SLIDES: A History of Climate Variability and Change in the American West

Kelly T. Redmond

A History
of Climate Variability and Change
in the American West

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Properties and Facets of Western Climate

Impossible to ignore, and cannot afford to in many cases.

The West has the hottest, coldest, wettest, driest, snowiest climates in the United States.

+134 F Death Valley

-70 F Rogers Pass

~280” Average annual precipitation upper Hoh River / Mt Olympus

0” Annual precipitation (twice) at Death Valley

1141” (minus October) snowfall in one season at Mt Baker WA

Holds the world records for greatest 24 hour temperature drop:

(+46 to –54 in about 18 hours, January 1916, Browning Montana)

and for the greatest 24-hour temperature rise:

(-54 to +49 in 23 hours, January 1972, Loma Montana)

Extreme spatial variations.

The odd and extreme juxtapositions that the West is known for.

Topography as a central and controlling influence

Aridity as a constant theme.

Western Hydrology

High elevations (supply region)

Low elevations (demand region)

Supply largely falls in winter.

Demand largely occurs in summer.

Usage is often far away from supply, in space and in time.

(Can become out of sight, out of mind.)

Climates elsewhere matter for local purposes.

Water flows toward

a) the gravitational center of the earth,

b) money.

Snow is extremely important (approx 3 / 4 of water supply).

Snow is the cheapest reservoir there is.


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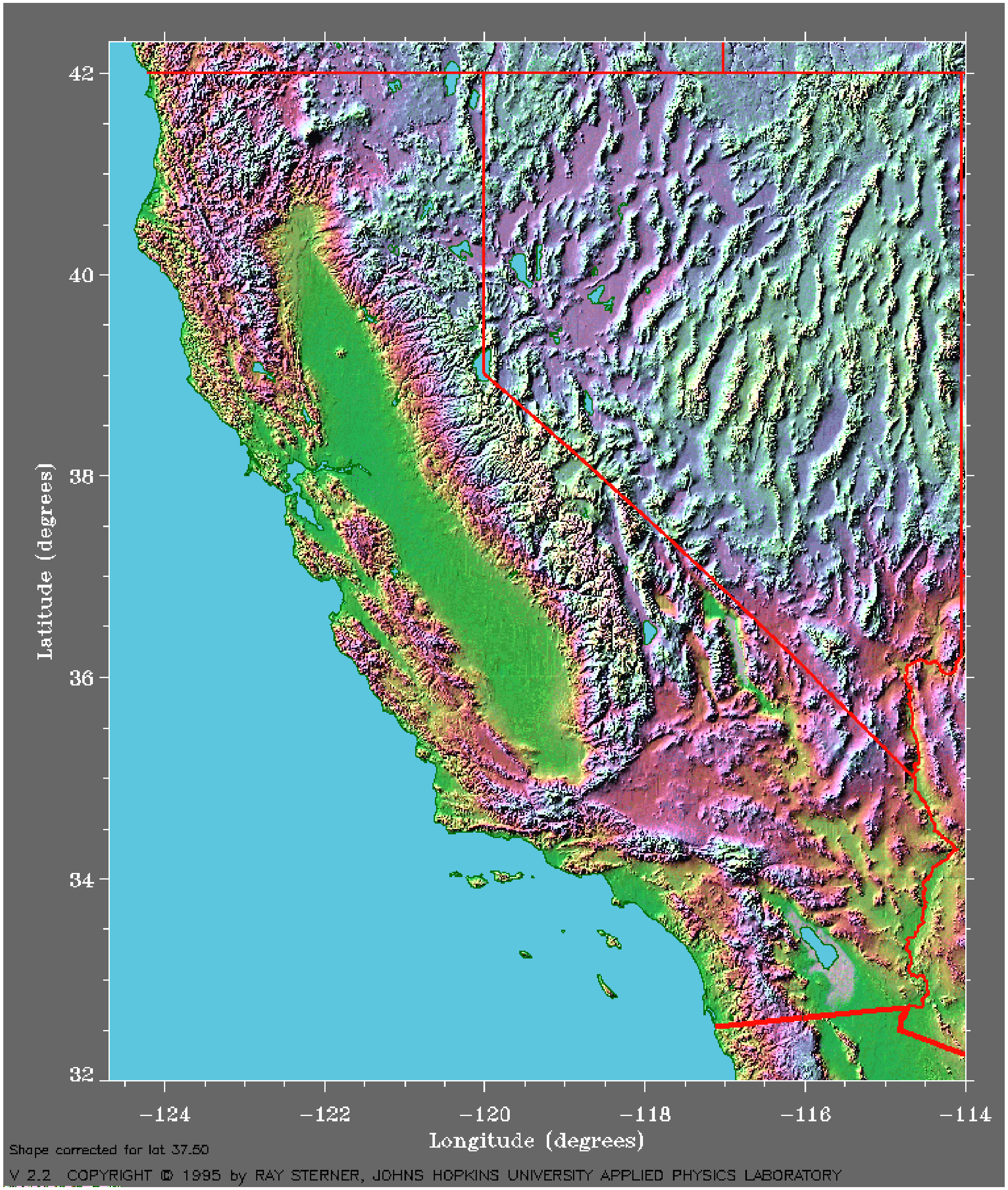

42
40
38
36
34
32
Latitude (degrees)
−124
−122
−120
−118
−116
−114
Longitude (degrees)
Shape corrected for lat 37.50
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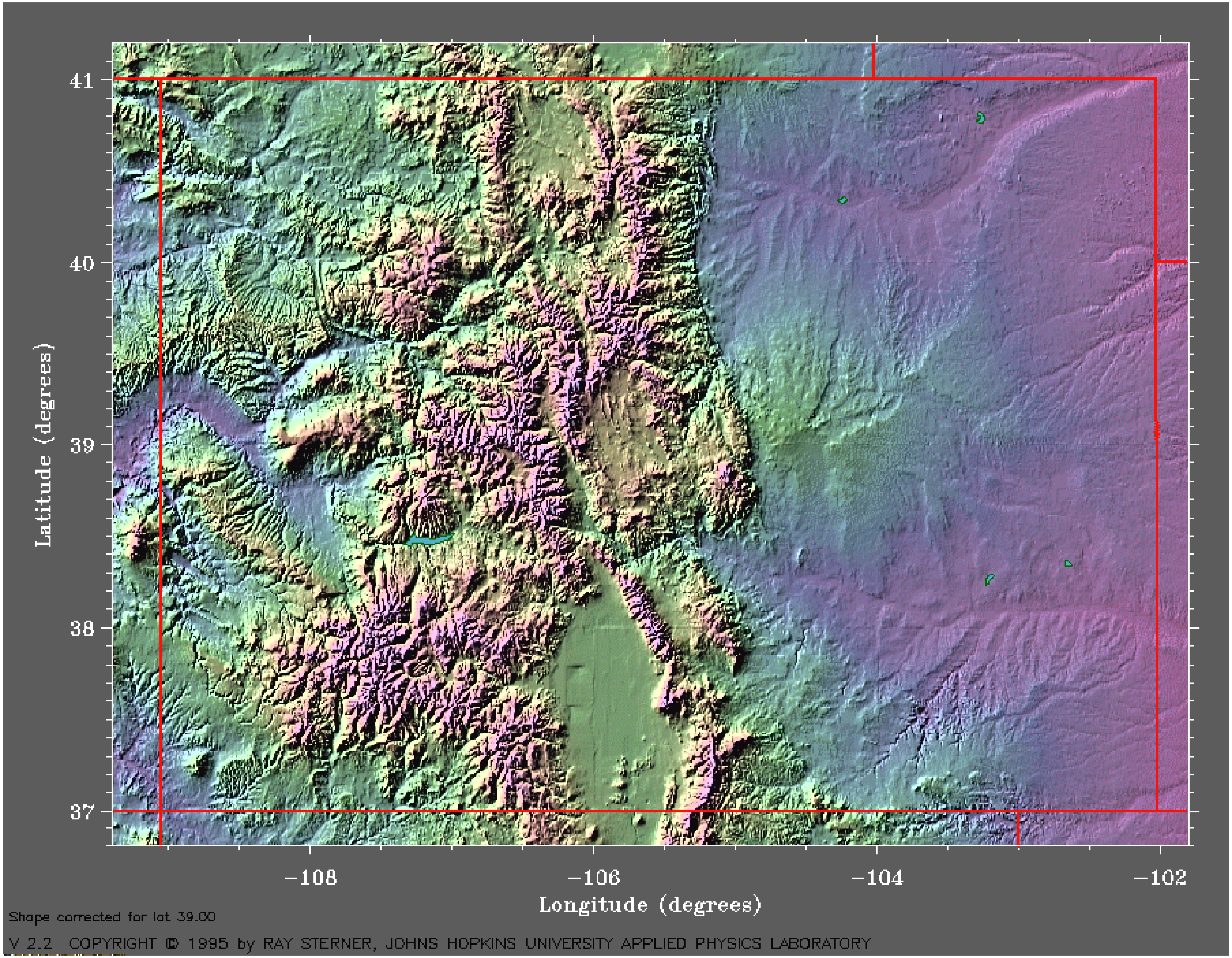
41
40
39
38
37
Latitude (degrees)
−108
−106
−104
−102
Longitude (degrees)
Shape corrected for lat 39.00
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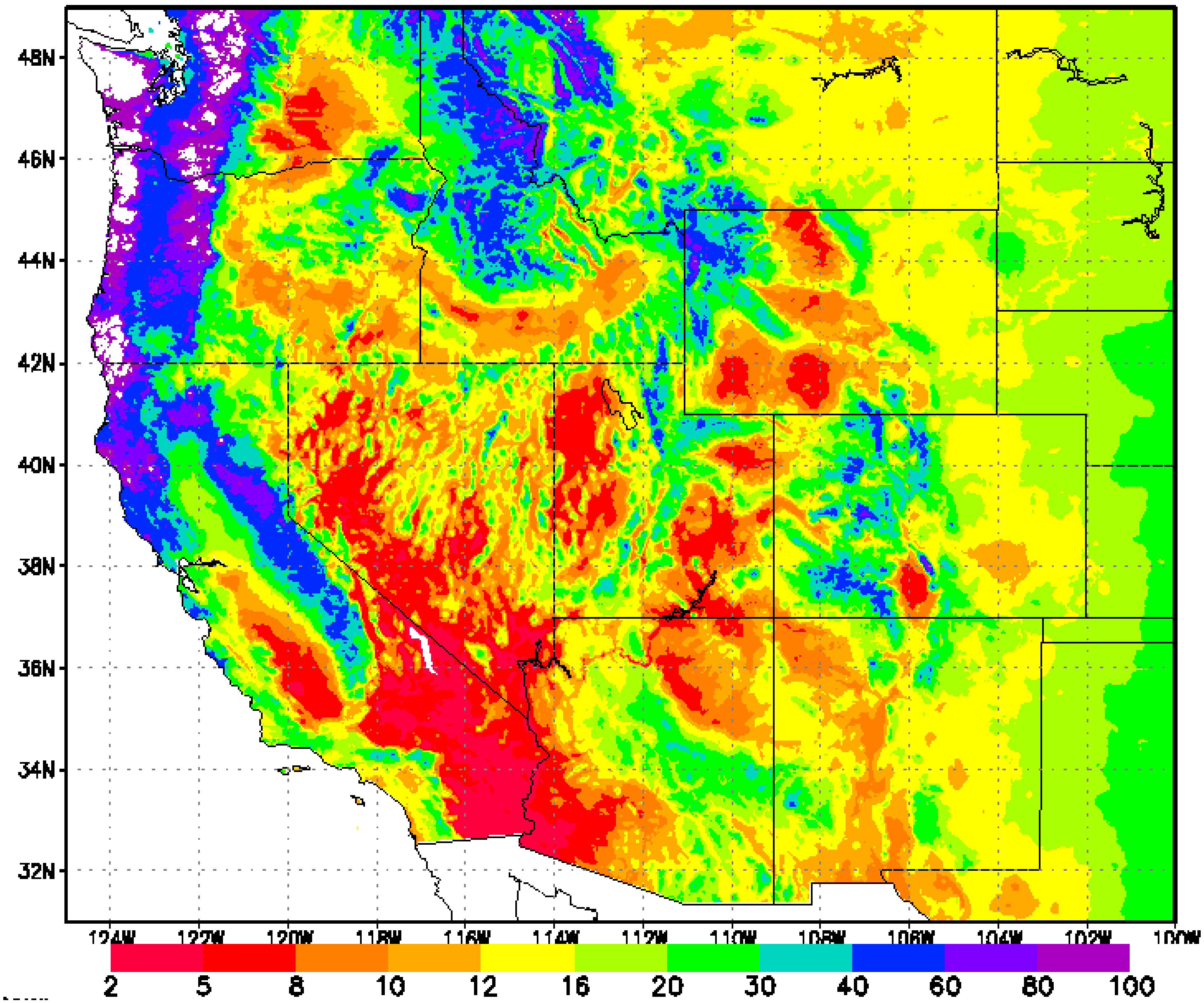
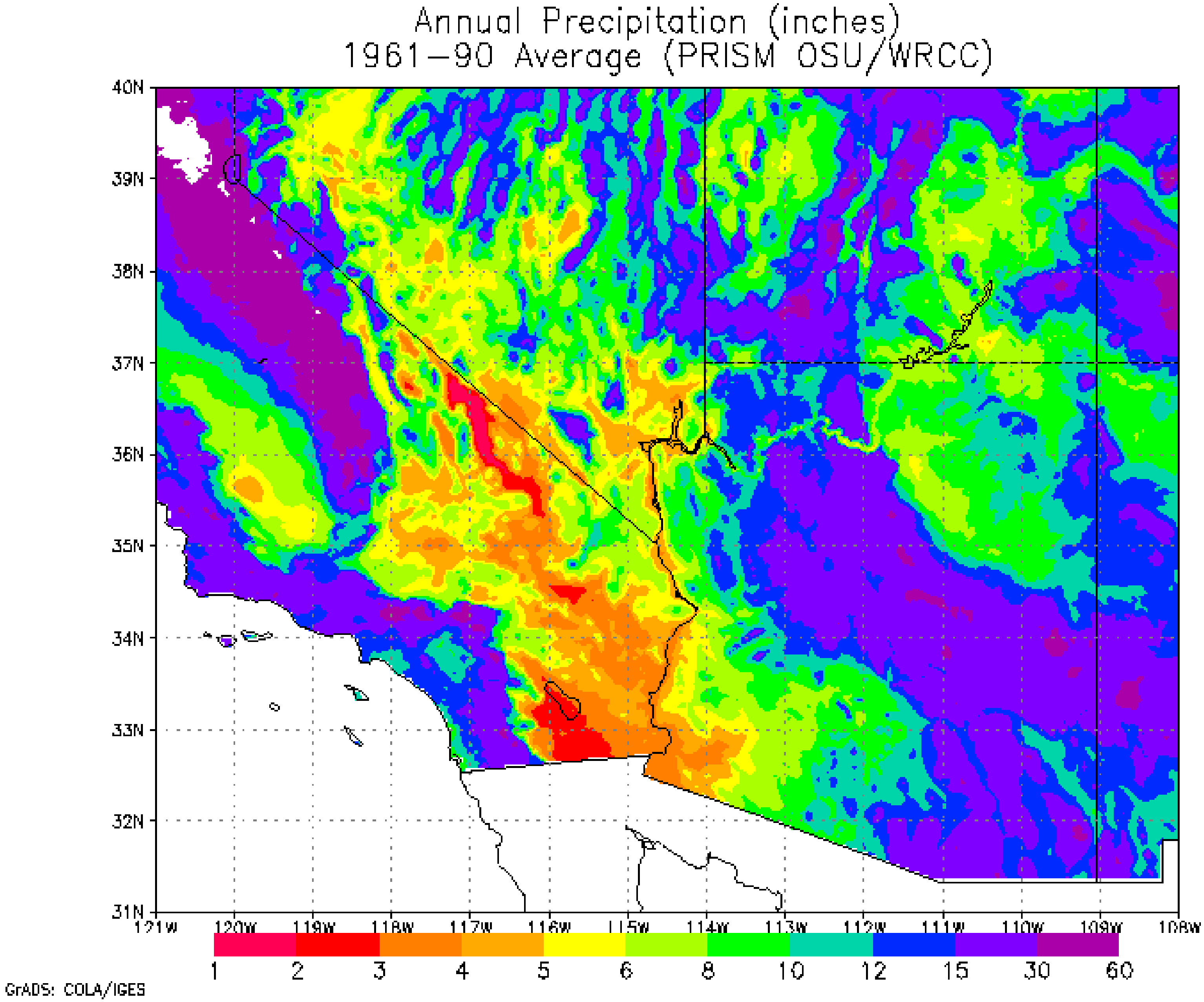
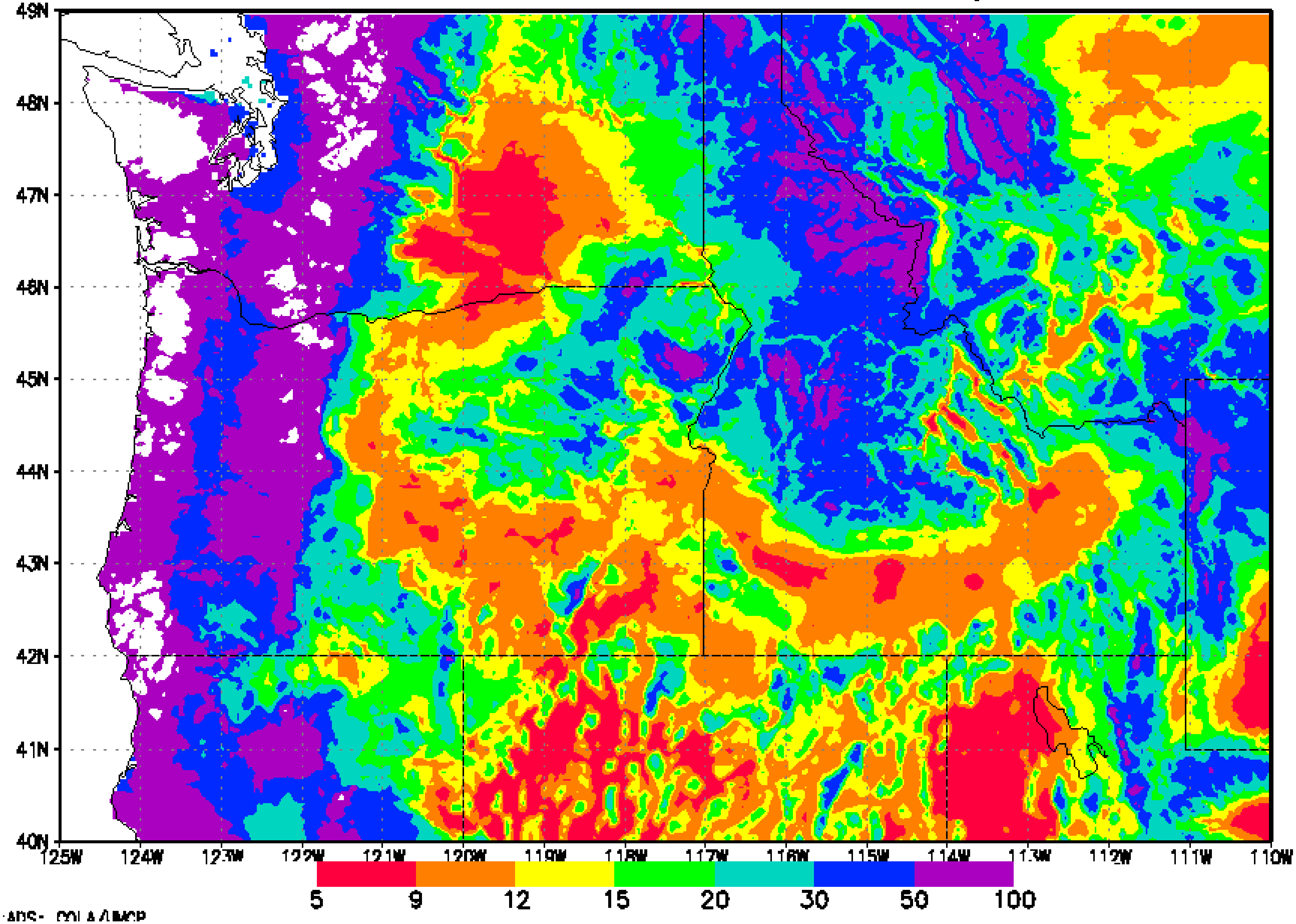
Annual Precipitation (inches)
1961–90 Average (PRISM OSU/WRCC)

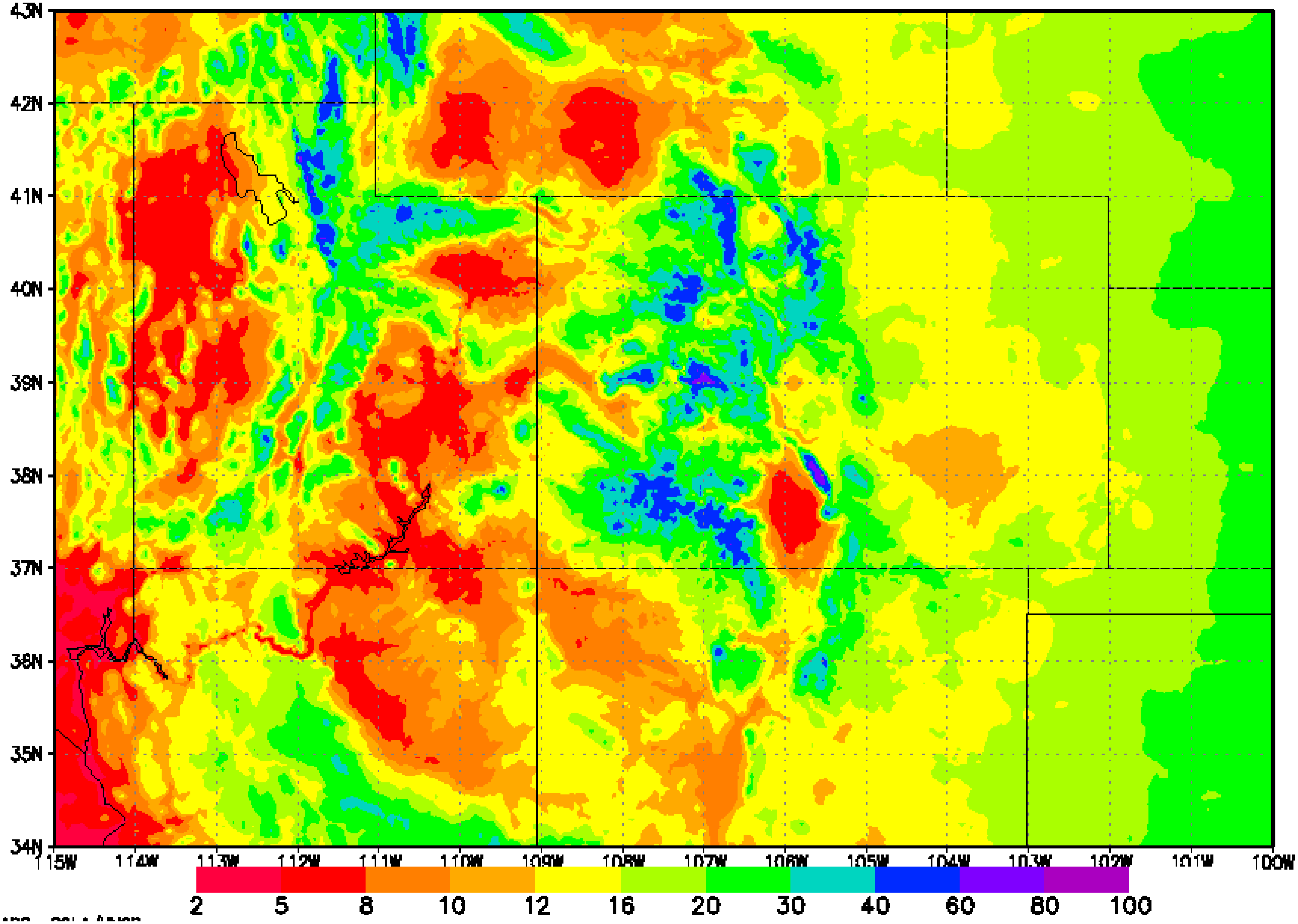


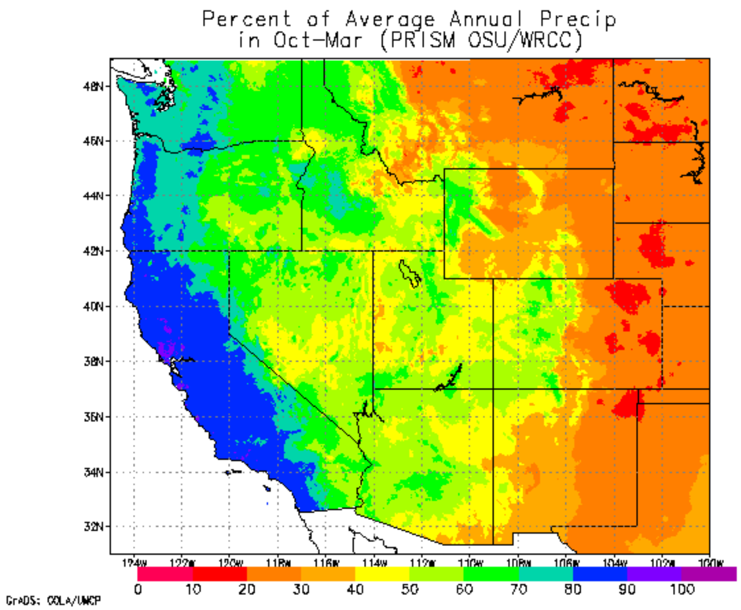

Annual Precipitation (inches)
1961–90 Average (PRISM OSU/WRCC)
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
121W
120W
119W
118W
117W
116W
115W
114W
113W
112W
111W
110W
109W
108W
1
2
3
4
5
6
8
10
12
15
30
60
GrADS: COLA/IGES

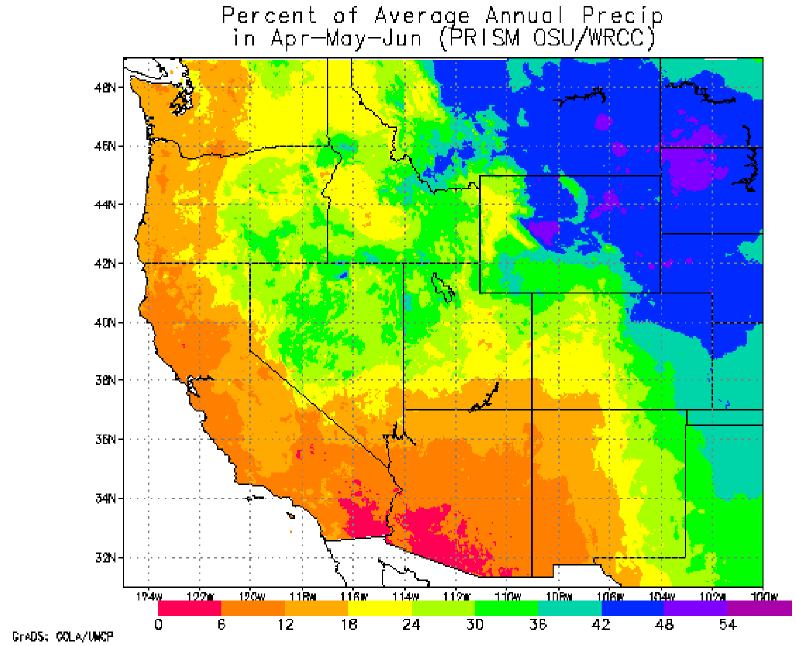
Annual Precipitation in Selected Ranges (inches)



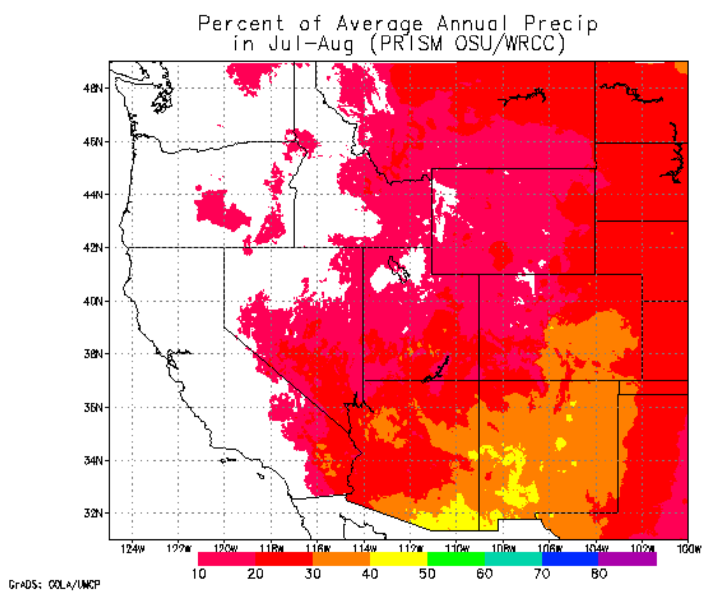
Annual Precipitation (inches) 1961-90 (PRISM OSU/WRCC)







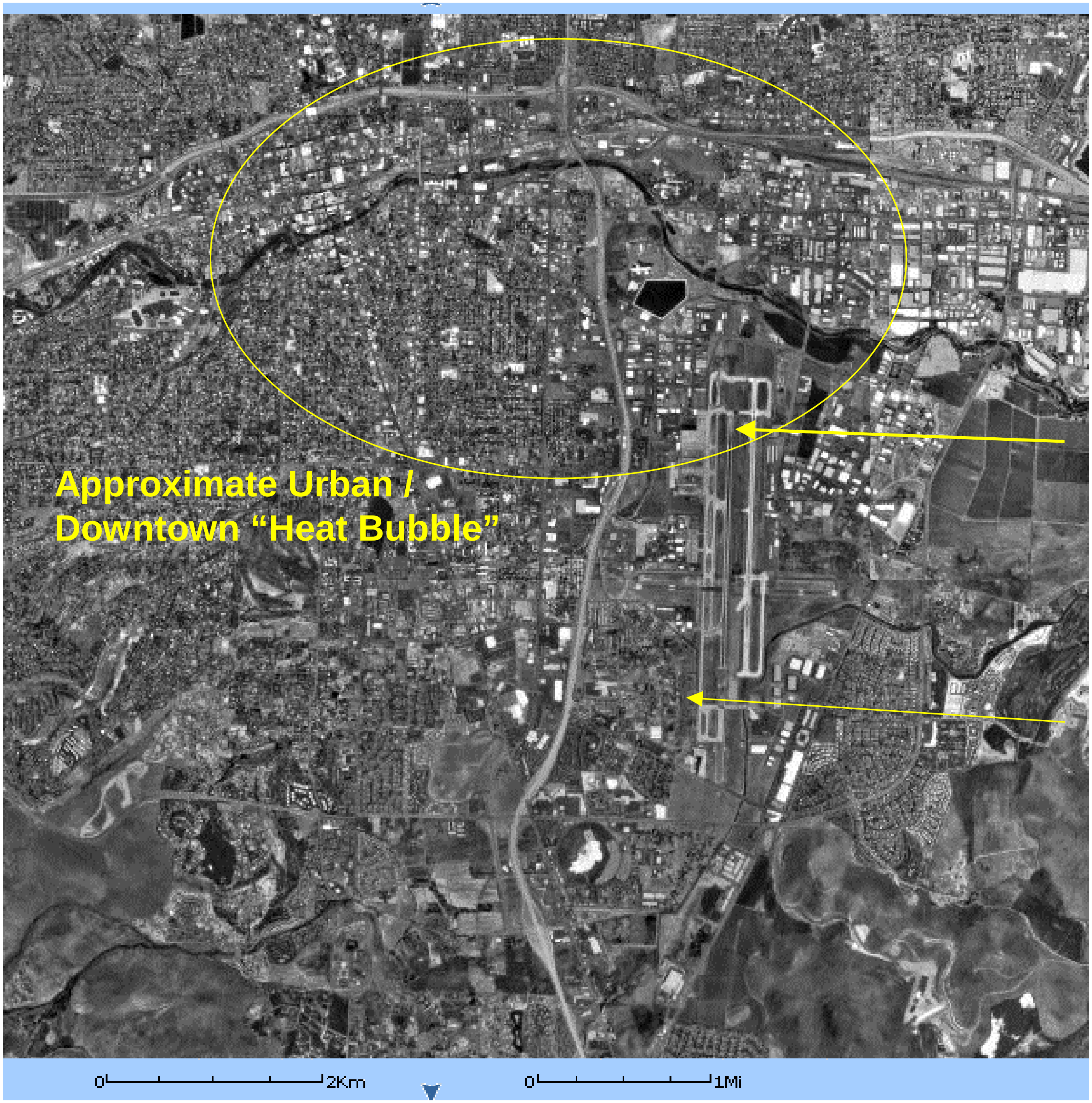
Oct-Mar **Apr-May-June**



Fraction of Annual Total Precipitation, by Season

July-Aug

Bozeman Airport (KBZN). Often find (legitimate) temperature variations of 10-20 degrees F from one end of the runway to the other (11,000 feet), in winter.



Reno Airport

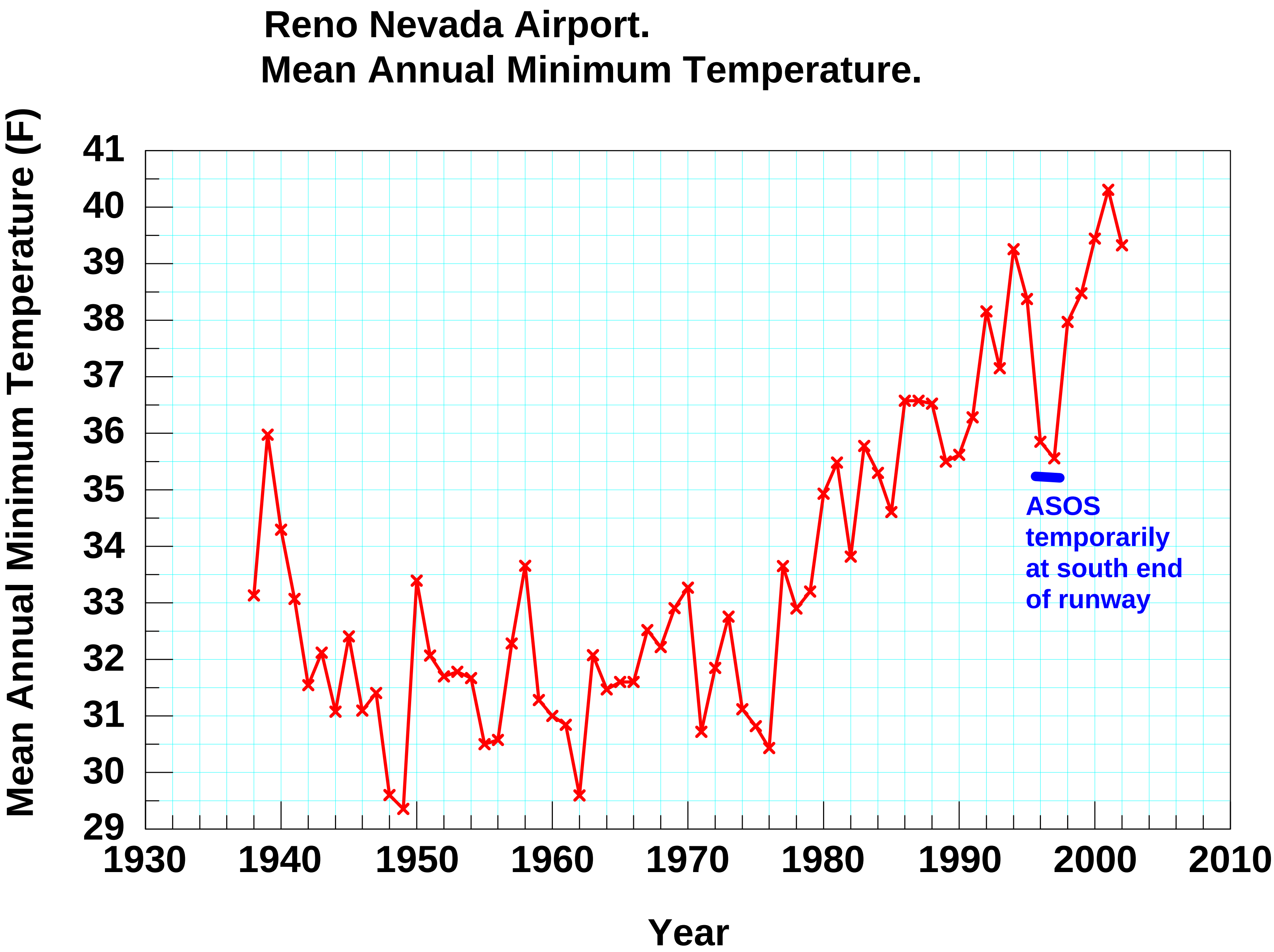
(KRNO)

KRNO ASOS
(between runways)

Temporary ASOS
(“not windy enough”)

****

Temperature differences can be 6-8 degrees F from one end of runway to the other, at night.


Reno Nevada Airport.
Mean Annual Minimum Temperature.
Mean Annual Minimum Temperature (F)
41
40
39
38
37
36
35
34
33
32
31
30
29
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
ASOS
temporarily
at south end
of runway

Mountains

Glaciers as climate indicators

ENSO influences

PDO influences

The monsoon

Insect outbreaks.

Fire and its role.

March 1, 1778 Captain James Cook names "Cape Foulweather" in pre-Oregon

Mandan, pre-North Dakota, Lewis and Clark, temperature to –45 in winter 1804-05

Seaside Oregon (Fort Clatsop) Rains 88 out of 100 days, 1805-1806 Lewis and Clark not "happy campers"

Donner "Party" - October 31st, 1846.

1861-1862 The Great California Flood. One quarter of the assessed value of California under water. On the Willamette, every town on the low side of the river was washed away.

1861-62 winter. People walked across the Columbia River on the ice at Vancouver. Horse teams across the Willamette at Portland.

1866-69 Severe shoveling. Central Pacific Railroad, Sierra Nevada.

The winter of 1887-88.

Columbia Flood, 1894. 1,200,000 cubic feet per second at Portland.

Heppner, Oregon, 247 people killed in 15 minutes, flash flood, June 14, 1903.

January 1909, Helen Mine CA, 71.54" of rain for the month.

Nov 9, 1914. Bagdad AZ, first rain in 767 days.

1919, December 10-17. Columbia completely frozen over at Vancouver, Dec 14-16 Willamette at Portland.

1924, December 16-26, Ford car driven across the Willamette several times at Portland.

1948 Vanport flood. Columbia 1,000,000 cfs, and a town of 19,000 completely gone.

1948-49. A standout winter in much of the West, cold and snowy. Snow in San Diego first time since 1882, 4.2” in Burbank CA.

January 13, 1952 The City of San Francisco. Train accidentally “on ice”.

1952-56 Southwest Drought.

October 1962 Columbus Day windstorm. Several billion board feet of timber downed, various gusts to 150, 160, 175, very highest possibly 192 mph at Cape Blanco.

1964 West Coast floods.

1984 record rises on Great Basin terminal lakes. Scary moments at Glen Canyon.

1986 Flood in California.

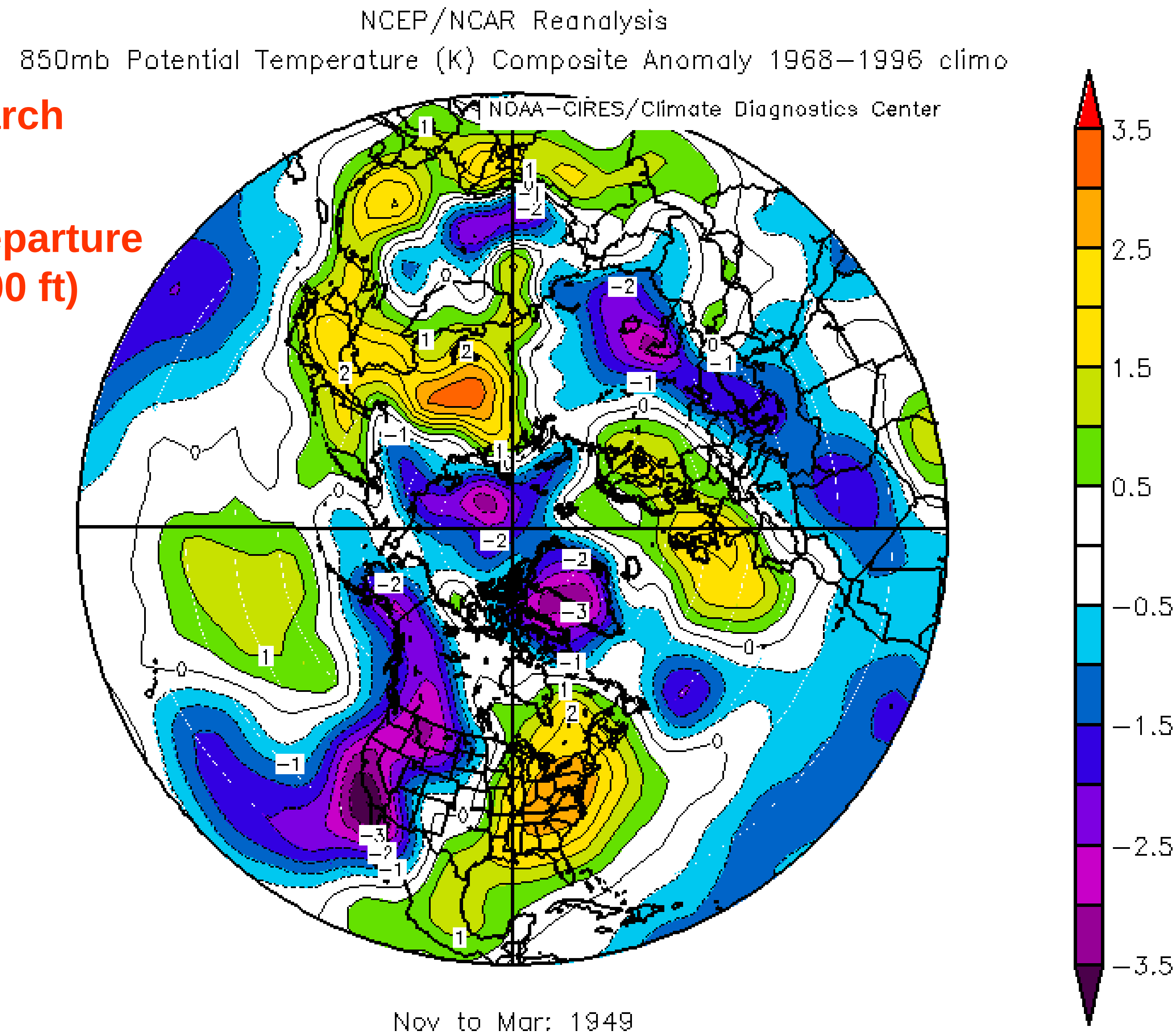
1990 July 11, half billion dollars in damage from Front Range hailstorm.

1986-87 to 1993-94 drought in the Sierra Nevada.

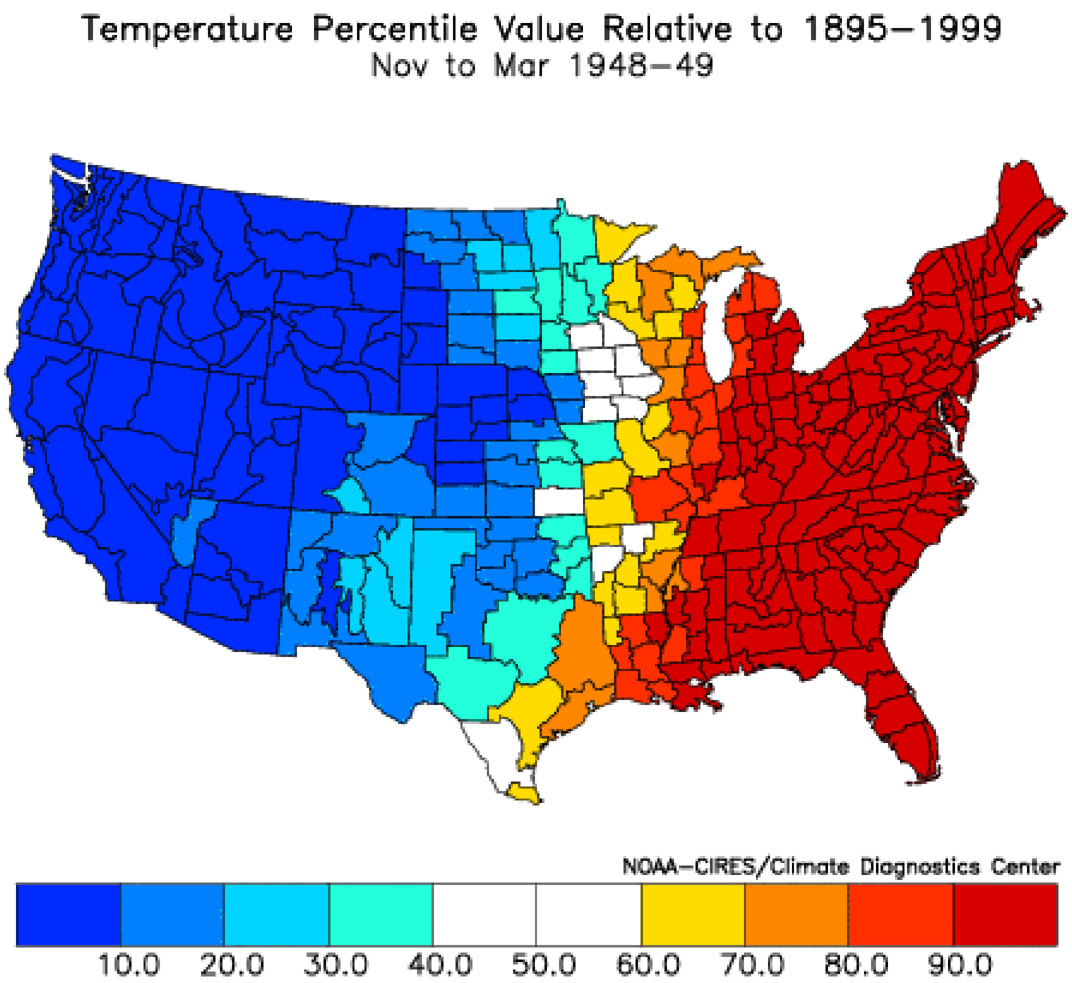
Winter 1992-1993 Floods in Arizona.

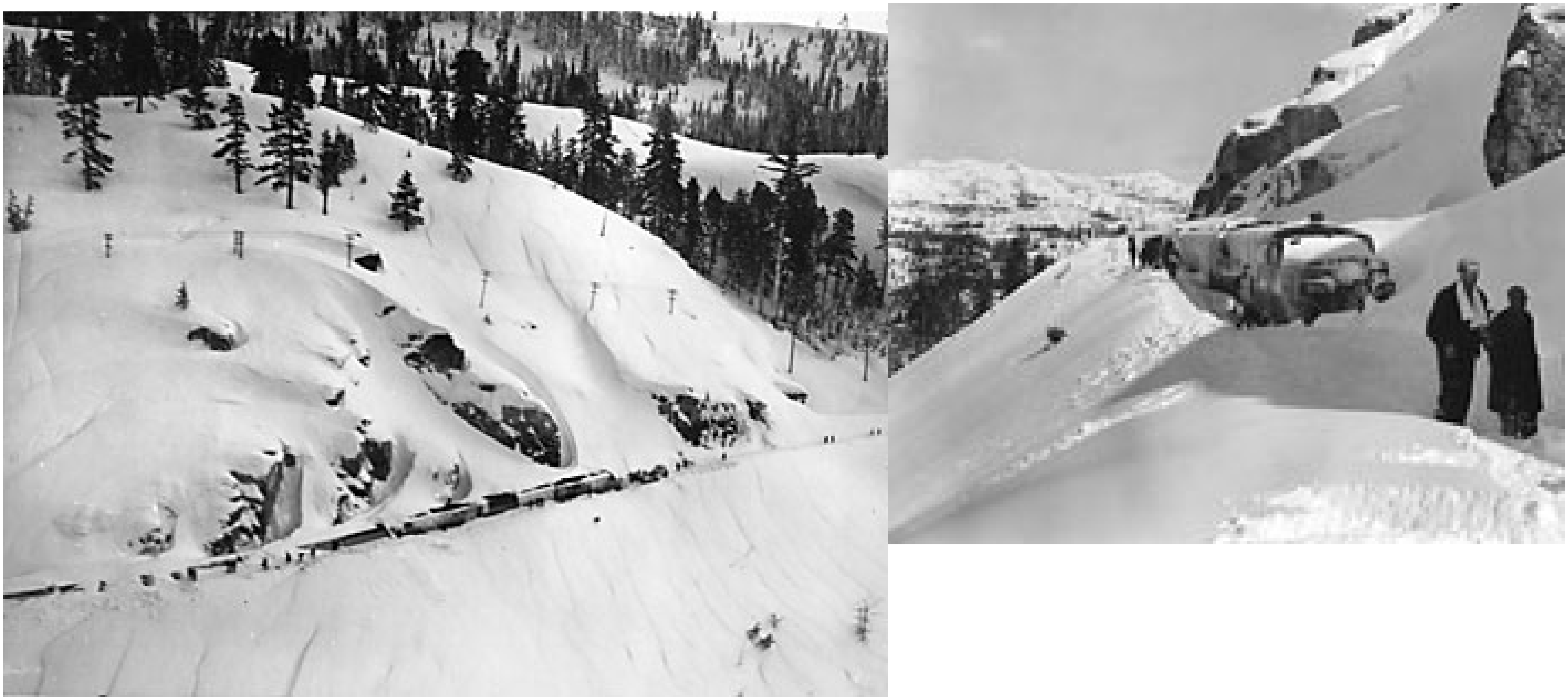
November – March 1948-1949

Temperature departure at 850 mb (~5000 ft)



Temperature Rank November-March 1948-49 out of 106 years.
0 = lowest. 100 = highest.





City of San Francisco, January 1952

Population is

- **Outdoors oriented.**
- **Growing rapidly.**
- **Recreationally overstimulated.**
  - **Skiing, rafting, biking, hiking, camping…**
- **Fitter and healthier (less capita per capita).**
- **More exposed to the sun.**

Climate as a psychological accompanyment

Climate and western U.S. literature

The Land of Little Rain. Mary Austin, 1903.

Genesis. Wallace Stegner, 1962 (in Wolf Willow).

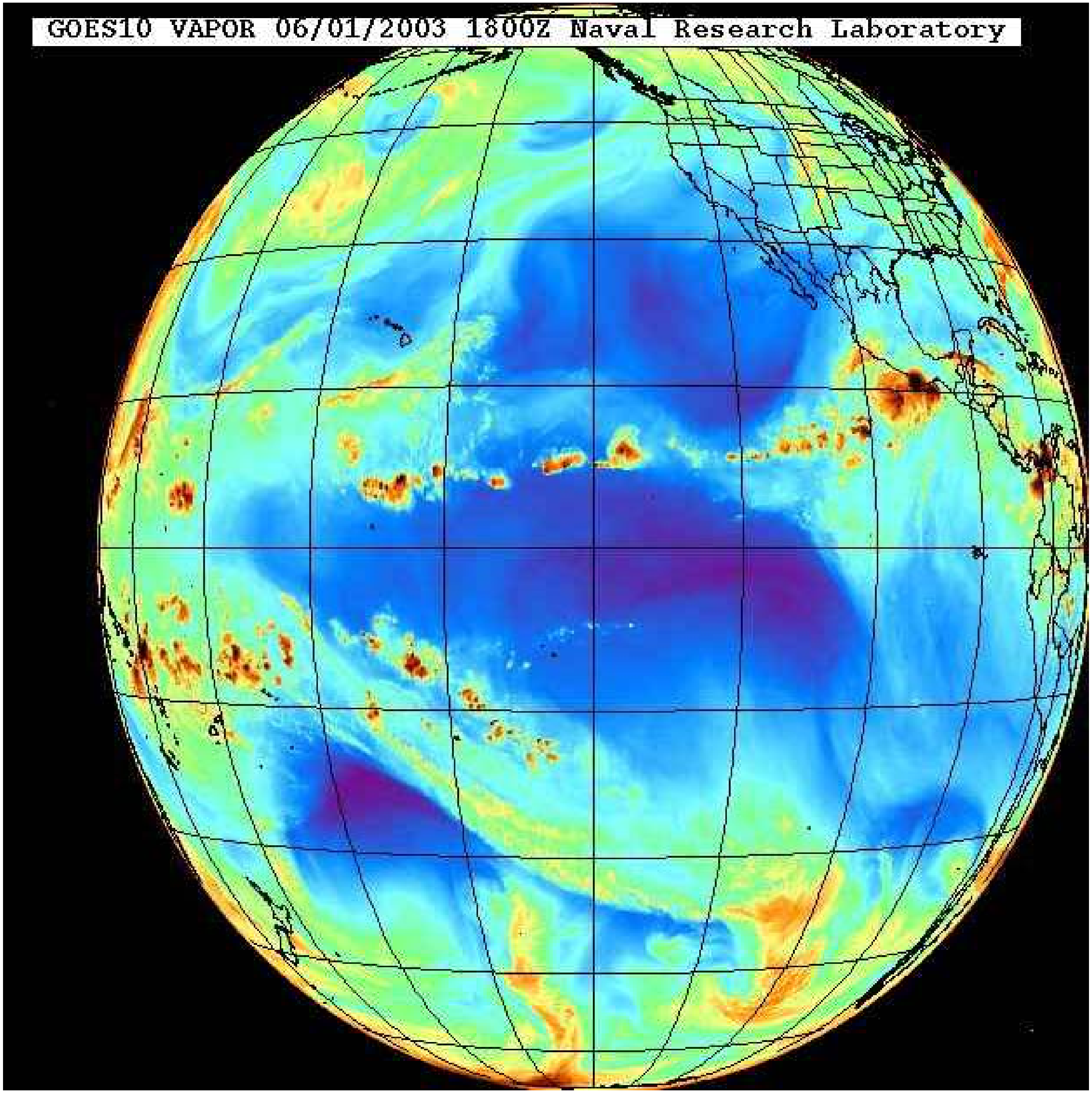
Desert Solitaire. Edward Abbey, 1968.

This House of Sky. Ivan Doig, 1978.

[Written from Seattle:]

"I walk back toward my typewriter, past a window framing the backyard fir trees. They are replaced by the wind-leaning jackpines of one Montana ridgeline or another. I glance higher for some hint of the weather, and the square of air broadens and broadens to become the blue expanse over Montana rangeland, so vast and vaulting that it rears, from the foundation-line of the plains horizon, to form the walls and roof of all of life's experience that my younger self could imagine, a single great house of sky."

Ivan Doig, *This House of Sky*, p 106.

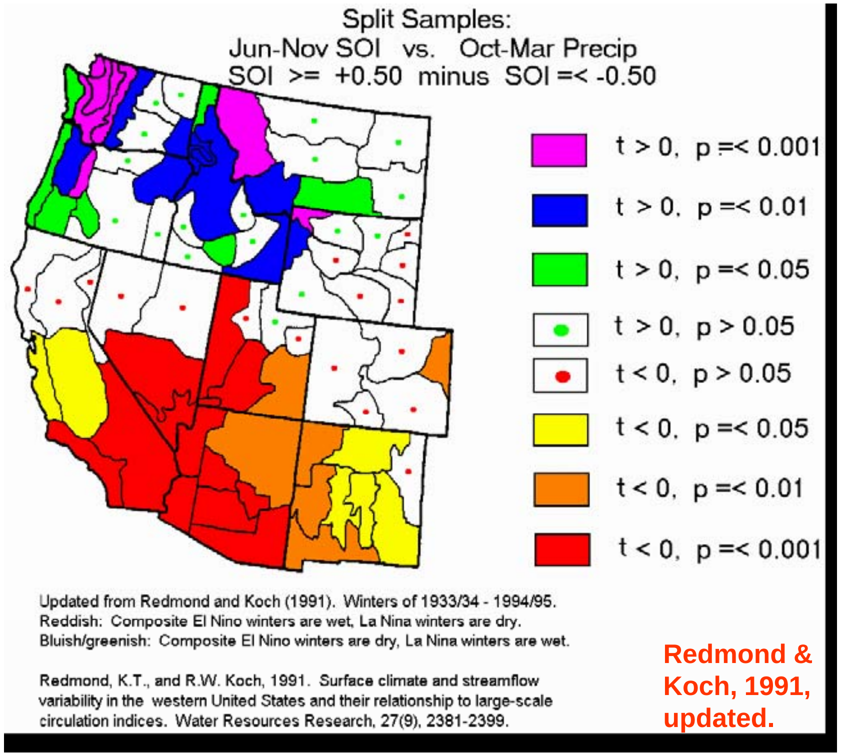


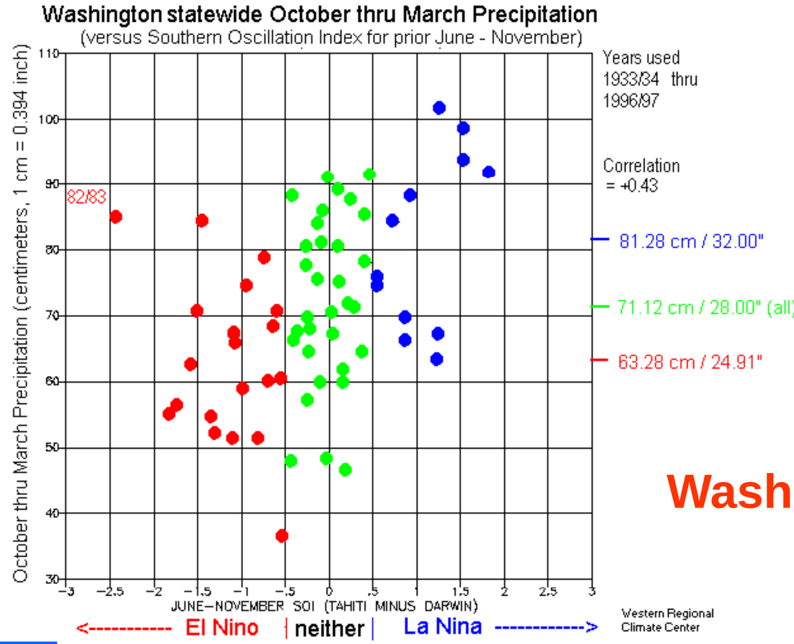
Water Vapor

June 1

2003

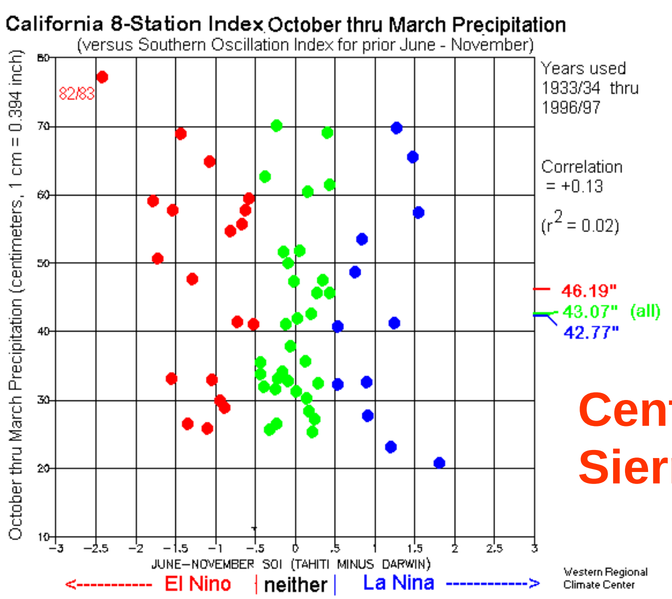
1800 GMT



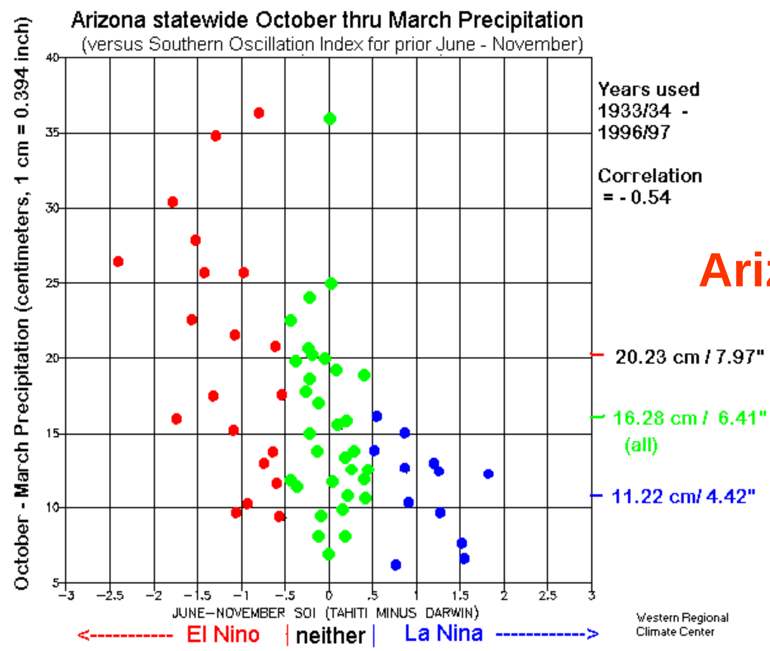


Washington

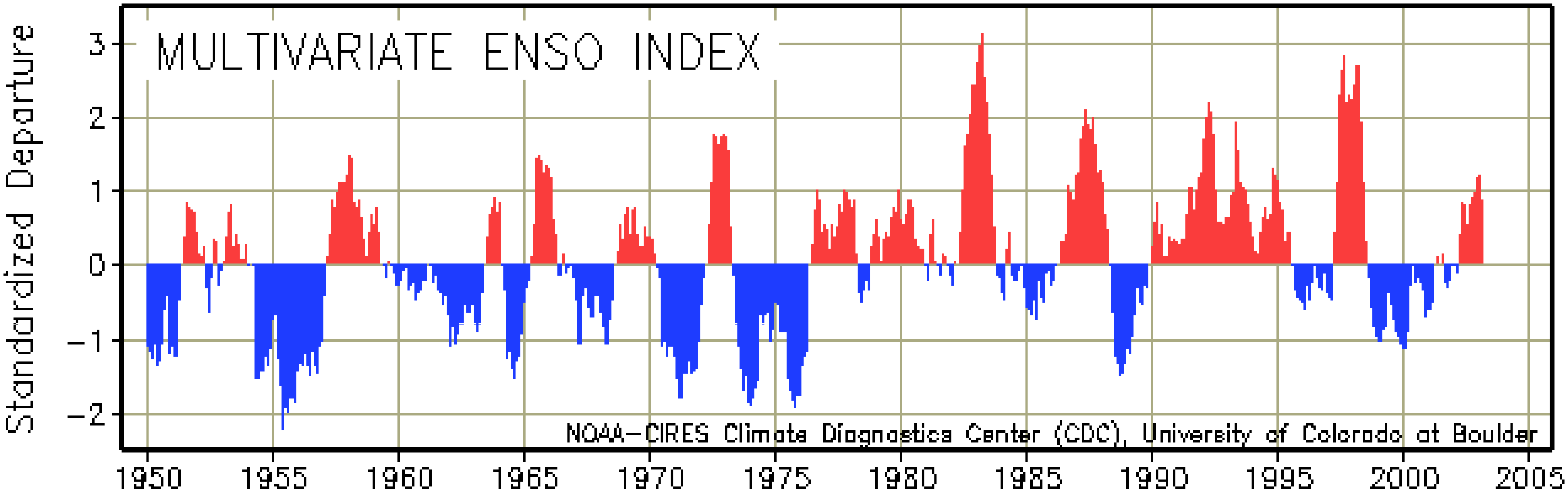
ENSO



Central Sierra



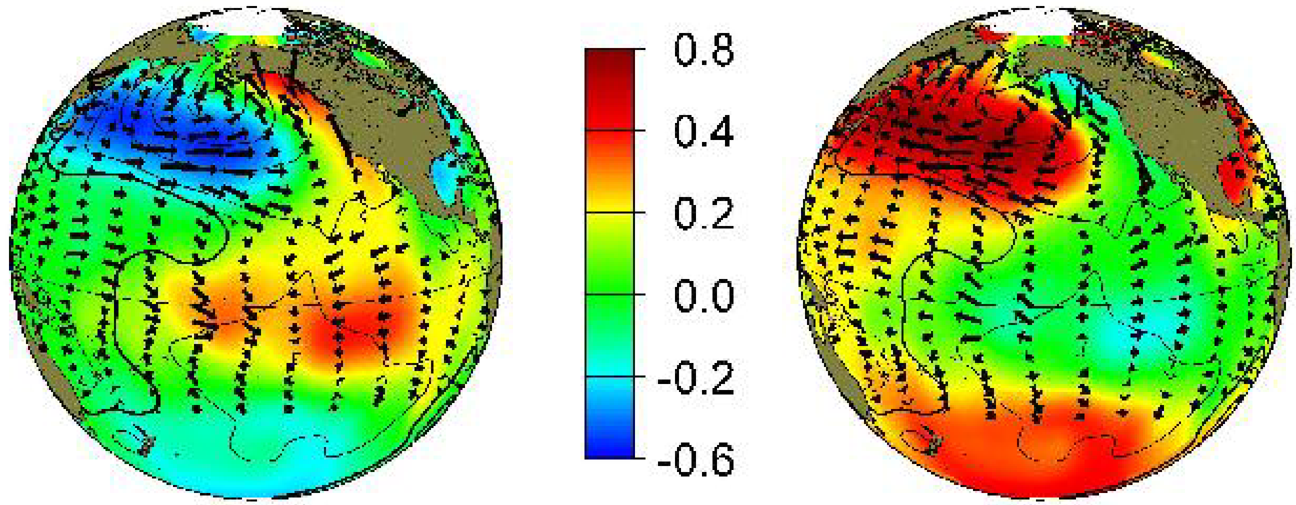
Arizona

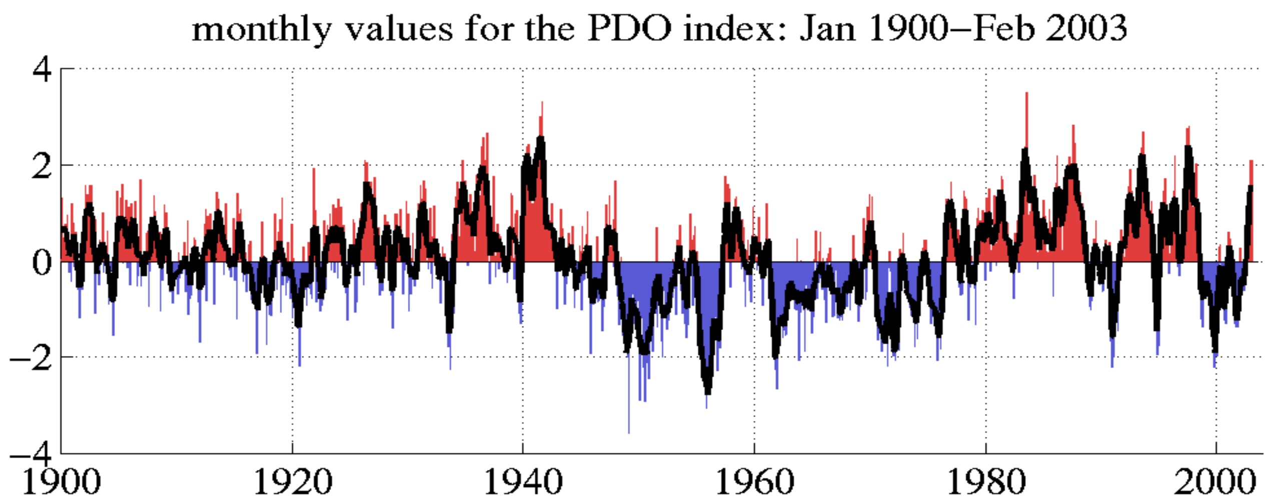


Courtesy Klaus Wolter & Mike Timlin, Climate Diagnostics Center

Positive **Negative**

Mantua et al.

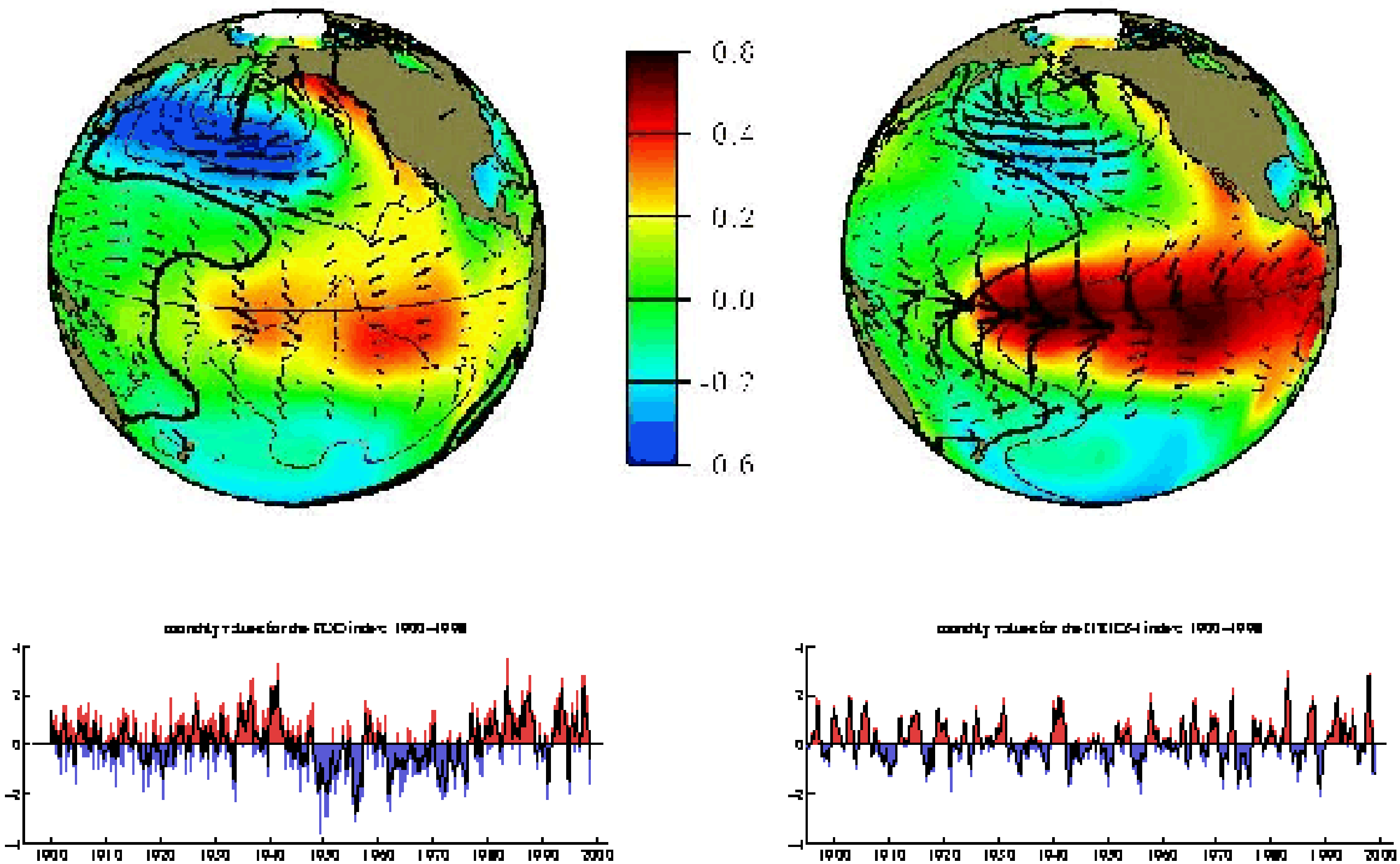




Courtesy of Nate Mantua, U Washington

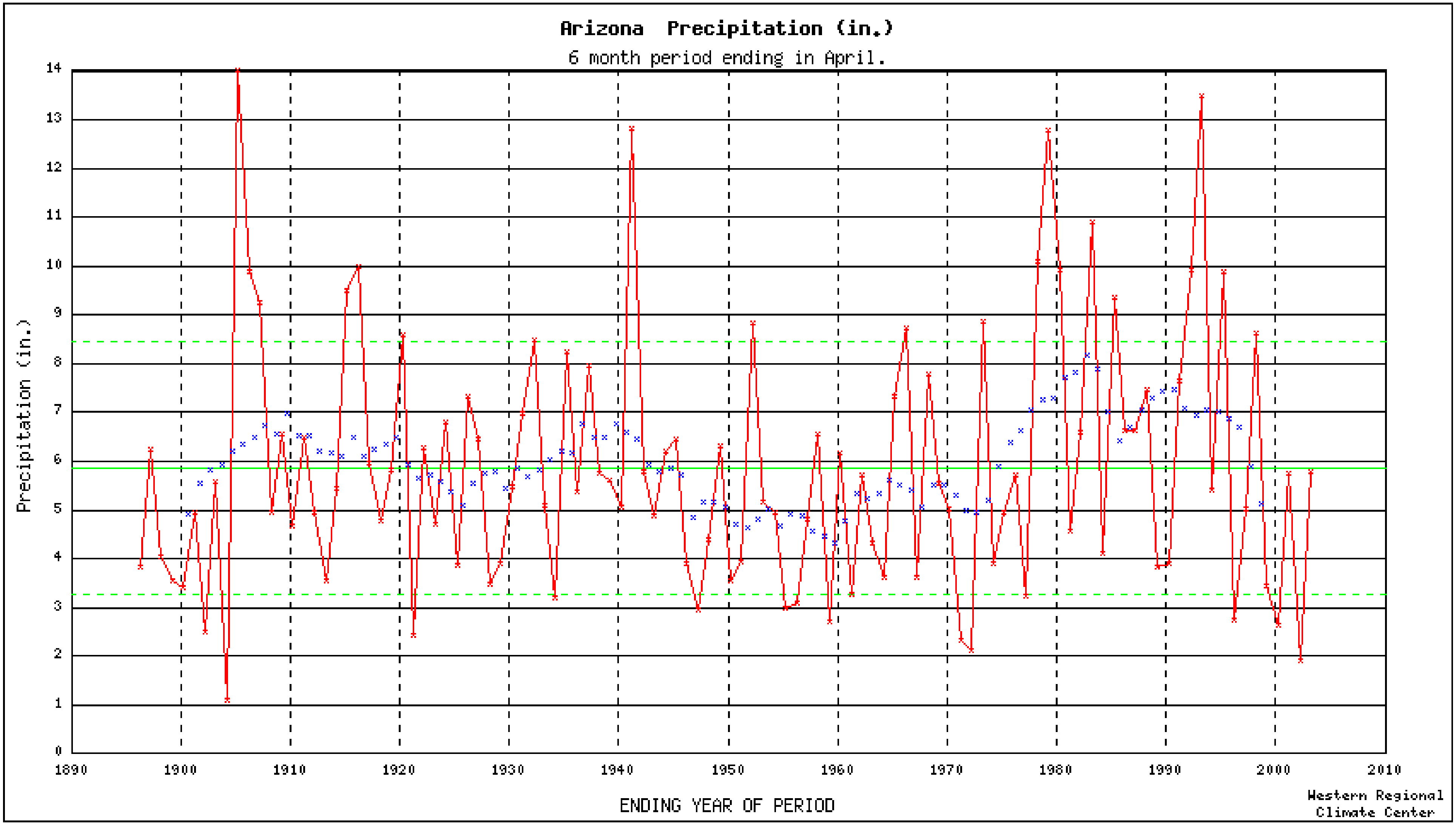
Pacific Decadal Oscillation

El Niño/Southern Oscillation

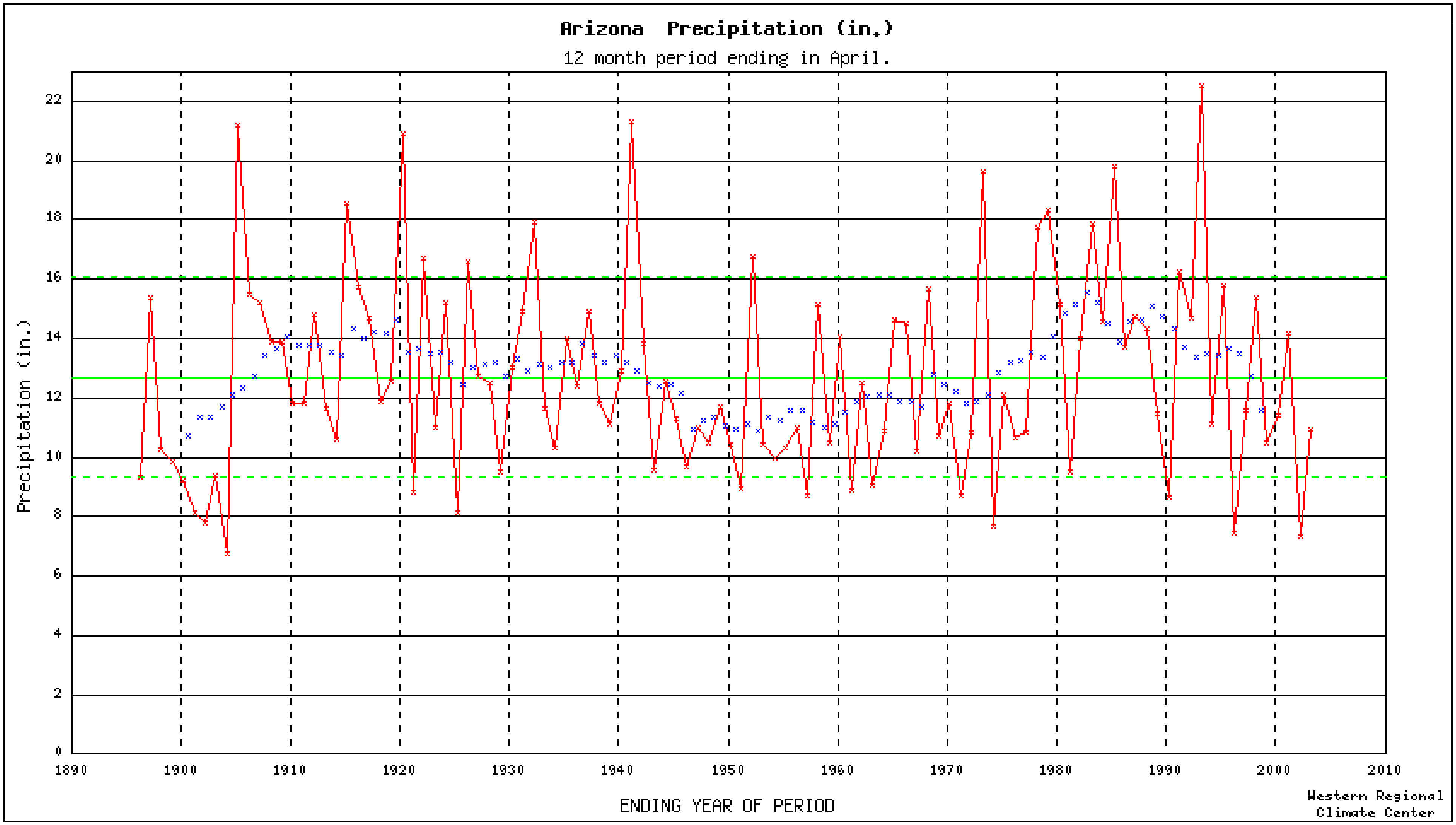


Arizona Statewide Winter Precipitation (Oct-Mar) & 10-Yr Running Mean

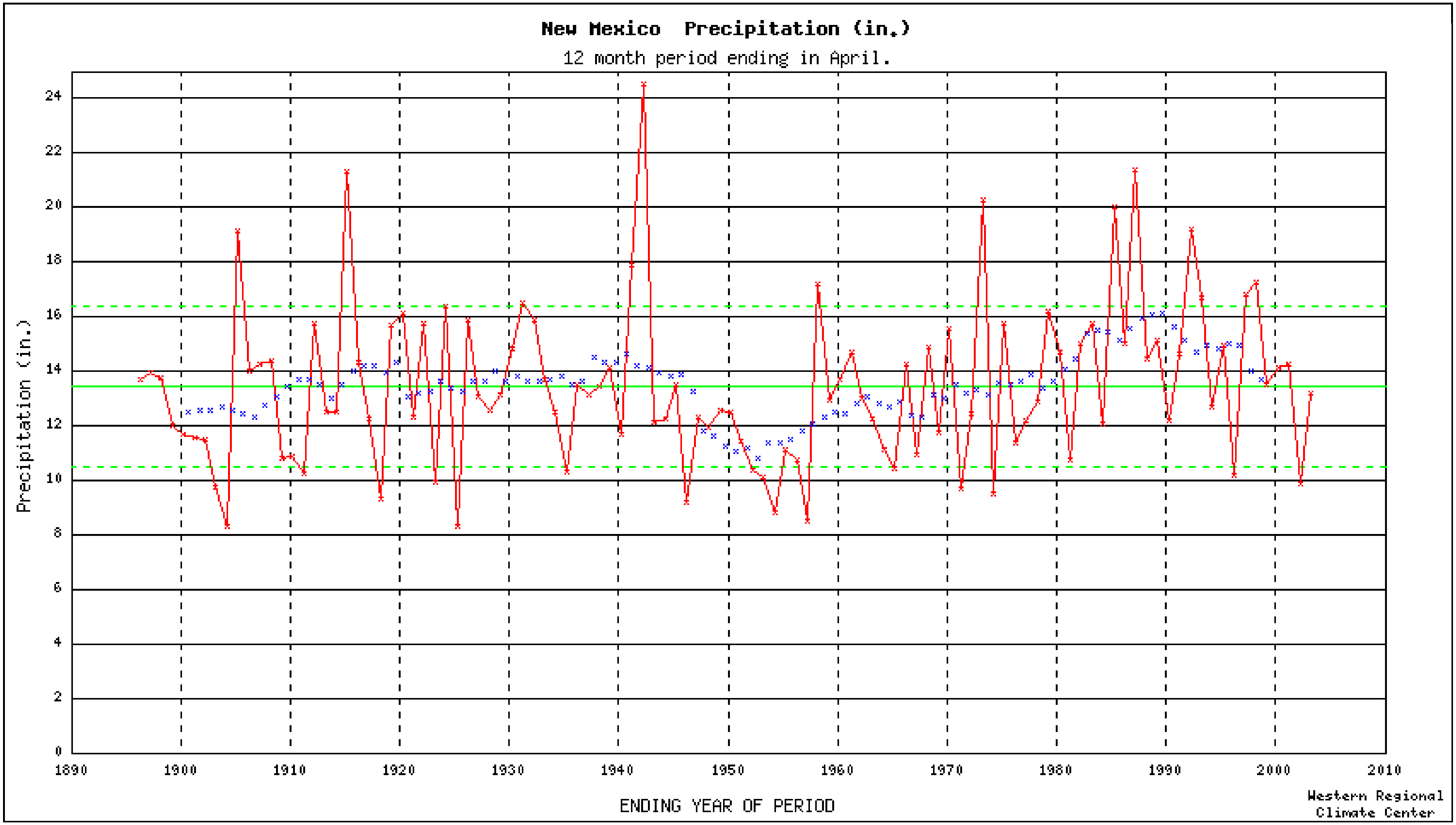
1895-2003



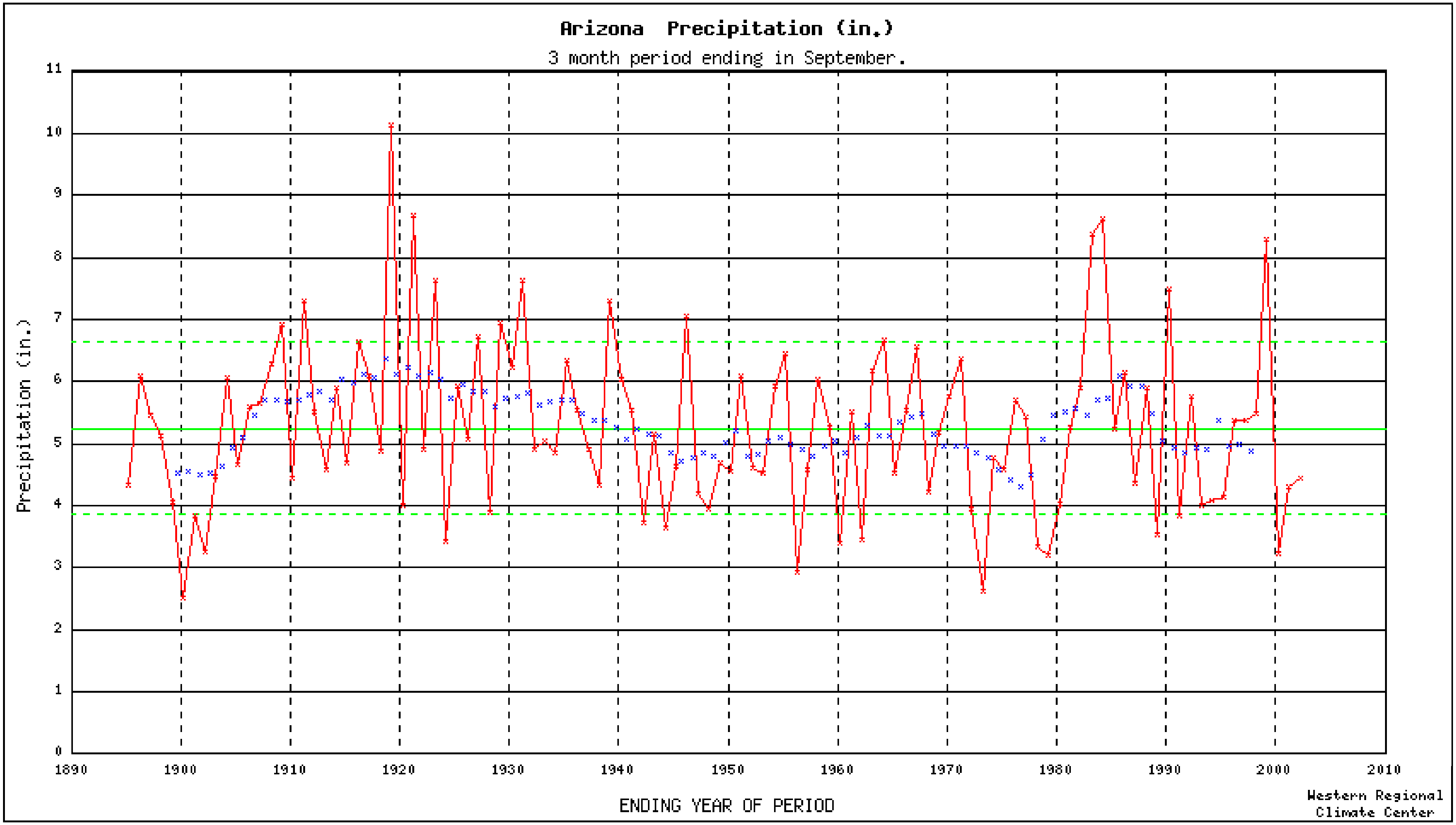
Arizona Statewide Precipitation (12-Months: May – April) & 10-Yr Running Mean 1895 - 2003



New Mexico Statewide Average Precipitation (May - April) & 10-Yr Running Mean 1895 - 2003

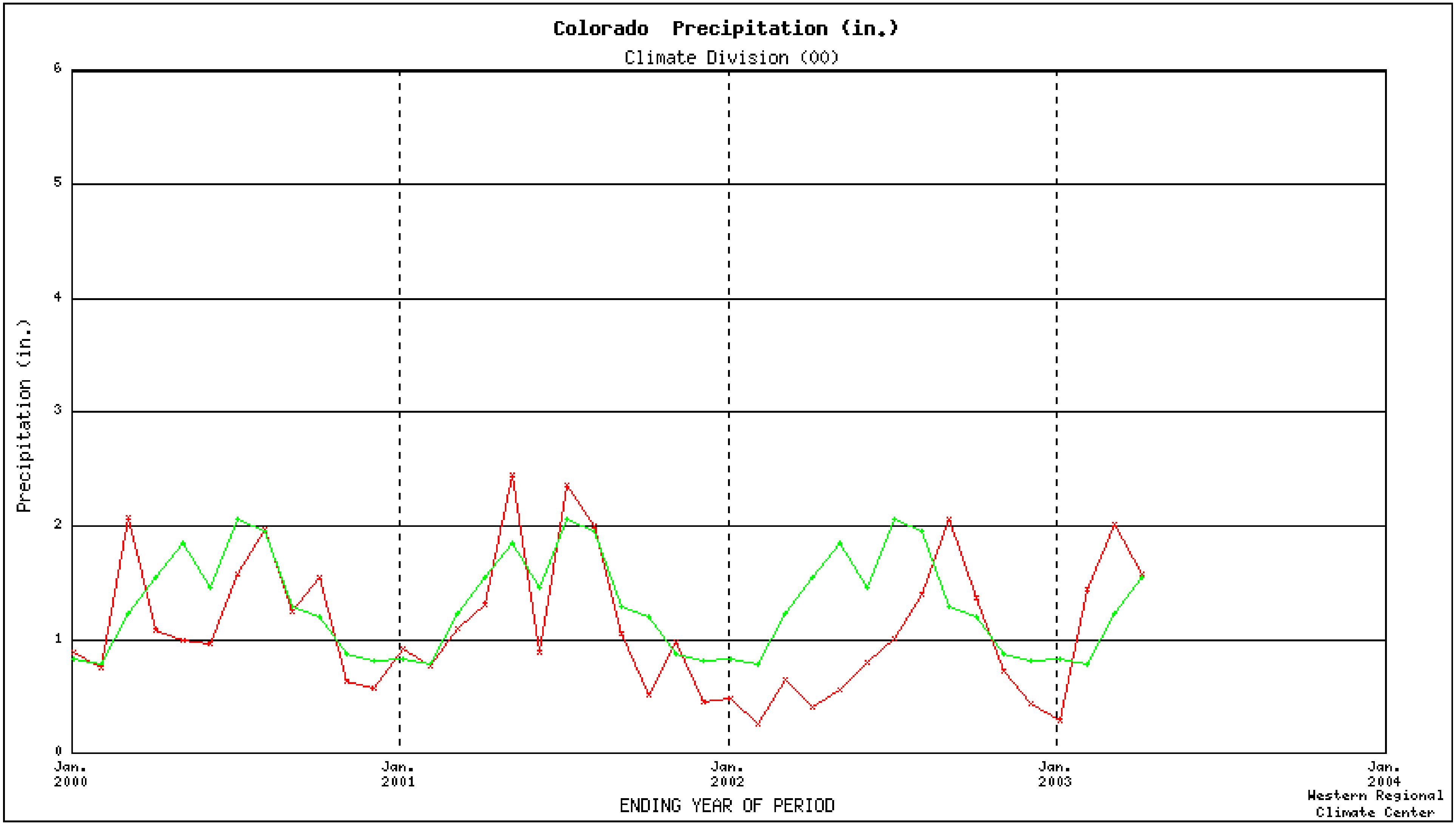


Arizona Monsoon. Statewide July-Sept precipitation. 1895-1902.
& 10-year running mean.



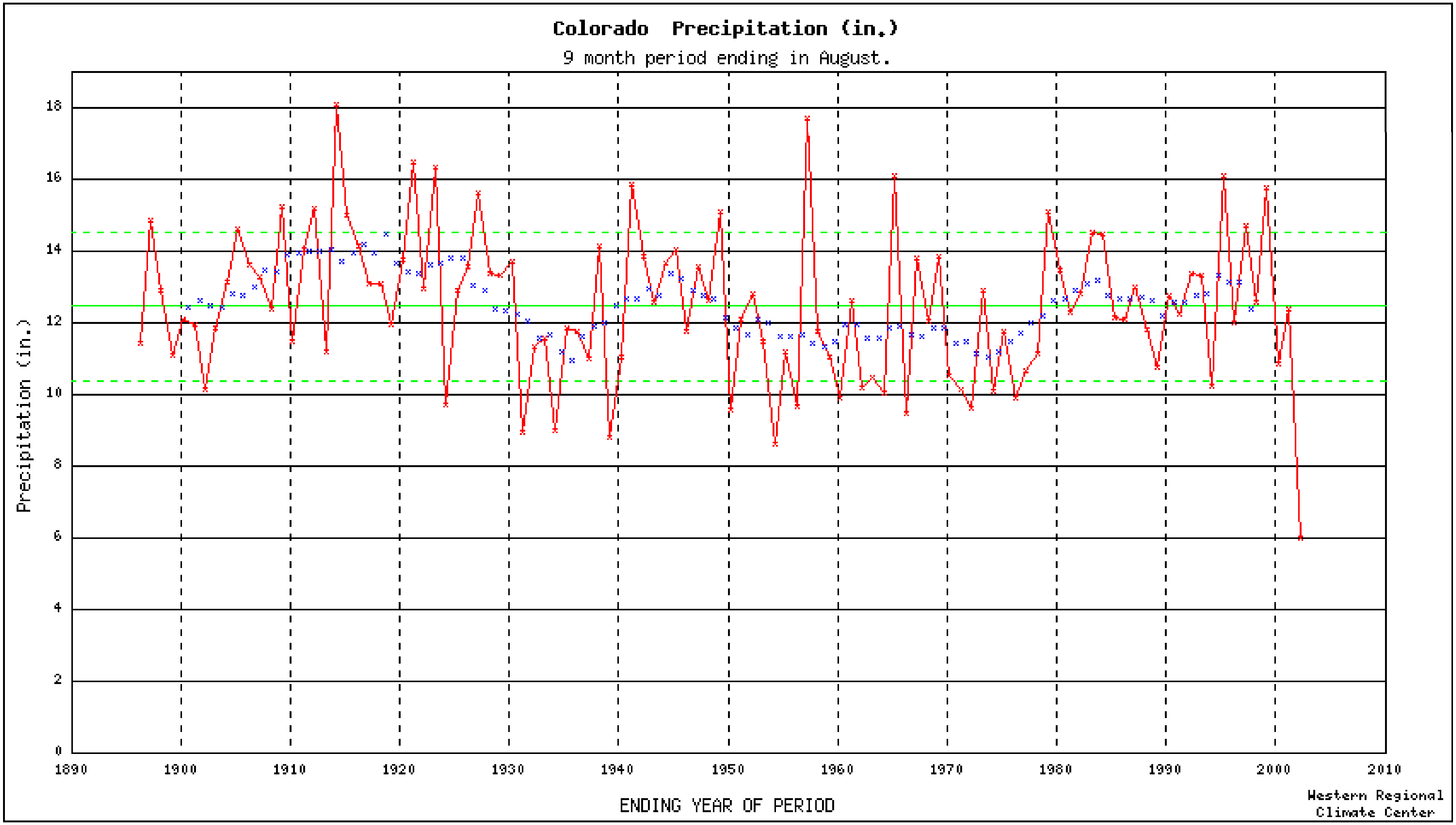
Colorado Statewide Average Precipitation, by Month. Jan 2000 – Apr 2003.

Long term Average (1895-2003)



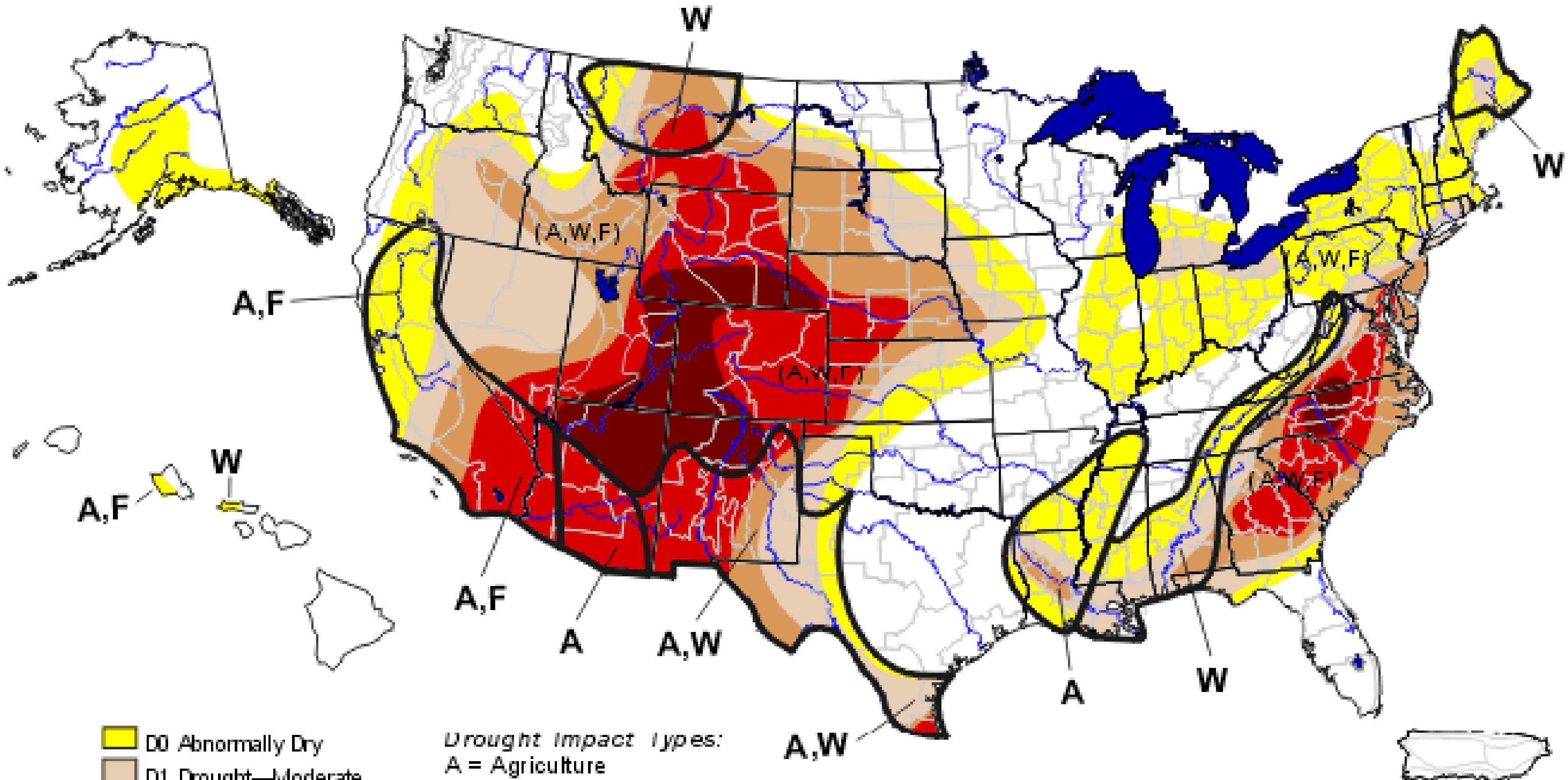
Jan 2000 Jan 2001 Jan 2001 Jan 2003

Colorado Statewide Average Precipitation Dec – Aug & 10-Year Running Mean 1895 – 2003. (9-month period)



U.S. Drought Monitor

July 23, 2002
Valid 8 a.m. EDT



D0 Abnormally Dry
D1 Drought—Moderate
D2 Drought—Severe
D3 Drought—Extreme
D4 Drought—Exceptional

Drought Impact Types:
A = Agriculture
W = Water (Hydrological)
F = Fire danger (Wildfires)
Delineates dominant impacts
(No type = All 3 impacts)

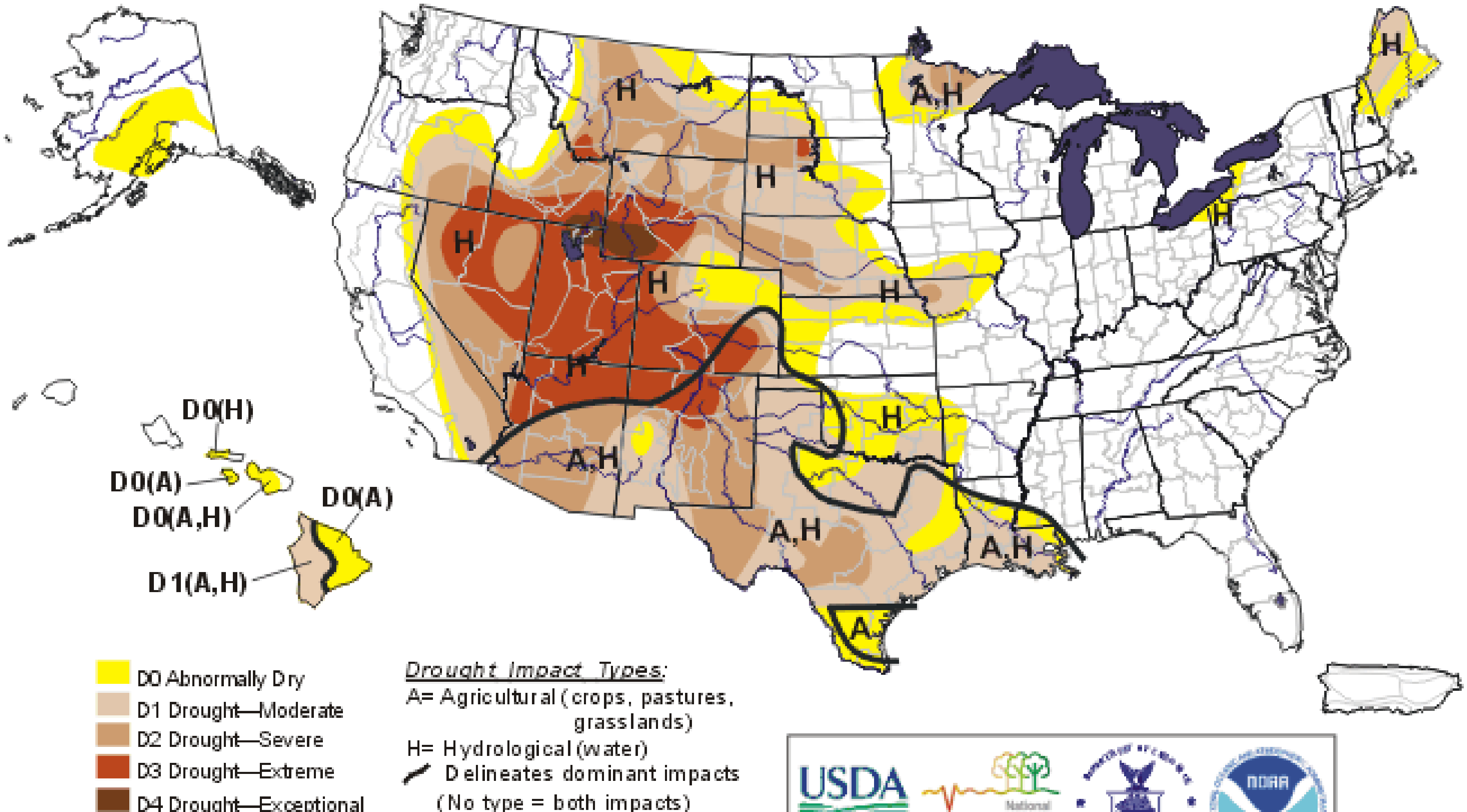
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, July 25, 2002
Author: *Brad Rippey, USDA*

U.S. Drought Monitor

May 27, 2003
Valid 8 a.m. EDT



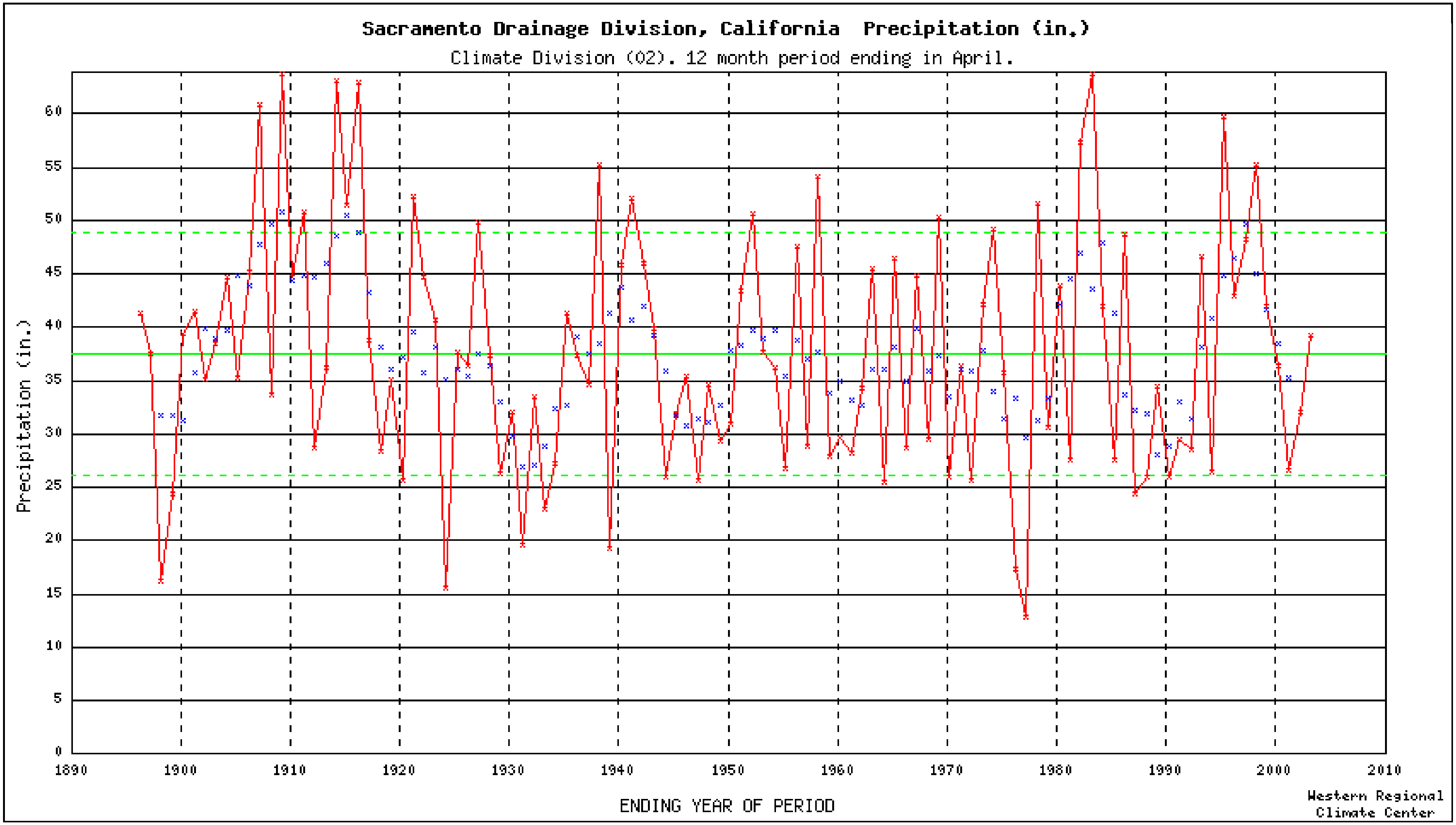
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

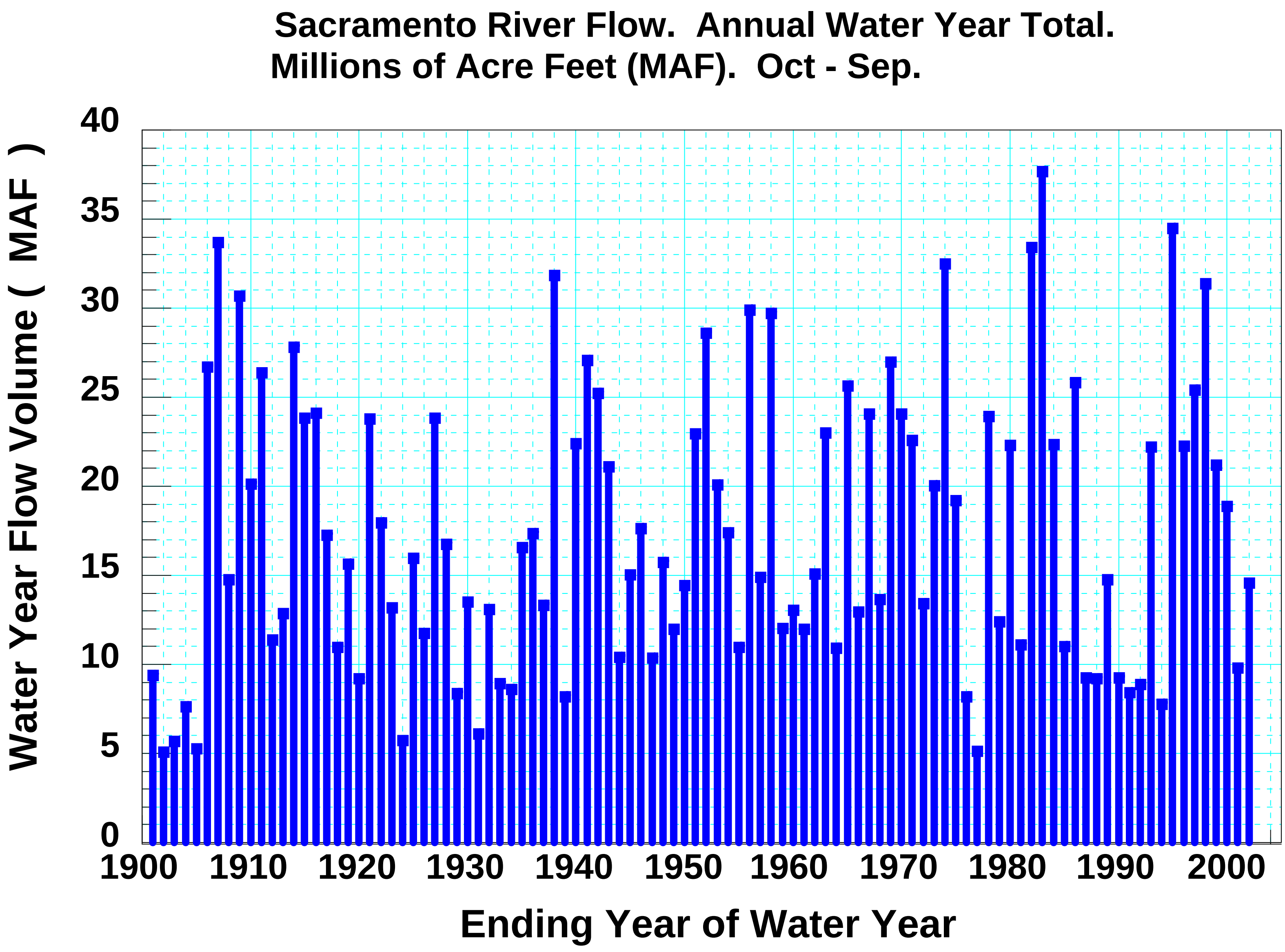
http://drought.unl.edu/dm

Released Thursday, May 29, 2003

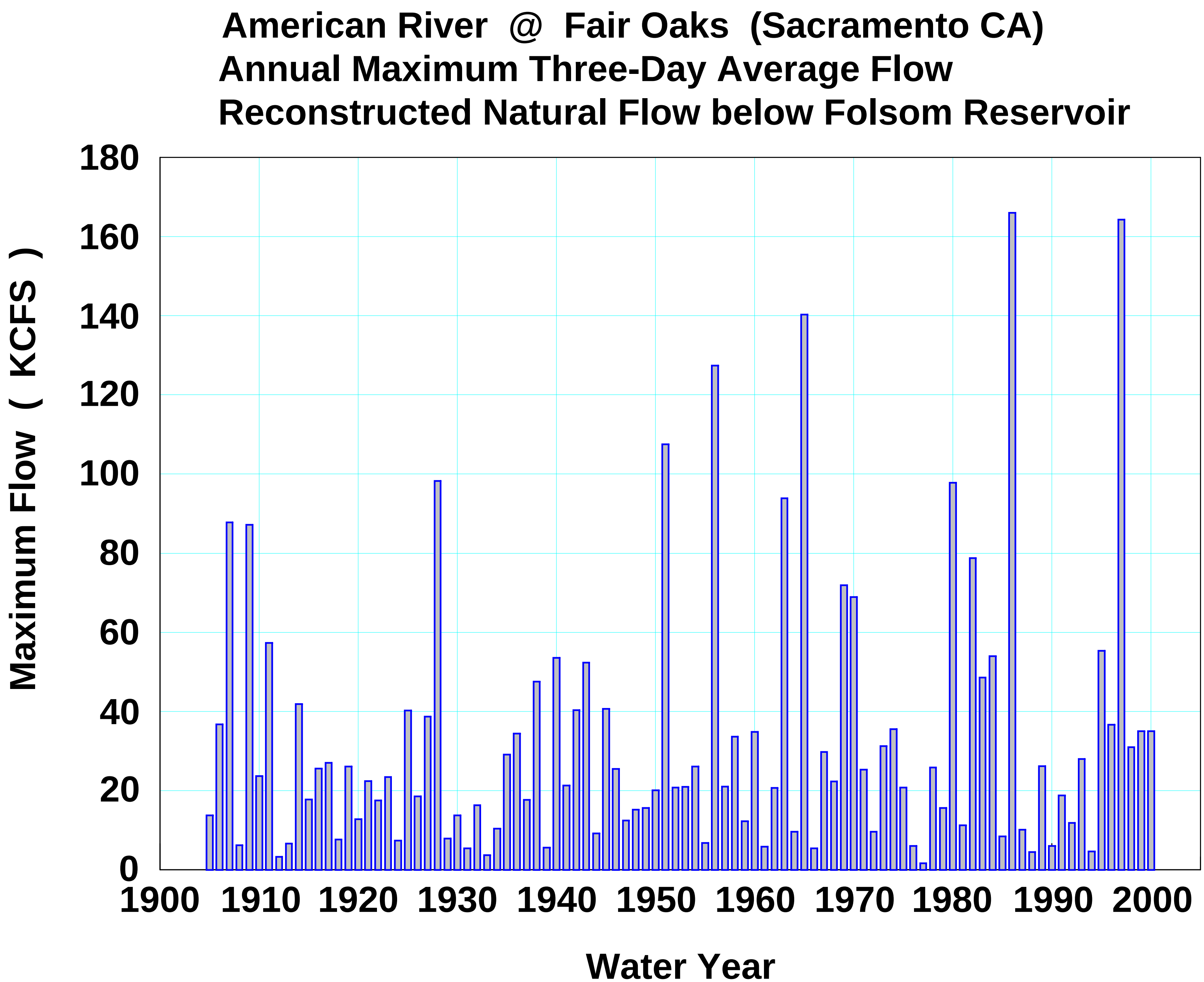
Authors: *Richard Heim/Candace Tankersley, NOAA/NCDC*

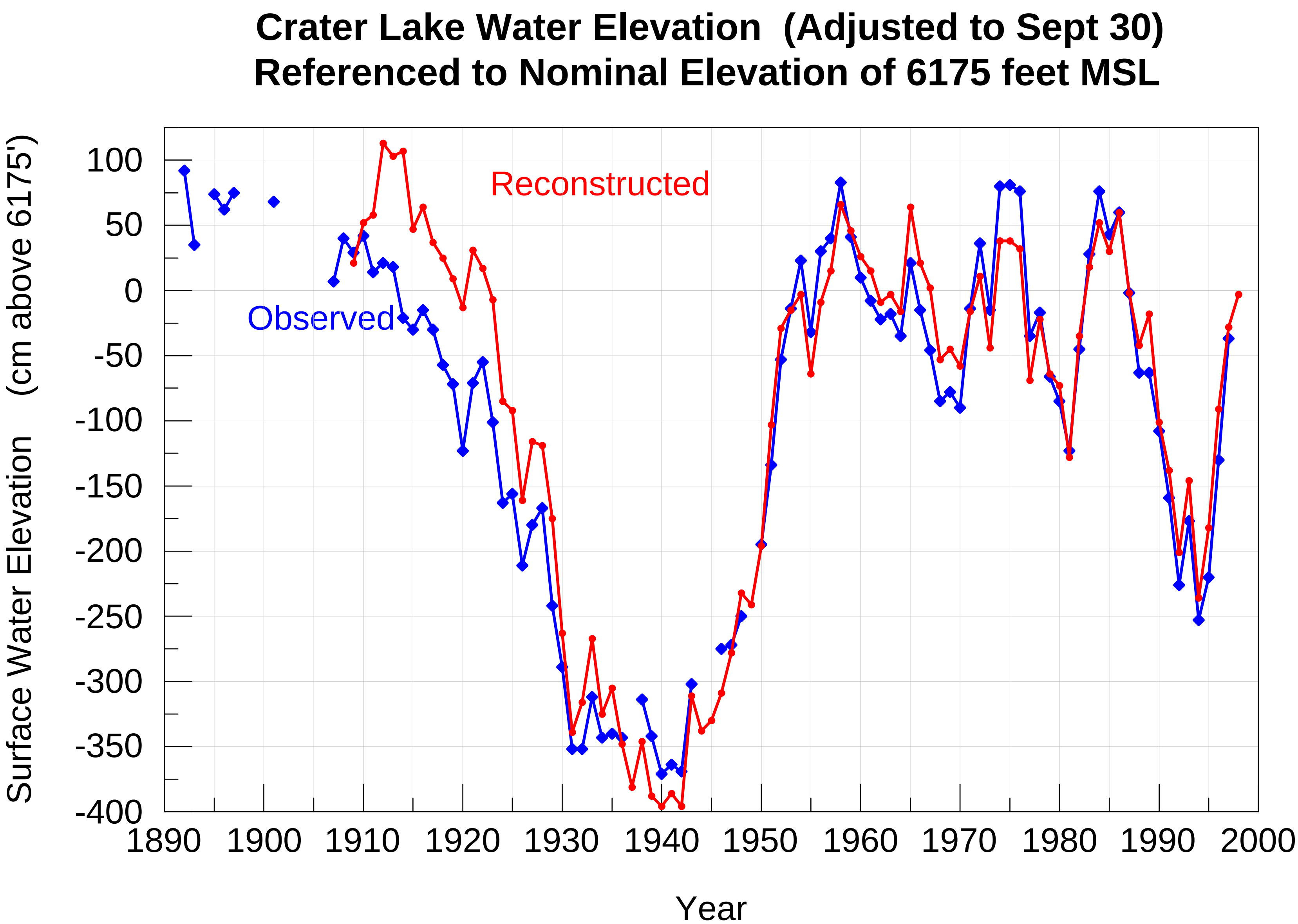
California Sacramento River Drainage Basin May – Apr Precipitation 1895 – 2003
& 5-Year running mean



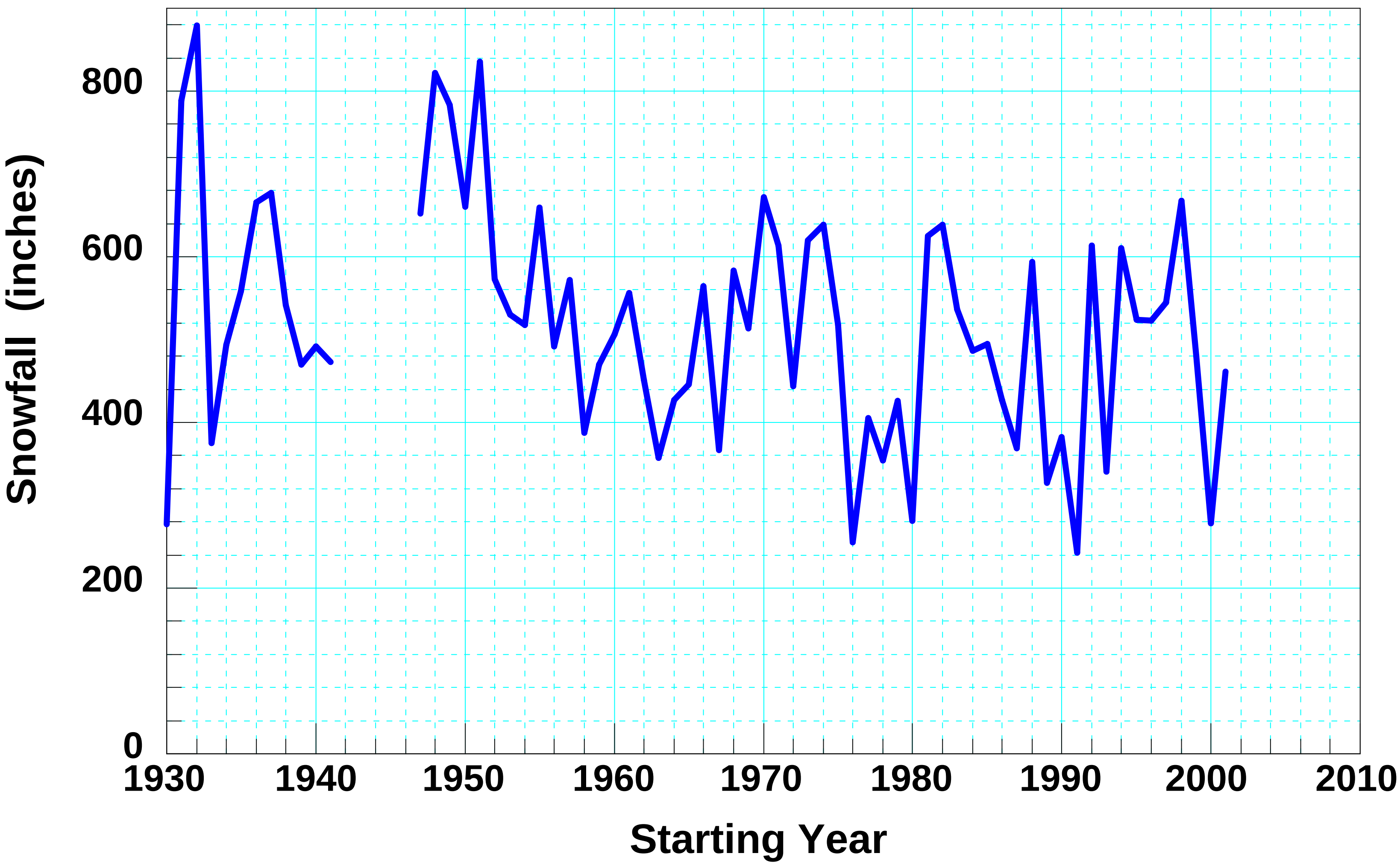


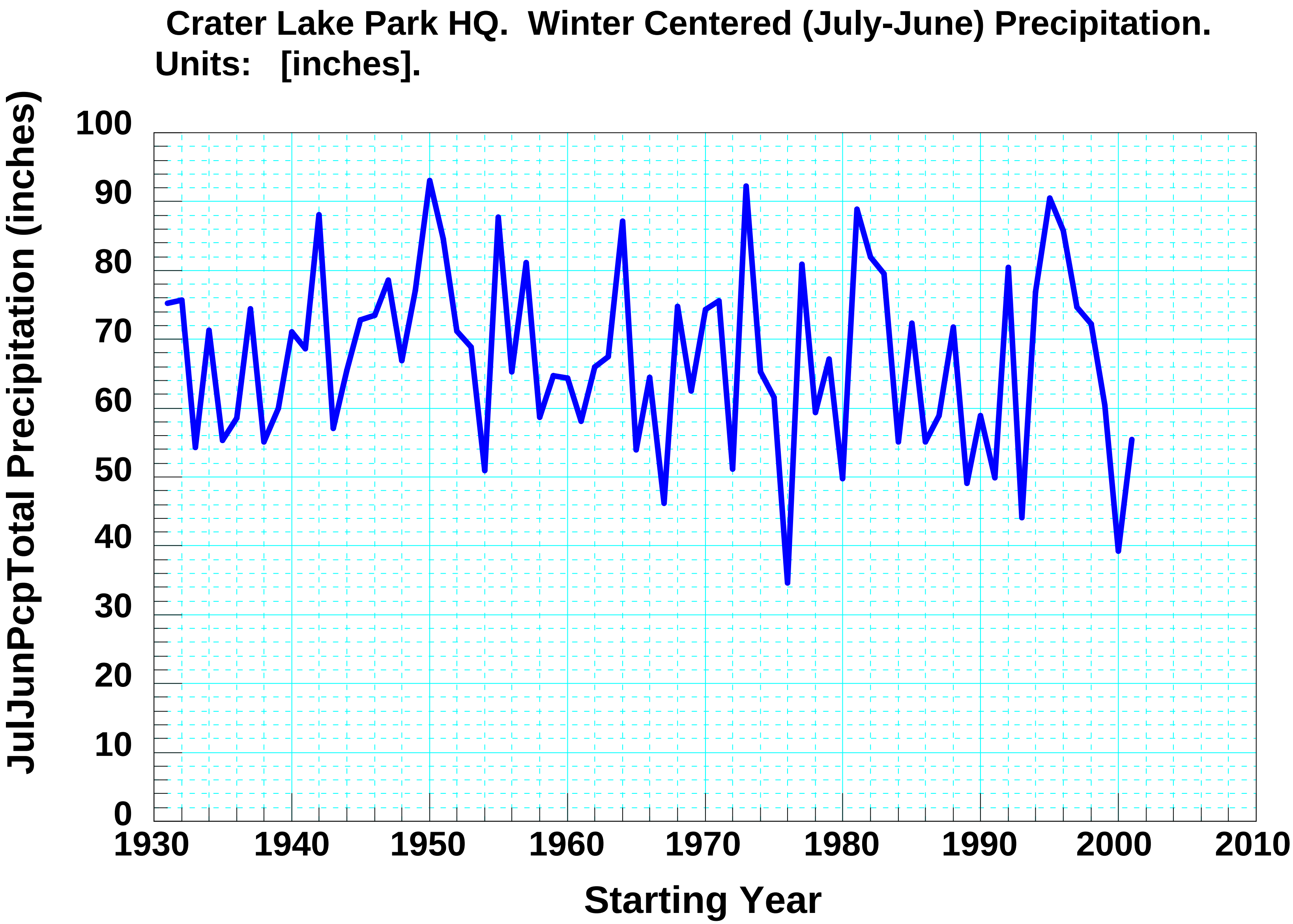
Sacramento River Flow. Annual Water Year Total.
Millions of Acre Feet (MAF). Oct - Sep.
Water Year Flow Volume (MAF)
0
5
10
15
20
25
30
35
40
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Ending Year of Water Year

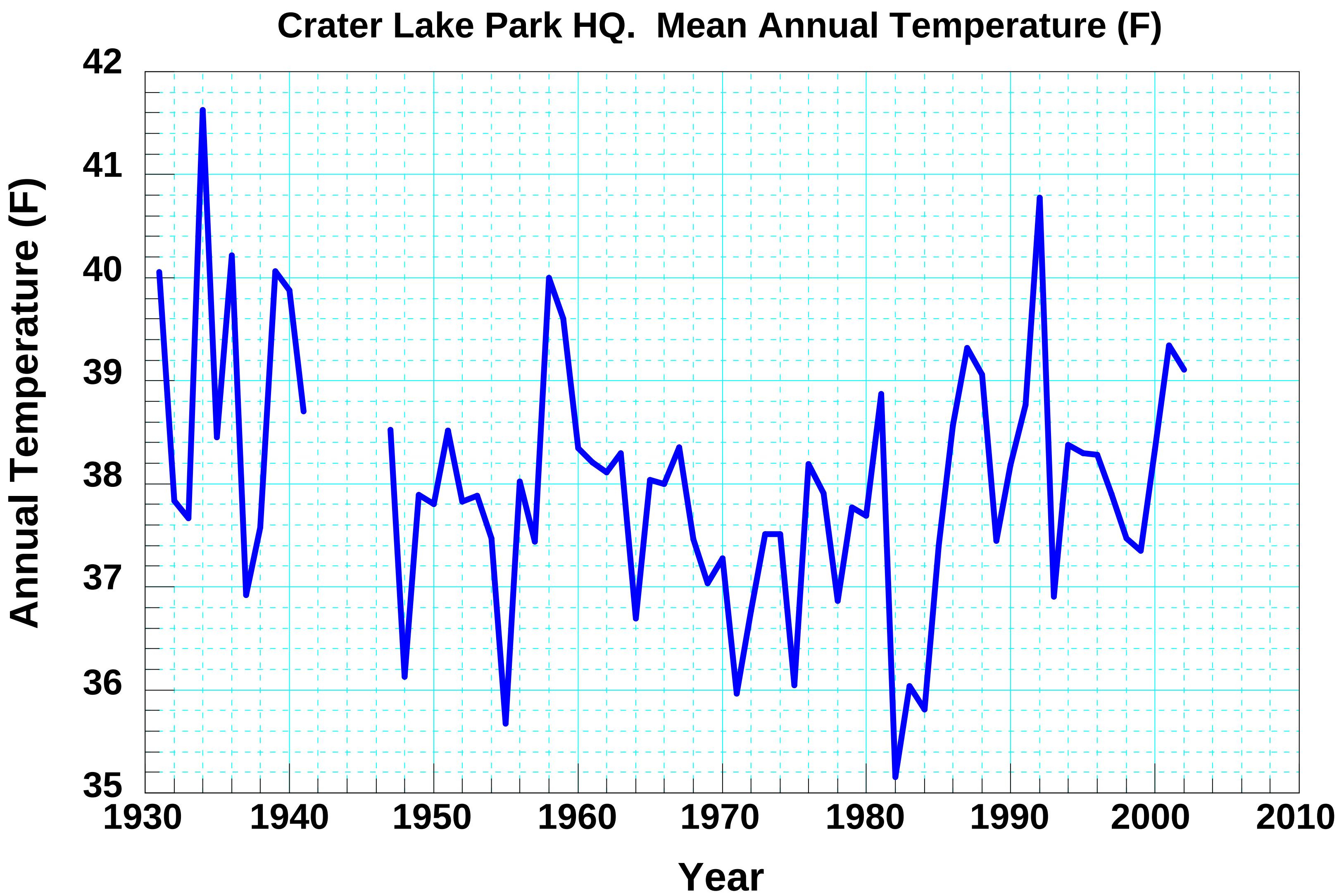

American River @ Fair Oaks (Sacramento CA)
Annual Maximum Three-Day Average Flow
Reconstructed Natural Flow below Folsom Reservoir
Maximum Flow (KCFS)
0
20
40
60
80
100
120
140
160
180
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Water Year

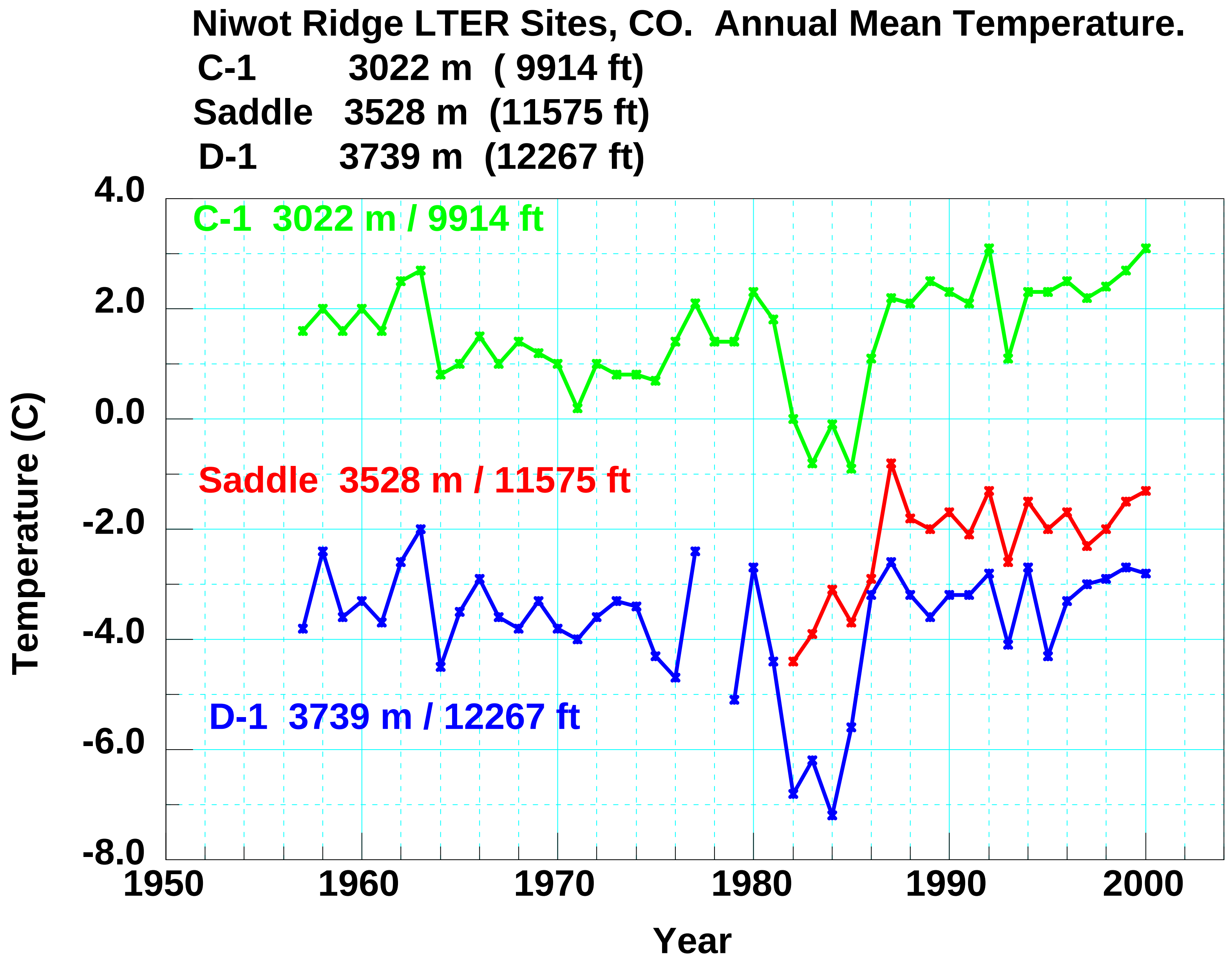

Crater Lake Water Elevation (Adjusted to Sept 30)
Referenced to Nominal Elevation of 6175 feet MSL
Reconstructed
Observed
Surface Water Elevation (cm above 6175')
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Year

Crater Lake Park HQ. Total Winter (July-June) Snowfall.
Units: Inches.

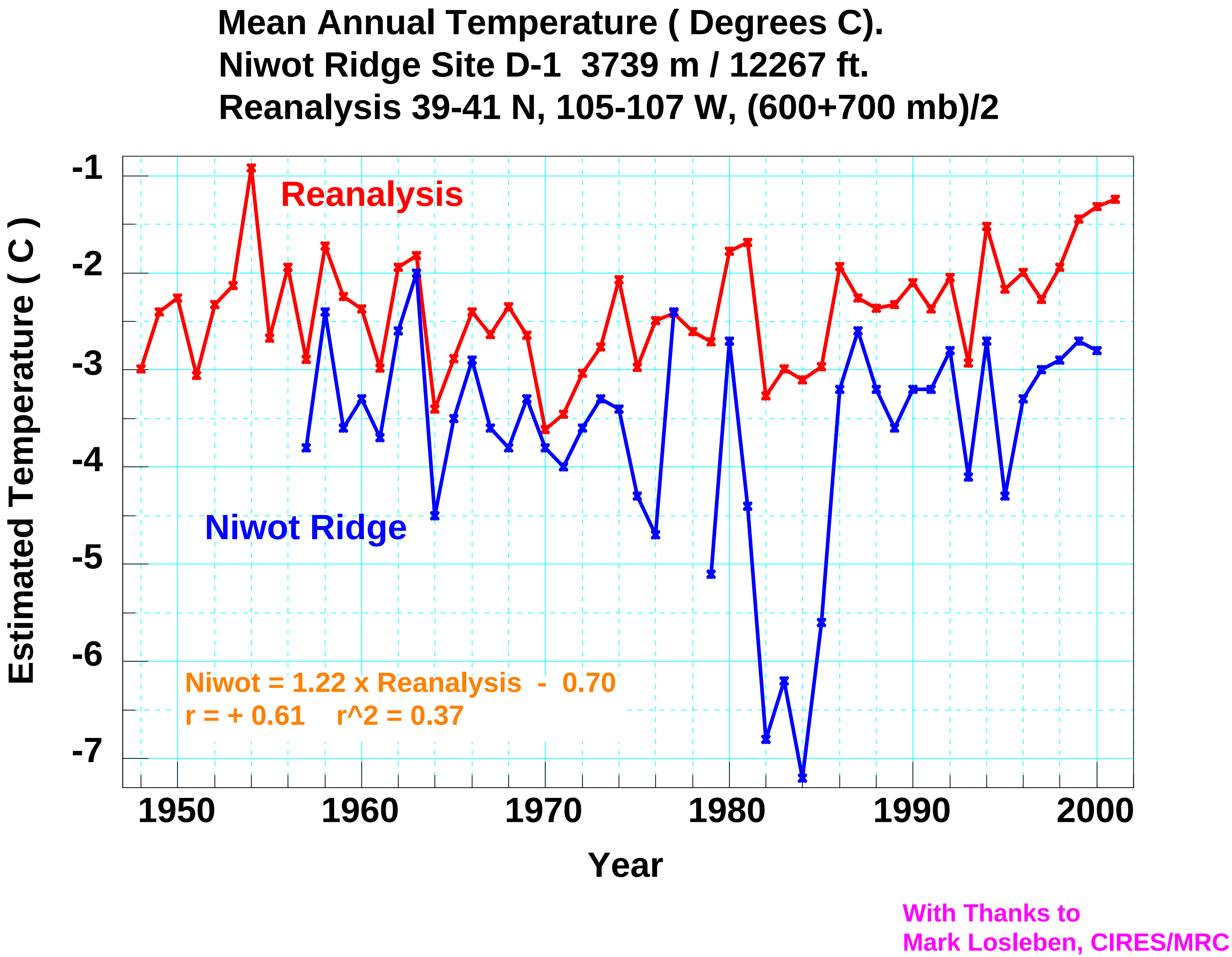



Crater Lake Park HQ. Winter Centered (July-June) Precipitation.
Units: [inches].
JulJunPcpTotal Precipitation (inches)
0
10
20
30
40
50
60
70
80
90
100
1930
1940
1950
1960
1970
1980
1990
2000
2010
Starting Year

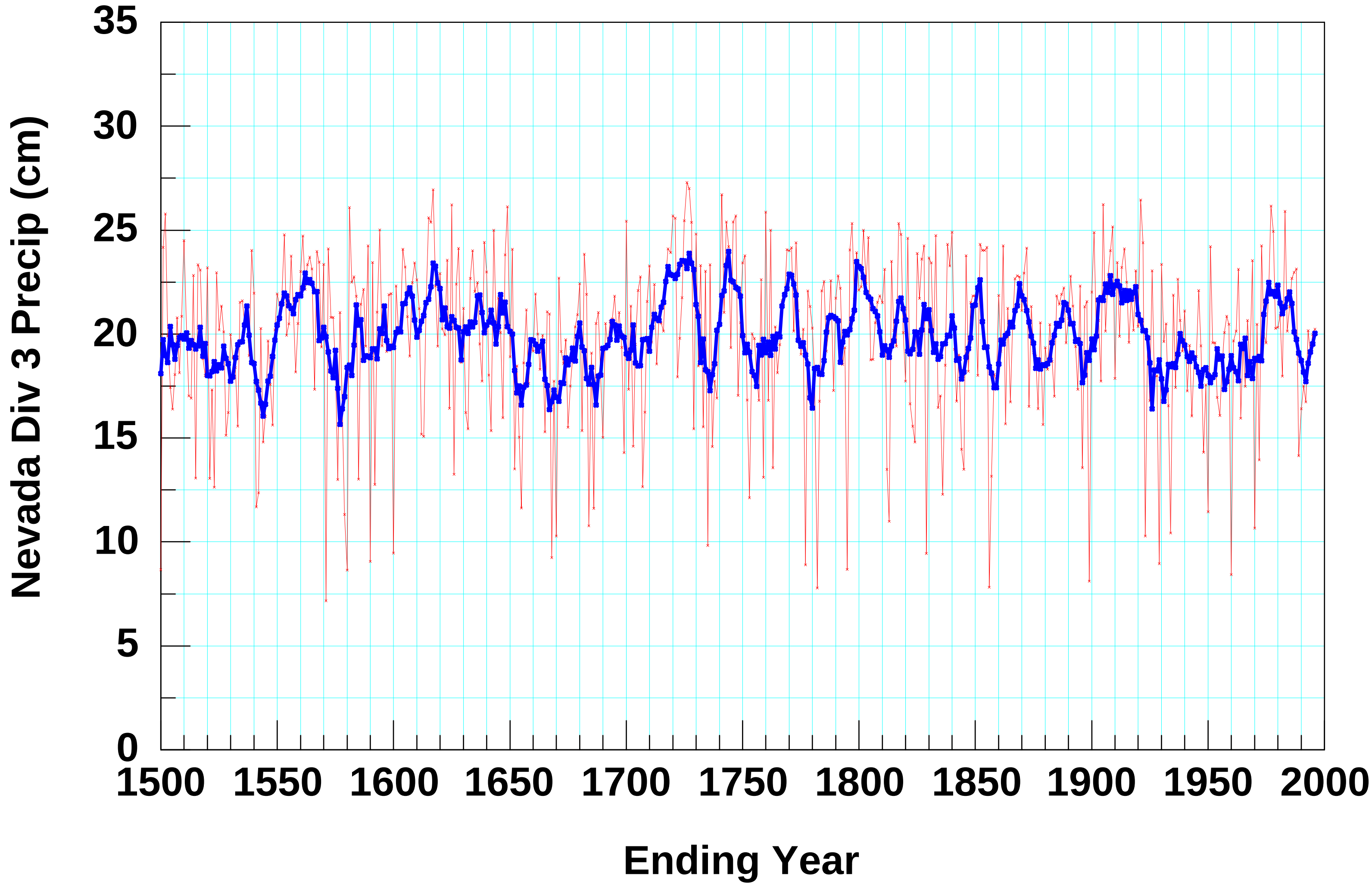

Crater Lake Park HQ. Mean Annual Temperature (F)
Annual Temperature (F)
42
41
40
39
38
37
36
35
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year

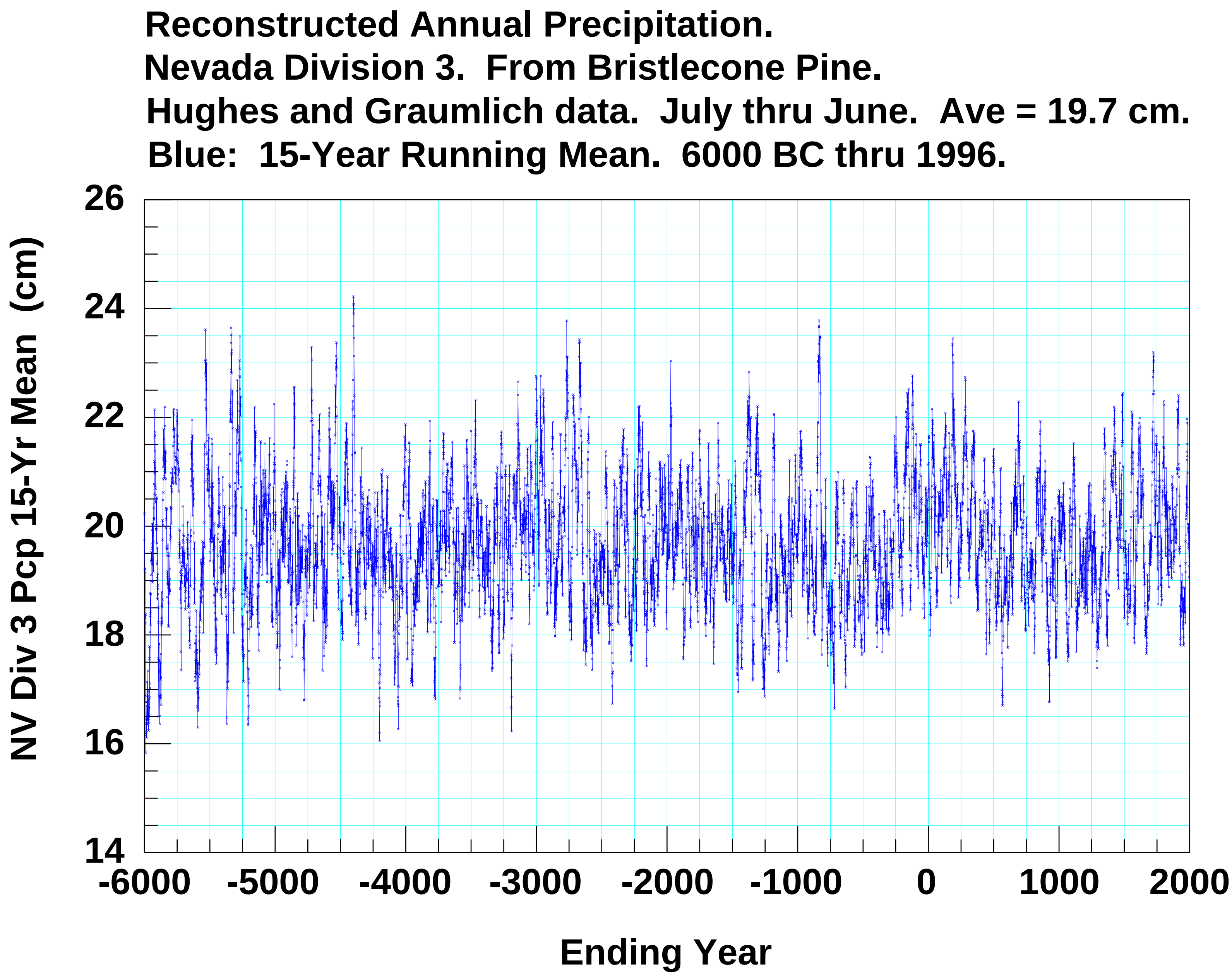


Data Ctsy of Mark Losleben,
Niwot LTER

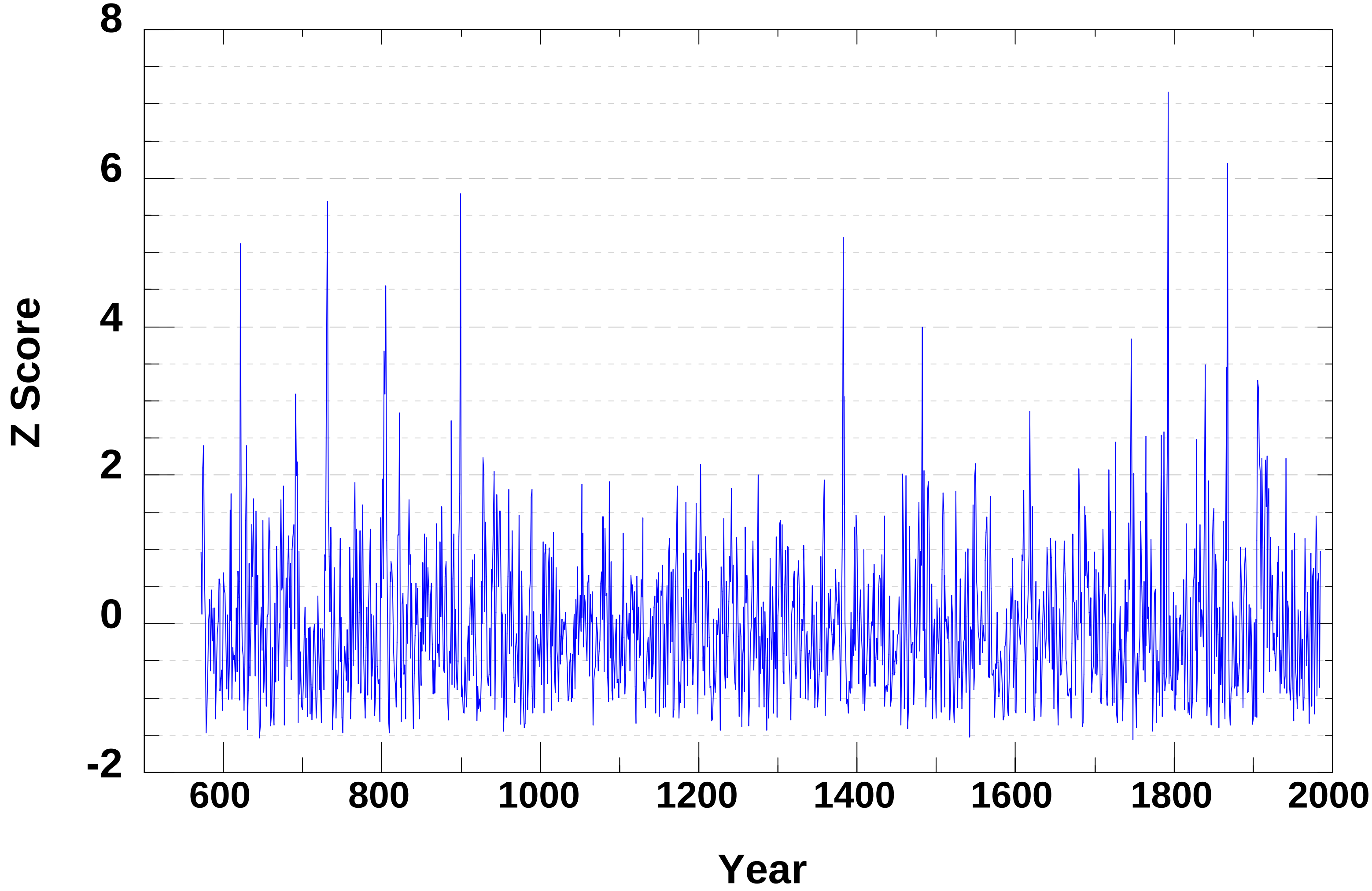

Mean Annual Temperature (Degrees C).
Niwot Ridge Site D-1 3739 m / 12267 ft.
Reanalysis 39-41 N, 105-107 W, (600+700 mb)/2
Reanalysis
Niwot Ridge
Niwot = 1.22 x Reanalysis - 0.70
r = + 0.61 r^2 = 0.37
Estimated Temperature (C)
-1
-2
-3
-4
-5
-6
-7
1950
1960
1970
1980
1990
2000
Year
With Thanks to
Mark Losleben, CIRES/MRC

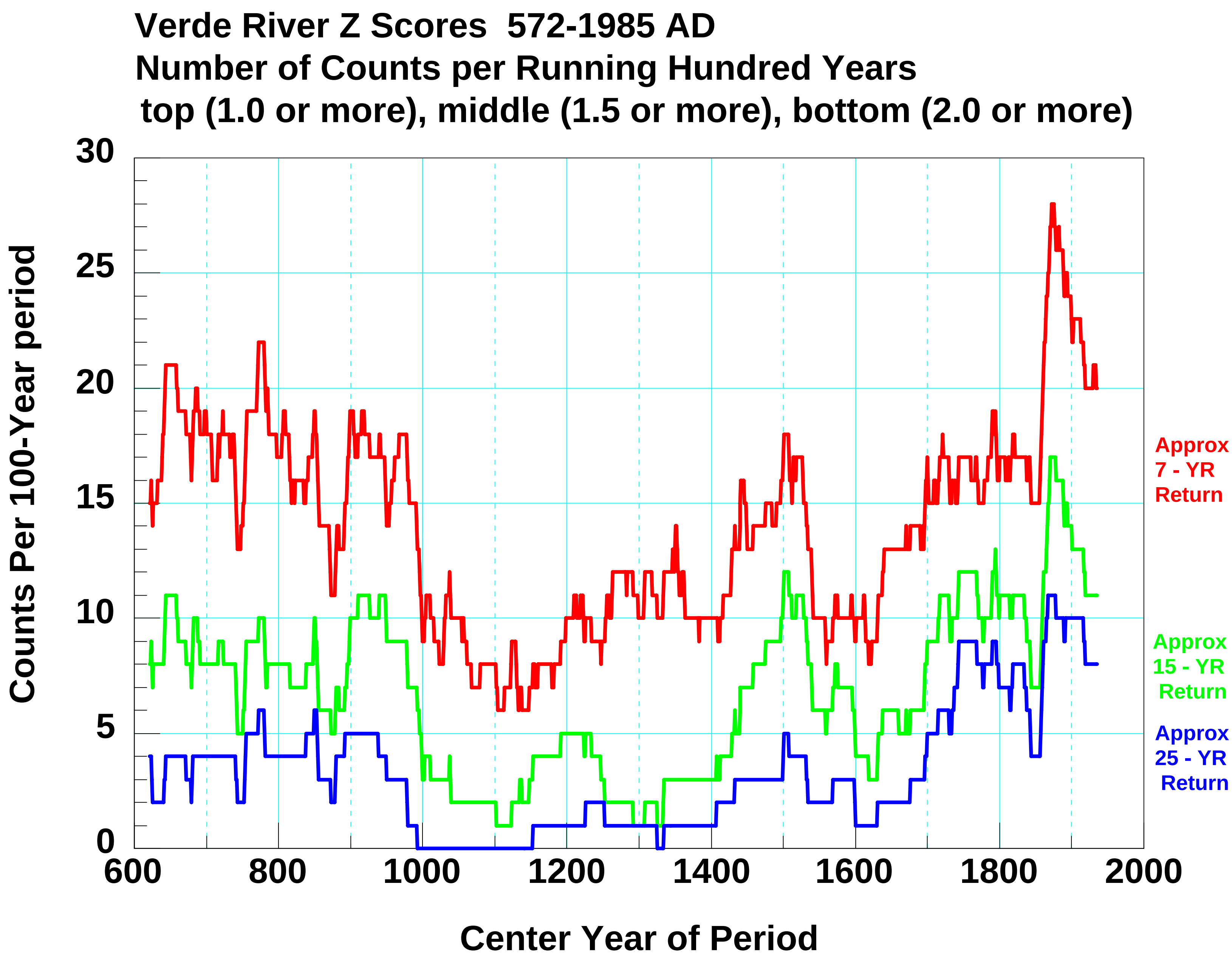
Reconstructed Annual Precipitation.
Nevada Division 3. From Bristlecone Pine.
Hughes and Graumlich data. July thru June.
Blue: 7-Year Running Mean. 1599/1600 - 1995/96.




Reconstructed Annual Precipitation.
Nevada Division 3. From Bristlecone Pine.
Hughes and Graumlich data. July thru June. Ave = 19.7 cm.
Blue: 15-Year Running Mean. 6000 BC thru 1996.
NV Div 3 Pcp 15-Yr Mean (cm)
26
24
22
20
18
16
14
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
Ending Year

Verde River. Reconstructed Flow. 572-1985 A.D.
Standardized Units.




Verde River Z Scores 572-1985 AD
Number of Counts per Running Hundred Years
top (1.0 or more), middle (1.5 or more), bottom (2.0 or more)
Counts Per 100-Year period
30
25
20
15
10
5
0
600
800
1000
1200
1400
1600
1800
2000
Center Year of Period
Approx
7 - YR
Return
Approx
15 - YR
Return
Approx
25 - YR
Return

reference lake with no influence of SDN (Fig. 3). Diatom analysis of these sediments also reveals only subtle variation and reflects constant oligotrophic conditions, consistent with no introduction of SDN. The greatest changes in the Frazer lake $\delta^{15}N$ and diatom records are associated with the introduction of sockeye salmon in recent decades[8].

The sustained multi-centennial regimes of anomalous salmon abundance, unprecedented during the historical period or during our short-term 300-year records[8], appear to be regional phenom-

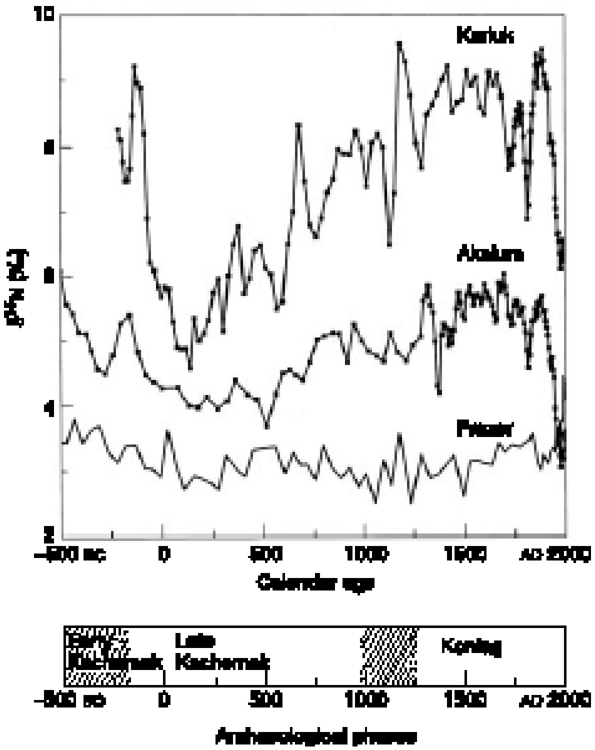


Figure 3 A regional comparison of sedimentary $\delta^{15}N$ profiles and the archaeological phases[10] from Kodiak Island, Alaska. Both Karluk and Akalura lakes are natural sockeye salmon nursery lakes. Frazer lake, our reference lake, was without sockeye salmon until the 1950s (when it was stocked and a fish ladder was constructed) because it has an impassable waterfall at its outlet. The importance of changes in sockeye salmon abundance to the indigenous peoples of Kodiak is reflected in archaeological deposits[14] and the delineation of cultural phases[13]. A shift towards greater abundance of fishing tools[14], greater housing densities and larger multi-room houses is evident during the Koniag phase[14,30].

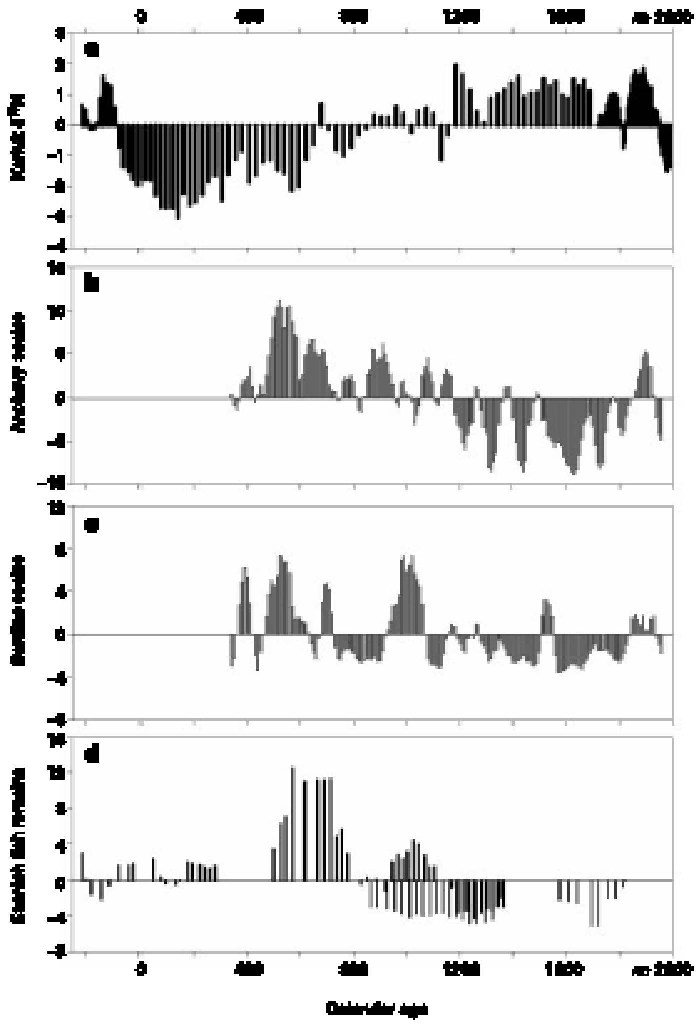


Figure 4 Reconstructions of fish abundances for the northeastern Pacific Ocean over the past ~2,200 years. Each series is plotted as the difference from the series mean calculated over the time period presented. **a**, The Karluk lake $\delta^{15}N$ profile (‰) as a proxy for sockeye salmon abundances in Alaska. **b**, **c**, Northern anchovy and Pacific sardine scales (no. of scales per 1,000 cm^2 per year) from the Santa Barbara basin, California[25]. A 50-year running average was applied to highlight long-term trends. **d**, Fish remains (including Pacific herring, Pacific hake and cartilaginous fish) (no. of fish remains per 100 cm^3) recovered from Saanich inlet, British Columbia[27]; data from two overlapping cores are presented.

Salmon populations vary.

Kodiak Island.

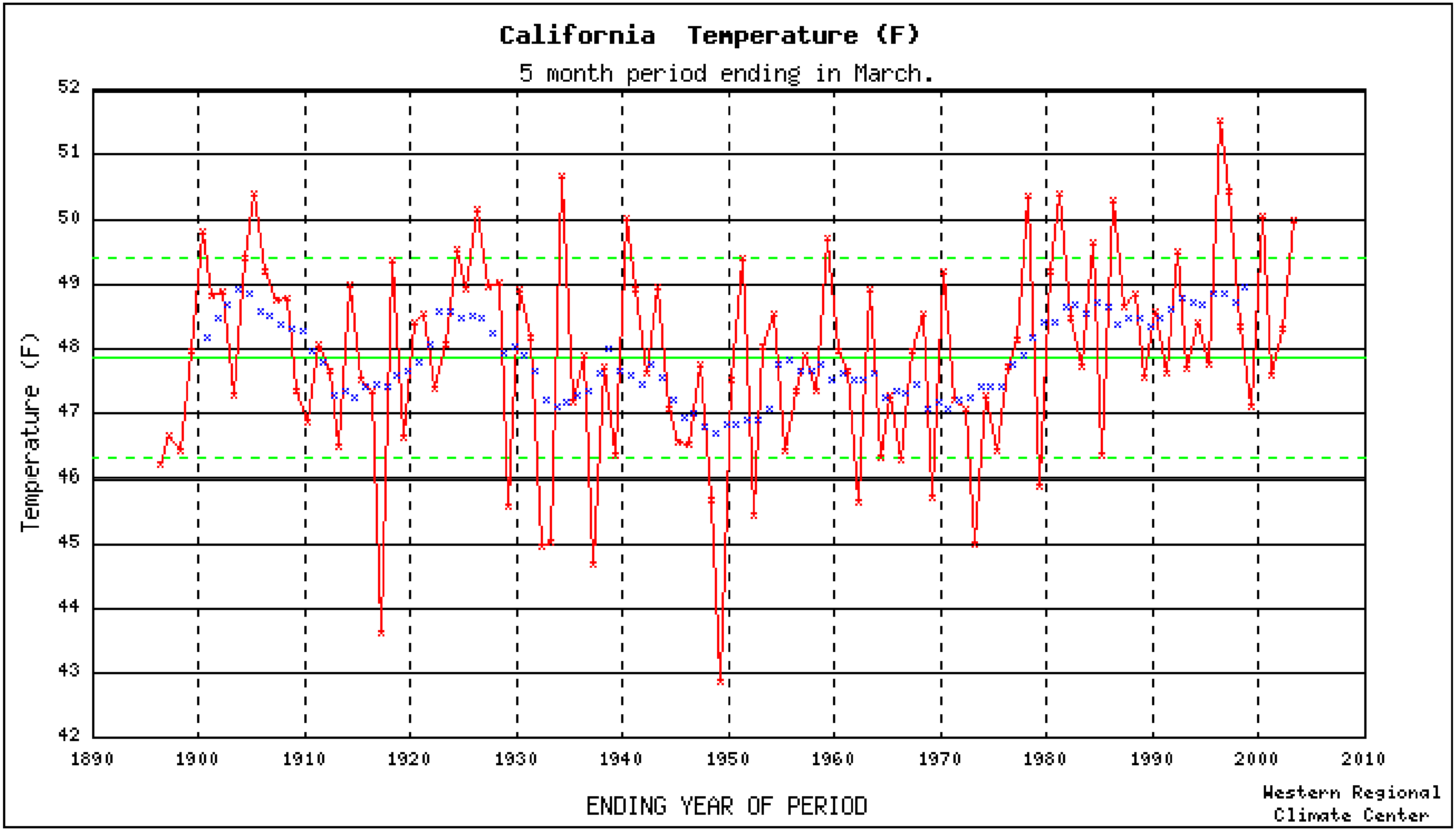
Past 2200 years.

Bruce Finney,

Nature, 2002, 413, p 731

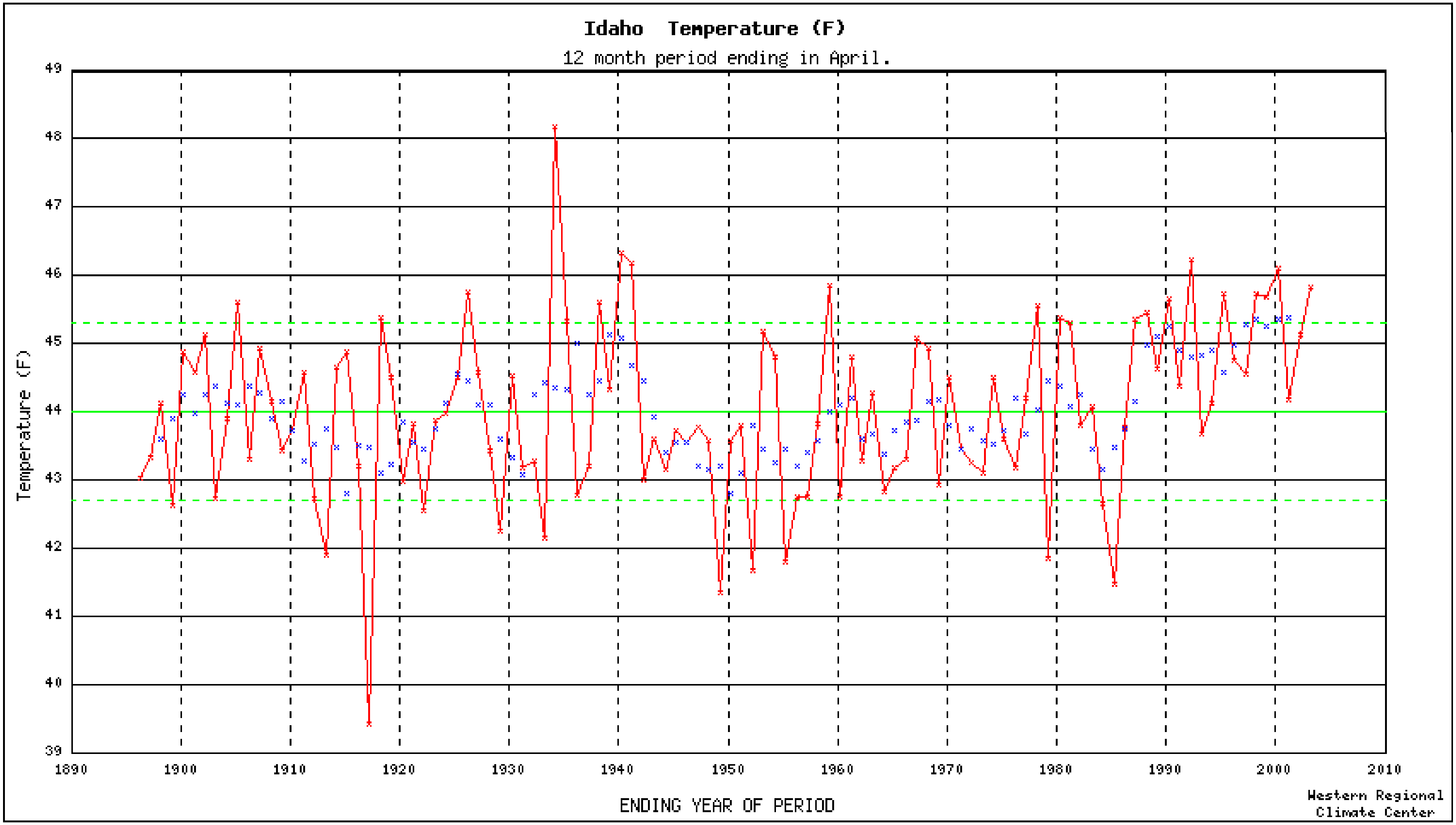
California Statewide Average Temperature Nov-Mar & 10-yr Running Mean

1895-2003

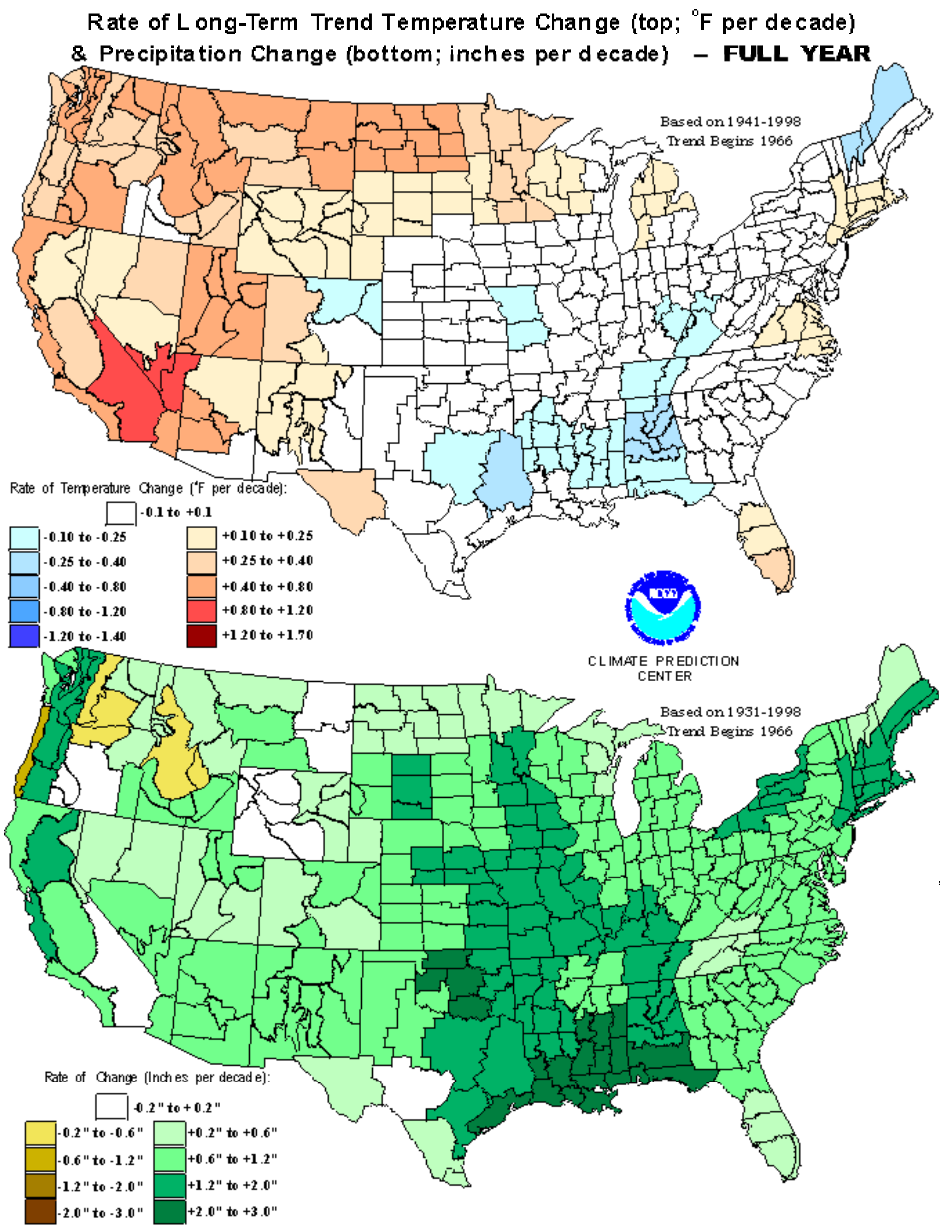


Idaho Statewide Mean Annual Temperature, 1895 – 2002.

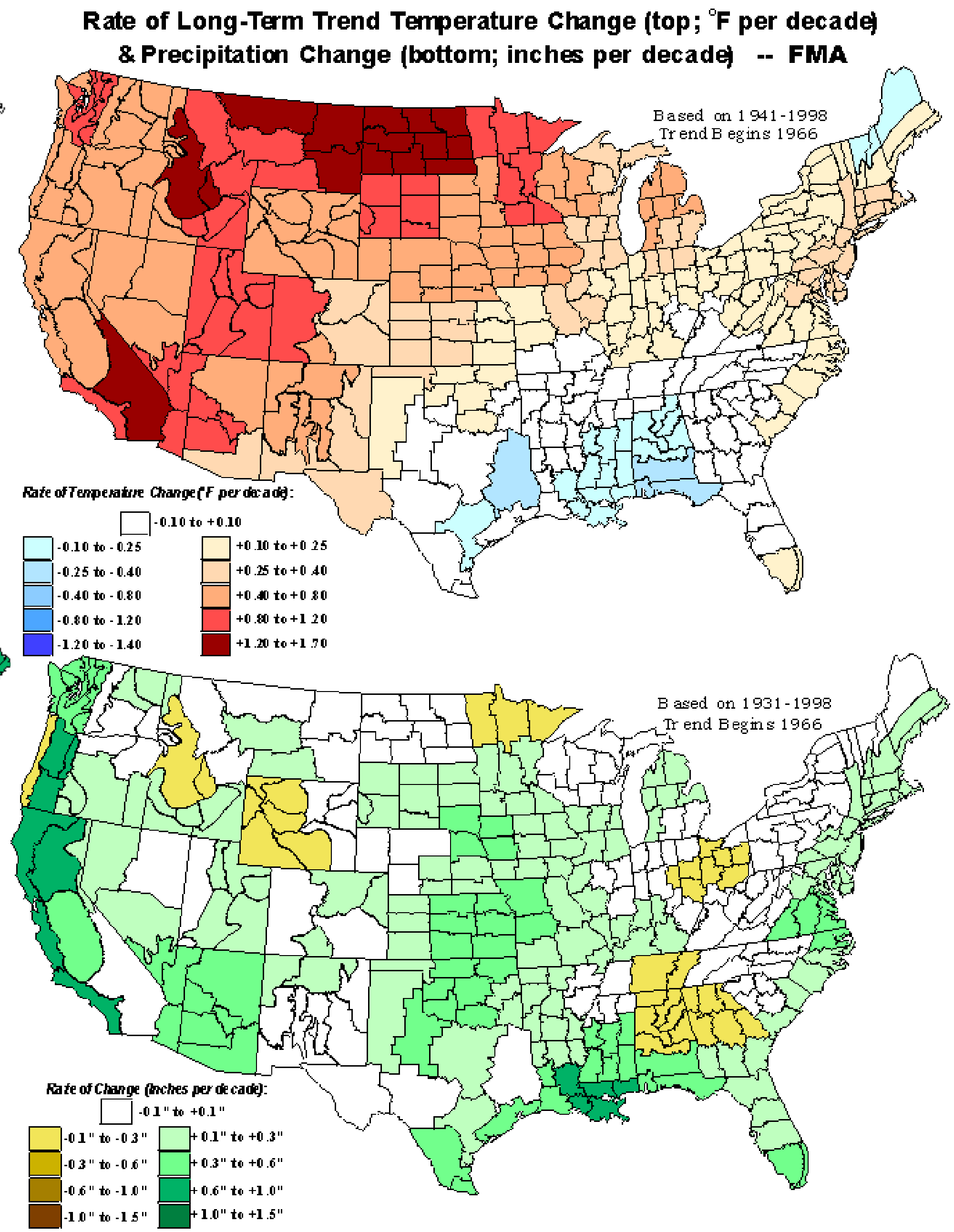
& 10-year running mean.

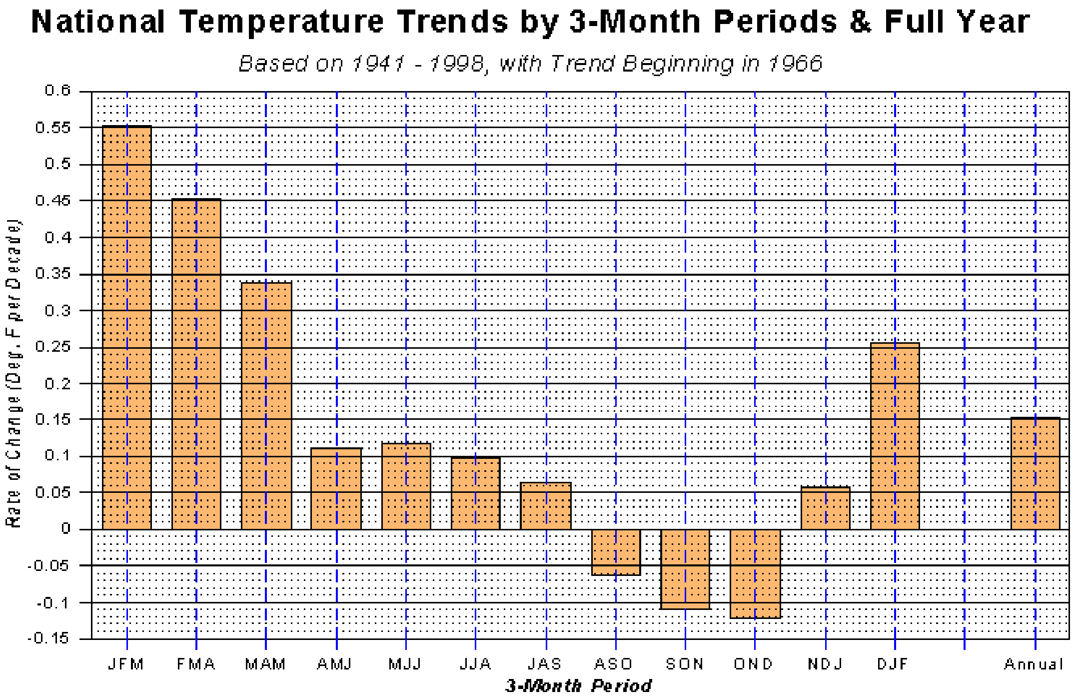


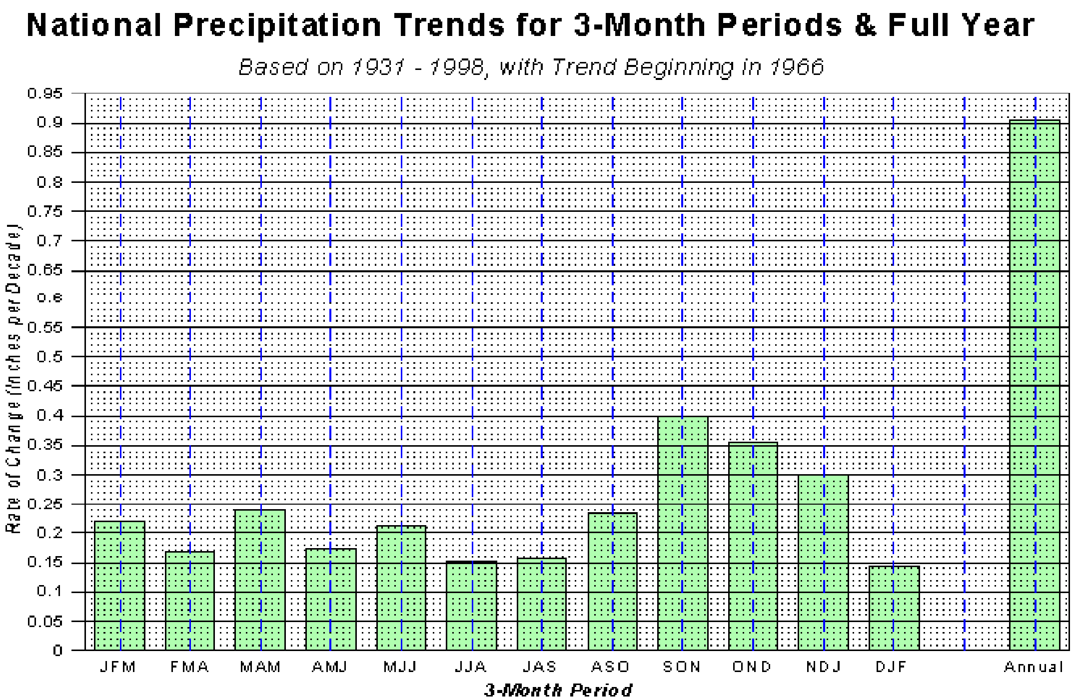
Trends 1966+ Annual, Full Year.



Trends 1966+ Feb-Mar-Apr







National Trends.

Three-Month Segments.

Done for climate forecasting purposes.

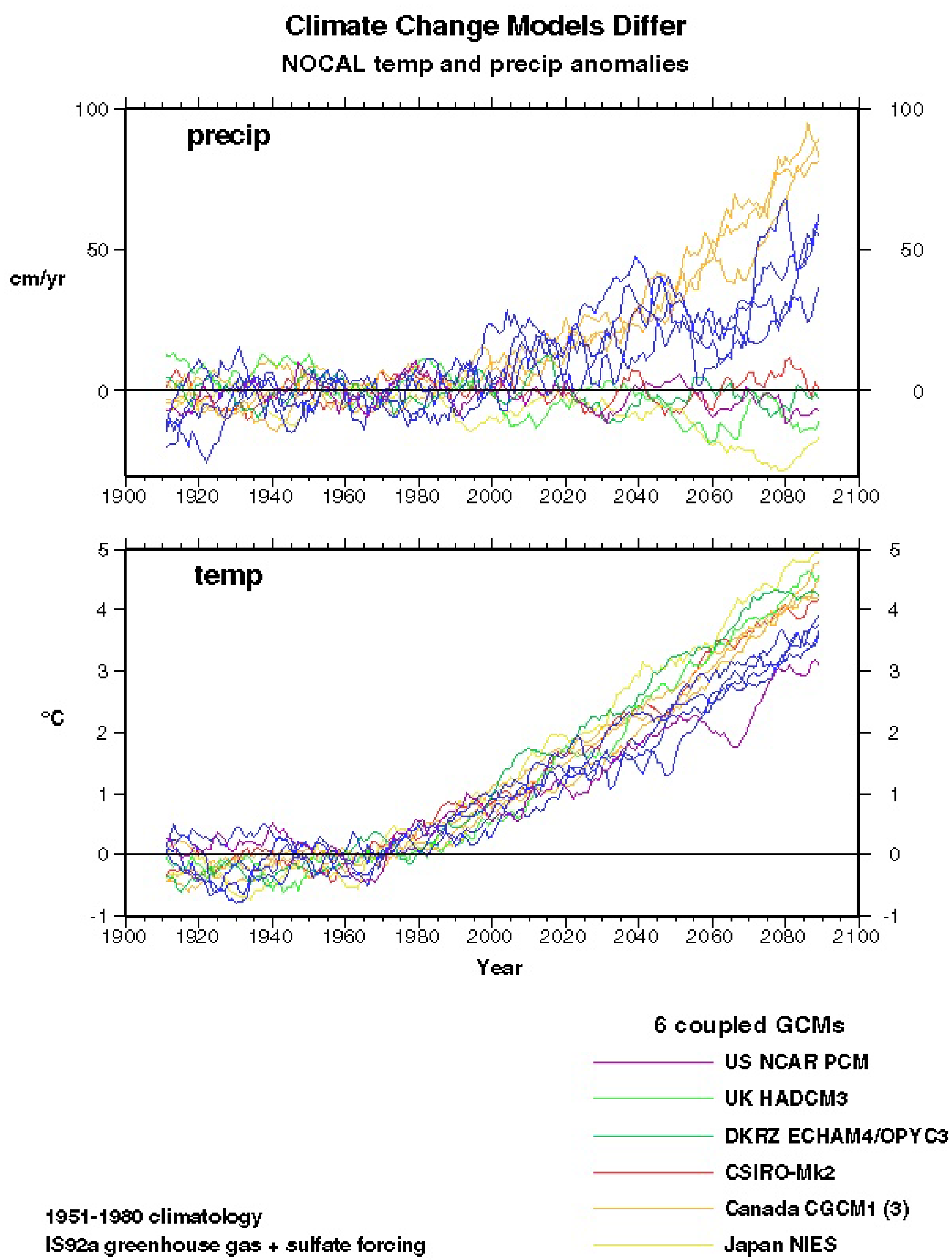
Temperature

Precipitation

Six models, 12 opinions, for Northern California. 1900-2100

Precipitation

Temperature



Thanks to Mike Dettinger, Scripps / USGS

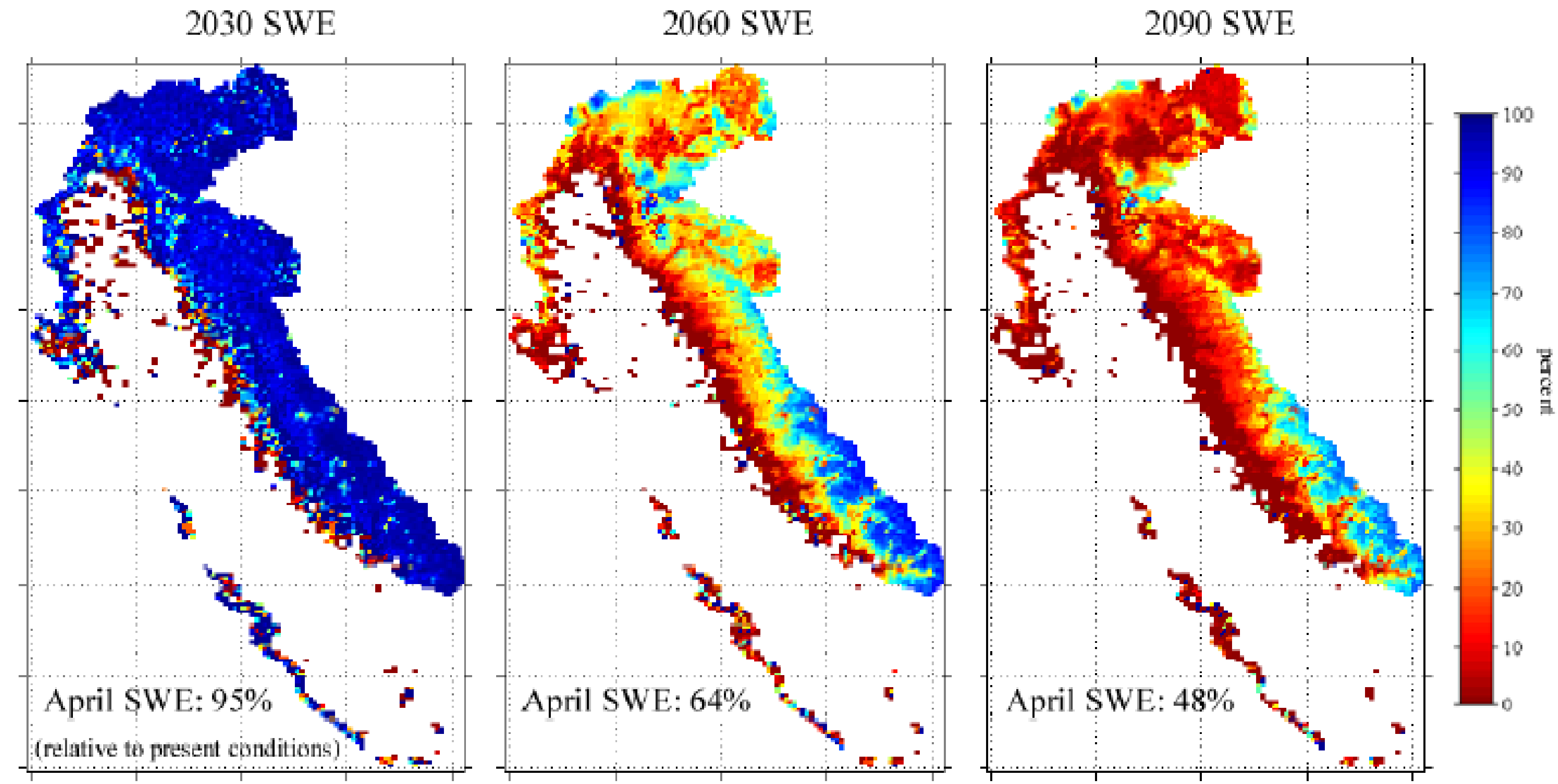


Figure 3. Simulated snow water equivalent (SWE) under a projected temperature increase for the periods 2020-2039, 2050-2069 and 2080-2099, expressed as a percentage of average present conditions.

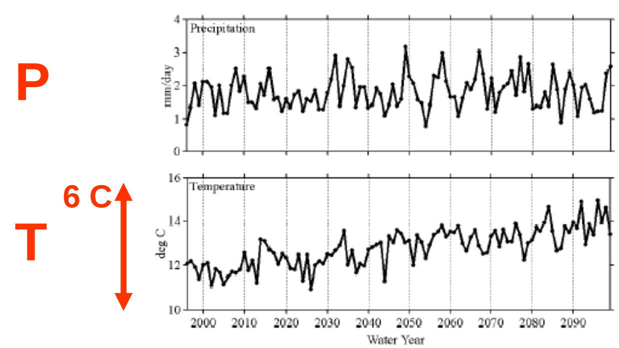
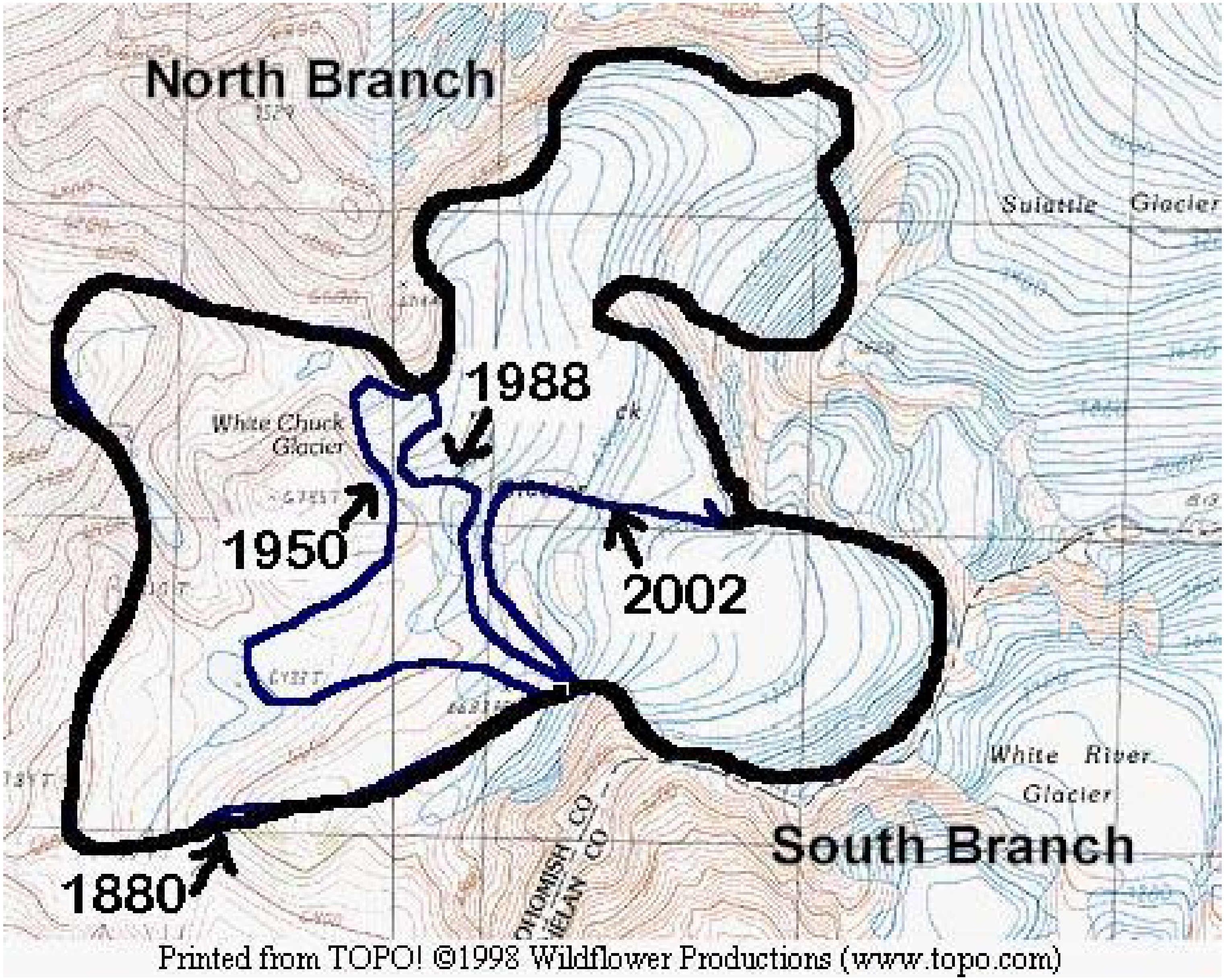


Figure 2. PCM-simulated watershed-averaged annual precipitation and temperature for WY 1995-2099.

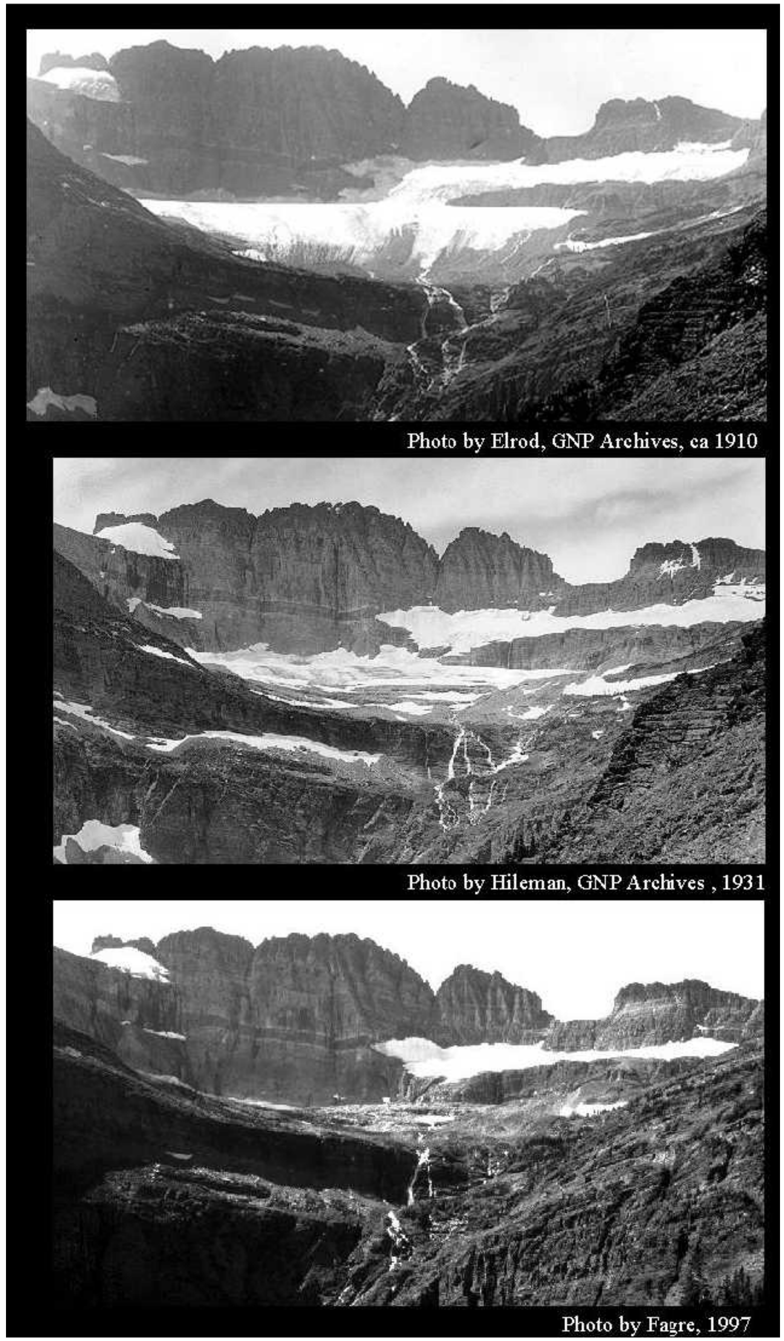
Potential effects of global warming on the Sacramento / San Joaquin watershed and the San Francisco estuary

Noah Knowles and Dan Cayan, Climate Research Division, Scripps Institution of Oceanography

Woodchuck Glacier Extent, North Cascades National Park



Grinnell Glacier from Grinnell Lake
Glacier National Park, 1910-1997



1910

Elrod, Glacier National Park Archives

1931

Hileman, Glacier National Park Archives

1997

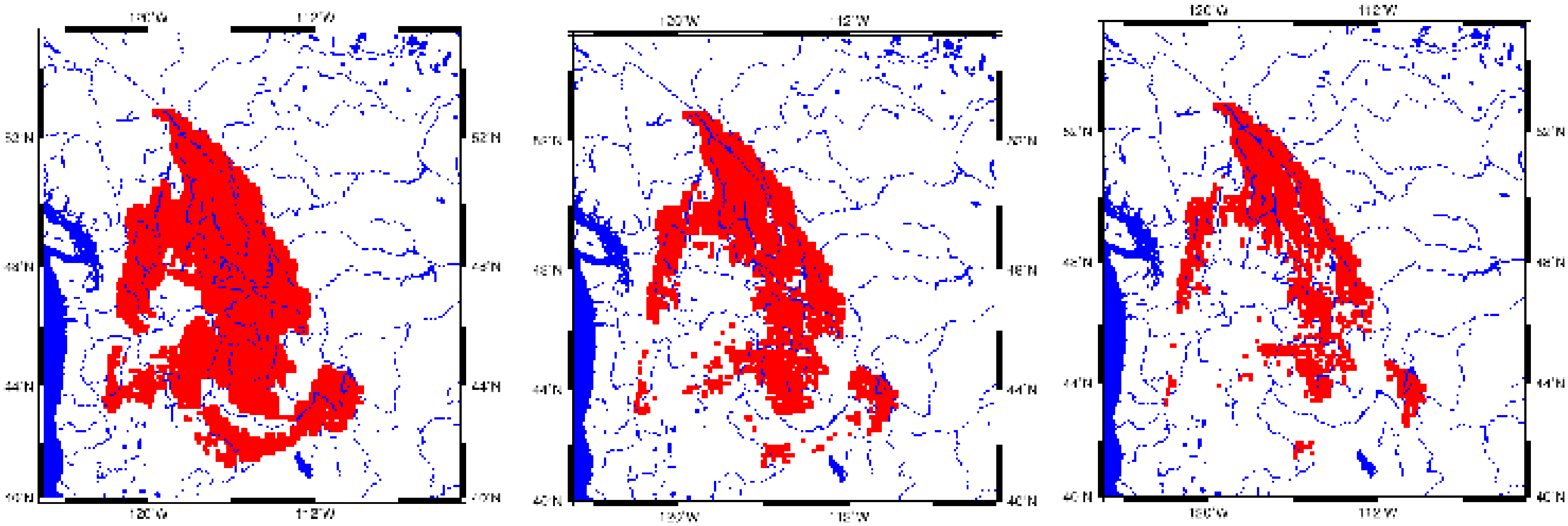
Fagre, USGS / Glacier National Park

Alan Hamlet & Dennis Lettenmeier

U of Washington.

VIC Simulations of April 1 Average Snow Cover Extent
MPI ECHAM4 Scenarios

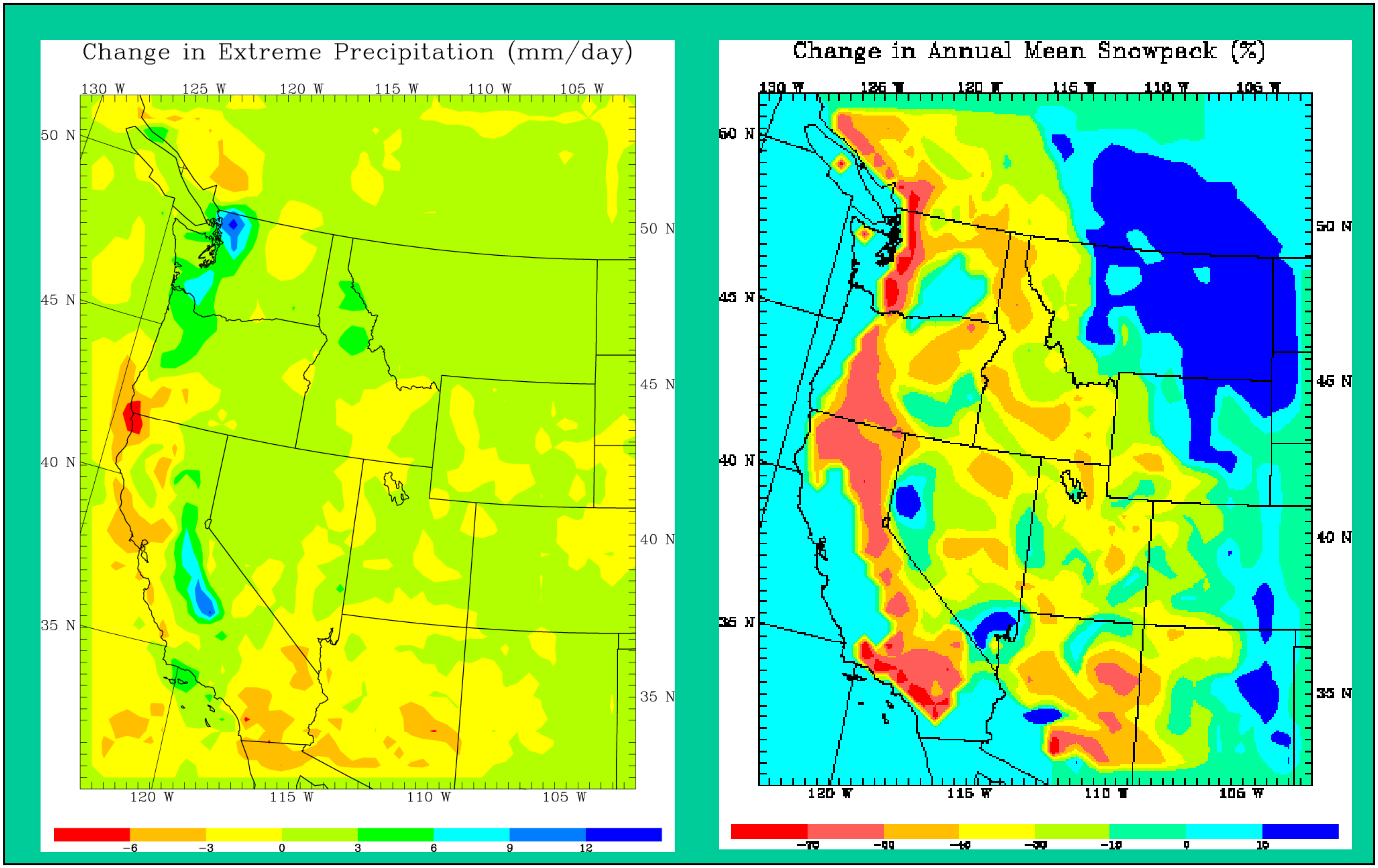
Base Case | ~2025 | ~2045



2040-2060, BAU Scenario. PCM (NCAR/DOE). **Ctsy Bill Pennell, Ruby Leung, PNNL.**

April 1 Snow Water Equivalent on right.

Extreme Precipitation / Snowpack Changes



Institutional change:

When change is widely desired, or thought to be needed, but various parties do not have the ability or will power to propose actions, and then to carry through,

Significant climate anomalies can act as a catalyst for change.

Large-scale drought is one such catalyst.

"We had to do it …. we had no choice !"

<u>Climate Stationarity</u>

"The history of climate is a non-stationary time series."   *

There are no true climatic "normals"
(states to which the climate *must* return).

Climate <u>never</u> repeats itself exactly.

Climate is <u>always</u> fluctuating, on all scales.

There are <u>always</u> surprises remaining.

We can thus <u>never</u> stop observing or monitoring.

* "The Paradigm of Climatology: An Essay"
Reid A. Bryson, Bulletin of the American Meteorological Society, 1997, 78(3), 449-455

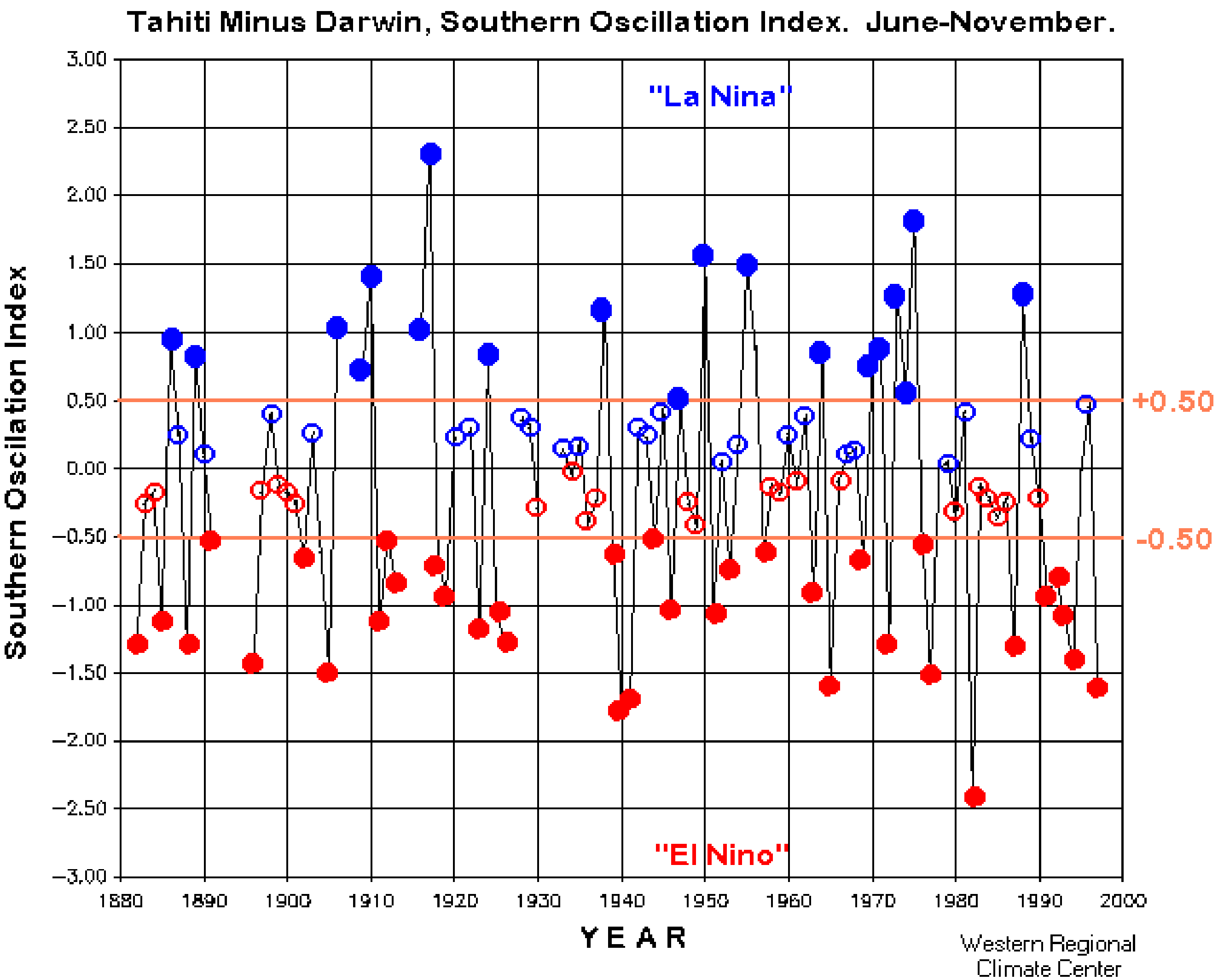
Preliminary, tentative, possible tendencies toward conclusions:

Climate matters.

History matters.

Climate history matters.

A final example:




WAITING FOR A CHINOOK