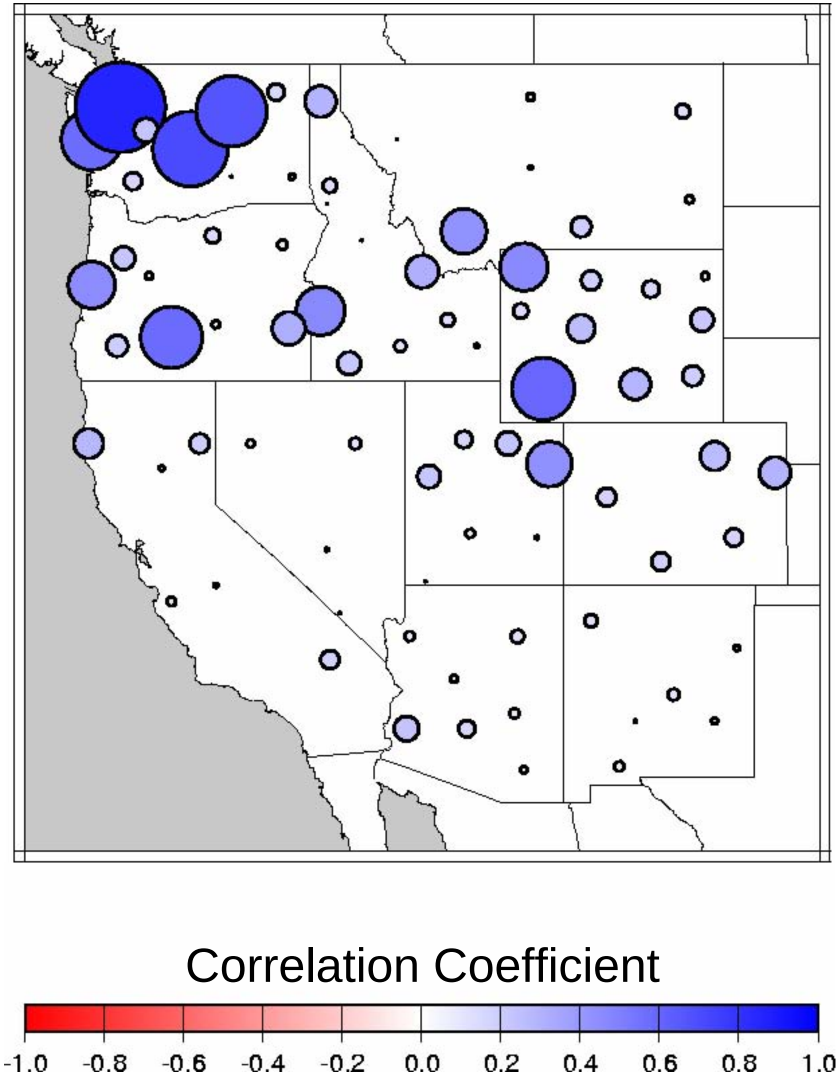
KEY:

- Drought to persist or intensify
- Drought ongoing, some improvement
- Drought likely to improve, impacts ease
- Drought development likely


Basin Average Snow Water Content. (% of Average.)
Percent of Average
> 200
175 to 200
150 to 175
125 to 150
110 to 125
90 to 110
75 to 90
50 to 75
25 to 50
< 25
Report Date:
JANUARY 18 , 2005
Provisional Data
Based on Mountain Data from NRCS SNOTEL Sites
Data provided by
Water and Climate Center
National Resource Conservation Service
Portland, Oregon
Western Regional Climate Center
Desert Research Institute
Reno, Nevada

For most of the western U.S. fall/early winter precipitation is not a good estimator of winter season precipitation

Correlation between OND precipitation and ONDJFM precipitation, 1896-2001



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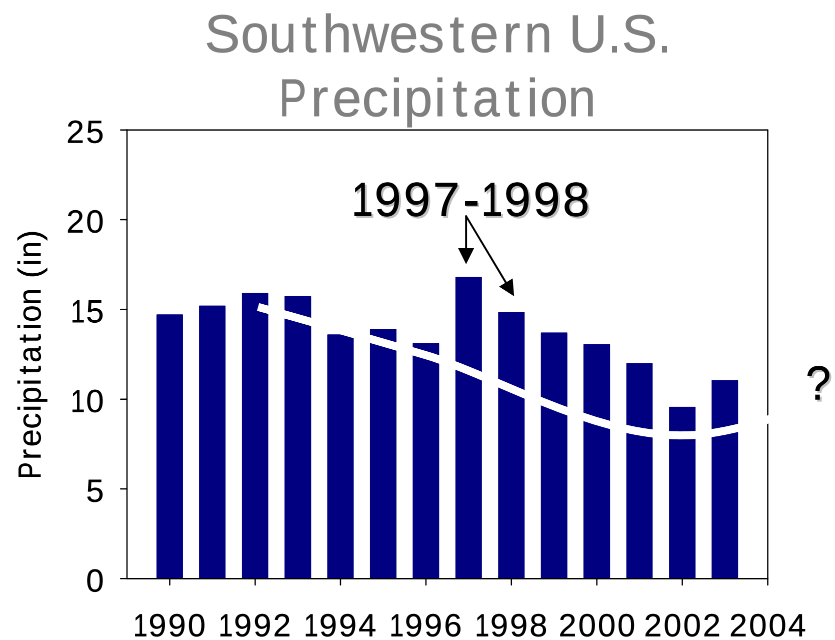
WGA's Drought Response Plan in 1996 was shelved during 1997-1998 El Niño



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

Some things to consider……

- Pacific and Atlantic Ocean sea-surface temperatures are significantly correlated with decadal-scale climatic conditions in the U.S.
- The current understanding of PDO and AMO provides explanatory utility, but not predictive capability.
- ENSO events can impose short-lived breaks in even the most severe droughts, testing the resolve of drought planners.
- If North Atlantic sea-surface temperatures remain anomalously warm will drought continue in the U.S.?
- Caution: one or two wet years <u>may not</u> mean the end of the drought.

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