Climate Change, Climate Variability, and Extreme Events

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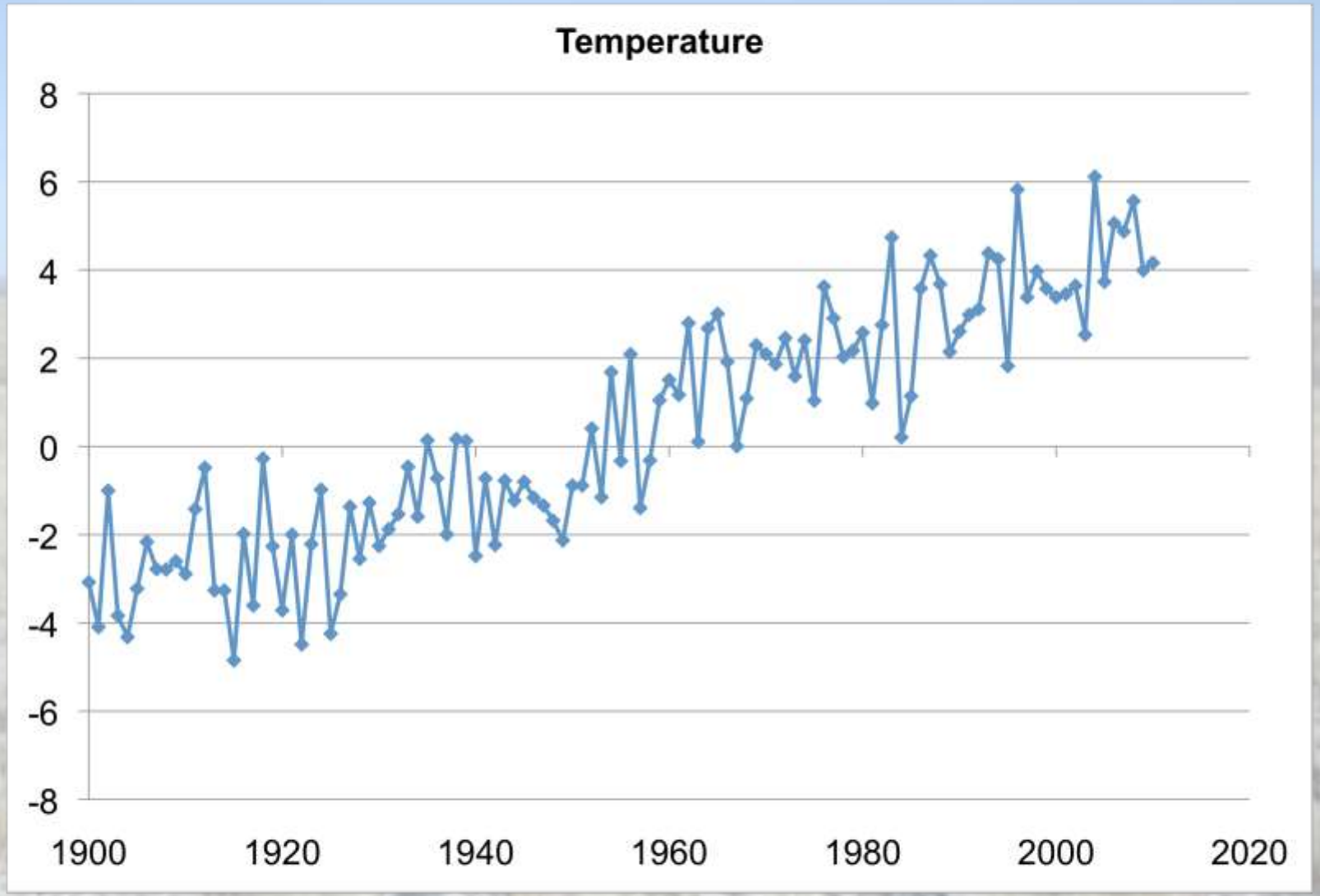
Future Extremes

- "The type, frequency and intensity of extreme events are expected to change as Earth's climate changes."
- "In other words, a warmer atmosphere from climate change likely yields greater extremes in weather."

What does an increase in extremes mean?

- More events outside the bounds of recorded history
- More variability
- A larger range over a given interval


Temperature
8
6
4
2
0
-2
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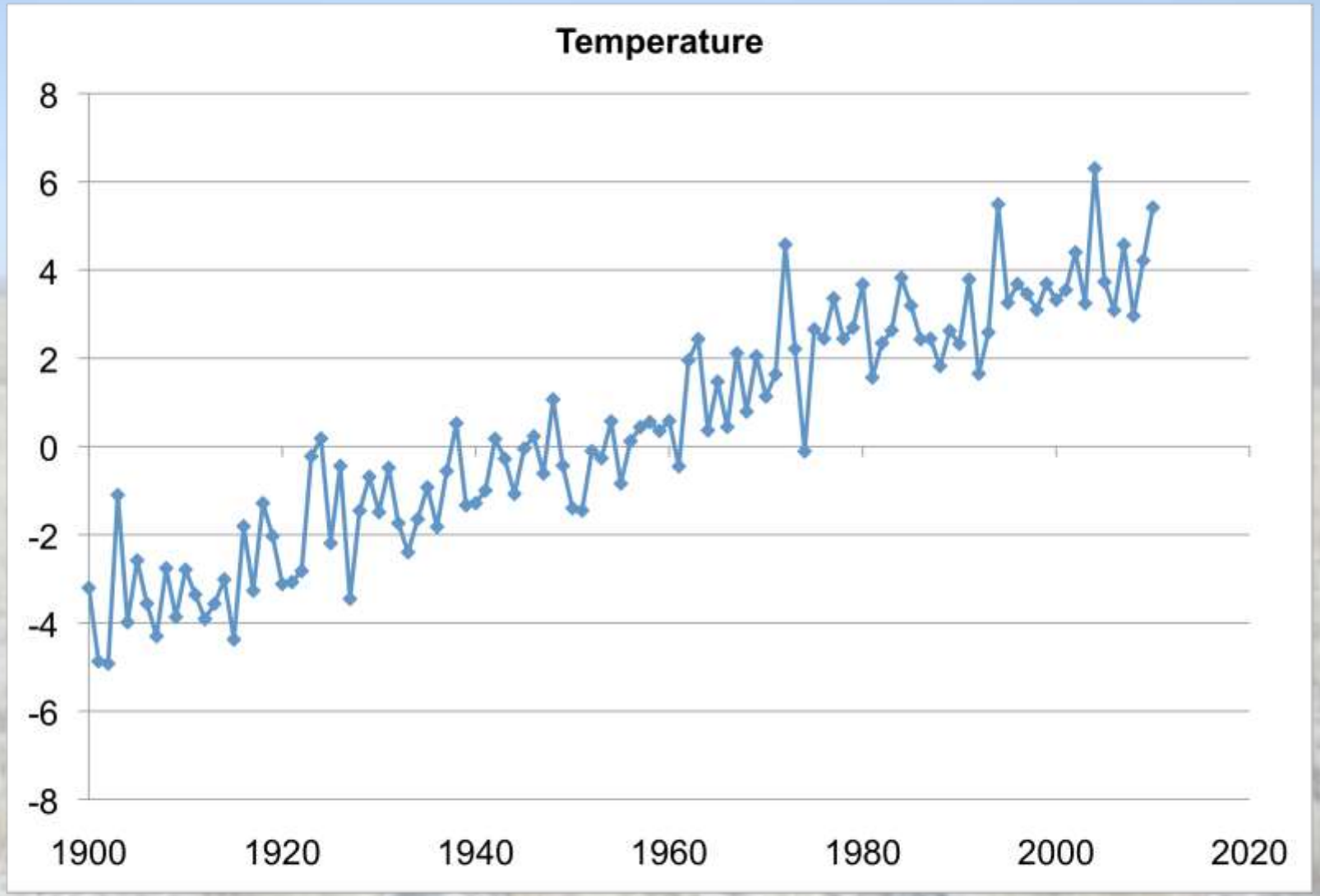
-6
-8
1900
1920
1940
1960
1980
2000
2020


Temperature
8
6
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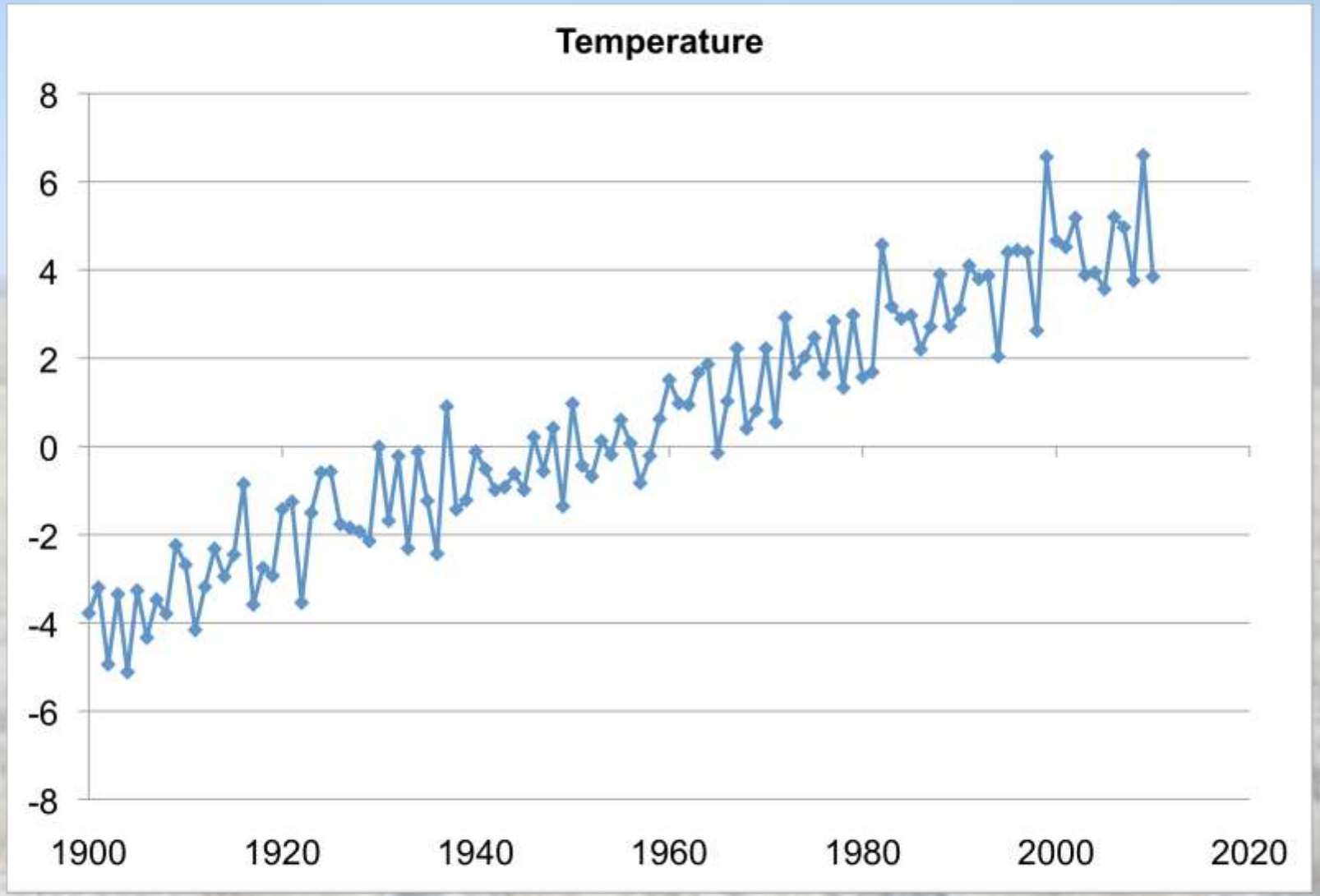
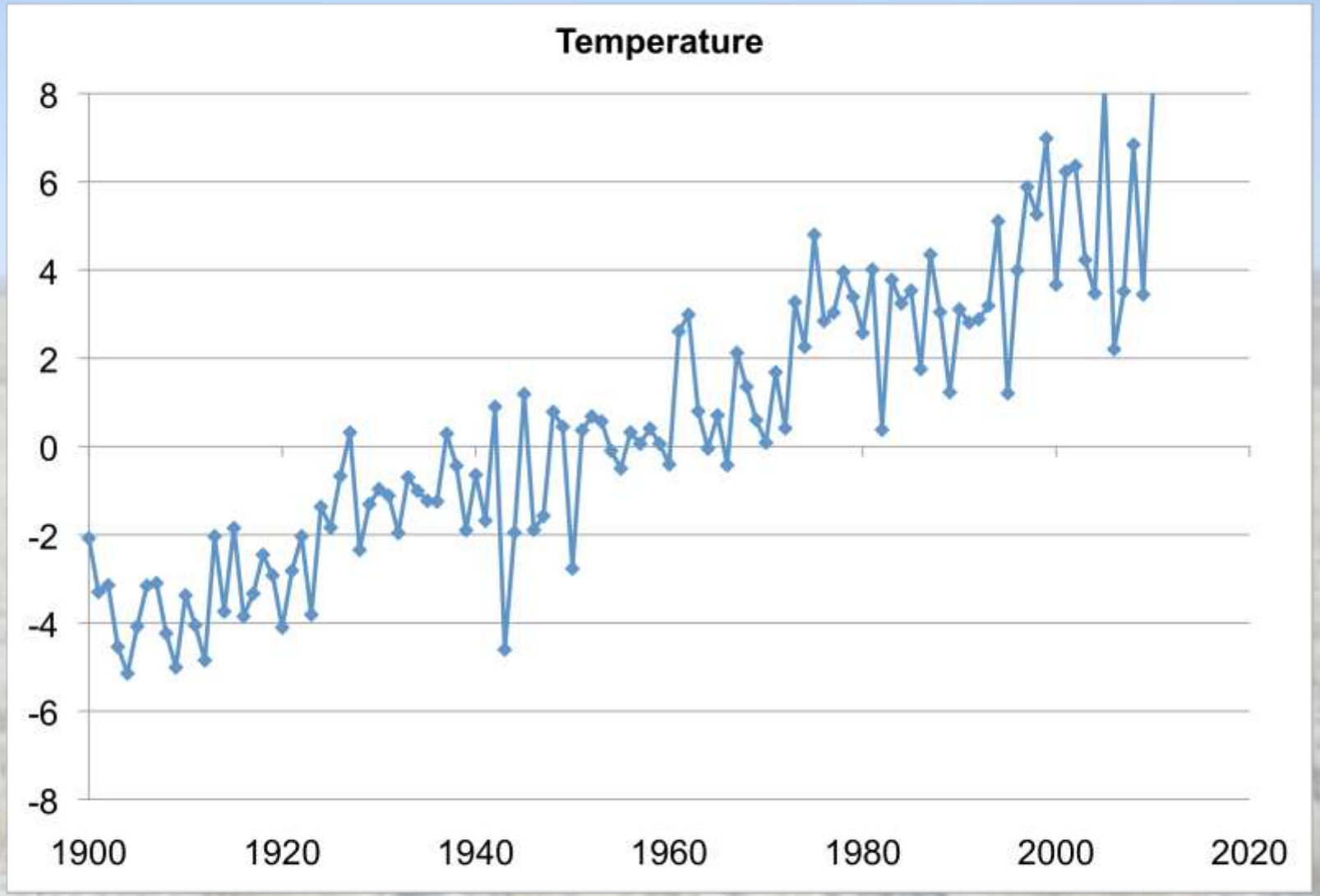
0
-2
-4
-6
-8
1900
1920
1940
1960
1980
2000
2020


Temperature
8
6
4
2
0
-2
-4
-6
-8
1900
1920
1940
1960
1980
2000
2020

What does an increase in extremes mean?

- More events outside the bounds of recorded history
- Automatically produced by an underlying trend


Temperature
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4
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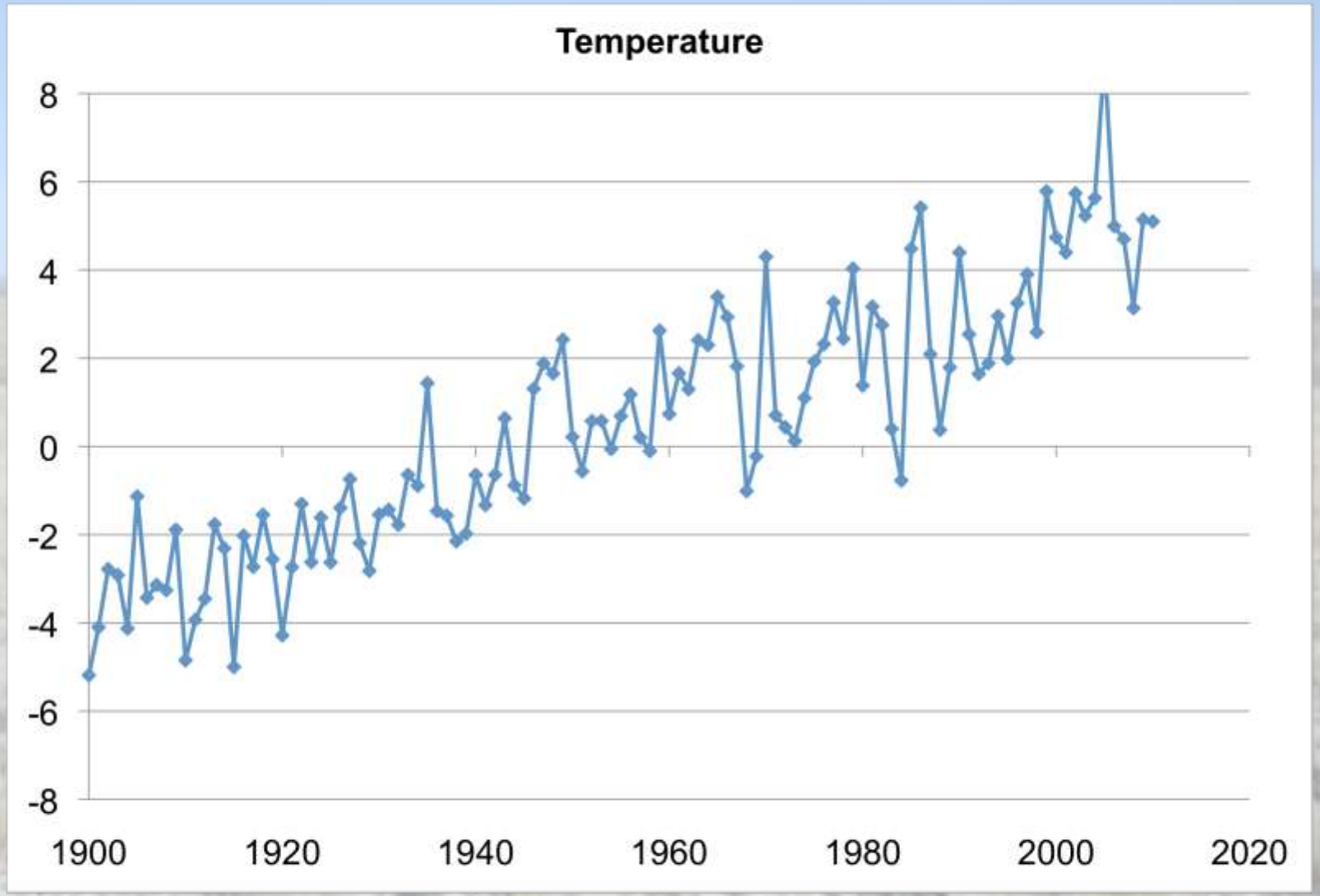
-2
-4
-6
-8
1900
1920
1940
1960
1980
2000
2020


Temperature
8
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0
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-6
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1900
1920
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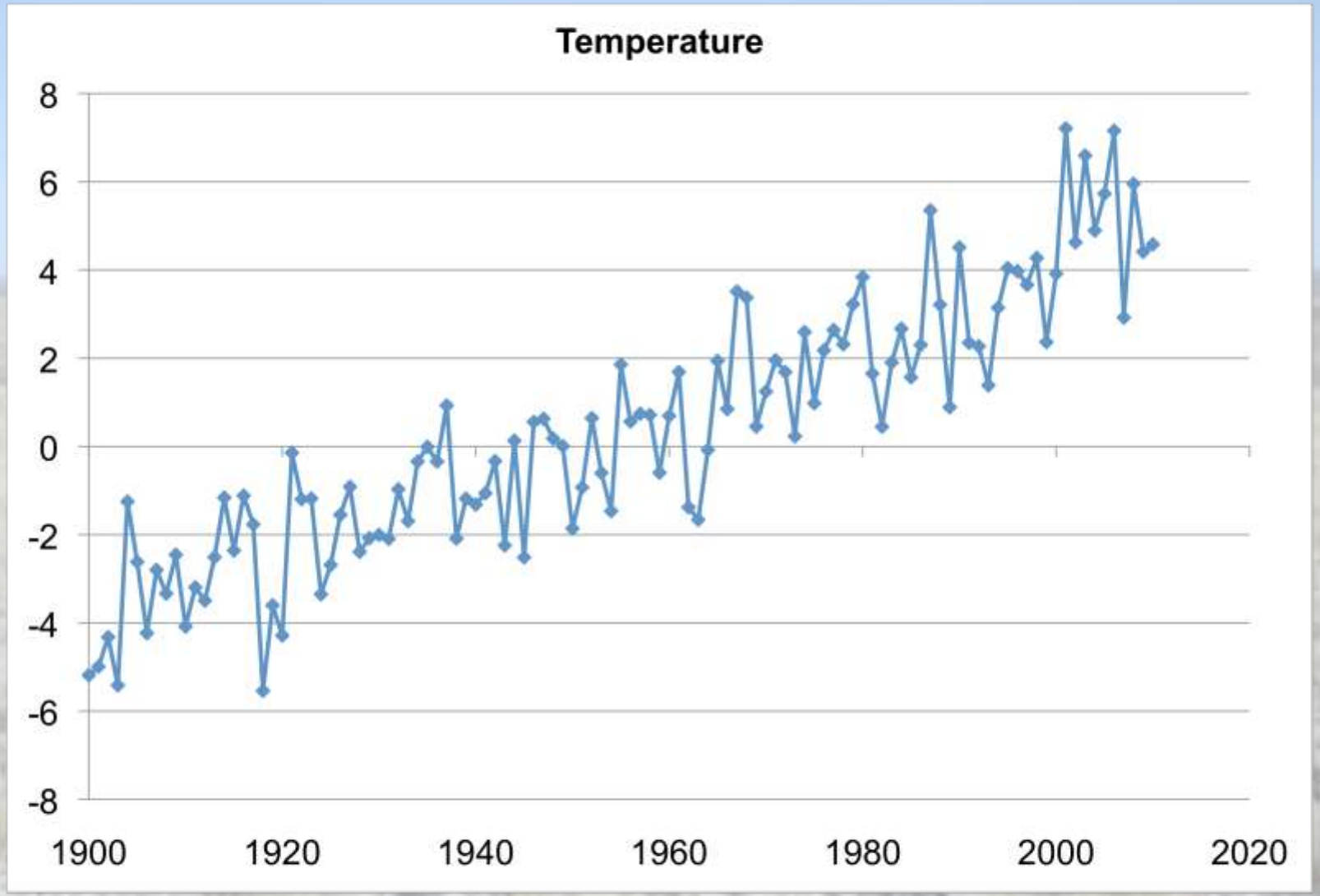
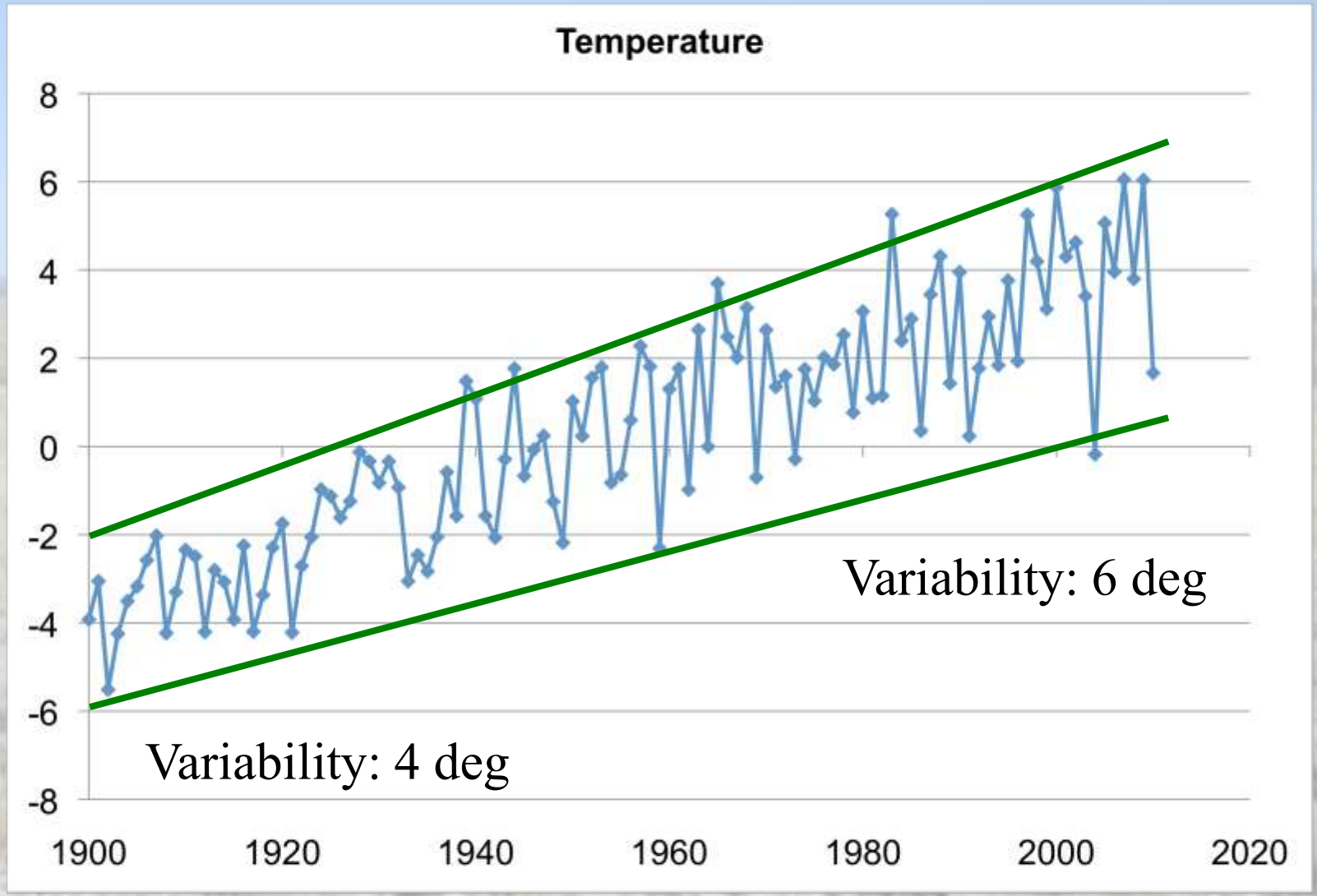
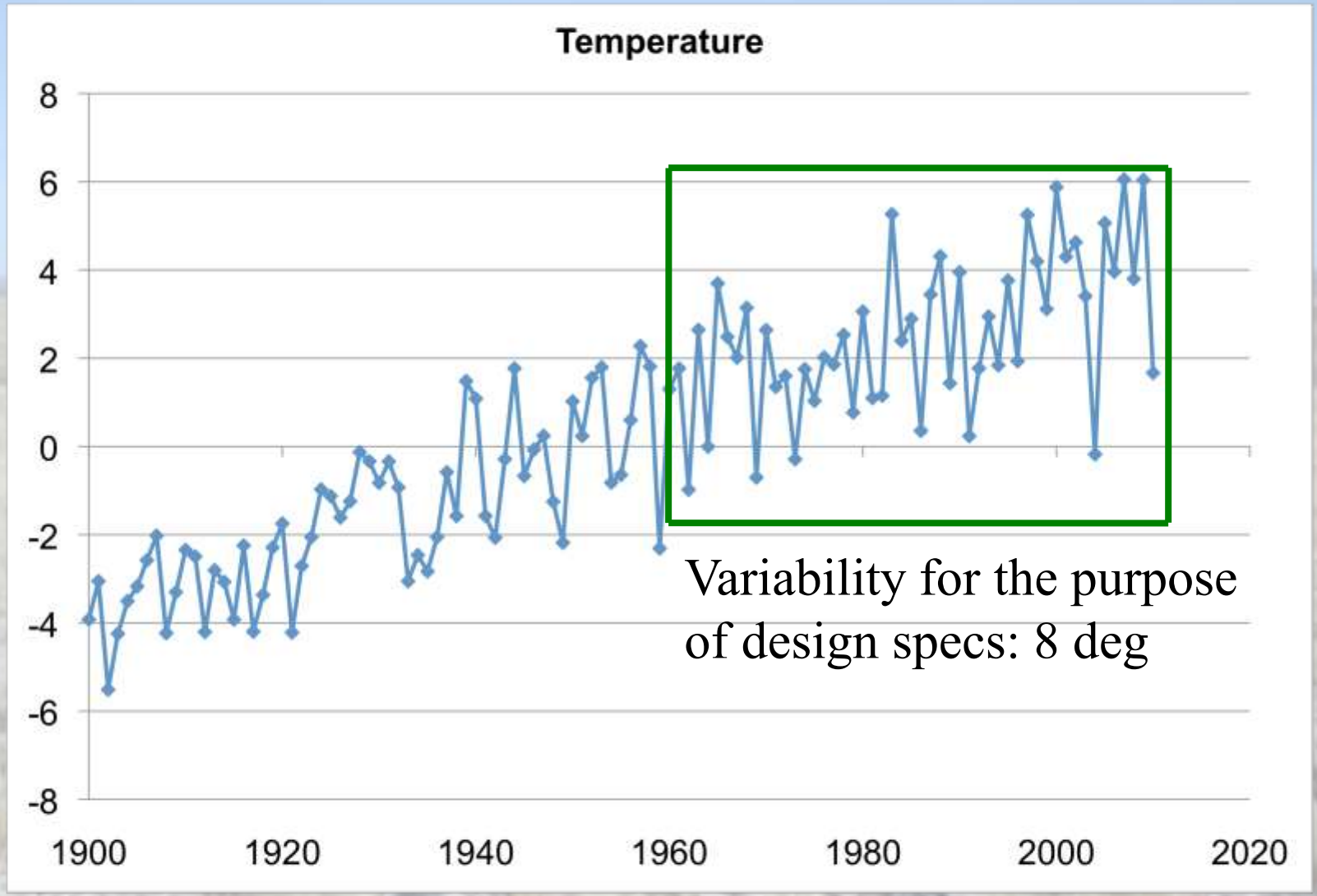
1960
1980
2000
2020


Temperature
8
6
4
2
0
-2
-4
-6
-8
1900
1920
1940
1960
1980
2000
2020

What does an increase in extremes mean?

- More variability
- Fewer events outside the bounds of recorded history!


Temperature
8
6
4
2
0
-2
-4
-6
-8
1900
1920
1940
1960
1980
2000
2020
Variability: 6 deg
Variability: 4 deg


Temperature
8
6
4
2
0
-2
-4
-6
-8
1900
1920
1940
1960
1980
2000
2020
Variability for the purpose of design specs: 8 deg

If the expected value of a climate variable is changing:

- More events outside the bounds of recorded history
- Maybe more variability, maybe less
- A larger range over a given interval

Drought: An extreme event

- Droughts are increasing

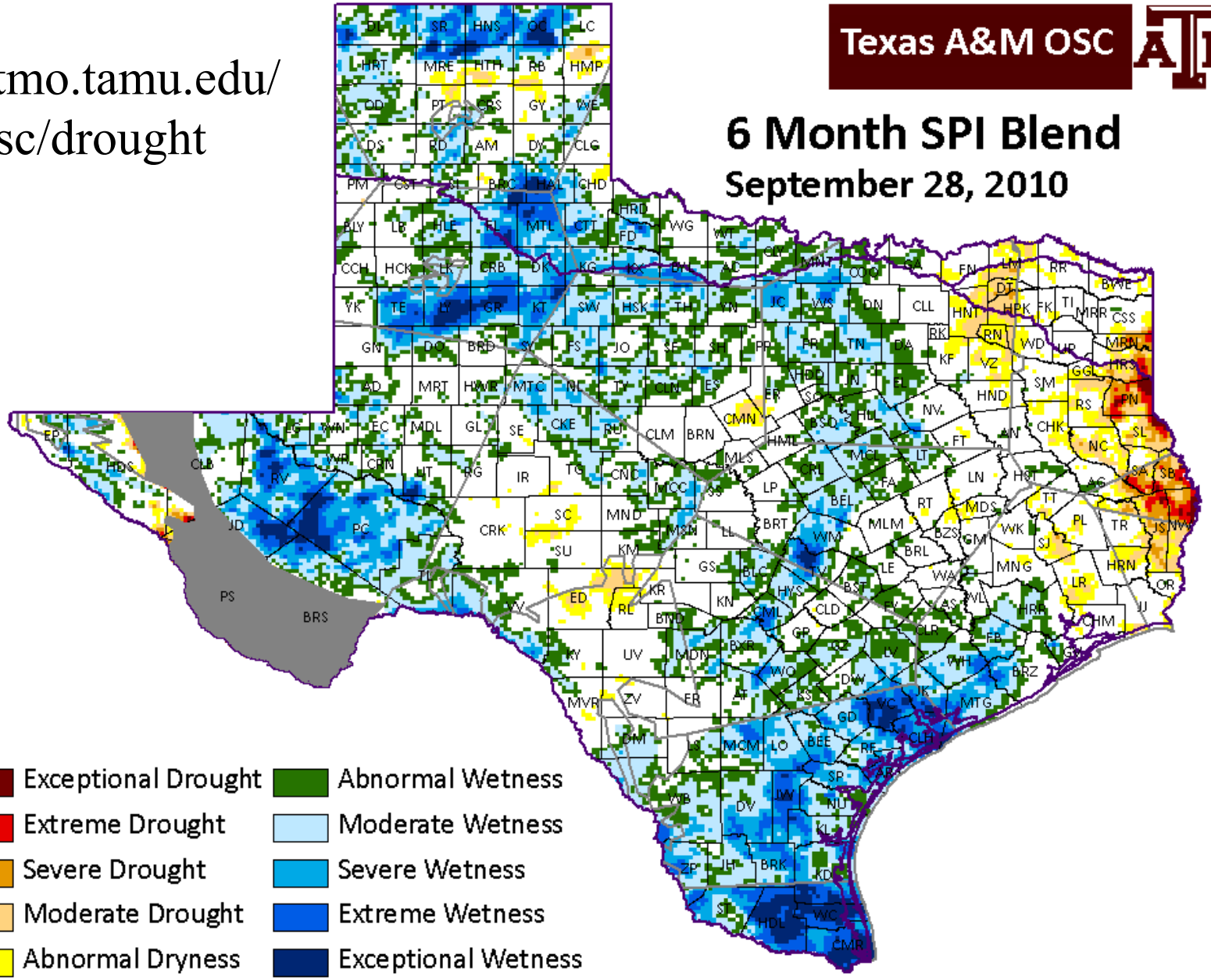
Drought: An extreme event

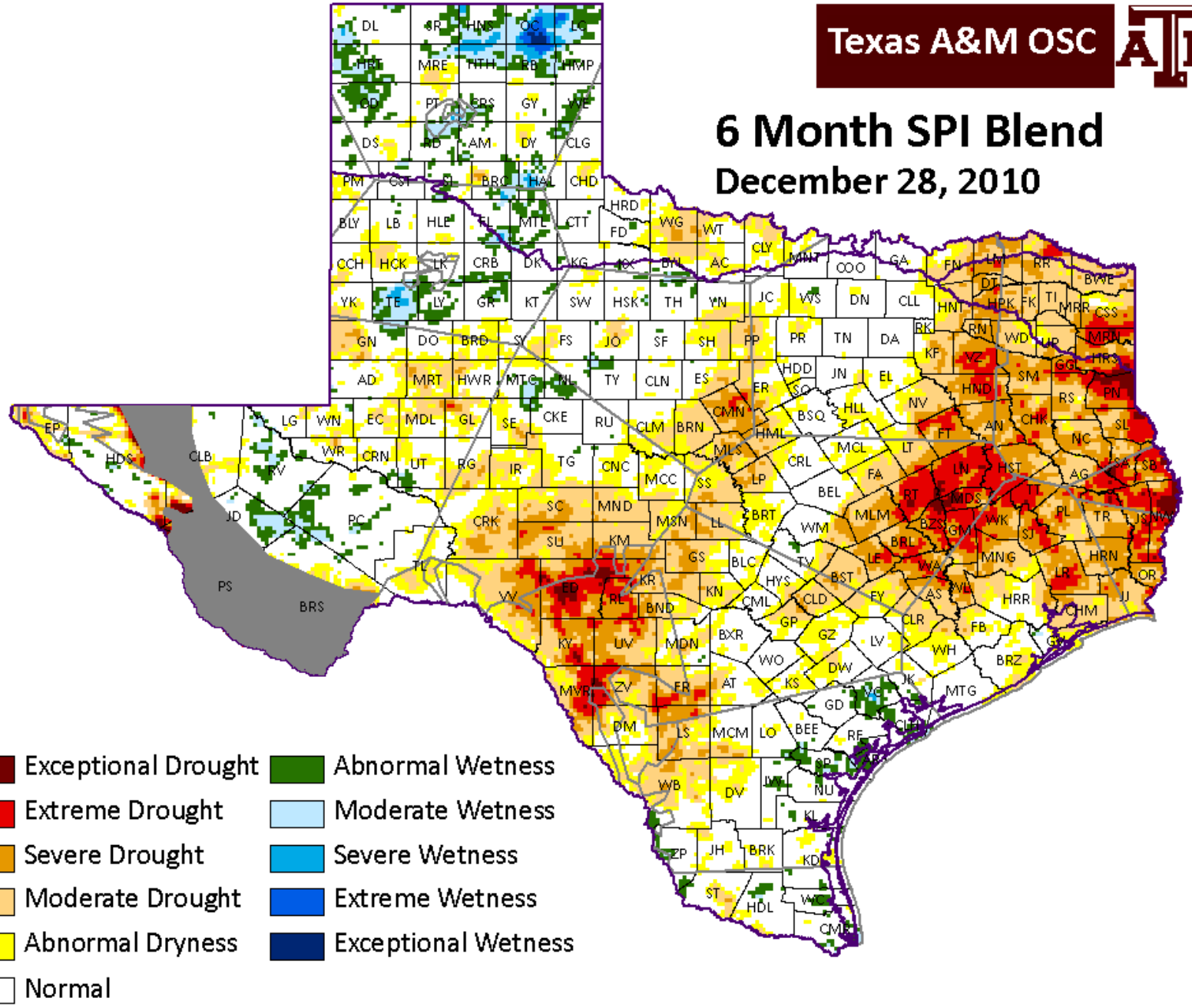
- Droughts are increasing
- Are droughts increasing here?

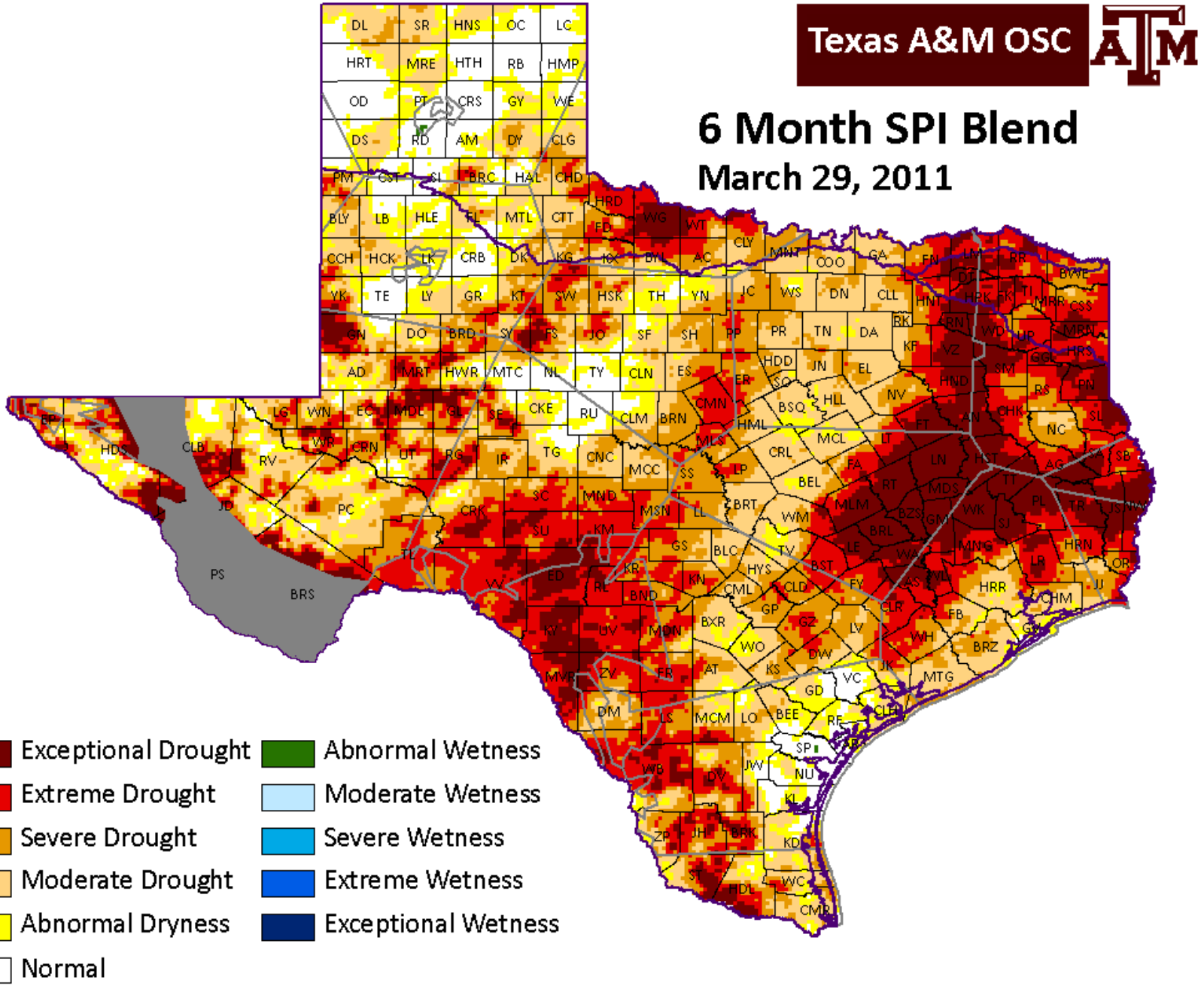
Drought: An extreme event

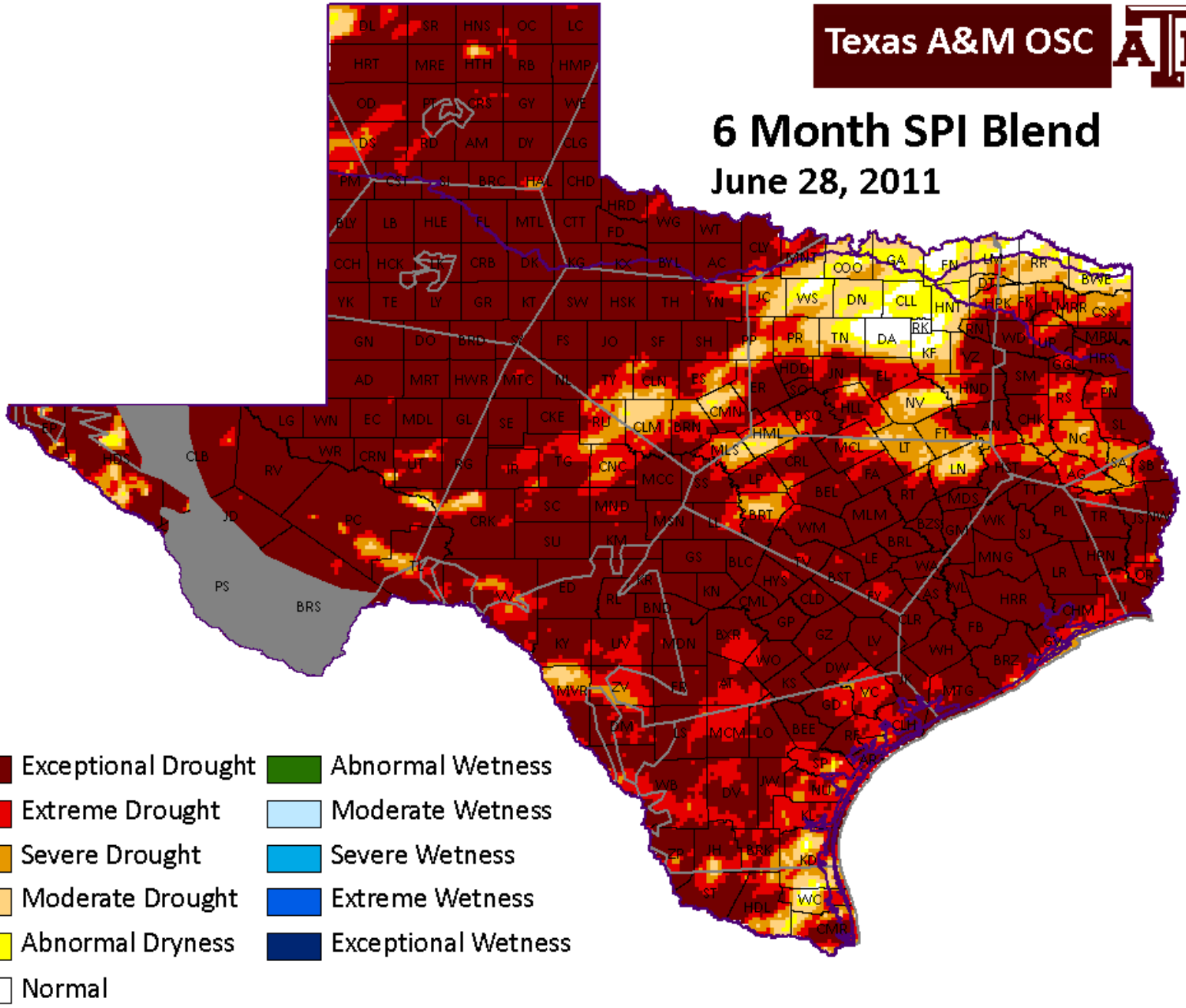
- Droughts are increasing
- Are droughts increasing here?
- Yes, if:
  - Rainfall trend negative
  - No rainfall trend, but increasing variability
  - No rainfall trend, but increasing temperatures

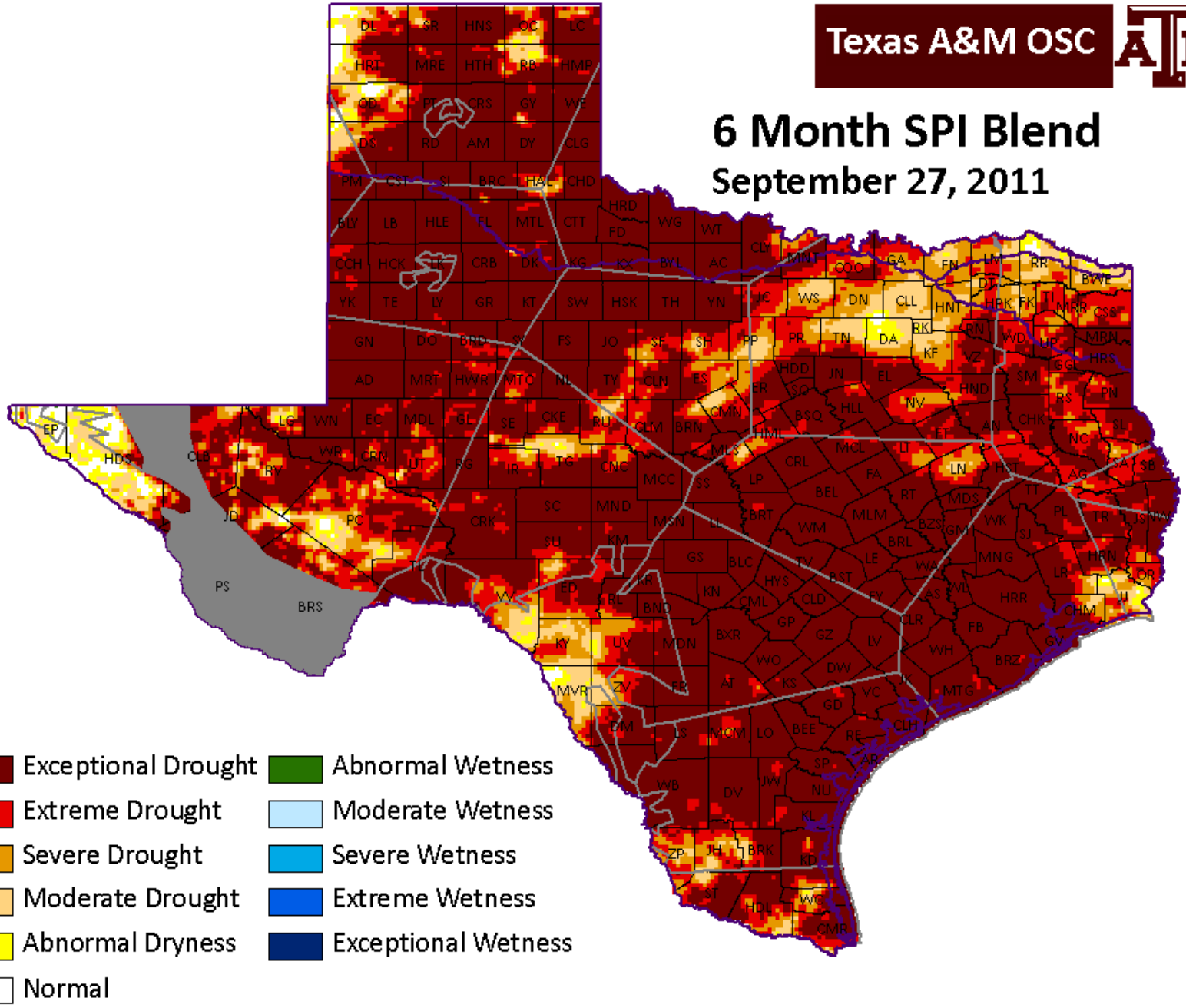
atmo.tamu.edu/
osc/drought

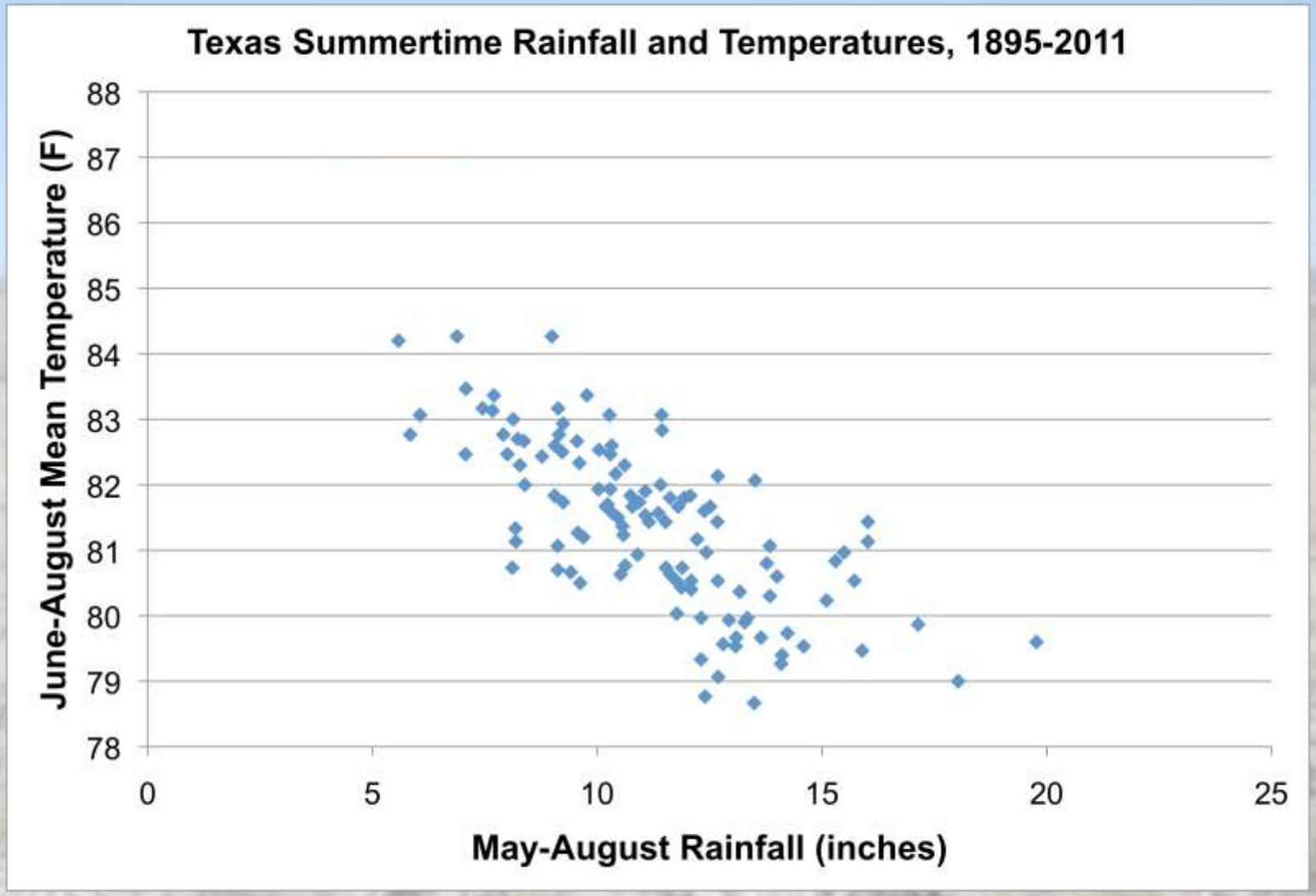


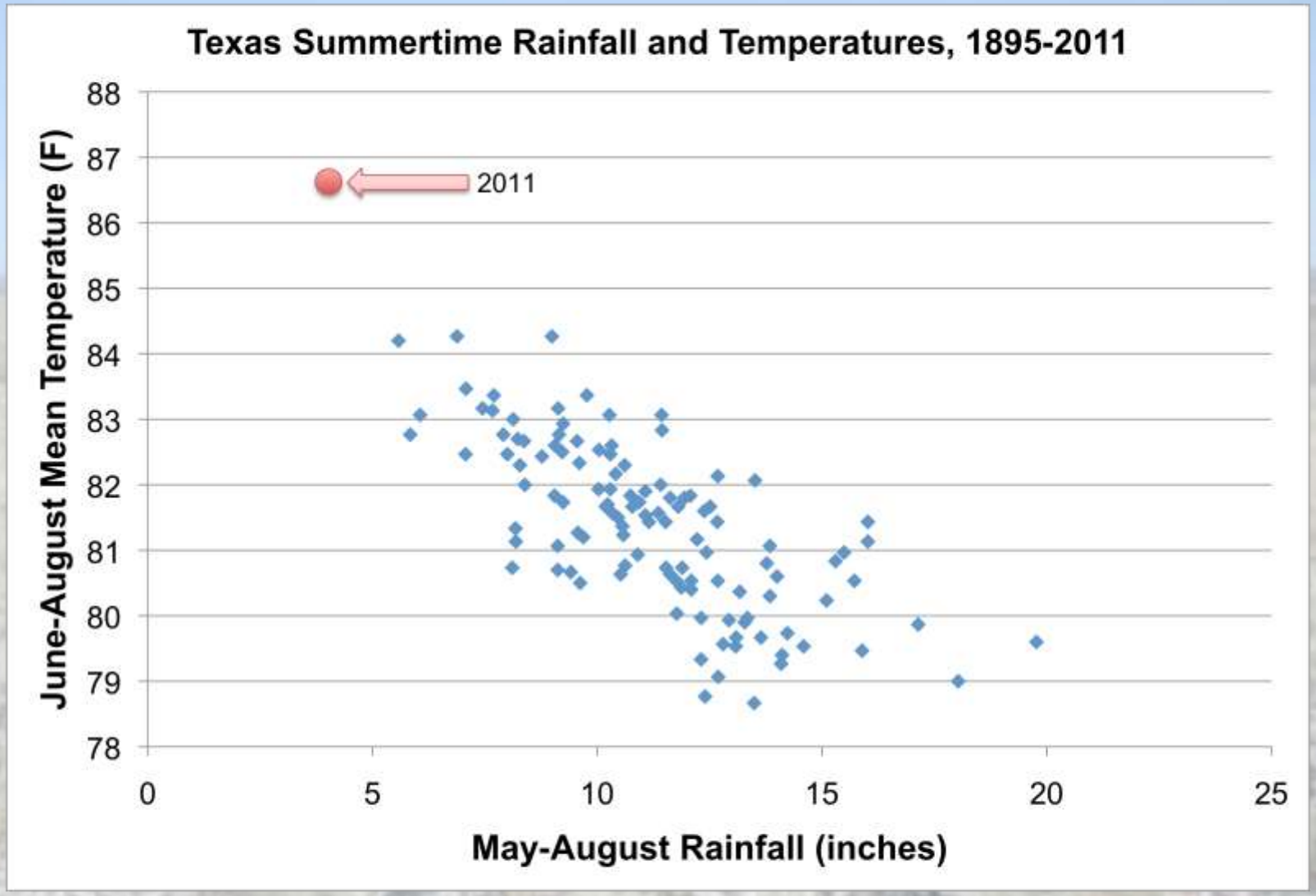

Texas A&M OSC
6 Month SPI Blend
December 28, 2010
Exceptional Drought
Extreme Drought
Severe Drought
Moderate Drought
Abnormal Dryness
Normal
Abnormal Wetness
Moderate Wetness
Severe Wetness
Extreme Wetness
Exceptional Wetness


Texas A&M OSC
6 Month SPI Blend
March 29, 2011
Exceptional Drought
Extreme Drought
Severe Drought
Moderate Drought
Abnormal Dryness
Normal
Abnormal Wetness
Moderate Wetness
Severe Wetness
Extreme Wetness
Exceptional Wetness


Texas A&M OSC
6 Month SPI Blend
June 28, 2011
Exceptional Drought
Extreme Drought
Severe Drought
Moderate Drought
Abnormal Dryness
Normal
Abnormal Wetness
Moderate Wetness
Severe Wetness
Extreme Wetness
Exceptional Wetness


Texas A&M OSC
6 Month SPI Blend
September 27, 2011
Exceptional Drought
Extreme Drought
Severe Drought
Moderate Drought
Abnormal Dryness
Normal
Abnormal Wetness
Moderate Wetness
Severe Wetness
Extreme Wetness
Exceptional Wetness


Texas Summertime Rainfall and Temperatures, 1895-2011
June-August Mean Temperature (F)
88
87
86
85
84
83
82
81
80
79
78
0
5
10
15
20
25
May-August Rainfall (inches)


Texas Summertime Rainfall and Temperatures, 1895-2011
June-August Mean Temperature (F)
88
87
86
85
84
83
82
81
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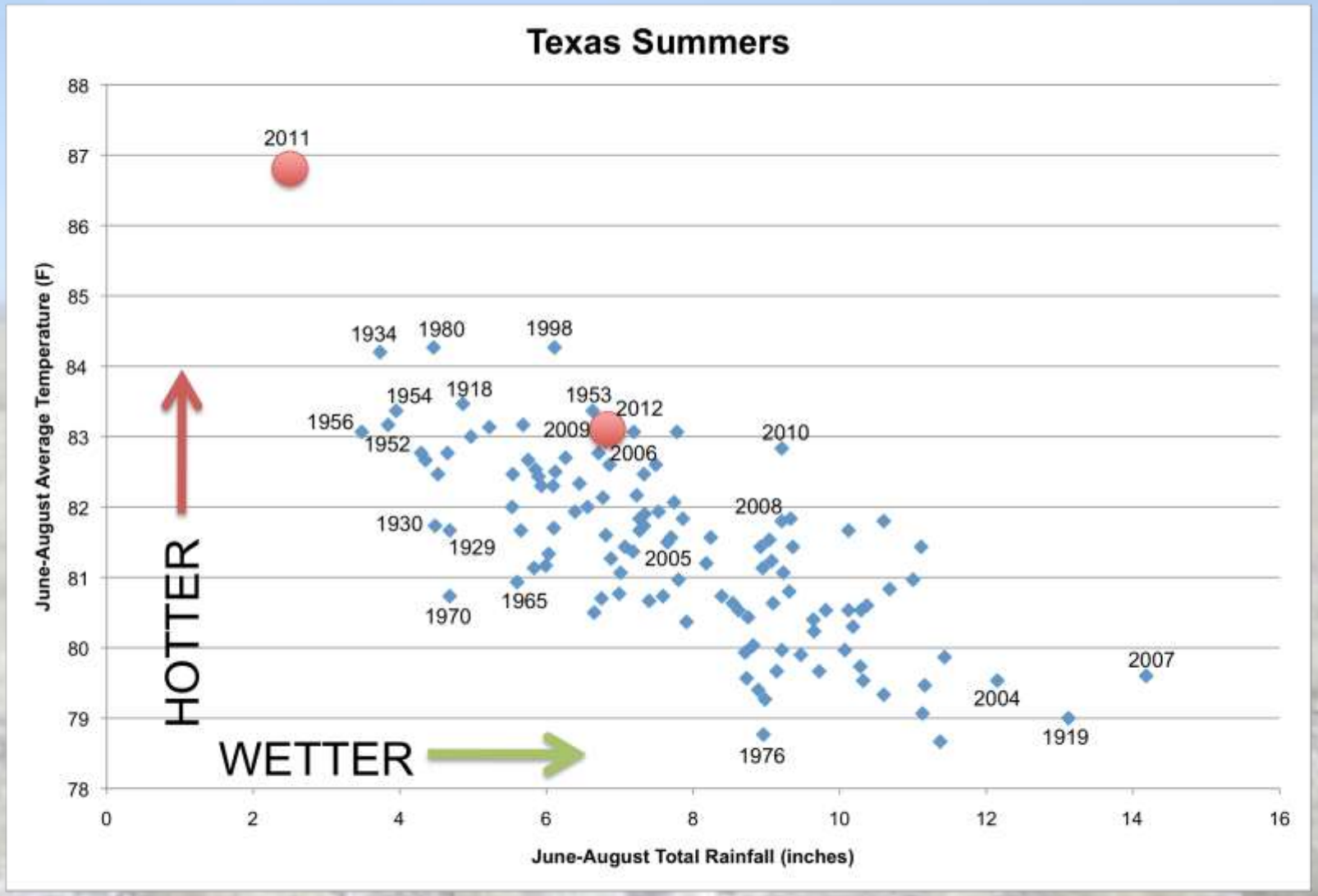
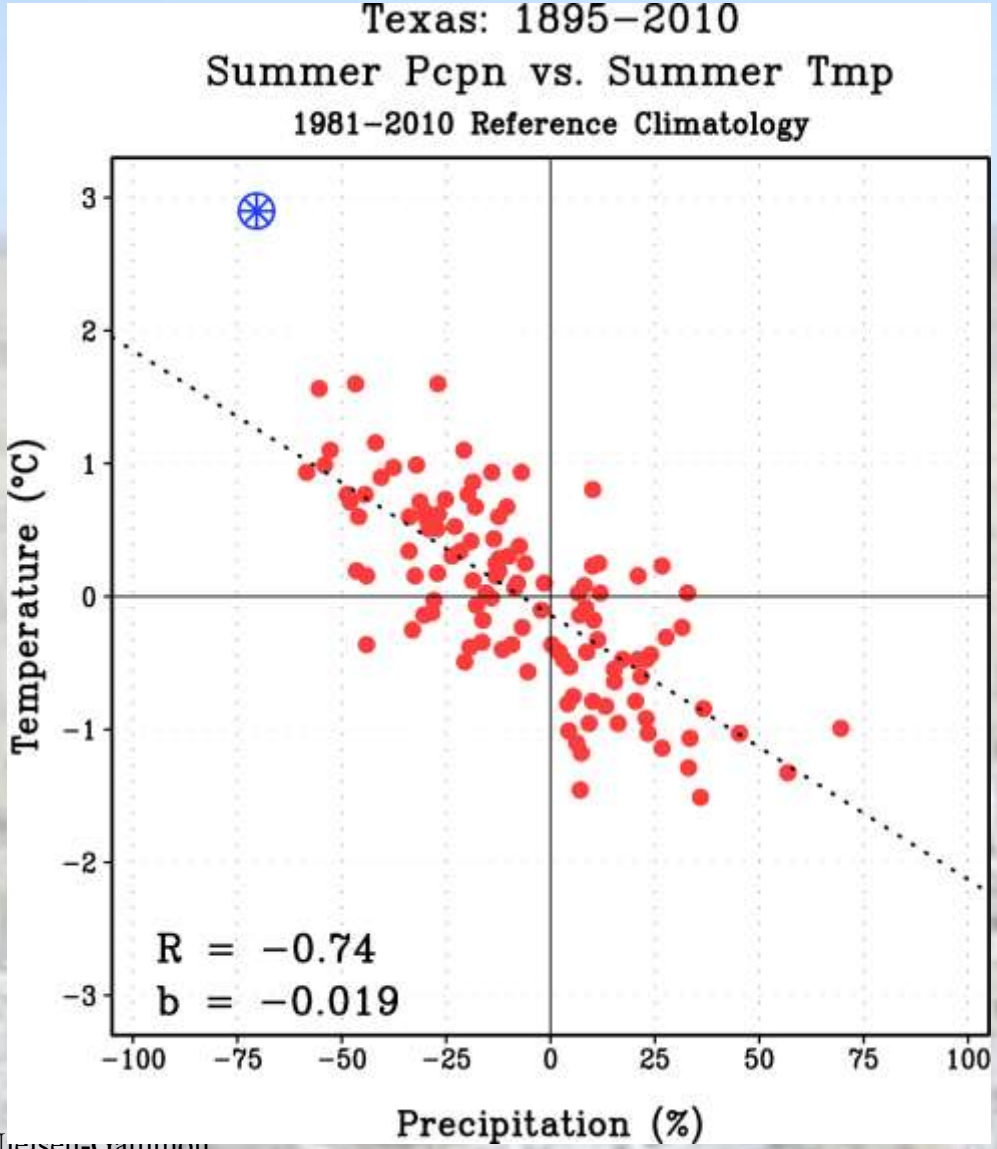
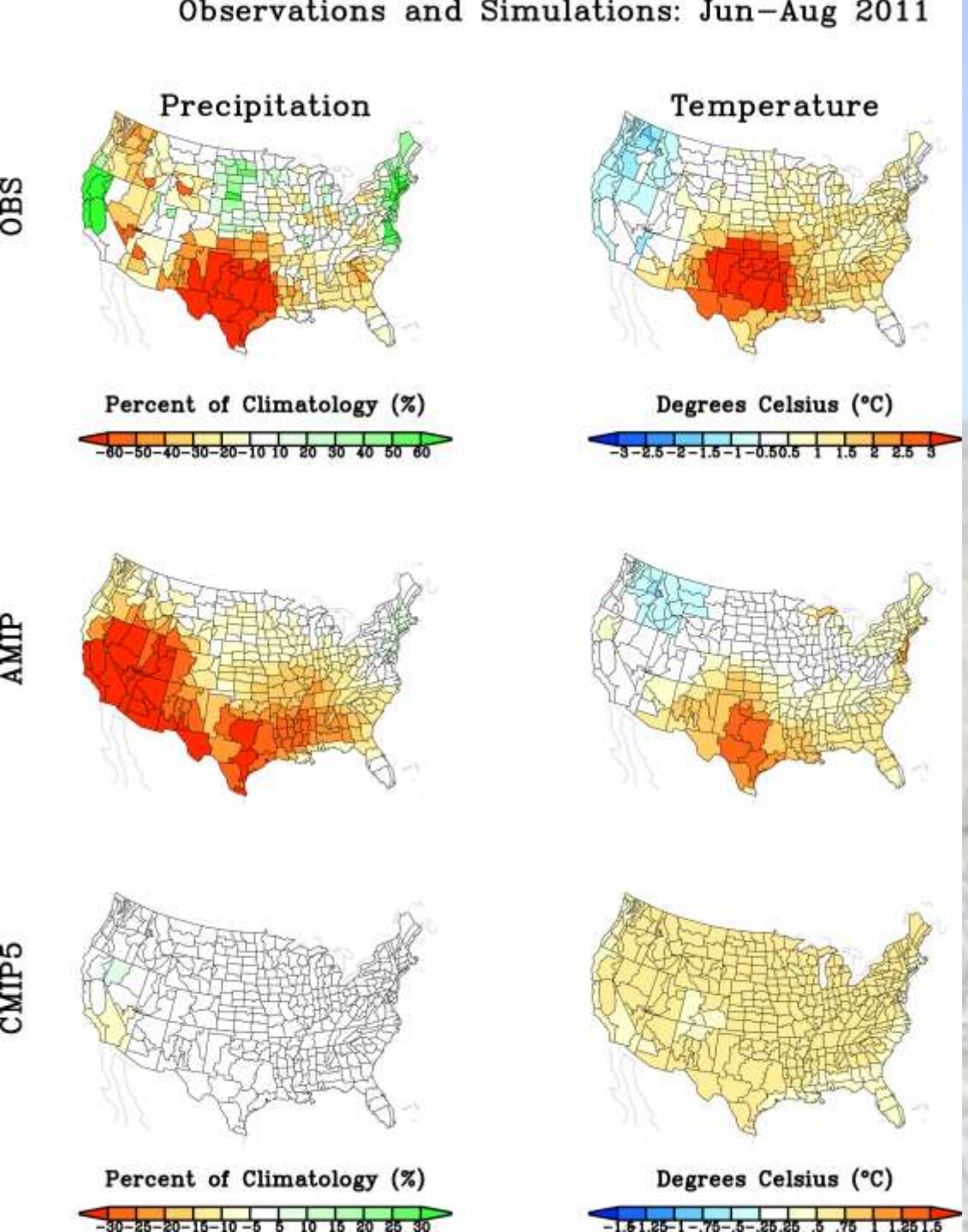
79
78
2011
0
5
10
15
20
25
May-August Rainfall (inches)


Texas Summers
June-August Average Temperature (F)
June-August Total Rainfall (inches)
HOTTER
WETTER
2011
1934
1980
1998
1954
1918
1953
2012
1956
2009
2010
1952
2006
2008
1930
1929
2005
1965
1970
2007
2004
1919
1976
88
87
86
85
84
83
82
81
80
79
78
0
2
4
6
8
10
12
14
16

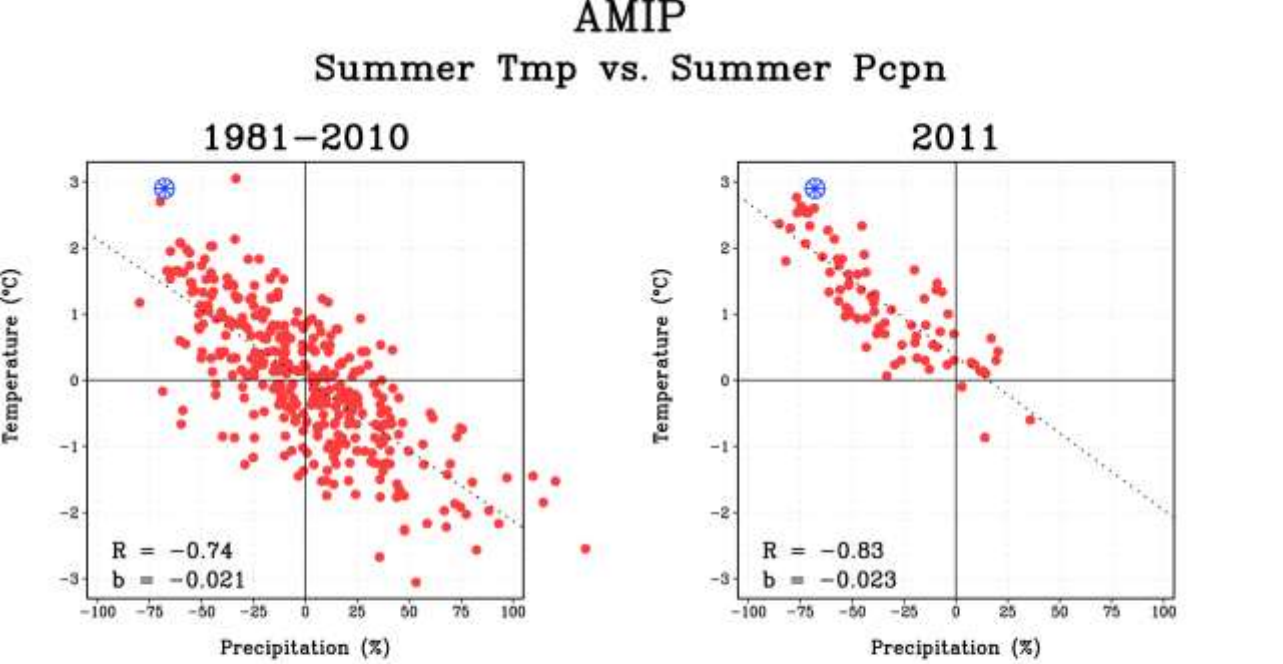
Historical relationship: Simulated Summer Precipitation and Temperature

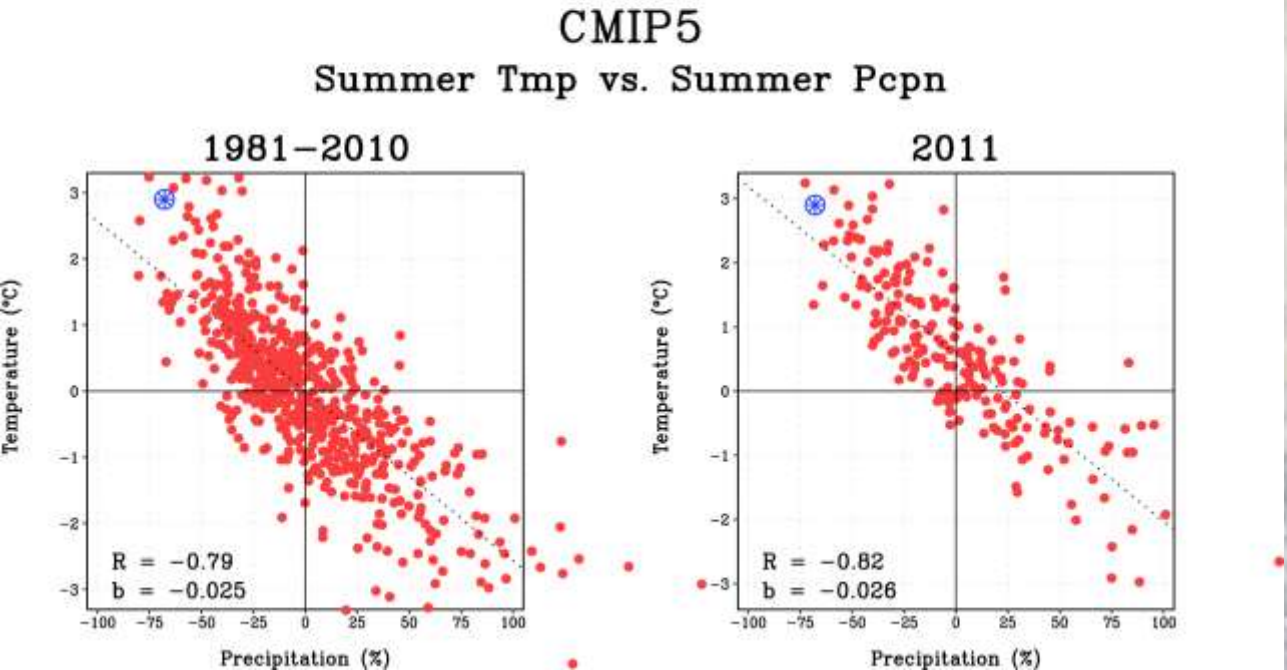




Atmosphere-only model, observed sea surface temperatures

Atmosphere-Ocean model, observed climate forcings

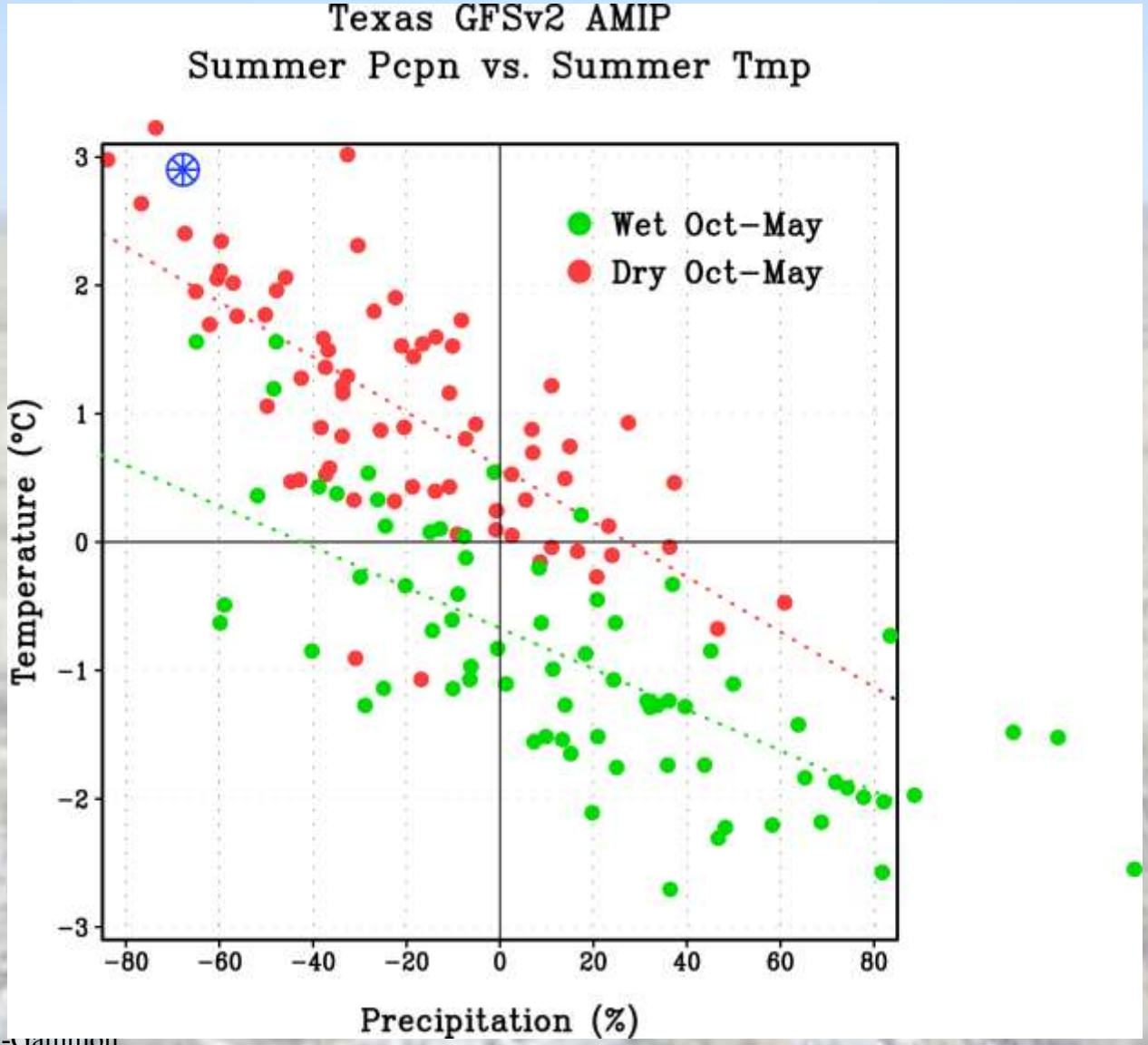




Atmosphere-only model, observed sea surface temperatures

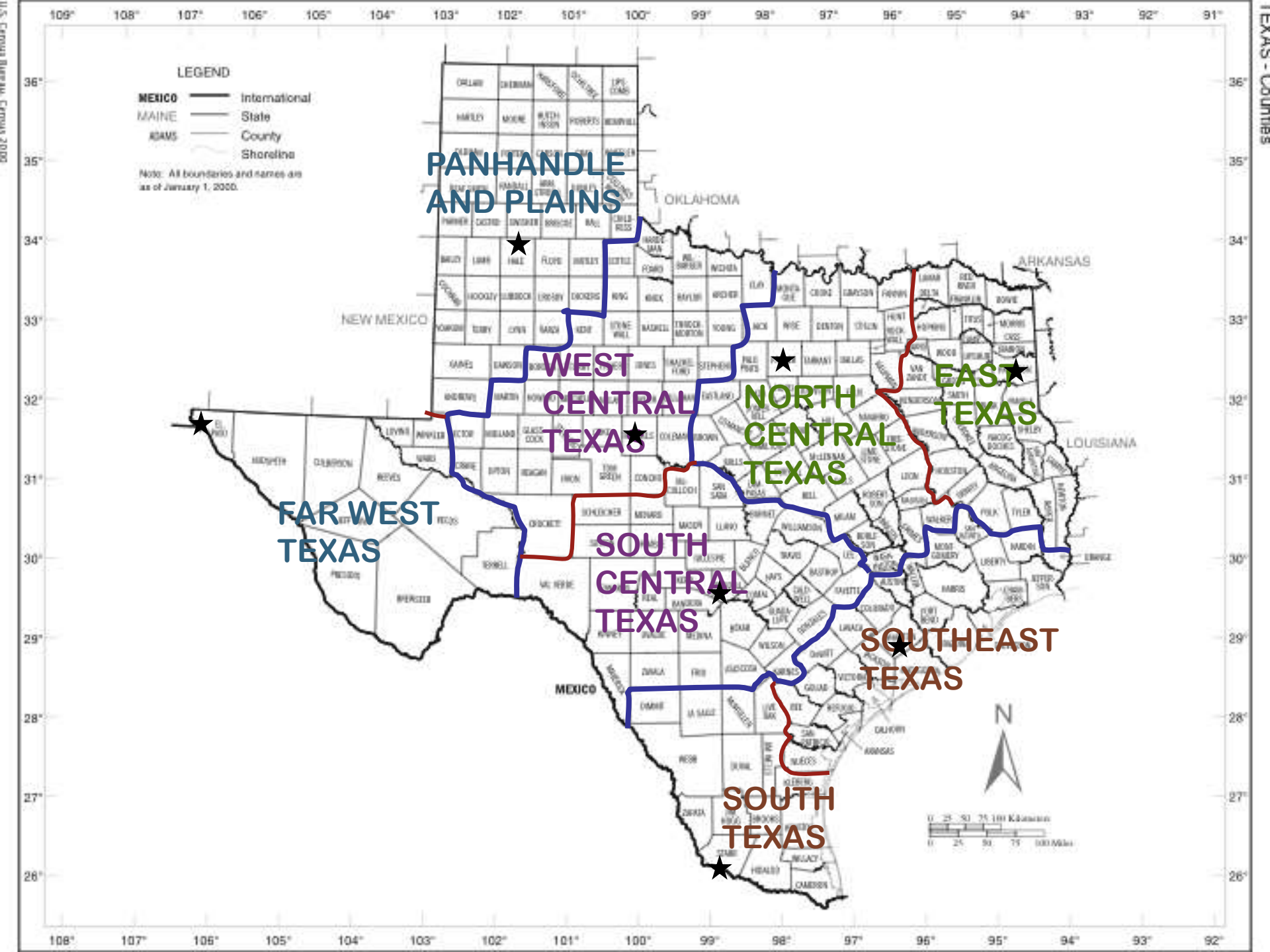
Atmosphere-Ocean model, observed climate forcings

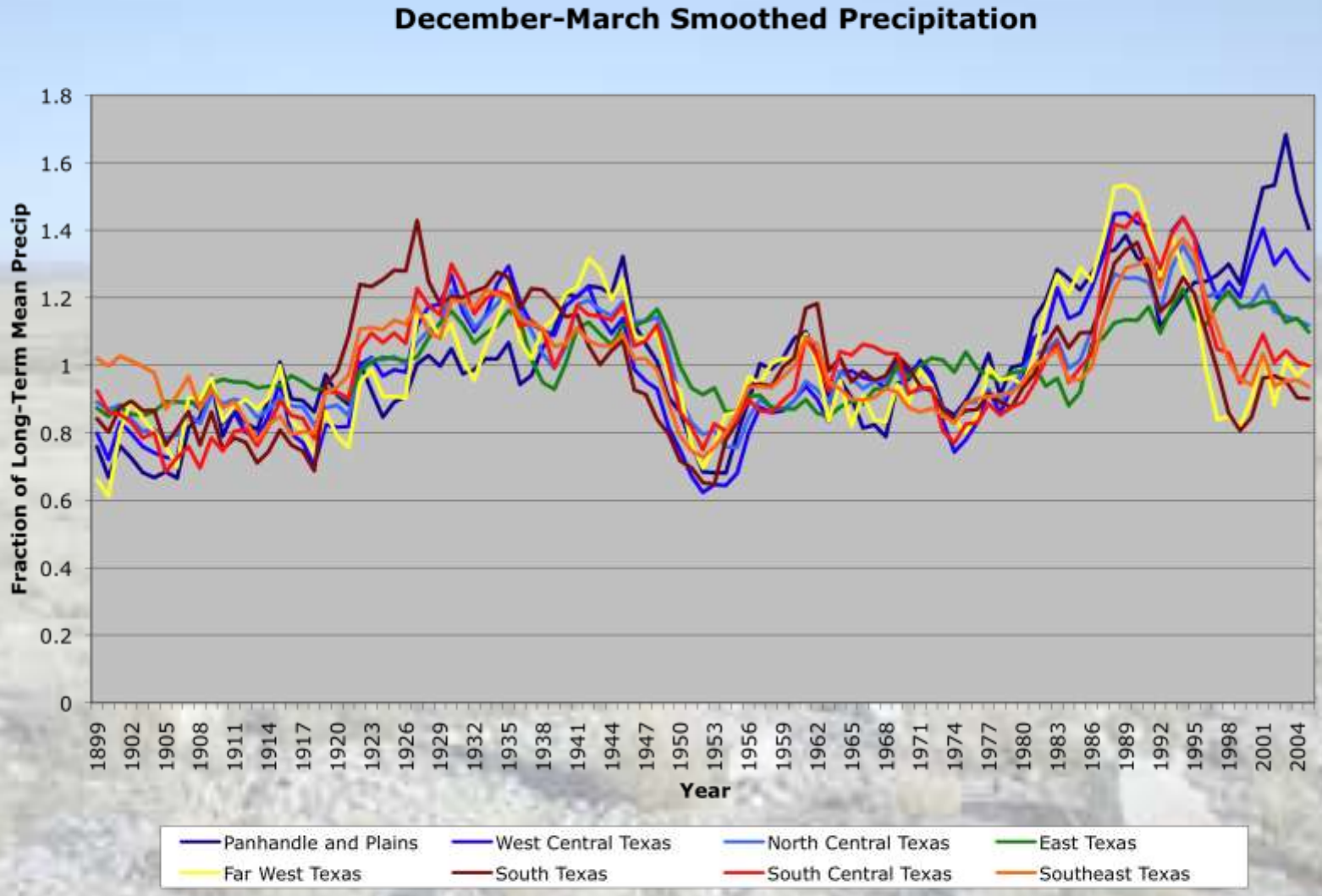
Simulations of 1950-2010

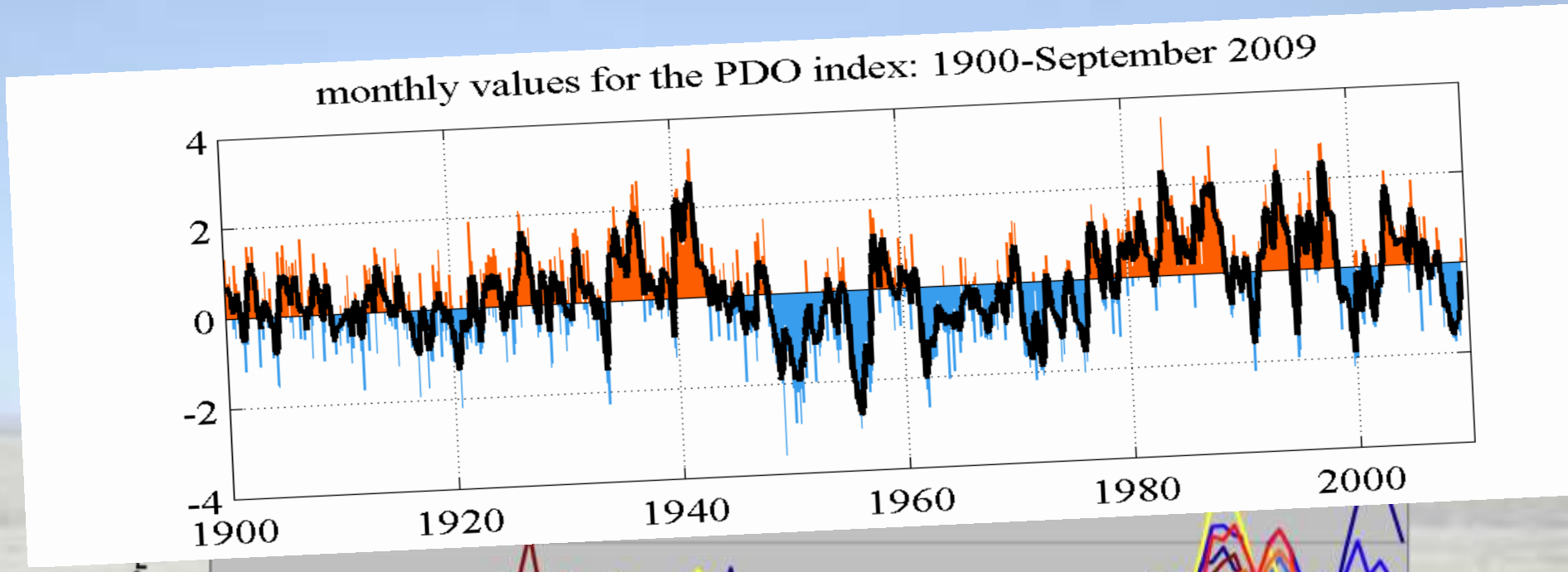


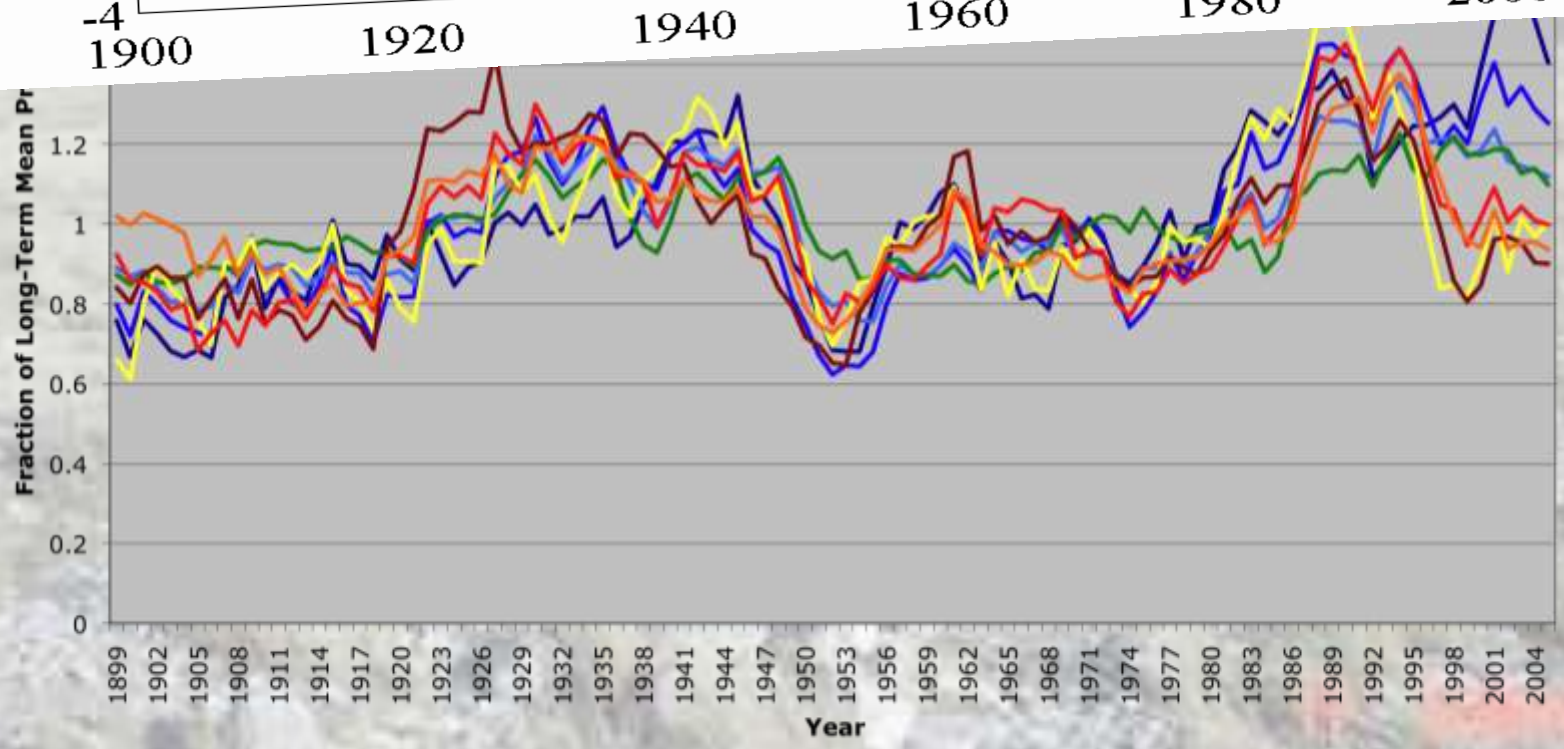
Results

- Not impossible through natural effects alone
- The lack of rain seems to have been natural
  - Long-term rainfall trend
  - SST patterns
- Much of heat due to sea surface temps
- Much of heat due to weather randomness
- Some of heat due to global warming


LEGEND
MEXICO International
MAINE State
ADAMS County
Shoreline
Note: All boundaries and names are as of January 1, 2000.
PANHANDLE AND PLAINS
WEST CENTRAL TEXAS
NORTH CENTRAL TEXAS
EAST TEXAS
FAR WEST TEXAS
SOUTH CENTRAL TEXAS
SOUTHEAST TEXAS
SOUTH TEXAS
OKLAHOMA
NEW MEXICO
ARKANSAS
LOUISIANA
MEXICO
N


December-March Smoothed Precipitation
Fraction of Long-Term Mean Precip
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1899
1902
1905
1908
1911
1914
1917
1920
1923
1926
1929
1932
1935
1938
1941
1944
1947
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
Year
Panhandle and Plains
West Central Texas
North Central Texas
East Texas
Far West Texas
South Texas
South Central Texas
Southeast Texas


monthly values for the PDO index: 1900-September 2009
4
2
0
-2
-4
1900
1920
1940
1960
1980
2000


Fraction of Long-Term Mean Pr
1.2
1
0.8
0.6
0.4
0.2
0
1899
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1926
1929
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1935
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1941
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1974
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Year
Panhandle and Plains
West Central Texas
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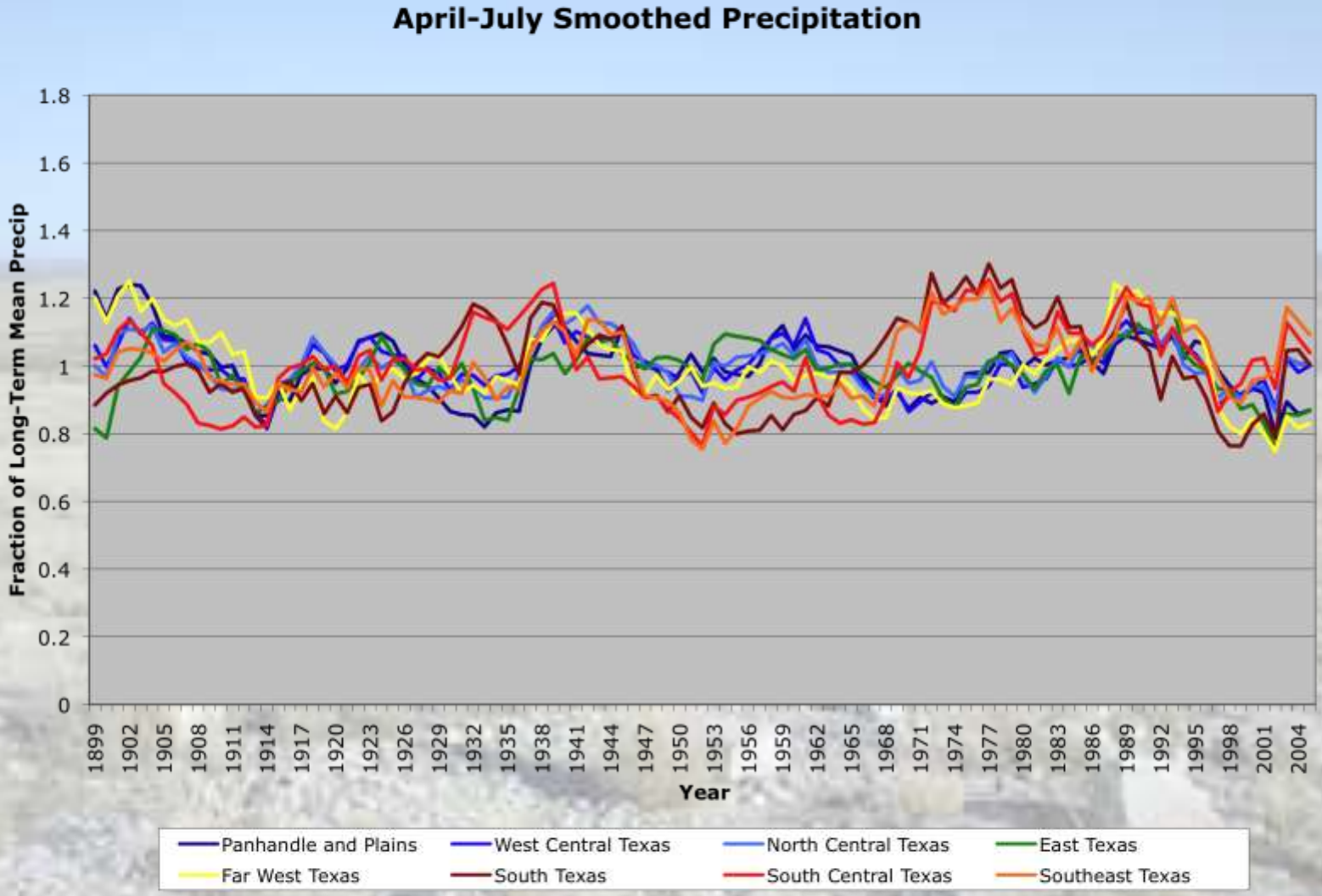
East Texas
Far West Texas
South Texas
South Central Texas
Southeast Texas


April-July Smoothed Precipitation
Fraction of Long-Term Mean Precip
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1899
1902
1905
1908
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1914
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1920
1923
1926
1929
1932
1935
1938
1941
1944
1947
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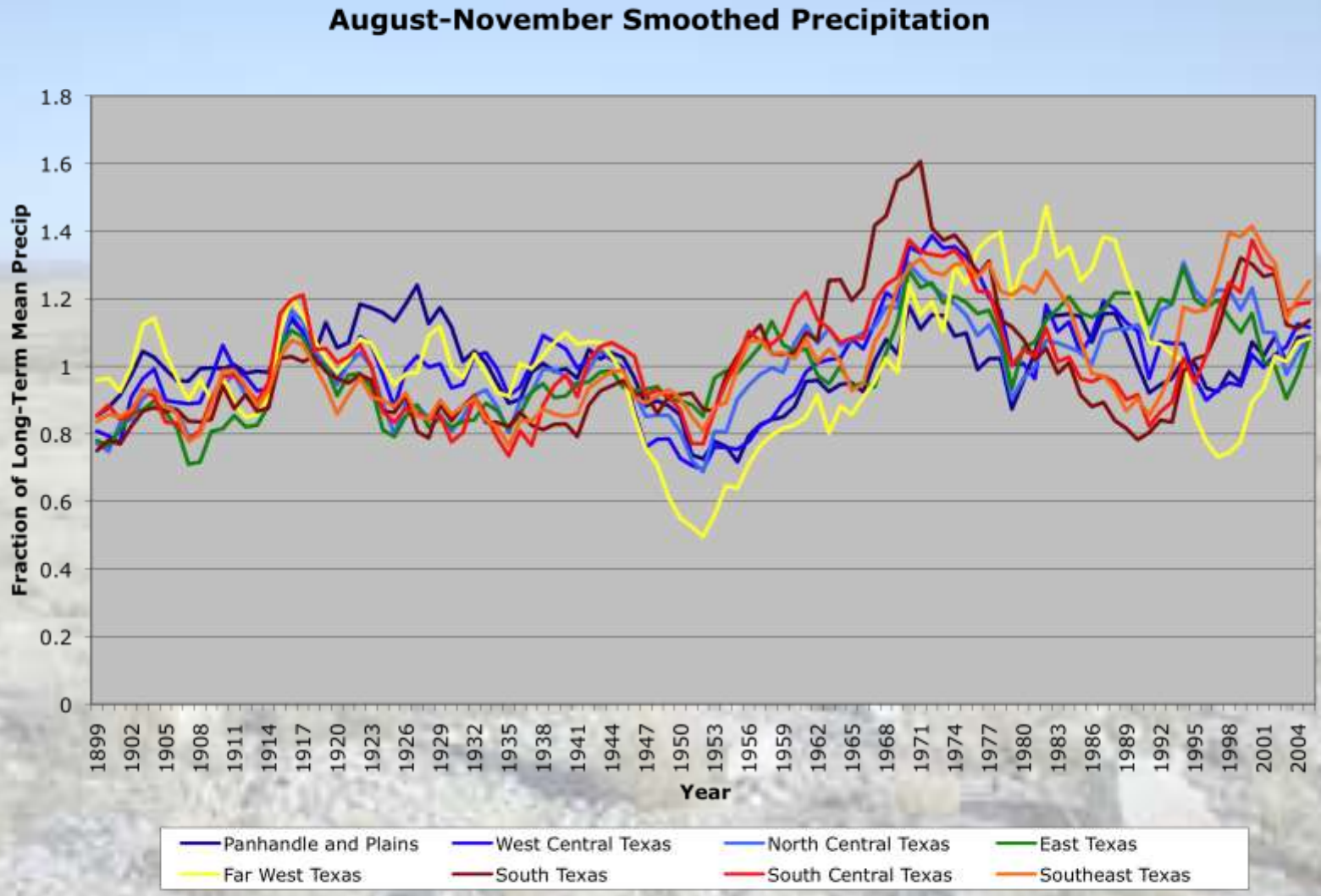
Panhandle and Plains
West Central Texas
North Central Texas
East Texas
Far West Texas
South Texas
South Central Texas
Southeast Texas


August-November Smoothed Precipitation
Fraction of Long-Term Mean Precip
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1899
1902
1905
1908
1911
1914
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1920
1923
1926
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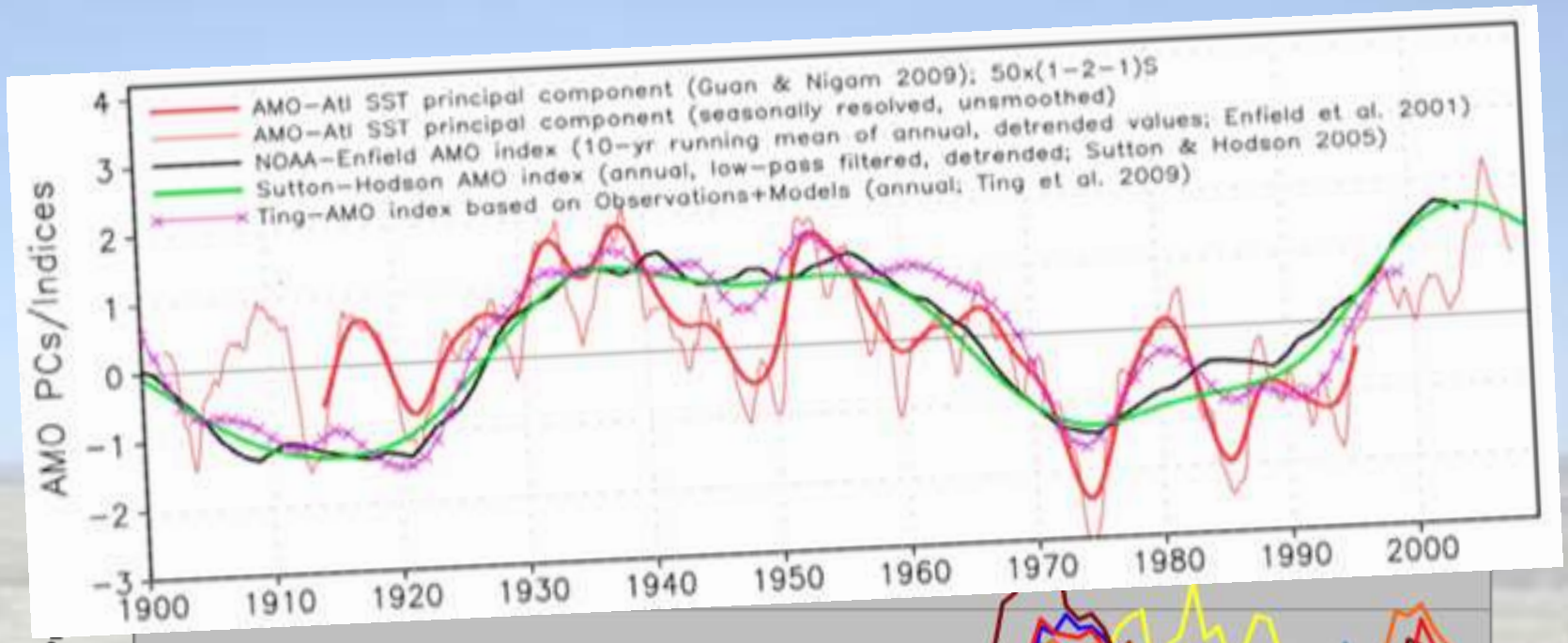
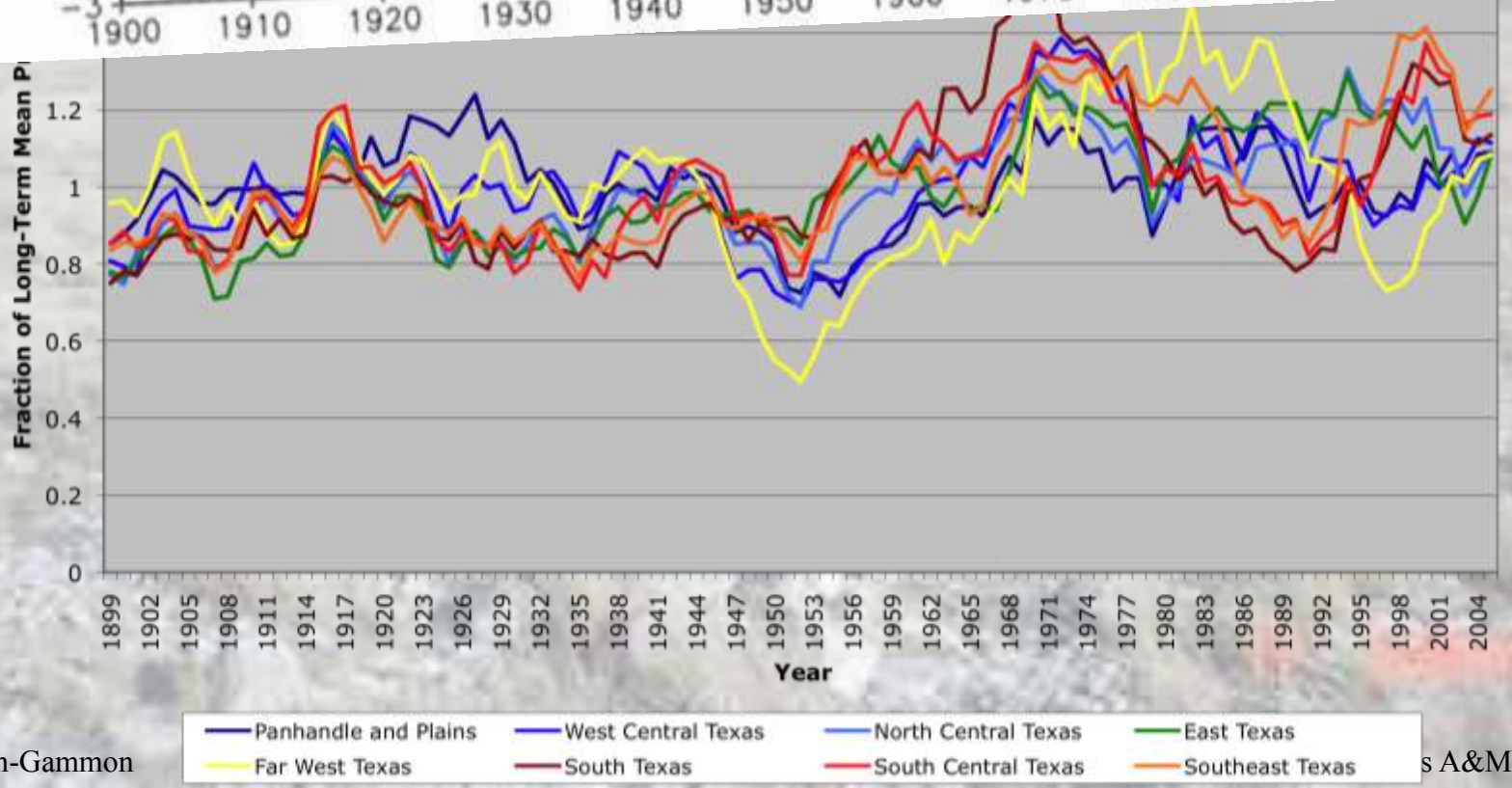
South Central Texas
Southeast Texas


AMO PCs/Indices
AMO–Atl SST principal component (Guan & Nigam 2009); 50x(1–2–1)S
AMO–Atl SST principal component (seasonally resolved, unsmoothed)
NOAA–Enfield AMO index (10–yr running mean of annual, detrended values; Enfield et al. 2001)
Sutton–Hodson AMO index (annual, low–pass filtered, detrended; Sutton & Hodson 2005)
Ting–AMO index based on Observations+Models (annual; Ting et al. 2009)
4
3
2
1
0
−1
−2
−3
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000


Fraction of Long-Term Mean P
1.2
1
0.8
0.6
0.4
0.2
0
1899
1902
1905
1908
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1926
1929
1932
1935
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1944
1947
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North Central Texas
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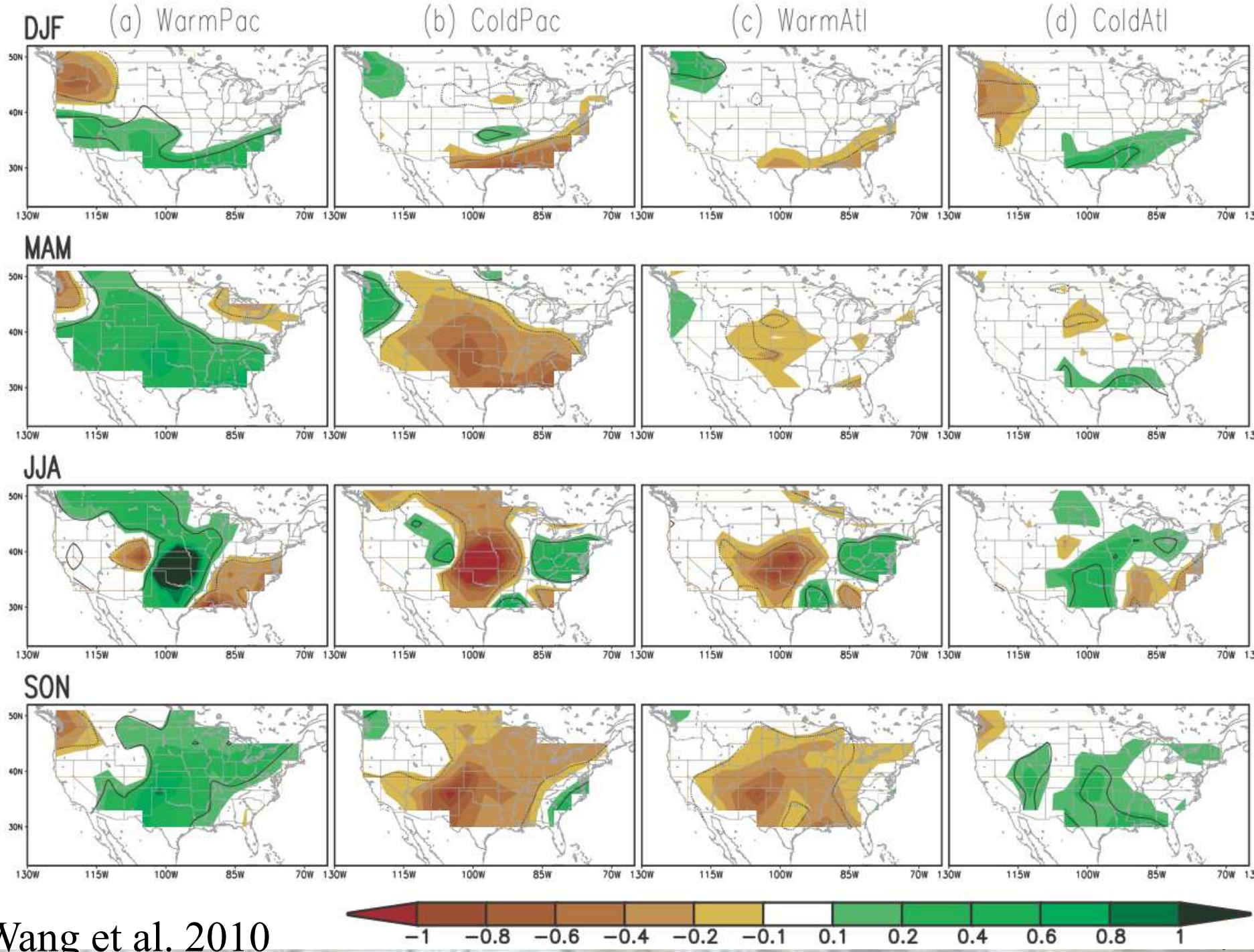
South Texas
South Central Texas
Southeast Texas

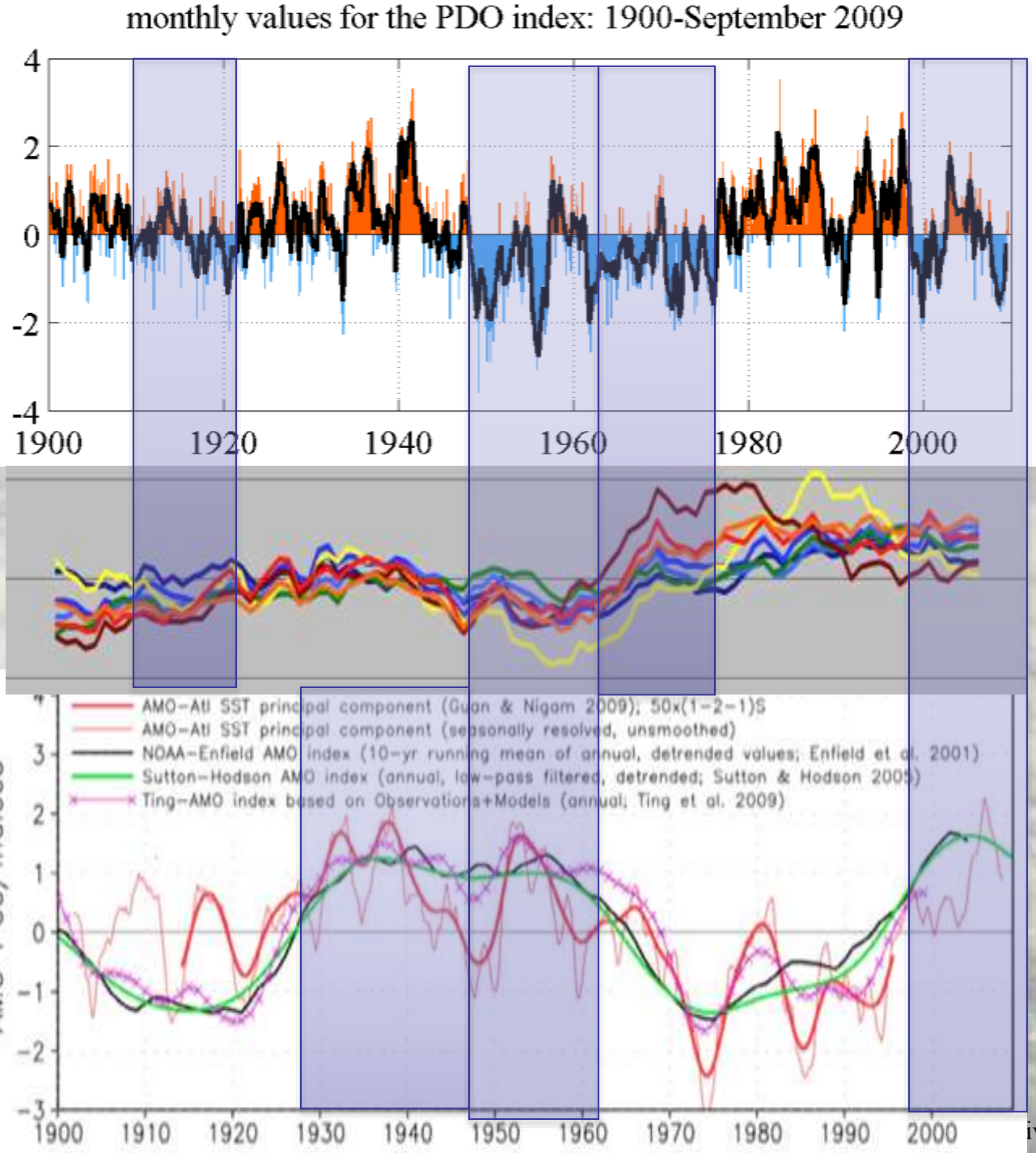


Wang et al. 2010

Pacific

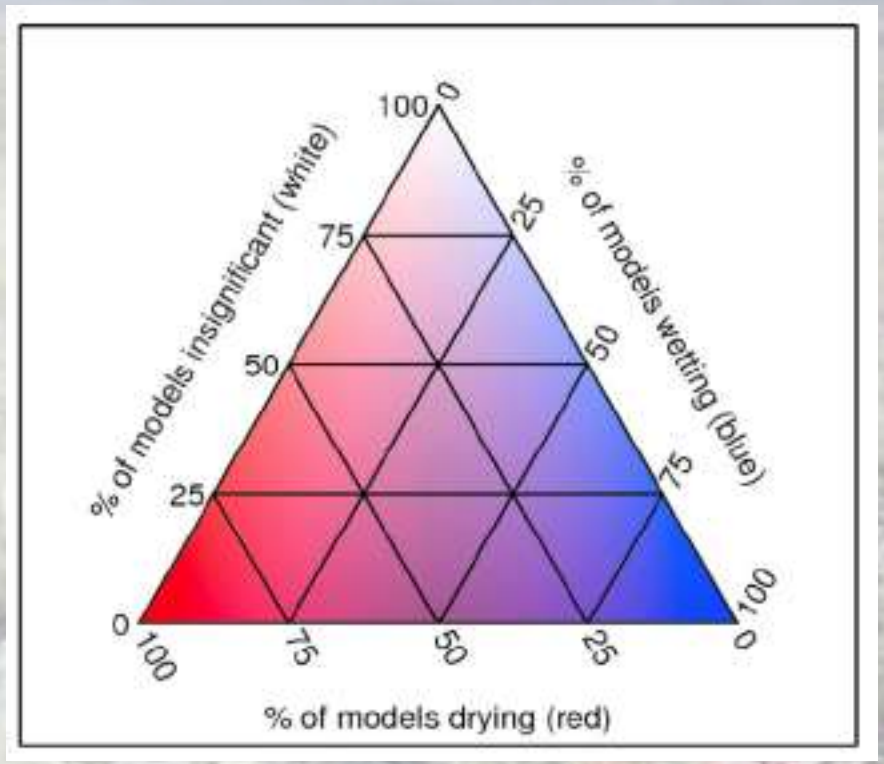
Texas

Atlantic



What can we say about future drought intensity?

Latest model projections (Scheff and Frierson 2012)



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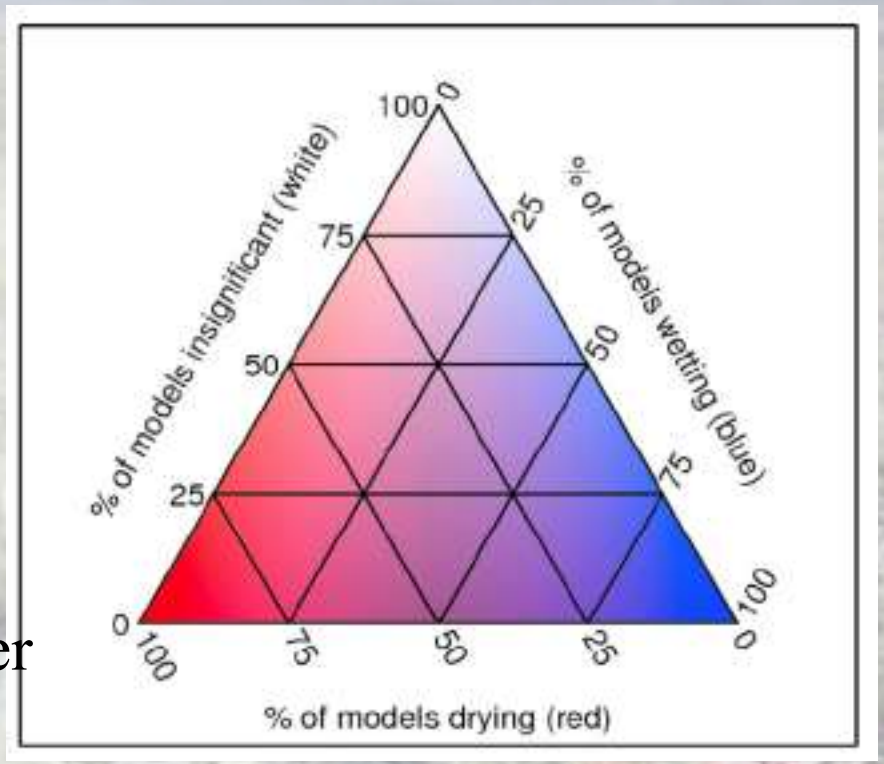

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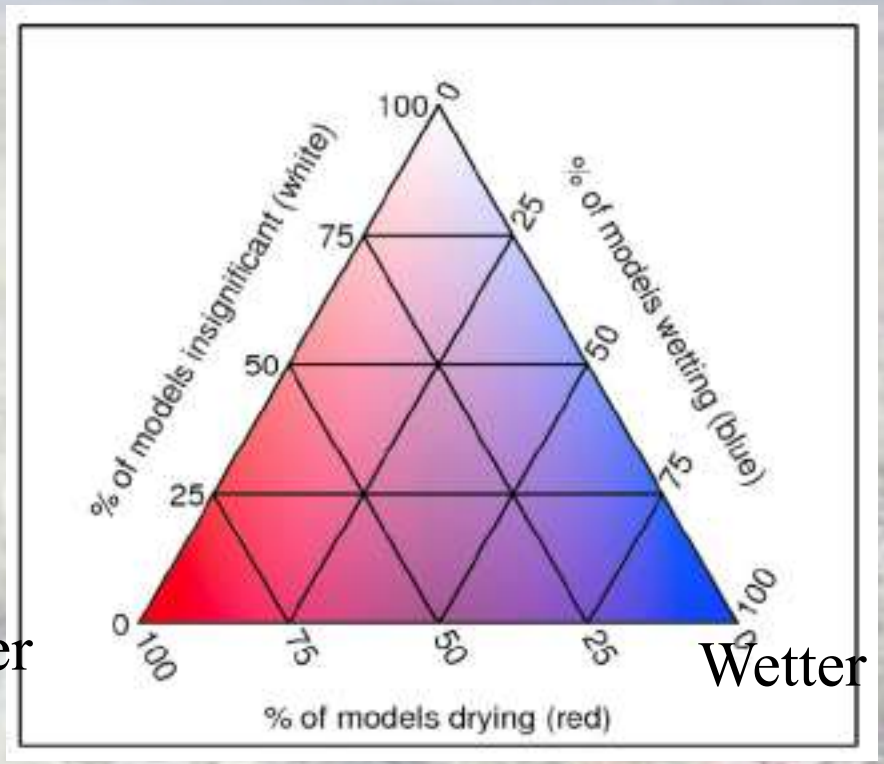

Drier

Wetter

What can we say about future drought intensity?

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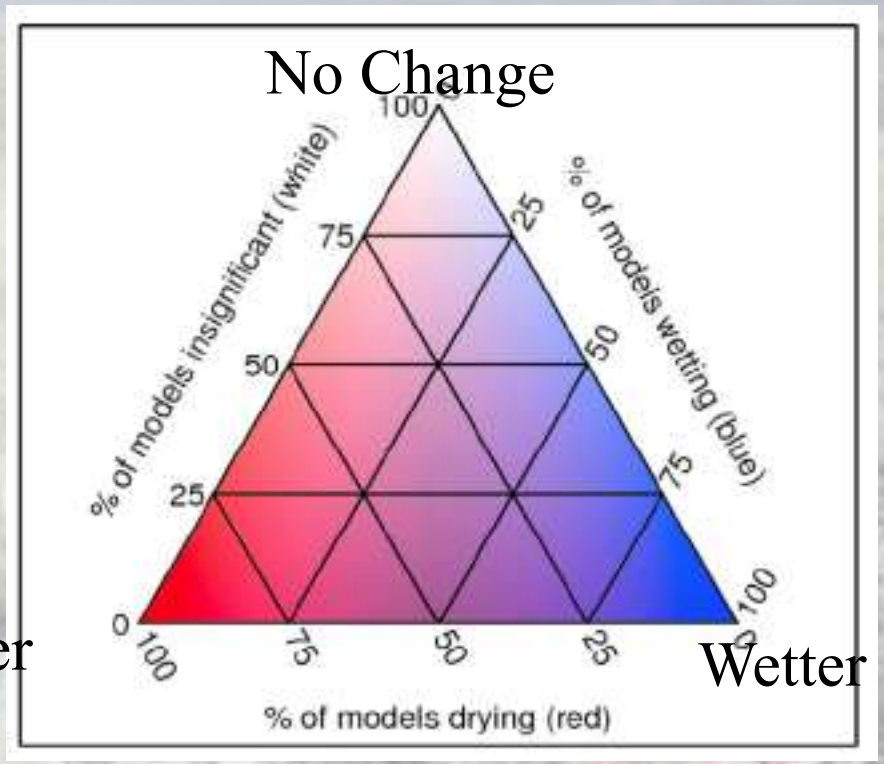

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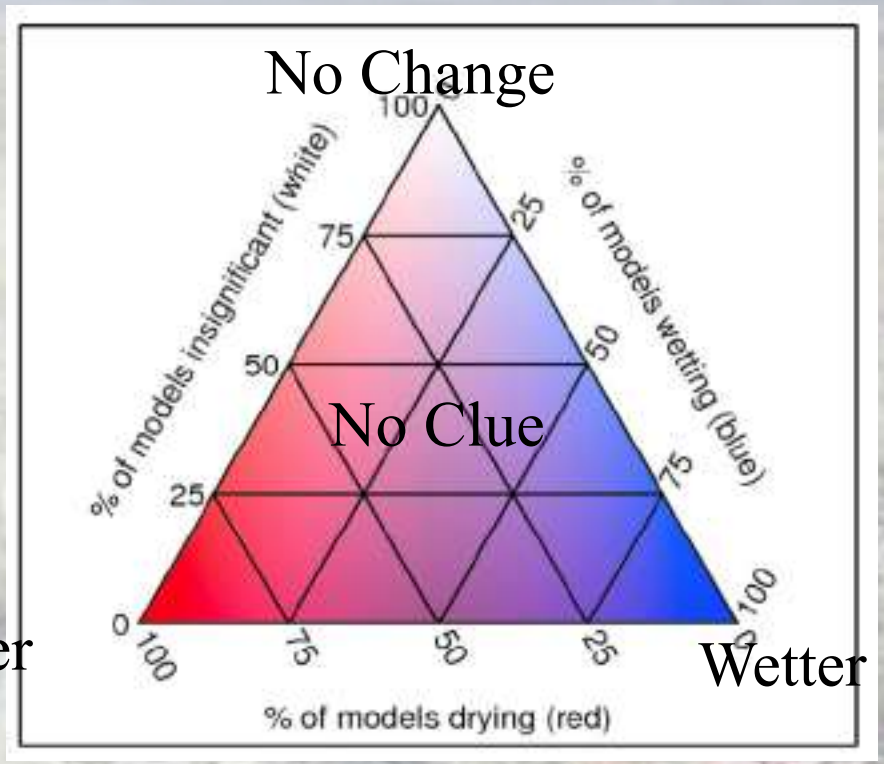

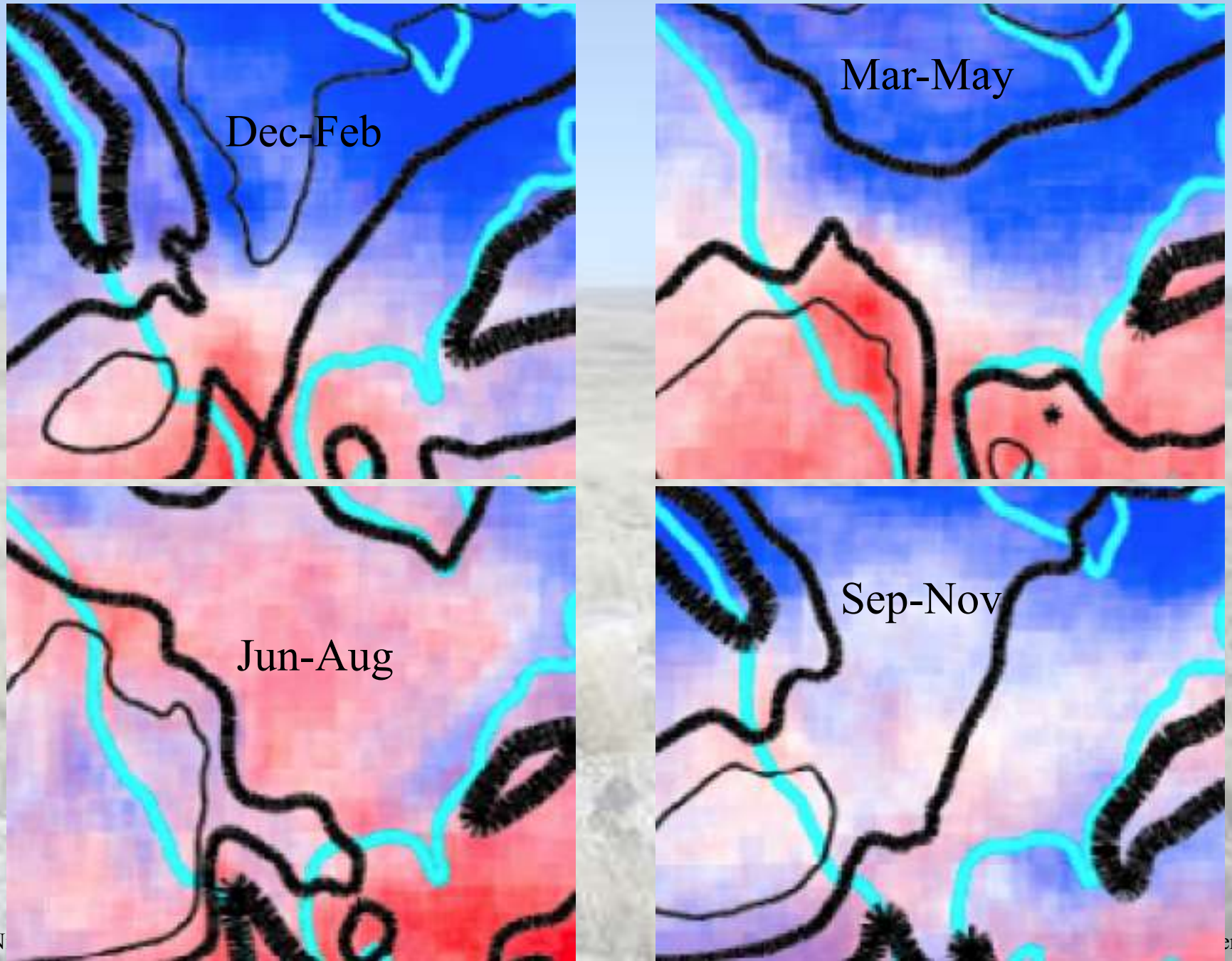
Dec-Feb
Mar-May
Jun-Aug
Sep-Nov

Bottom Line for Texas Droughts

- Underlying physical processes
  - Expected drought frequency temporarily high due to natural variability
  - Expected drought frequency not changing much due to global warming
  - Expected characteristics of droughts changing
    - Future droughts will be warmer

Contact Info

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- http://climatexas.tamu.edu
- 979-862-2248