DRI Desert Research Institute

What is Climate Change ?

How is it Manifested in the Western U.S. ?

Kelly T. Redmond

Western Regional Climate Center

Desert Research Institute

Reno Nevada

Climate Change Science for Effective Resource Management and Public Policy in the Western United States

EPSCoR Western Tri-State Consortium

UNLV Las Vegas 2013 March 27-28

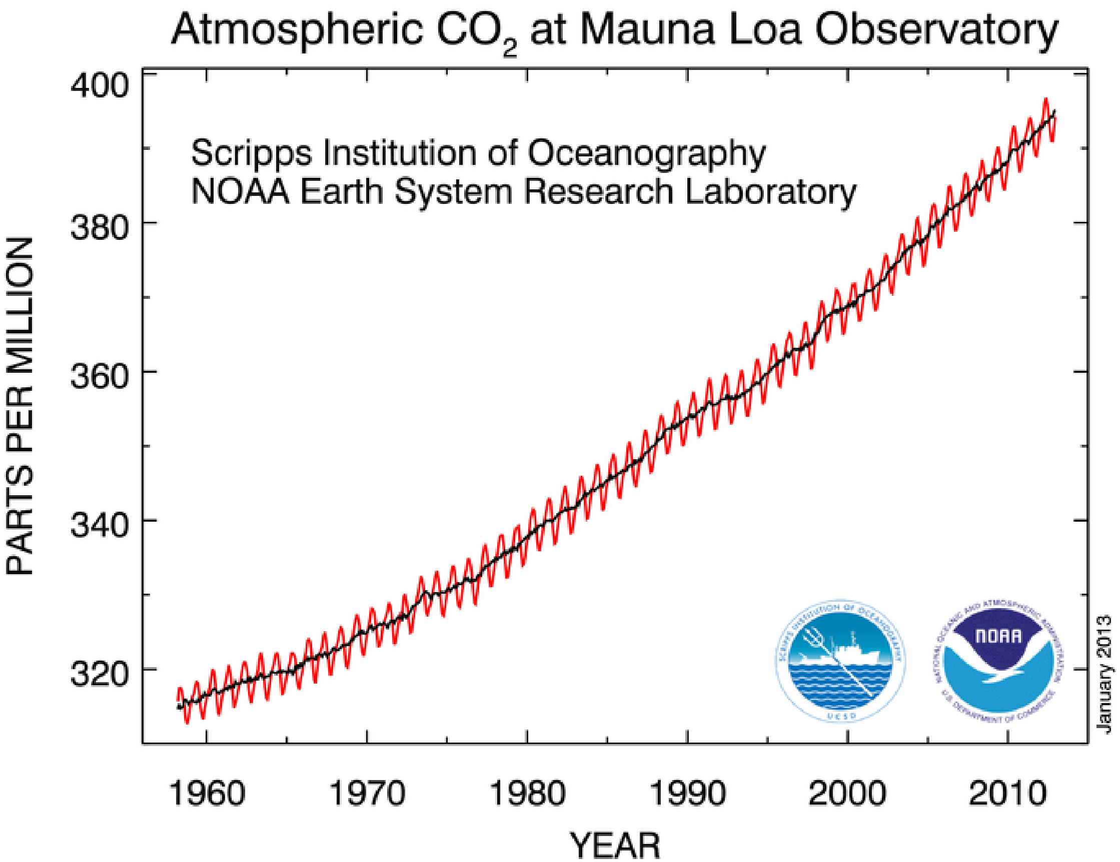
Western Regional Climate Center

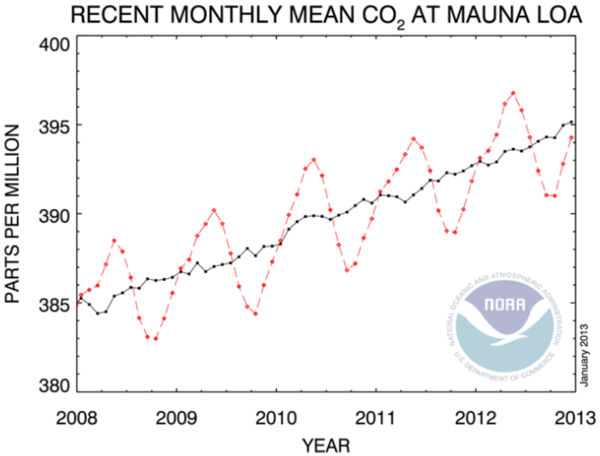
Southwest Climate Science Center

California Nevada Applications Program CNAP

NOAA

What's all the fuss about ???





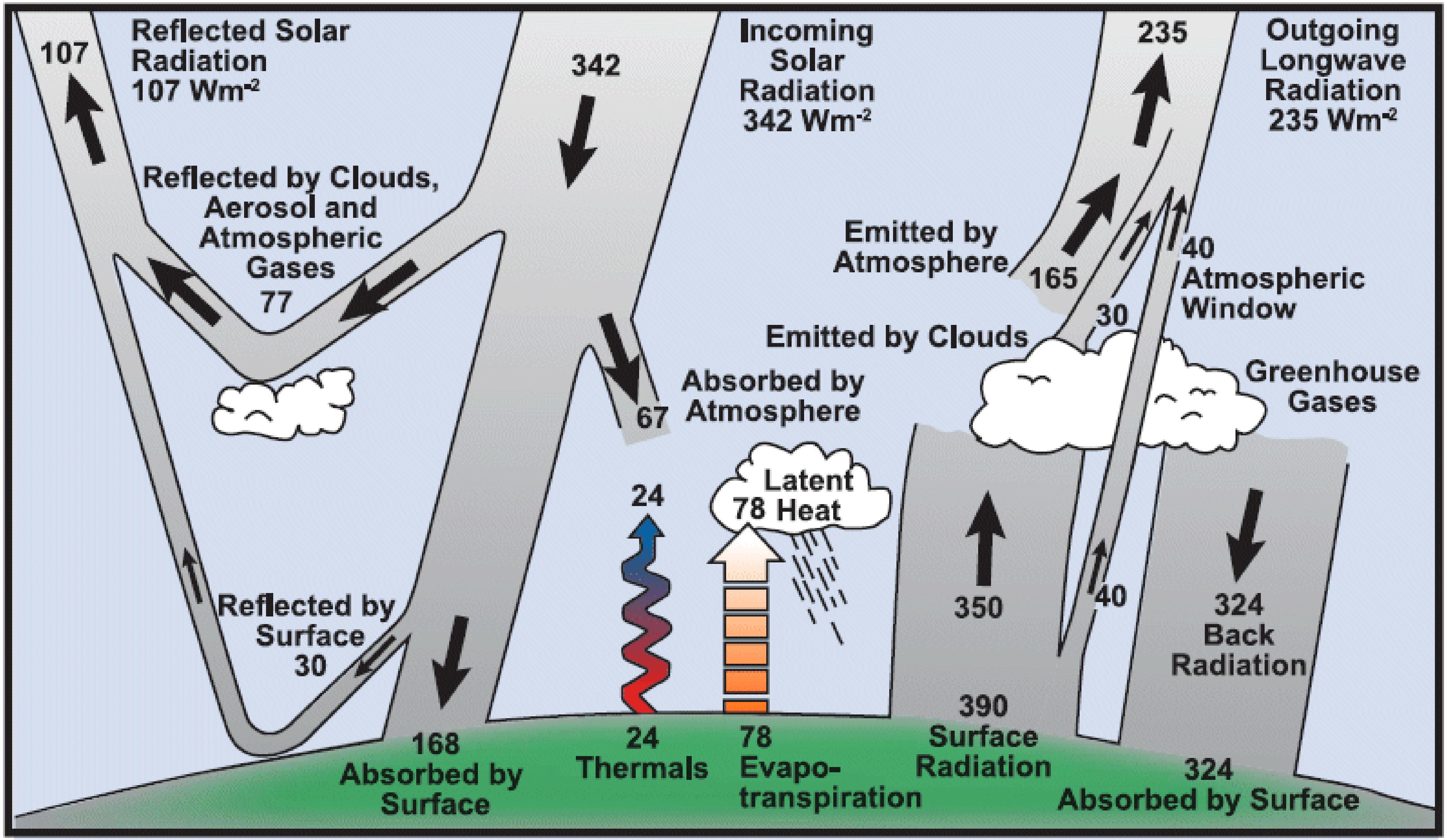
316 ppmv
1959

+25 %

395
January 2013

The Planetary Radiation Budget

Net incoming 342 – 107 = 235 W/m² | **Net outgoing = 235 W / m²**



IPCC AR4, Kiehl and Trenberth (1997)

How much energy ?

60 watt light bulb

Mostly heat (infrared radiation)

2 x CO_2 forcing increase is about 4 W / m^2 +/- 10 %

4 W / m^2 is about one bulb per 4x4 m

Earth surface covers about 510 trillion square meters

Place 30 trillion 60-watt bulbs uniformly over the earth

As of 2013, about 19 trillion in place

Warming influences

Greenhouse gases
- **CO2 - carbon dioxide ****
  (about 2/3 of total effect)
- **CH4 - methane**
- **N20 - nitrous oxide**
- **03 - ozone**
- **CFC - chloroflourocarbons**

Some kinds of soot

Some land use changes (minor)

Solar activity (minor)

Cooling influences

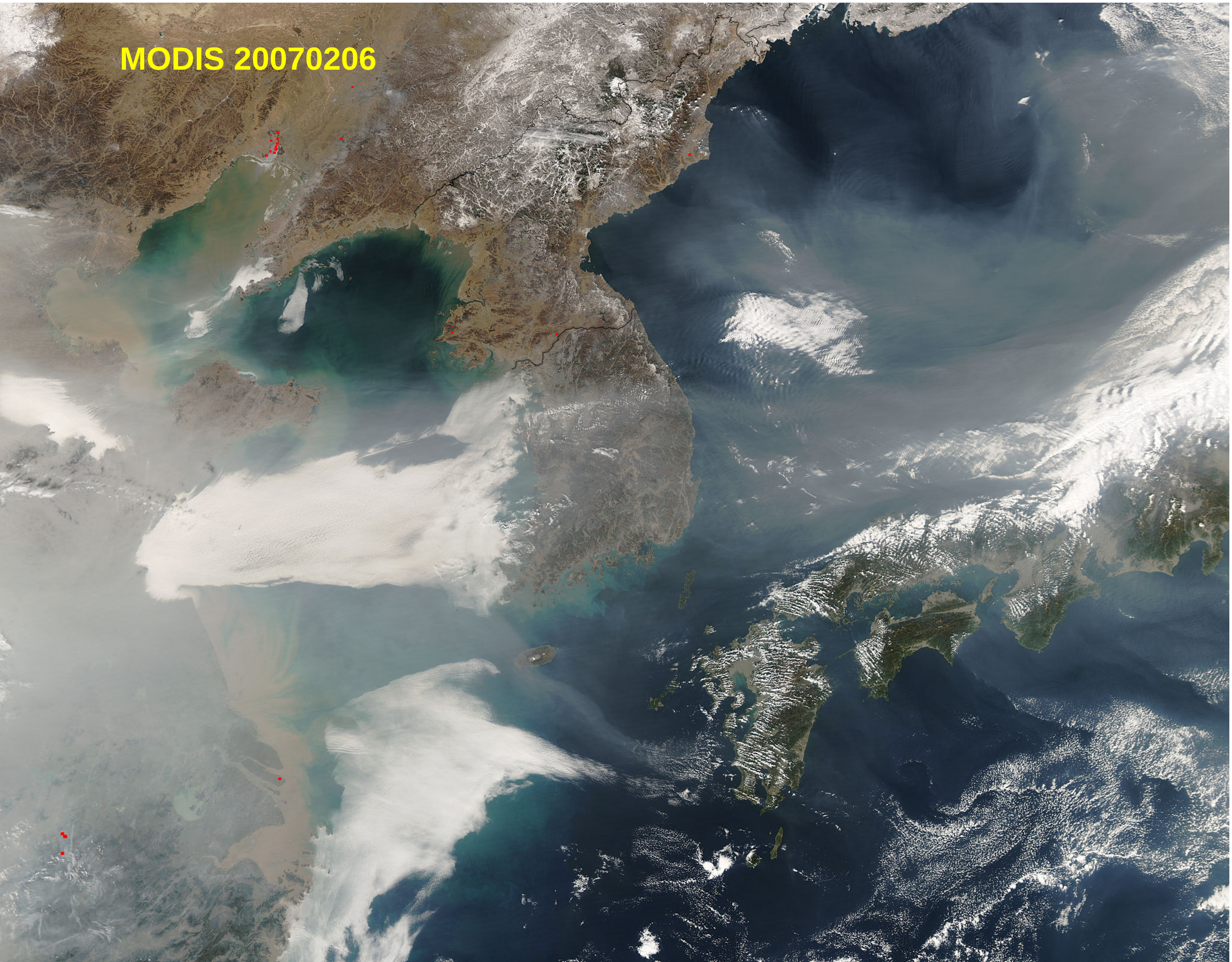
Pollution and most aerosols
- **Direct reflection**
- **Make clouds brighter**

Occasional volcanoes

Some land use changes (minor)

**** Side Note. Ocean Acidification.**

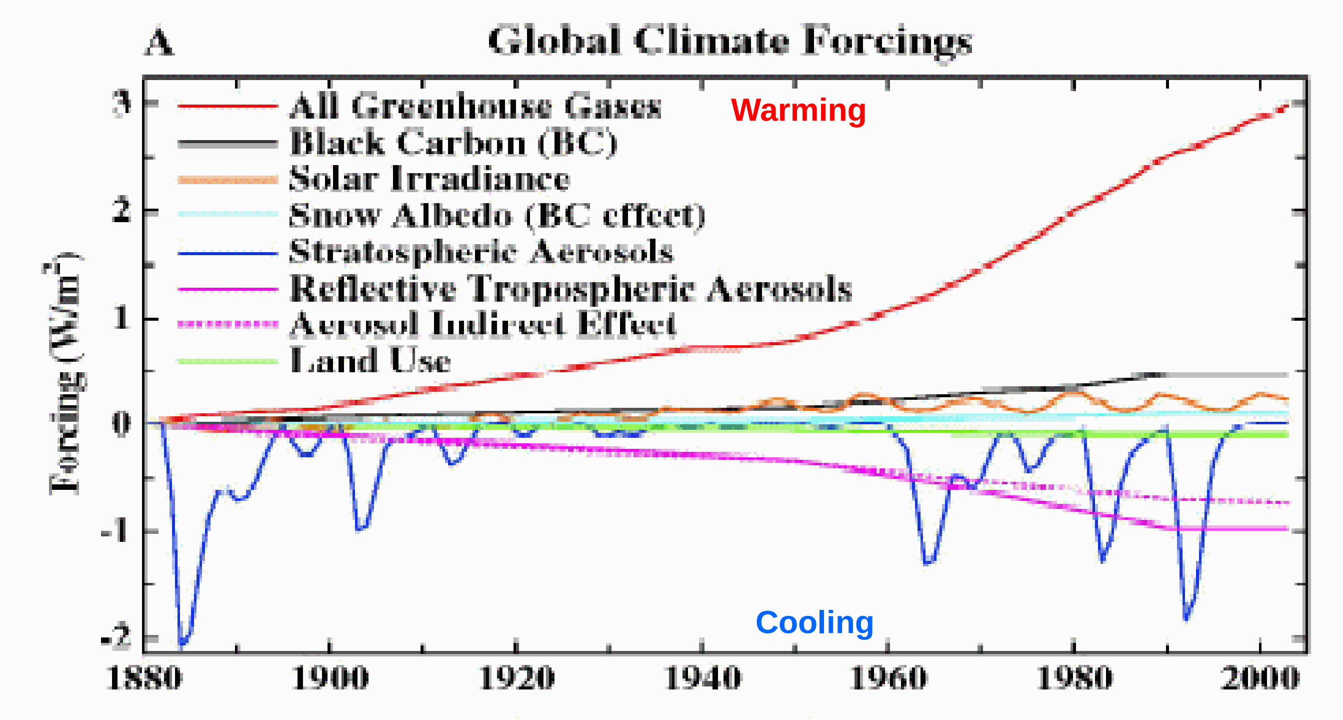
Not a <u>climate</u> issue (not too much).
But it is (very much) a <u>carbon</u> issue.
A major issue, by itself.


MODIS 20070206

090327:1925 GMT Redoubt Eruption
From Homer AK. Jonathan Dehn.

History of Atmospheric Forcings

Hansen et al, 2005. Earth's energy imbalance: Confirmation and implications. *Science,* 308, 1431.



1880 1900 1920 1940 1960 1980 2000

Radiative Factors that Control Global Climate

Gazing into the future .....

Western Great Basin

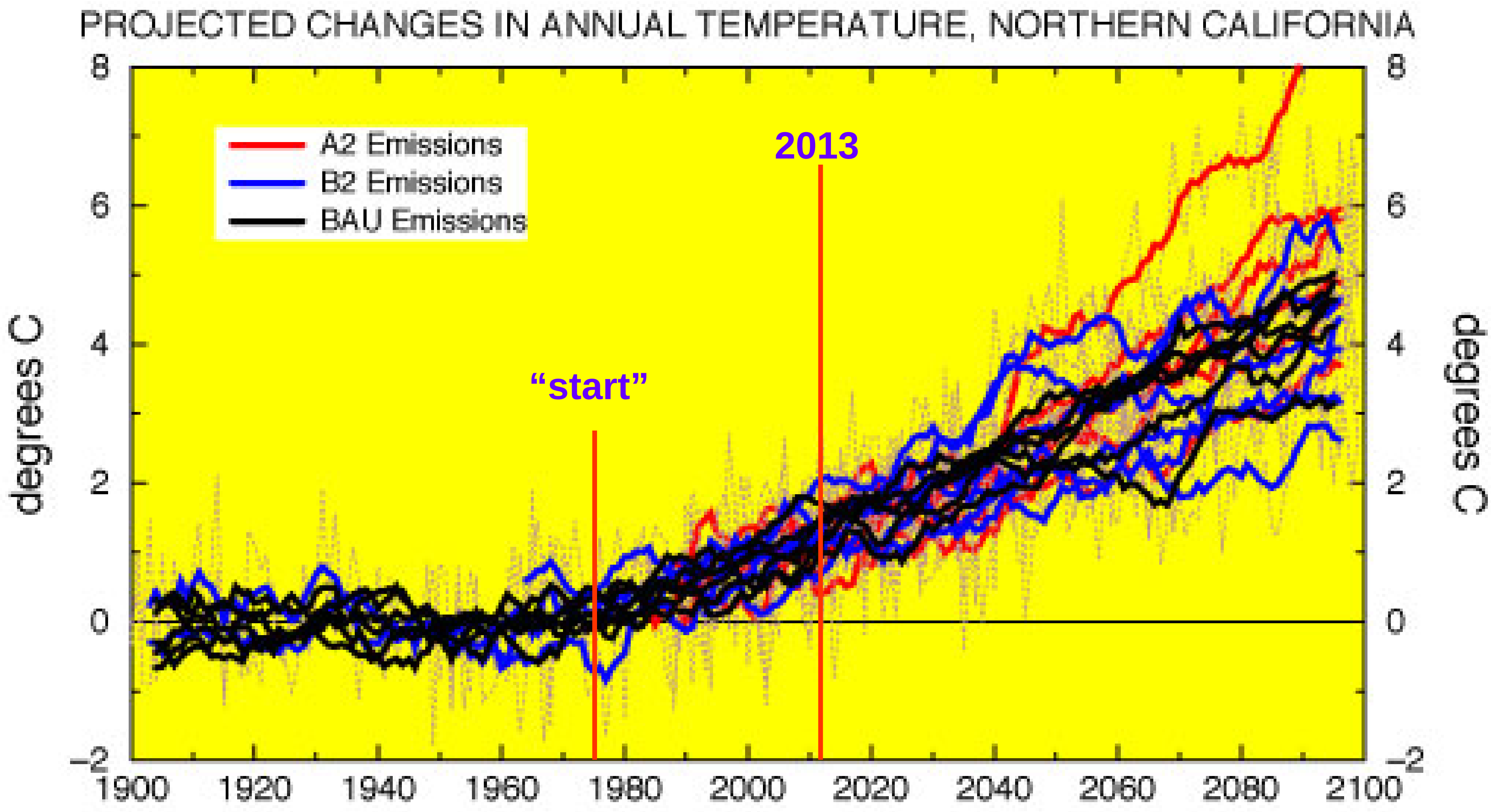
1900-2100

Temp and Precip

Projections

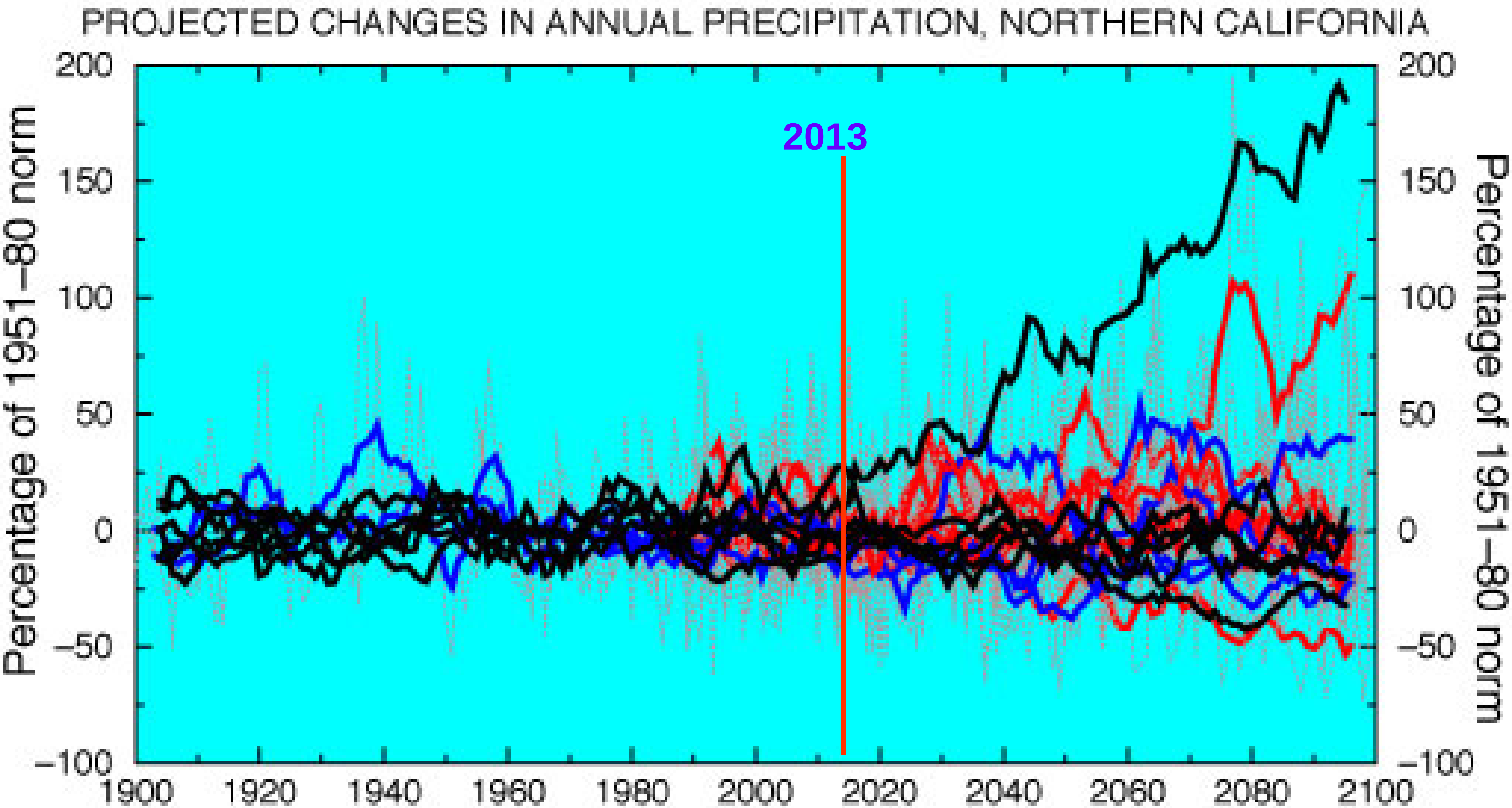
One style of presentation

Courtesy of Mike Dettinger, USGS / Scripps.



Dettinger MD. 2005. From climate change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science. Vol. 3, Issue 1, (March 2005), Article 4. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4

Courtesy of Mike Dettinger, USGS / Scripps.



Dettinger MD. 2005. From climate change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science. Vol. 3, Issue 1, (March 2005), Article 4. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4

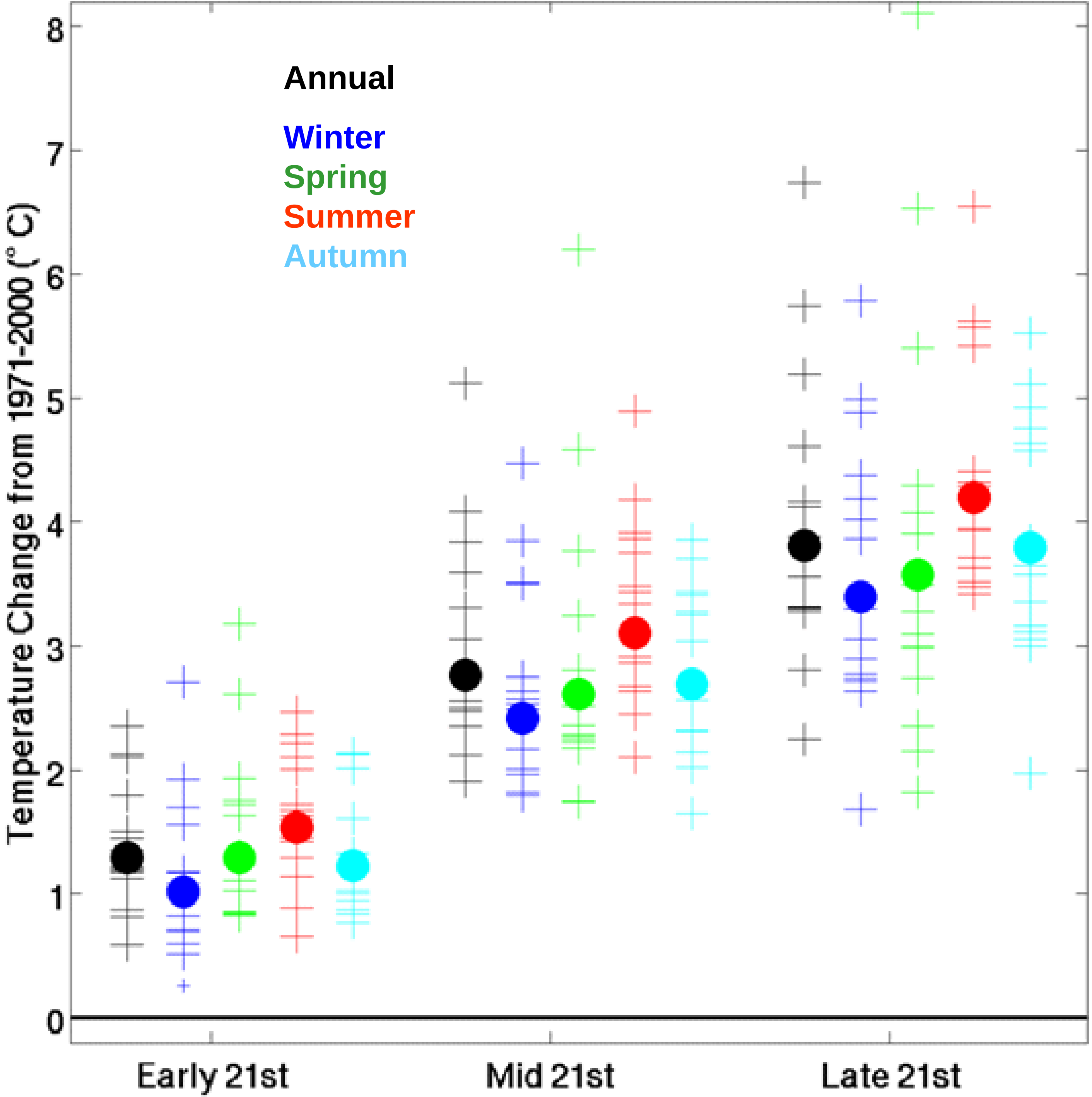
Central Great Basin

2000 - 2100

Temp and Precip

Projections

Another style of presentation



East Central Nevada

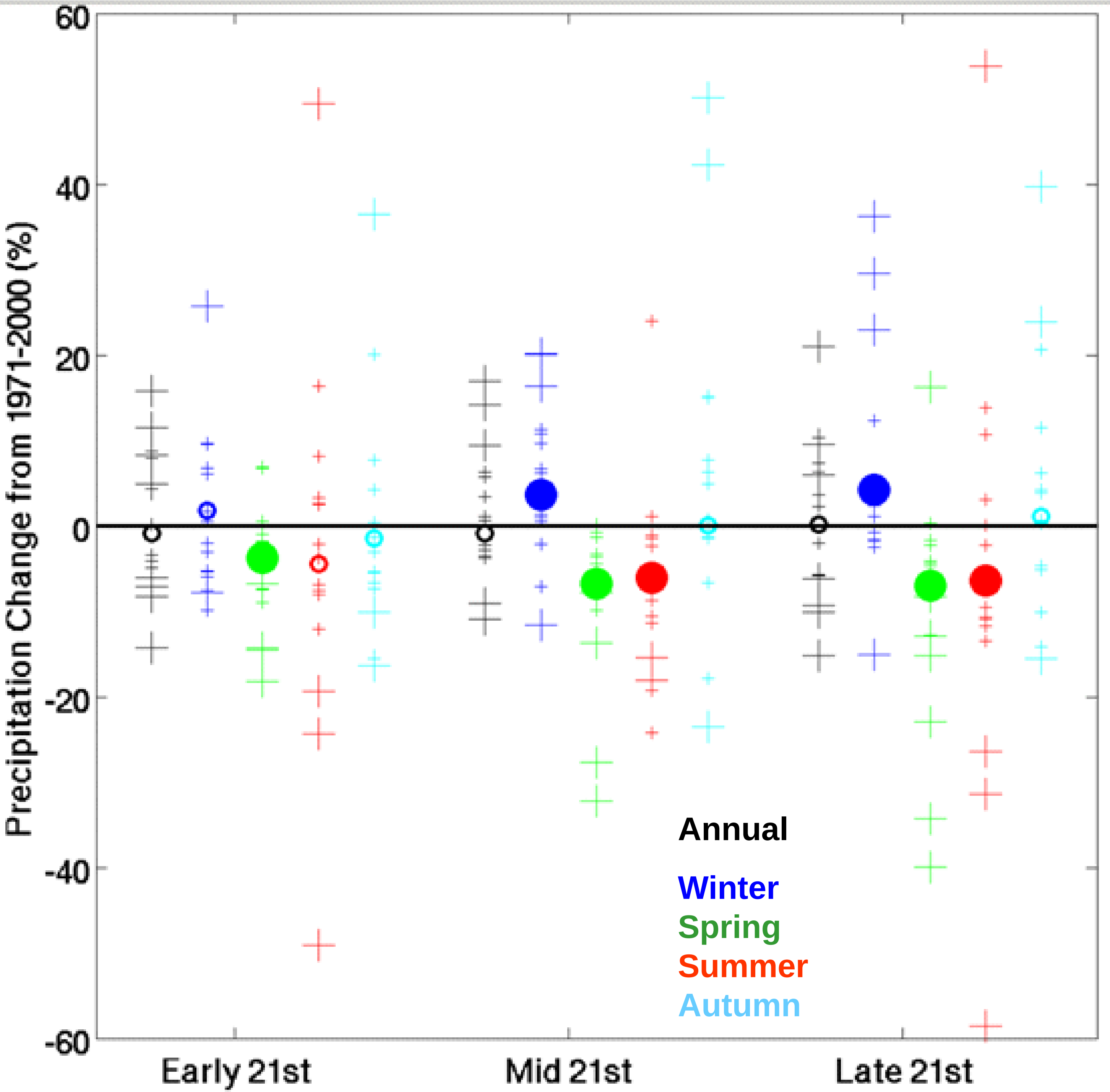
Projected Temperature Changes (C)

Early 21st 2011-2040

Middle 21st 2041-2070

Late 21st 2071-2100

Figure: John Abatzoglou



East Central Nevada

Projected Precipitation Changes (%)

Early 21st 2011-2040

Middle 21st 2041-2070

Late 21st 2071-2100

Figure: John Abatzoglou

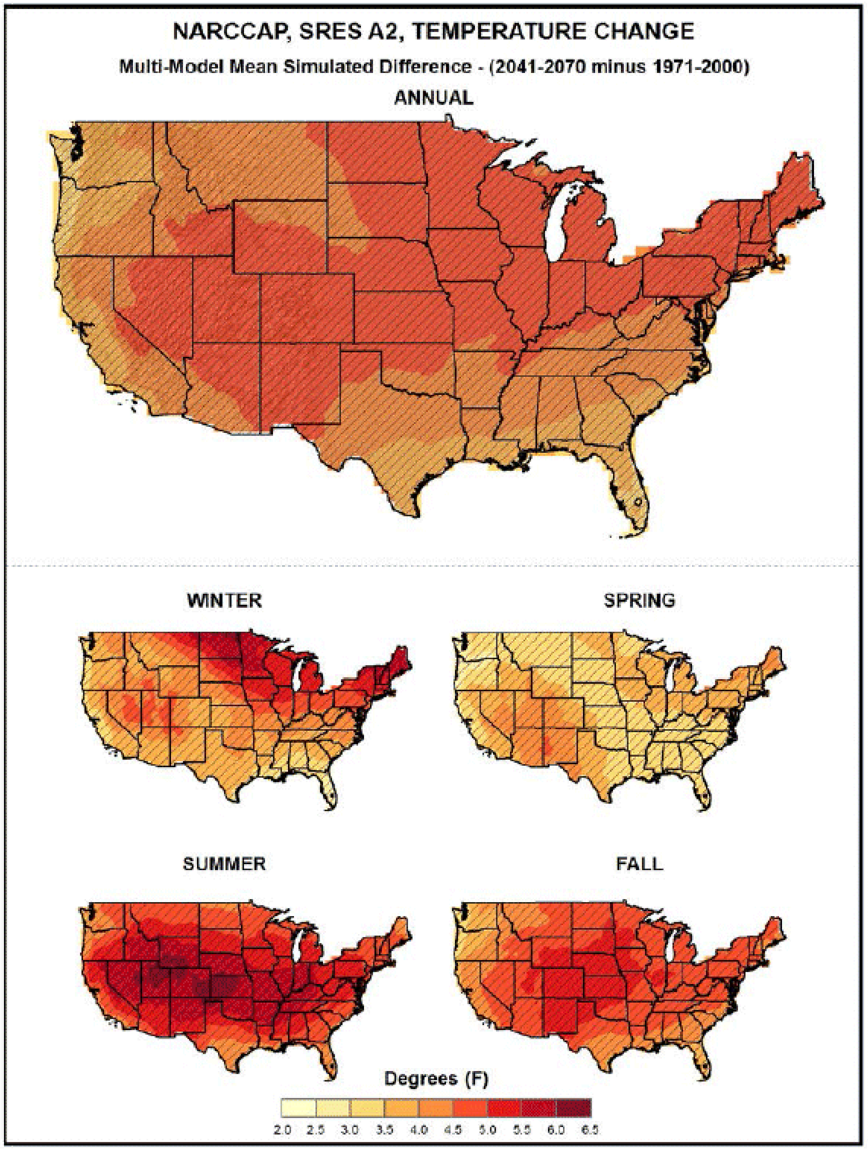


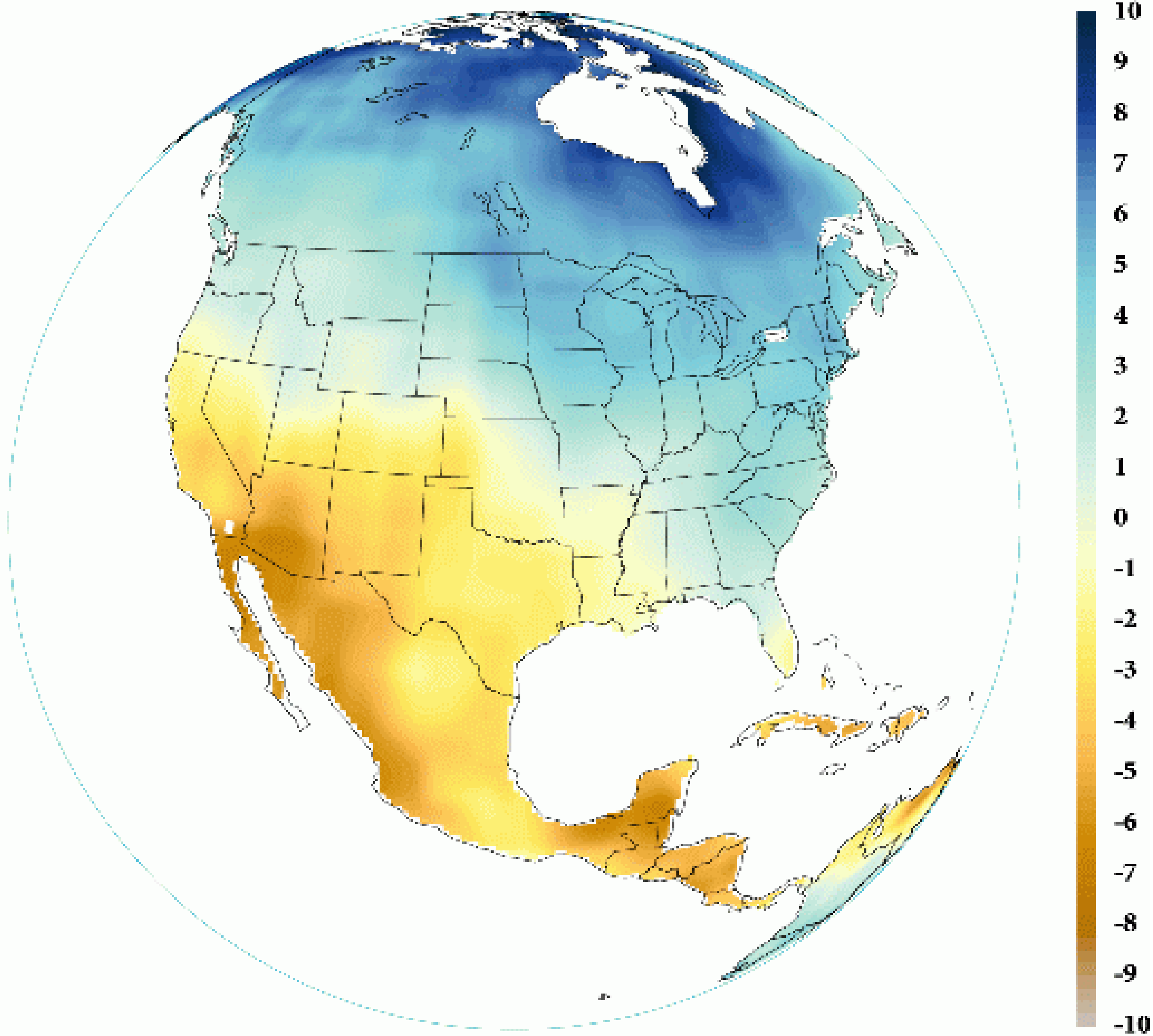
Figure 21. Simulated difference in annual and seasonal mean temperature (°F) for the contiguous United States, for 2041-2070 with respect to the reference period of 1971-2000. These are multi-model means from 11 NARCCAP regional climate simulations for the high (A2) emissions scenario. Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change (see text). Note that the color scale is different from that of Fig. 20. Annual temperature changes for the NARCCAP simulations are similar to those for the CMIP3 global models (Fig. 20, middle left panel). Seasonal changes are greatest for summer and smallest for spring.

Temperature Change

2041-2070 (~ 2055)
minus
1971-2000

Regional Climate Trends and Scenarios for the U.S. National Climate Assessment.
NOAA Technical Report NESDIS 142.
Draft
January 2013.
Part 9. Climate of the Contiguous United States

Projected Change in Precipitation 1950-2000 to 2021-2040
(Percent of 1950-2000)



Average of 19 climate models. 2007.

17 years from 2013

Figure by Gabriel Vecchi.

www.ldeo.columbia.edu/res/div/ocp/drought/science.shtml

R. Seager, M.F. Ting, I.M. Held, Y. Kushnir, J. Lu, G. Vecchi, H.-P. Huang, N. Harnik, A. Leetmaa, N.-C. Lau, C. Li, J. Velez, N. Naik, 2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. *Science*, DOI: 10.1126/science.1139601

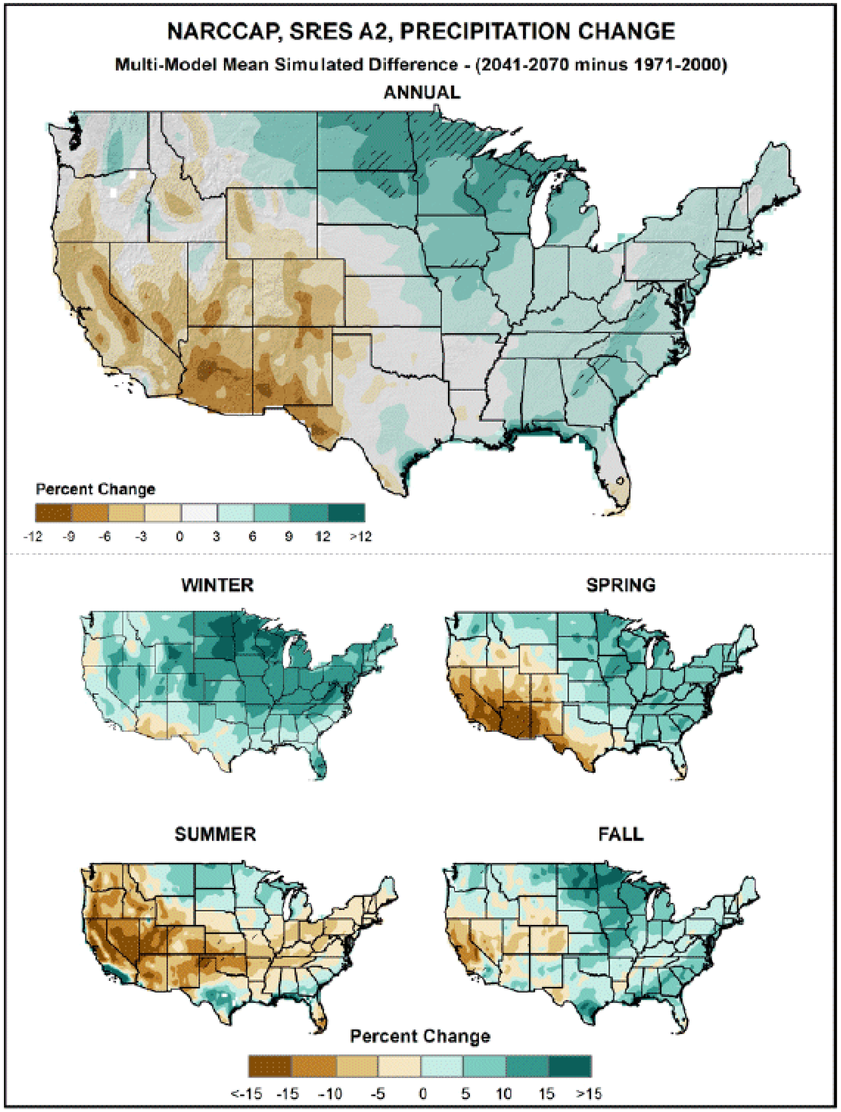


Figure 32. Simulated difference in annual and seasonal mean precipitation (%) for the contiguous United States, for 2041-2070 with respect to the reference period of 1971-2000. These are multi-model means from 11 NARCCAP regional climate simulations for the high (A2) emissions scenario. Color only (category 1) indicates that less than 50% of the models show a statistically significant change in precipitation. Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change in the number of days, and more than 67% agree on the sign of the change Whited out areas (category 2) indicate that more than 50% of the models show a statistically significant change in precipitation, but less than 67% agree of the sign of the change (see text). Note that top and bottom color scales are unique, and different from that of Fig. 31. The annual change is upward in the northern and eastern U.S. and downward in the southwest. Changes are mostly upward in winter, spring, and fall, and downward in summer.

Precipitation change

2041-2070 (~2055) percent change from 1971-2000

Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. NOAA Technical Report NESDIS 142. Draft January 2013. Part 9. Climate of the Contiguous United States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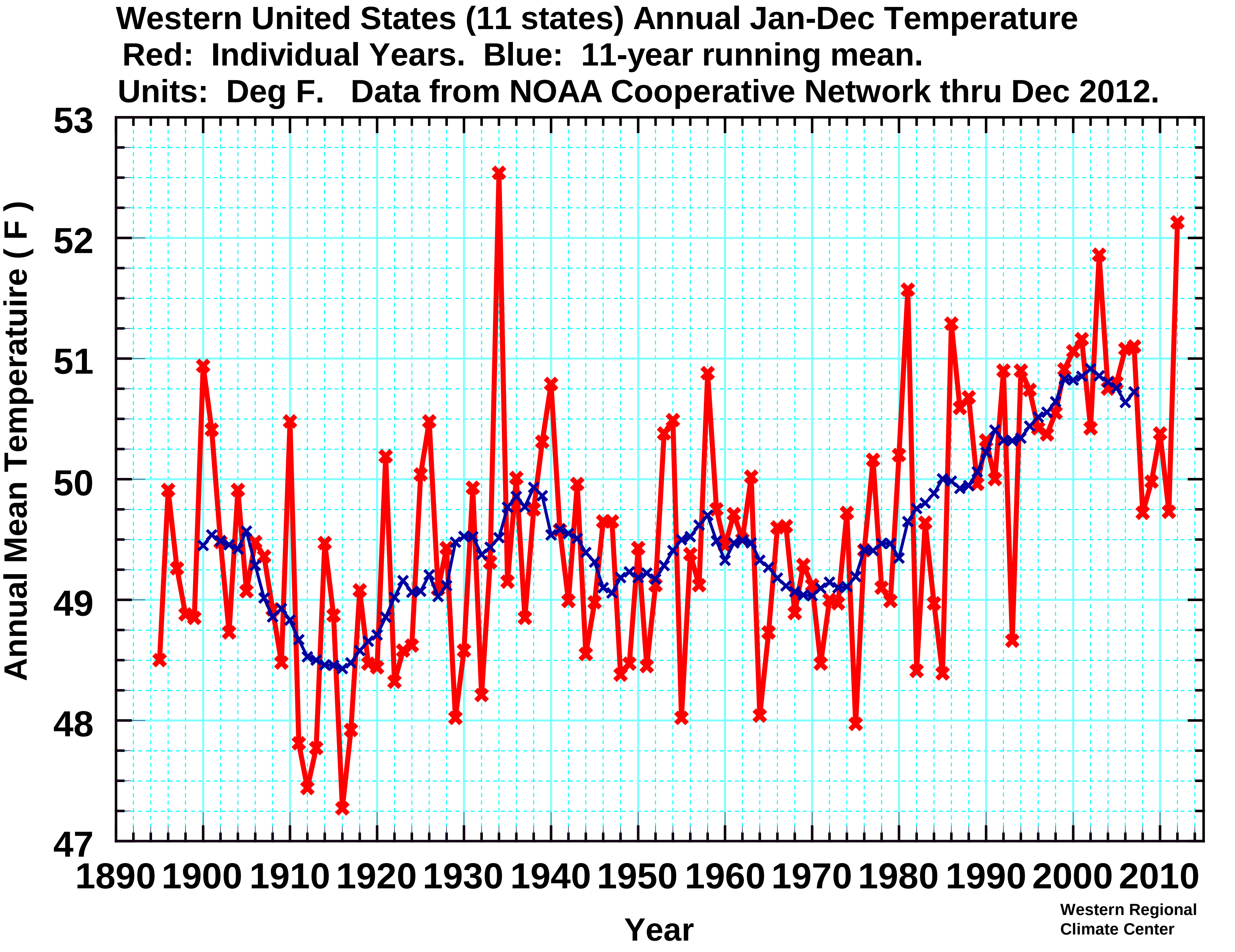
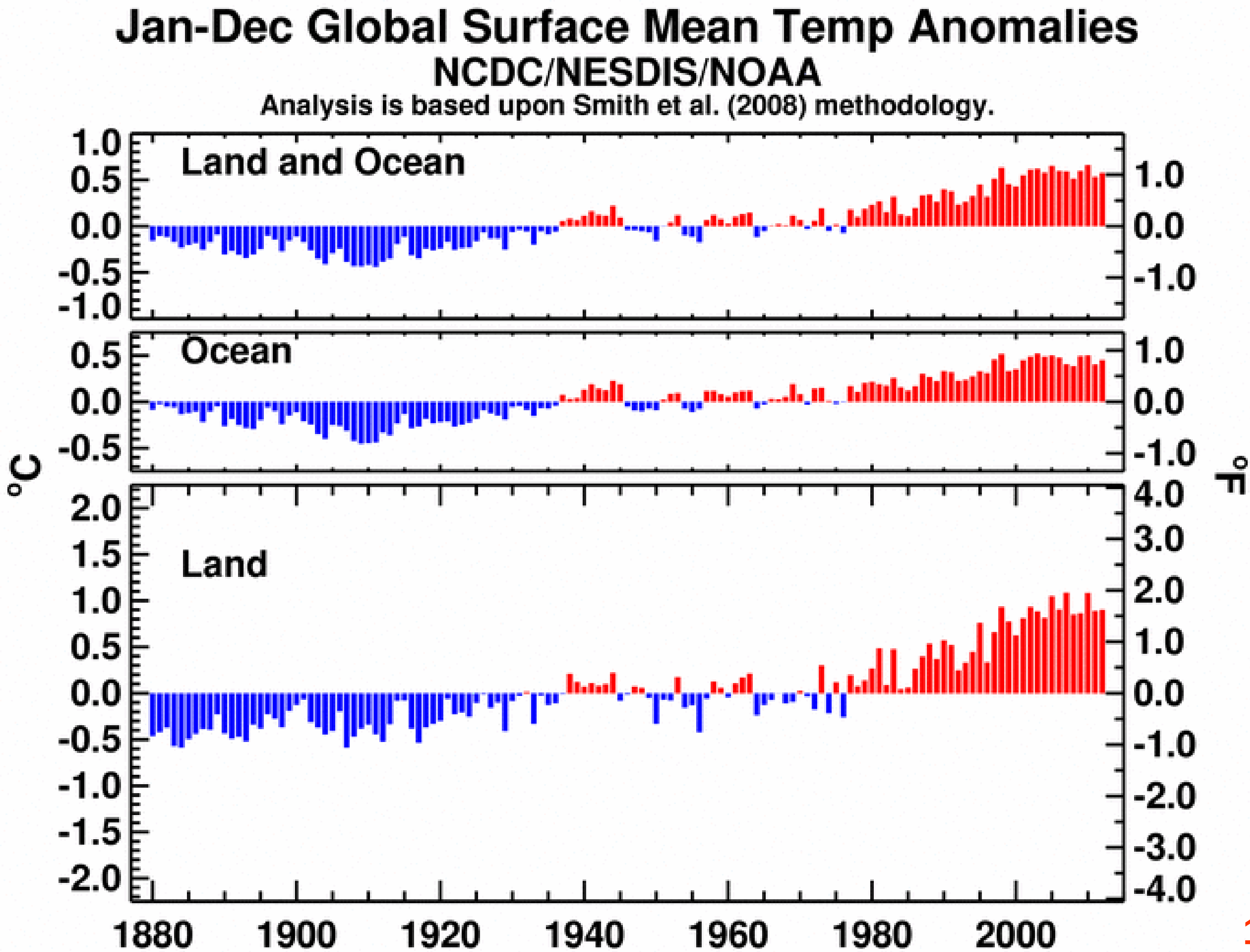

Western United States (11 states) Annual Jan-Dec Temperature
Red: Individual Years. Blue: 11-year running mean.
Units: Deg F. Data from NOAA Cooperative Network thru Dec 2012.
Annual Mean Temperatuire (F)
53
52
51
50
49
48
47
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center



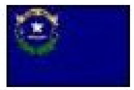
Annual
1880 - 2012
from
NOAA
NCDC

Nevada Climate Tracker
(state average only for now)

With thanks to John Abatzoglou

Nevada Climate Tracker

Select from the Menu to the Right



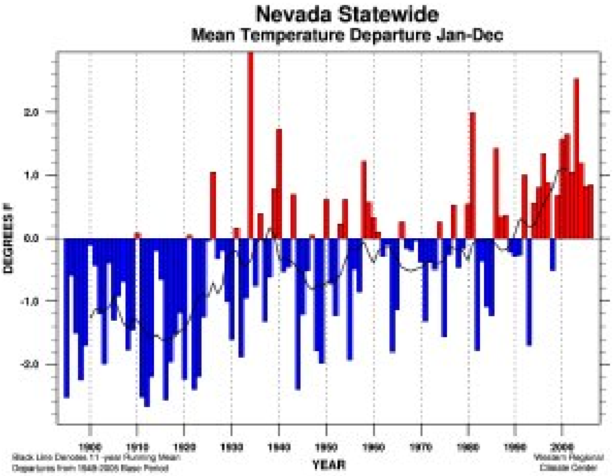
Time Series

Select Variable

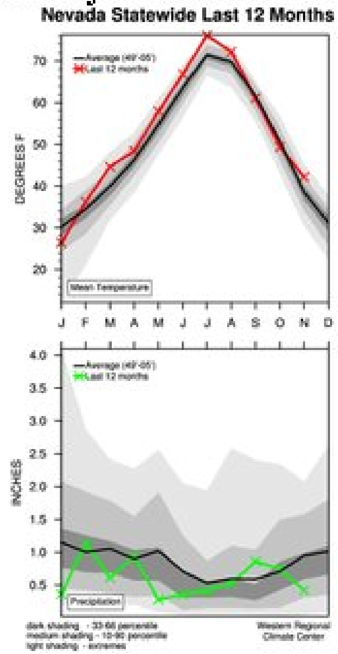
Select Time Period

Select

Time Series



Summary of Past 12 Months



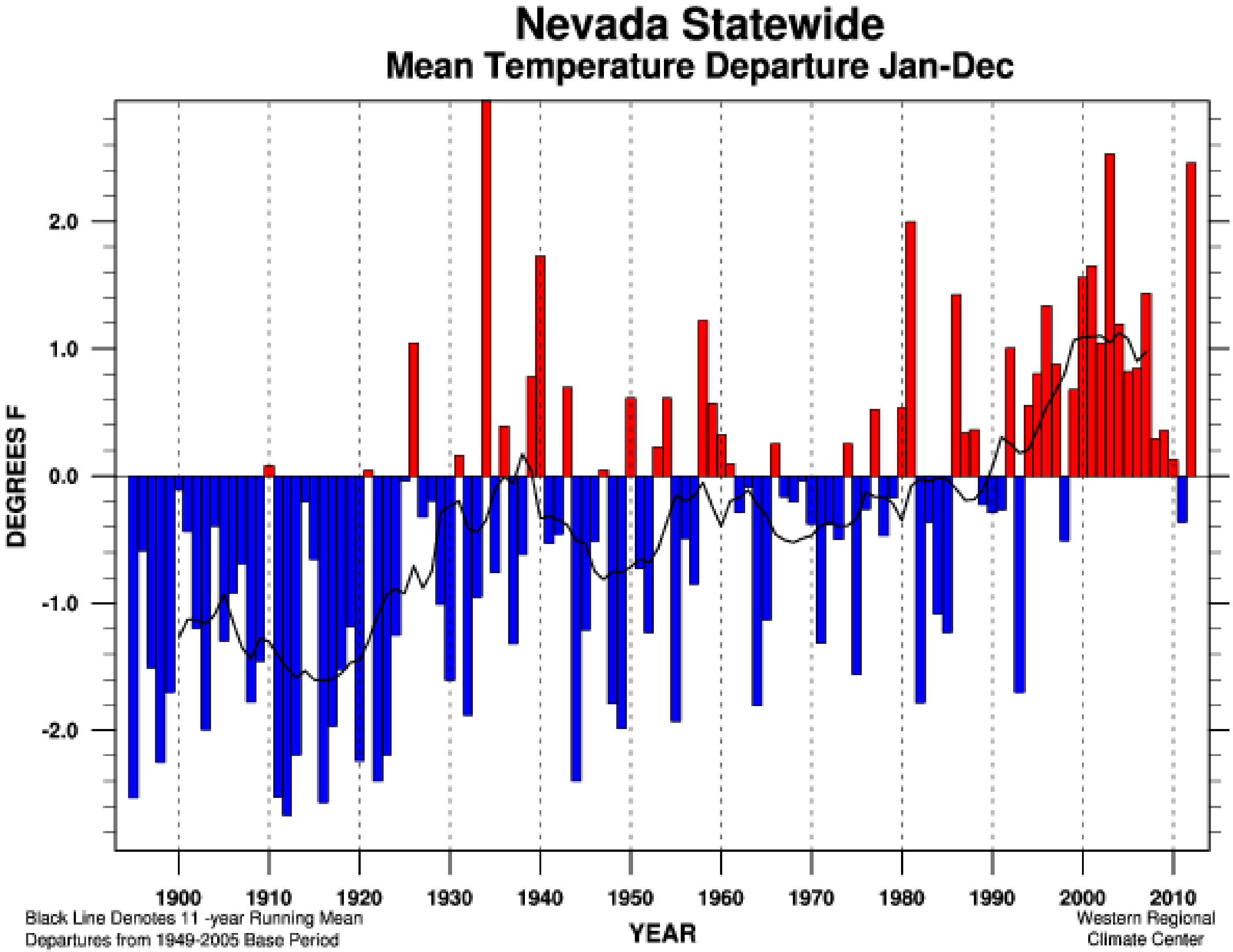
Summary of Past 12 Months

Plot Time Series
List Entire History
More Info

Return to the WRCC

Western Regional Climate Center

Powered by ACIS
NOAA Regional Climate Centers



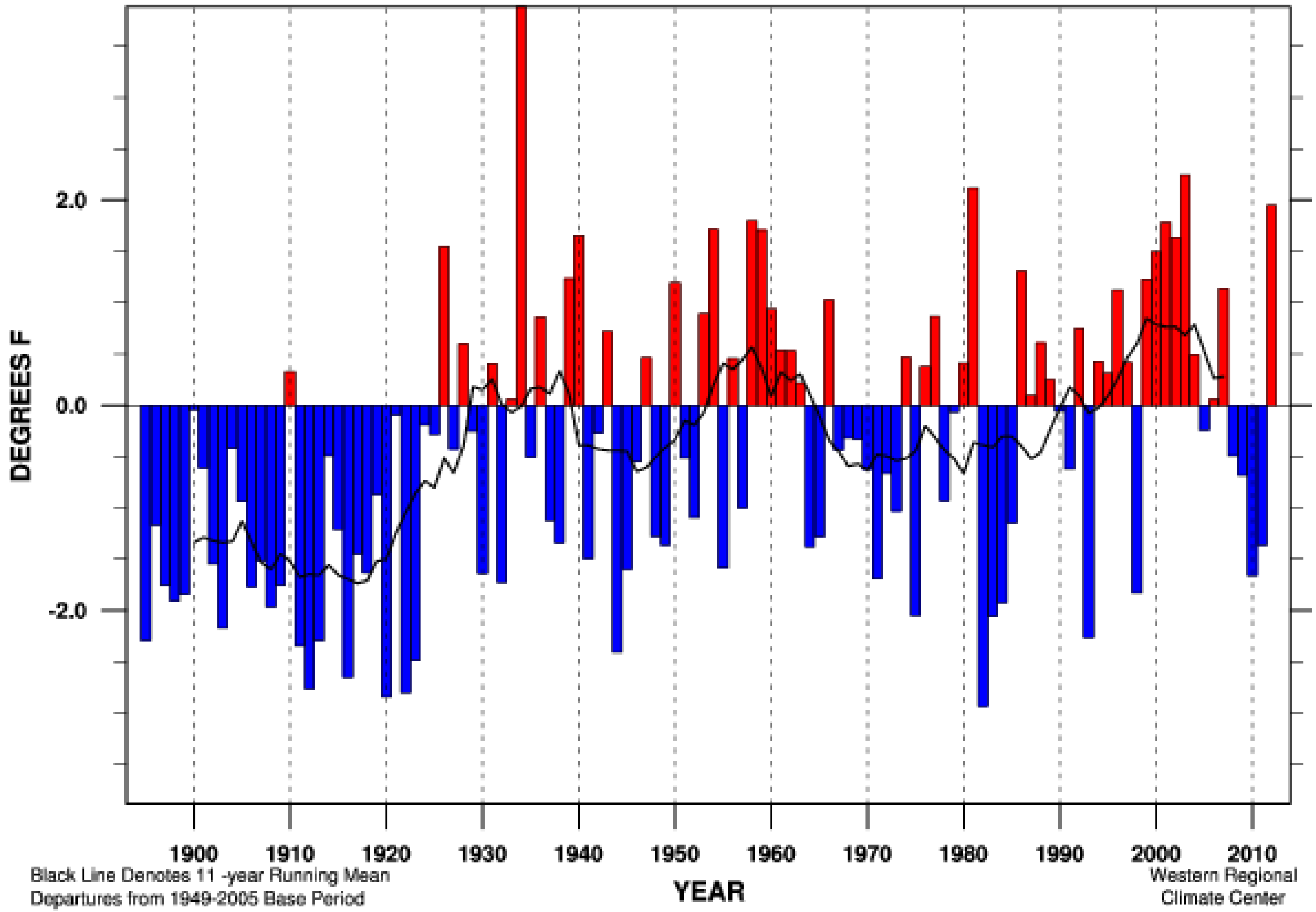
Nevada Statewide Temperature

Annual Calendar Year

1895 - 2012

Linear Trend 1895-present		+ 1.93 ± 0.53 °F/100yr	
Linear Trend 1949-present		+ 2.64 ± 1.24 °F/100yr	
Linear Trend 1975-present		+ 4.42 ± 2.88 °F/100yr	
Warmest Year		52.3 °F (+ 2.9 °F) in 1934	MEAN 49.4 °F
Coldest Year		46.7 °F (- 2.7 °F) in 1912	STDEV 1.02 °F
Jan-Dec	2012	51.8 °F (+ 2.5 °F)	RANK 116 of 118

Nevada Statewide
Maximum Temperature Departure Jan-Dec



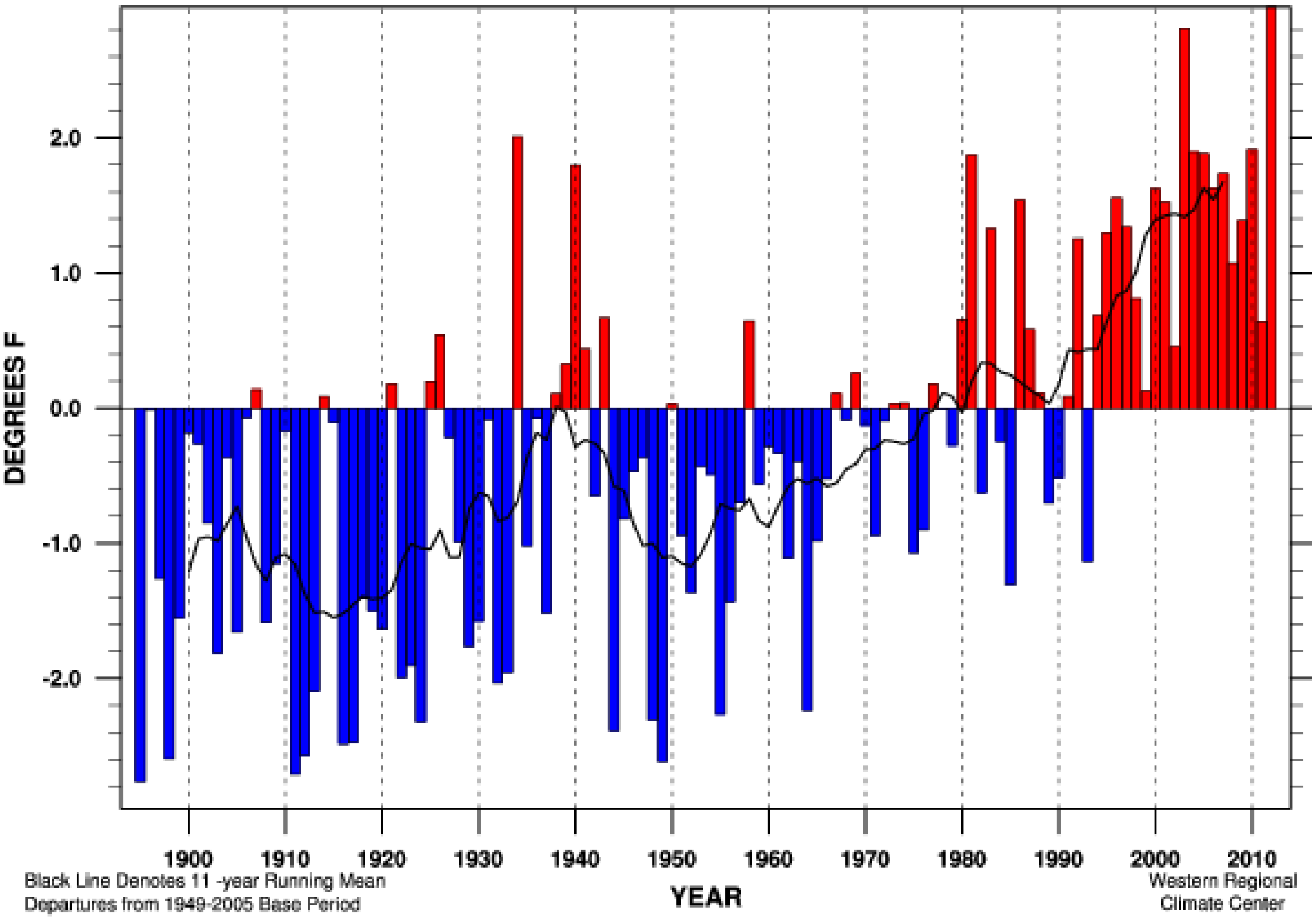
Linear Trend 1895-present		+ 1.52 ± 0.67 °F/100yr	
Linear Trend 1949-present		+ 0.53 ± 1.68 °F/100yr	
Linear Trend 1975-present		+ 2.57 ± 3.99 °F/100yr	
Warmest Year		67.9 °F (+ 3.9 °F) in 1934	MEAN 64.0 °F
Coldest Year		61.1°F (- 2.9 °F) in 1982	STDEV 1.23 °F
Jan-Dec	2012	66.0 °F (+ 1.9 °F)	RANK 115 of 118

Nevada Statewide Maximum Temperature

Annual Calendar Year

1895 - 2012

Nevada Statewide
Miniumum Temperature Departure Jan-Dec

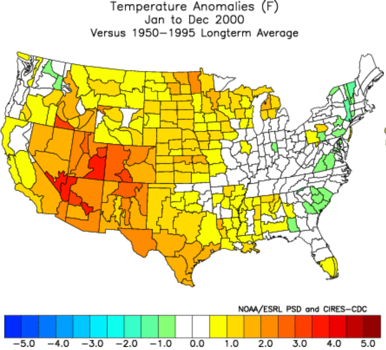


Linear Trend 1895-present		+ 2.35 ± 0.54 °F/100yr	
Linear Trend 1949-present		+ 4.75 ± 1.09 °F/100yr	
Linear Trend 1975-present		+ 6.26 ± 2.55 °F/100yr	
Warmest Year		37.7 °F (+ 3.0 °F) in 2012	MEAN 34.7 °F
Coldest Year		32.0 °F (- 2.8 °F) in 1895	STDEV 1.13 °F
Jan-Dec	2012	37.7 °F (+ 3.0 °F)	RANK 118 of 118

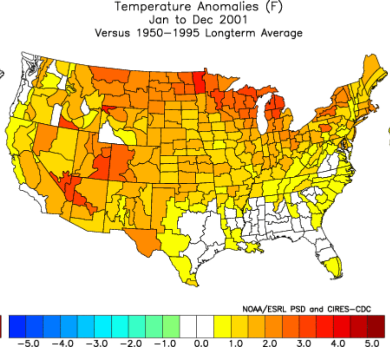
Nevada Statewide Minimum Temperature

Annual Calendar Year

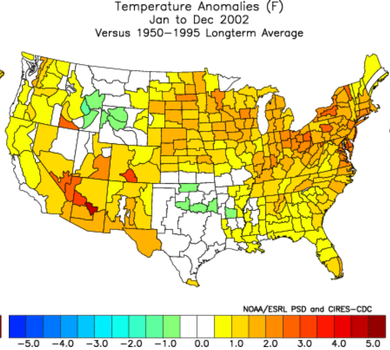
1895 - 2012



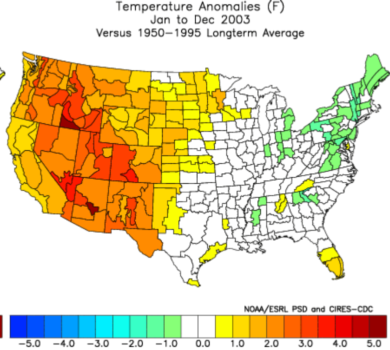
2000



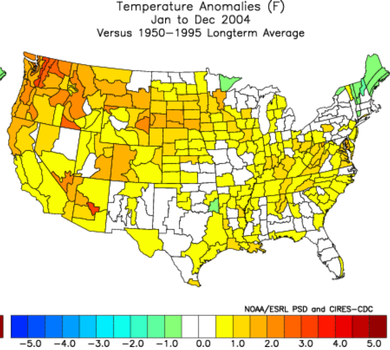
2001



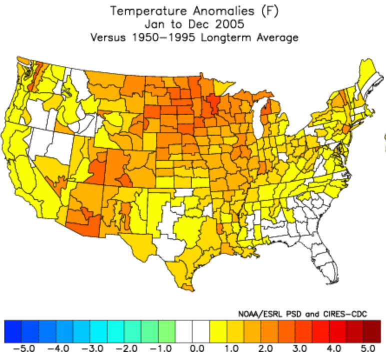
2002



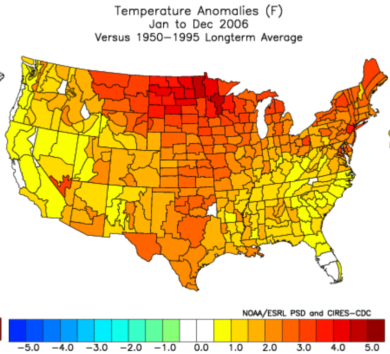
2003



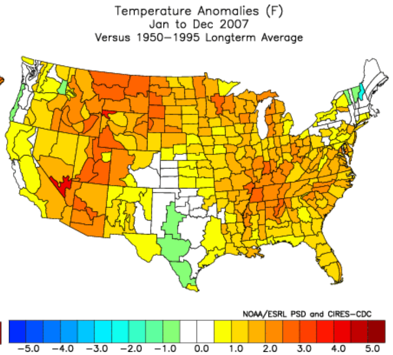
2004



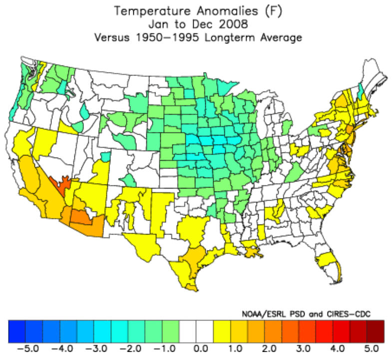
2005



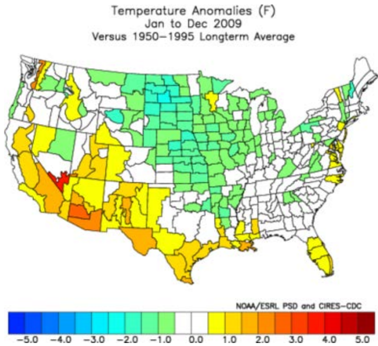
2006



2007



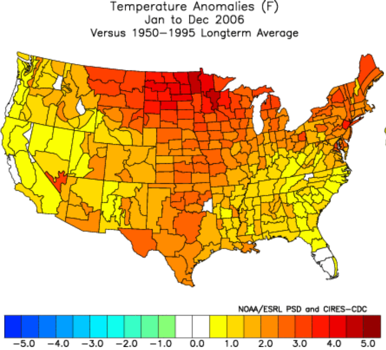
2008

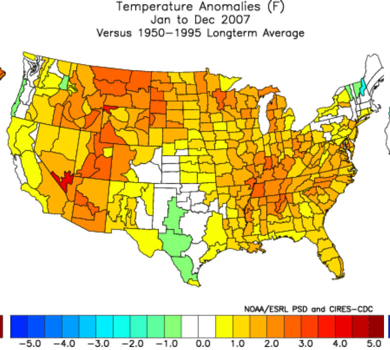


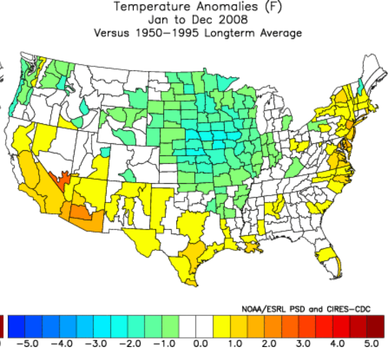
2009

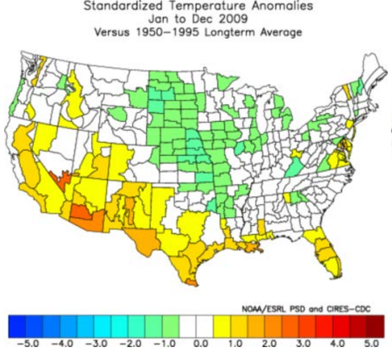
United States Annual Temperature Departure from 1950-1995 Mean

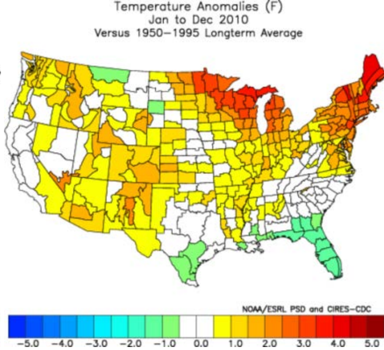
NOAA Divisional Data, Western Regional Climate Center, Plotted by ESRL PSD



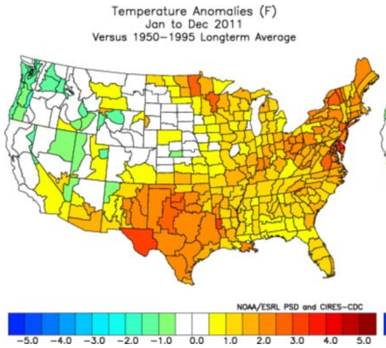


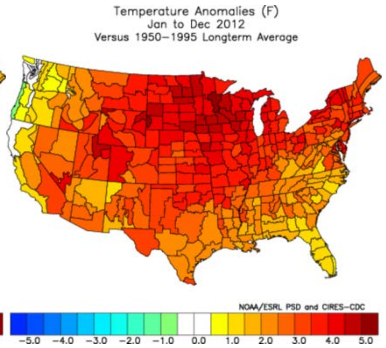


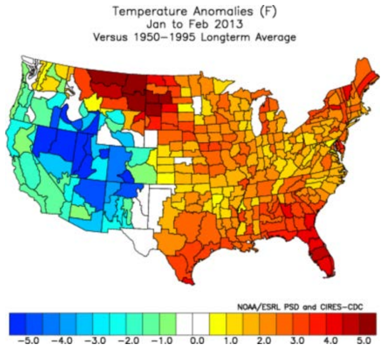




2006 **2007** **2008** **2009** **2010**



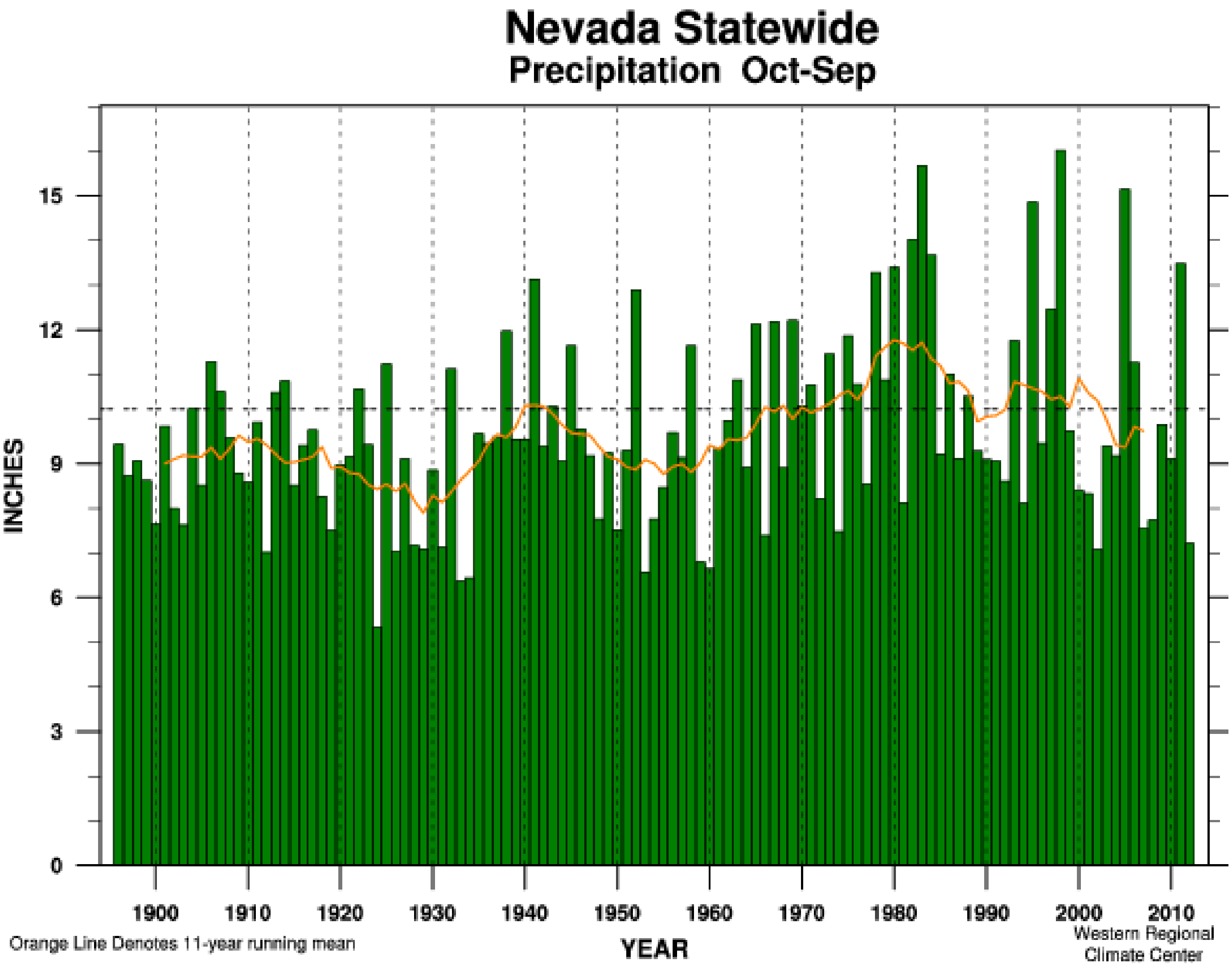




2011 **2012** **2013 thru Feb**

United States Annual Temperature Departure from 1950-1995 Mean

NOAA Divisional Data, Western Regional Climate Center, Plotted by ESRL PSD



Linear Trend 1895-present	+ 1.66 ± 1.08 in.	(+ 16 ± 10%) per 100 yr	
Linear Trend 1949-present	+ 1.68 ± 3.26 in.	(+ 16 ± 31%) per 100 yr	
Linear Trend 1975-present	- 5.59 ± 7.84 in.	(- 54 ± 76%) per 100 yr	
Wettest Year	16.02 in. (156%) in 1998	MEAN	10.22 in.
Driest Year	5.34 in. (52%) in 1924	STDEV	2.35 in.
Oct-Sep 2012	7.21 in. (70%)	RANK	13 of 117

Nevada Statewide Precipitation

Water Year Oct - Sep

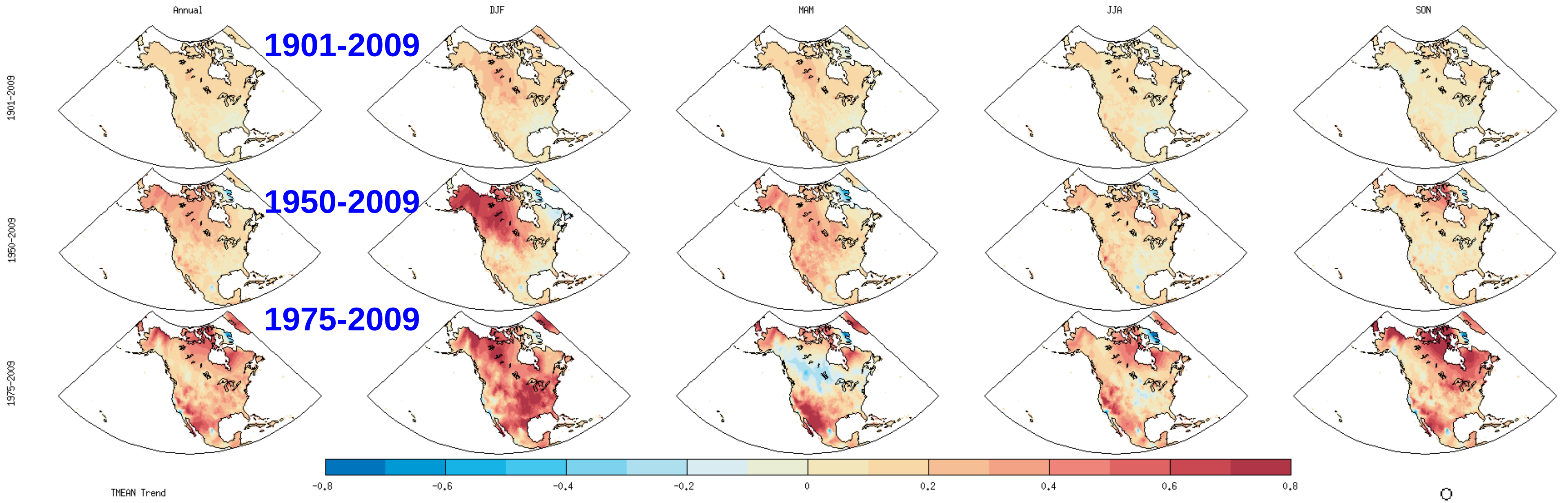
1895 / 1896 thru 2011 / 2012

Trends in North America Surface Temperature

CRUTS3.1

(thanks to John Abatzoglou)

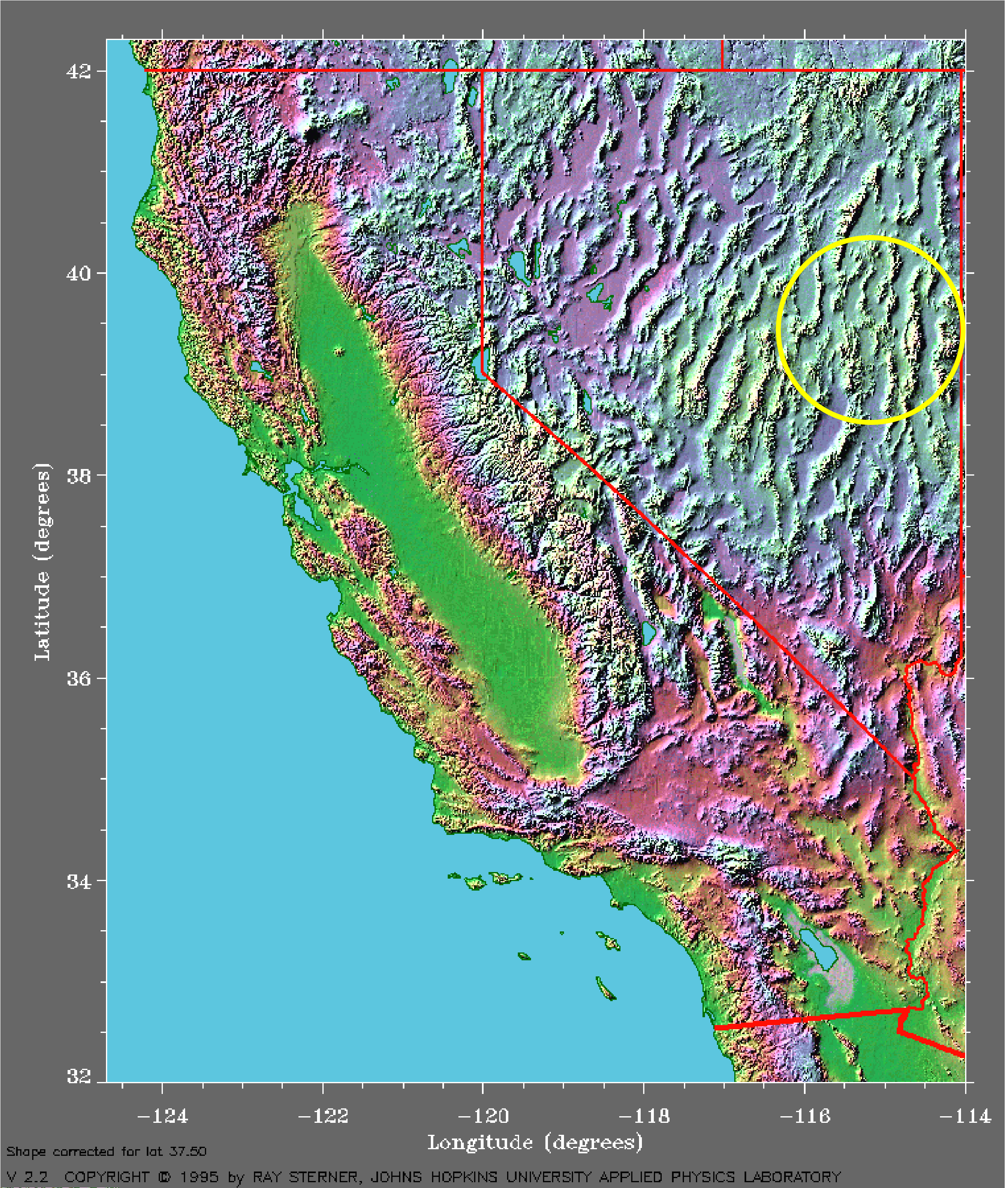
Annual **Winter** **Spring** **Summer** **Autumn**



-0.8 **-0.4** **Deg C / Decade** **+0.4** **+0.8**

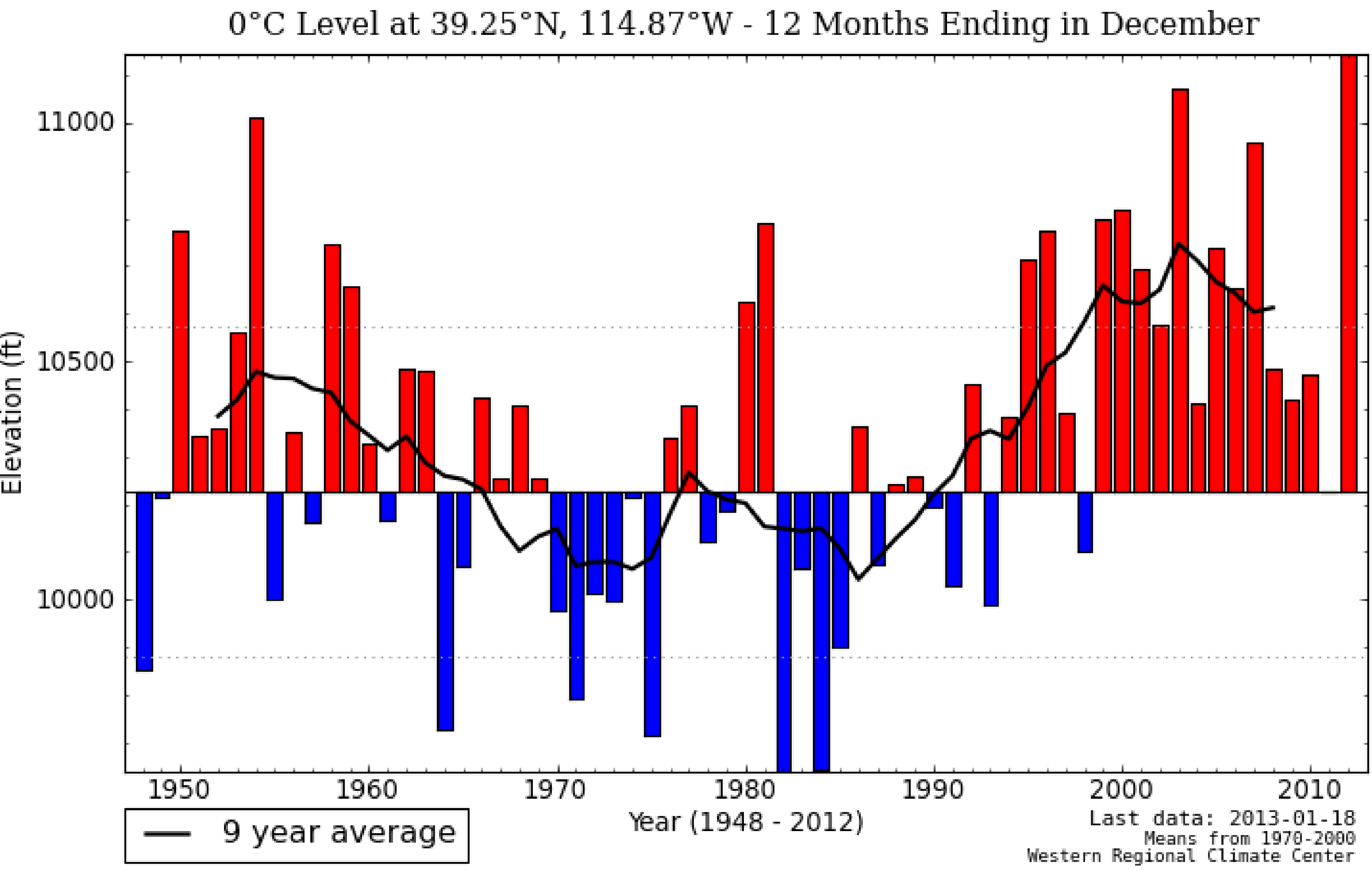
Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.


March 10, 2004
70” / 1800 mm
55” / 1400 mm
12” / 300 mm
7.5” / 170 mm



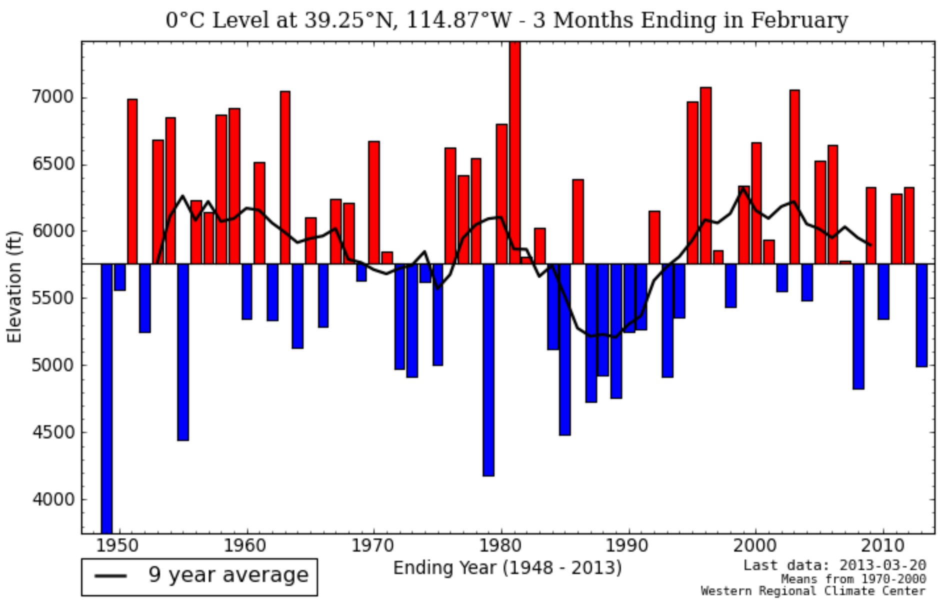
North American Freezing Level Tracker

Annual mean freezing level over Ely Nevada. 1948-2012. NCEP Reanalysis

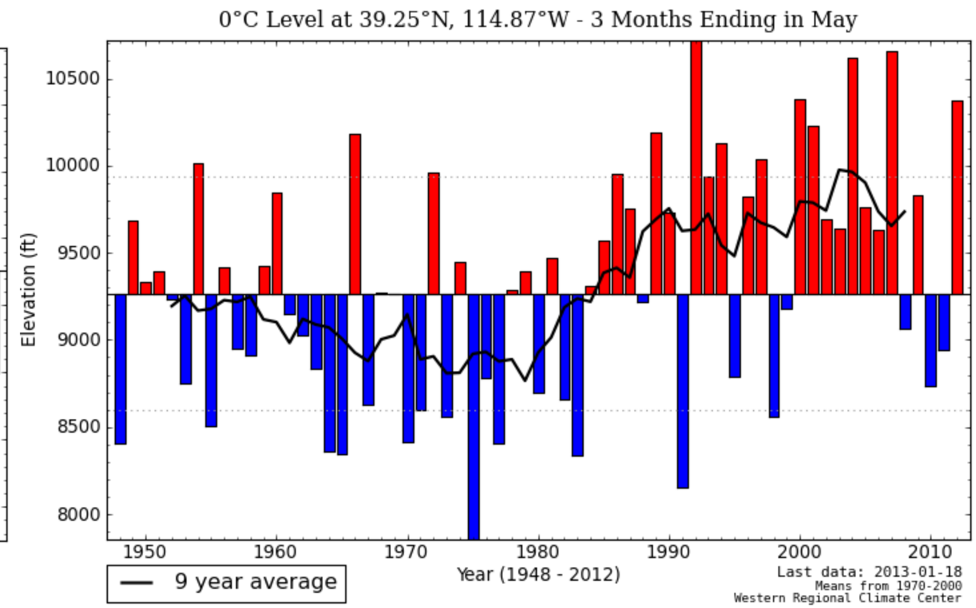


Freezing Level over Ely Nevada

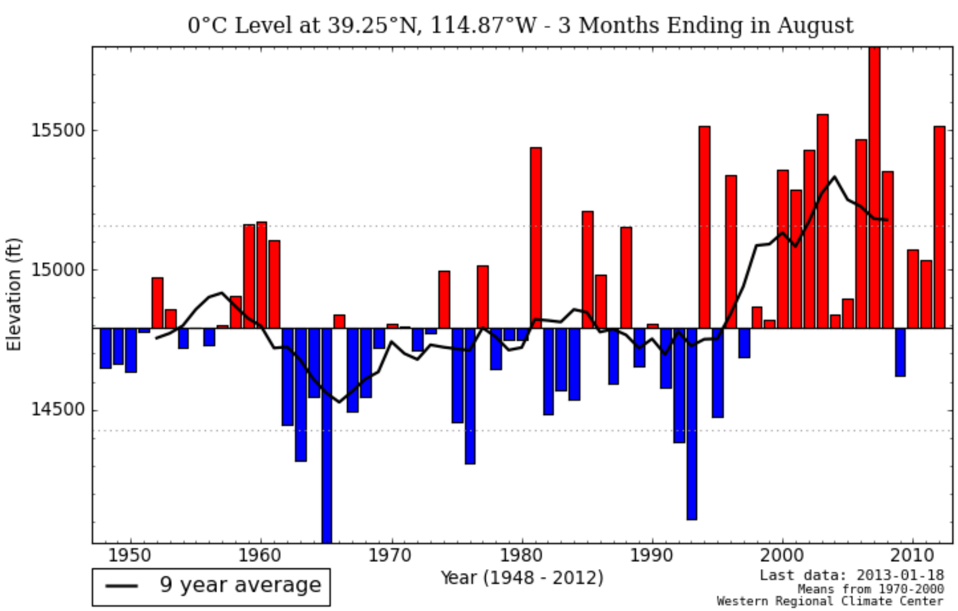
Winter



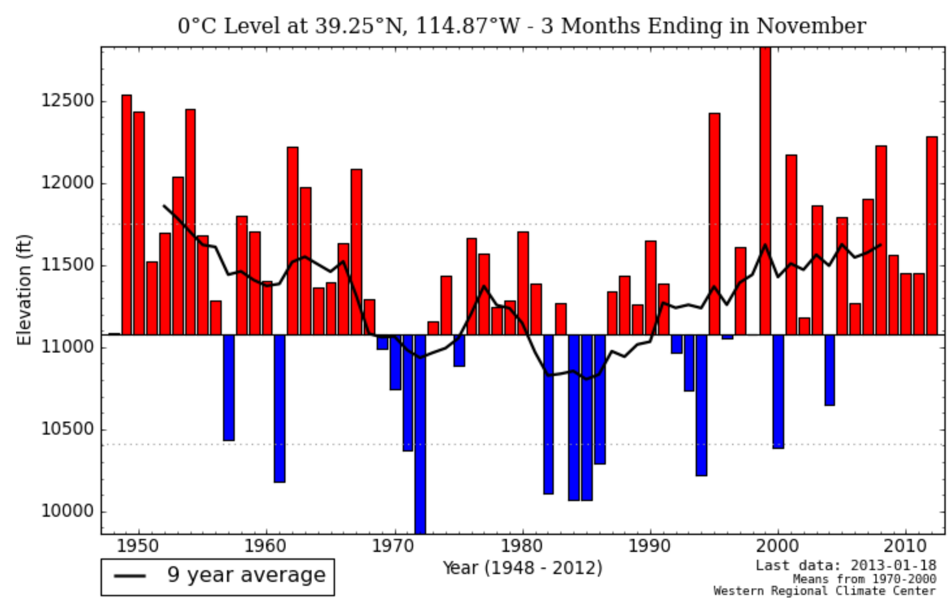
Spring

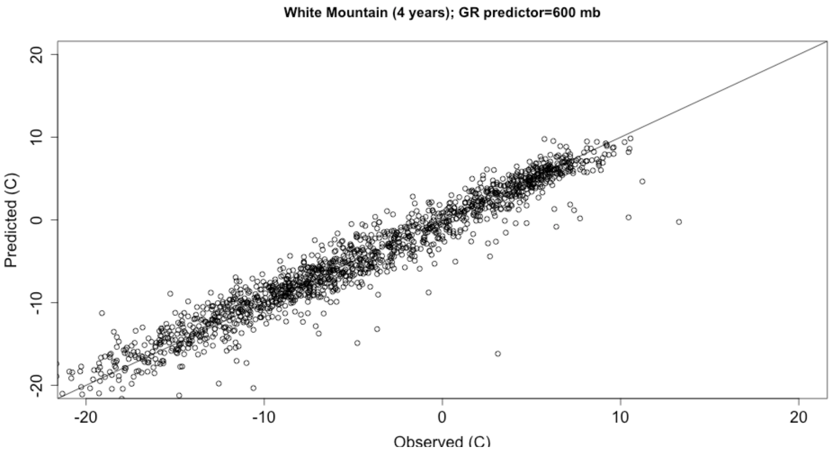


Summer



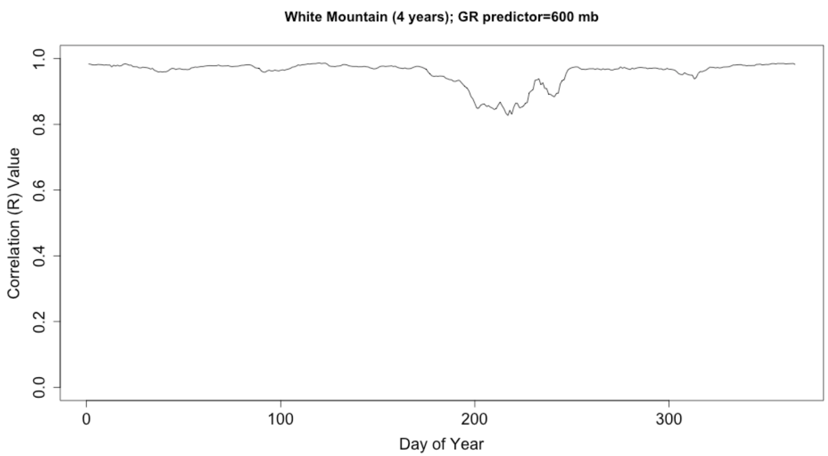
Autumn





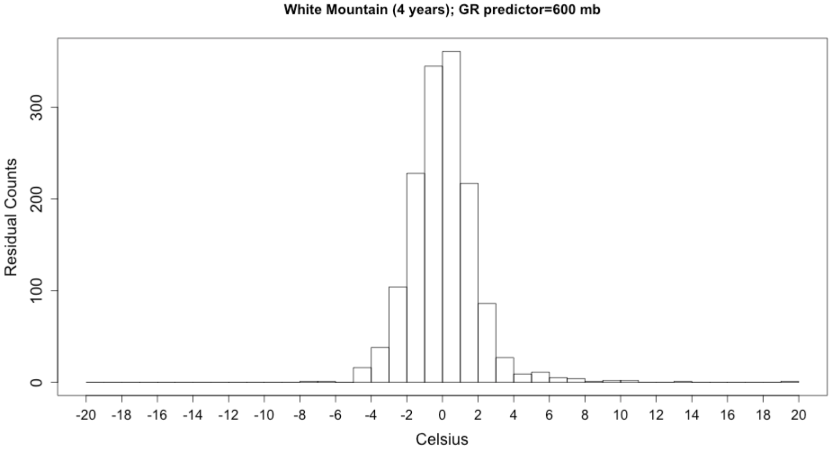
White Mountain Summit (14,245 ft)

Summit Station Measured Daily Temp
vs
Temp Estimated from 600mb Global Reanalysis



Correlation Coefficient

30-day running mean



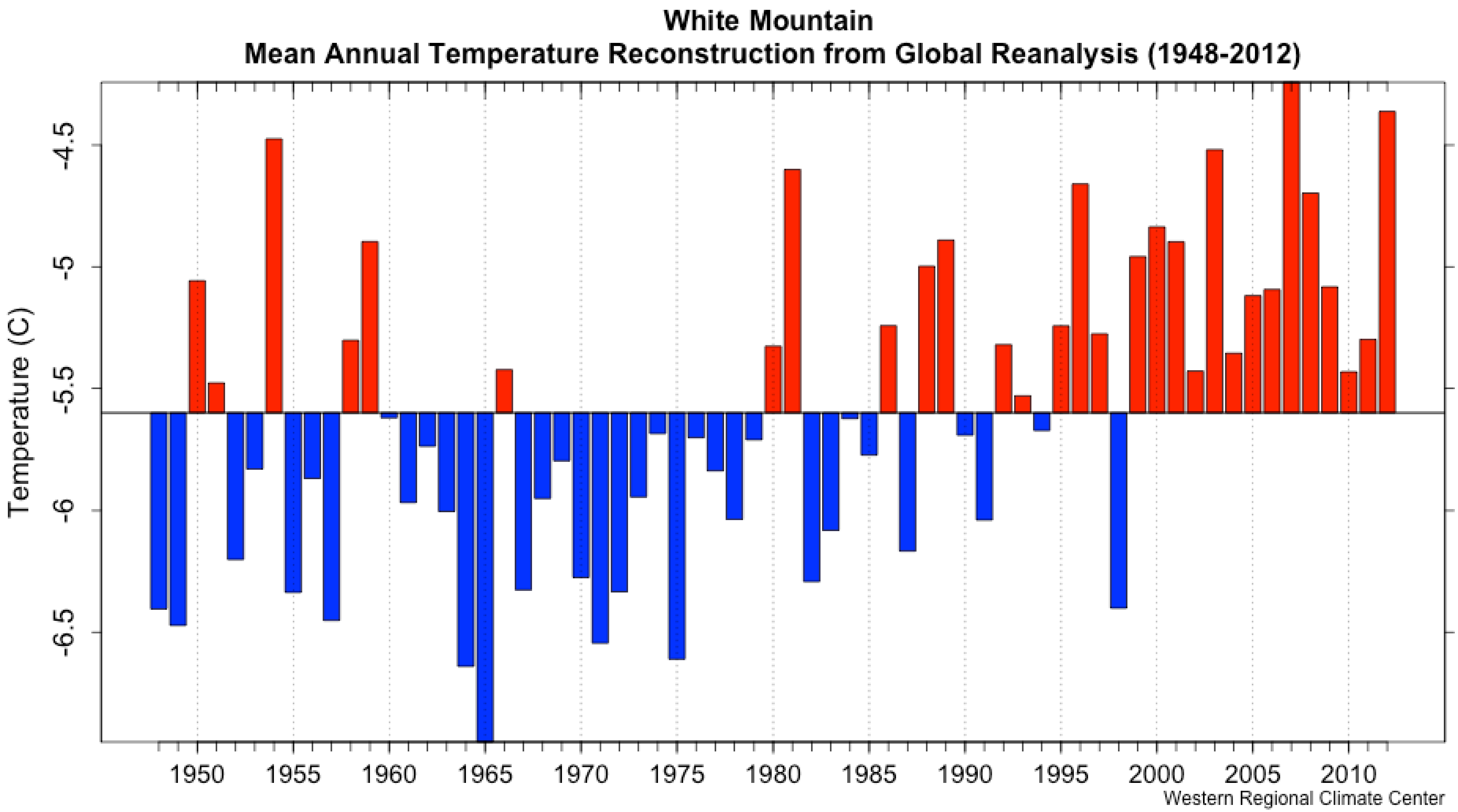
Frequency Distribution

of errors

Estimated minus Observed

For NPS Southern Sierra Project
Thanks to Matt Fearon

Reconstructed Annual Temperature of White Mountain Summit (14245 ft) based on NCAR/NCEP Global Reanalysis. 1948 - 2012.

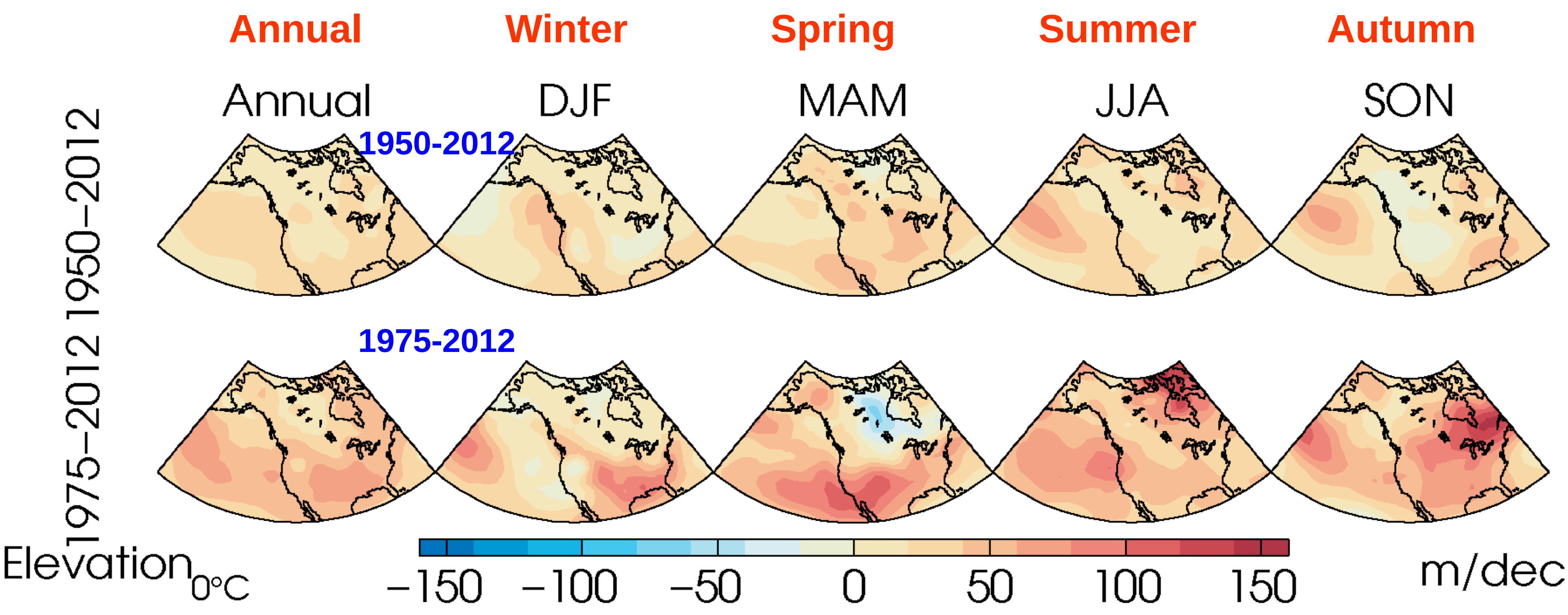


~4 years of overlap
Thanks to Matt Fearon

Trends in North America Freezing Level Elevation

CRUTS3.1

(thanks to John Abatzoglou)



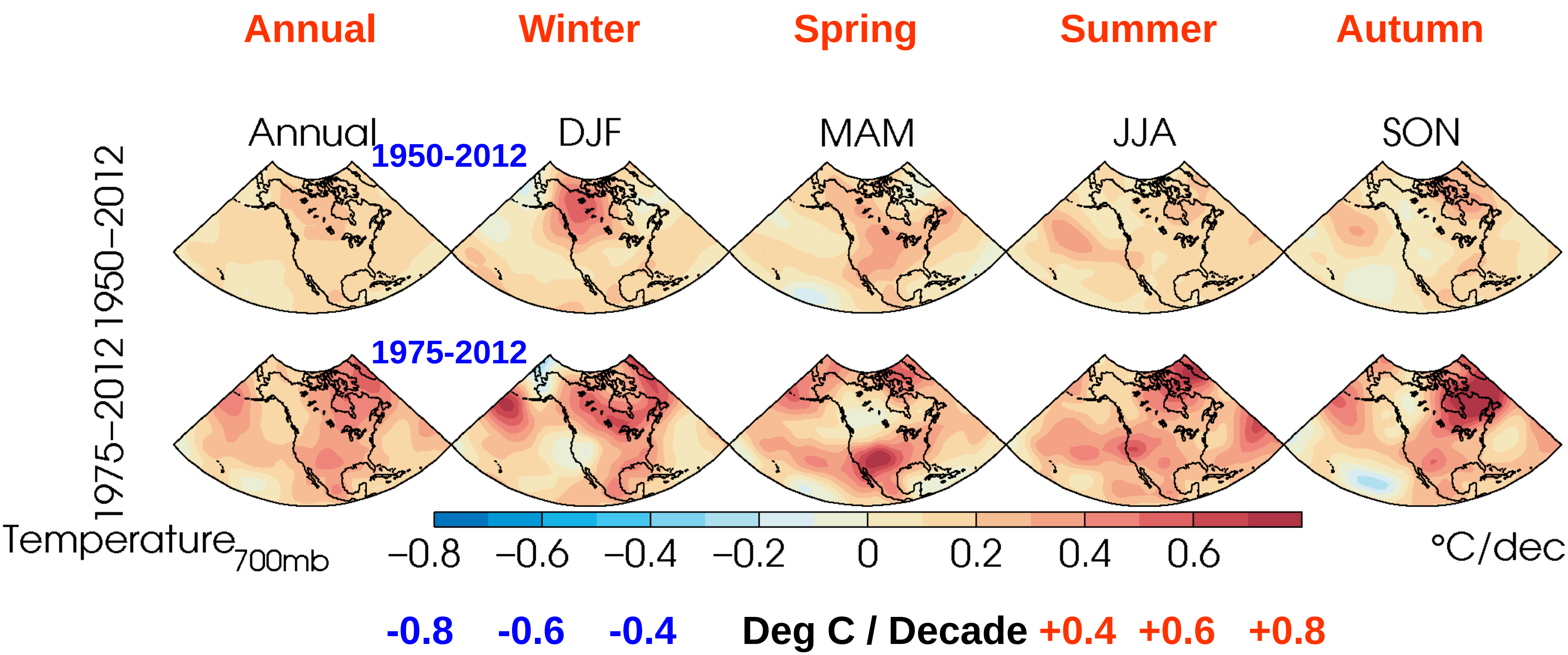
meters / Decade

Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.

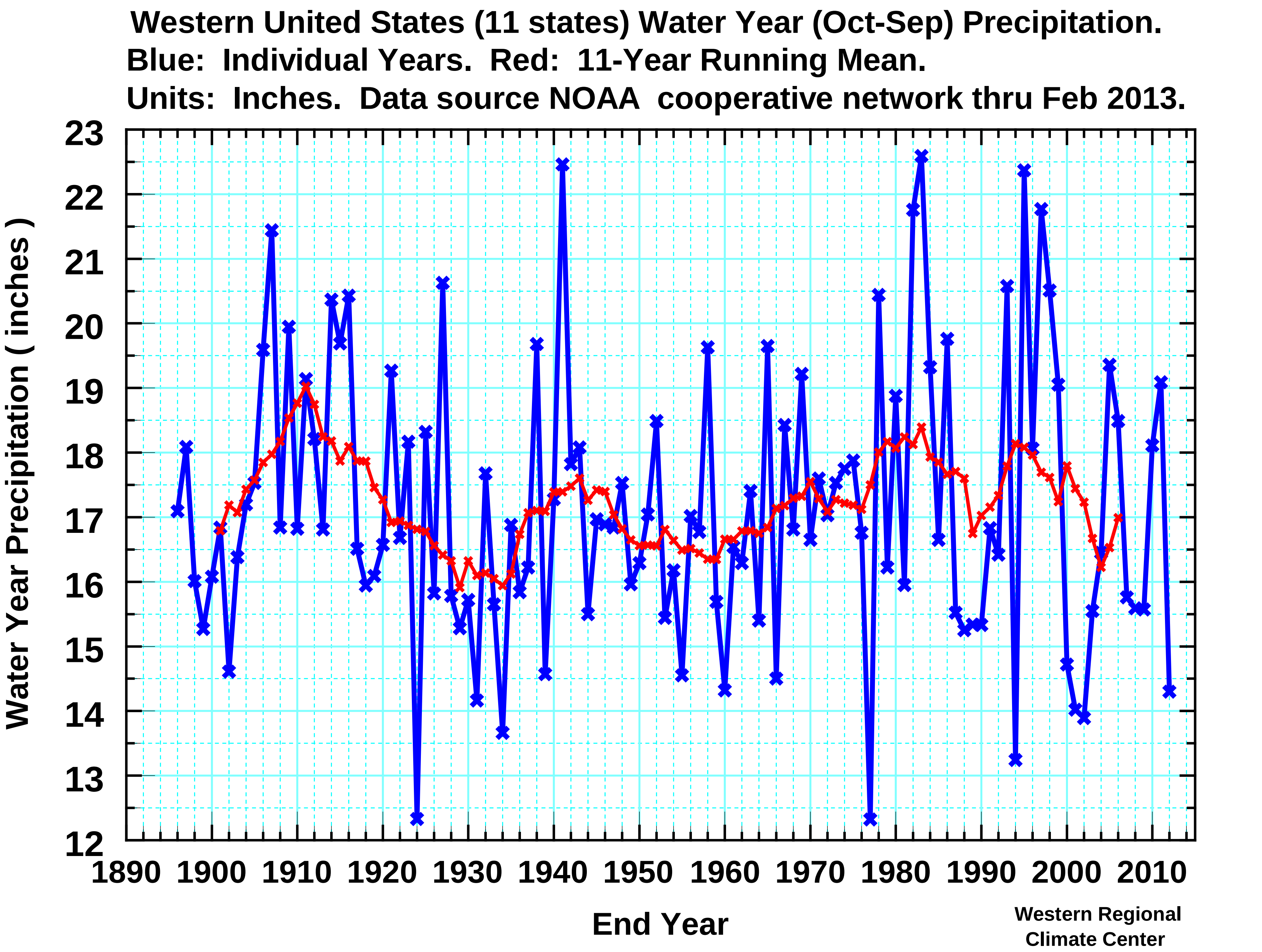
Trends in North America 700 mb (~10,000 ft) Temperature

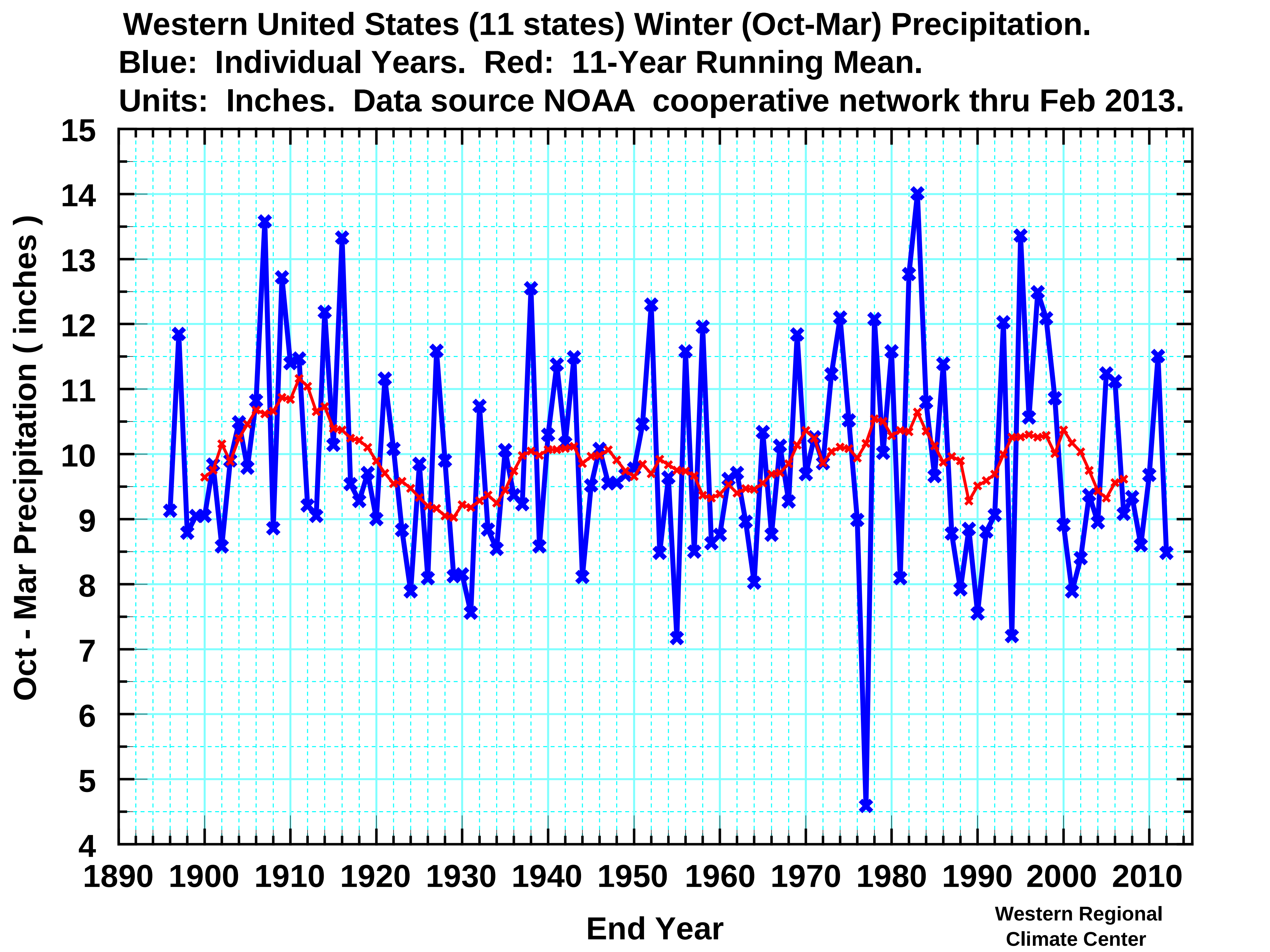
CRUTS3.1

(thanks to John Abatzoglou)



Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.


Western United States (11 states) Water Year (Oct-Sep) Precipitation.
Blue: Individual Years. Red: 11-Year Running Mean.
Units: Inches. Data source NOAA cooperative network thru Feb 2013.
Water Year Precipitation (inches)
23
22
21
20
19
18
17
16
15
14
13
12
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
End Year
Western Regional
Climate Center

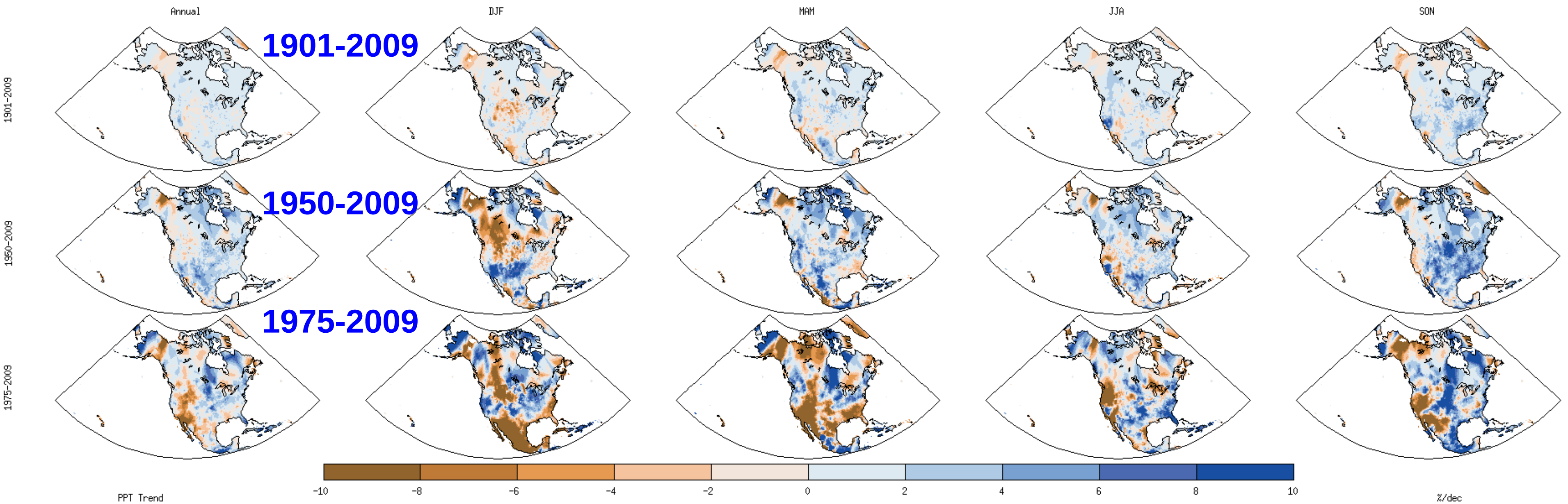

Western United States (11 states) Winter (Oct-Mar) Precipitation.
Blue: Individual Years. Red: 11-Year Running Mean.
Units: Inches. Data source NOAA cooperative network thru Feb 2013.
Oct - Mar Precipitation (inches)
15
14
13
12
11
10
9
8
7
6
5
4
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
End Year
Western Regional
Climate Center

Trends in North America Station Precipitation

CRUTS3.1

(thanks to John Abatzoglou)

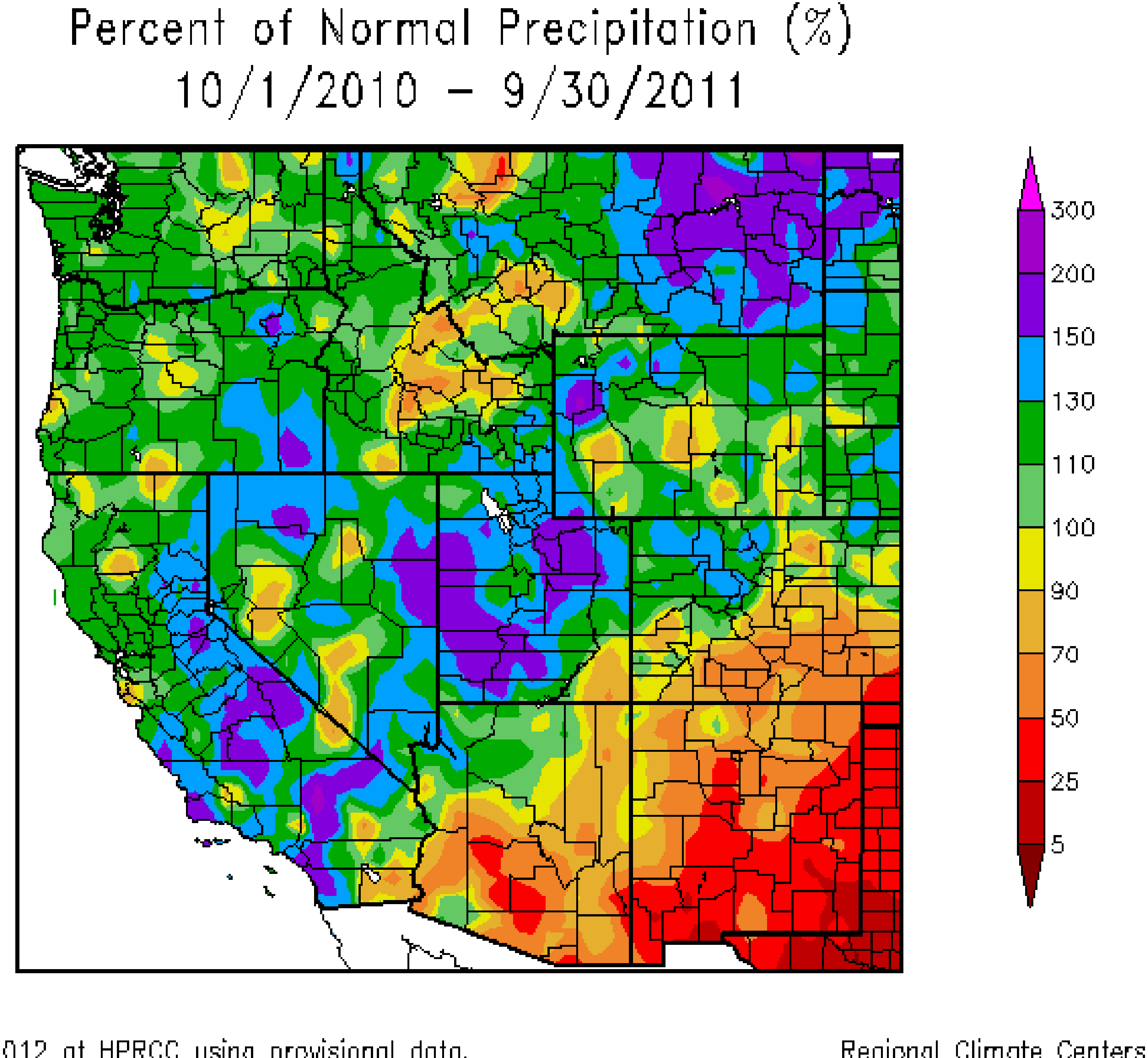
Annual | **Winter** | **Spring** | **Summer** | **Autumn**



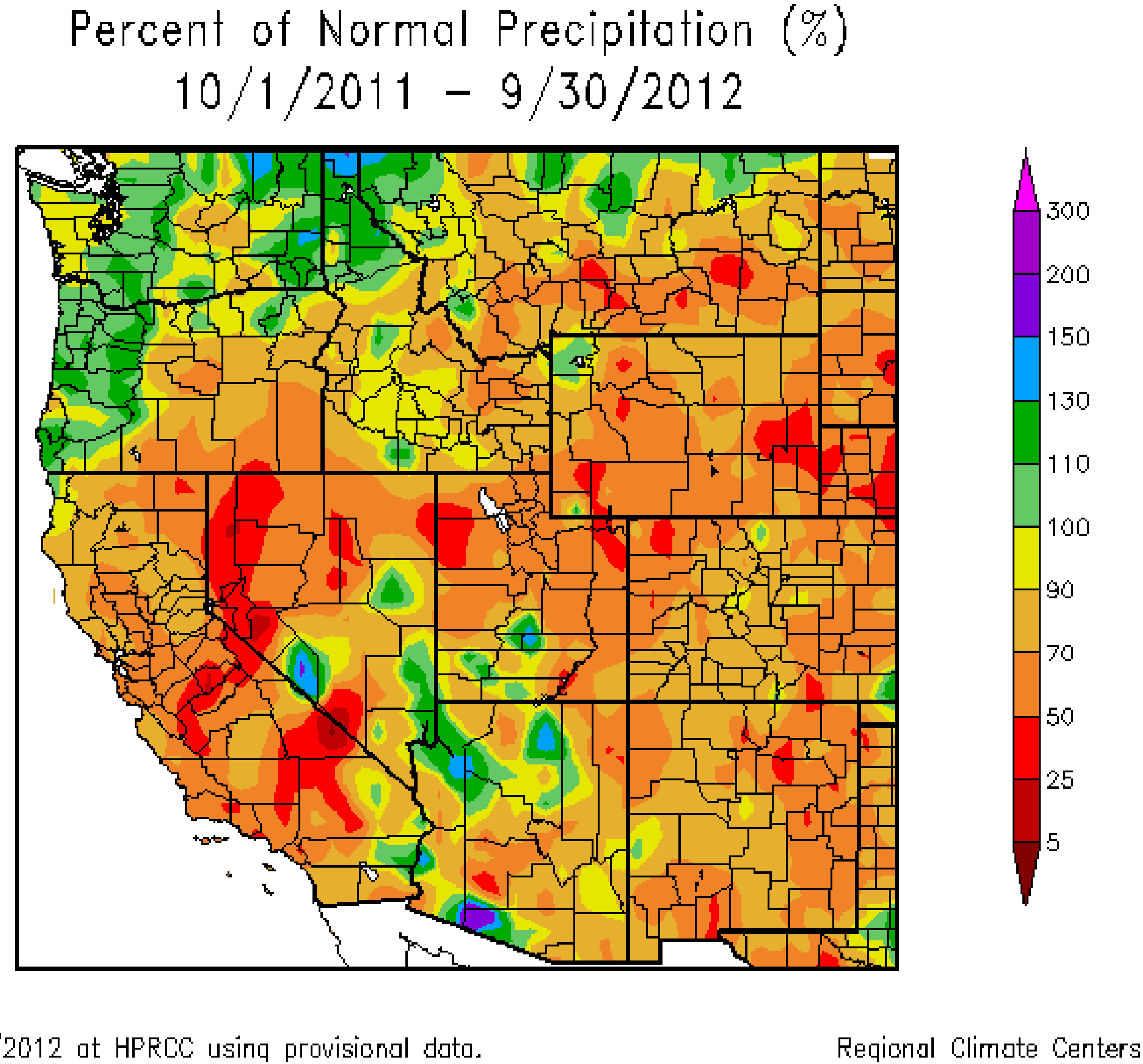
-10 -8 -6 -4 Percent / Decade +4 +6 +8 +10

Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.

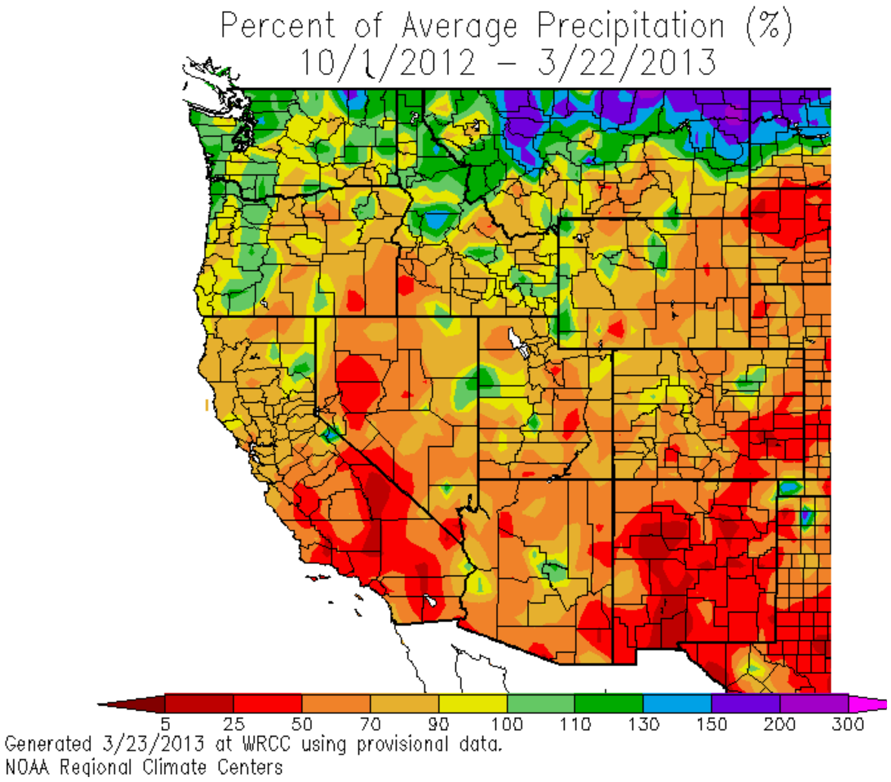
Water Year 2010-11 01 Oct 2010 Thru 30 Sep 2011

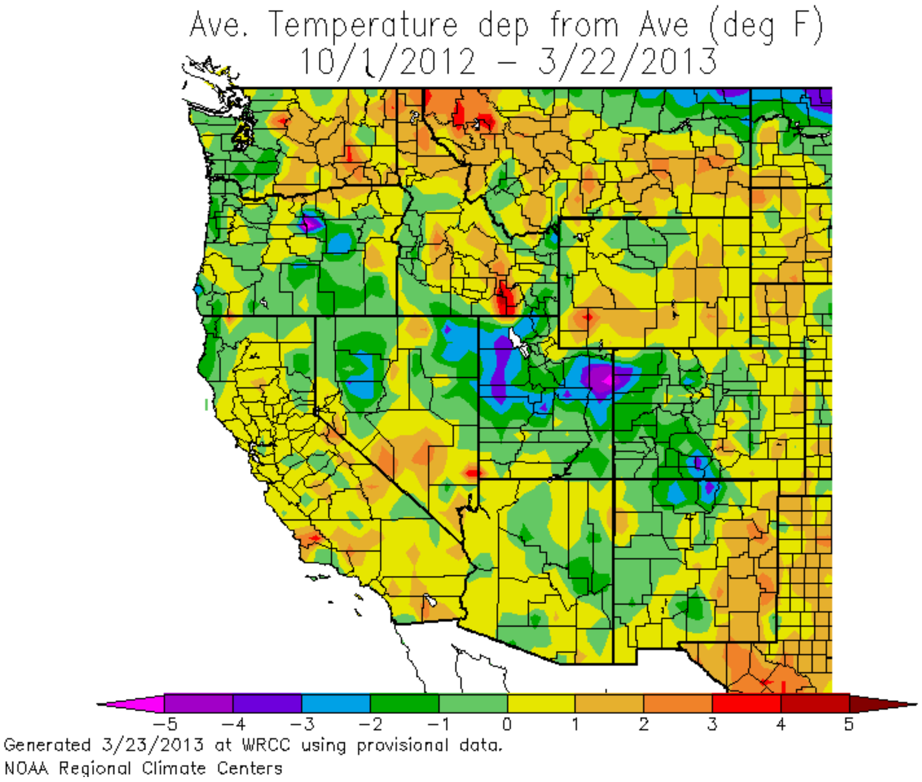


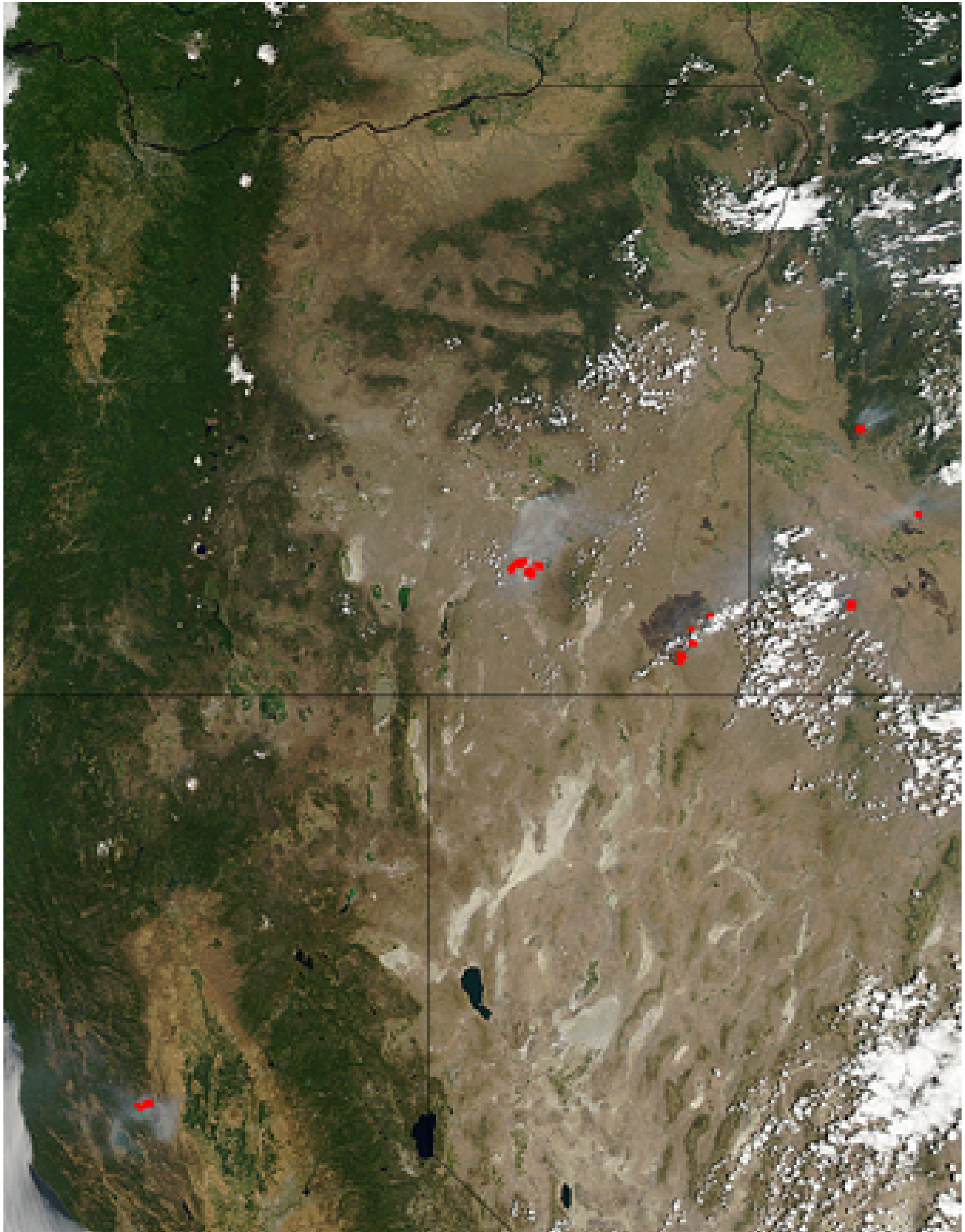
Water Year 2011-12
01 Oct 2011
Thru
30 Sep 2012



Precipitation **Water Year To Date (Mar 22, 2013)** **Temperature**







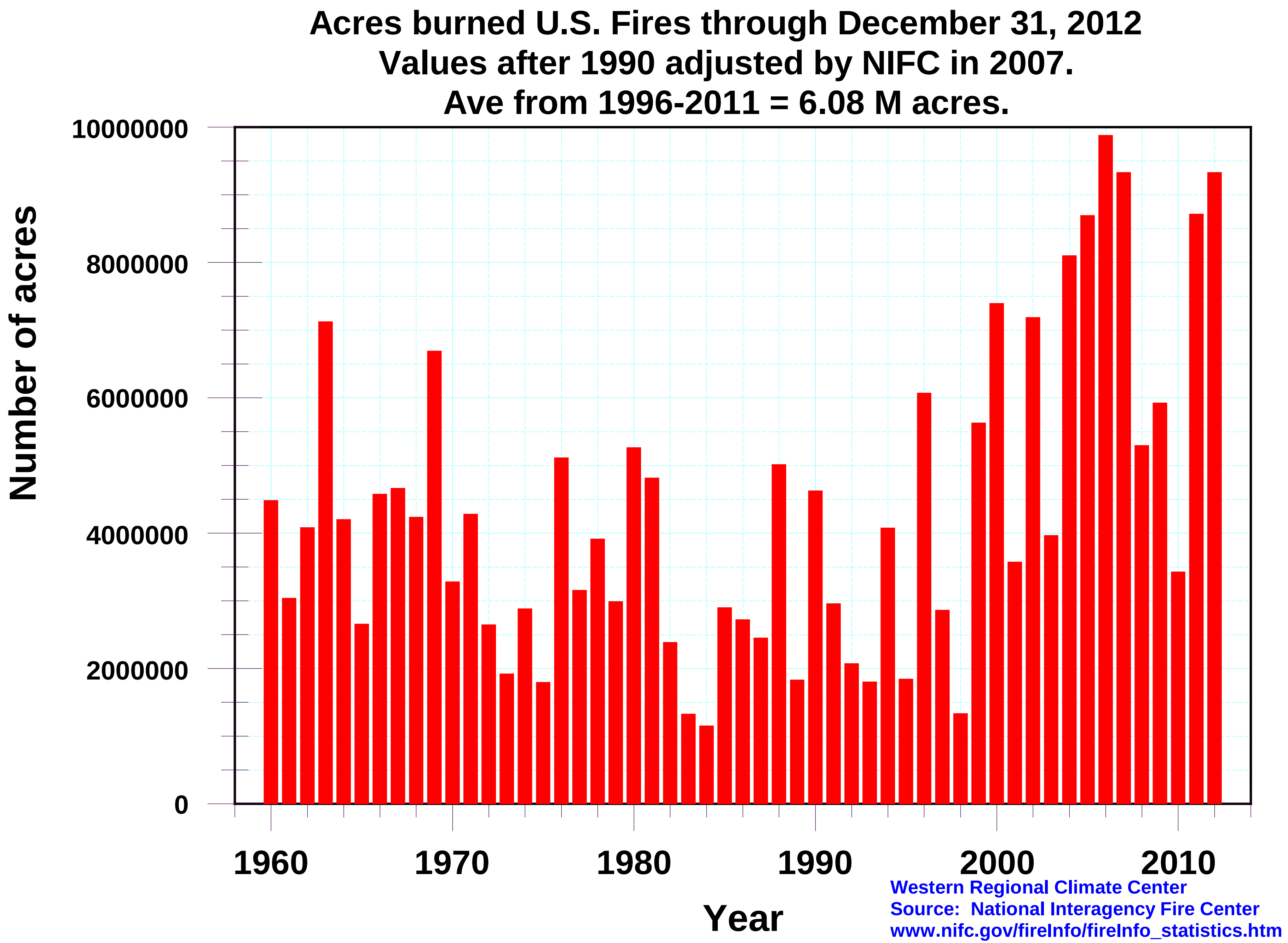
Long Draw Fire
557,648 acres as of July 17
Oregon's largest fire ever
MODIS 1 km
2012 July 11

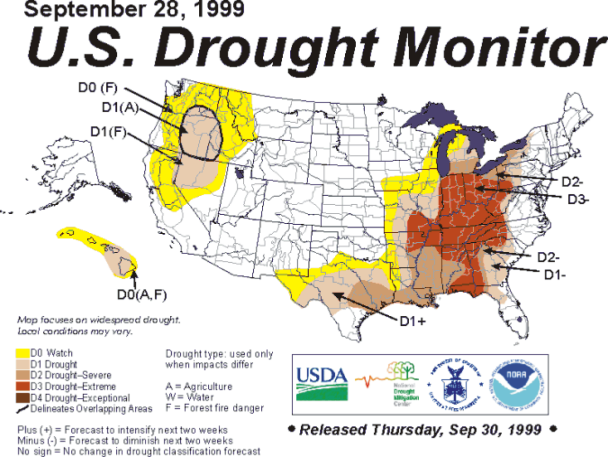
Long Draw Fire SE Oregon 2012 July 24

Jamie Francis, Oregonian

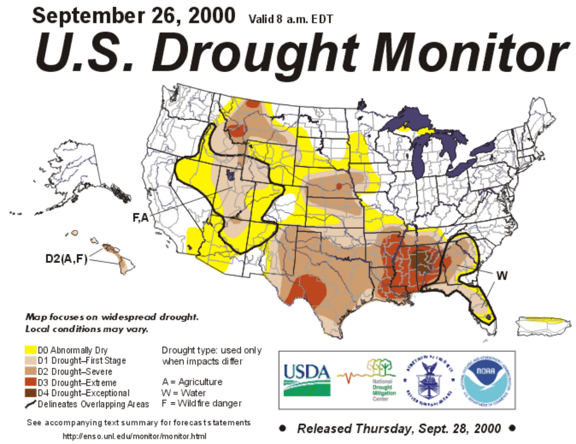
Long Draw Fire SE Oregon 2012 July 24

Jamie Francis, Oregonian

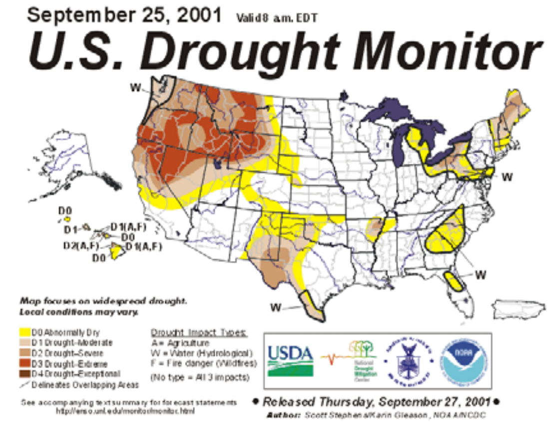

Acres burned U.S. Fires through December 31, 2012
Values after 1990 adjusted by NIFC in 2007.
Ave from 1996-2011 = 6.08 M acres.
10000000
8000000
6000000
4000000
2000000
0
Number of acres
1960
1970
1980
1990
2000
2010
Year
Western Regional Climate Center
Source: National Interagency Fire Center
www.nifc.gov/fireInfo/fireInfo_statistics.htm



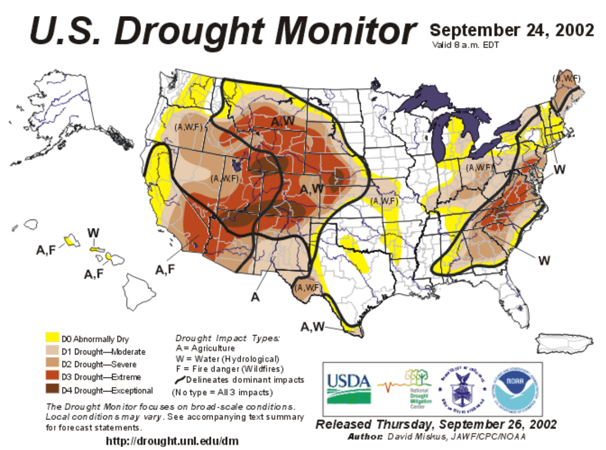
Sep 28, 1999



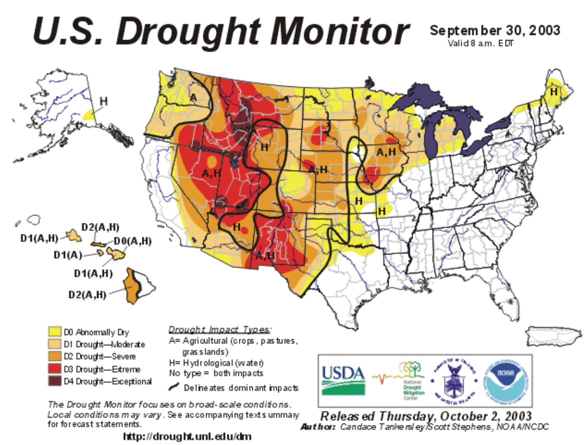
Sep 26, 2000



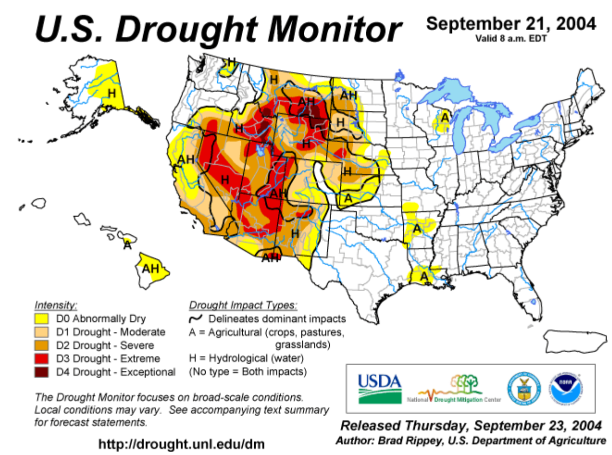
Sep 25, 2001



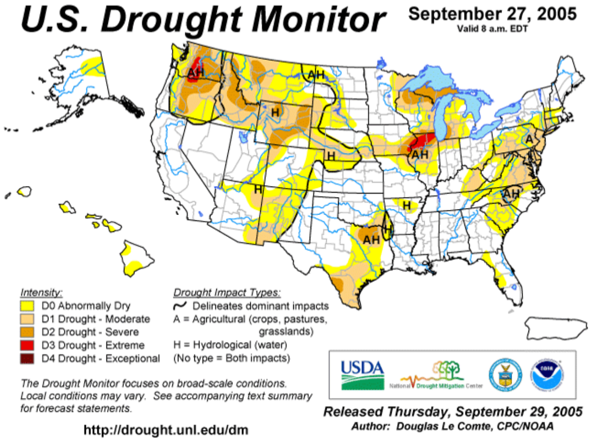
Sep 24, 2002



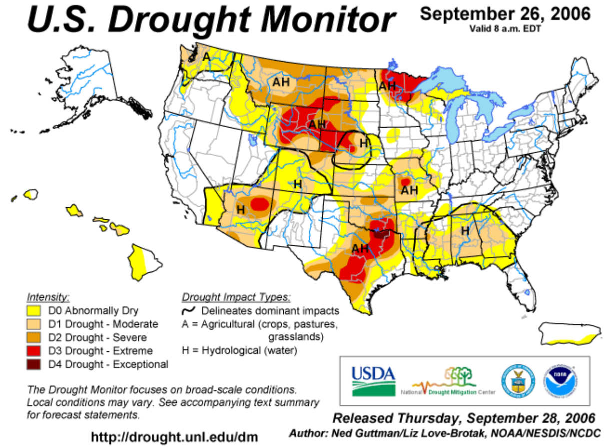
Sep 30, 2003



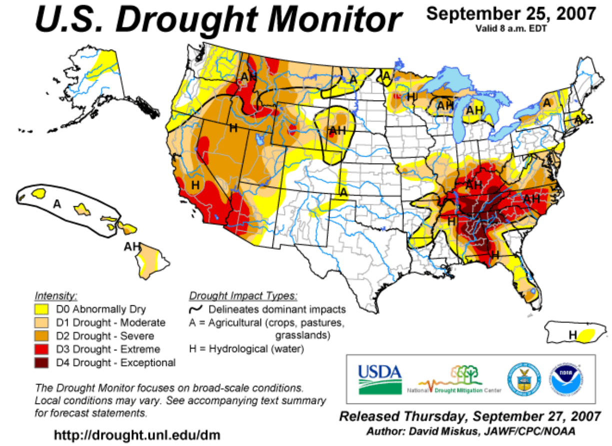
Sep 21, 2004



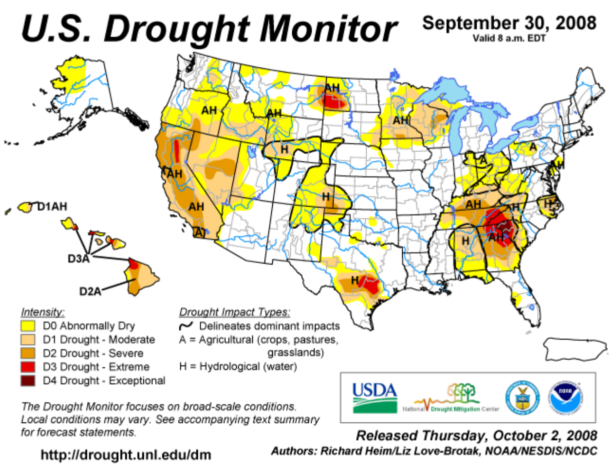
Sep 27, 2005



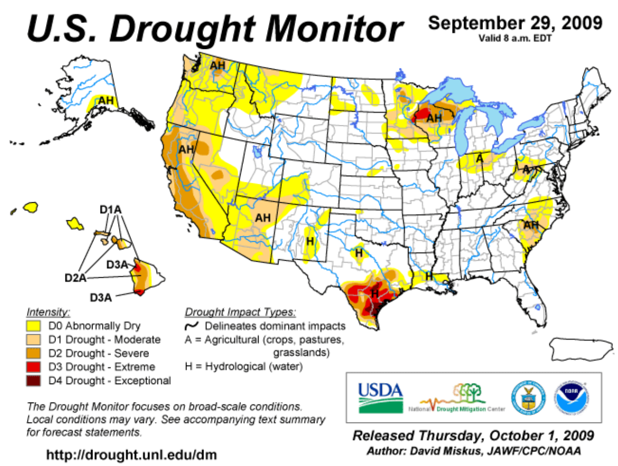
Sep 26, 2006



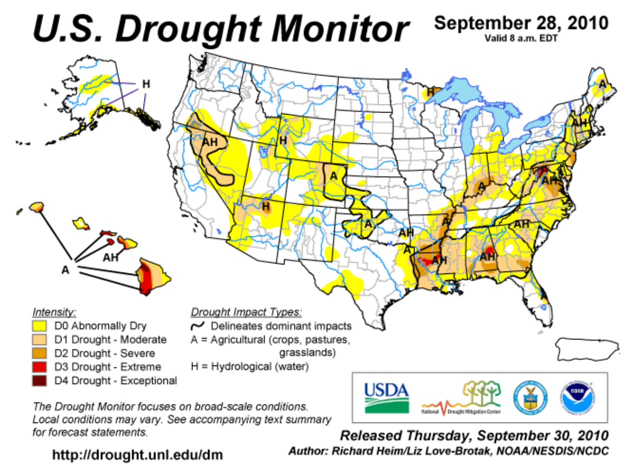
Sep 25, 2007



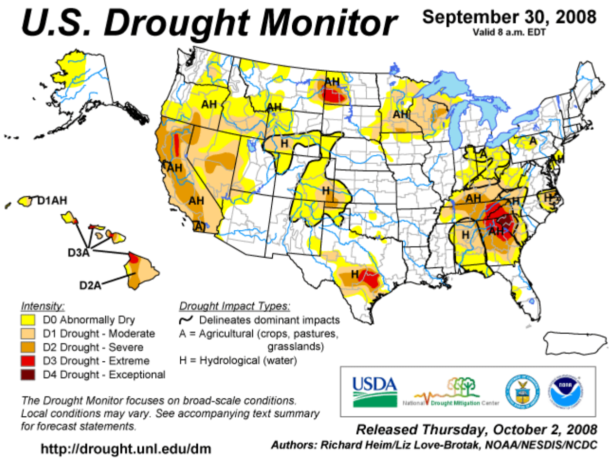
Sep 30, 2008



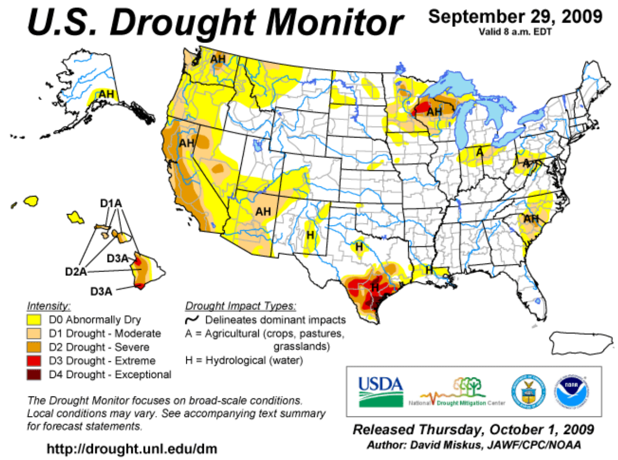
Sep 29, 2009



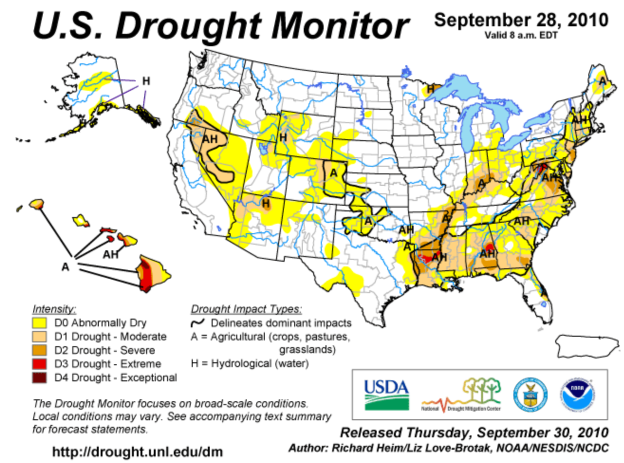
Sep 28, 2010



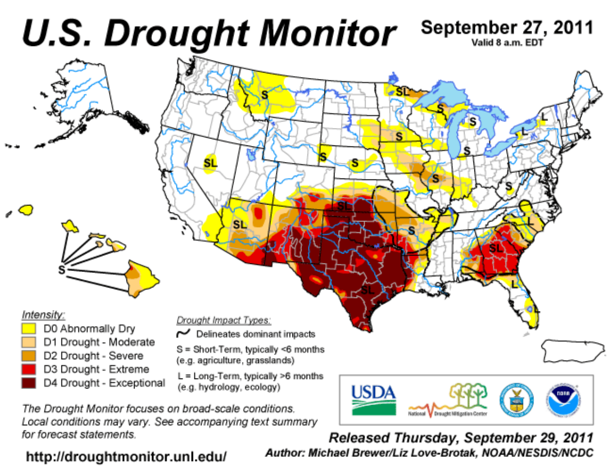
Sep 30, 2008



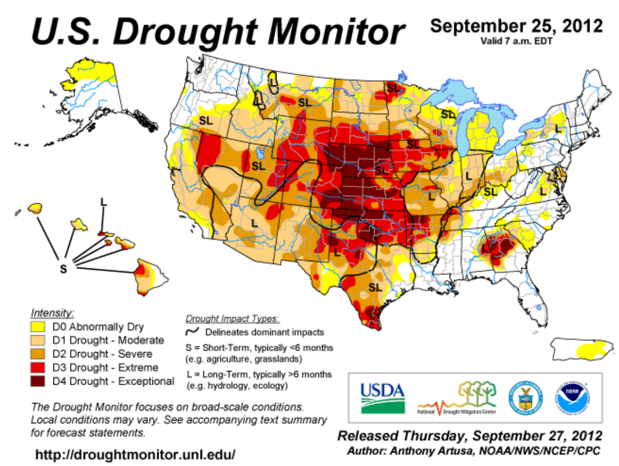
Sep 29, 2009



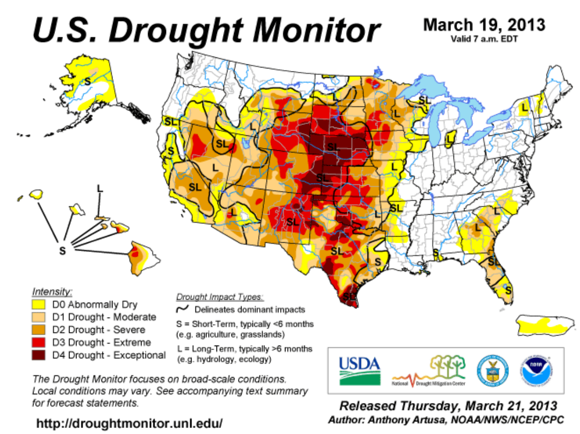
Sep 28, 2010



Sep 27, 2011



Sep 25, 2012



Mar 19, 2013

Leave Feedback

WestWideDroughtTracker

About | Current Maps | Archived Maps | Time Series | Contact

Select Year: 1934 Select Month: 12

Submit

Choose Year/Month, press Submit and then choose product below

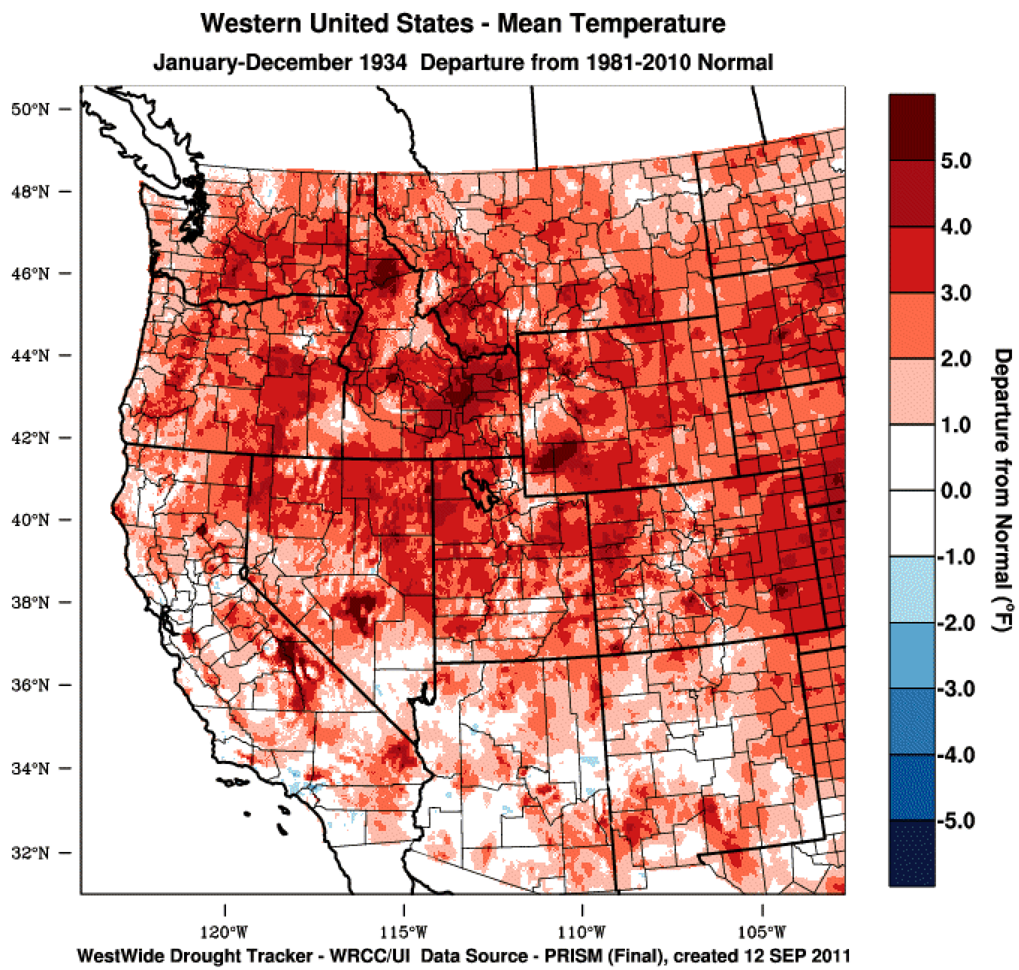
Climate Product Options

Expand All | Contract All

- Variable
  - Drought Index
  - Climate
    - Temperature
      - Anomaly
        - Last Full Month
        - Last 2-Months
        - Last 3-Months
        - Last 4-Months
        - Last 5-Months
        - Last 6-Months
        - Last 7-Months
        - Last 8-Months
        - Last 9-Months
        - Last 10-Months
        - Last 11-Months
        - Last 12-Months
      - Percentile
    - Precipitation
- Region
  - Western US
  - Arizona
  - California
  - Colorado
  - Idaho
  - Montana
  - Nevada
  - New Mexico
  - Oregon
  - Utah
  - Washington
  - Wyoming
  - United States

Archived Image: Jan - Dec 1934

PRISM > 012/1934 > Temperature Anomaly 12 Month > Western US



Download PRISM Temperature Anomaly 12 Month NETCDF Data for United States

Download PRISM Temperature Anomaly 12 Month GeoTIFF Data for United States

A New Tool

WRCC web pages

Monthly 4 km PRISM data

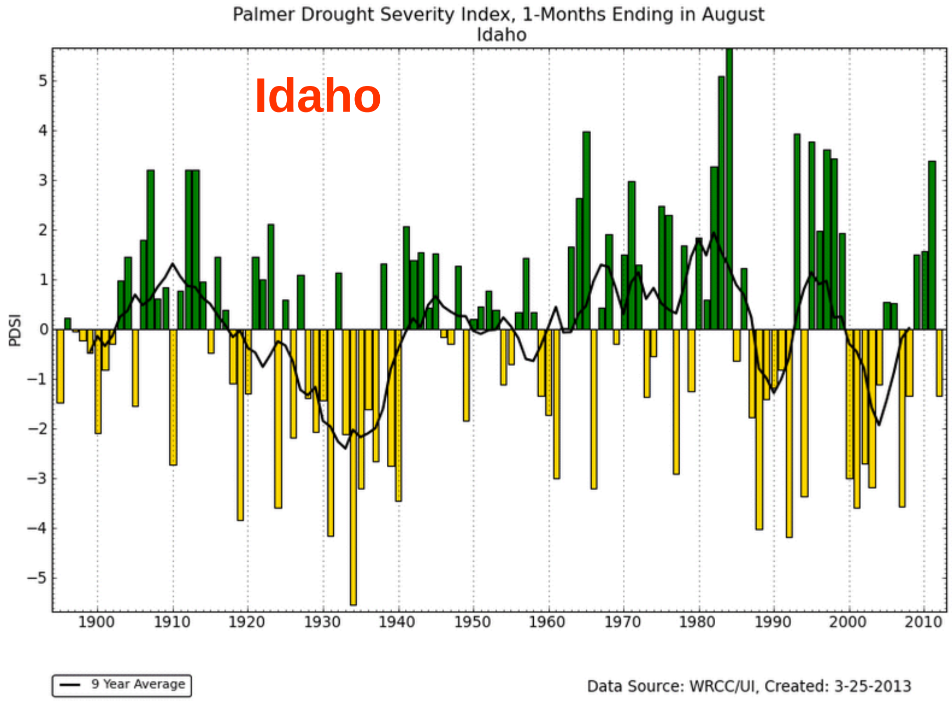
T, P, Palmer, SPI, SPEI

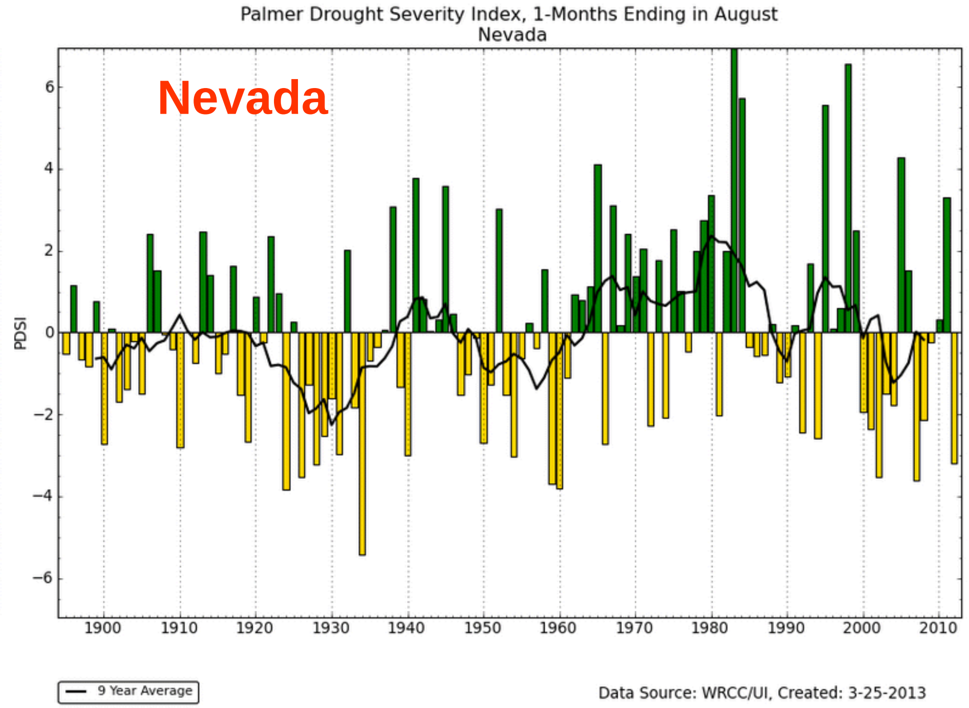
1-12 months

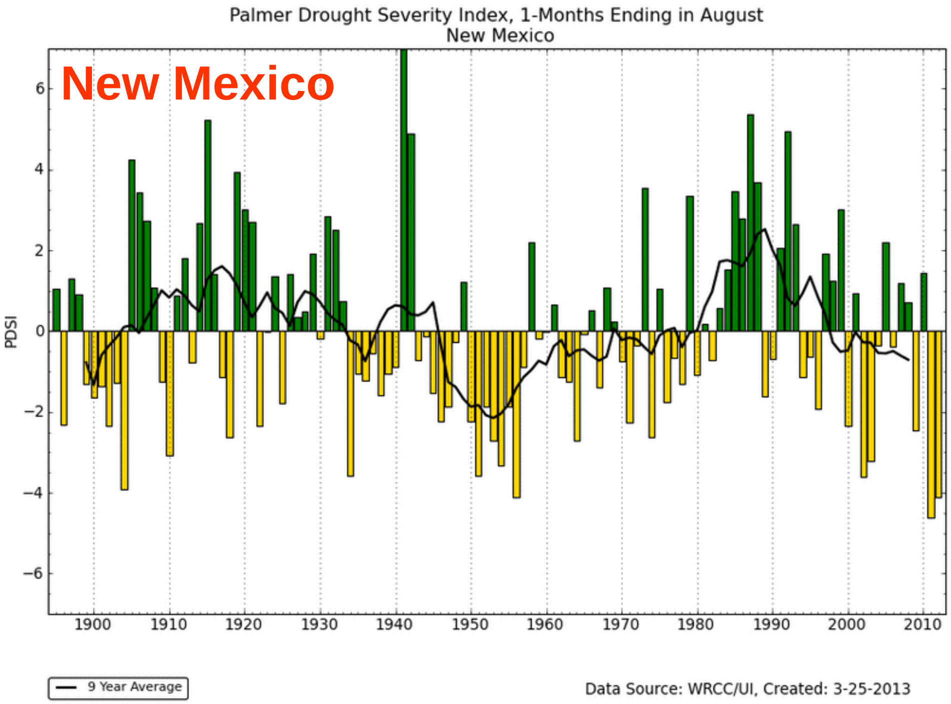
1895 - current

Maps and Time Series

Updated monthly







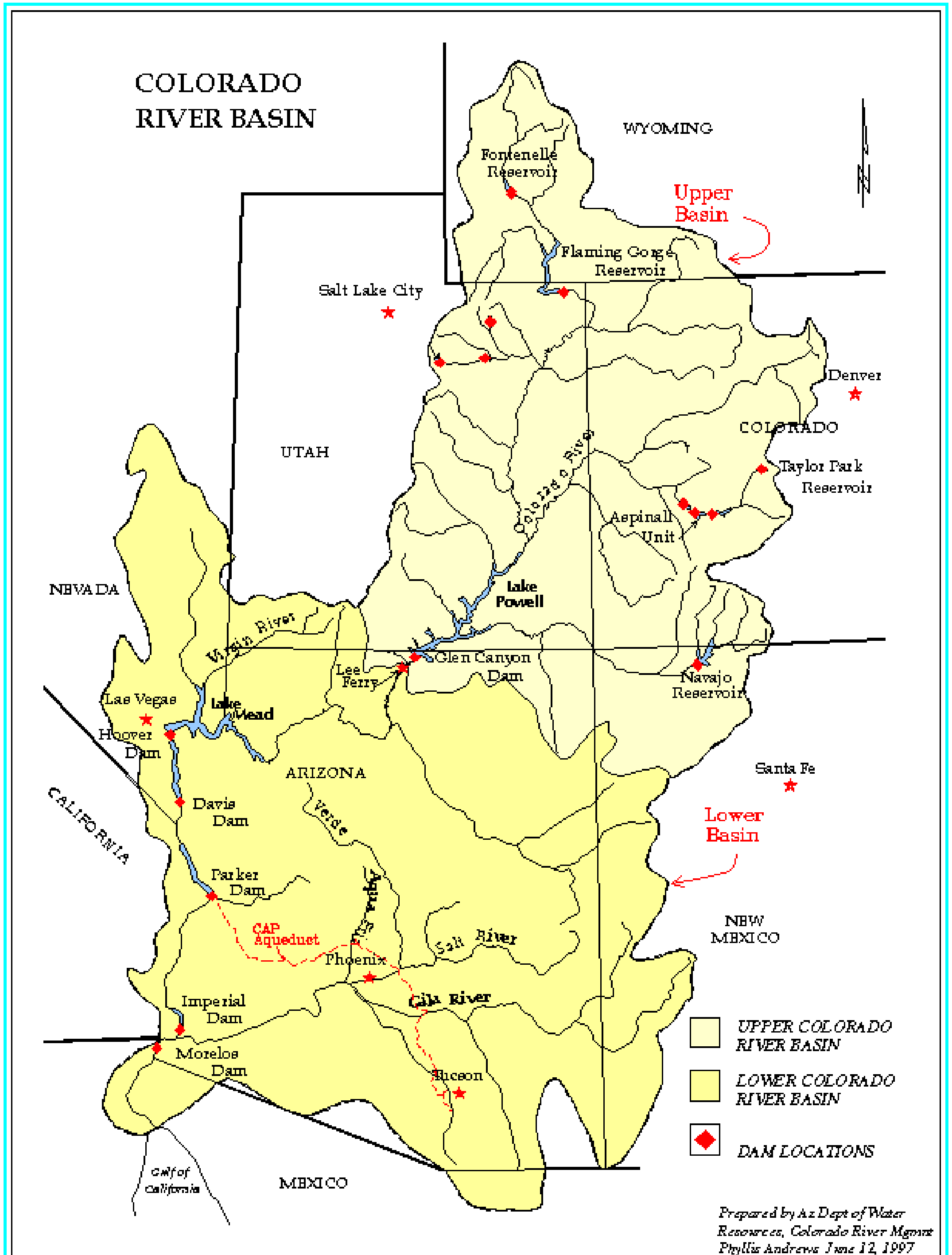
WestWide Drought Tracker

West-Wide (or Fine Scale) Drought Tracker

Palmer Drought Severity Index

August

1895 - 2012



Flow Projections

Temperature increase is equivalent to Precipitation decrease

Colorado River at Lees Ferry

Decline of 2-9 % per degree C

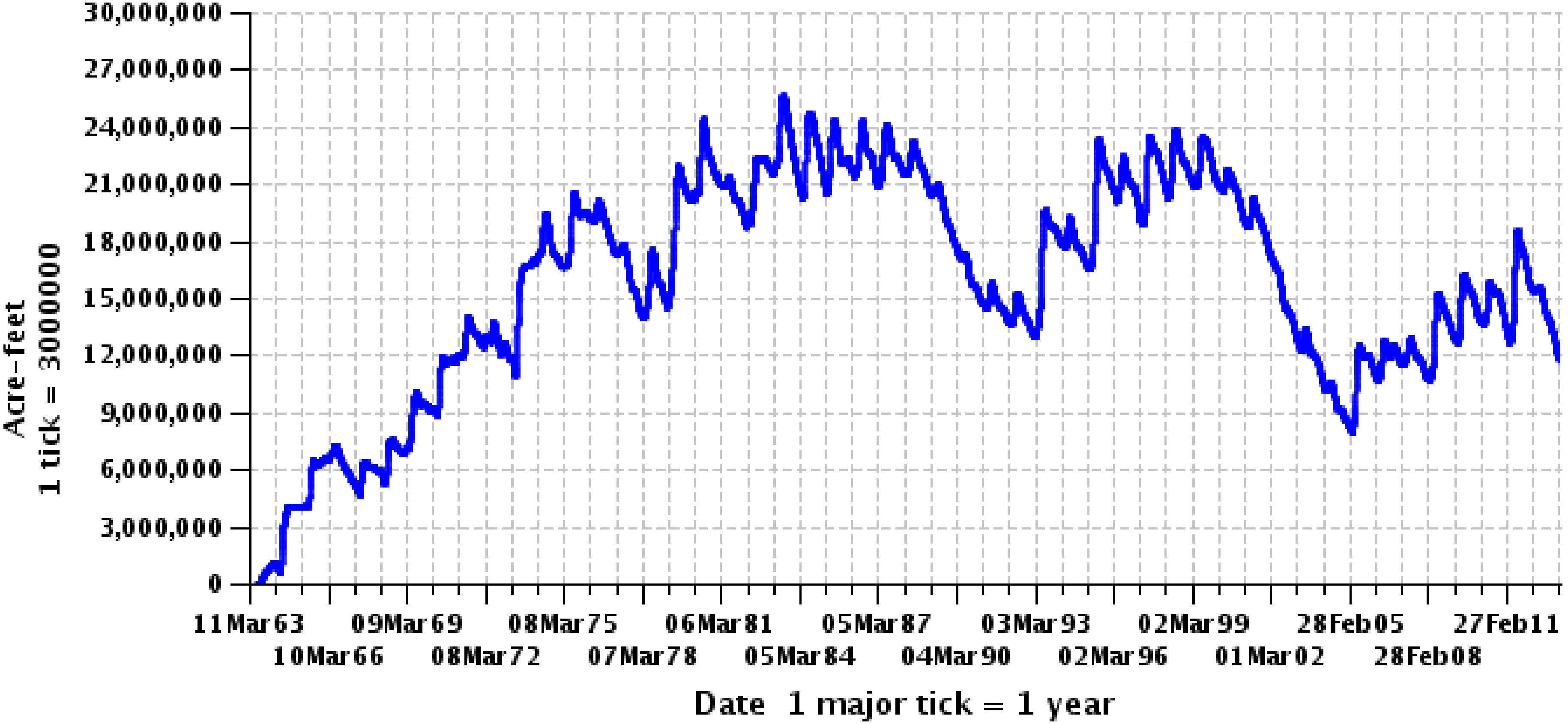
Decline of 1-5 % per degree F

Or, for +3 C rise by 2060,

Best estimate: 10-20 % decline

Vano, Das, Lettenmaier, 2012.
Hydrologic Sensitivities of Colorado River Runoff to Changes in Precipitation and Temperature.
J Hydrometeorology, 13, 932-949.
DOI: 10.1175/JHM-D-11-069.1

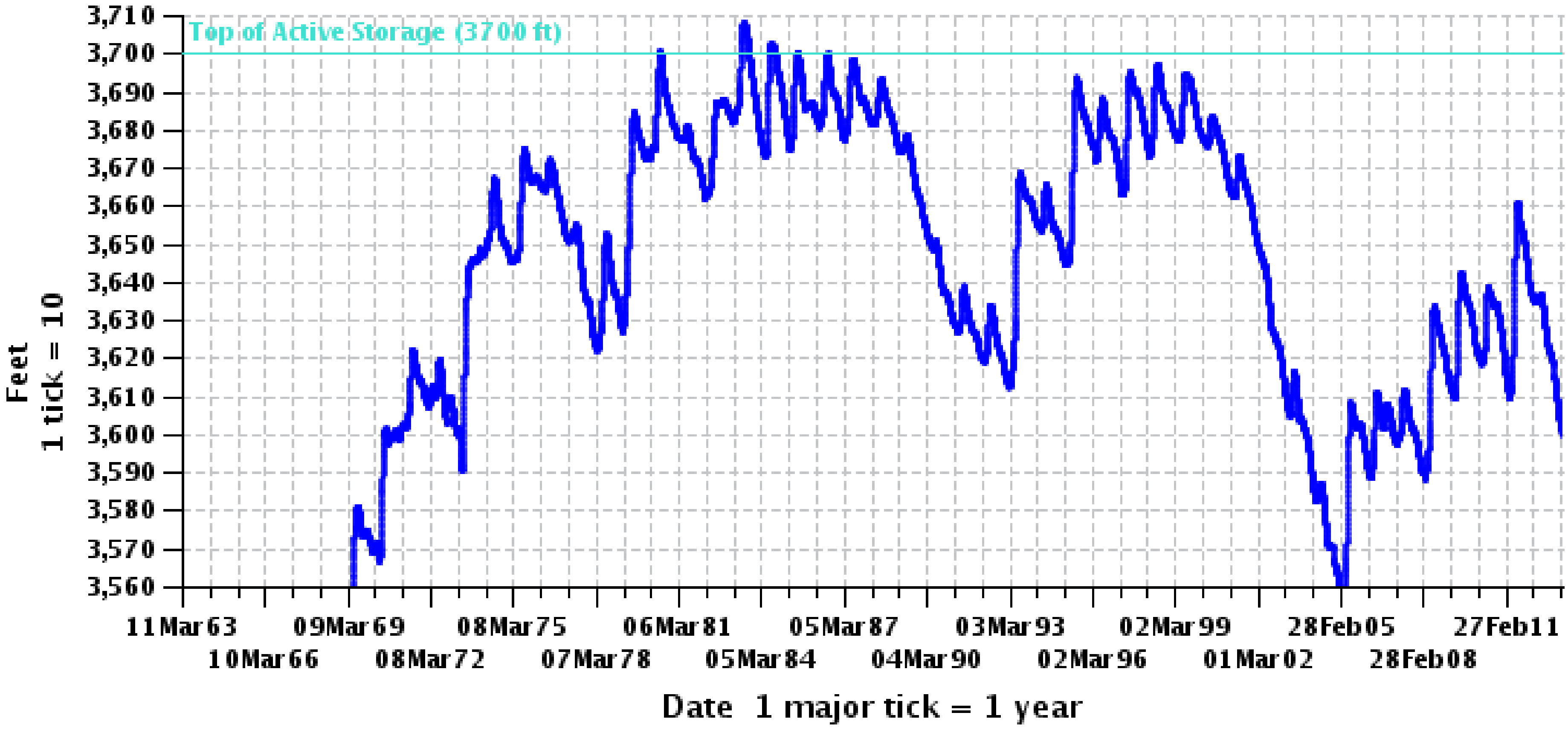
Lake Powell Storage Through March 22, 2013



Currently 49 % full (capacity 24.17 MAF)

Minimum: 33 % full on April 8, 2005

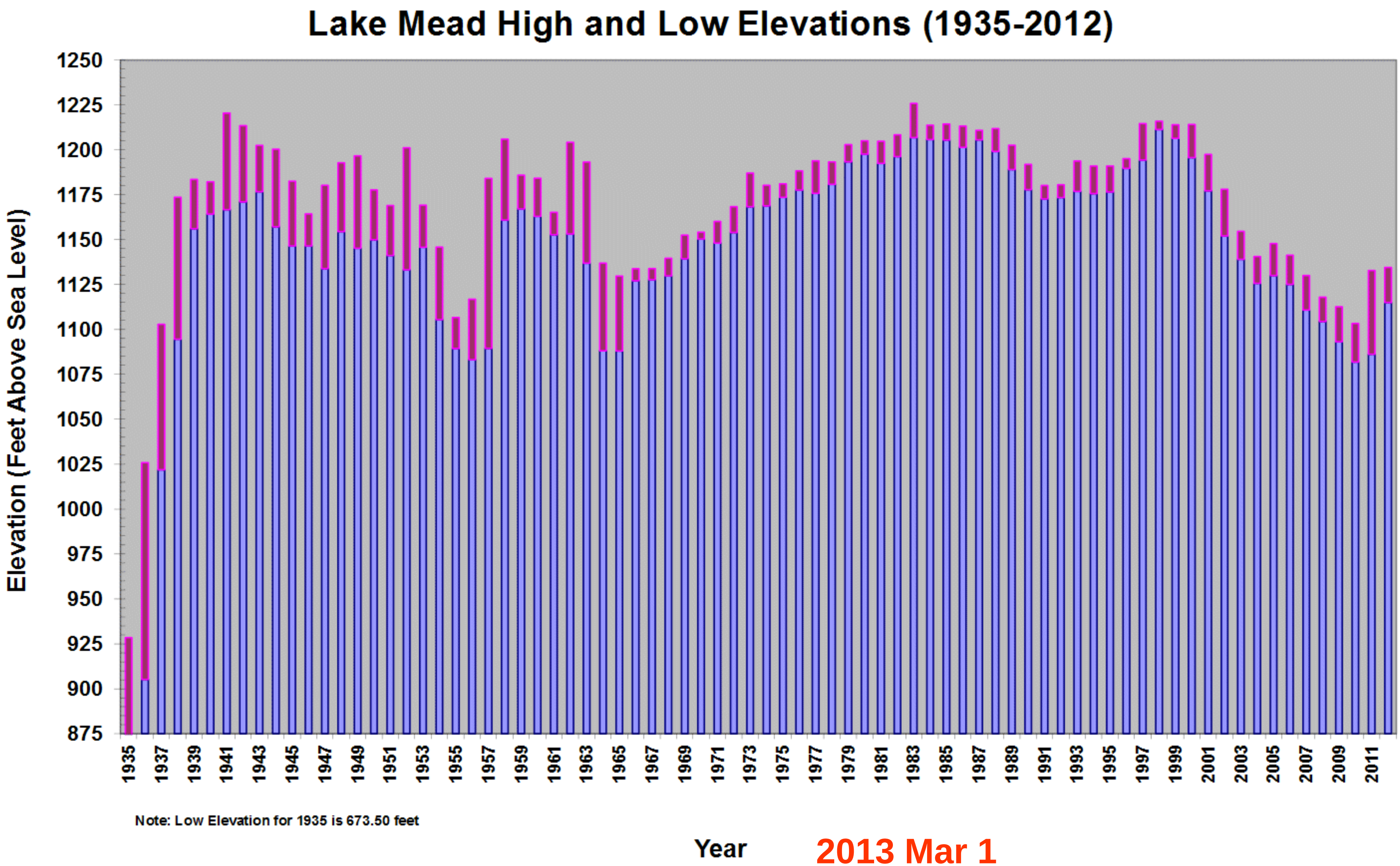
Lake Powell Elevation Through March 22, 2013



Water level on Mar 3, 2011 was 3599.89 ft, - 100 ft below full.

Minimum level on April 8, 2005 was 3555 ft, -145 ft below full.

Source: www.usbr.gov/uc/water/index.htl



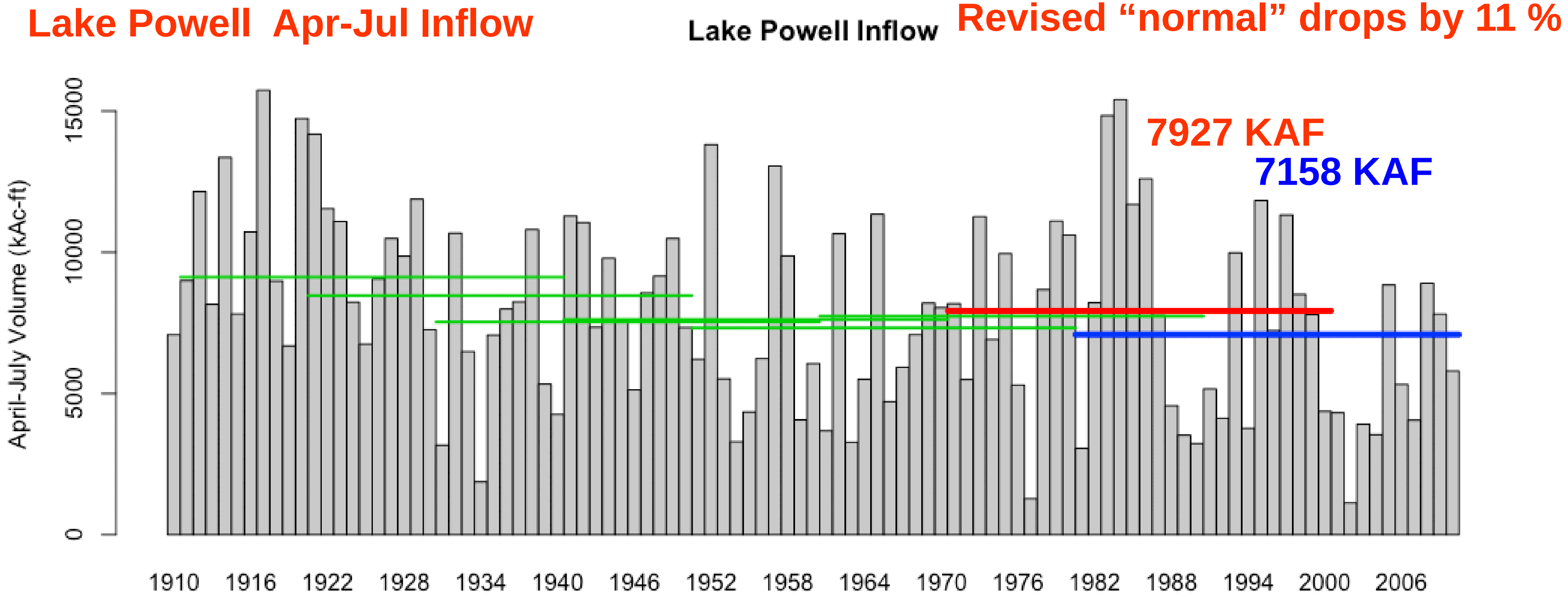
2013 Mar 1
Powell 49 % Mead 53%
Powell WY2011 fcst inflow is
54 % of average (Apr-July 54 %)

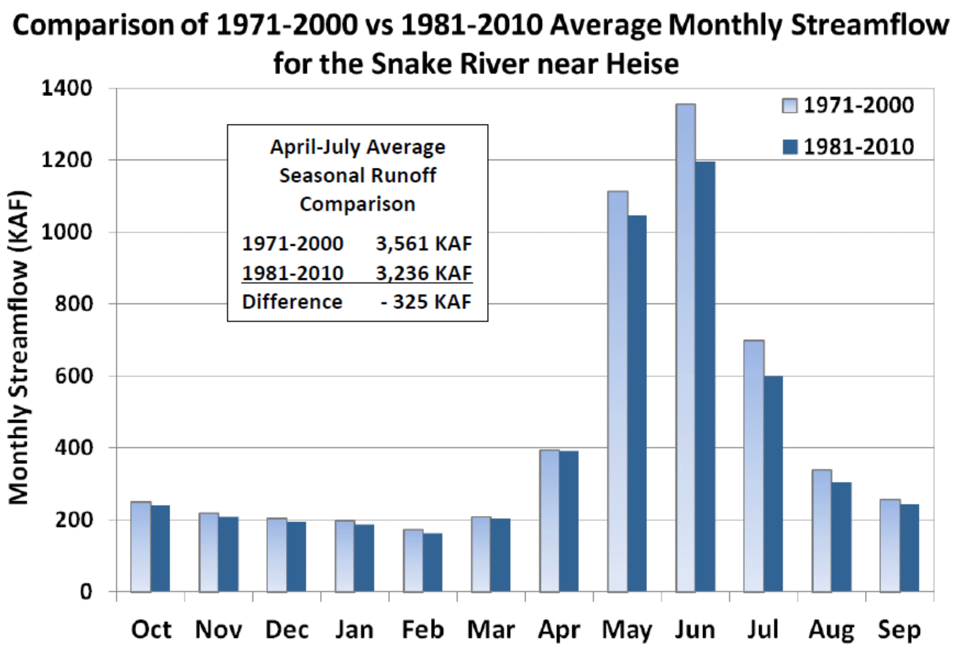
Lake Mead, October 2007

Photo by Ken Dewey

Lake Powell Apr-Jul Inflow

Revised "normal" drops by 11 %





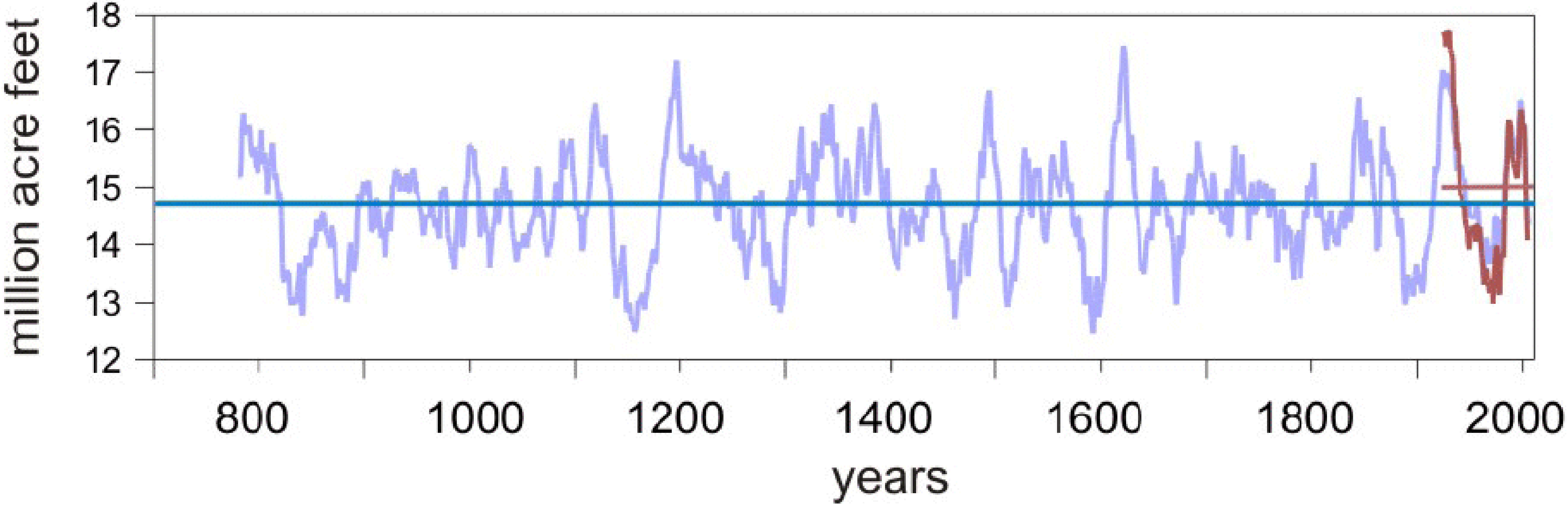
Idaho Example, Too.

Snake River near Heise.

drop by 9 %

Lessons from History.

Colorado River Flow. Lees Ferry. Reconstructed 762 thru 2005 A.D.

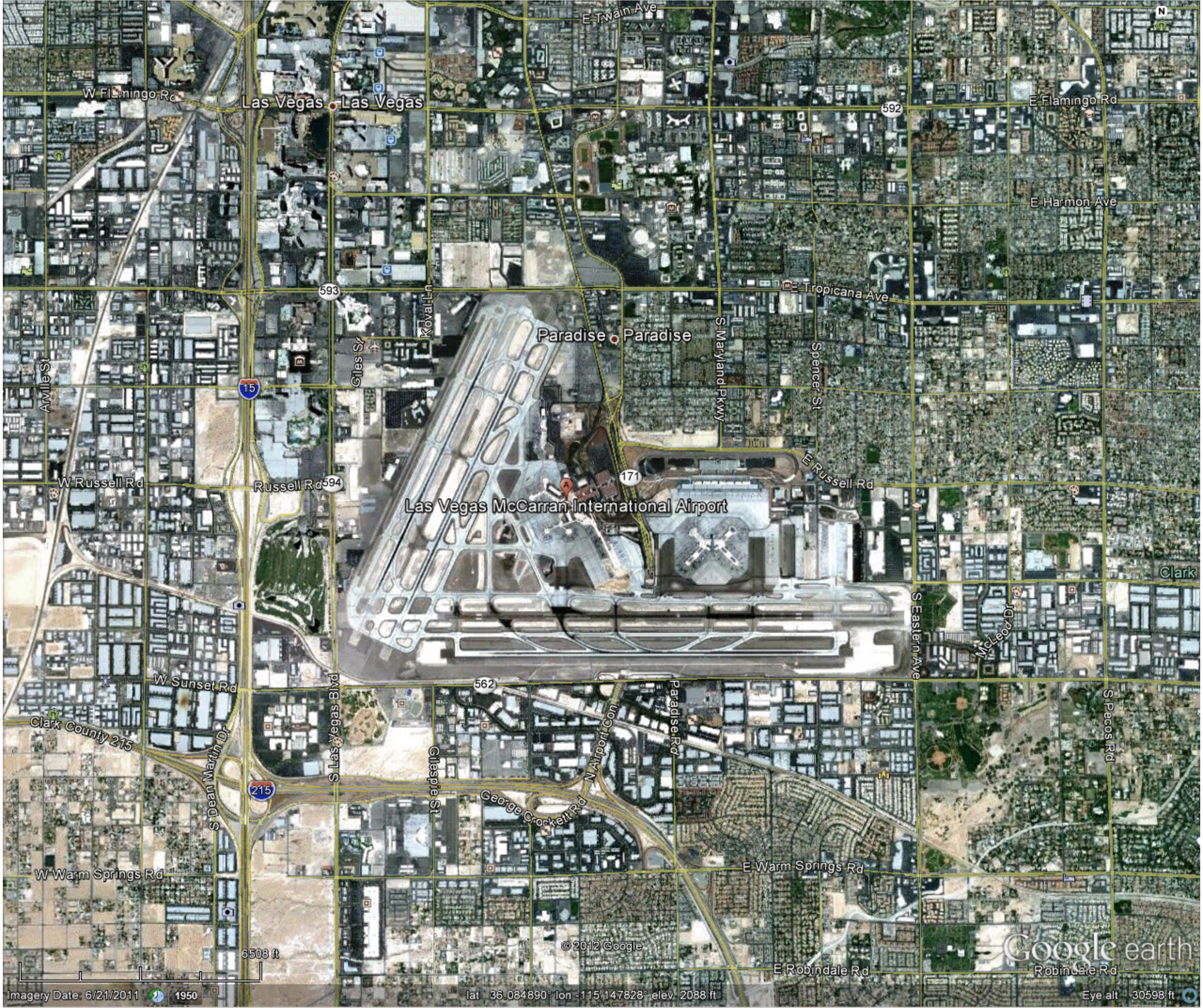


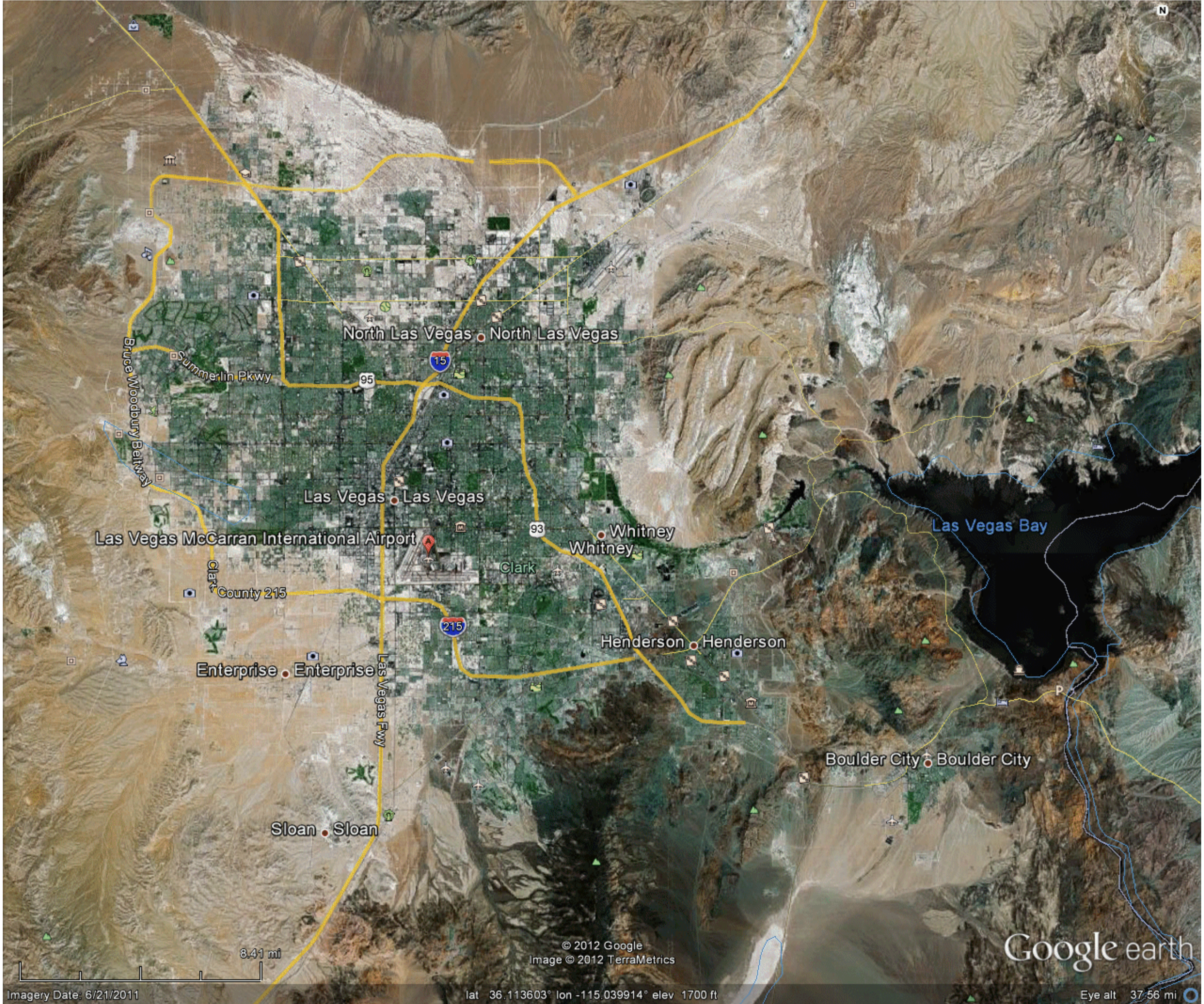
Red: Gauged record.
Blue: Reconstructed record.
20-Year moving averages.

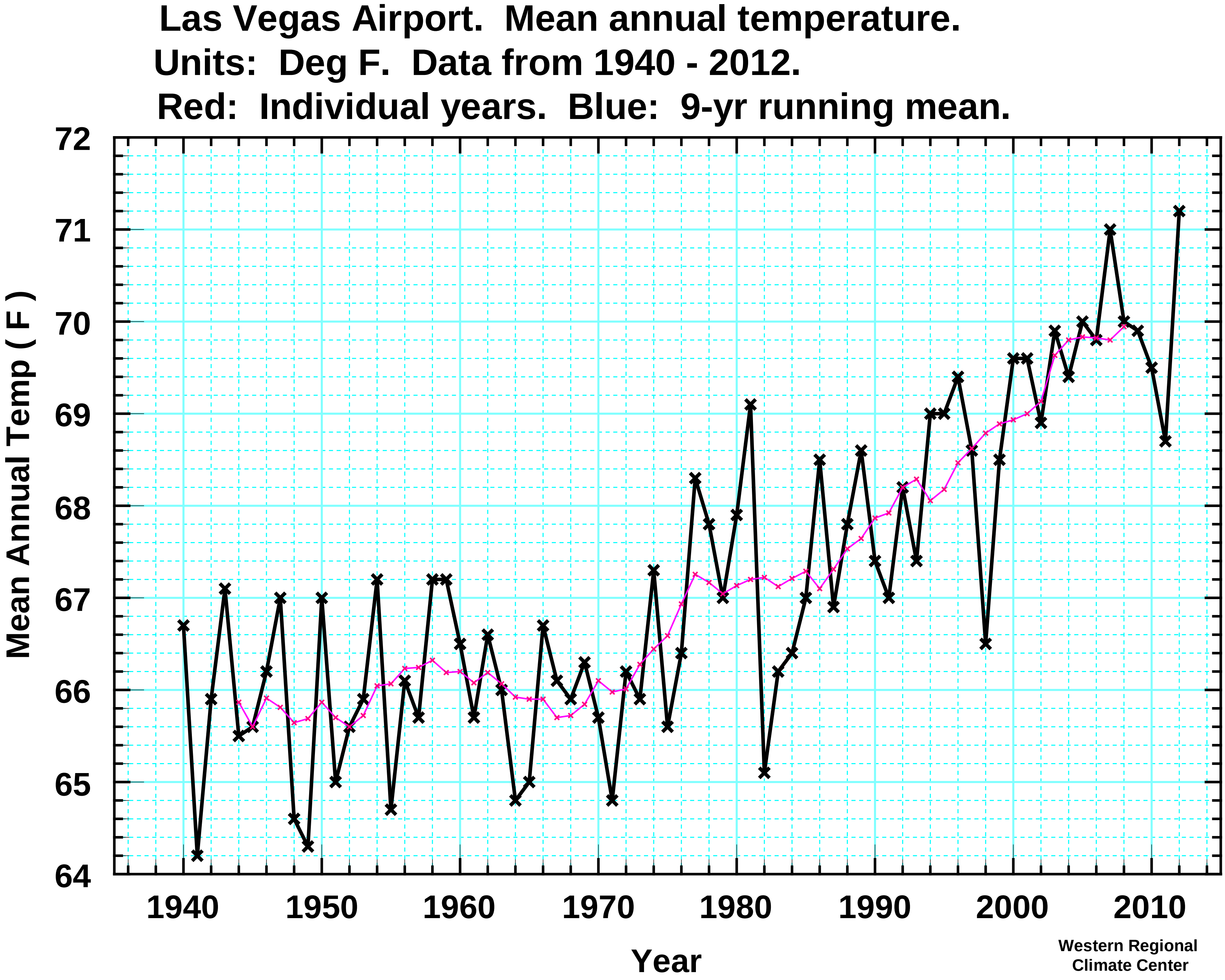
Meko, D.M., C.A. Woodhouse, C.H. Baisan, T. Knight, J.J. Lukas, M.K. Hughes, and M.W. Salzer, 2007. Medieval drought in the upper Colorado River basin. Geophysical Research Letters 34m L10705, doi: 10.1029/2007GL029988

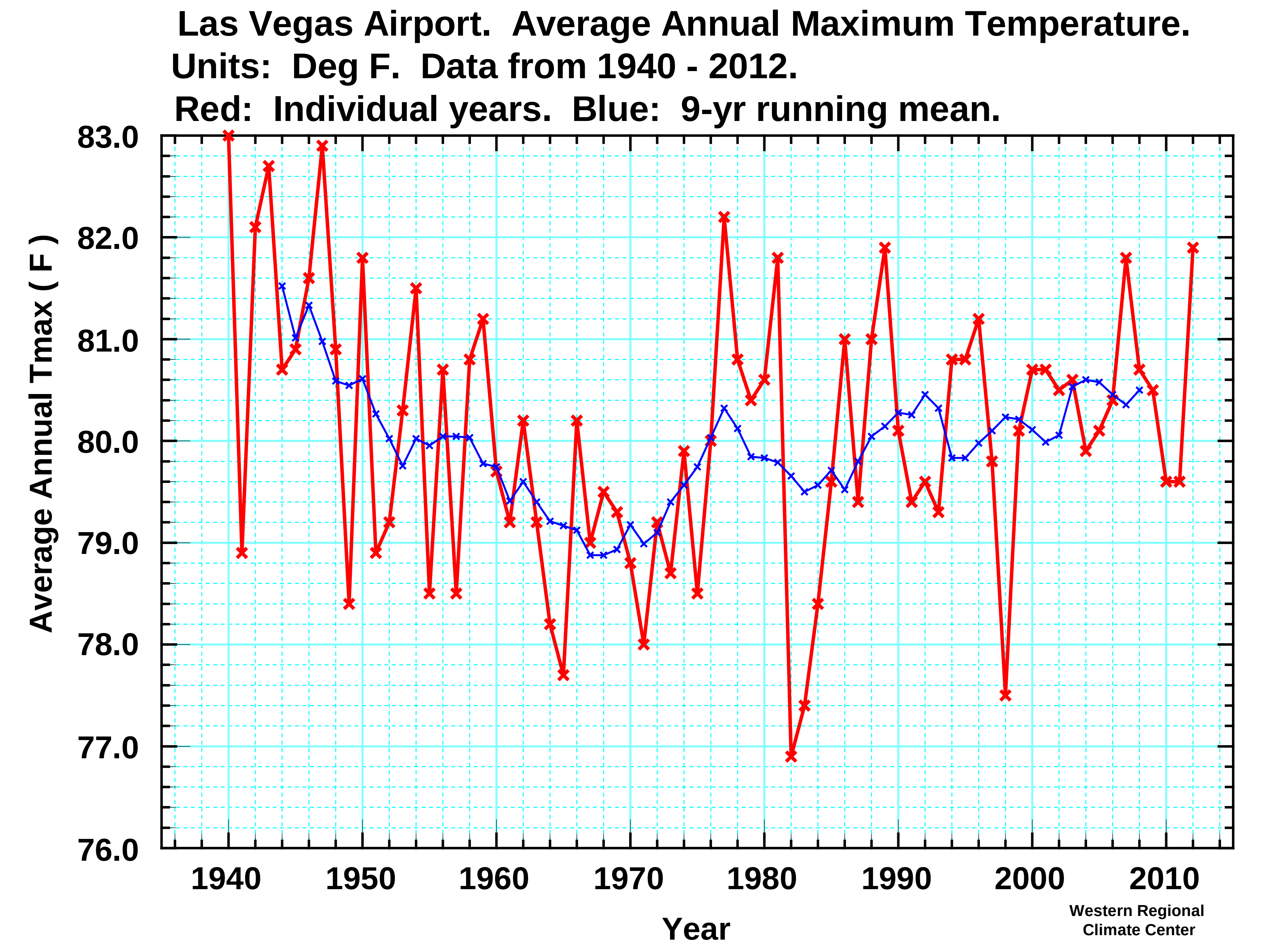
The Climate We Remember

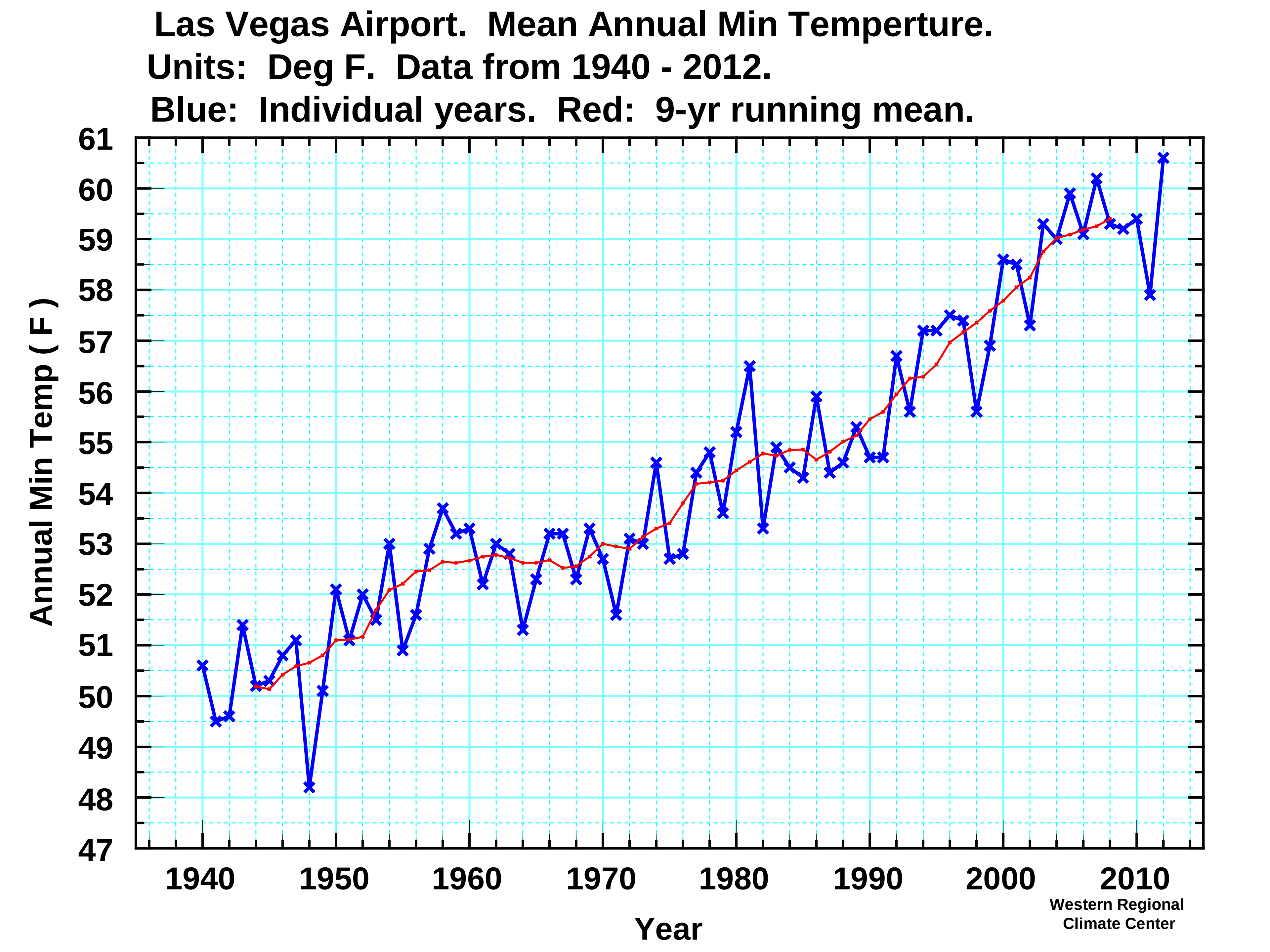
Extremes

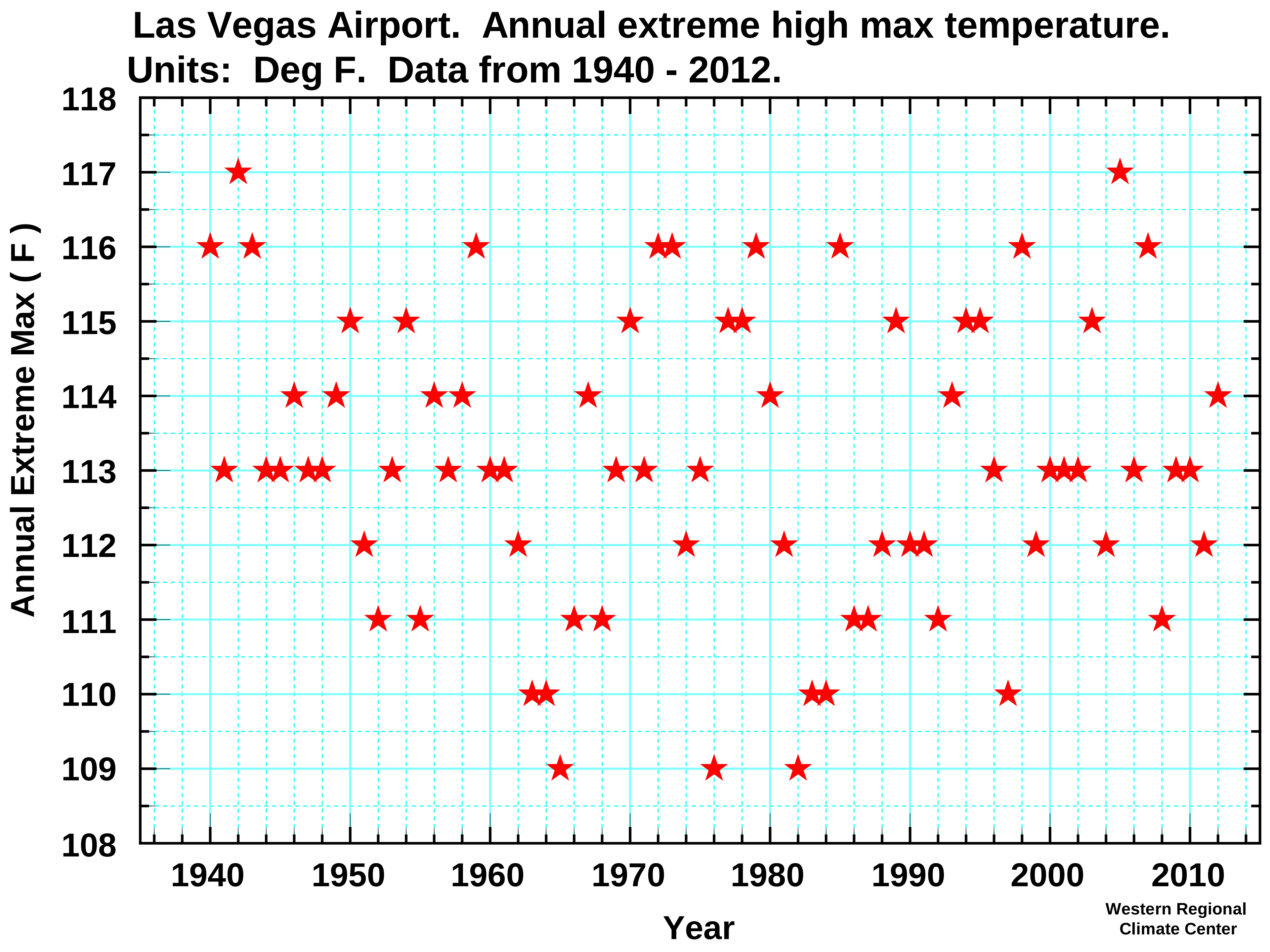

E Twain Ave
W Flamingo Rd
Las Vegas
Las Vegas
592
E Flamingo Rd
E Harmon Ave
593
Tropicana Ave
Paradise
Paradise
Koval Ln
Giles St
S Maryland Pkwy
Spencer St
Arville St
15
171
E Russell Rd
W Russell Rd
Russell Rd
594
Las Vegas McCarran International Airport
Clark
S Eastern Ave
McLeod Dr
W Sunset Rd
562
Paradise Rd
S Pecos Rd
Clark County 215
S Dean Martin Dr
S Las Vegas Blvd
Gilespie St
N Airport Con
215
George Crockett Rd
W Warm Springs Rd
E Warm Springs Rd
© 2012 Google
Google earth
6508 ft
E Robindale Rd
Robindale Rd
Imagery Date: 6/21/2011
1950
lat 36.084890° lon -115.147828° elev 2088 ft
Eye alt 30598 ft

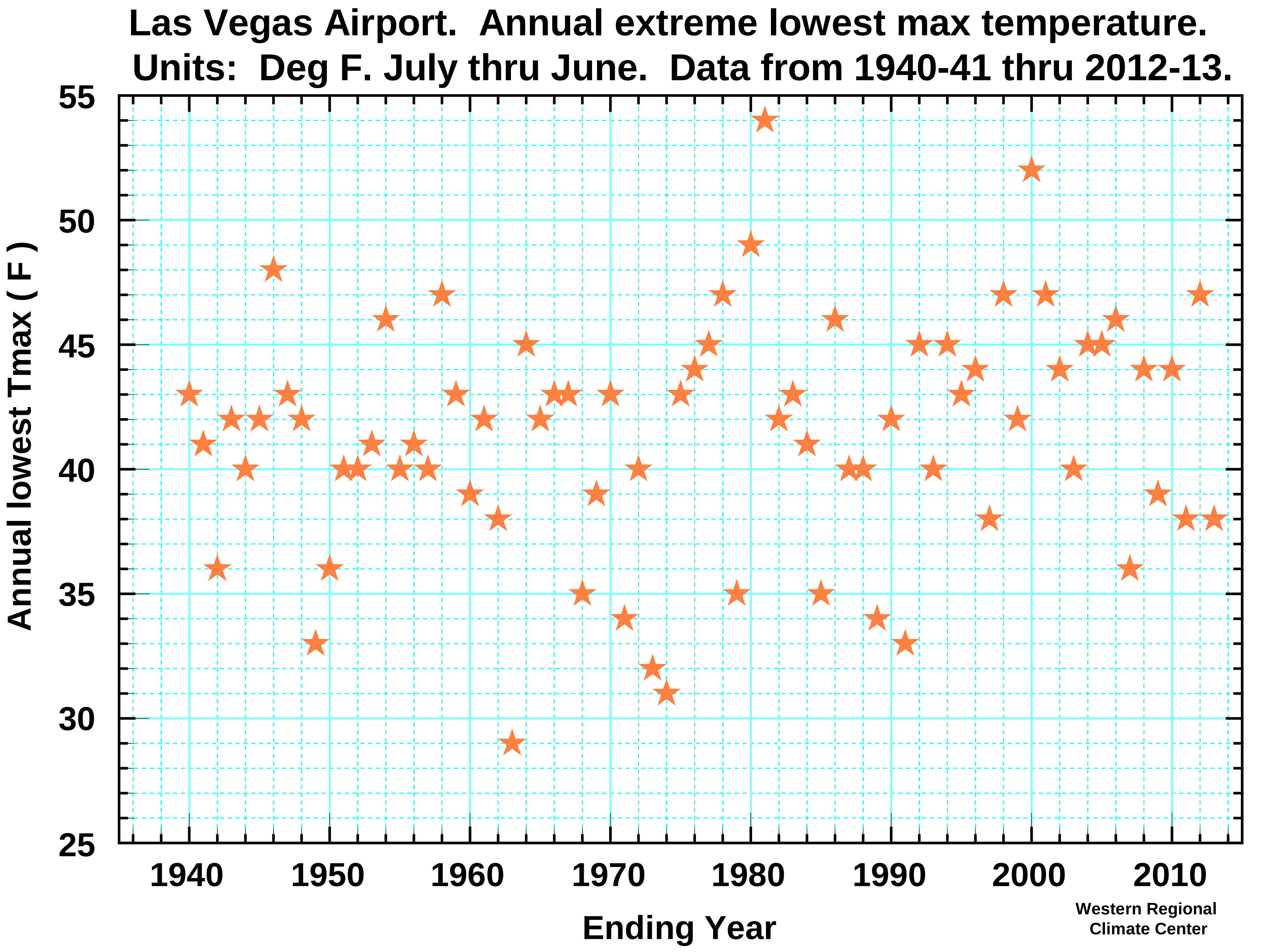

North Las Vegas
North Las Vegas
15
95
Summerlin Pkwy
Bruce Woodbury Beltway
Las Vegas
Las Vegas
Las Vegas McCarran International Airport
93
Whitney
Whitney
Clark
Clark
County 215
215
Henderson
Henderson
Enterprise
Enterprise
Las Vegas Fwy
Las Vegas Bay
Boulder City
Boulder City
Sloan
Sloan
8.41 mi
© 2012 Google
Image © 2012 TerraMetrics
Google earth
Imagery Date: 6/21/2011
lat 36.113603° lon -115.039914° elev 1700 ft
Eye alt 37.56 mi


Las Vegas Airport. Mean annual temperature.
Units: Deg F. Data from 1940 - 2012.
Red: Individual years. Blue: 9-yr running mean.
72
71
70
69
68
67
66
65
64
Mean Annual Temp (F)
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

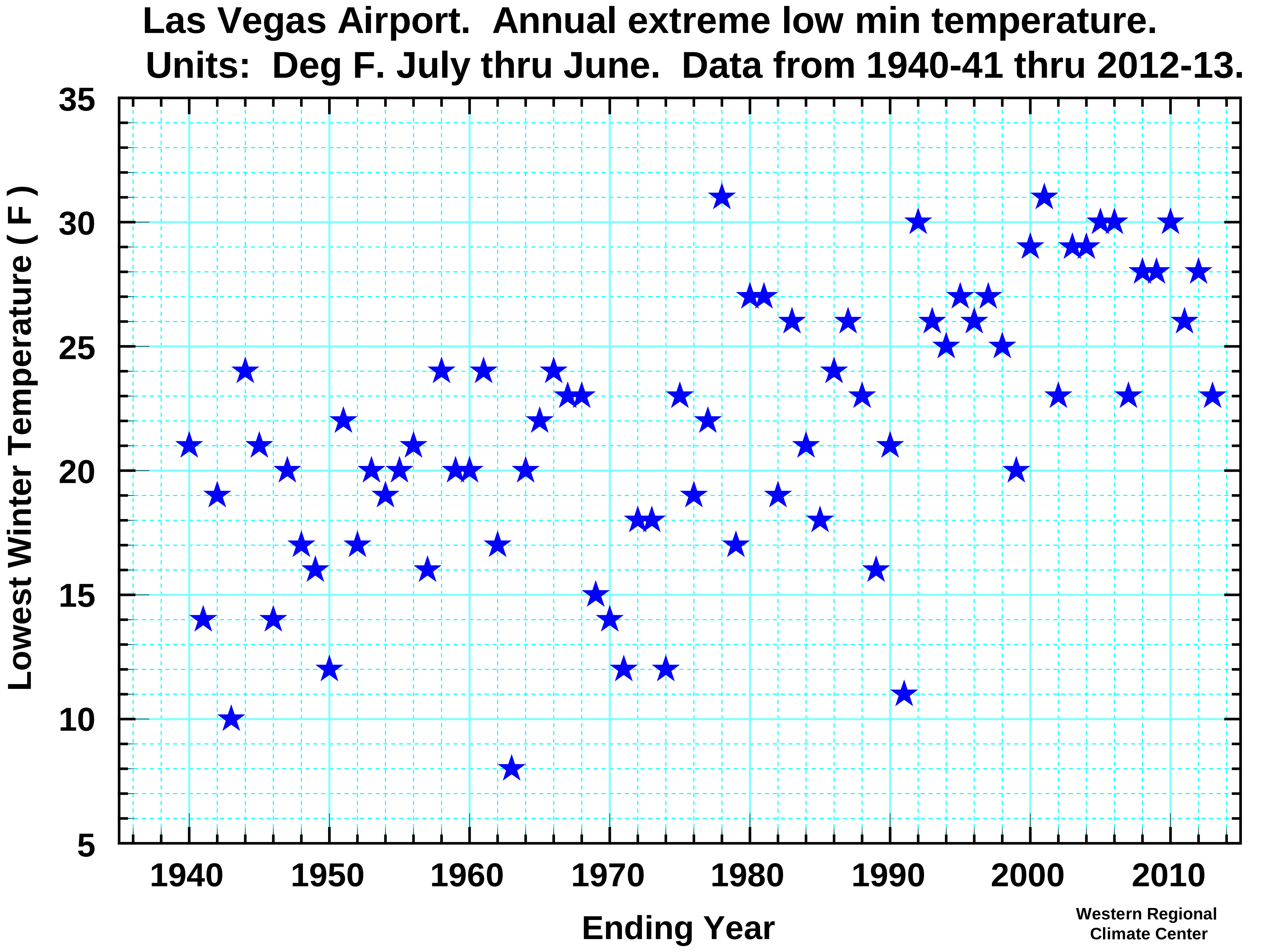

Las Vegas Airport. Average Annual Maximum Temperature.
Units: Deg F. Data from 1940 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Average Annual Tmax (F)
83.0
82.0
81.0
80.0
79.0
78.0
77.0
76.0
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center


Las Vegas Airport. Mean Annual Min Temperture.
Units: Deg F. Data from 1940 - 2012.
Blue: Individual years. Red: 9-yr running mean.
Annual Min Temp (F)
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

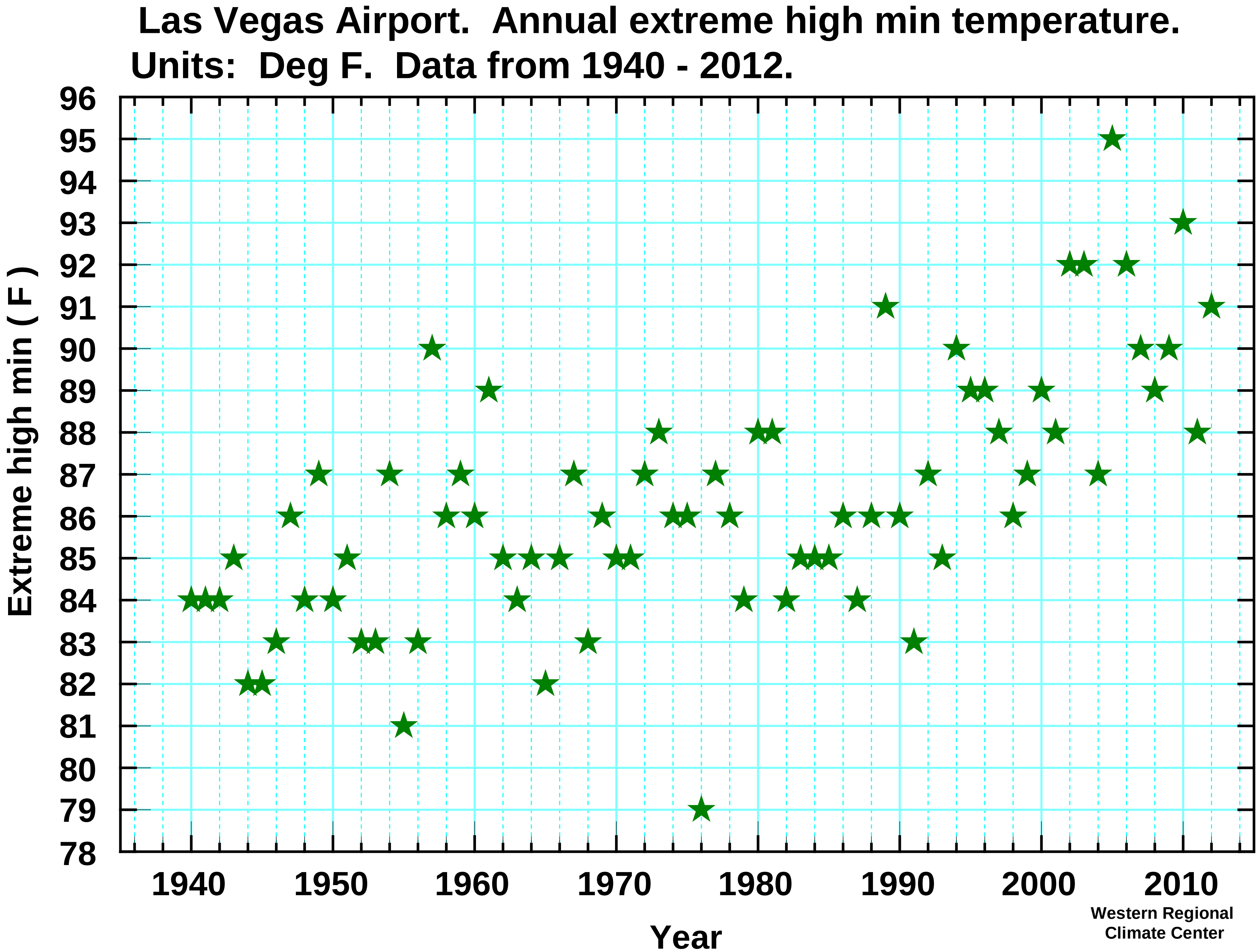

Las Vegas Airport. Annual extreme high max temperature.
Units: Deg F. Data from 1940 - 2012.
118
117
116
115
114
113
112
111
110
109
108
Annual Extreme Max (F)
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center



Las Vegas Airport. Annual extreme lowest max temperature.
Units: Deg F. July thru June. Data from 1940-41 thru 2012-13.
Annual lowest Tmax (F)
55
50
45
40
35
30
25
1940
1950
1960
1970
1980
1990
2000
2010
Ending Year
Western Regional
Climate Center



Las Vegas Airport. Annual extreme low min temperature.
Units: Deg F. July thru June. Data from 1940-41 thru 2012-13.
Lowest Winter Temperature (F)
35
30
25
20
15
10
5
1940
1950
1960
1970
1980
1990
2000
2010
Ending Year
Western Regional
Climate Center

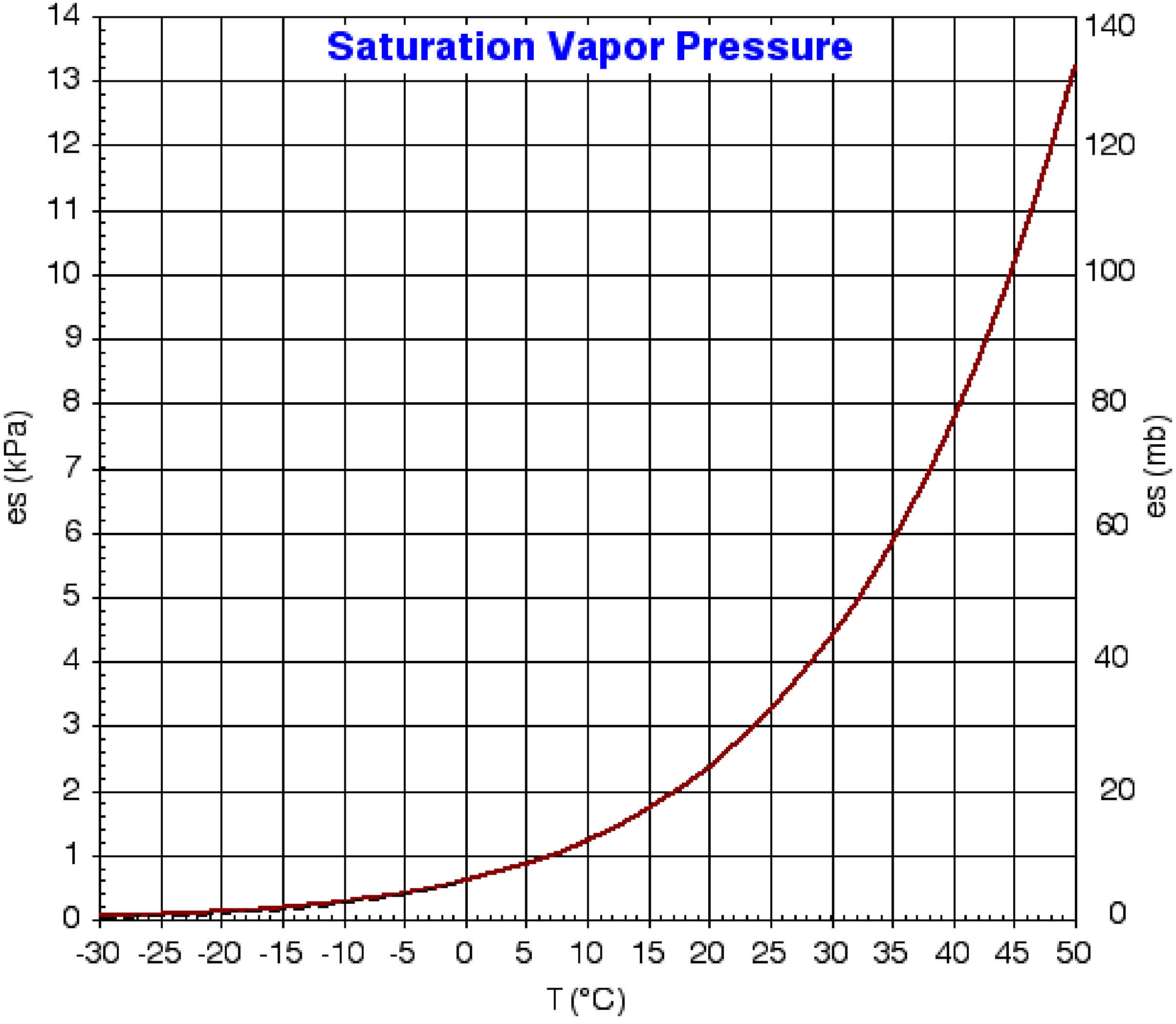


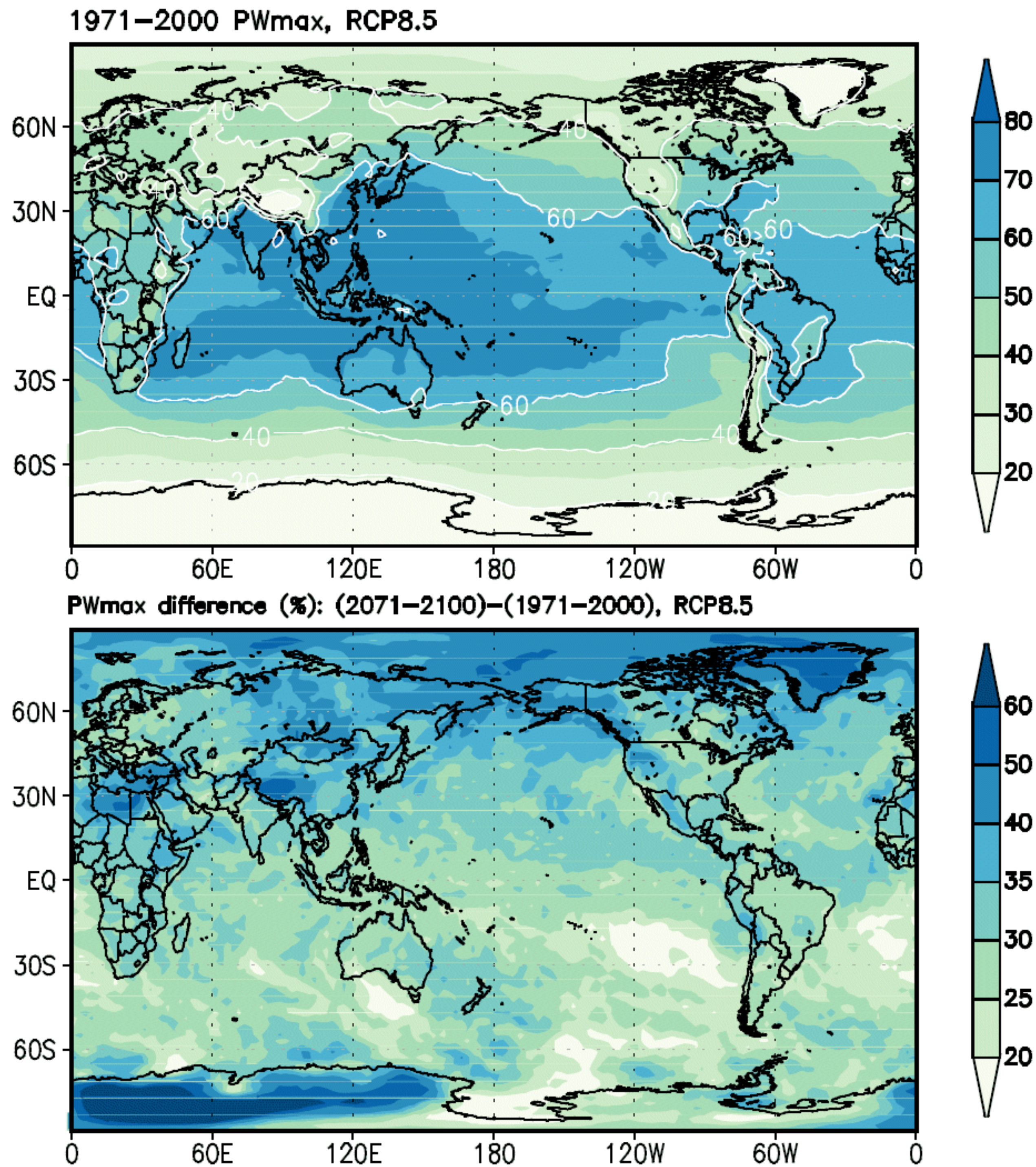
Las Vegas Airport. Annual extreme high min temperature.
Units: Deg F. Data from 1940 - 2012.
96
95
94
93
92
91
90
89
88
87
86
85
84
83
82
81
80
79
78
Extreme high min (F)
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

How much water can the atmosphere “hold” ?

Clausius-Clapeyron relation for plane (flat) water surface

Saturation vapor pressure increases 35-40 % per 5 C increase





Precipitable Water

Maximum Values

7 CMIP5 Models

<u>Present</u>
1971-2000

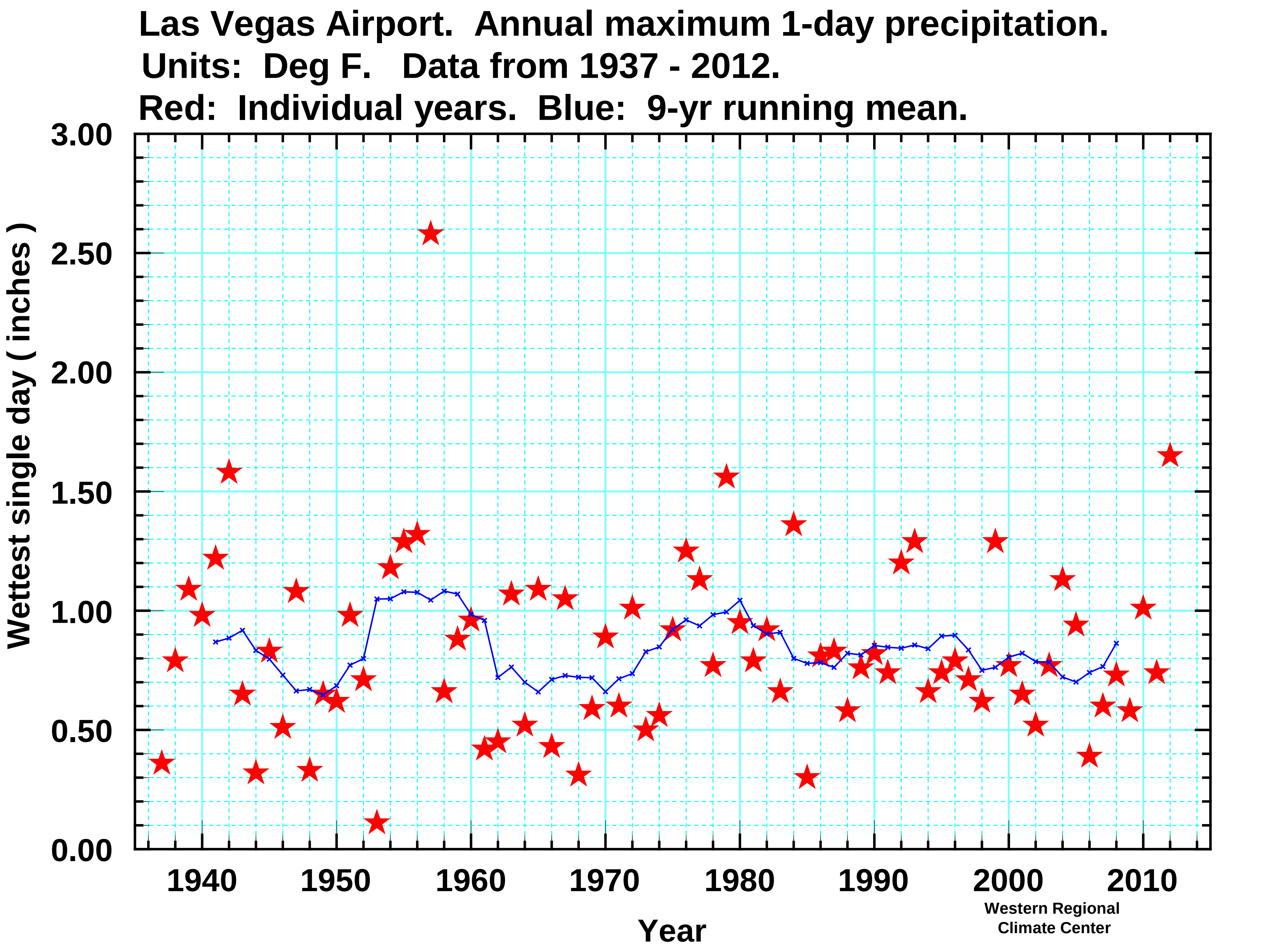
mm

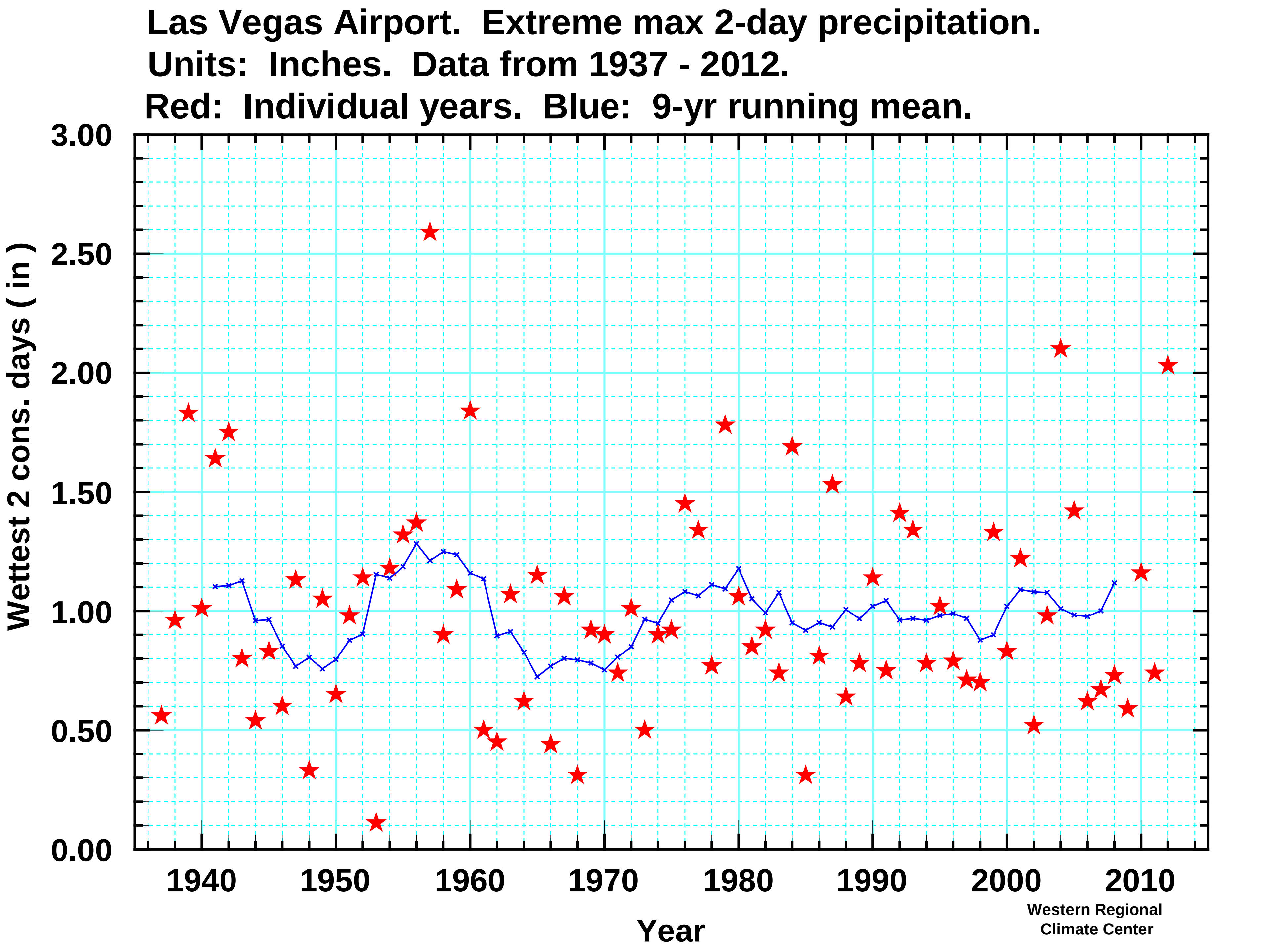
<u>Future</u>
2071-2100 / 1970-2000

Percent increase

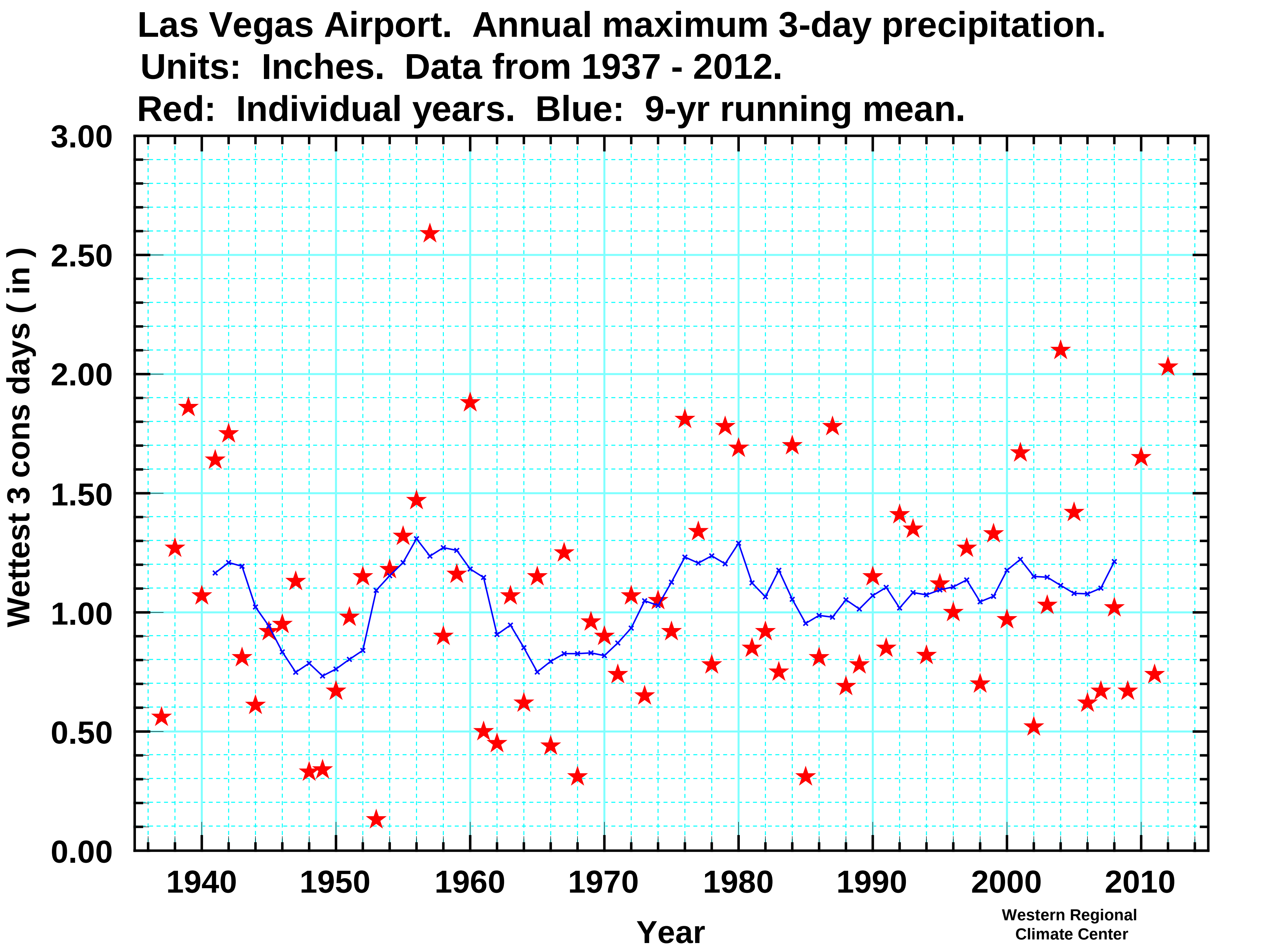
Probable Maximum Precipitation (PMP) and Climate Change.

Kunkel, Karl, Easterling, Redmond, Young, Yin, Hennon. 2013.
Geophysical Research Letters

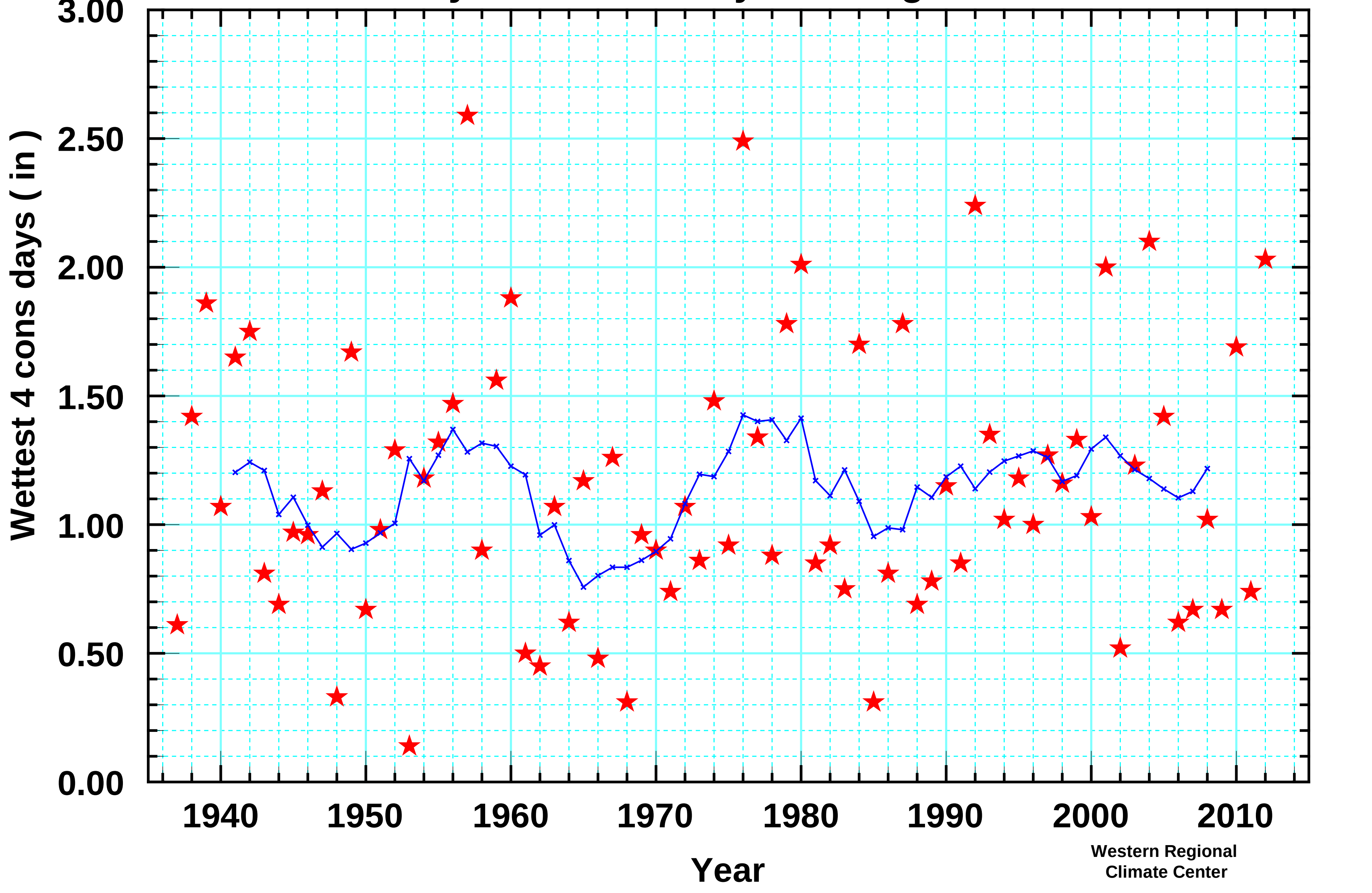

Las Vegas Airport. Annual maximum 1-day precipitation.
Units: Deg F. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest single day (inches)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

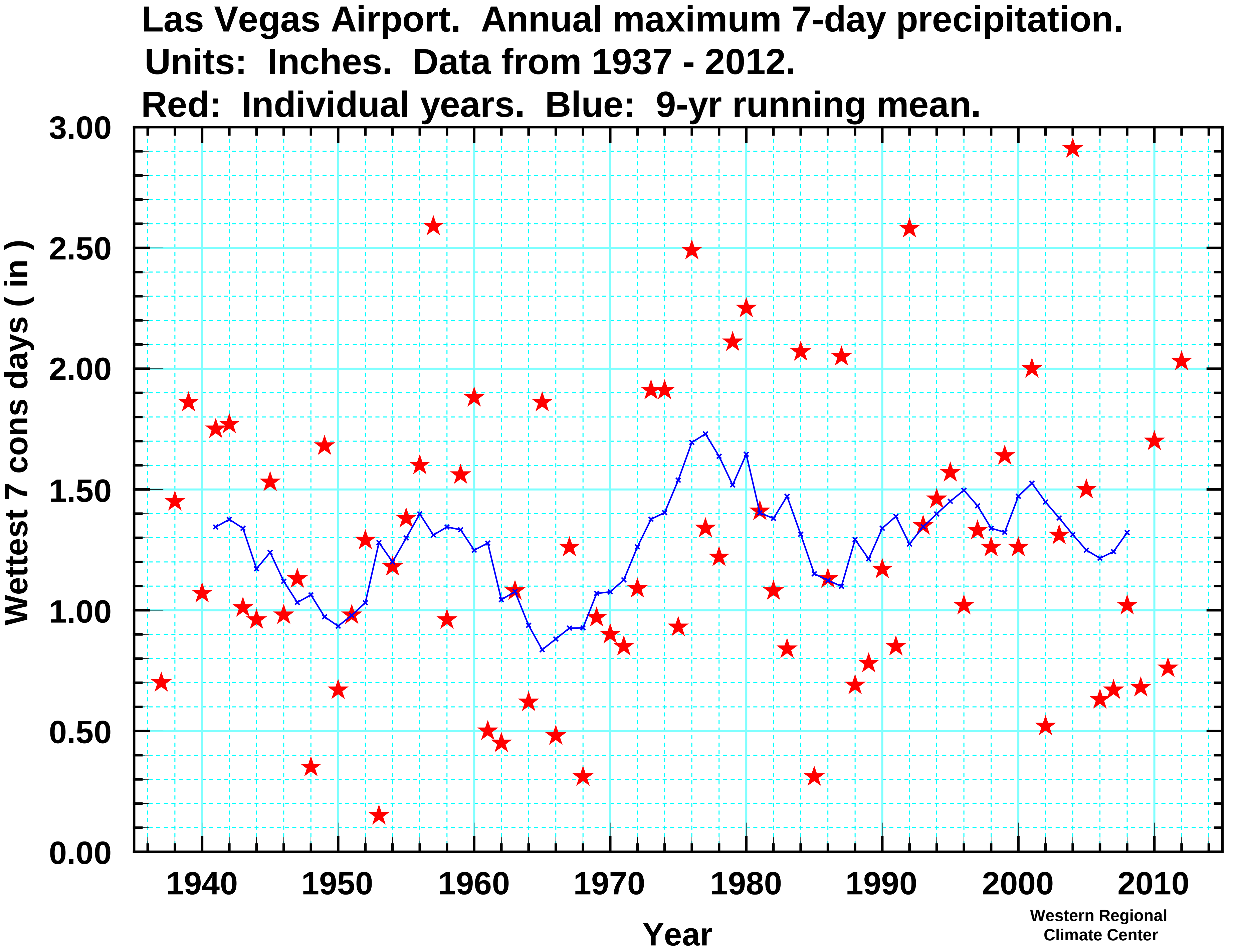


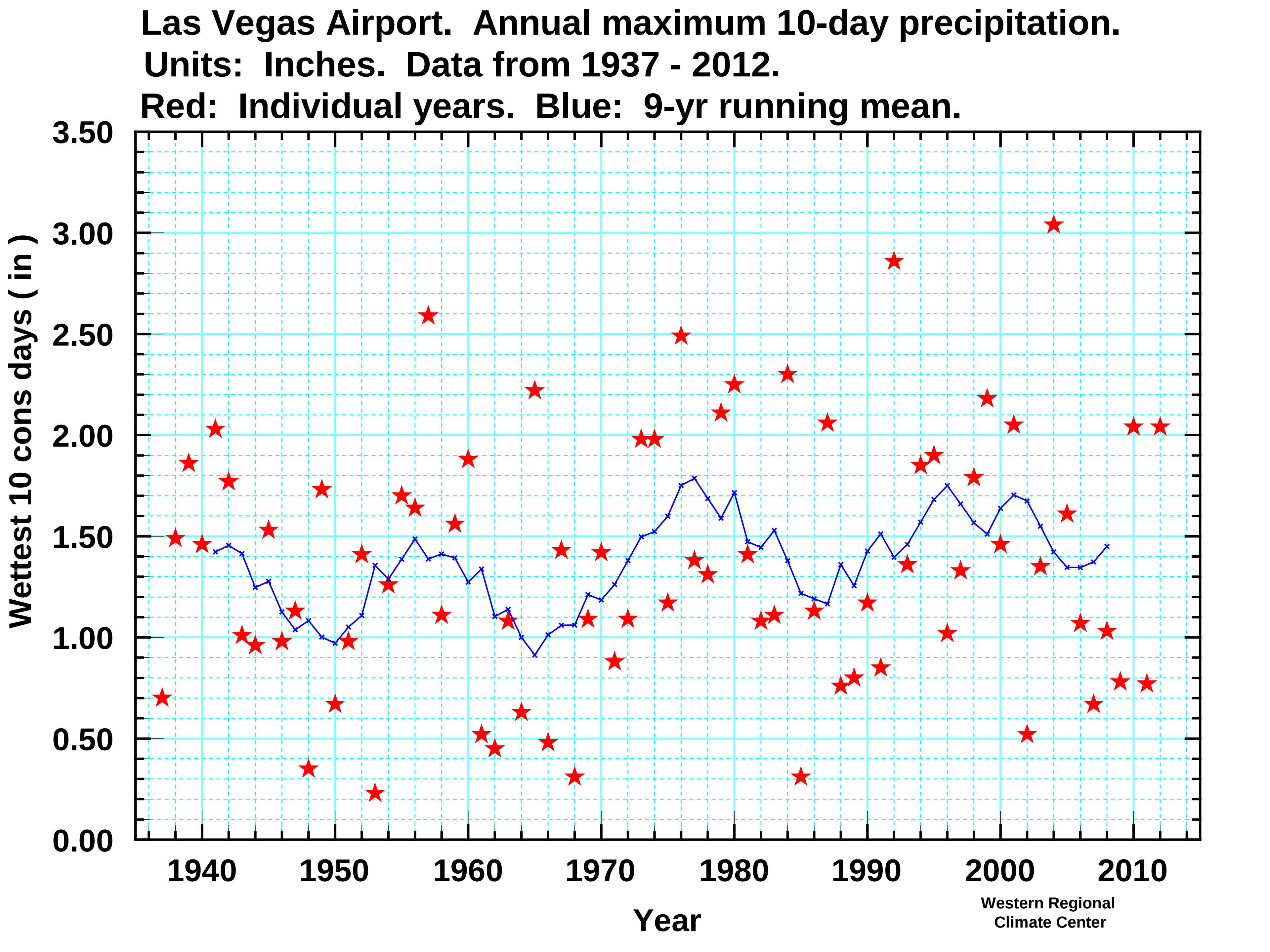
Las Vegas Airport. Extreme max 2-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest 2 cons. days (in)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

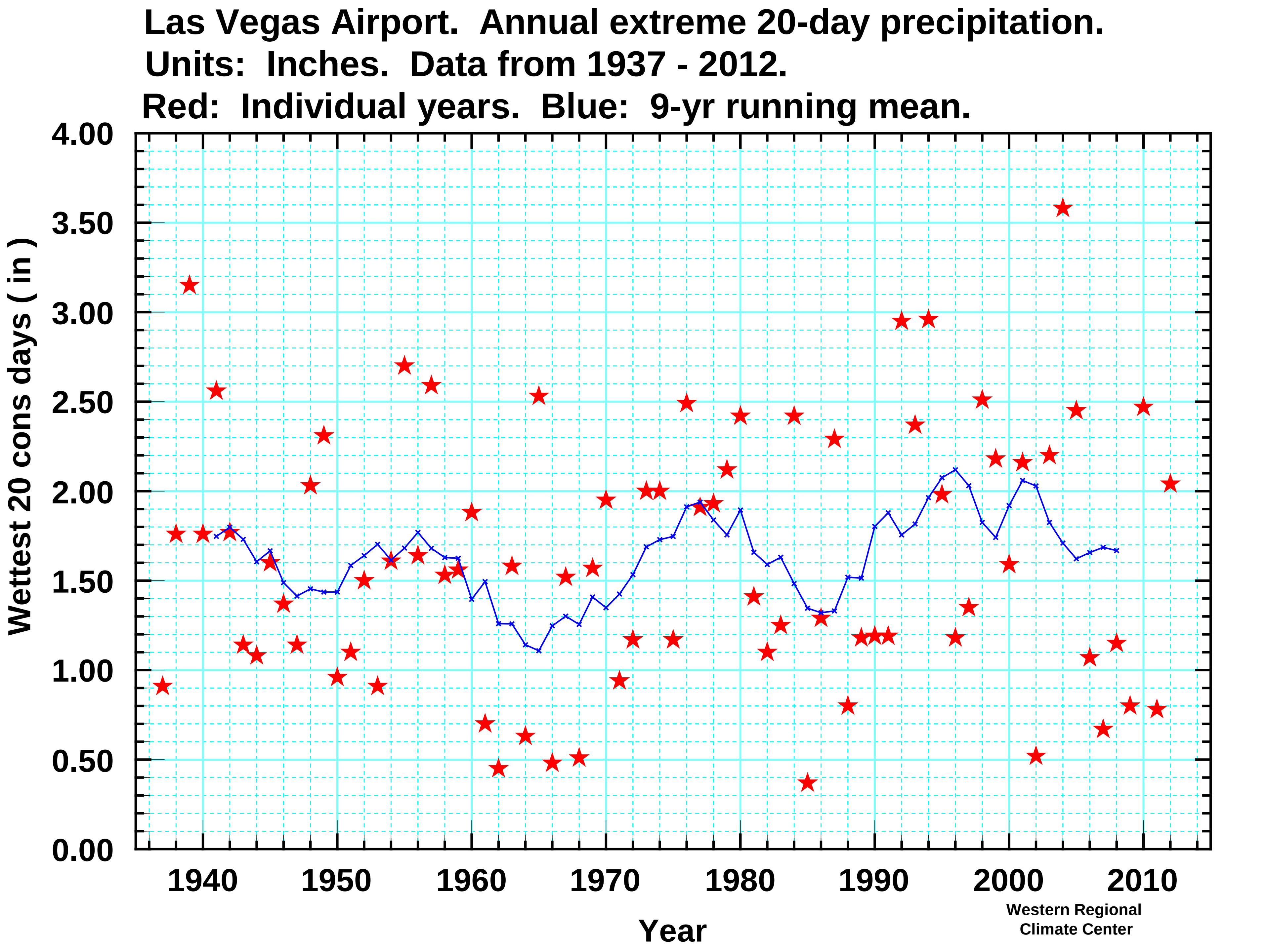

Las Vegas Airport. Annual maximum 3-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest 3 cons days (in)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

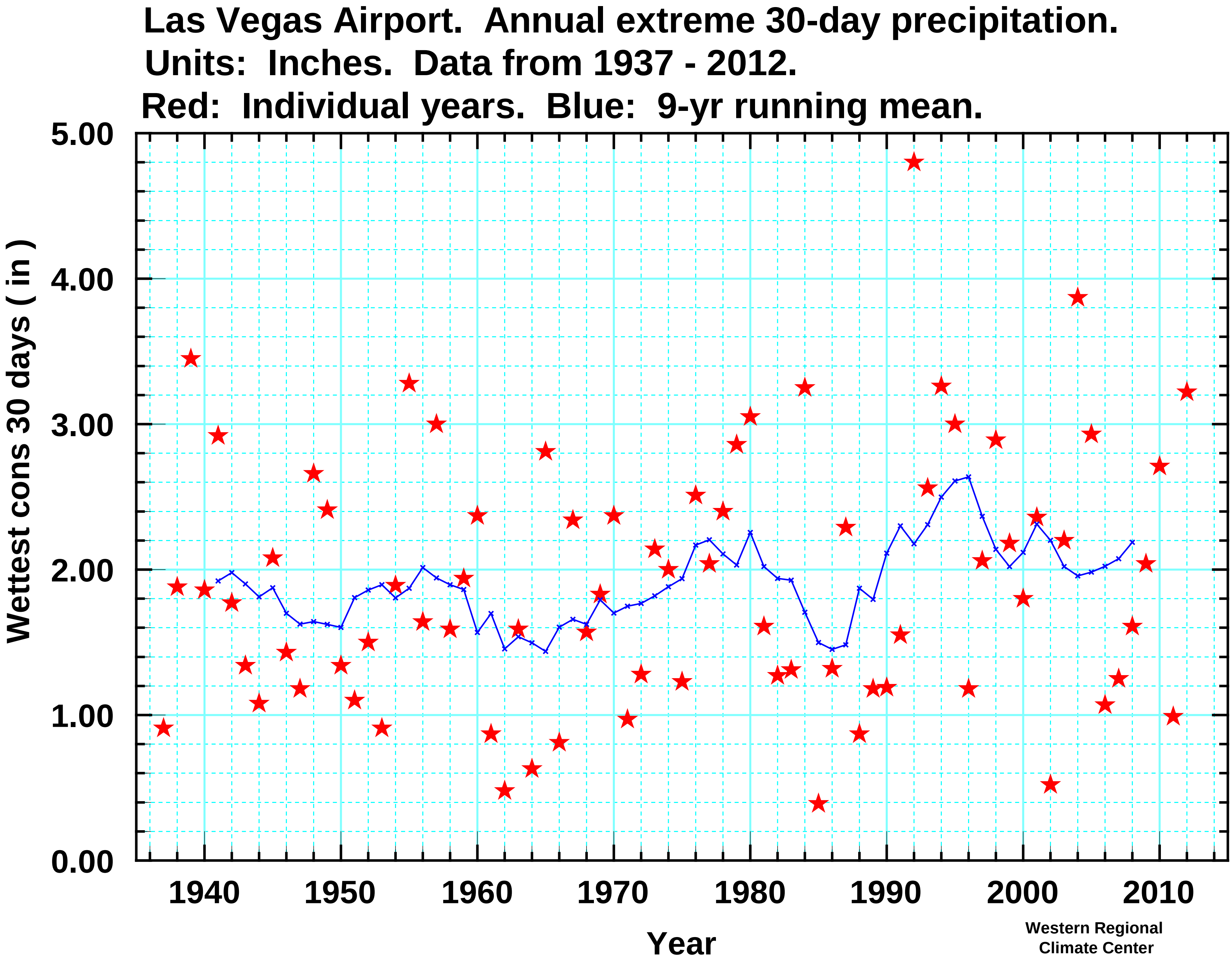
Las Vegas Airport. Annual maximum 4-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.




Las Vegas Airport. Annual maximum 7-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest 7 cons days (in)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center


Las Vegas Airport. Annual maximum 10-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest 10 cons days (in)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center


Las Vegas Airport. Annual extreme 20-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest 20 cons days (in)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center



Las Vegas Airport. Annual extreme 30-day precipitation.
Units: Inches. Data from 1937 - 2012.
Red: Individual years. Blue: 9-yr running mean.
Wettest cons 30 days (in)
5.00
4.00
3.00
2.00
1.00
0.00
1940
1950
1960
1970
1980
1990
2000
2010
Year
Western Regional
Climate Center

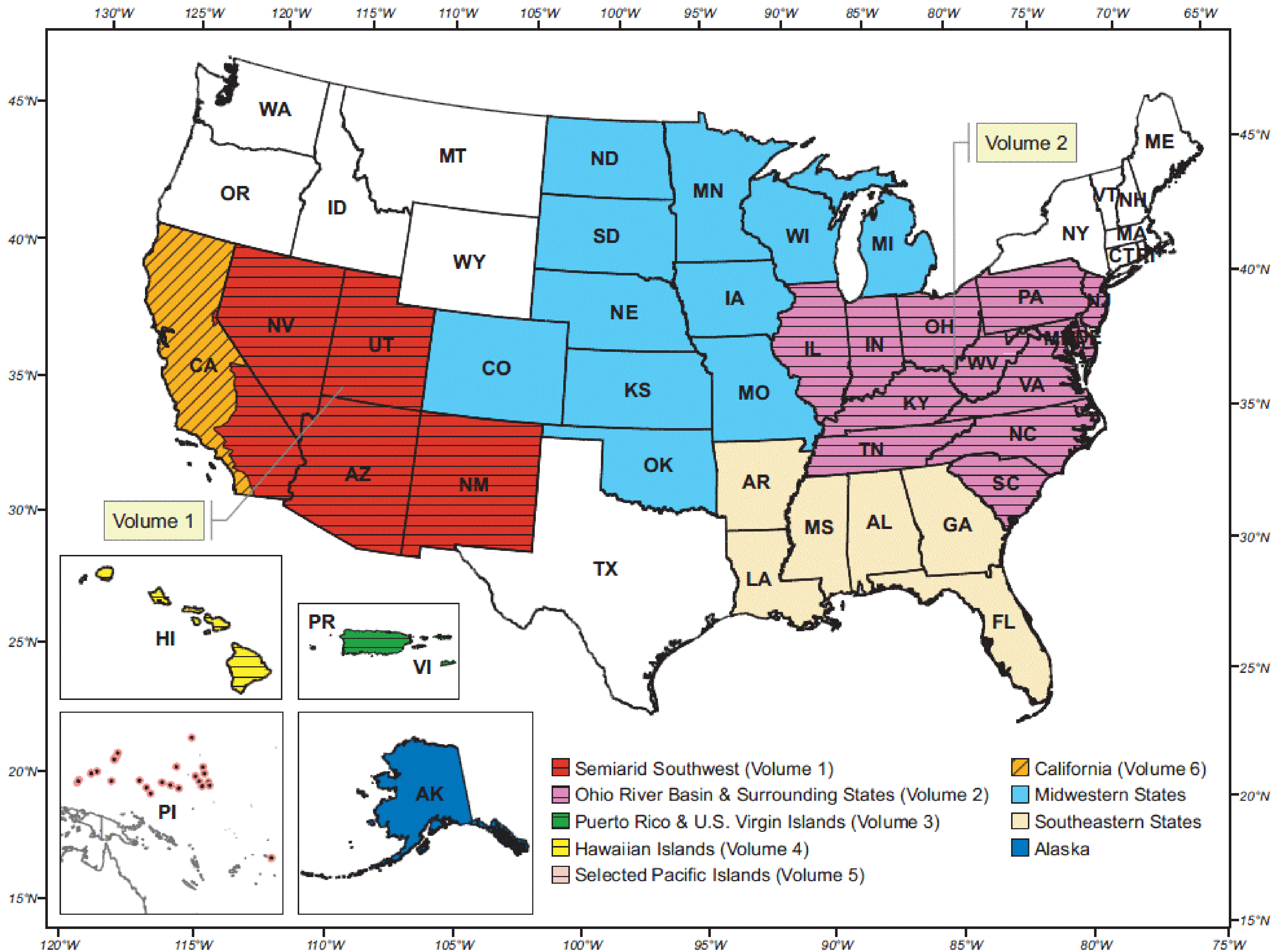


FIGURE 1. NOAA Atlas 14 Volume Domains.

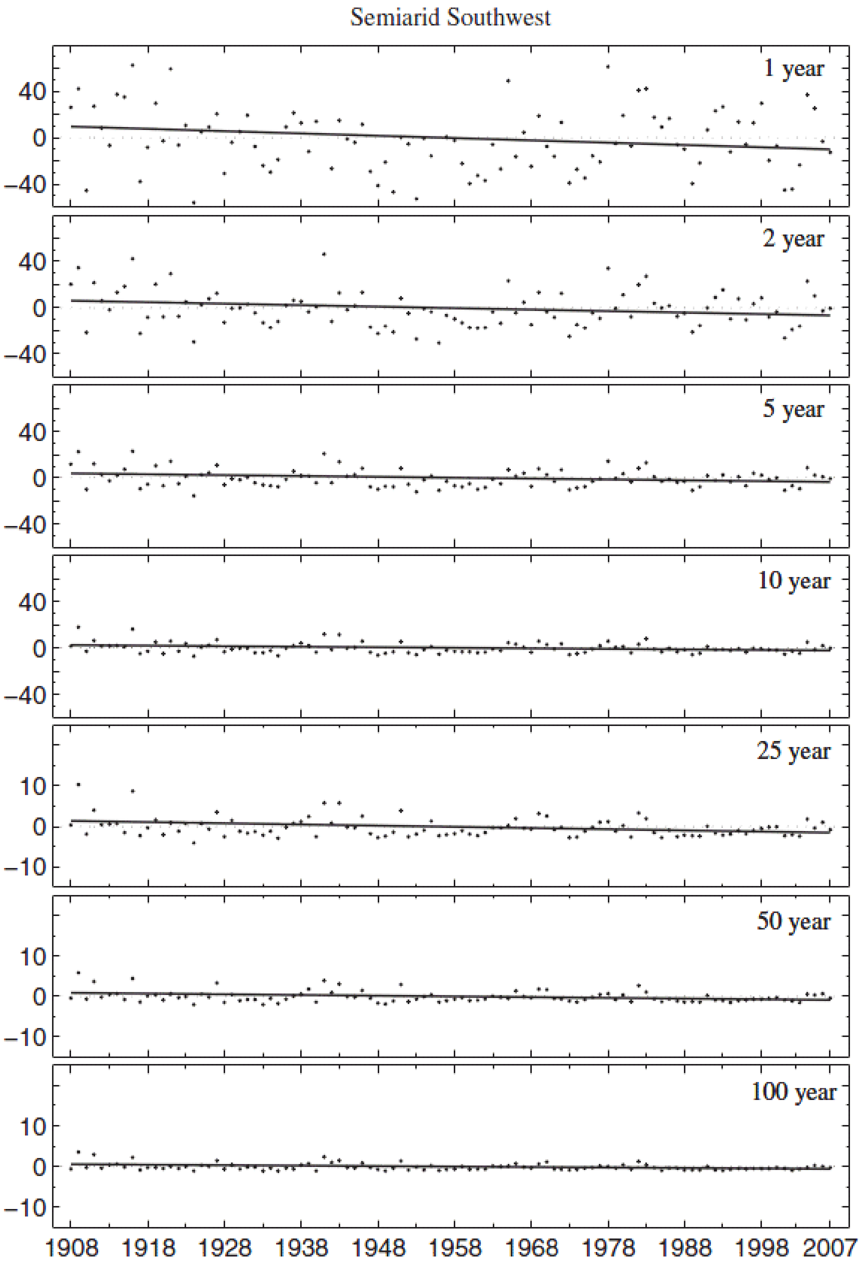


FIGURE 3. Semiarid Southwest One-Day Exceedances. Similar to Figure 2, except the period covered is 1908-2007. Similar results were obtained at other multiday durations.

1 - Year Return Value

2 - Year Return

5 - Year Return

10 - Year Return

25 - Year Return

50 - Year Return

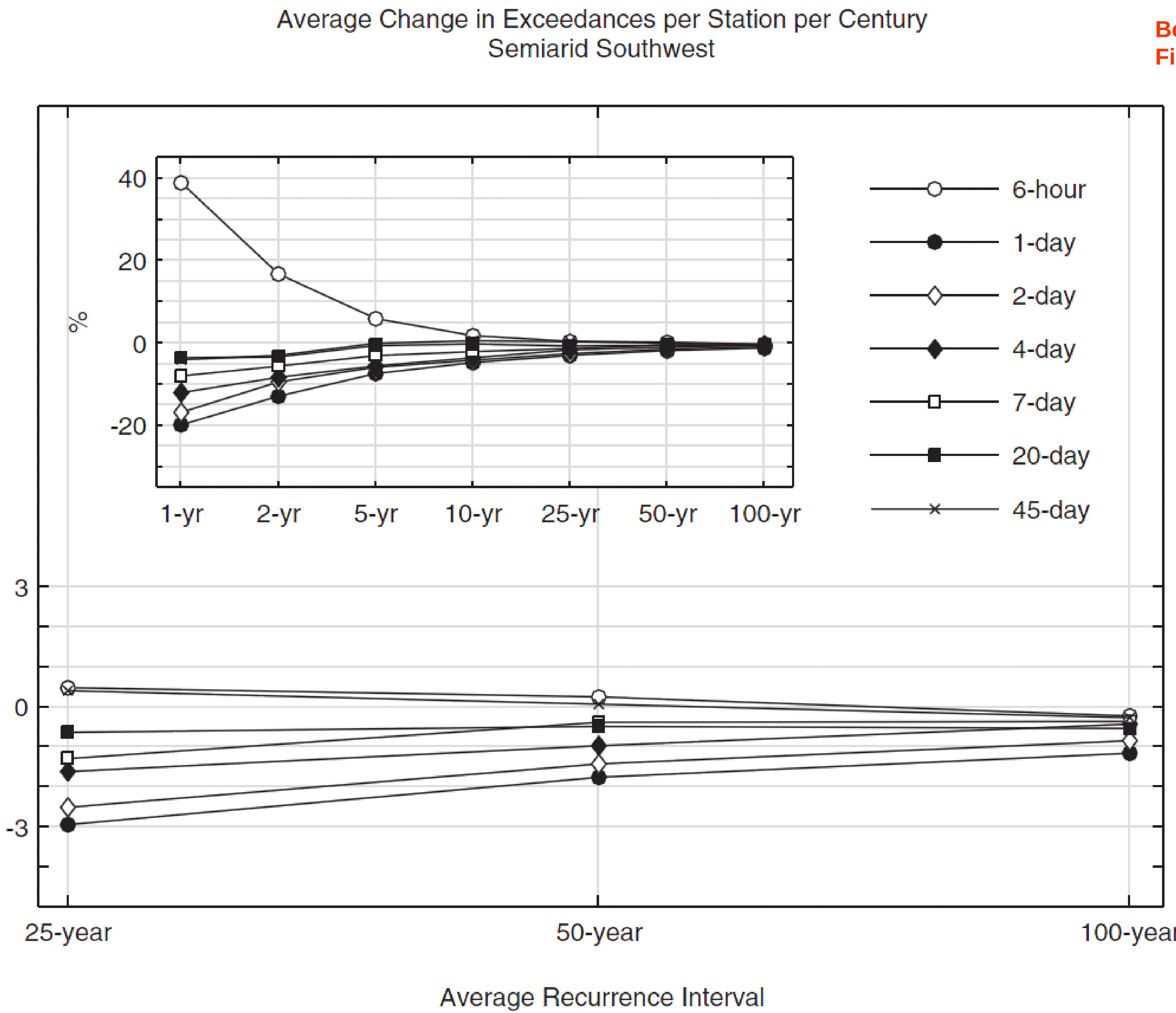
100 - Year Return Value

Trends in 1-Day Exceedance Values for Precipitation.

Southwest USA.

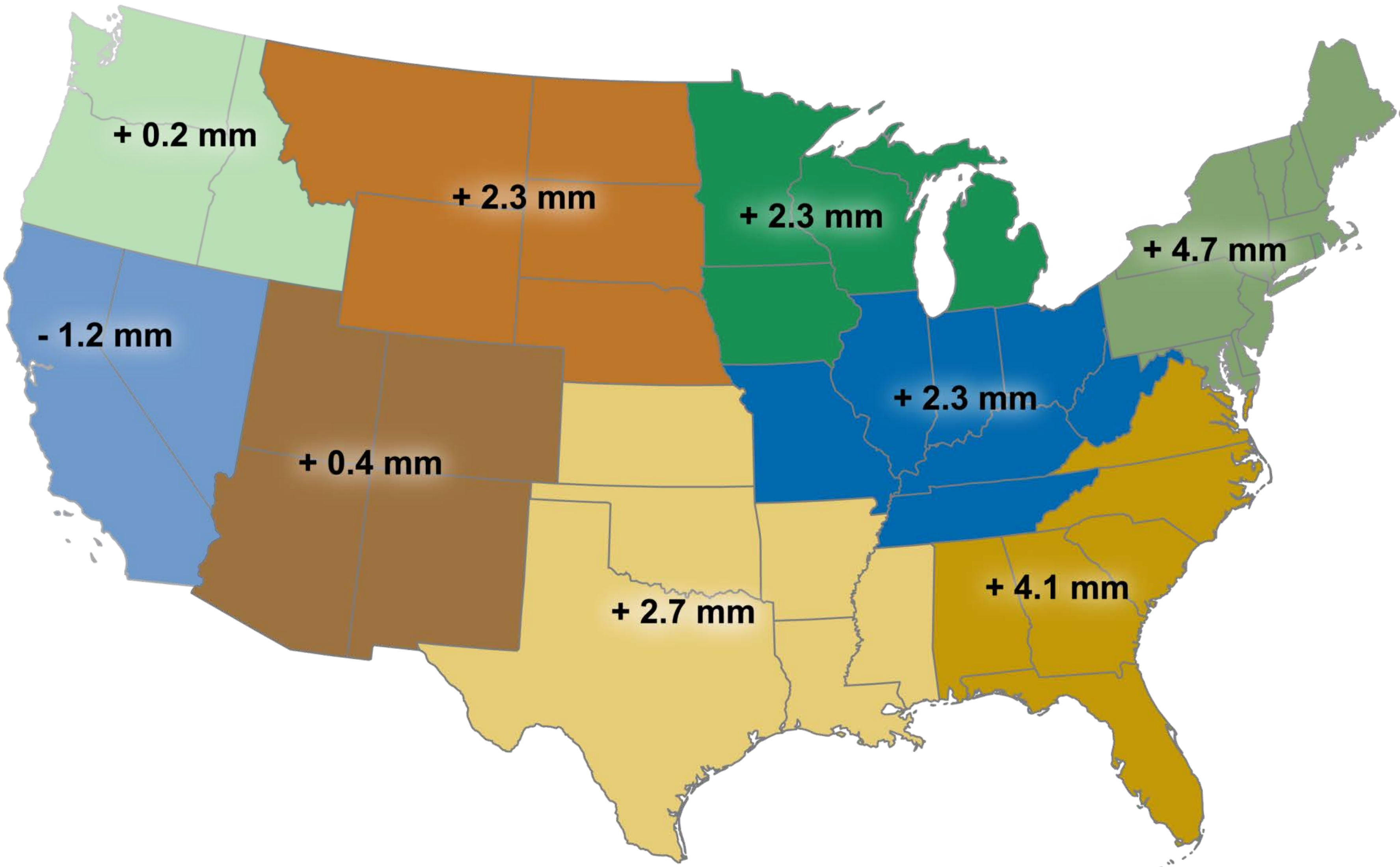
1908-2007.

Geoffrey M Bonnin, Kazungu Maitaria, Michael Yekta. 2011. Trends in Rainfall Exceedances in the Observed Record in Selected Areas of the United States. Journal of the American Water Resources Association, 47(6), 1173-1182.



Bonnin et al, 2011. Figure 6.

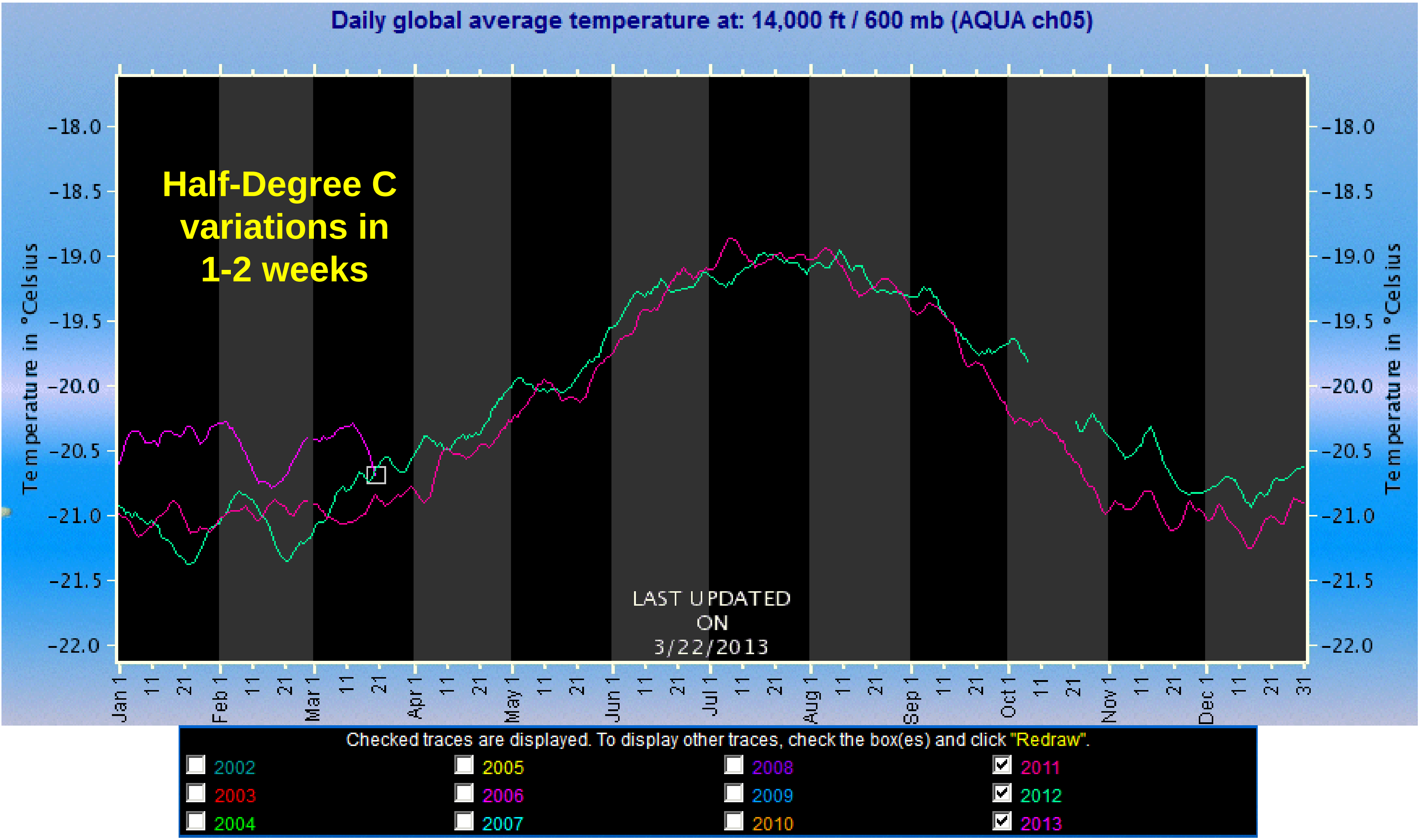
Observed difference in extreme event precipitable water: 1982-2009 minus 1961-1981 (Kunkel, AMS 2011)



The Global Average Temperature Can Change Fairly Rapidly

Microwave Sounding Unit Daily Temperatures 2011, 2012, 2013 thru Mar 22

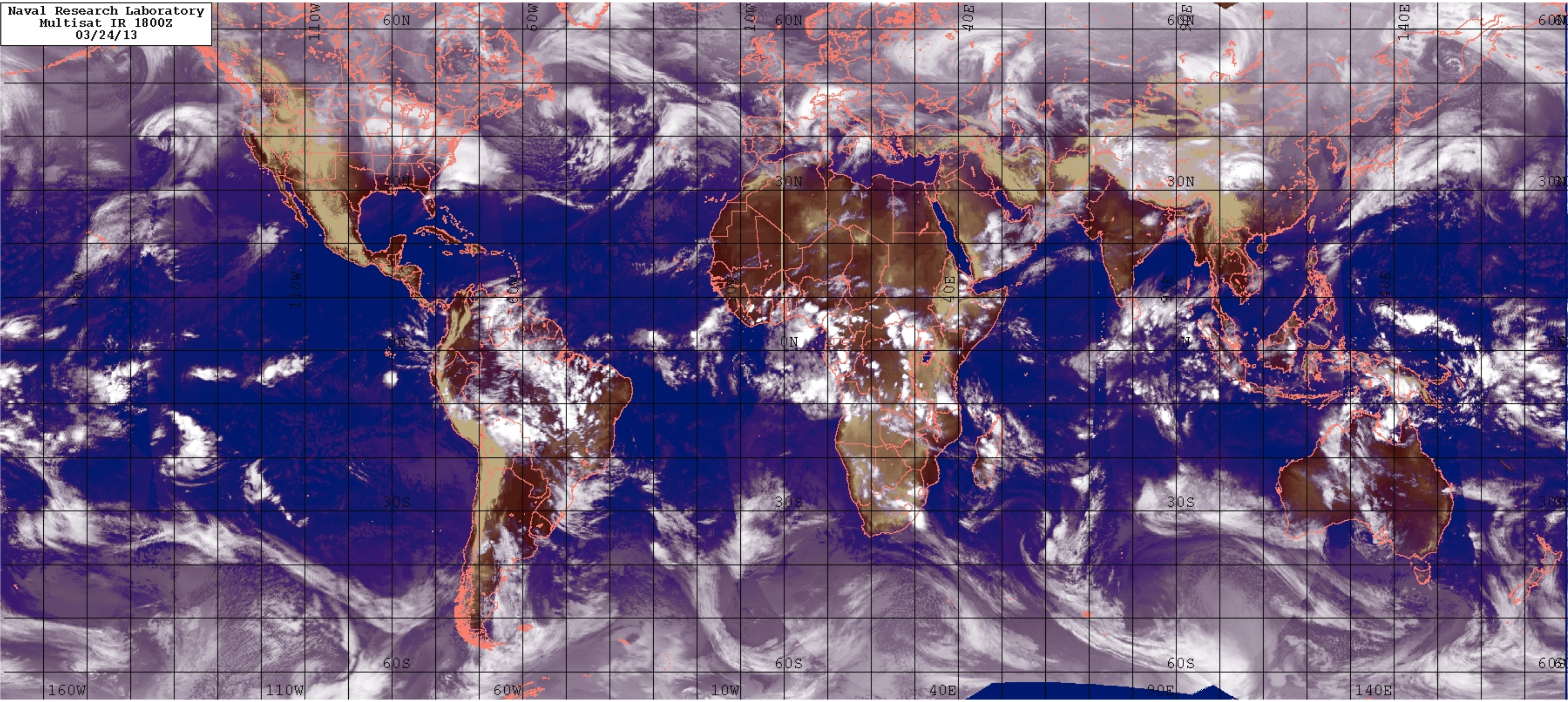
The likely suspect: Clouds.



Climate Complexity

Our ability to predict aspect of this system is not as hopeless as it might seem !

Stitched Image IR, 2013 Mar 24   1800 GMT

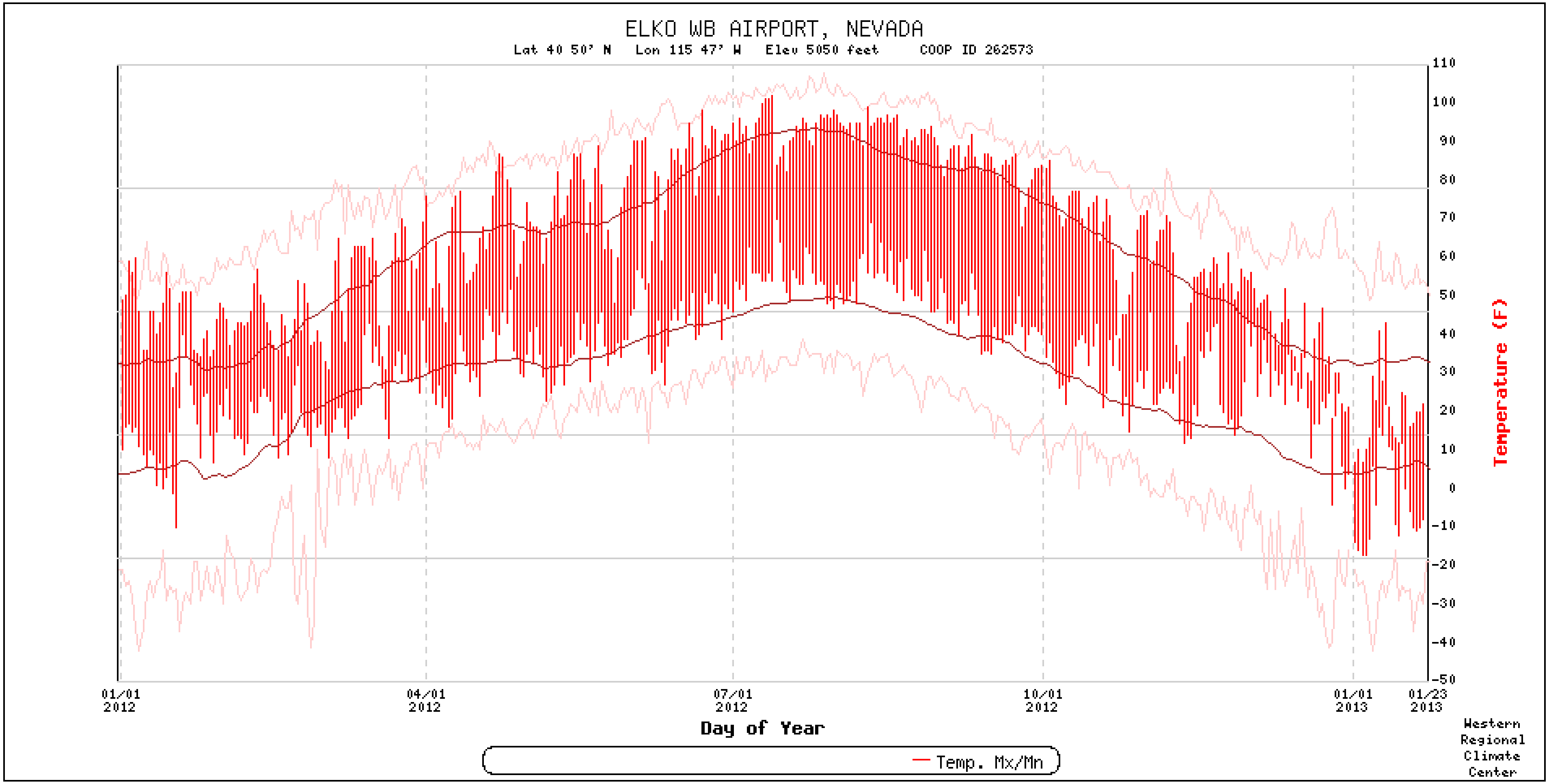


How would climate change actually be played out ?

50 years = 18,262 days = 438,291 hours

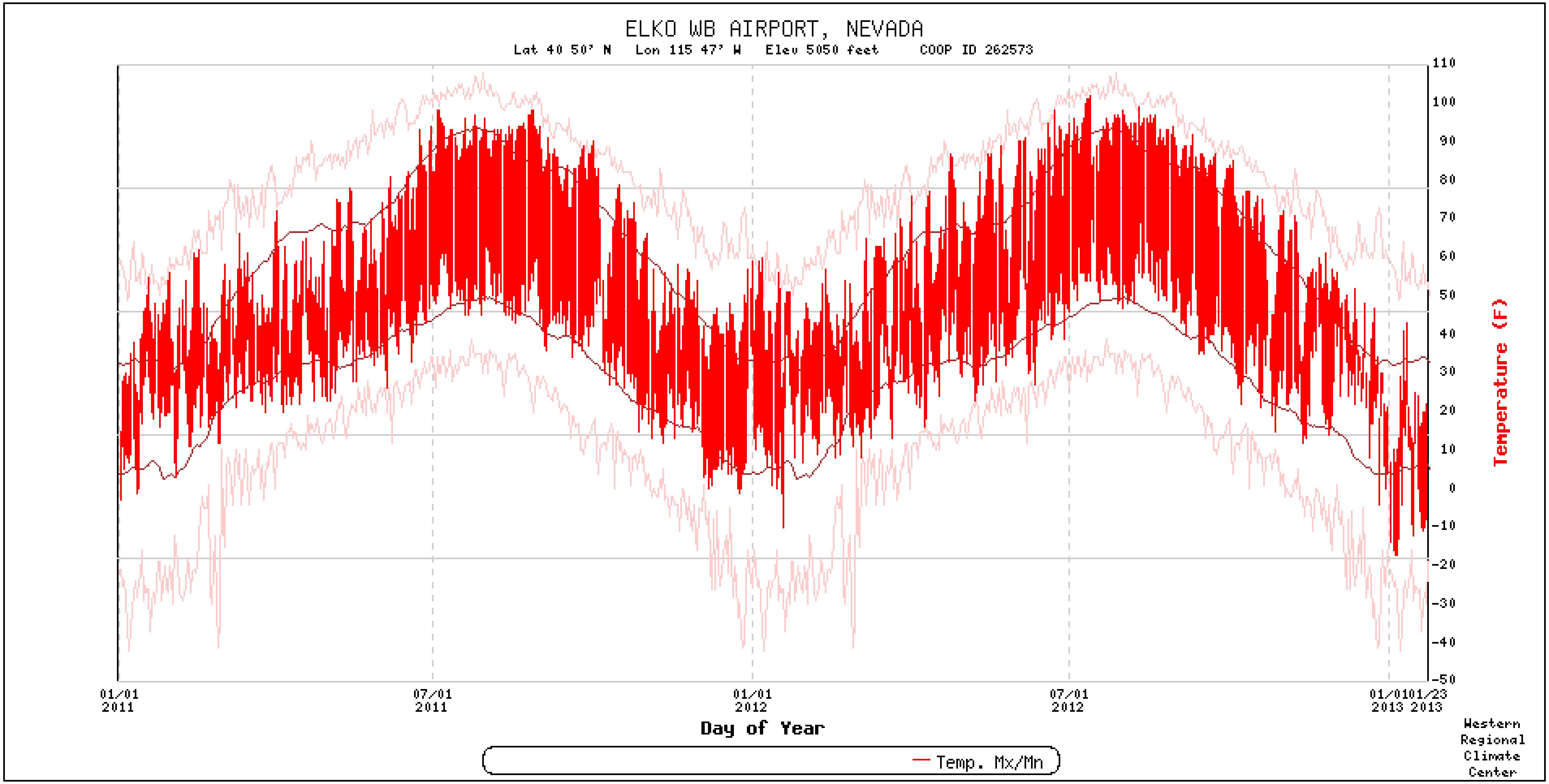
Fluctuations in climate will be experienced through weather

Elko Daily Temperatures
Past ~387 days



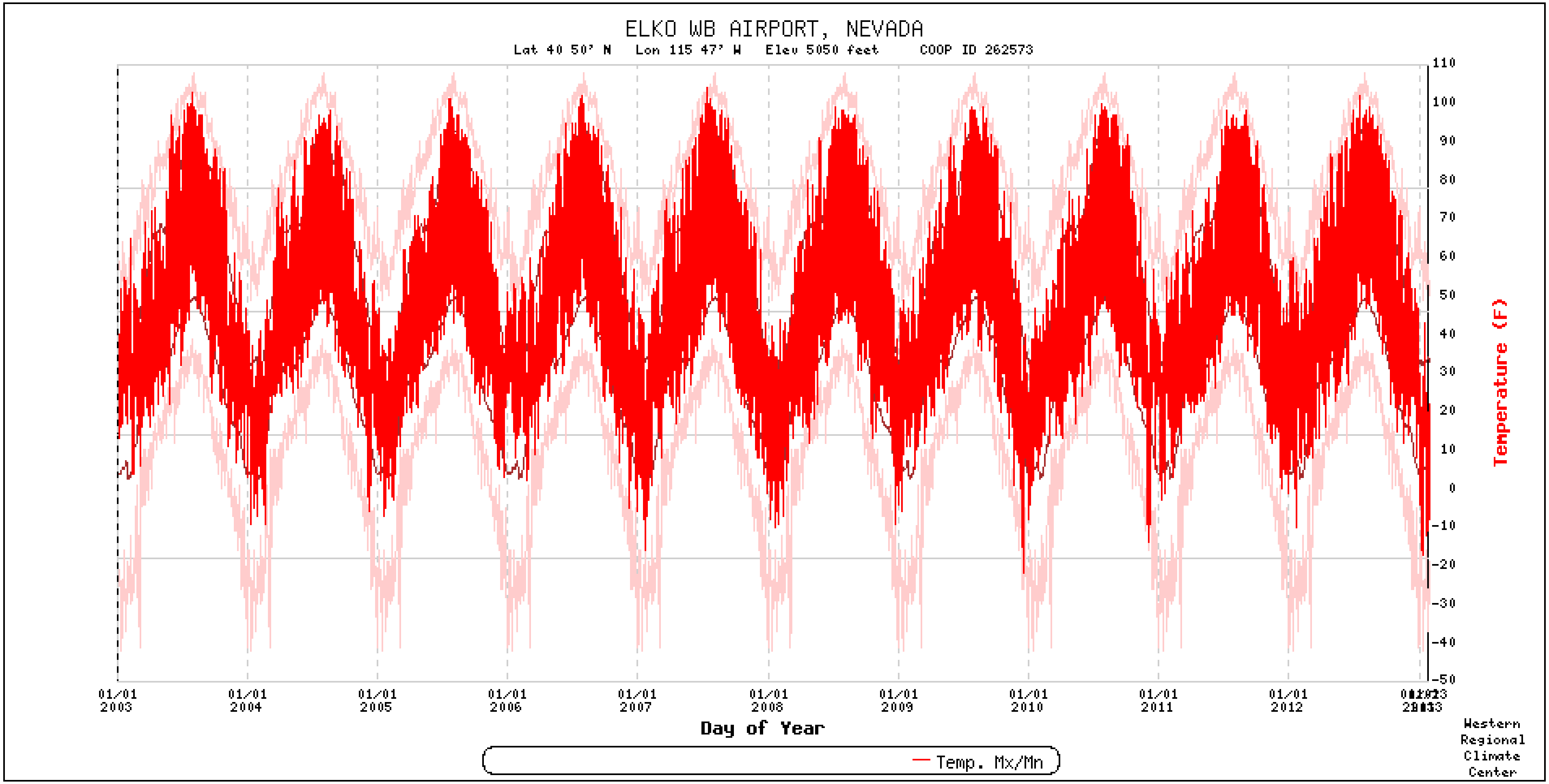
2012 Jan 1 **2013 Jan 21**

Elko Daily Temperatures
Past ~752 days



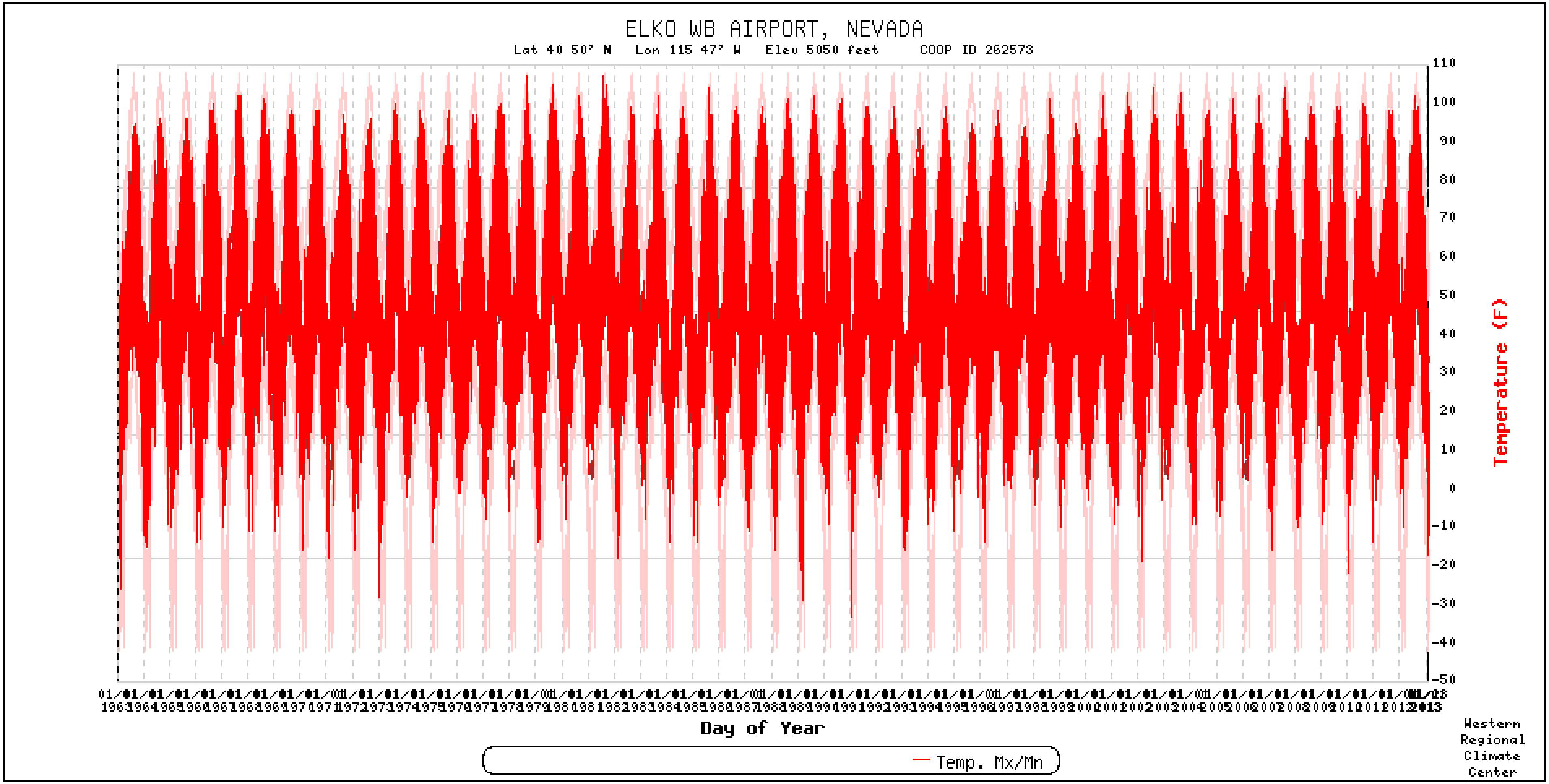
2011 Jan 1 **2013 Jan 21**

Elko Daily Temperatures
Past ~3673 days



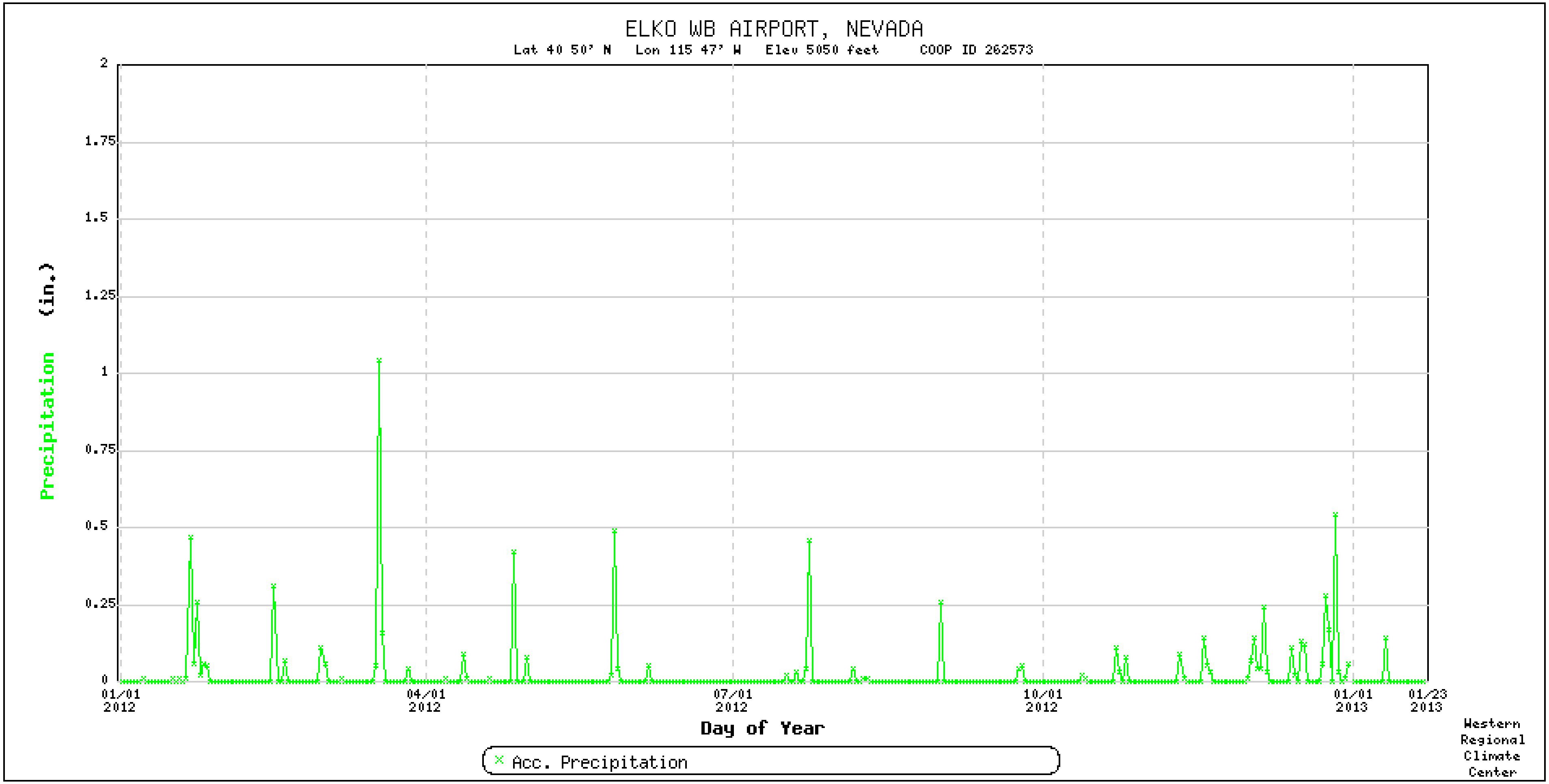
2003 Jan 1 **2013 Jan 21**

Elko Daily Temperatures
Past ~18283 days



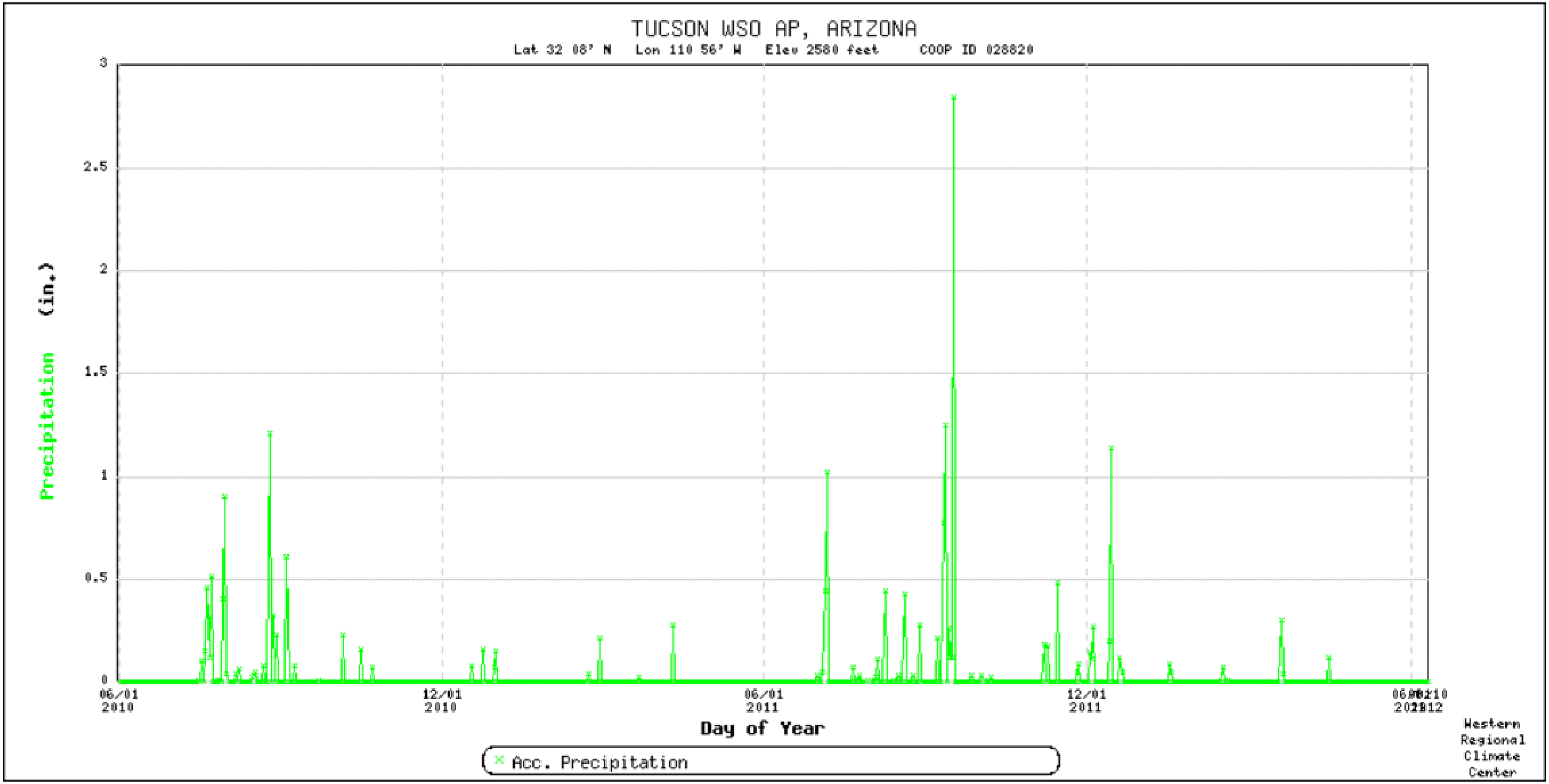
1963 Jan 1 **2013 Jan 21**

Elko Daily Precipitation
Past ~387 days



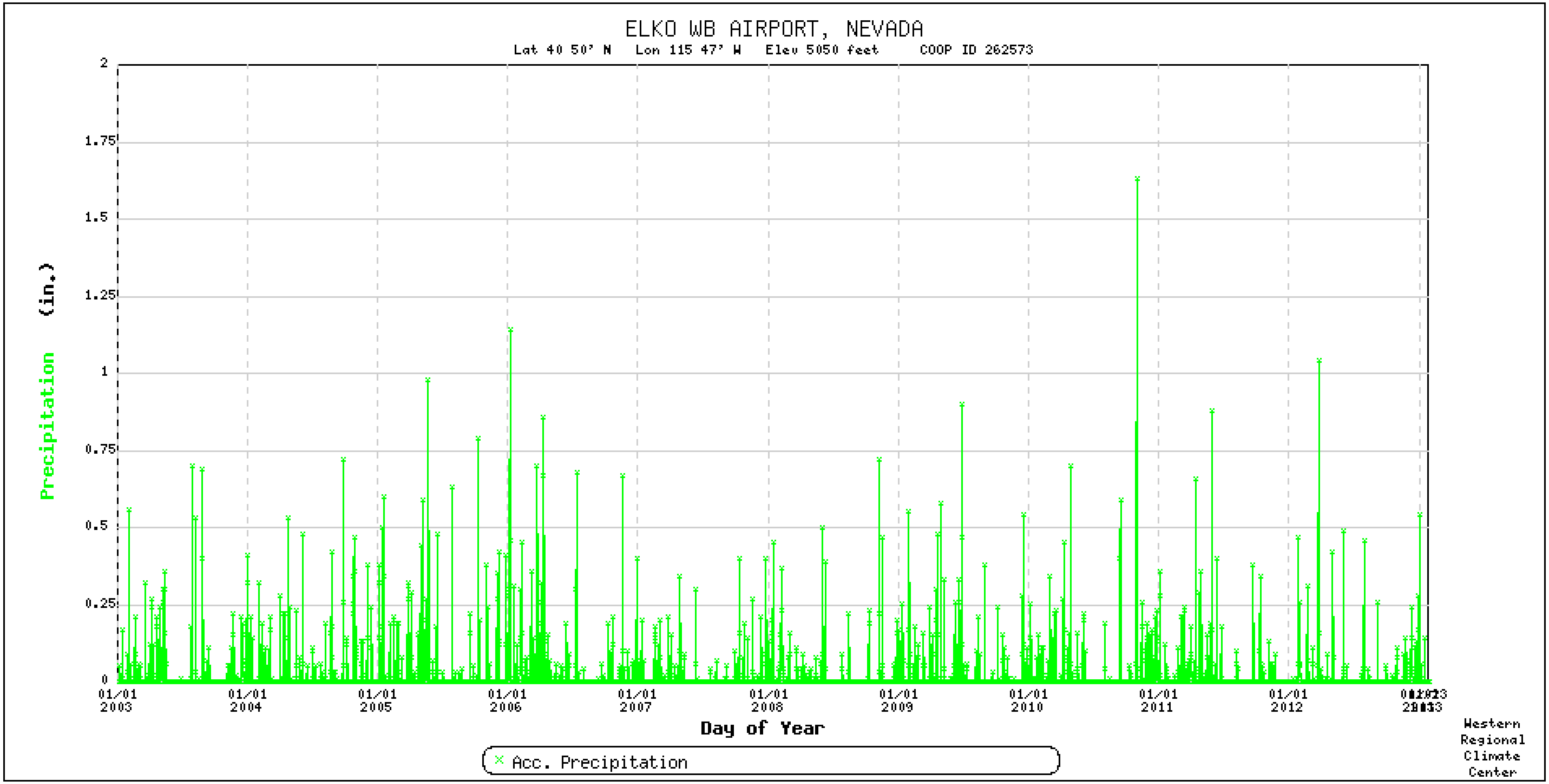
2012 Jan 1 **2013 Jun 21**

Elko Daily Precipitation
Past ~752 days



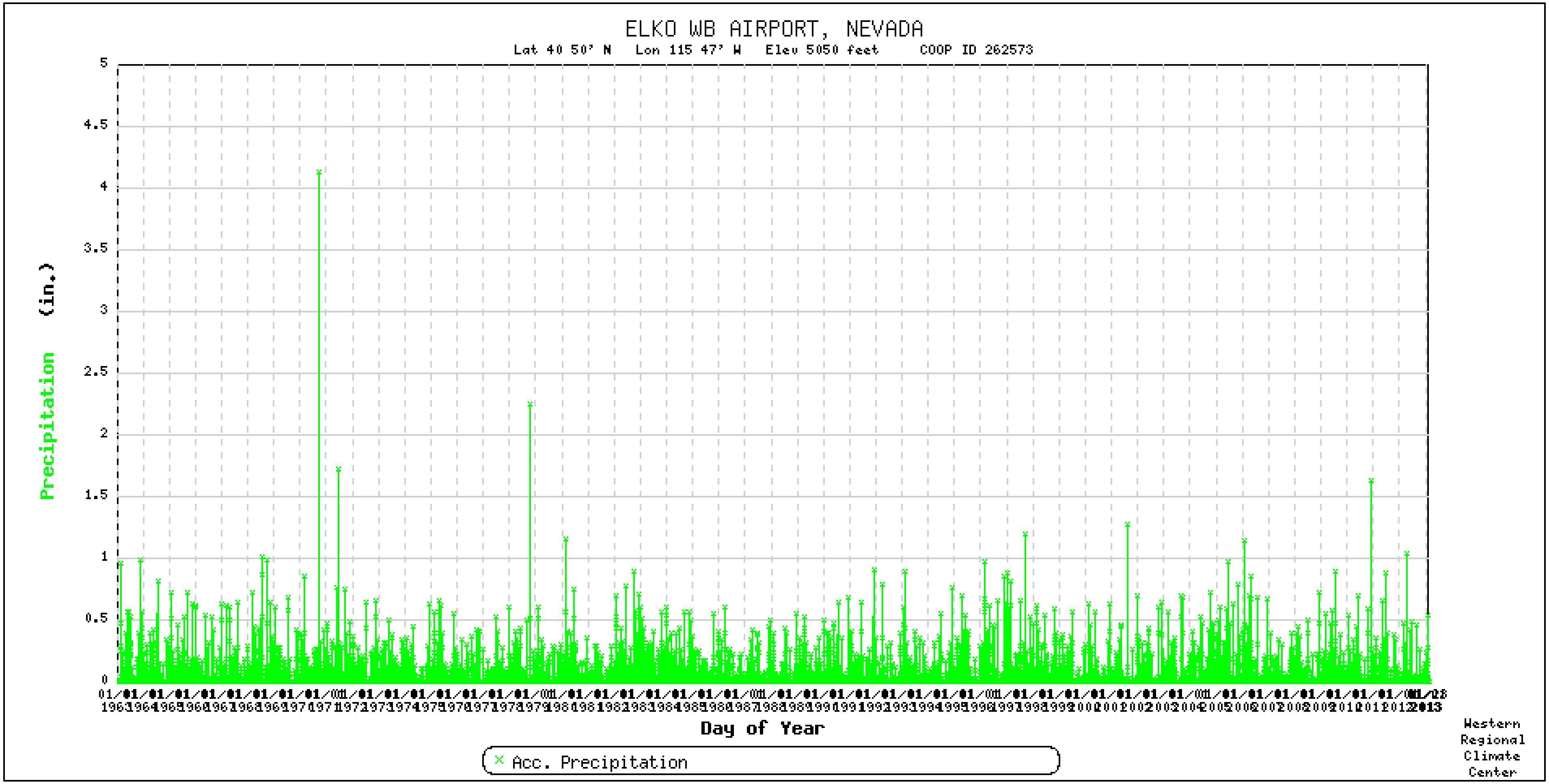
2011 Jan 1 **2013 Jan 21**

Elko Daily Precipitation
Past ~3673 days

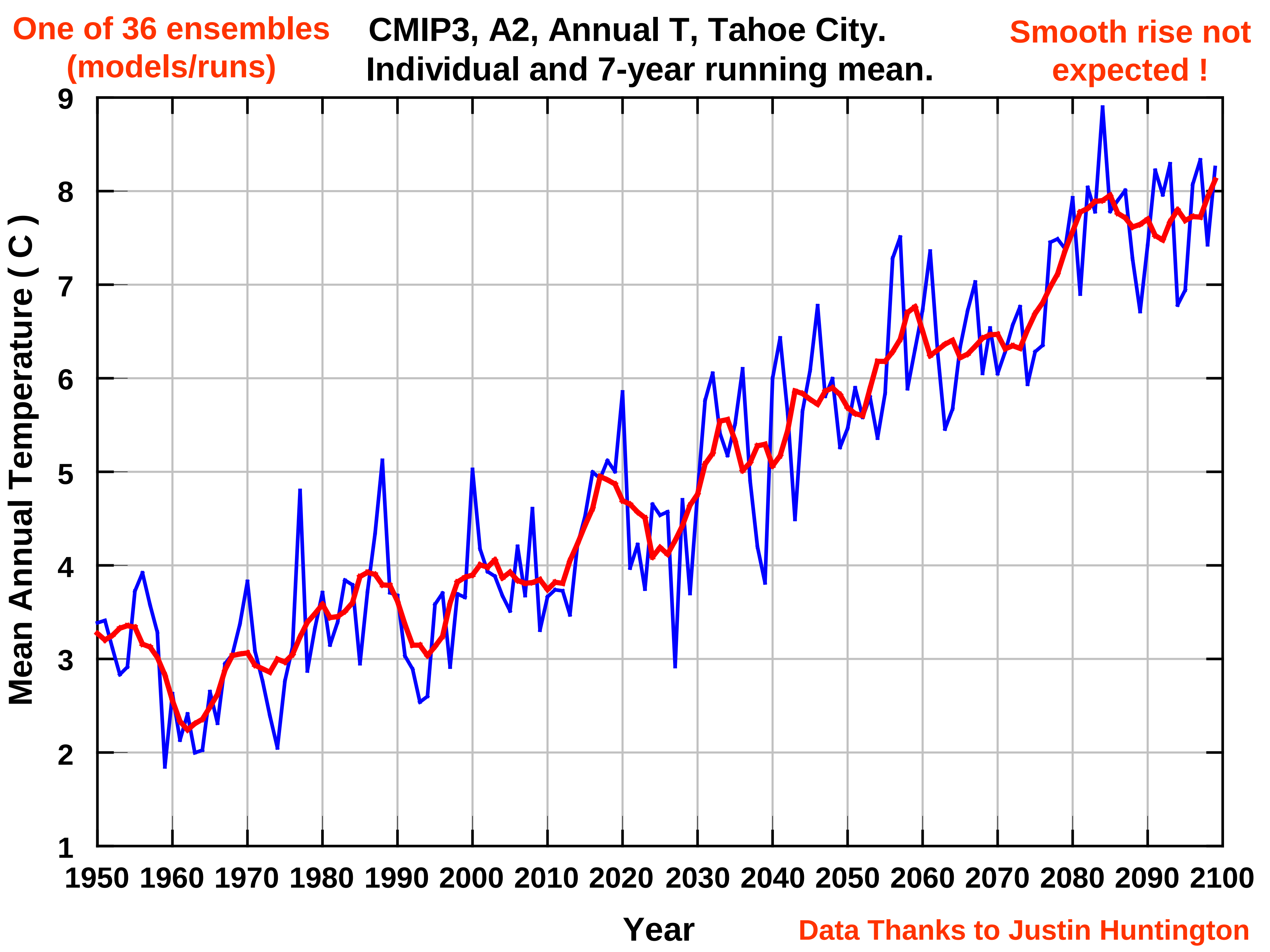


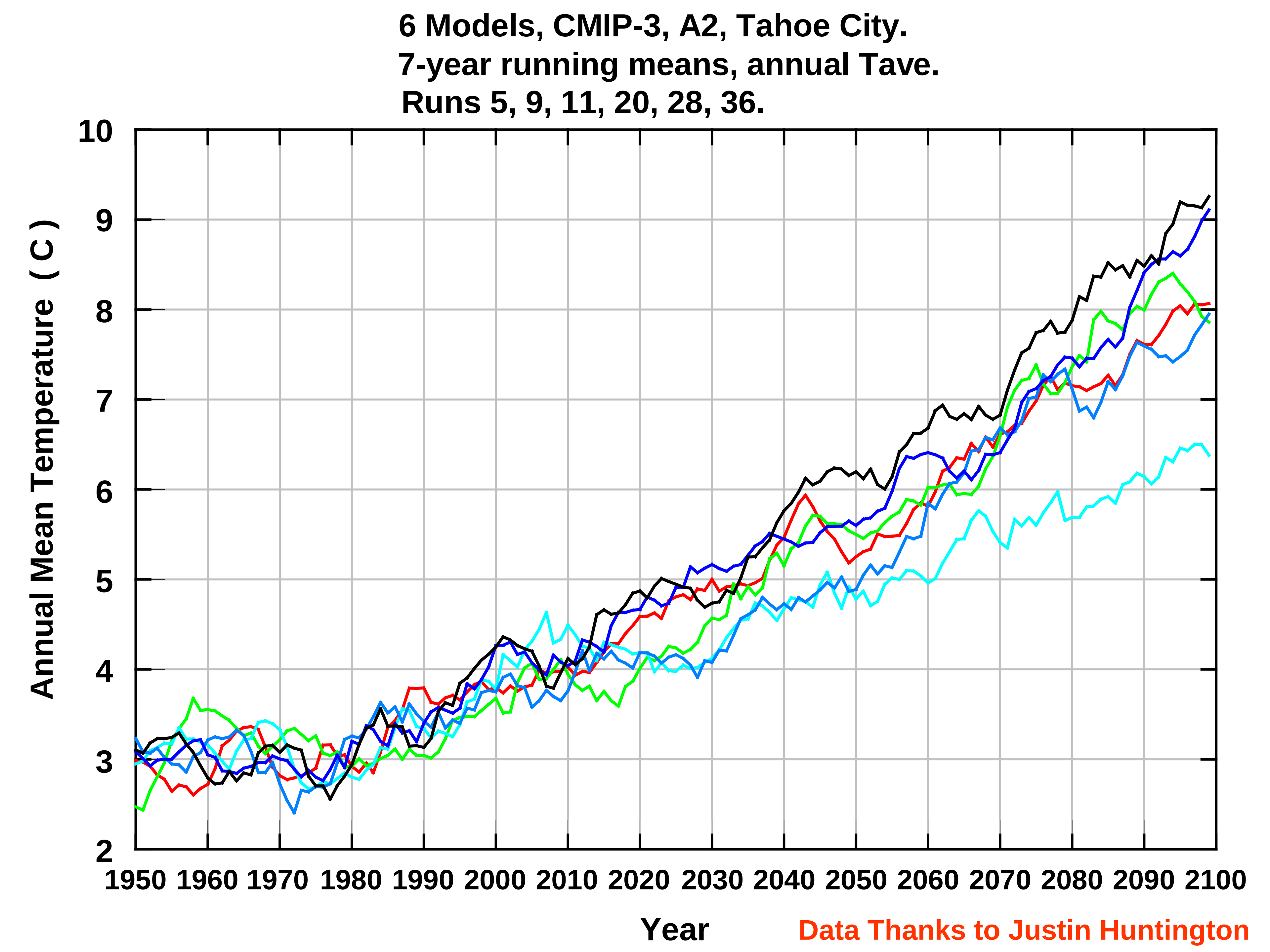
2003 Jan 1 **2013 Jan 21**

Elko Daily Precipitation
Past ~18283 days
About 3500 days with 0.01” or more



1963 Jan 1 **2013 Jan 21**

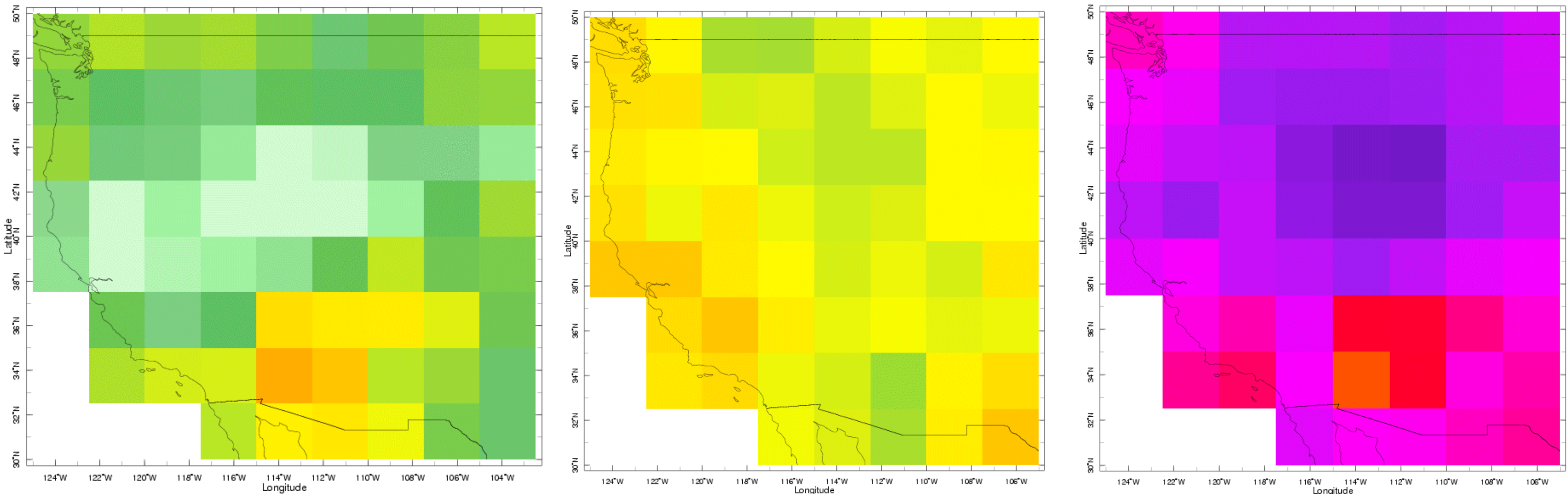

One of 36 ensembles
(models/runs)
CMIP3, A2, Annual T, Tahoe City.
Individual and 7-year running mean.
Smooth rise not
expected !
Mean Annual Temperature (C)
9
8
7
6
5
4
3
2
1
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Data Thanks to Justin Huntington

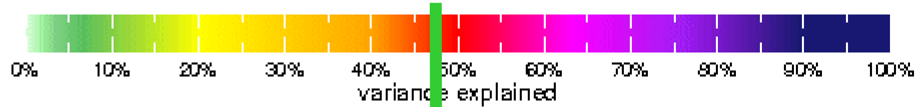

6 Models, CMIP-3, A2, Tahoe City.
7-year running means, annual Tave.
Runs 5, 9, 11, 20, 28, 36.
Annual Mean Temperature (C)
10
9
8
7
6
5
4
3
2
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Data Thanks to Justin Huntington

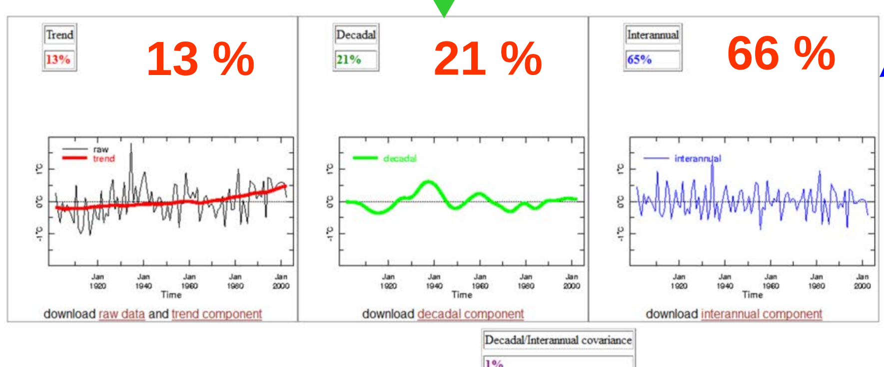
Climate Fluctuates on Different Time Scales for Different Reasons

IRI Time Scales Map Room Exploratory Tool

Slowly Changing Trend | **Decadal Scale Variability** | **Year-to-Year Variability**



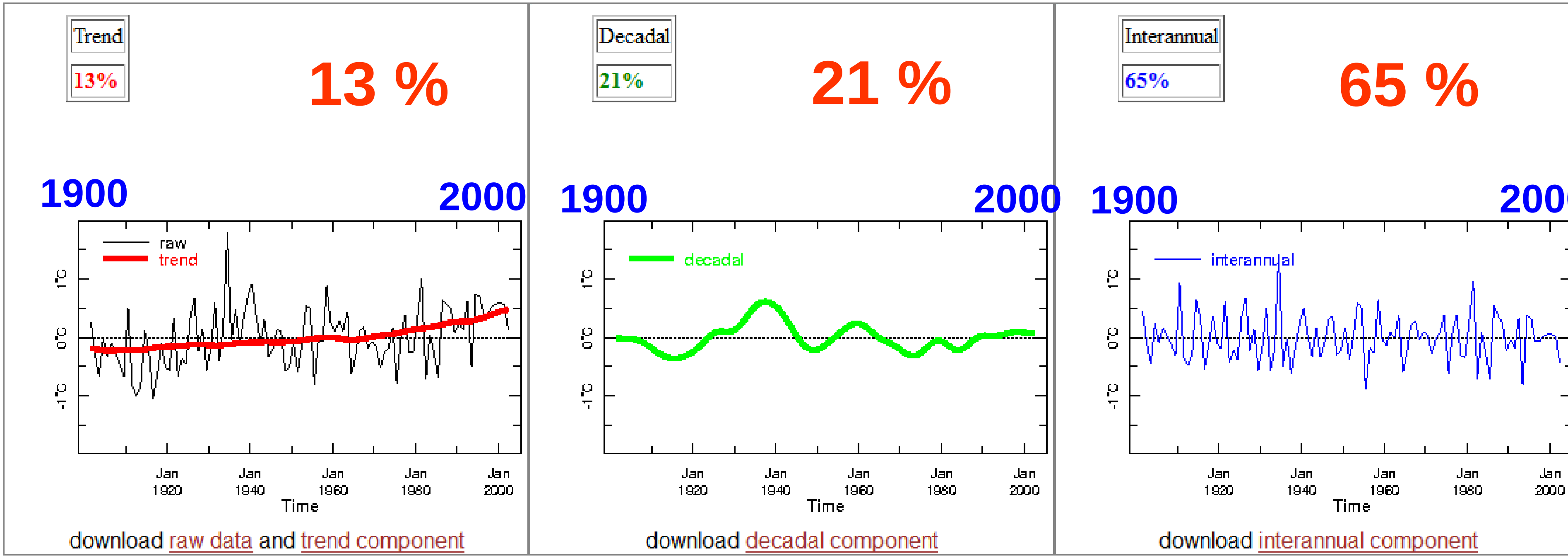




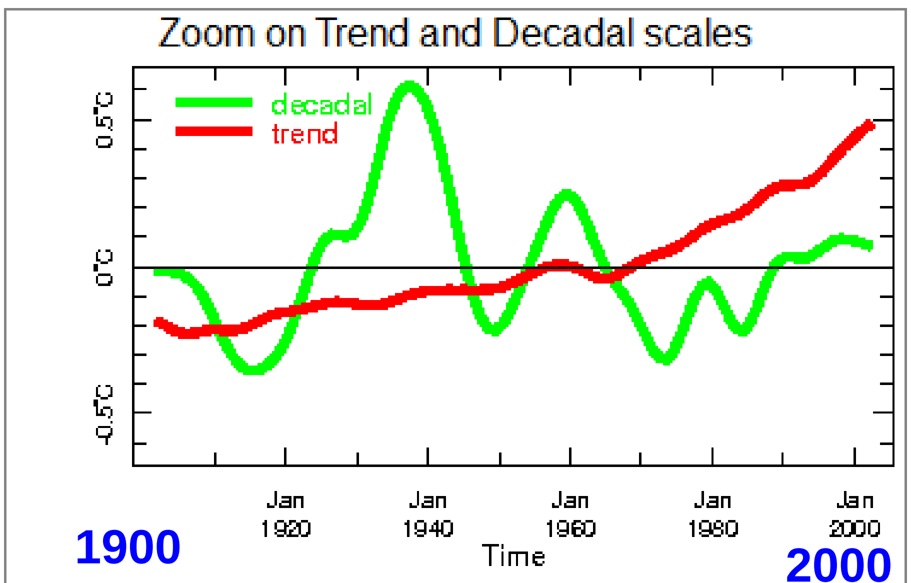
Graphs are averages of domain above

Annual Mean Temperature

http://iridl.ldeo.columbia.edu/maproom/.Global/.Time_Scales/



Decadal/Interannual covariance
1%

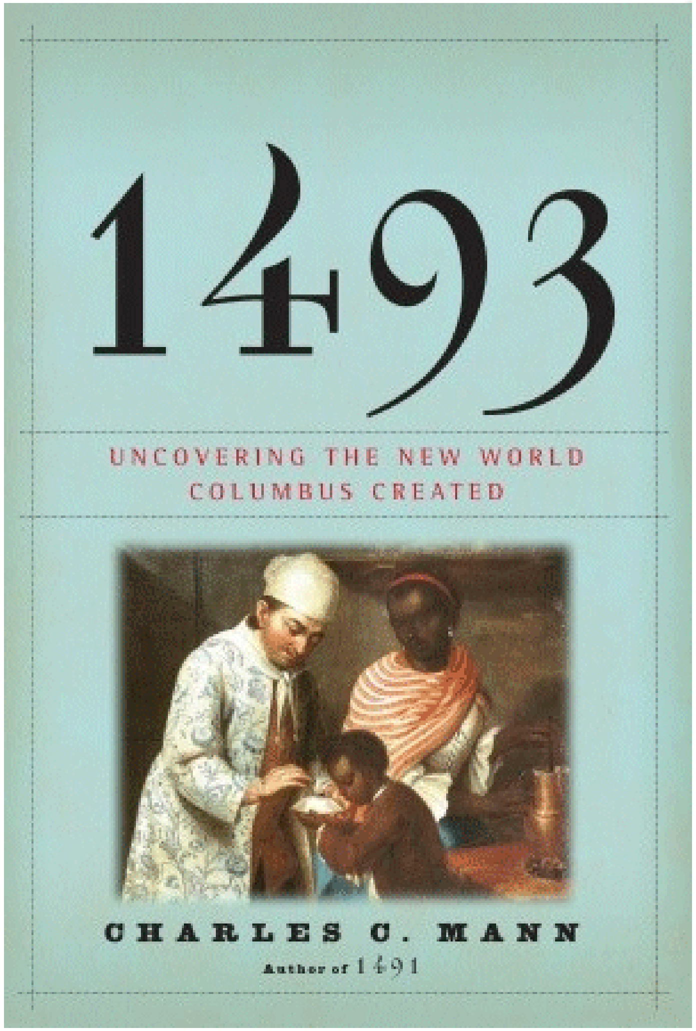


Climate variability remains a very big deal!

A.M. Green, L. Goddard, R. Cousin. Web Tool Deconstructs Variability in Twentieth-Century Climate. Nov 2011. EOS, AGU, 92(45), 397-398.

Change is not new.

Change in the pipeline.
Cannot be called back.



Summary Points

Climate Change and the West

Provides one more source of variability. "Old" variability continues.

Local and regional responses do not have to be the same as global scale.
- **Temp – Strongest consensus among the various climate elements**
- **Temp – All show warming, amounts differ modestly among projections.**
- **Precip – Sign, amounts, seasonality, frequency all matter.**
- **Precip – Character of precipitation can be as important as amount.**
- **Precip – More consensus for T than P, but some precip progress**

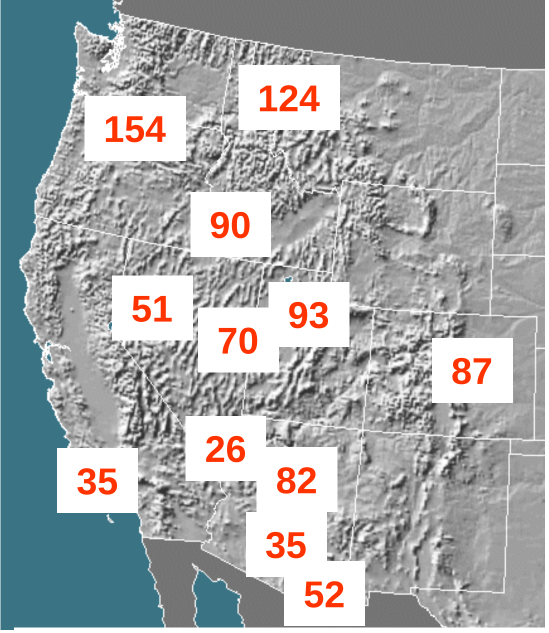
Precipitation change – more winter, less spring, summer, autumn?
Precipitation change – Annual increase north / decrease south
More floods (winter) & droughts (summer) possible
Temperature is a hydrologic element – has significant implications
Temperature change is under way, began without our noticing.
Western Mountains seem particularly vulnerable to climate change
System still has "unrealized warming;" earth radiation not in balance

Choice: Adaptation versus mitigation

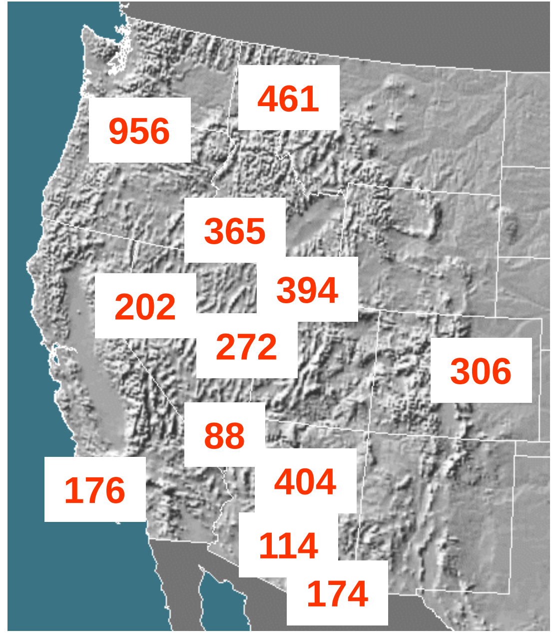
"Managing the unavoidable and avoiding the unmanageable"


Thank You !

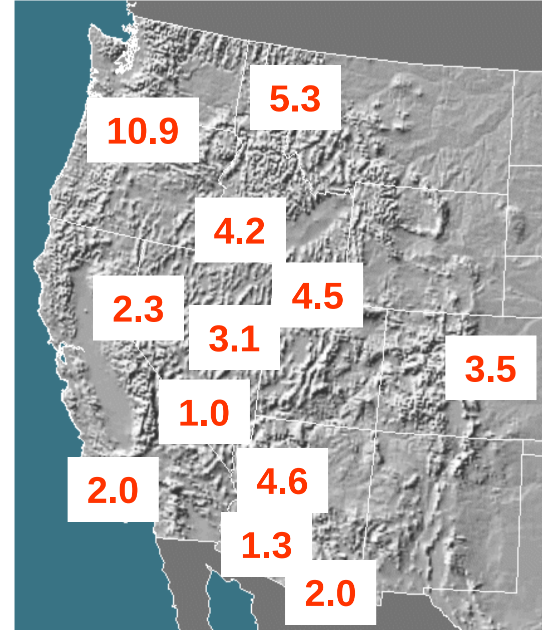
Discards



Precip Days Per Year 0.01”

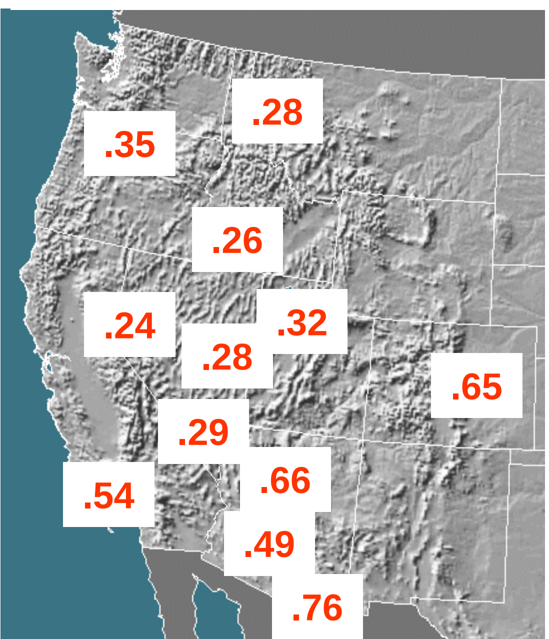


Ave Hours Precip Per Year

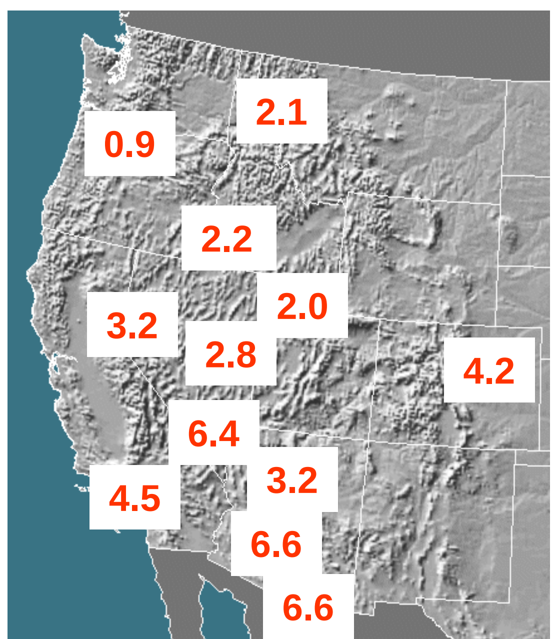


Ave Percent Hours Precip / yr

Once per year wettest hour (in.)



Ann wettest hr Pct of Ann Ave



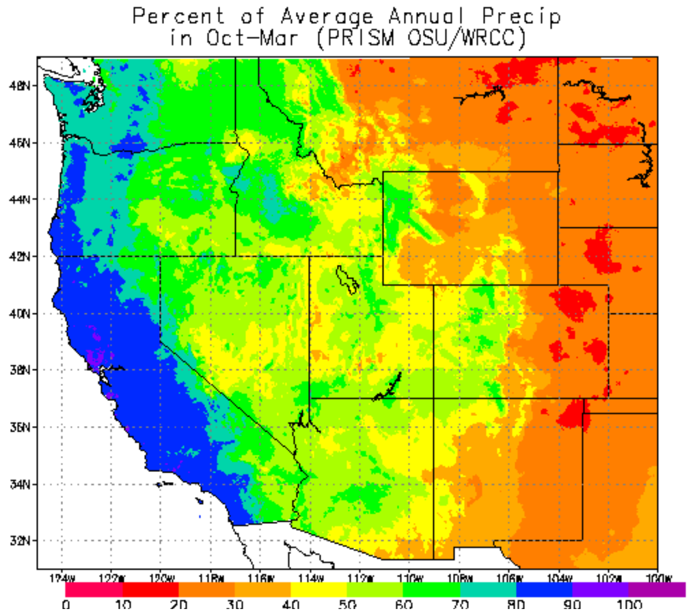
Intermountain Precipitation Stats

Importance of a few opportunities

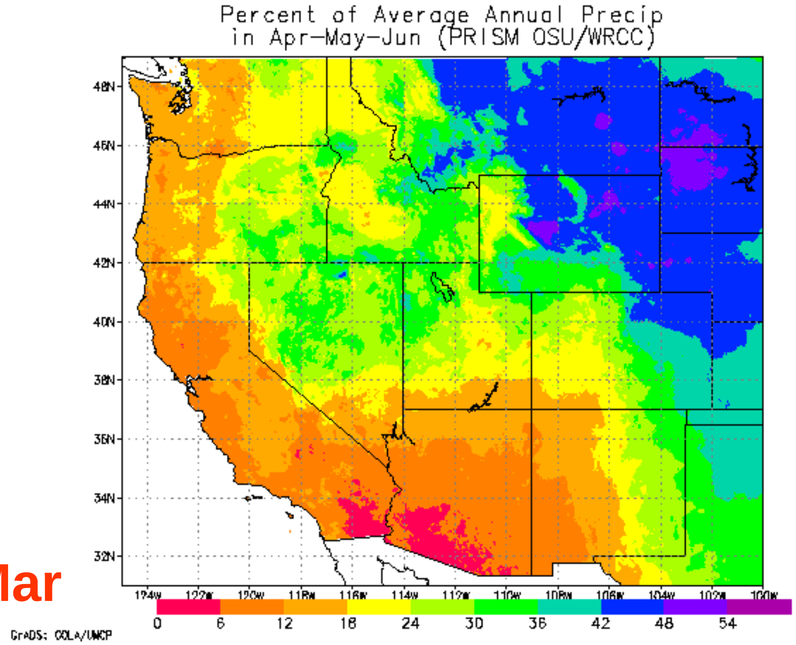
Precip Days per Year (POR)

Hourly (approx 1949 to 2009)

How many hours per year ?
Wettest hour of typical year ?
Percent of hours with precip
How important is wettest hour?

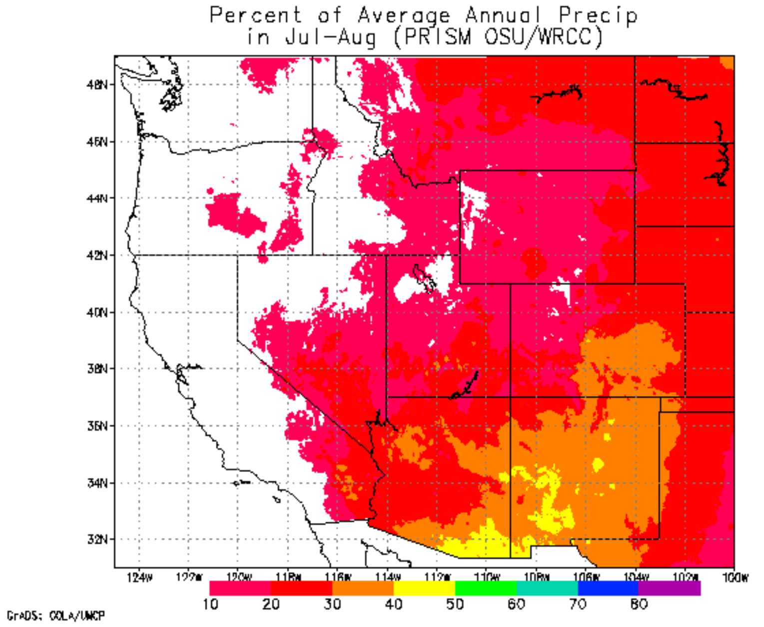


Oct-Mar



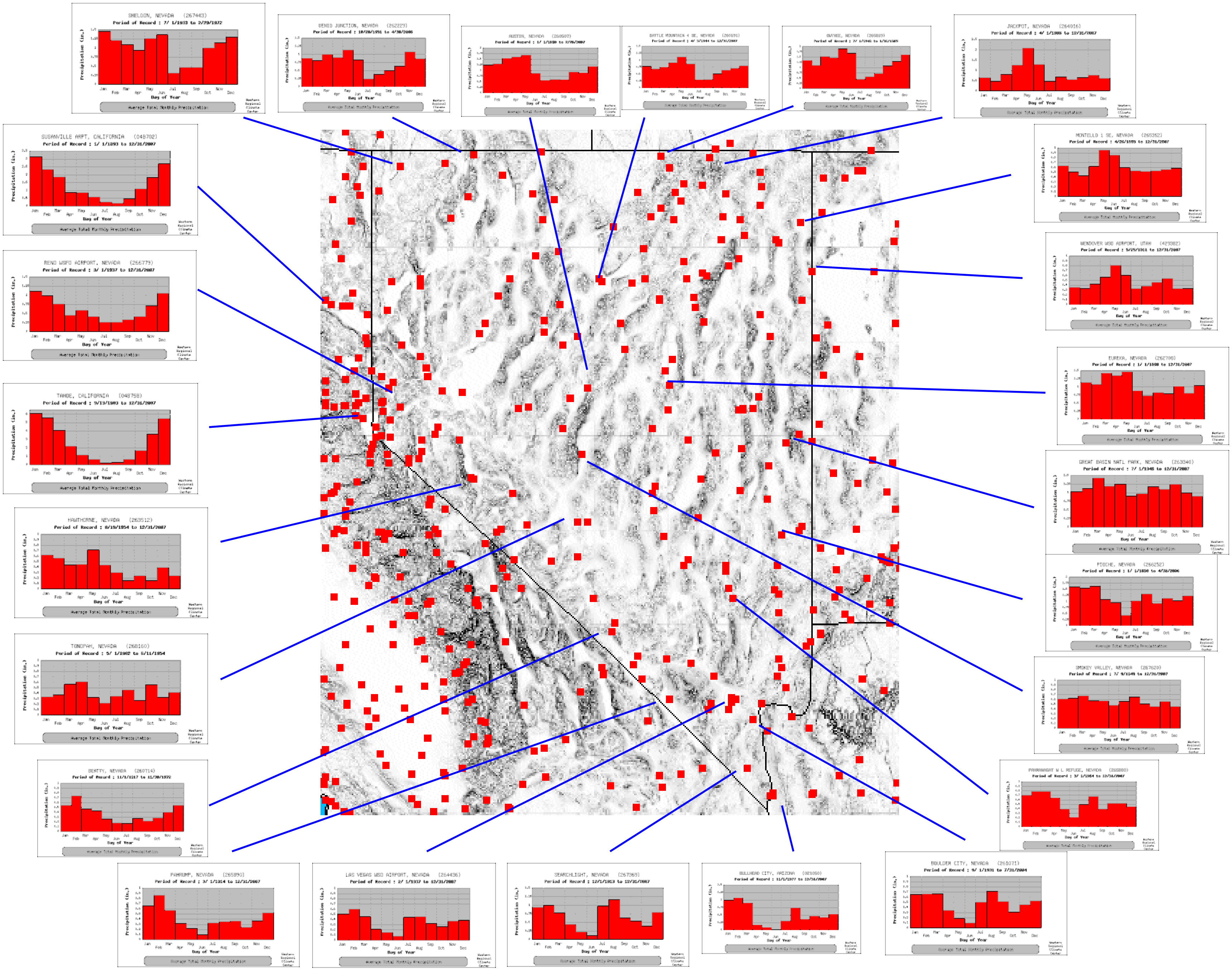
Apr-May-June

Fraction of Annual Total Precipitation, by Season



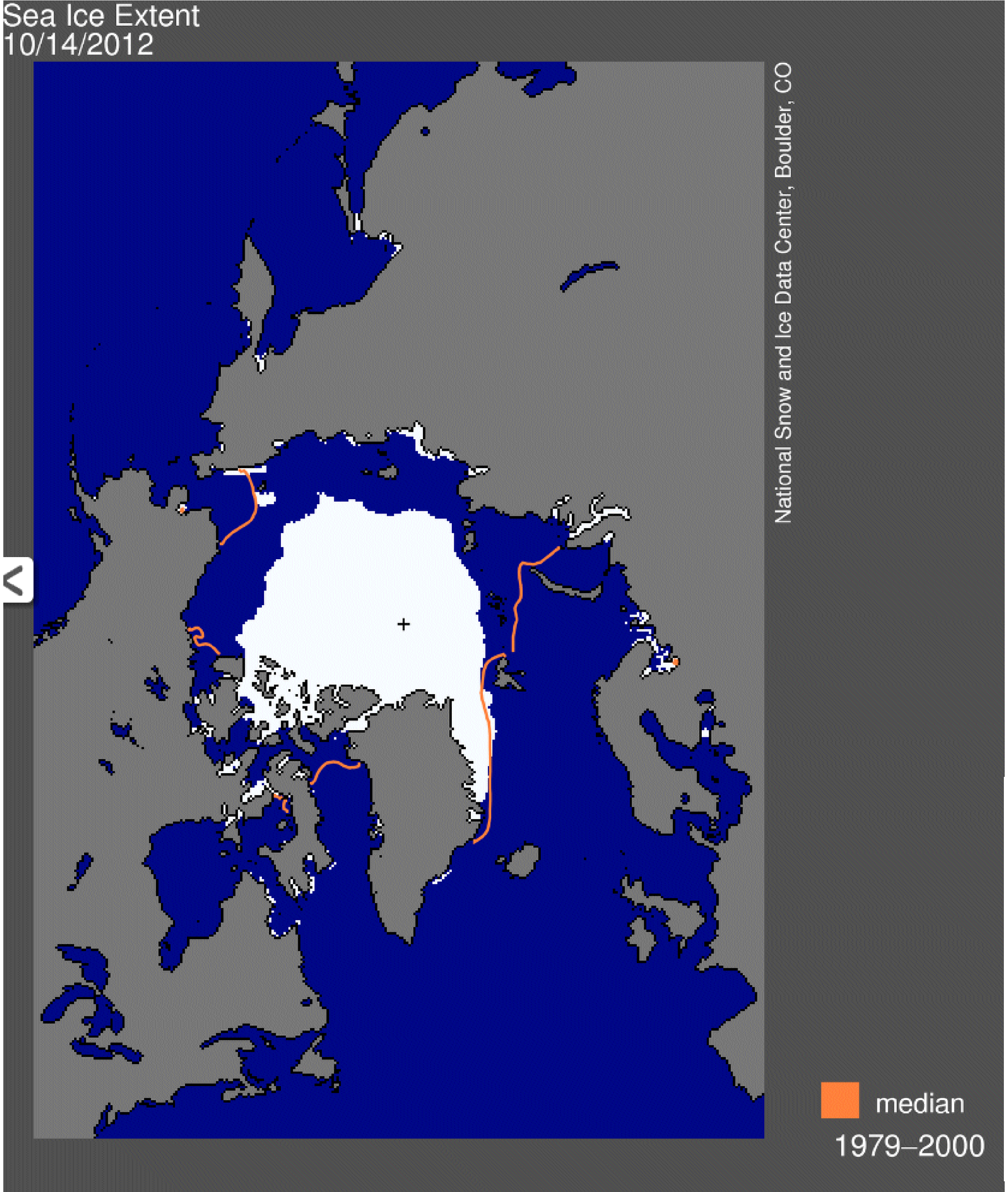
July-Aug

Nevada Annual Precipitation Cycle



Next to Long Draw Fire SE Oregon 2012 July 24

Jamie Francis, Oregonian

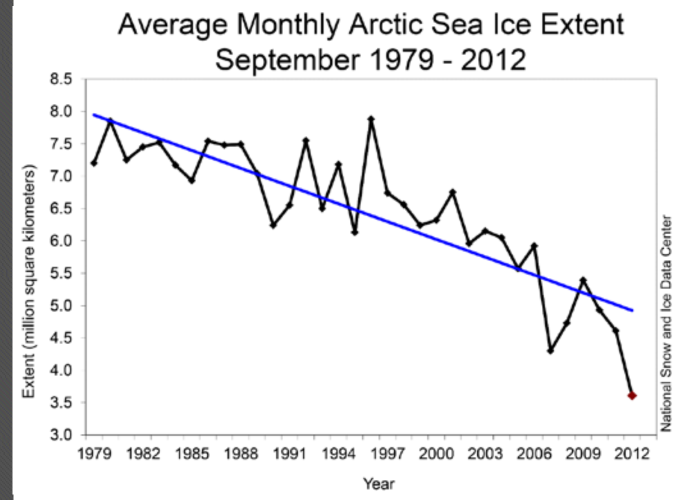


Lowest Arctic Ice Pack

on record

mid-Sept 2012

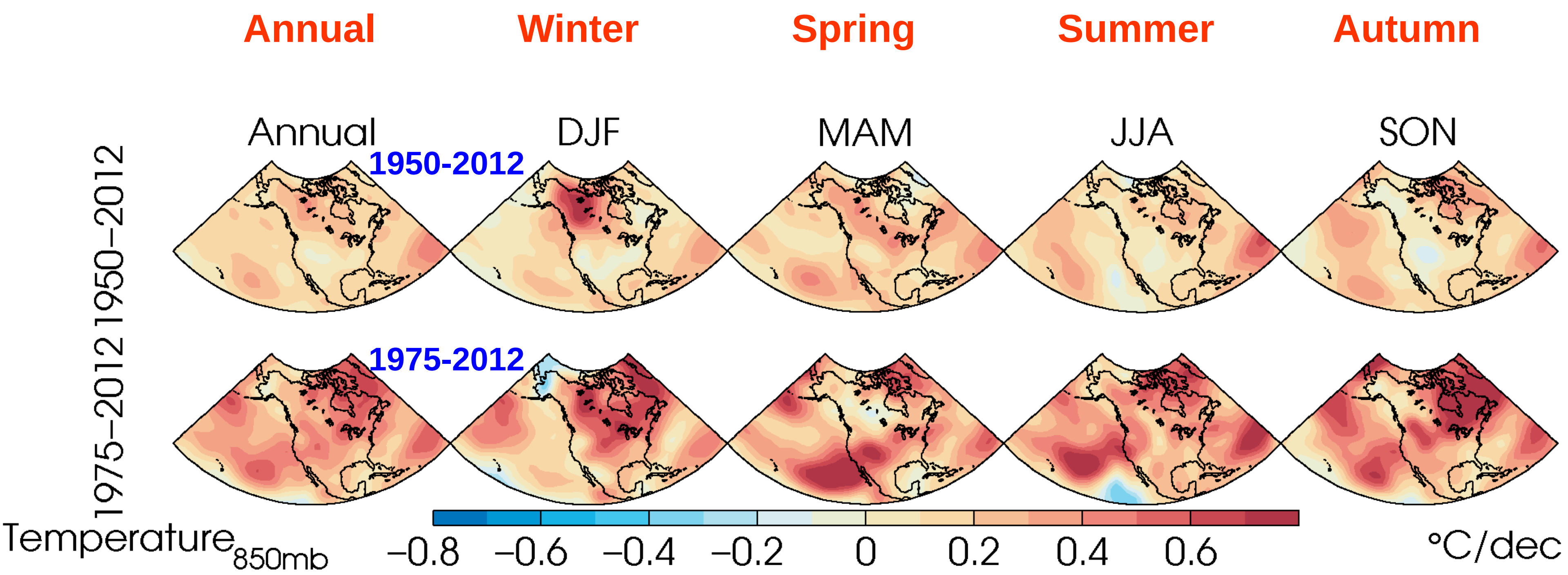
Surrounding ocean absorbed much more solar radiation this summer.



Trends in North America 850 mb (~5000 ft) Temperature

CRUTS3.1

(thanks to John Abatzoglou)



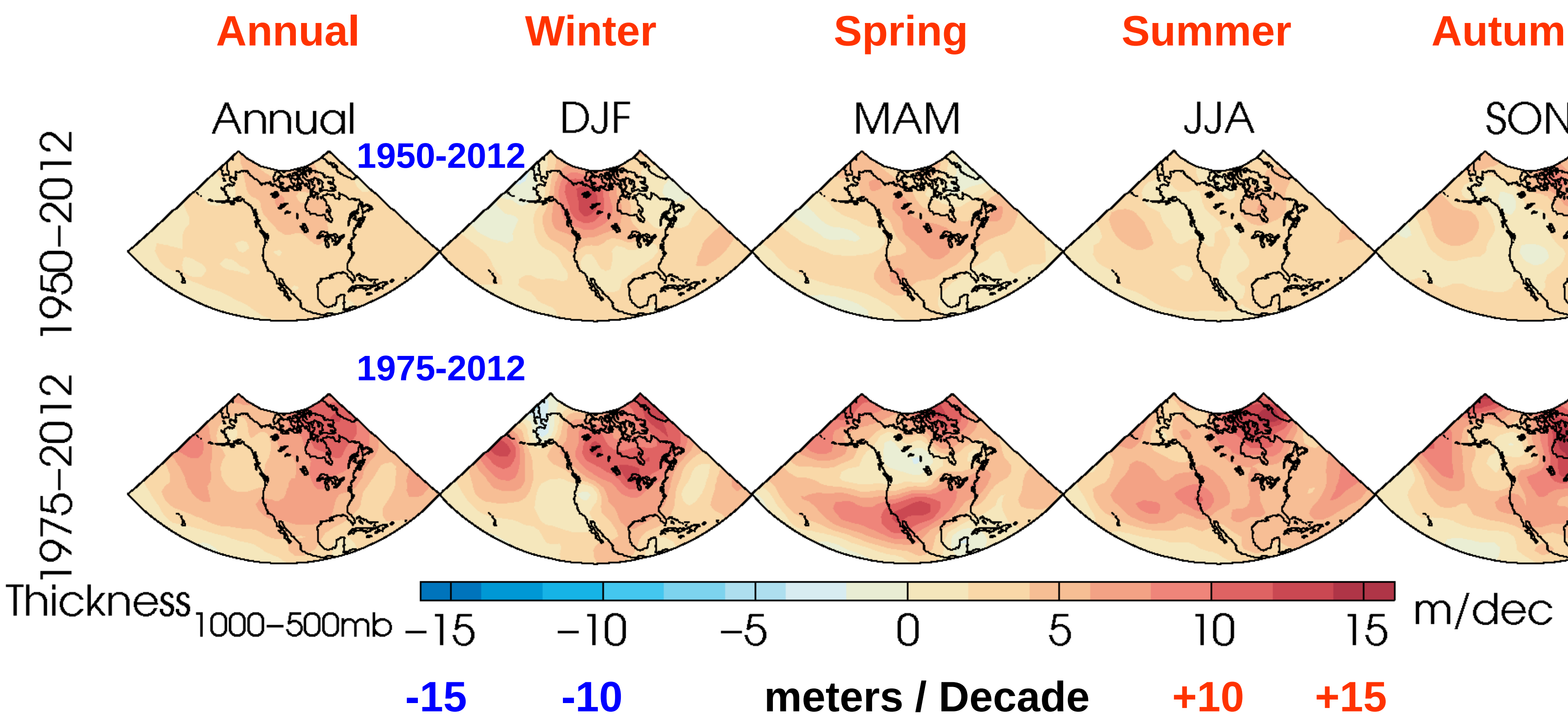
-0.8 -0.6 -0.4 Deg C / Decade +0.4 +0.6 +0.8

Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.

Trends in North America 1000-500 mb Thickness (Lower Atm Temperature

CRUTS3.1

(thanks to John Abatzoglou)

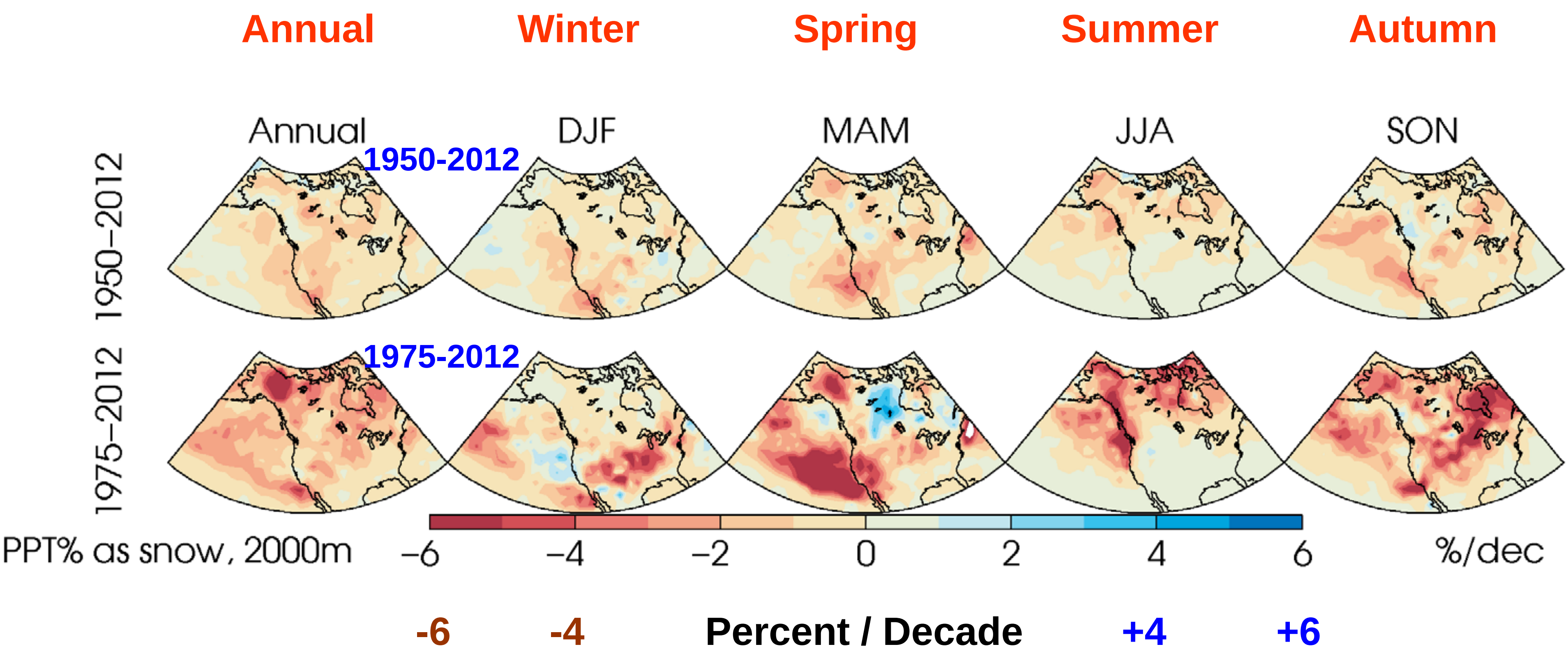


Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.

Trends in North America Estimated "Rain" vs "Snow" at 2000 m (~6600 ft)

CRUTS3.1

(thanks to John Abatzoglou)

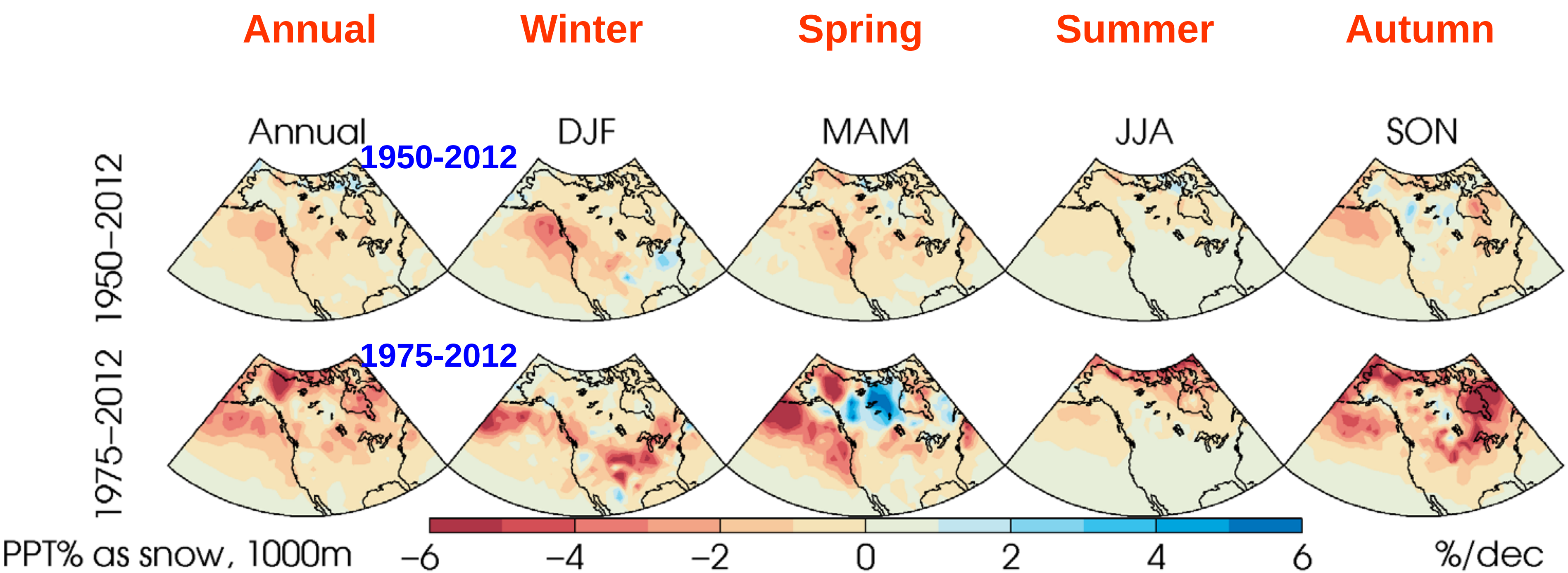


Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.

Trends in North America Estimated “Rain” vs “Snow” at 1000 m (~3300 ft)

CRUTS3.1

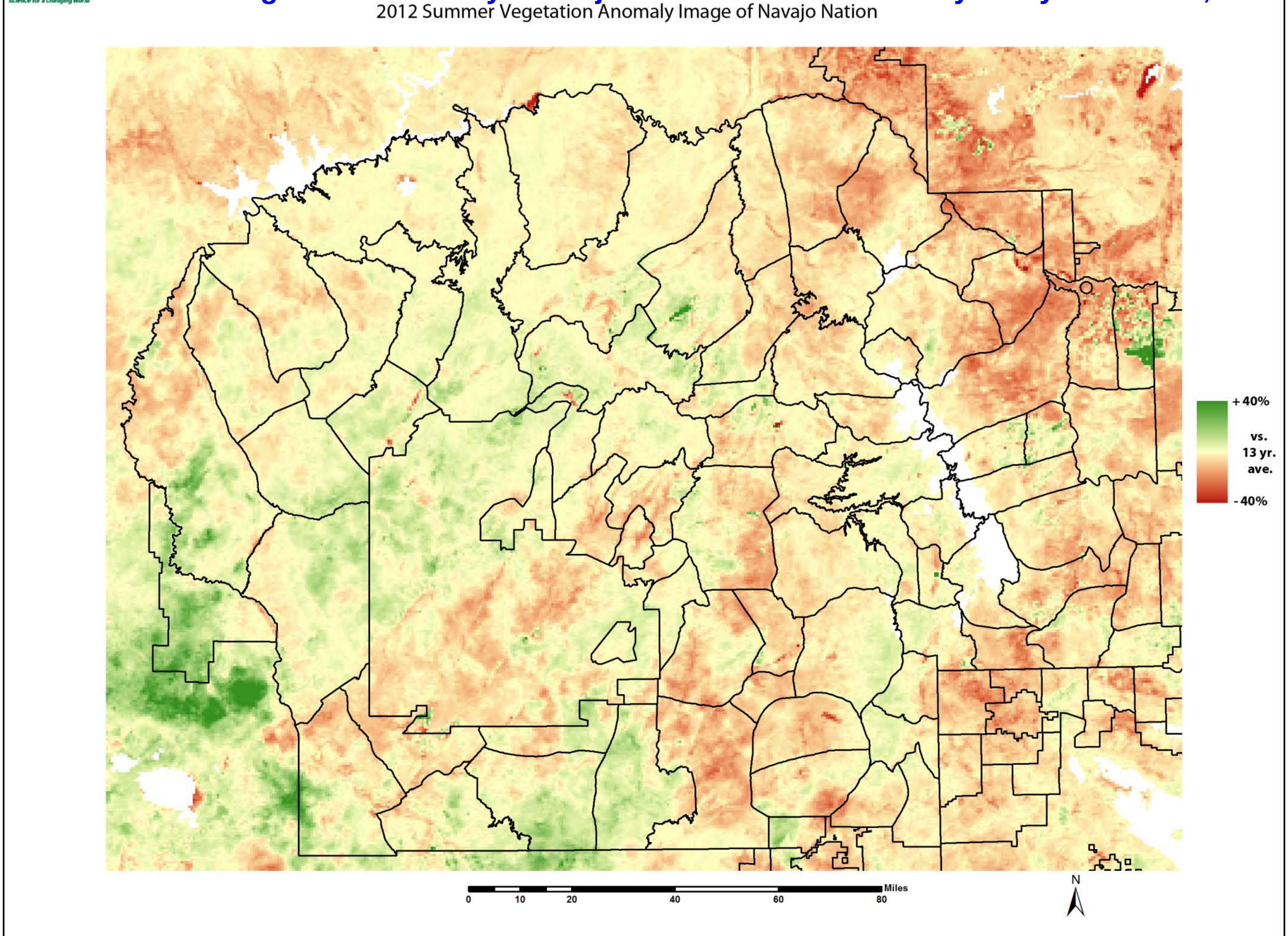
(thanks to John Abatzoglou)



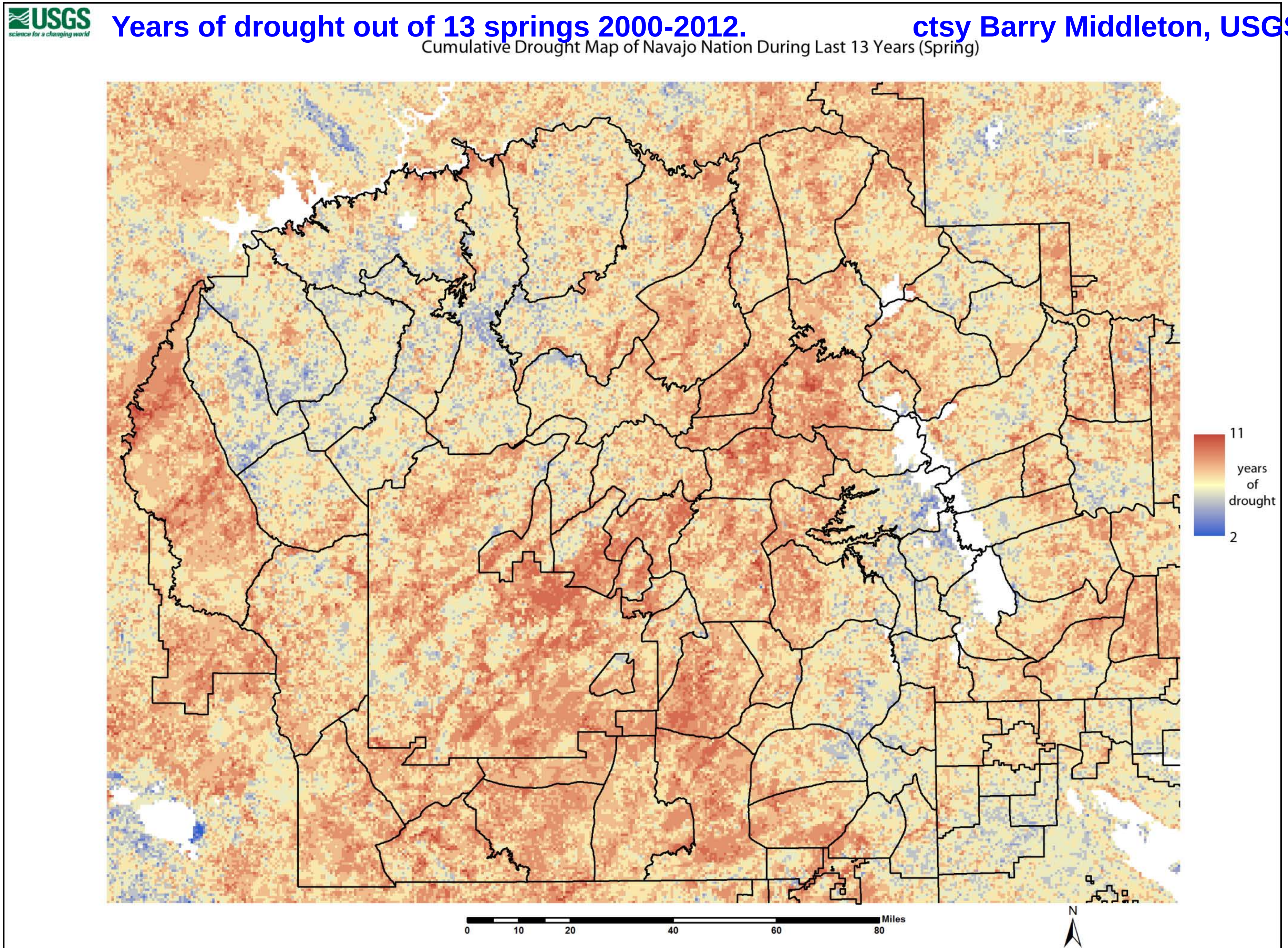
-6 -4 Percent / Decade +4 +6

Redmond and Abatzoglou, submitted 2013
Current Climate and Recent Trends. Ch 2.
Climate Change in North America.
George Ohring, ed. Springer.

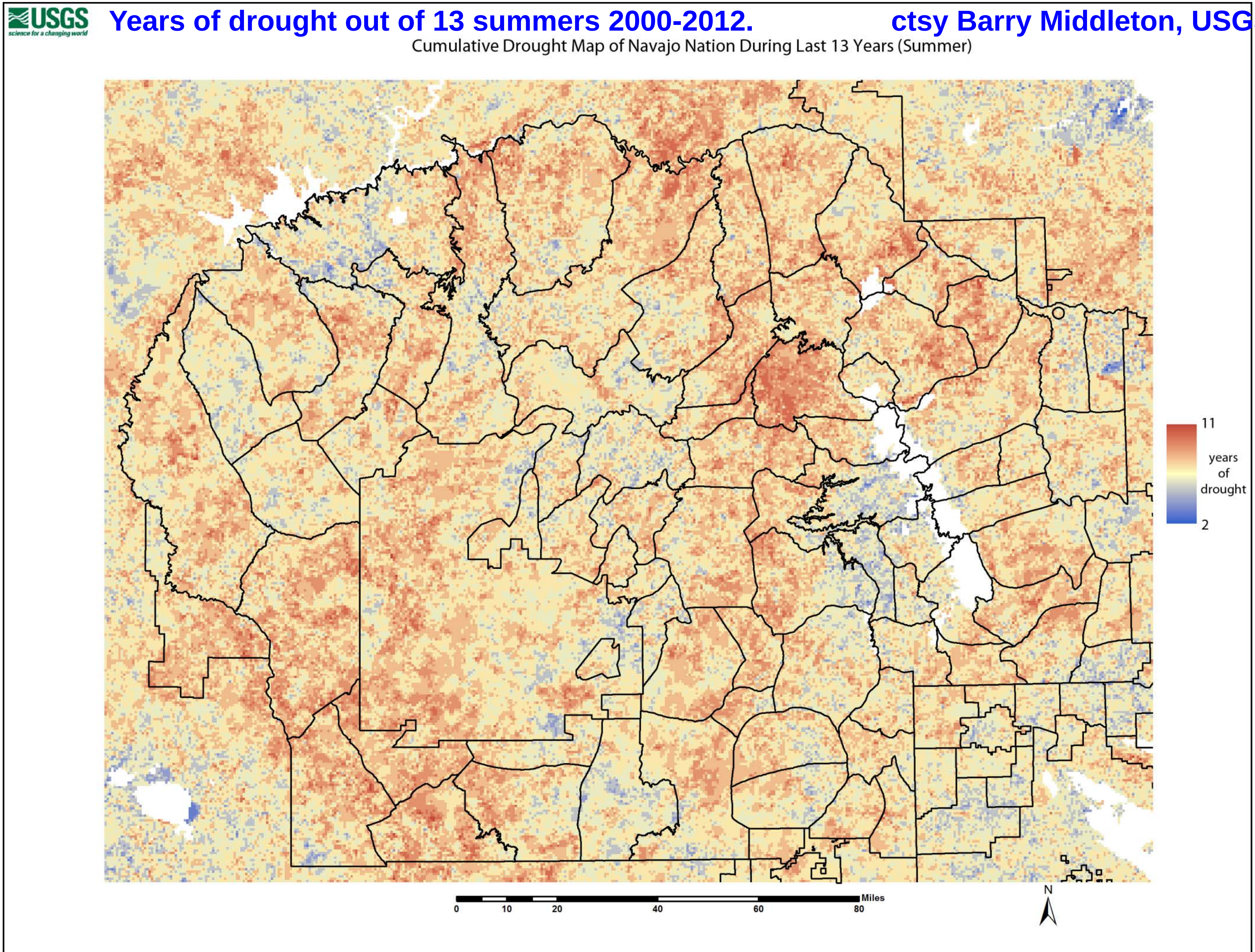
Summer vegetation anomaly. Navajo Nation. 2012. **ctsy Barry Middleton, USGS.**

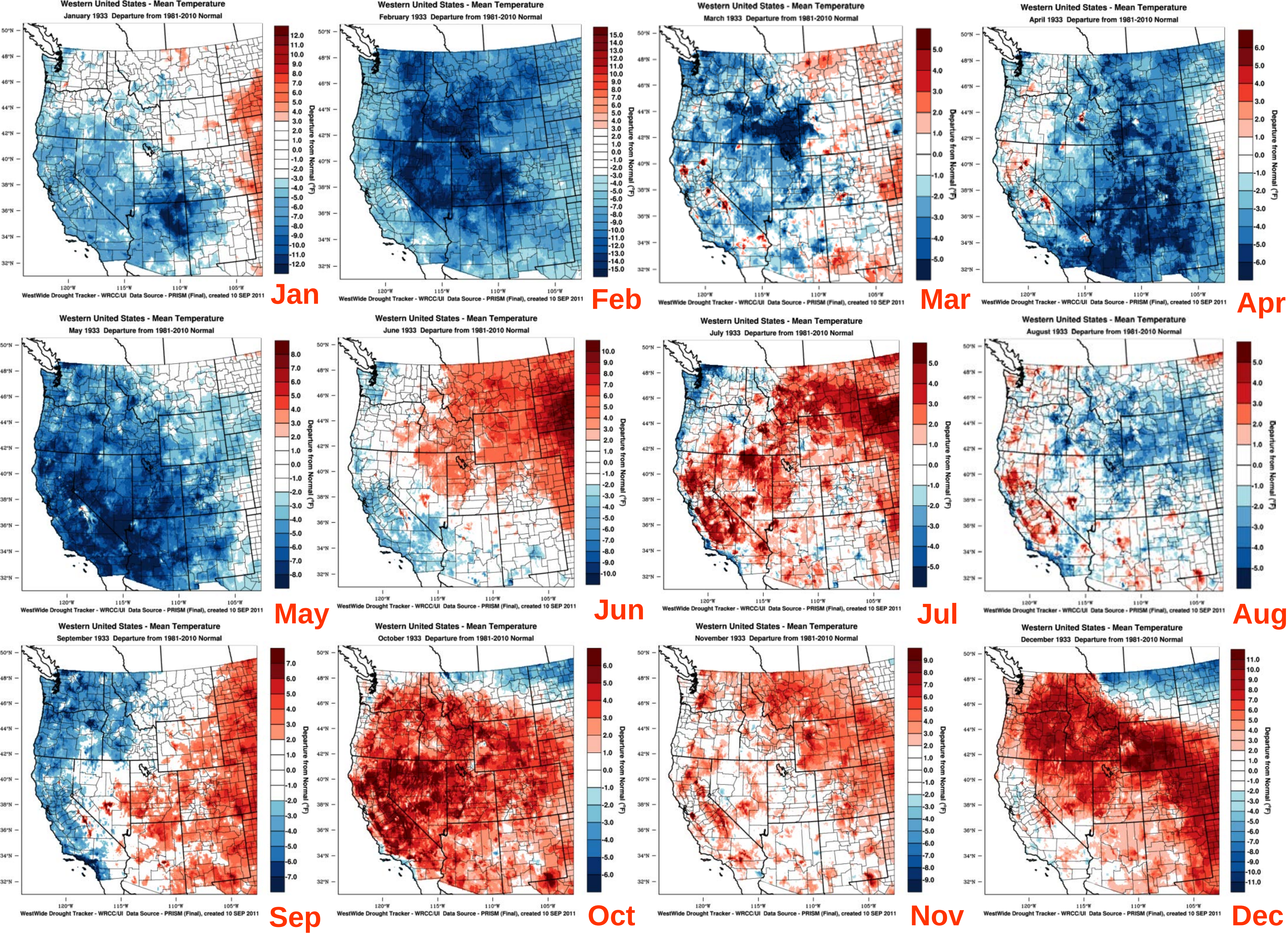


Years of drought out of 13 springs 2000-2012.   ctsy Barry Middleton, USGS

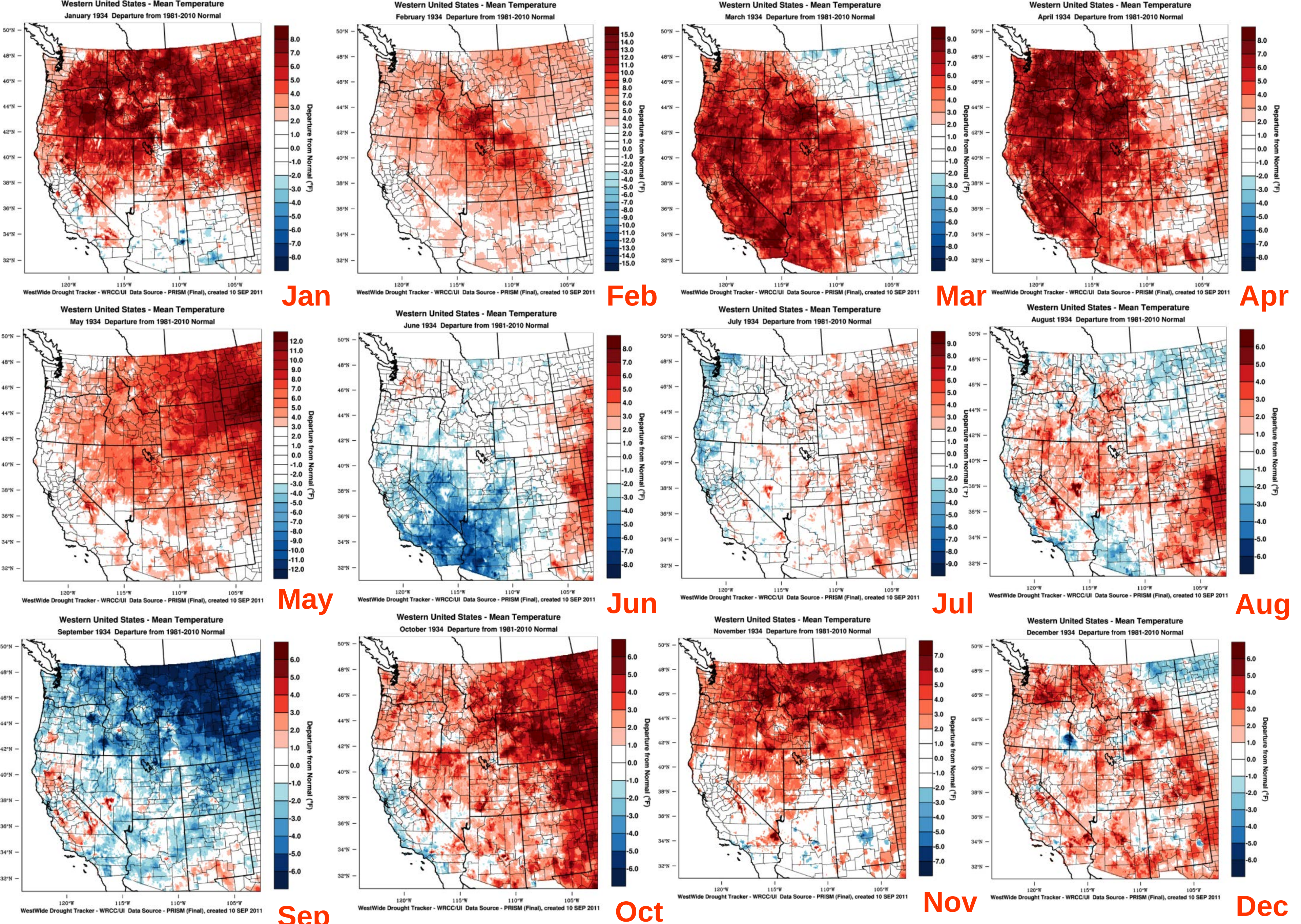


Years of drought out of 13 summers 2000-2012. **ctsy Barry Middleton, USGS**



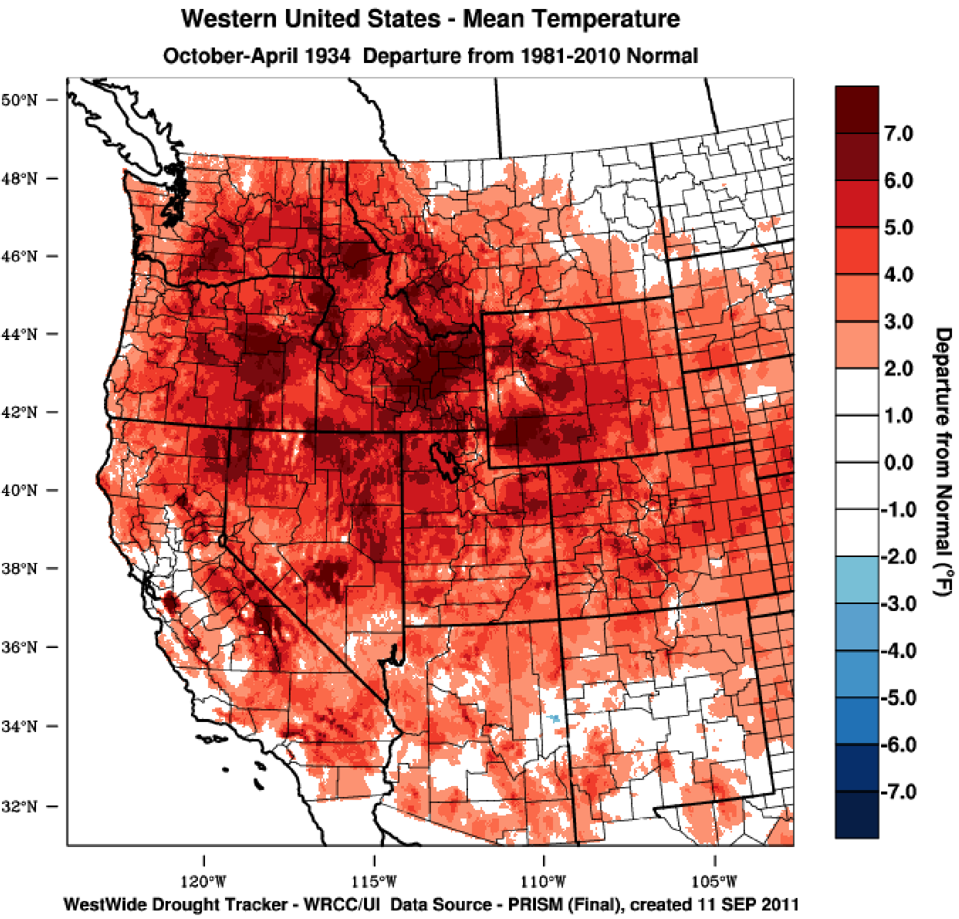


Jan thru Dec 1933

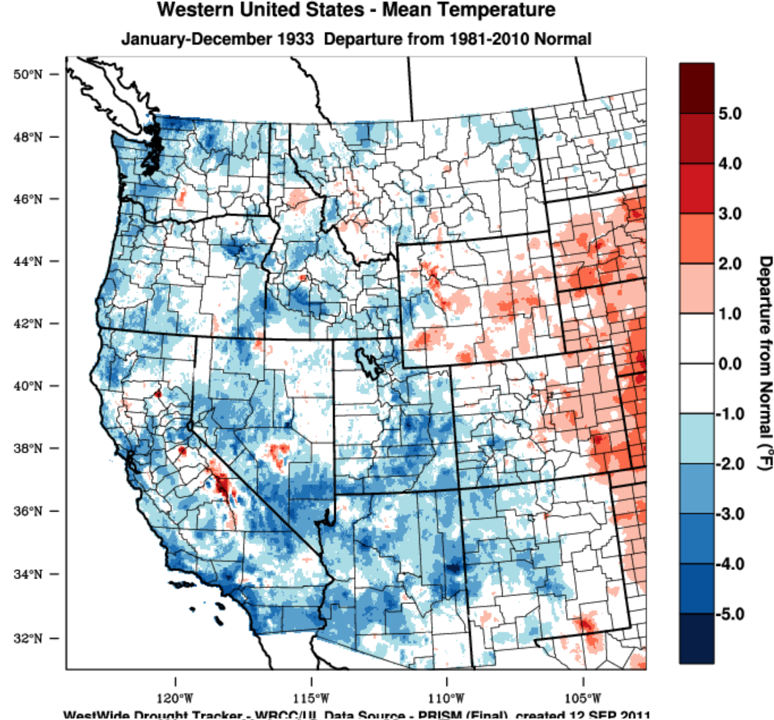


Jan thru Dec 1934

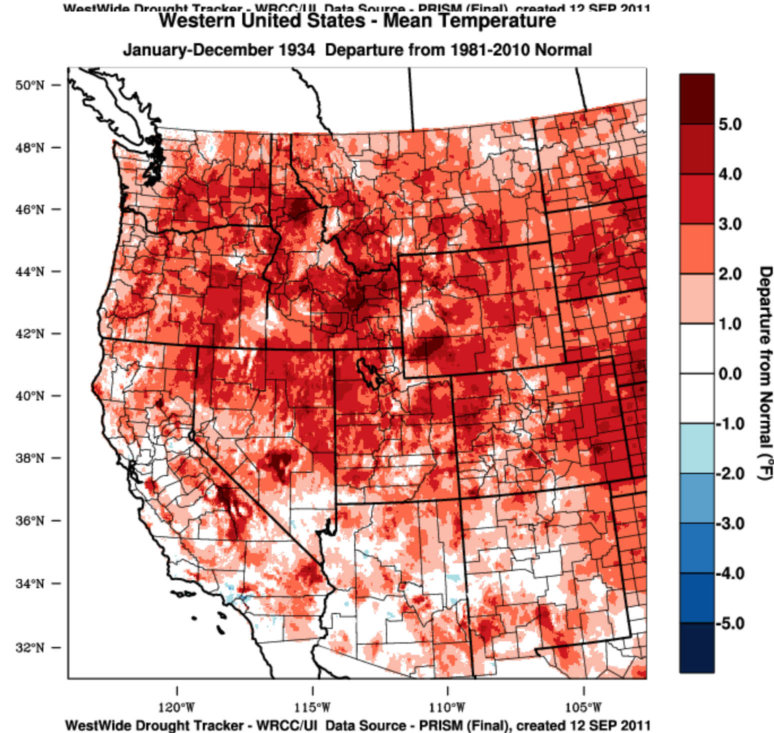
Oct - Apr 1933-34



Annual 1933

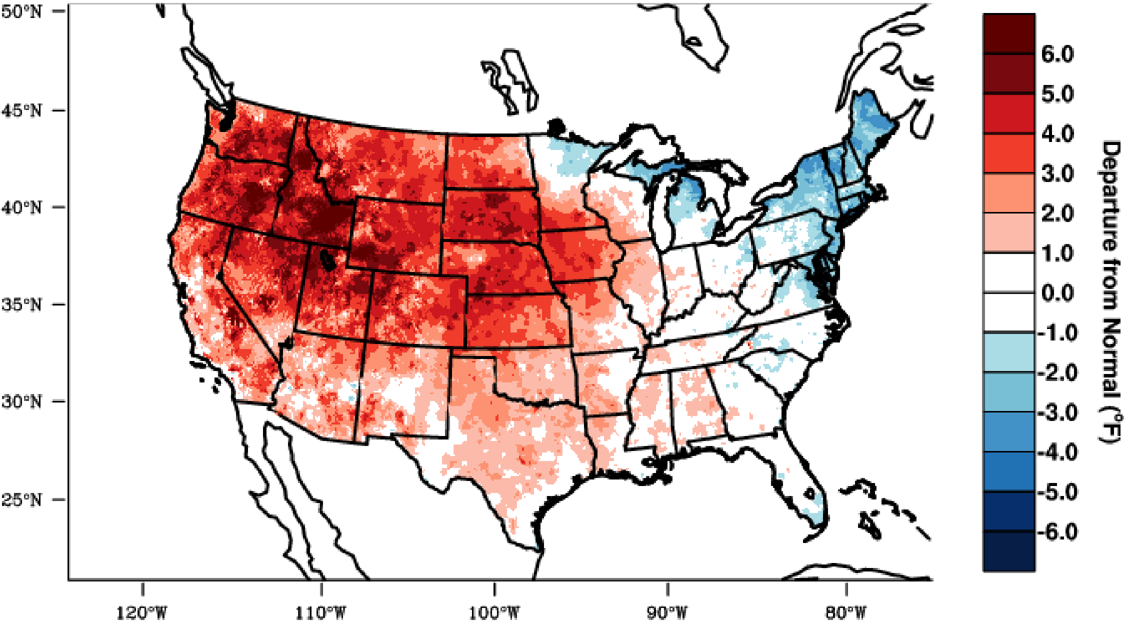


Annual 1934



Continental United States - Mean Temperature

January-June 1934 Departure from 1981-2010 Normal



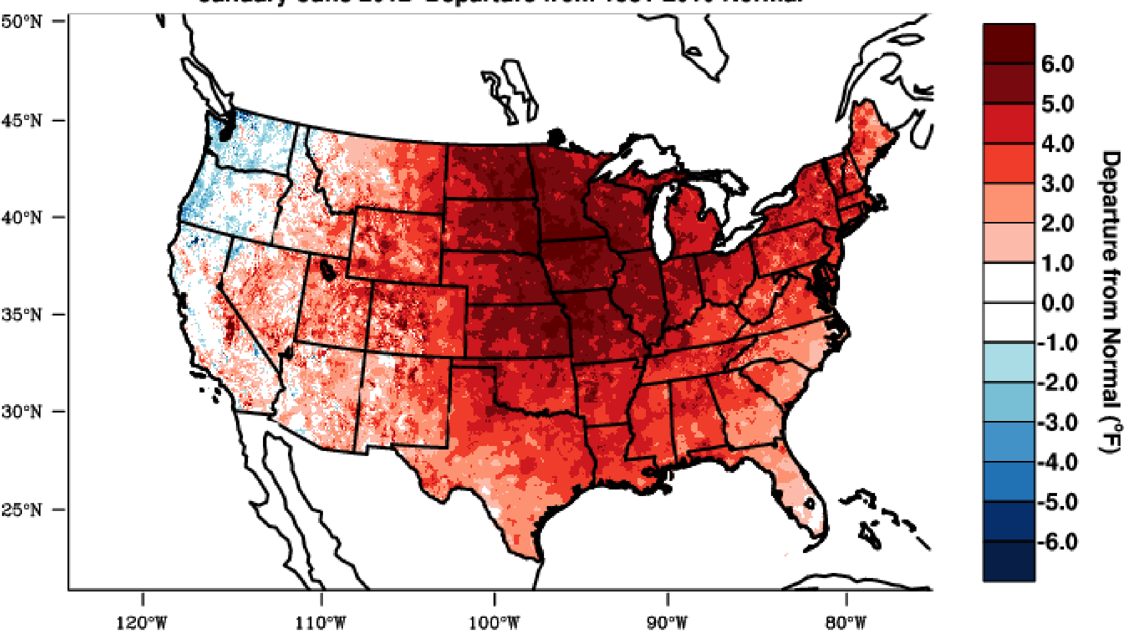
WestWide Drought Tracker - WRCC/UI Data Source - PRISM (Final), created 11 SEP 2011

Jan - Jun 1934

Temp

Continental United States - Mean Temperature

January-June 2012 Departure from 1981-2010 Normal



WestWide Drought Tracker - WRCC/UI Data Source - PRISM (Prelim), created 28 JUL 2012

Jan - Jun 2012

Temp