The Tahoe Basin and Climate Change

Kelly T. Redmond

Western Regional Climate Center

Desert Research Institute

Reno Nevada

Coping with Climate Change in Sierran Systems:
Incorporating Climate into Land and Resource Management
and Developing Adaptation Strategies
Tahoe Environmental Sciences Building, Incline Village NV
March 17-18, 2009

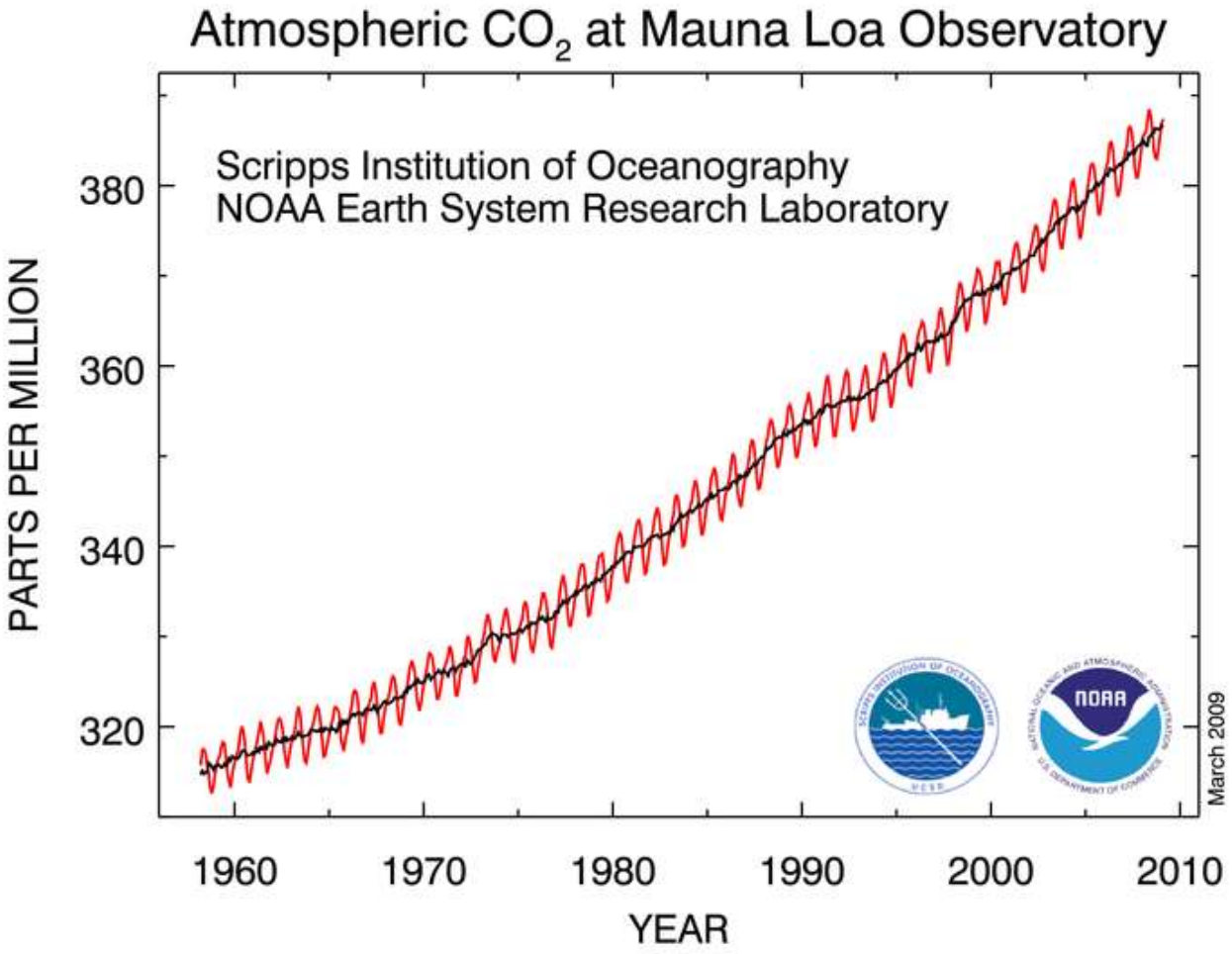
Potential external sources of climate change

Human

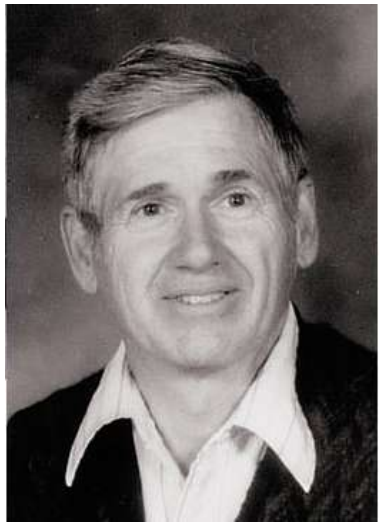
- Greenhouse gasses
  - Carbon dioxide
  - Methane
  - Nitrous oxide
  - Ozone
  - Chloroflourocarbons
- Aerosols
  - Radiative effects (the flow of radiant energy)
  - Microphysics effects (how clouds form and how they work)
- Land use / land cover changes
  - Changes in albedo
  - Changes in water vapor
  - Changes in vegetative influence / participation in energy and mass flows

Natural

- Astronomical radiation forcing
- Solar variations
- Volcanoes



Dave Keeling, Scripps

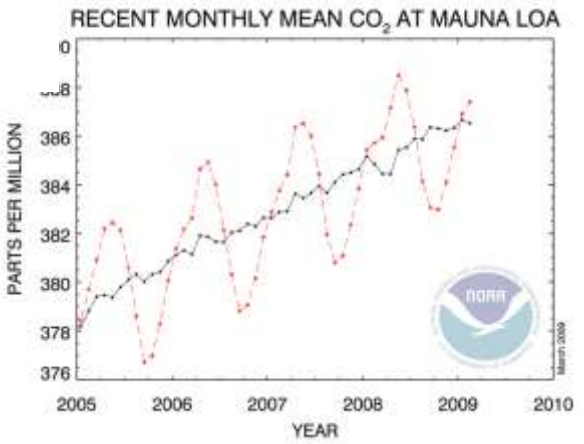


1928 April 20 - 2005 June 20

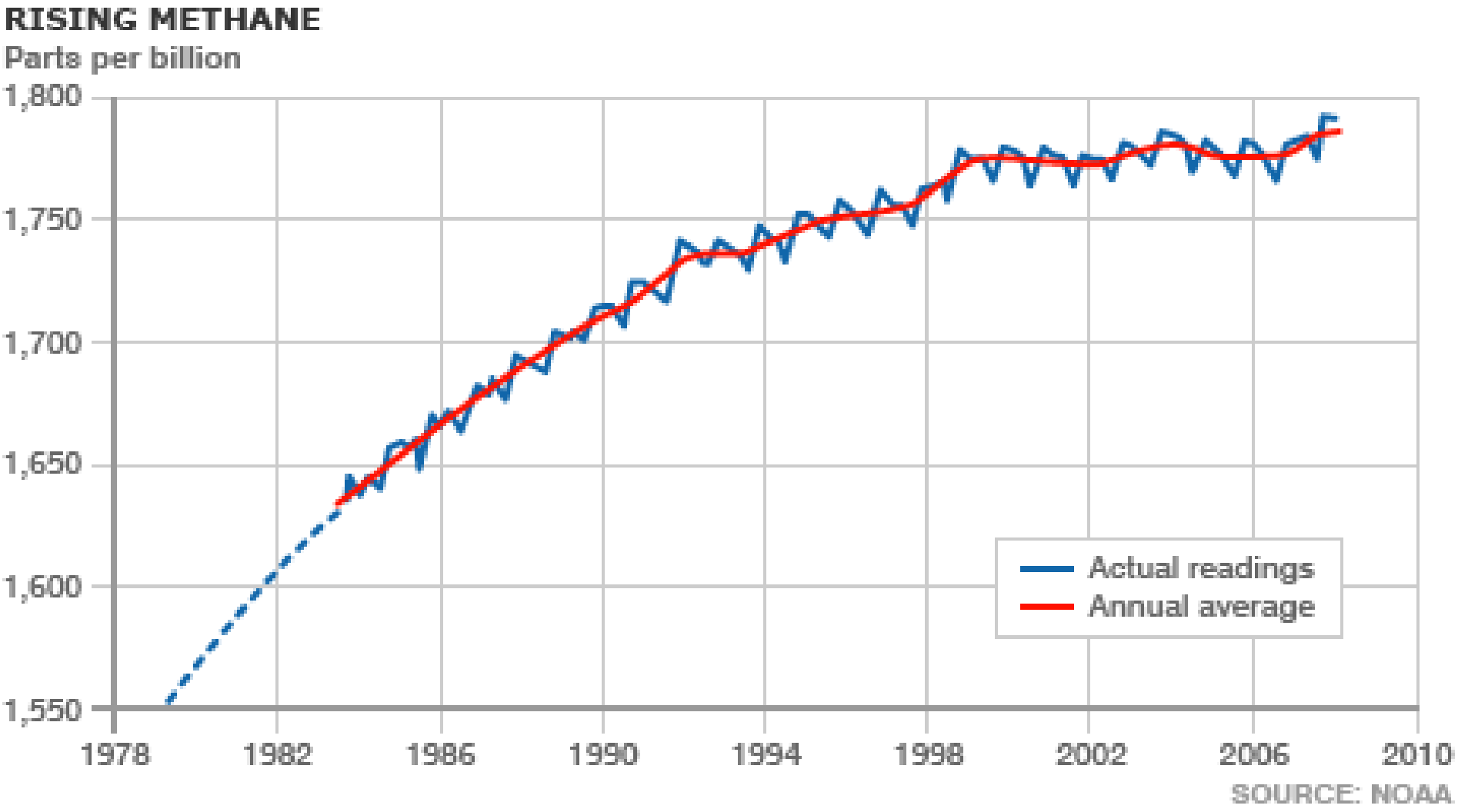
1959: 316 ppmv

+22 %

387
Mar 2009

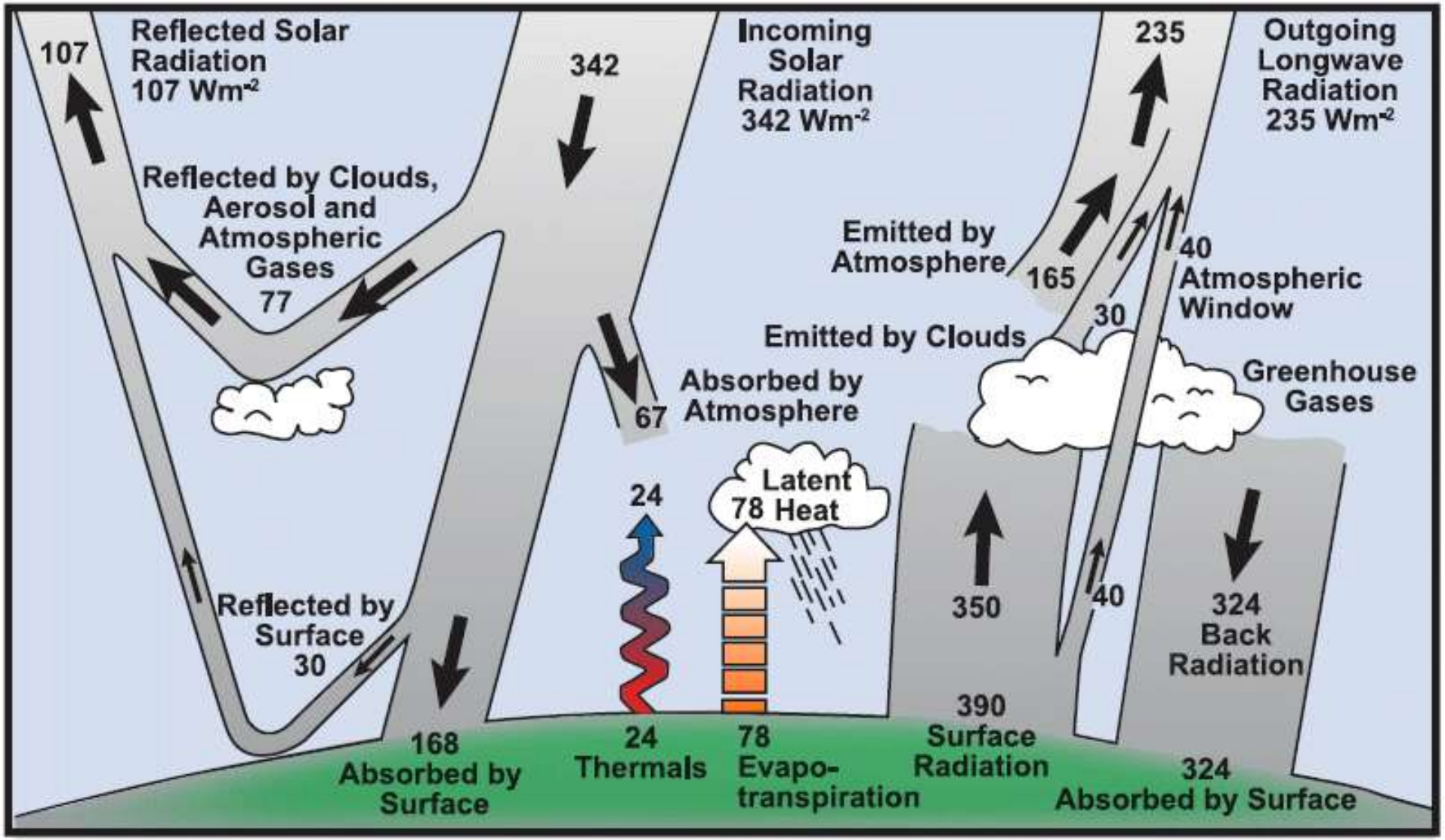


Atmospheric Methane: Resumption of its Rise???
Methane is 23 times more potent as a greenhouse gas than CO2



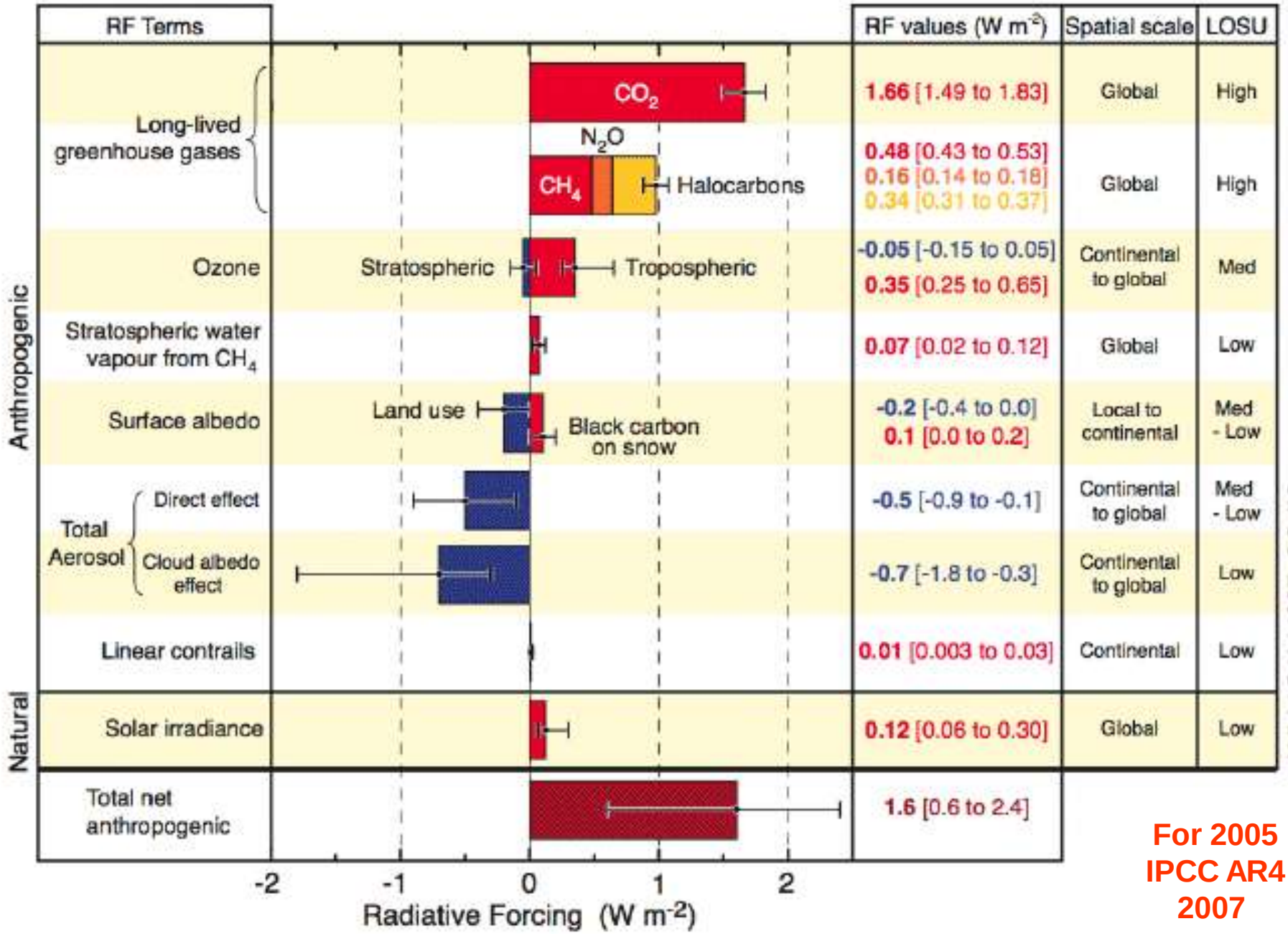
The Planetary Radiation Budget

Net incoming 342 – 107 = 235 W/m^2 **Net outgoing = 235 W / m^2**



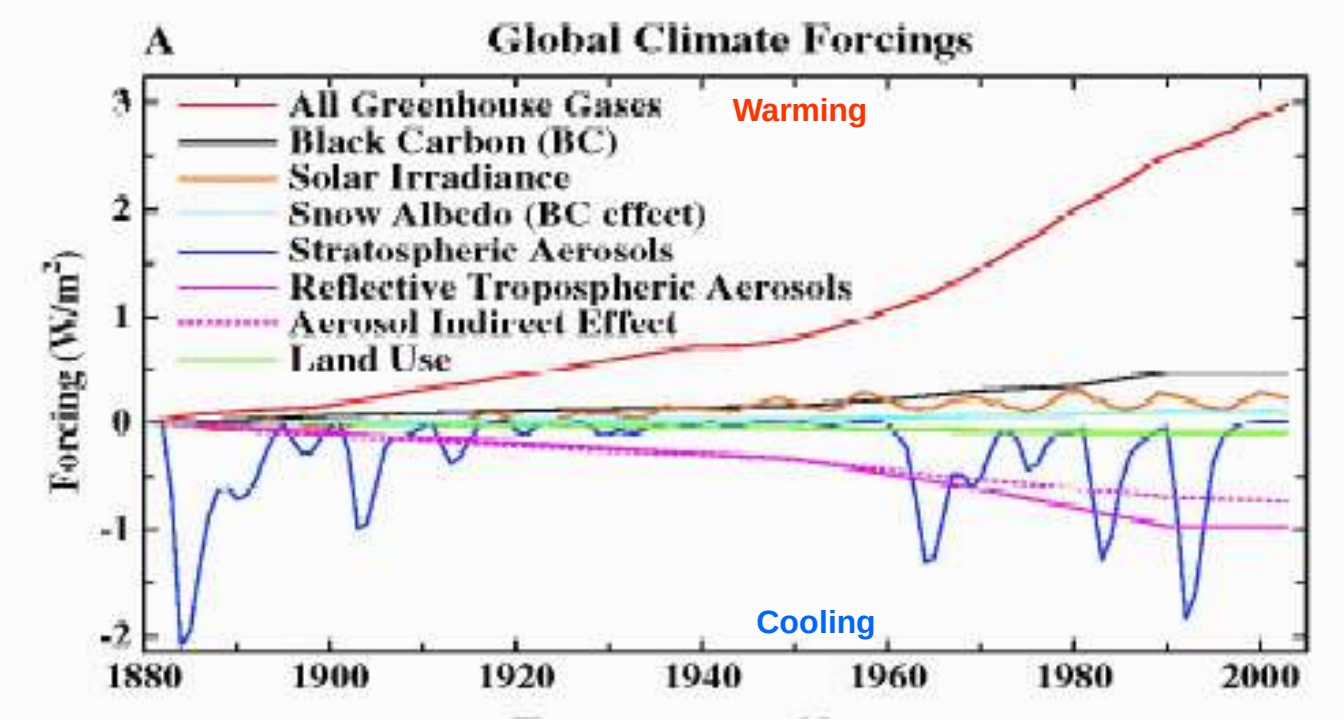
IPCC AR4, Kiehl and Trenberth (1997)

Global Radiative Forcing Components



For 2005
IPCC AR4
2007

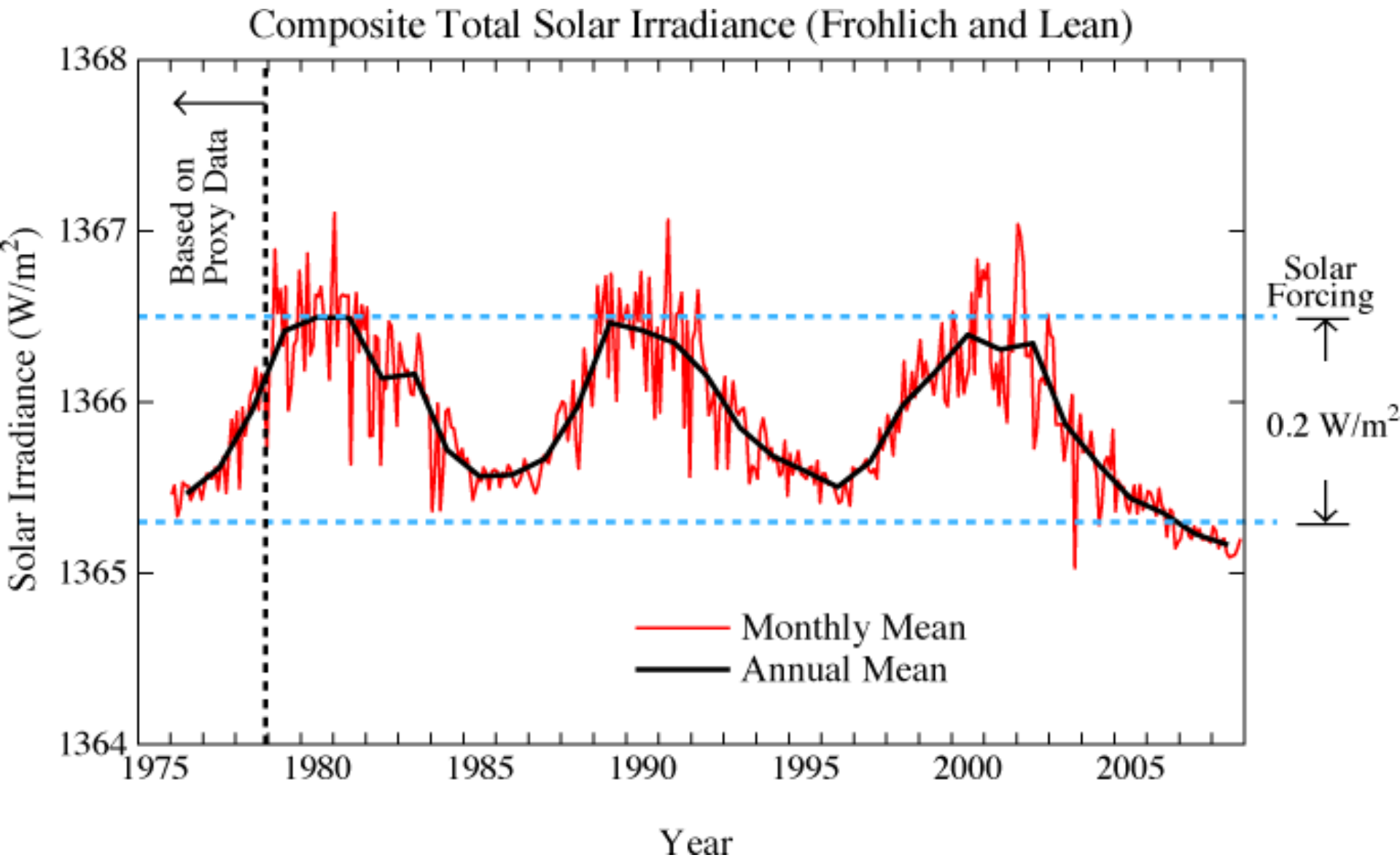
History of Atmospheric Forcings



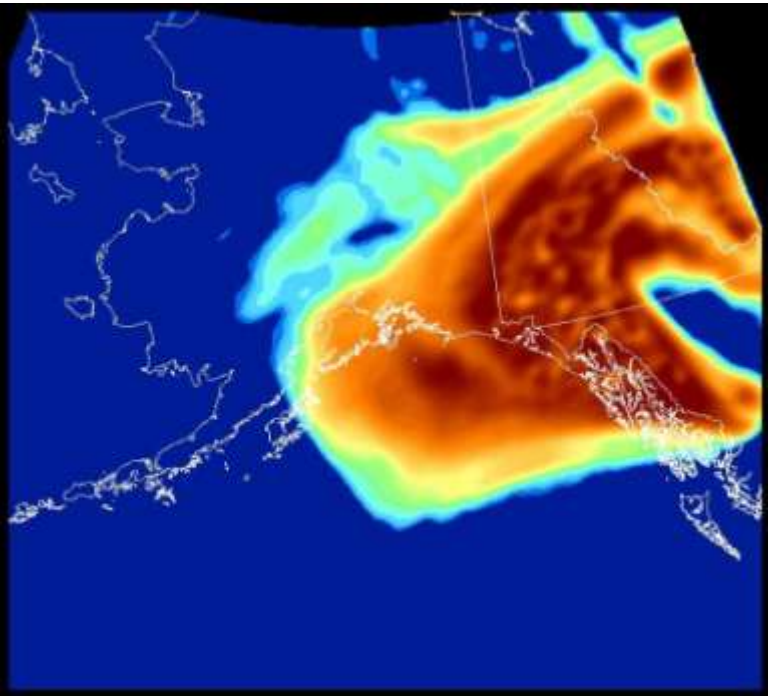
Hansen et al, 2005. Earth's energy imbalance: Confirmation and implications. *Science,* 308, 1431.

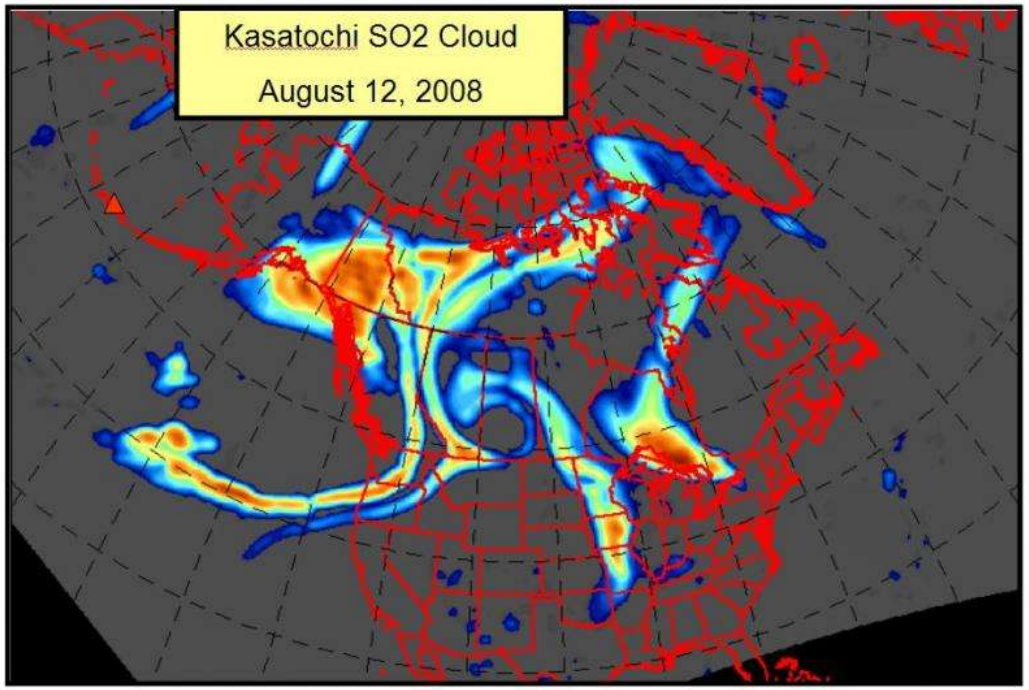
Solar Output During the Satellite Era

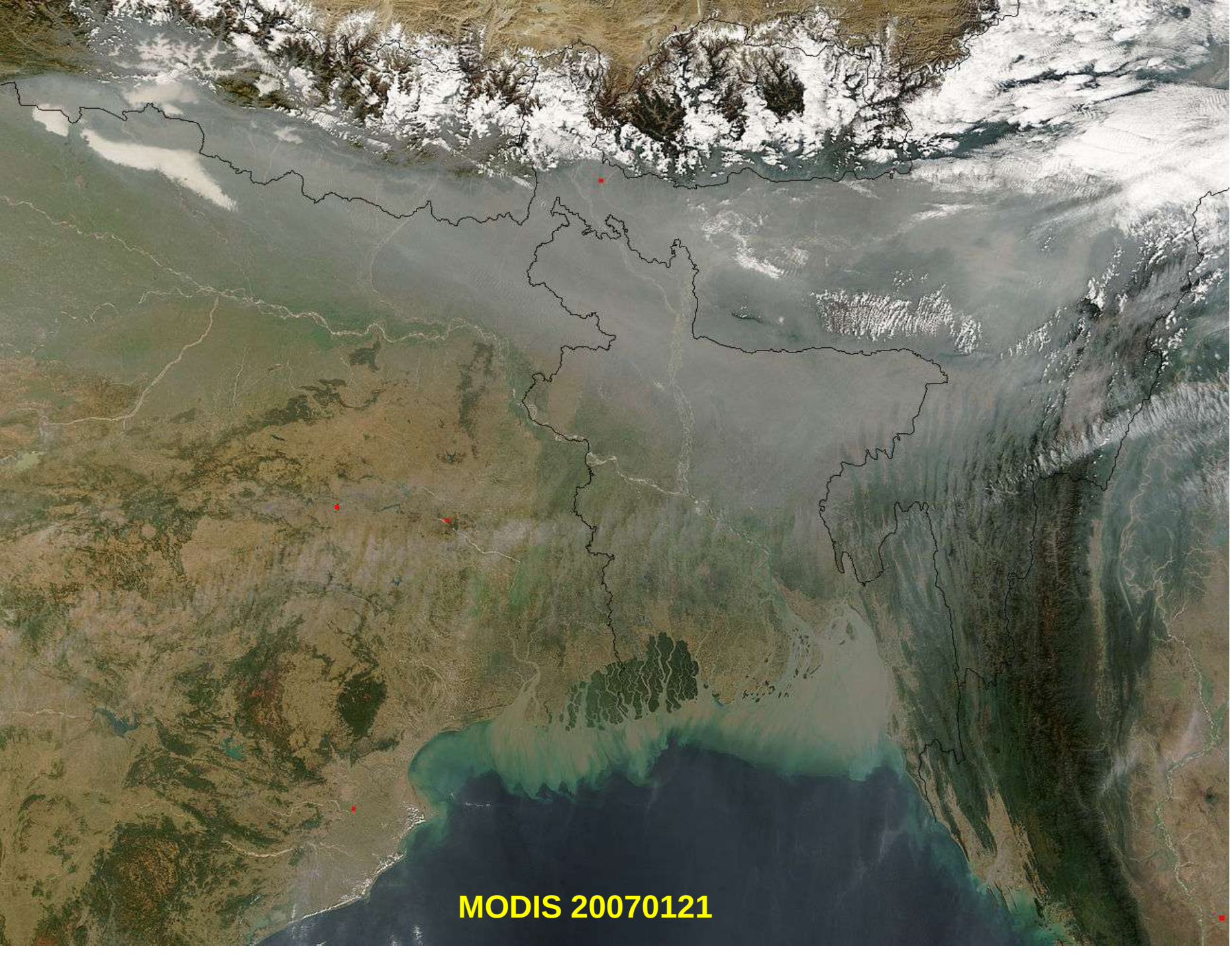
Through late December 2008

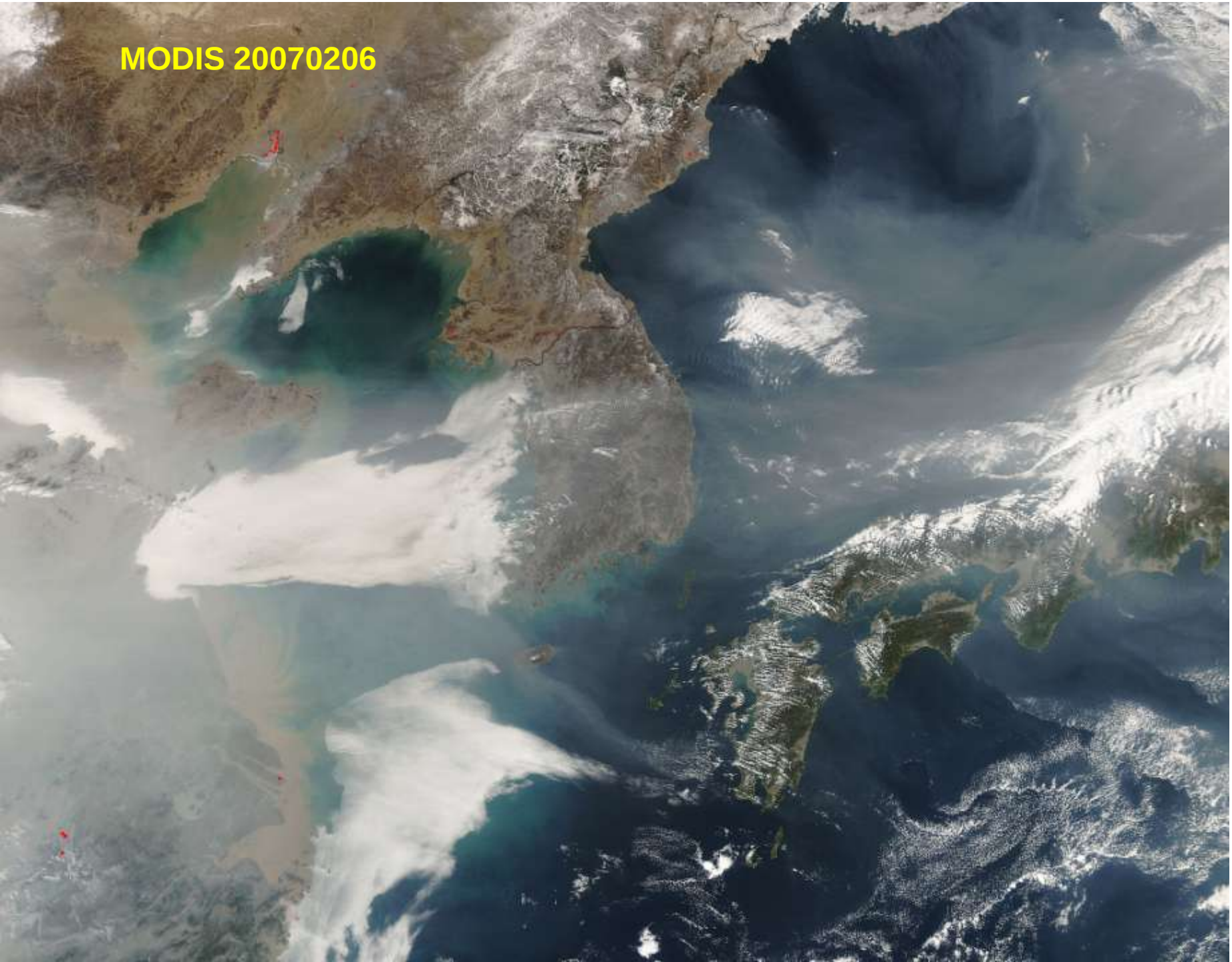


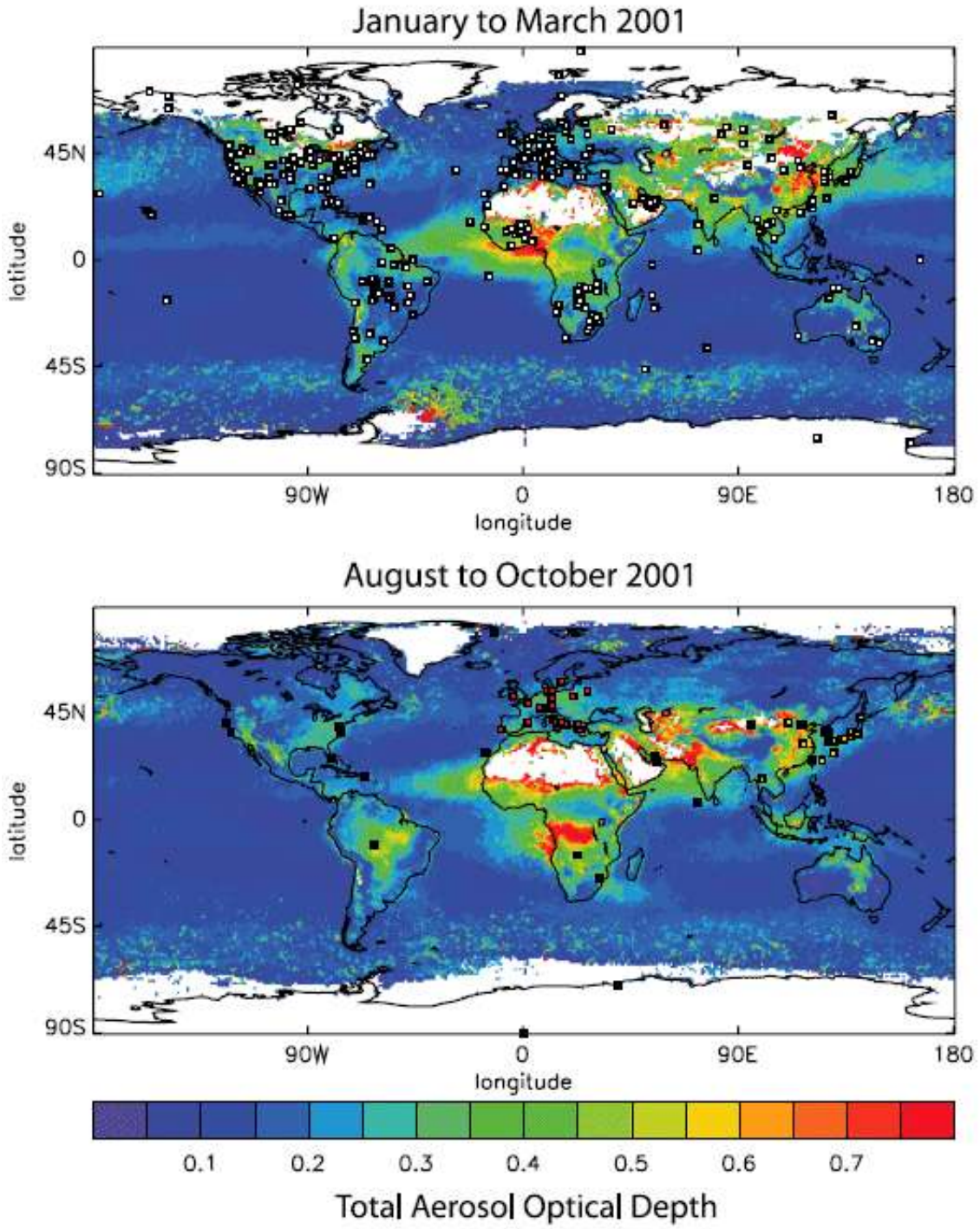
Kasatochi 20081023:1500ADT Jerry Morris






MODIS 20070121


MODIS 20070206



Pollution is a global atmospheric concern

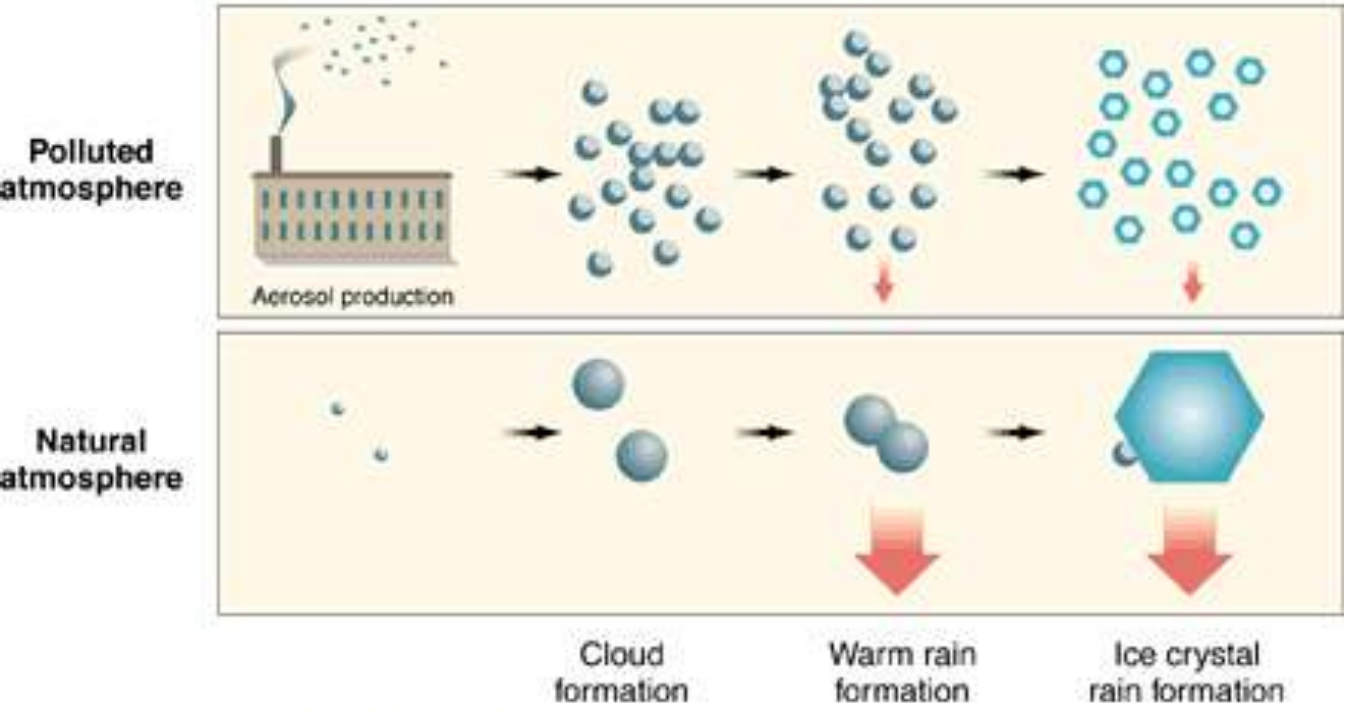
Obviously for health reasons

But, also,

Aerosols have effects on

Temperature
And
Precipitation

Also note:
Aerosols are unequally distributed around the earth



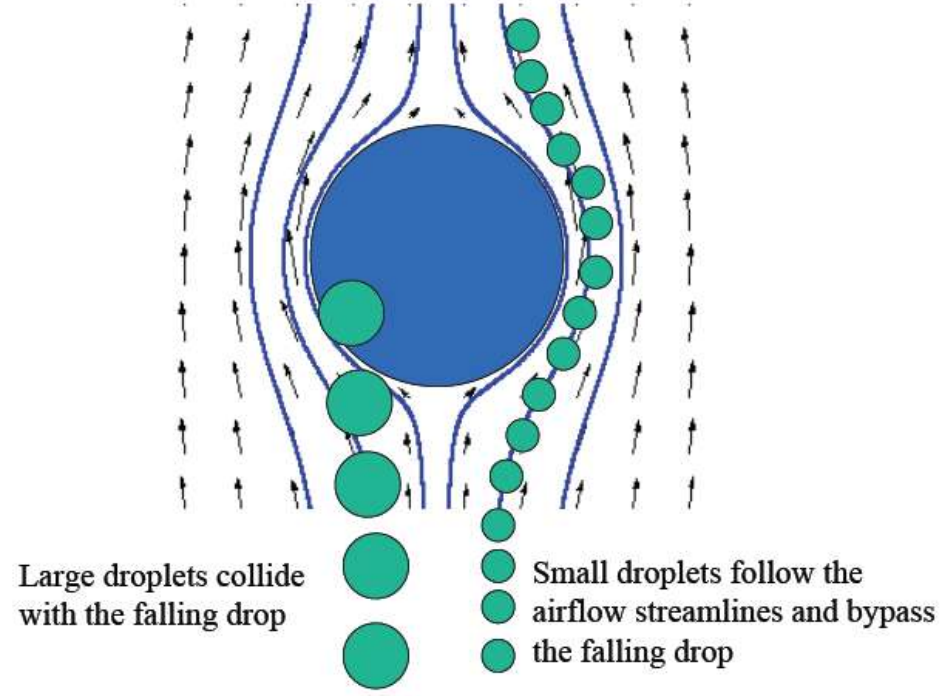
Owen B. Toon

How Pollution Suppresses Rain

Science Magazine,

10 March 2000

287 (5459), 1763-1765



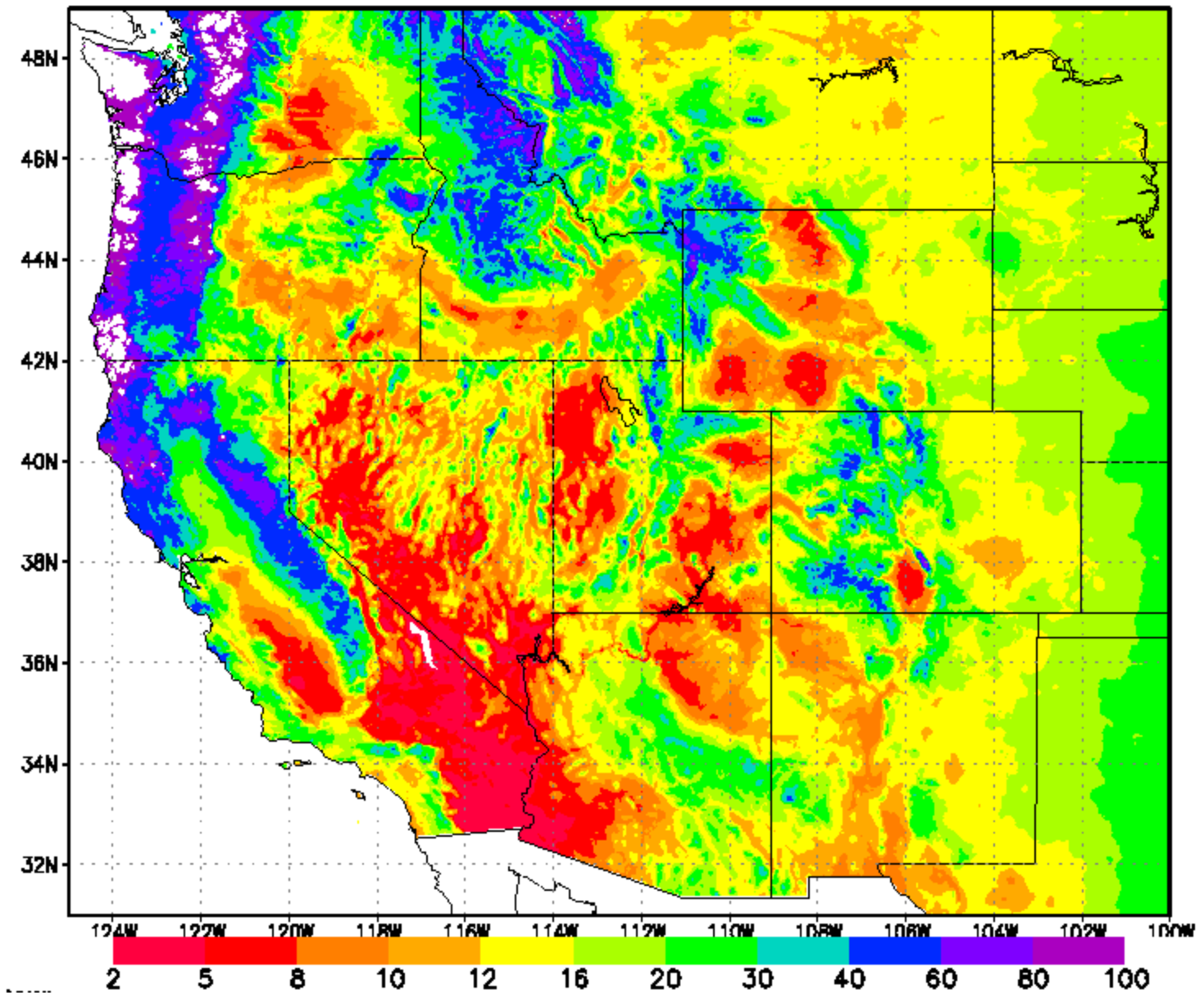
Daniel Rosenfeld

Aerosols Suppressing Precipitation in the Central Sierra: Results of the 2006 Winter Field Campaign

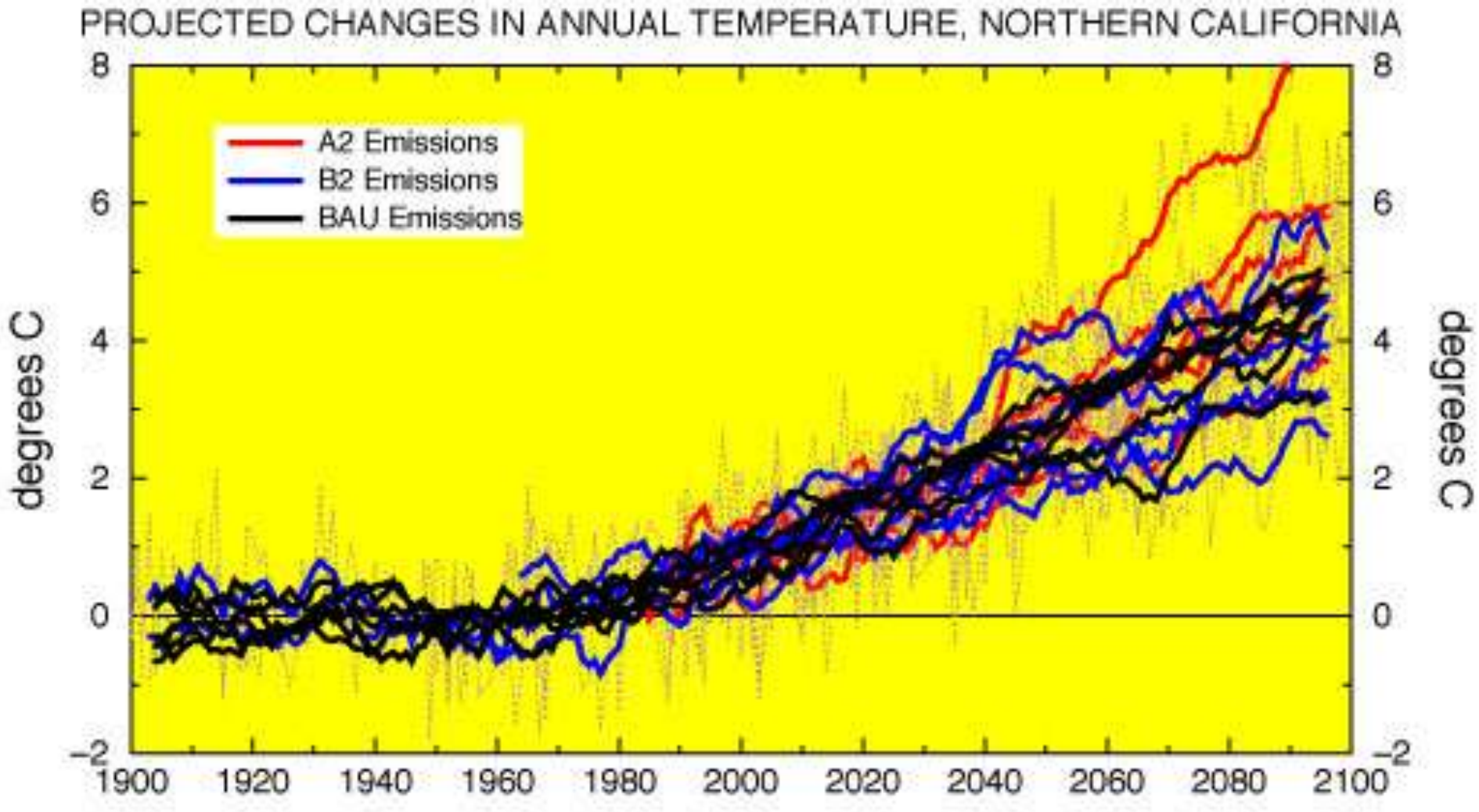
!4 Sep 2006. California Climate Change Research Conference.

Suppression of Rain and Snow by Industrial and Urban Air Pollution. Science, 2000, March 10, 287, 1793-1796.

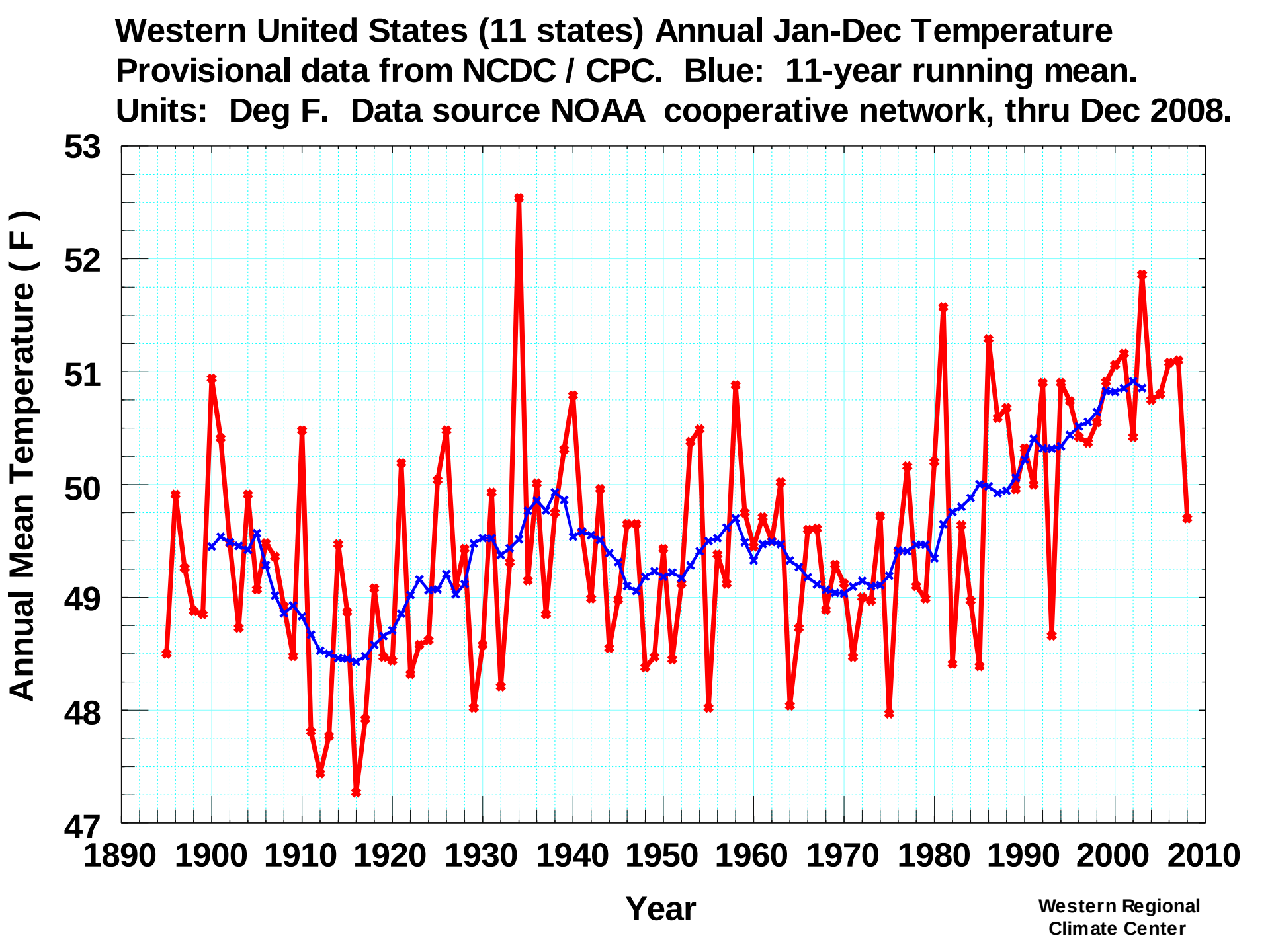

Ship trails 20030630

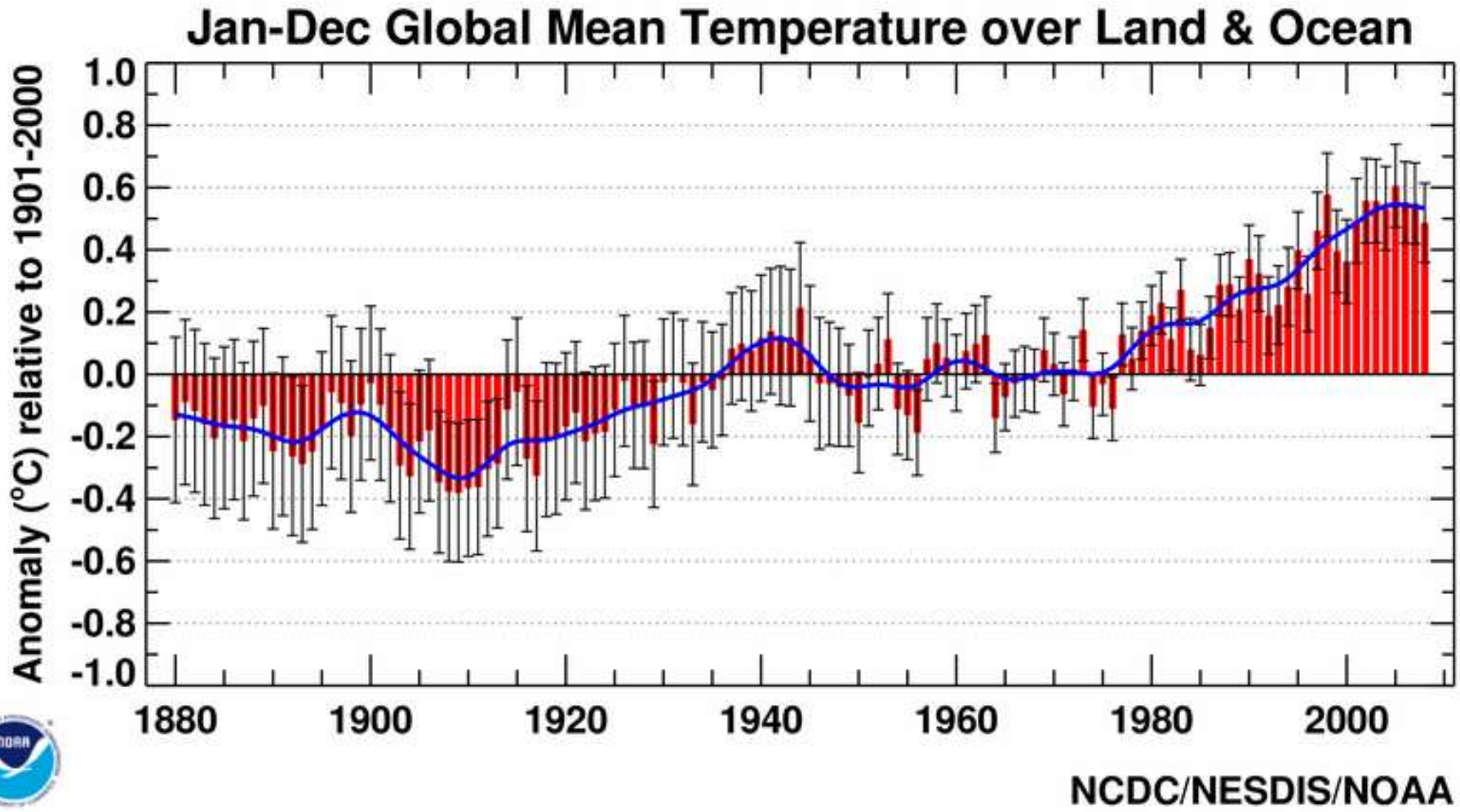

Annual Precipitation (inches)
1961–90 Average (PRISM OSU/WRCC)
48N
46N
44N
42N
40N
38N
36N
34N
32N
124W
122W
120W
118W
116W
114W
112W
110W
108W
106W
104W
102W
100W
2
5
8
10
12
16
20
30
40
60
80
100

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


Western United States (11 states) Annual Jan-Dec Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Deg F. Data source NOAA cooperative network, thru Dec 2008.
Annual Mean Temperature (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

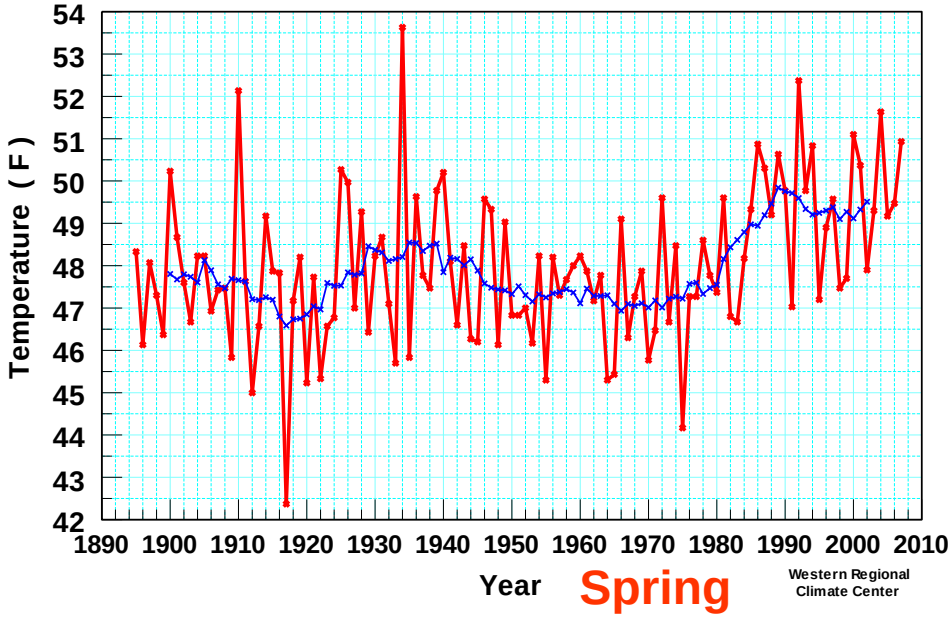


Thru Dec 2008

NOAA

National Climatic Data Center

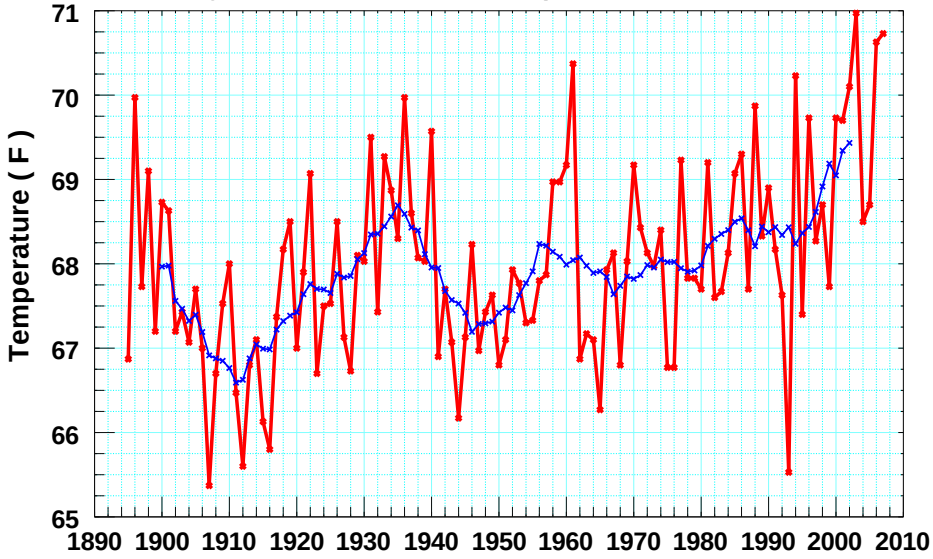
Western United States (11 states) Mar-Apr-May Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Deg F. Data source NOAA cooperative network, thru Oct 2007.



Spring

Western Regional Climate Center

Western United States (11 states) June-July-August Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Deg F. Data source NOAA cooperative network, thru Oct 2007.

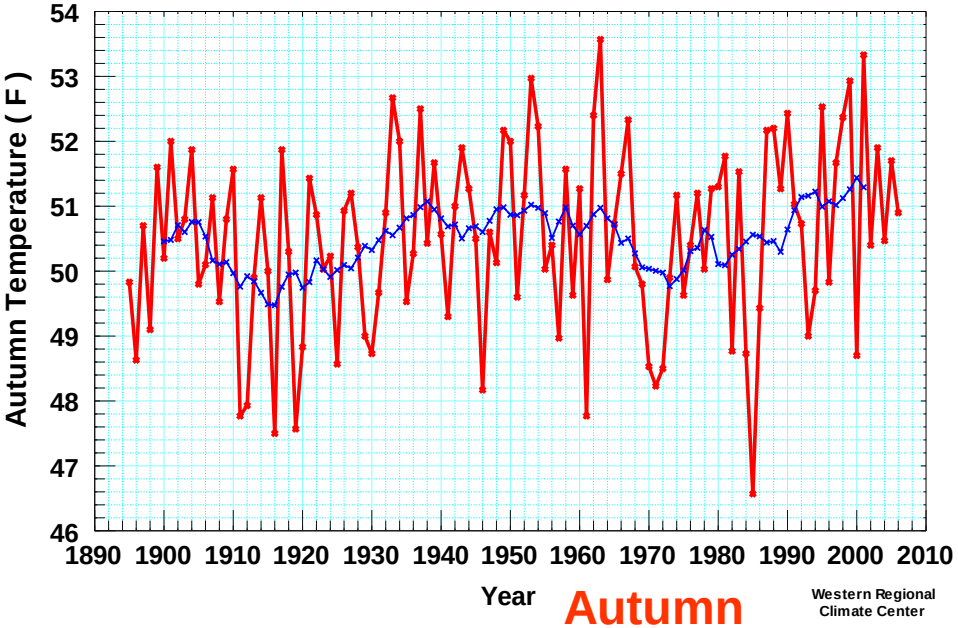


Temperature

Summer

Western Regional Climate Center

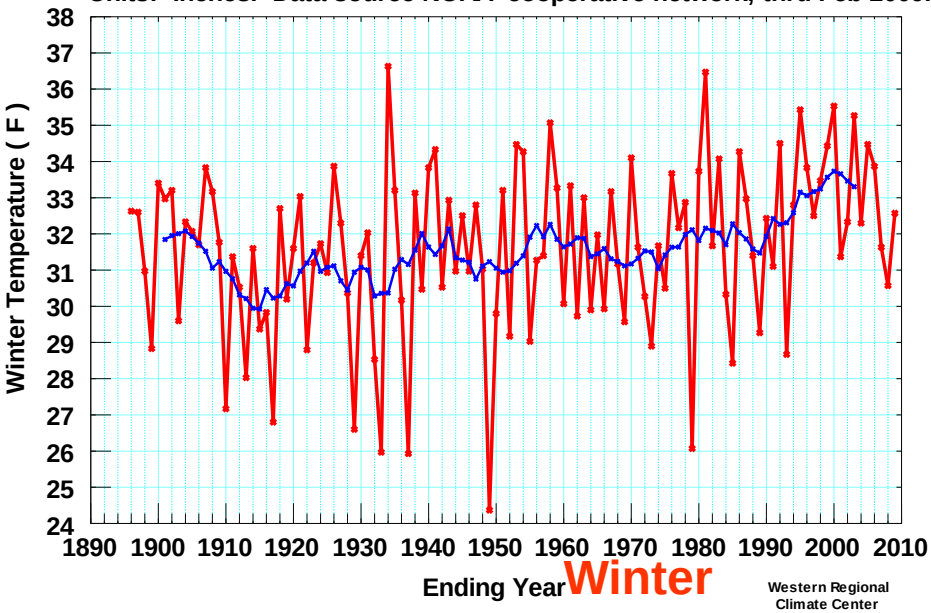
Western United States (11 states) Sept-Oct-Nov Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Deg F. Data source NOAA cooperative network, thru Nov 2006.



Autumn

Western Regional Climate Center

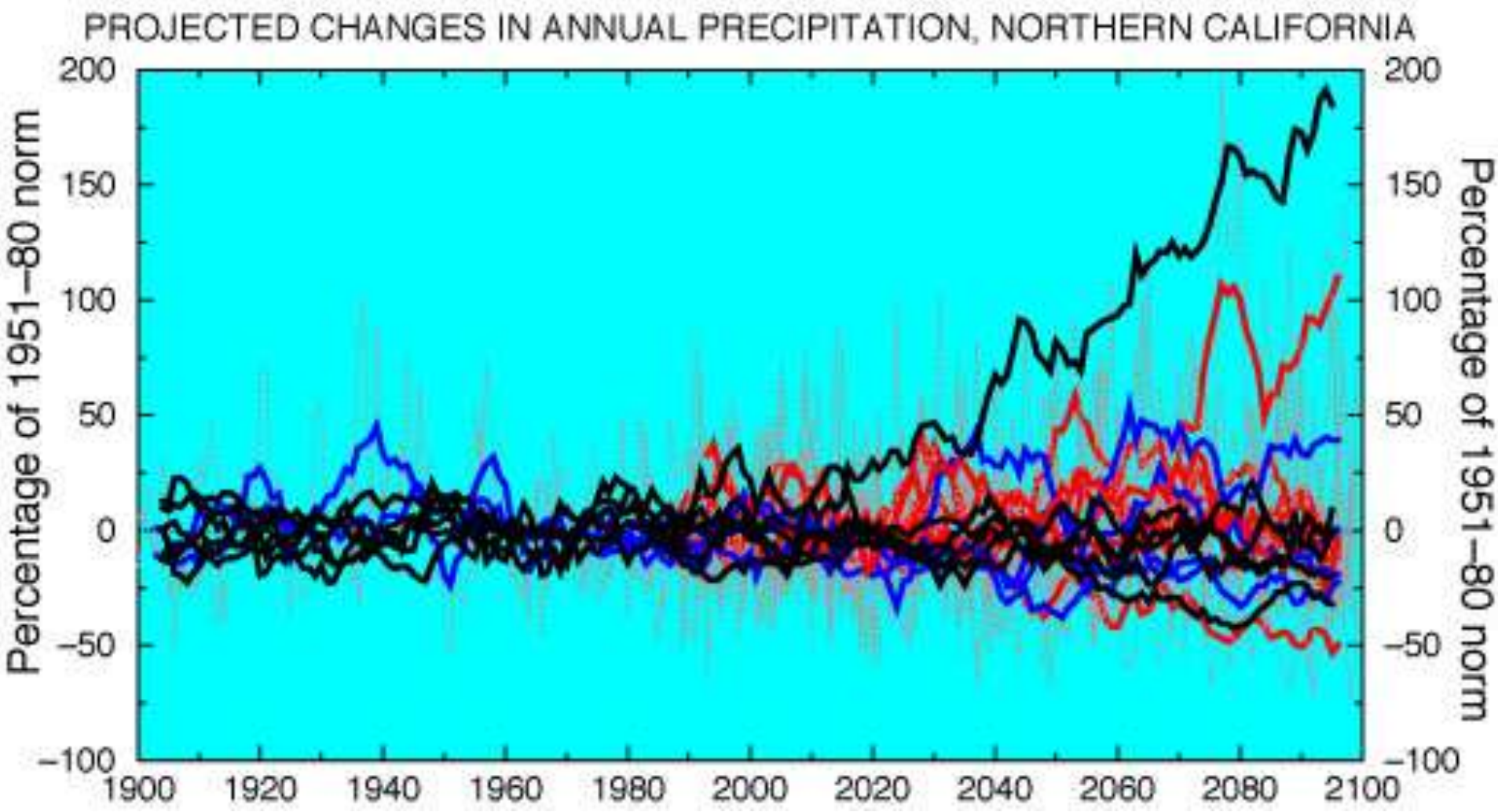
Western United States (11 states) Dec-Jan-Feb Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Inches. Data source NOAA cooperative network, thru Feb 2009.



Winter

Western Regional Climate Center

Courtesy of Mike Dettinger, USGS / Scripps.



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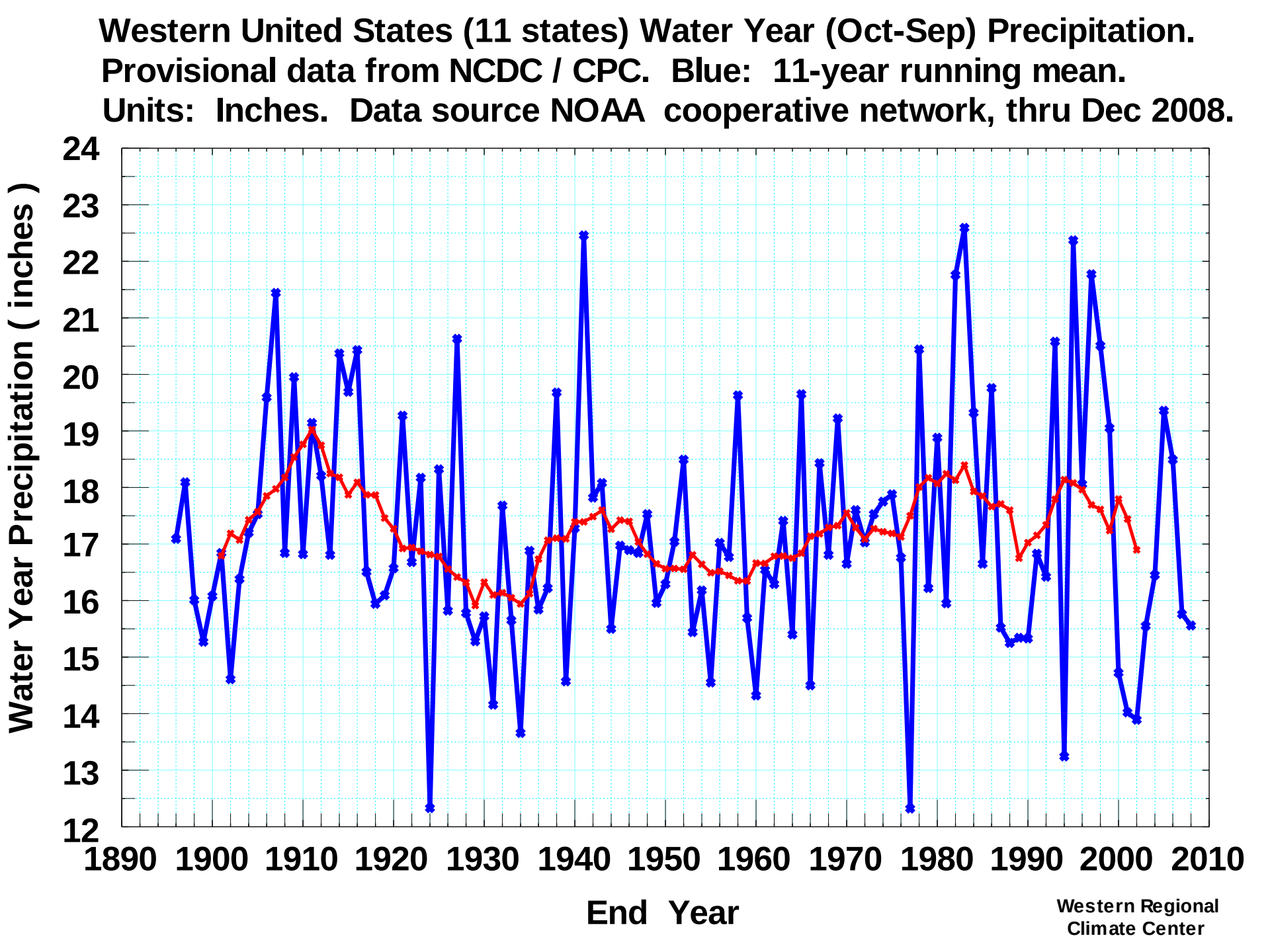
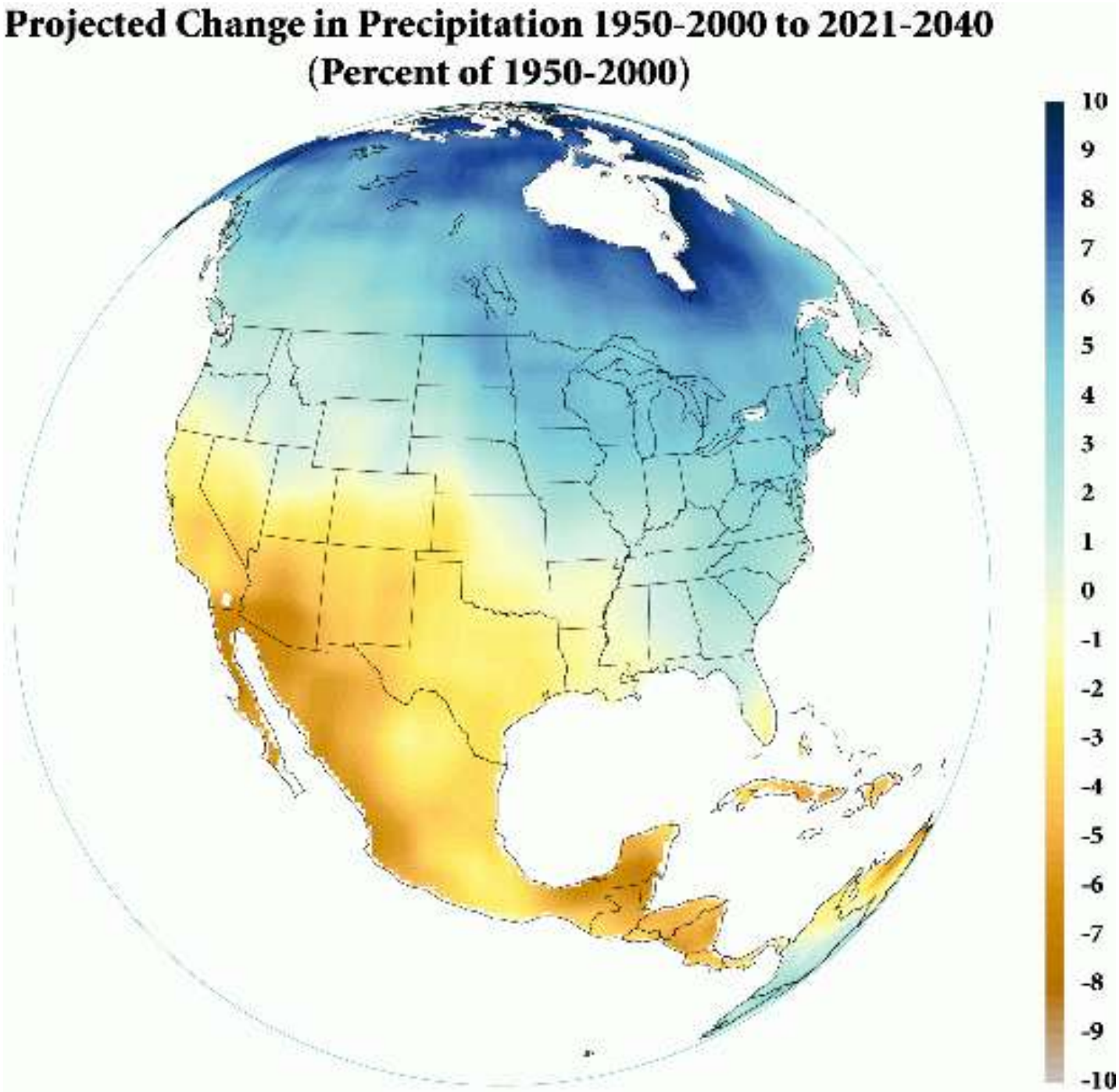

Western United States (11 states) Water Year (Oct-Sep) Precipitation.
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Inches. Data source NOAA cooperative network, thru Dec 2008.
Water Year Precipitation (inches)
24
23
22
21
20
19
18
17
16
15
14
13
12
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
End Year
Western Regional
Climate Center

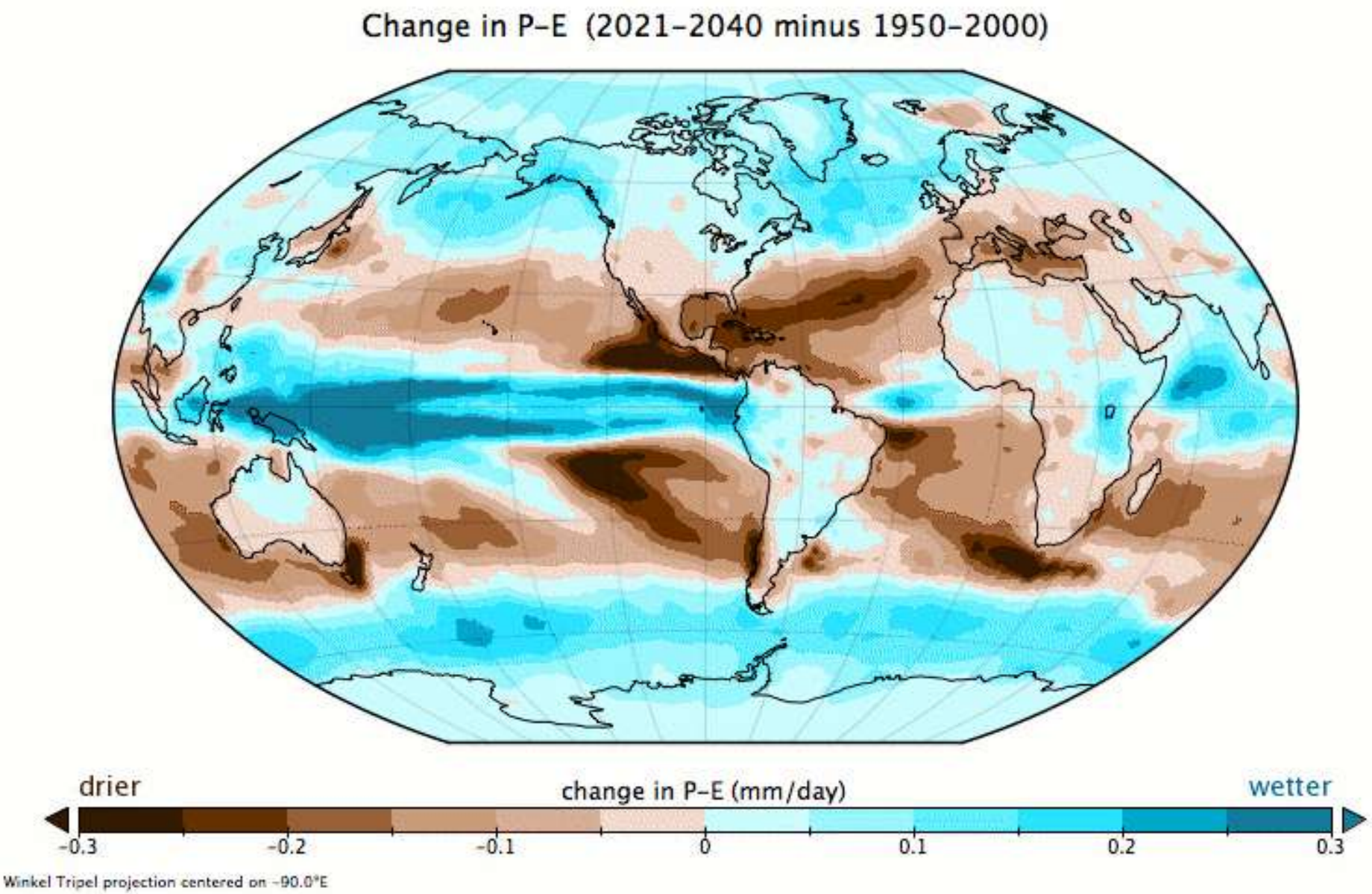


Average of 19 climate models. 2007.

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



Seager et al, 2007. Average of 19 climate models. Figure by Naomi Naik.

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

IPCC Emissions Scenarios.

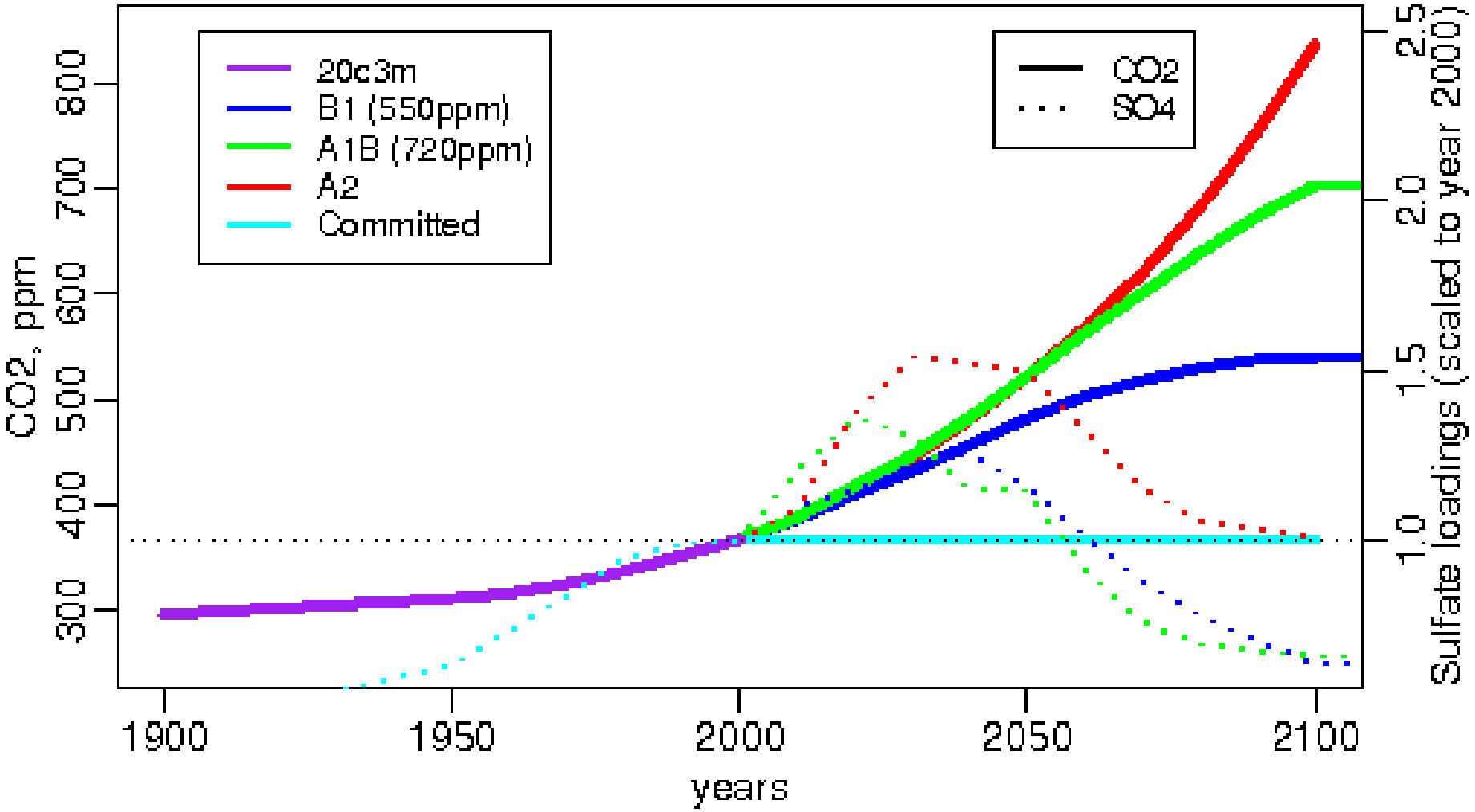
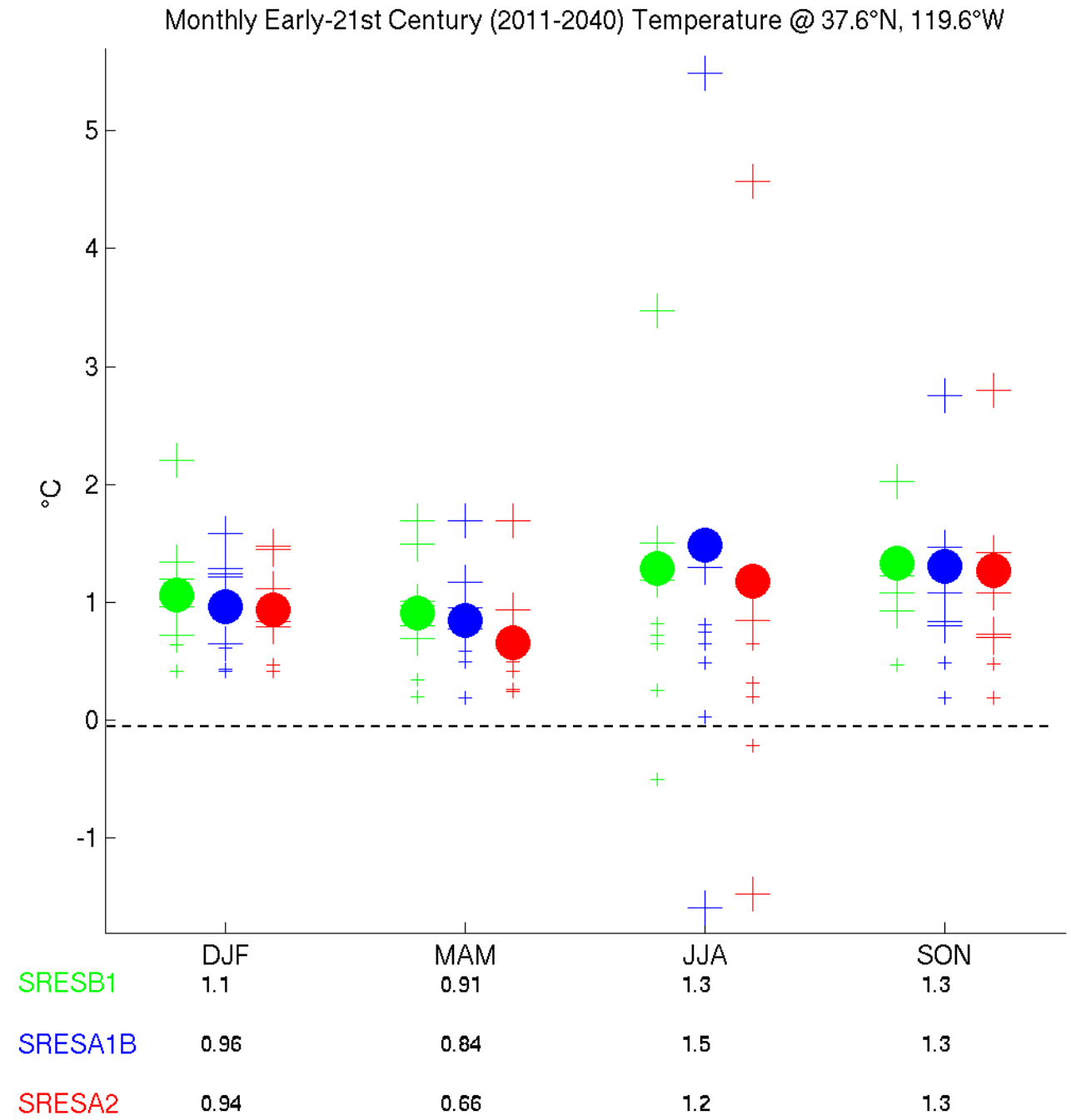


Figure from Environment Canada, 2005.



Yosemite / Mariposa

Projected Temp Change (C)

Early 21st Century

Three Scenarios

B1
A1B
A2

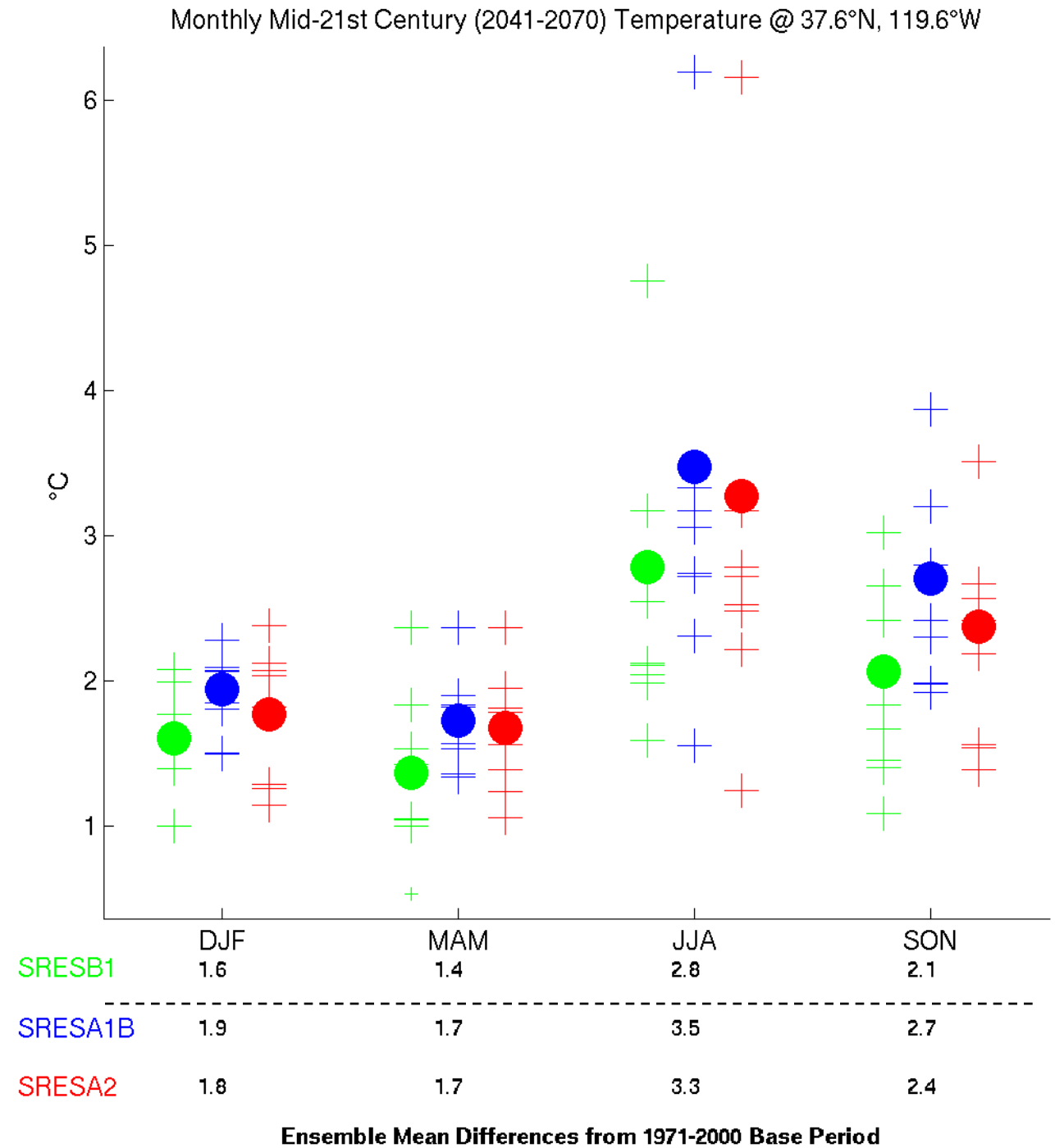
Winter

Spring

Summer

Autumn

Figure from John Atazoglou



Yosemite / Mariposa

Projected Temp Change (C)

Middle 21st Century

Three Scenarios

B1
A1B
A2

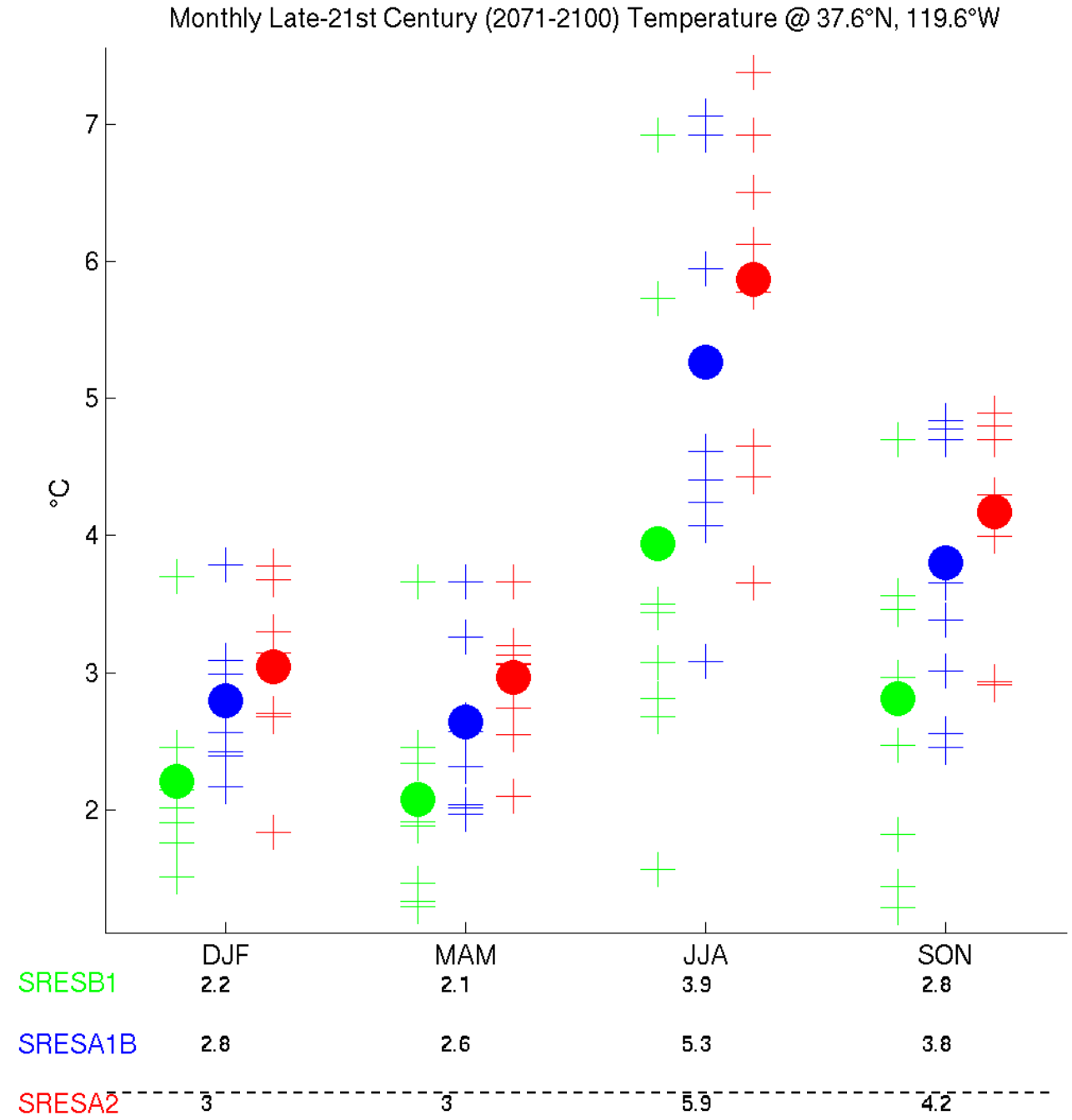
Winter

Spring

Summer

Autumn

Figure from John Atazoglou



Yosemite / Mariposa

Projected Temp Change (C)

Late 21st Century

Three Scenarios

B1
A1B
A2

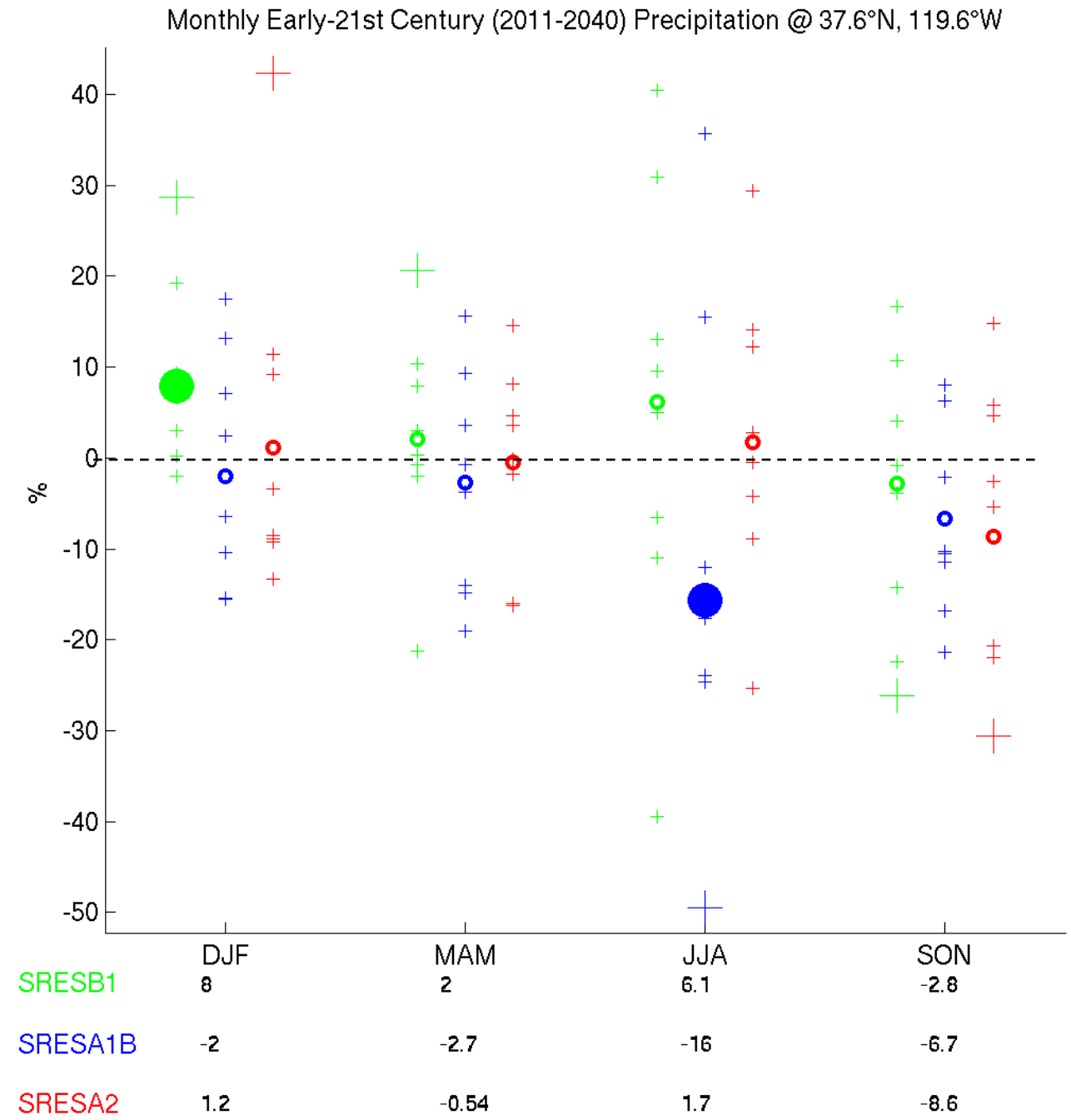
Winter

Spring

Summer

Autumn

Figure from John Atazoglou



Yosemite / Mariposa

Projected
Precip Change (%)

Early 21st Century

Three Scenarios

B1
A1B
A2

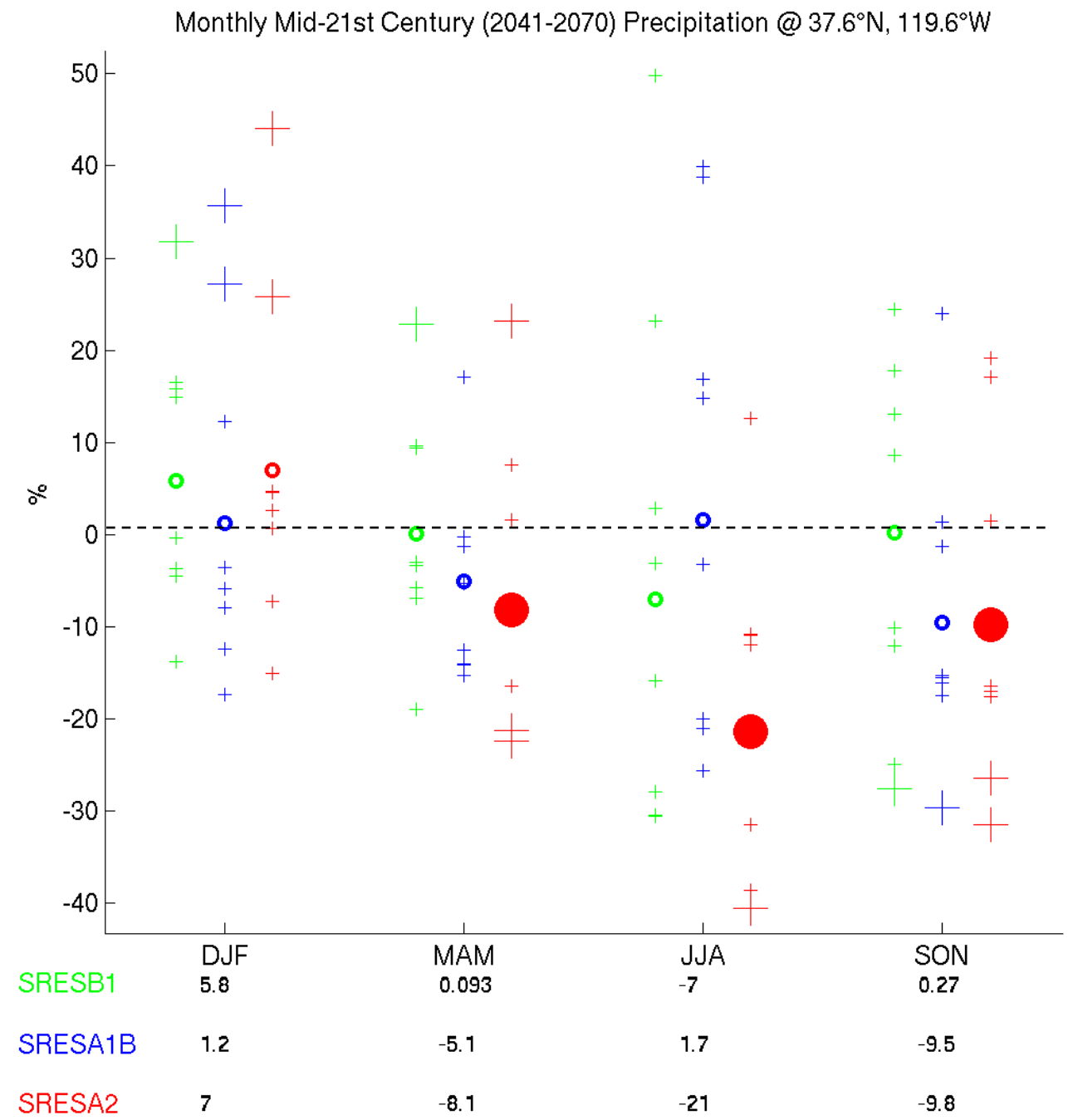
Winter

Spring

Summer

Autumn

Figure from John Atazoglou



Yosemite / Mariposa

Projected Precip Change (%)

Middle 21st Century

Three Scenarios

B1
A1B
A2

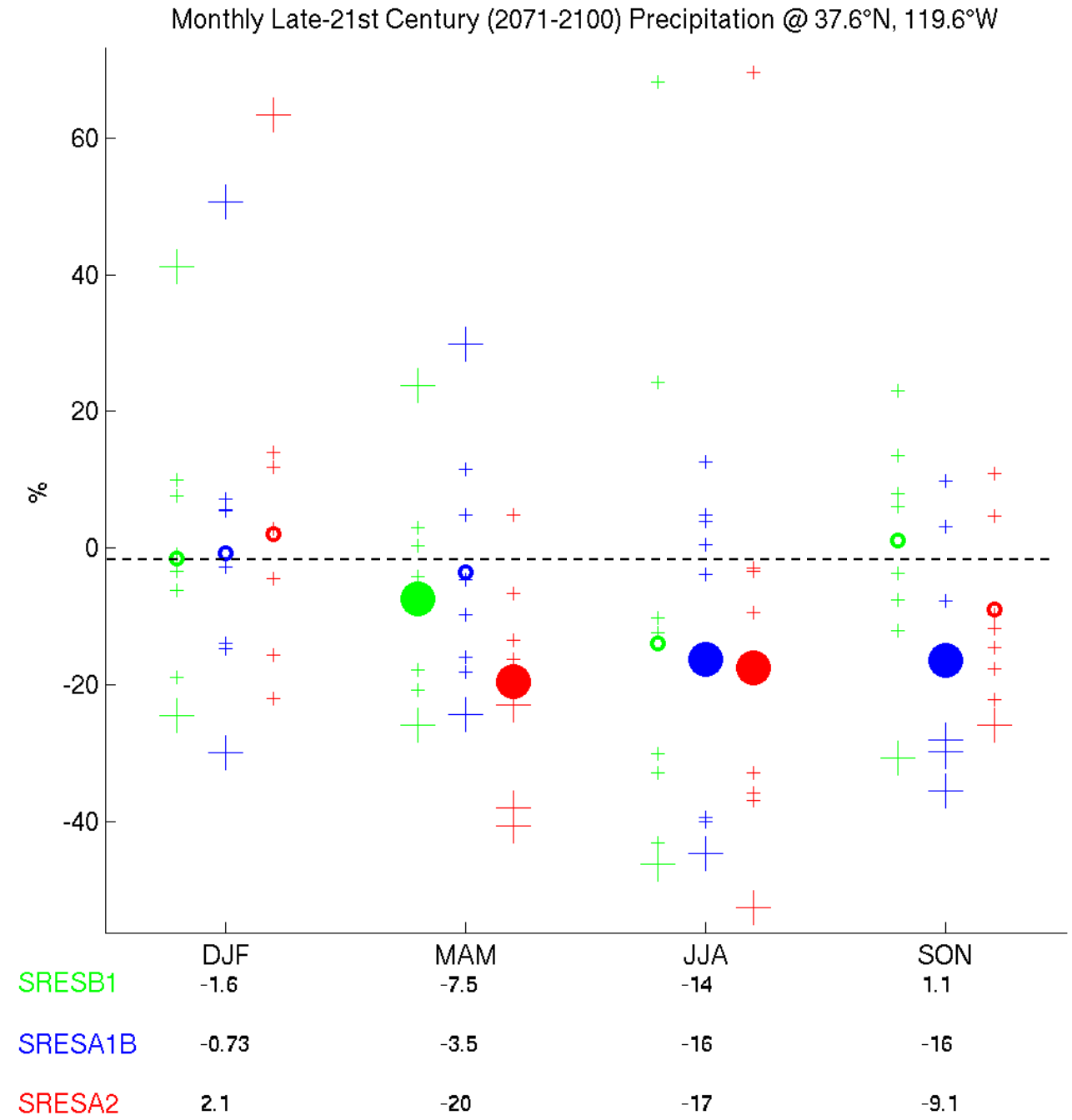
Winter

Spring

Summer

Autumn

Figure from John Atazoglou



Yosemite / Mariposa

Projected Precip Change (%)

Late 21st Century

Three Scenarios

B1
A1B
A2

Winter

Spring

Summer

Autumn

Figure from John Atazoglou

Anticipated changes in Sierra Nevada next several decades:

Increased temperatures

A little more warming in summer, a little less warming in winter

Precipitation increases during the mid-winter months

Precipitation reduction from late winter onward

More rain, less snow at most elevations except highest

Higher freezing levels

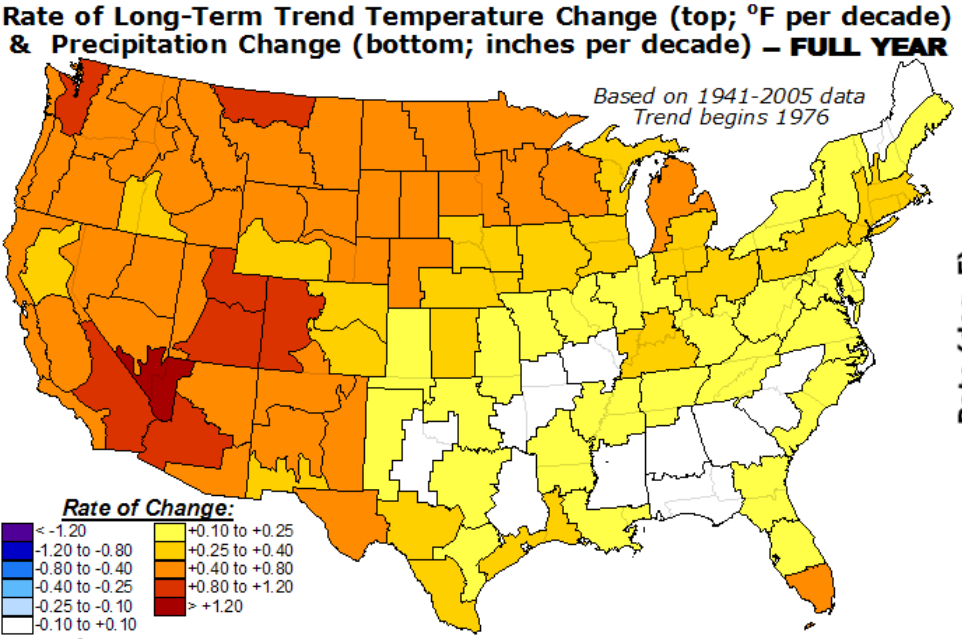
Somewhat shorter and more intense precipitation supply season

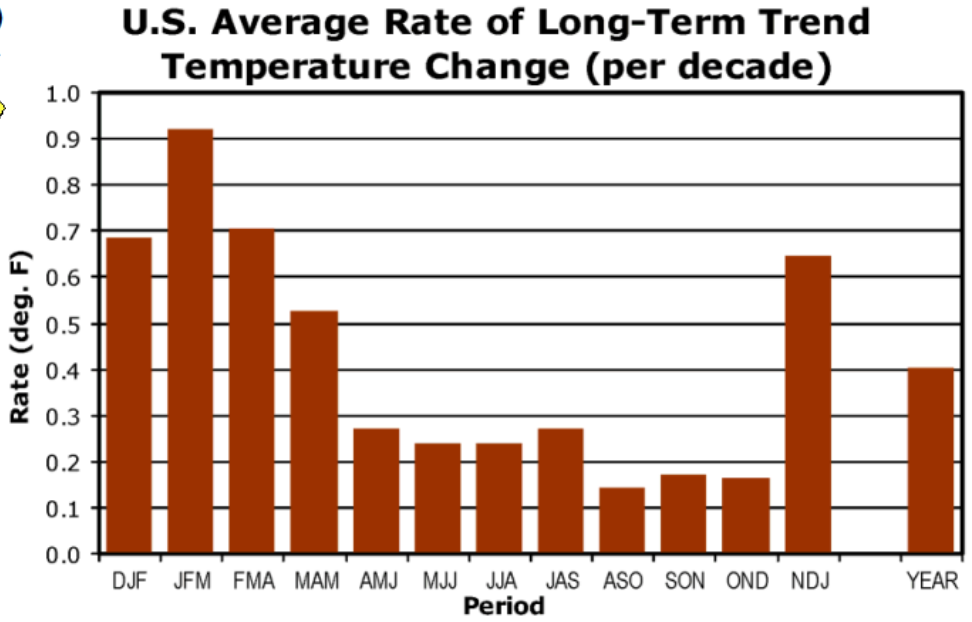
Longer demand season, starts earlier in spring, lasts later in autumn

Seemingly paradoxically, possibly more floods and droughts (!)

Total annual precipitation not greatly different than now

Same precipitation with higher temperatures is “like” less precipitation



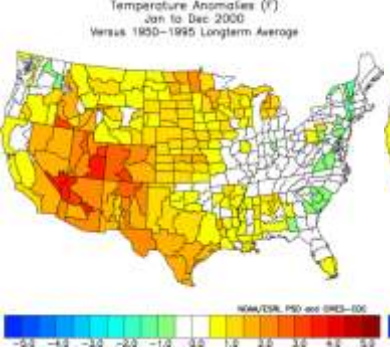


Winter Spring Summer Autumn Annual

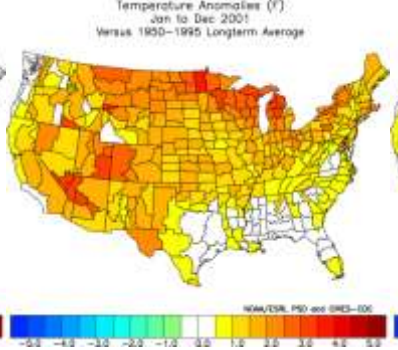
Annual Temperature Trend 1976 - 2005

National Temperature Trend by Season

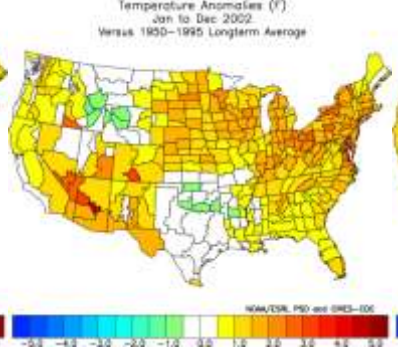
The Last 30 Years



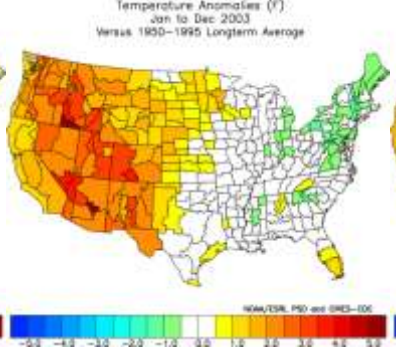
2000



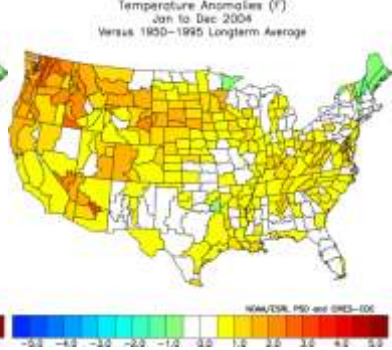
2001



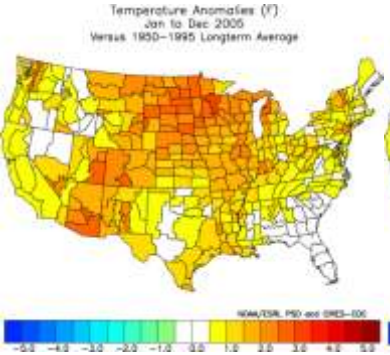
2002



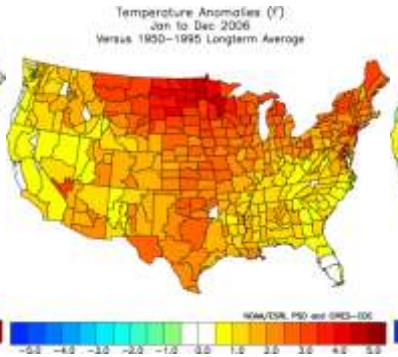
2003



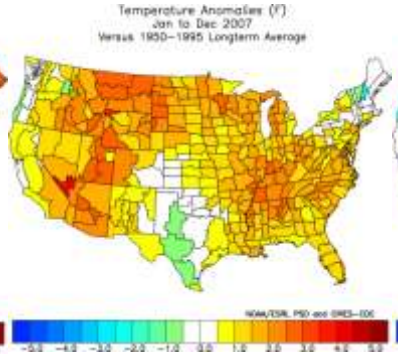
2004



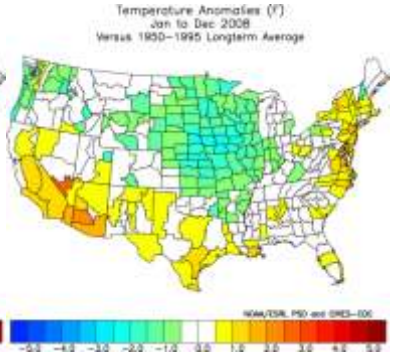
2005



2006



2007

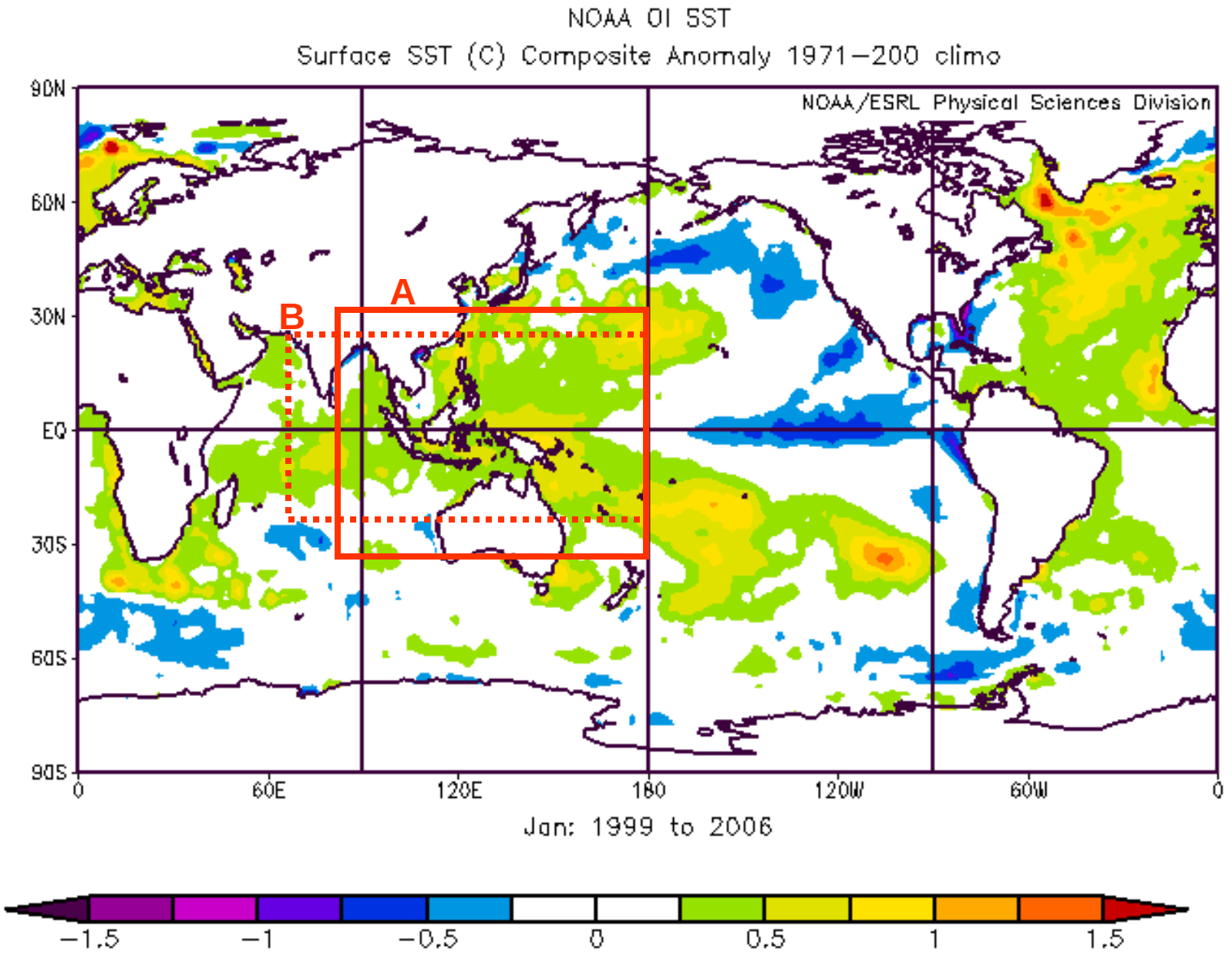


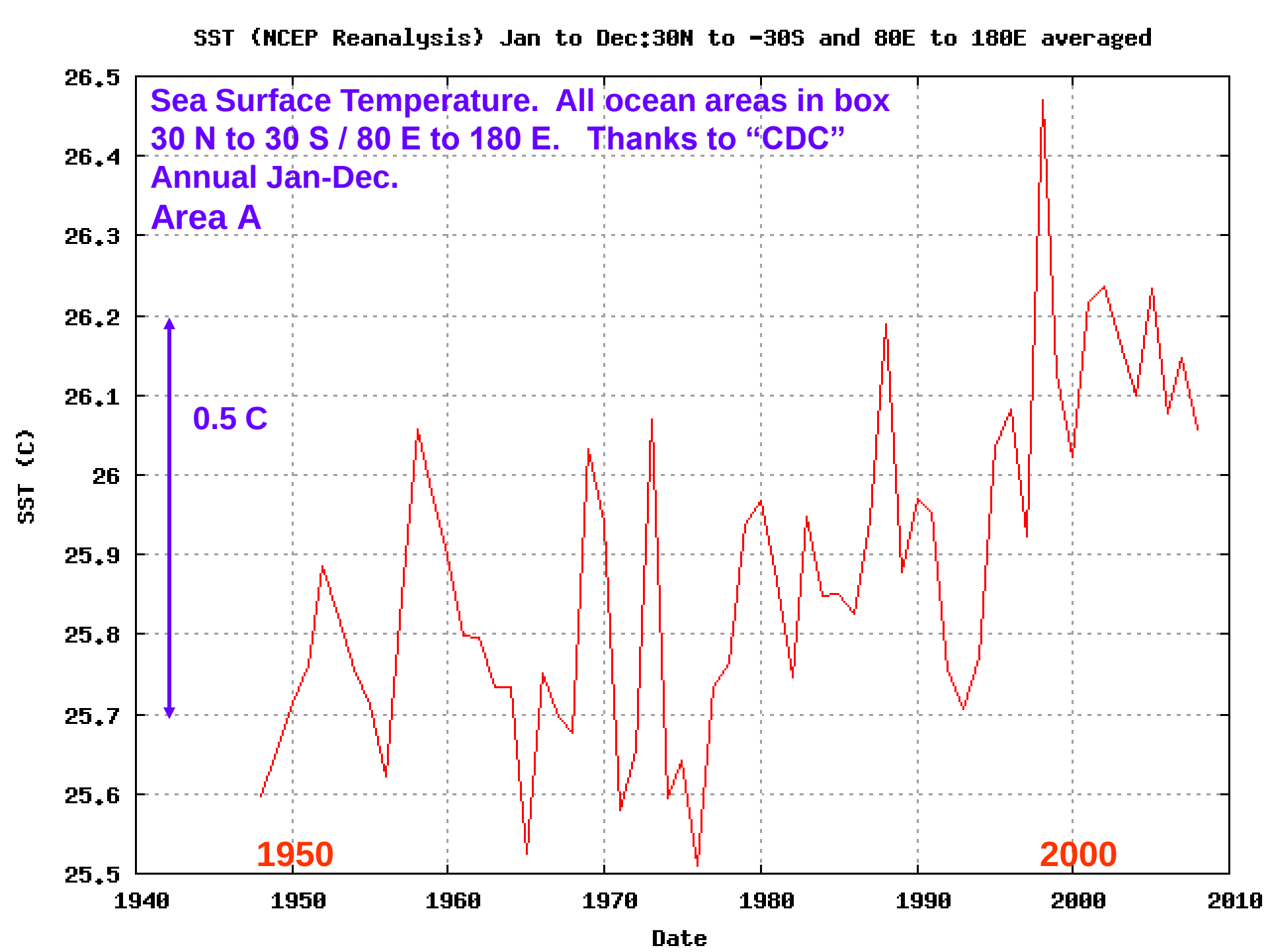
2008

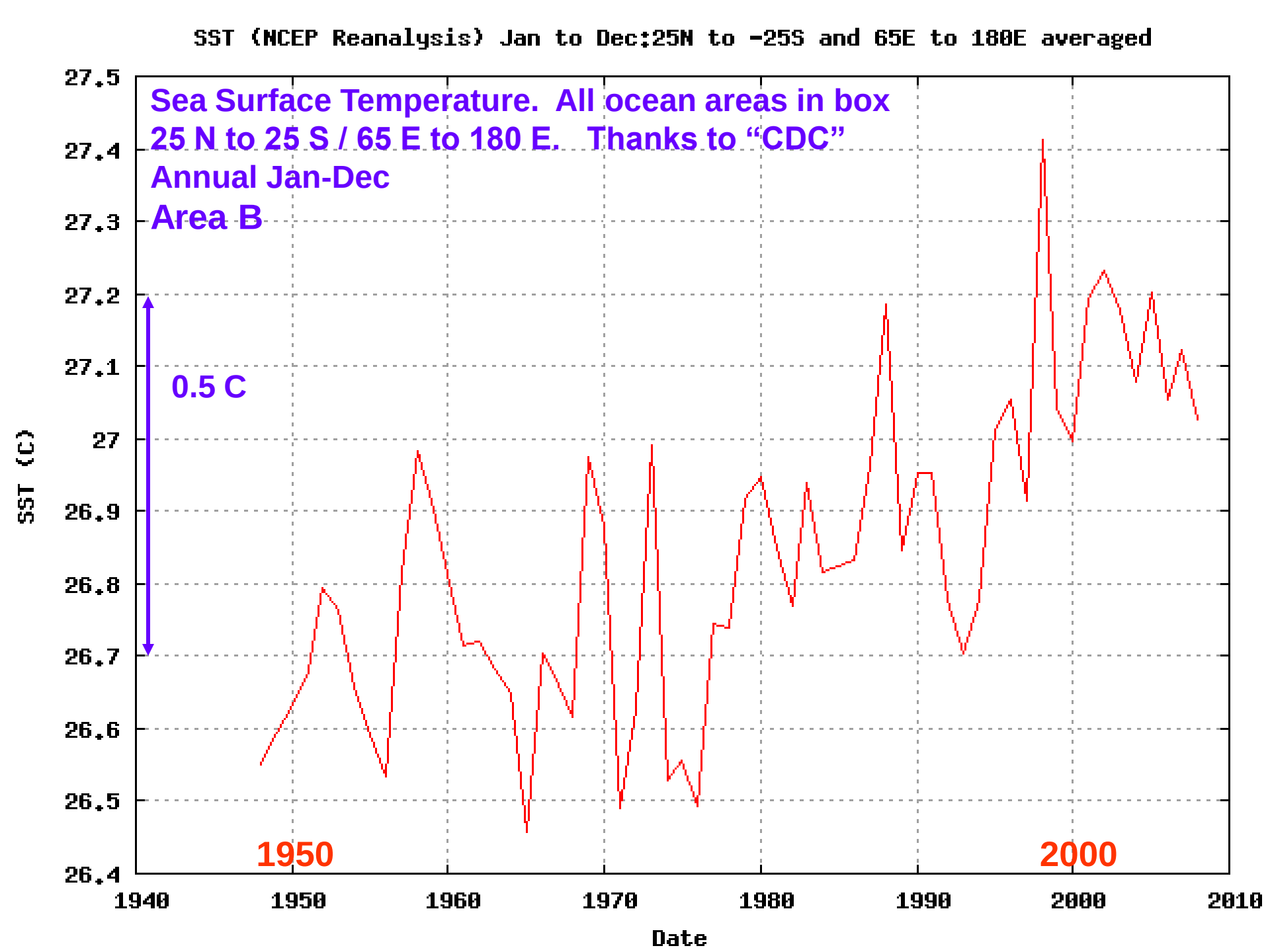
United States Annual Temperature Departure from 1950-1995 Mean

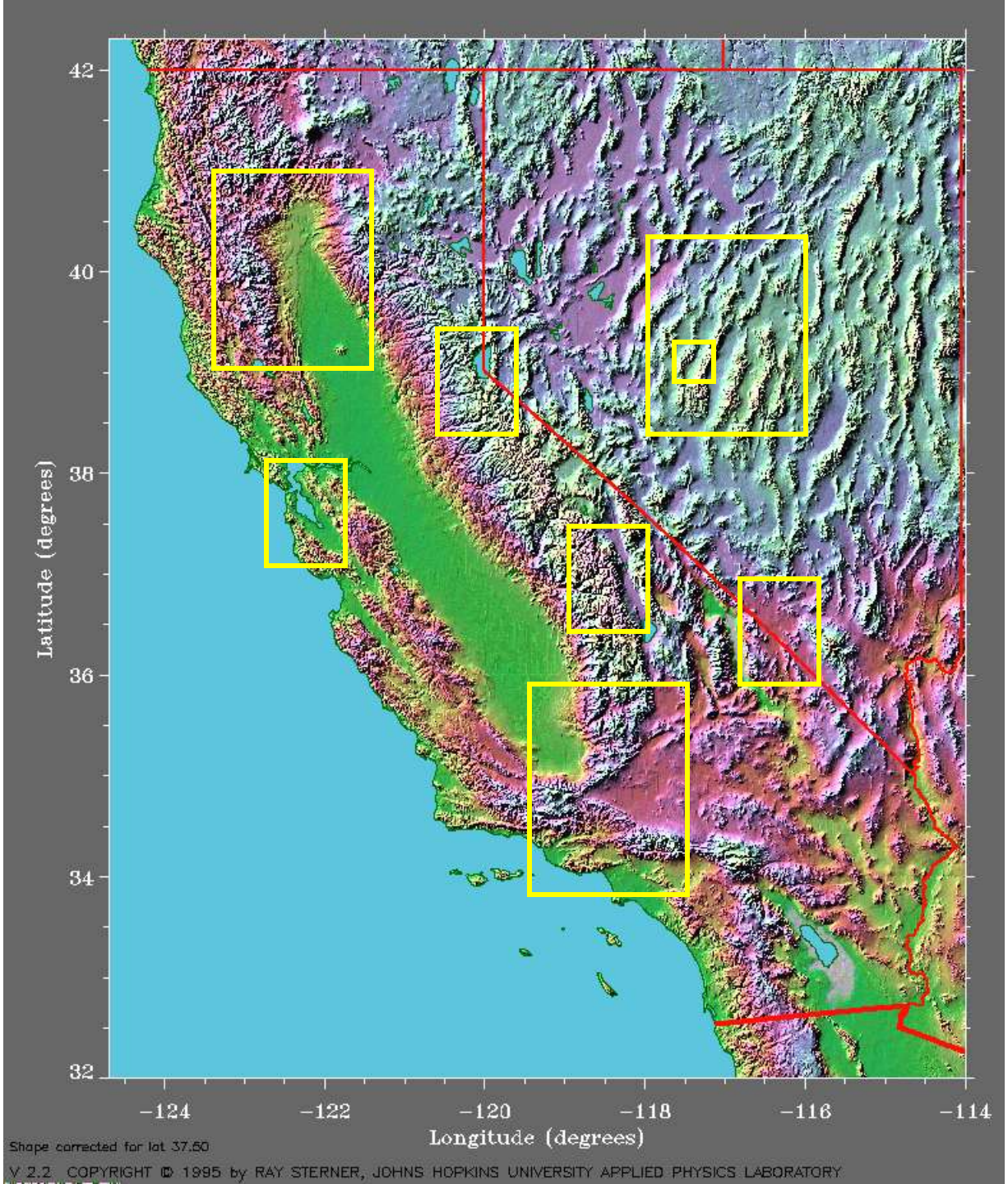
NOAA Divisional Data, Western Regional Climate Center, Plotted by ESRL PSD

SST Departure from Climatology, Annual Jan-Dec, for 8 years 1999-2006.




SST (NCEP Reanalysis) Jan to Dec;30N to -30S and 80E to 180E averaged
Sea Surface Temperature. All ocean areas in box
30 N to 30 S / 80 E to 180 E. Thanks to "CDC"
Annual Jan-Dec.
Area A
0.5 C
1950
2000
SST (C)
Date
26.5
26.4
26.3
26.2
26.1
26
25.9
25.8
25.7
25.6
25.5
1940
1950
1960
1970
1980
1990
2000
2010


SST (NCEP Reanalysis) Jan to Dec:25N to -25S and 65E to 180E averaged
Sea Surface Temperature. All ocean areas in box
25 N to 25 S / 65 E to 180 E. Thanks to "CDC"
Annual Jan-Dec
Area B
0.5 C
1950
2000
SST (C)
Date
27.5
27.4
27.3
27.2
27.1
27
26.9
26.8
26.7
26.6
26.5
26.4
1940
1950
1960
1970
1980
1990
2000
2010



Grid resolution:

Global Climate Model and Reanalysis

Global

Regional
(slightly smaller; pixel resolution)

AR4 Models ~ 1 degree on a side

Desired Resolution About 1 km

.

Or less


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

Mapping New Terrain

Climate Change and America's West

Anticipating Challenges to Western Mountain Ecosystems and Resources

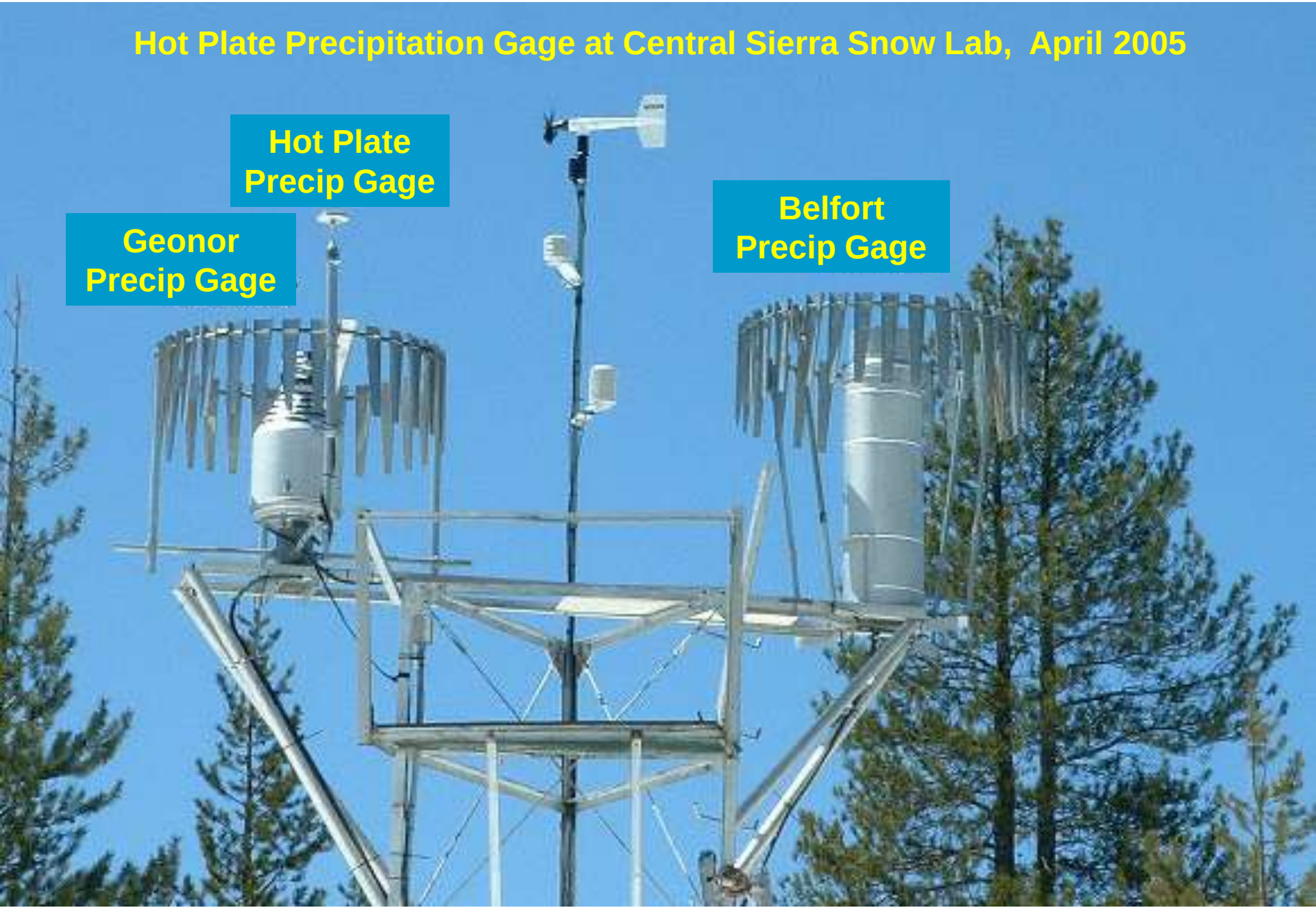
The Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT)

July 2006

South **Central Sierra Snow Lab** East

Photo: Dave Simeral

Hot Plate Precipitation Gage at Central Sierra Snow Lab, April 2005




Slide Mountain
Toward SSW


Slide Mountain
Toward NW
Needs AC Power!
Our current mission

Ward Peak. Lake Tahoe Basin. 8600 feet.

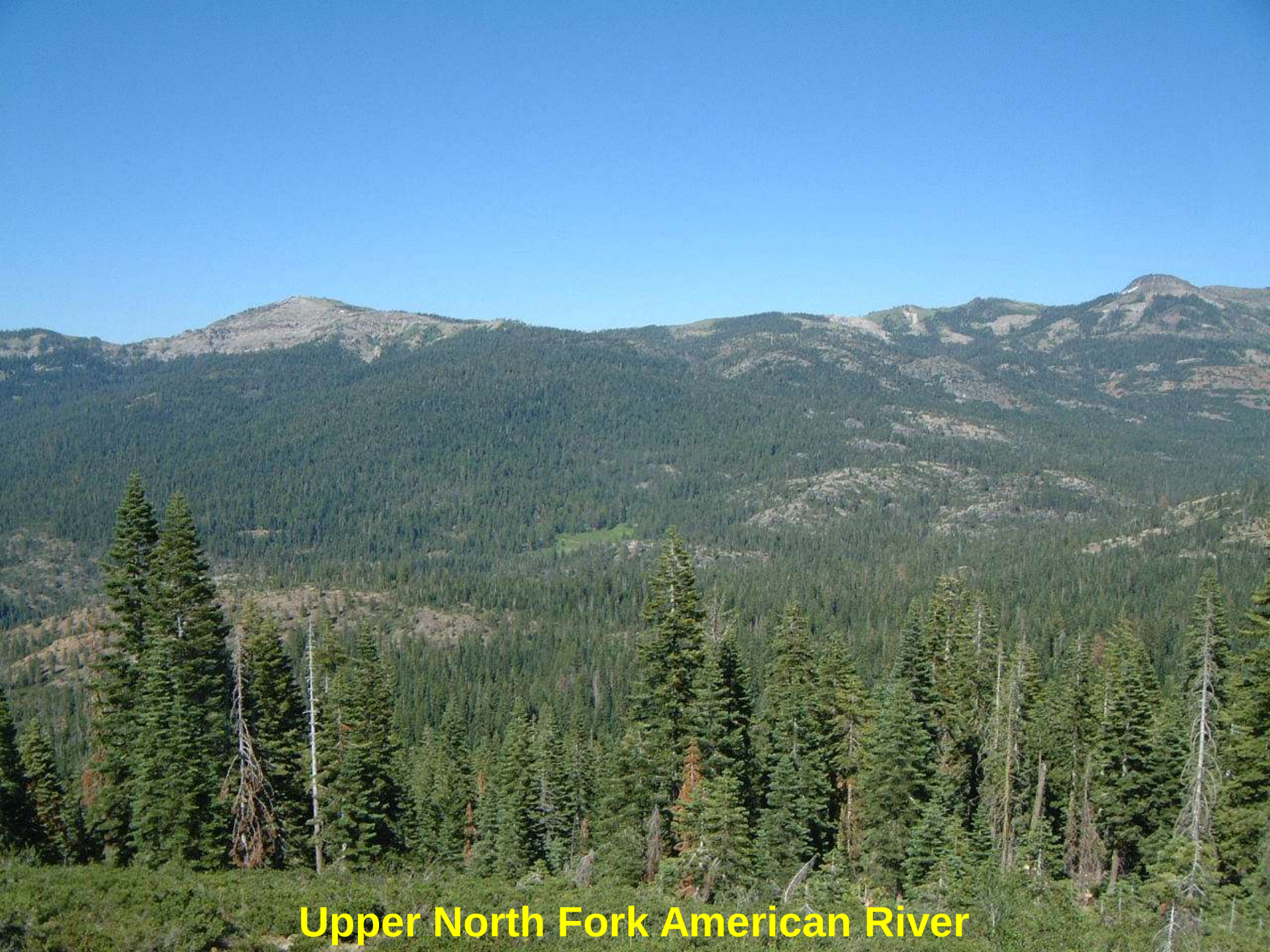
Photo: Arlen Huggins

operations? or testing ?

Ice
+
Wind
+
Imbalance
+
Shaking
+
Clouds
+
Battery Discharge
+
Many Hours
=
“Interesting Data”

Ward Peak. Lake Tahoe Basin. 8600 feet.

Photo: Arlen Huggins


Upper North Fork American River


Sugar Bowl


Mt Warren Summit Station 12,327 ft


White Mtn Summit, 14246 ft
Reconfigured July 2004

Western United States Warming Climate Evidence

1. Warming - thermometers (NOAA coop surface data network)
2. Warming - thermometers (NOAA upper air data network)
3. Warming - thermometers (subsurface, western boreholes)
4. Snowpack decrease in spring months (Snotel network)
5. More rain / less snow in winter months (NOAA coop network)
6. Earlier snowmelt runoff pulse (date shift, USGS stream gage network)
7. Earlier blooming of lilacs and honeysuckles (phenology networks)
8. Mountain glacier recession and mass loss
9. Upward movement of plant / animal habitat zones
10. Warmer river and lake temperatures

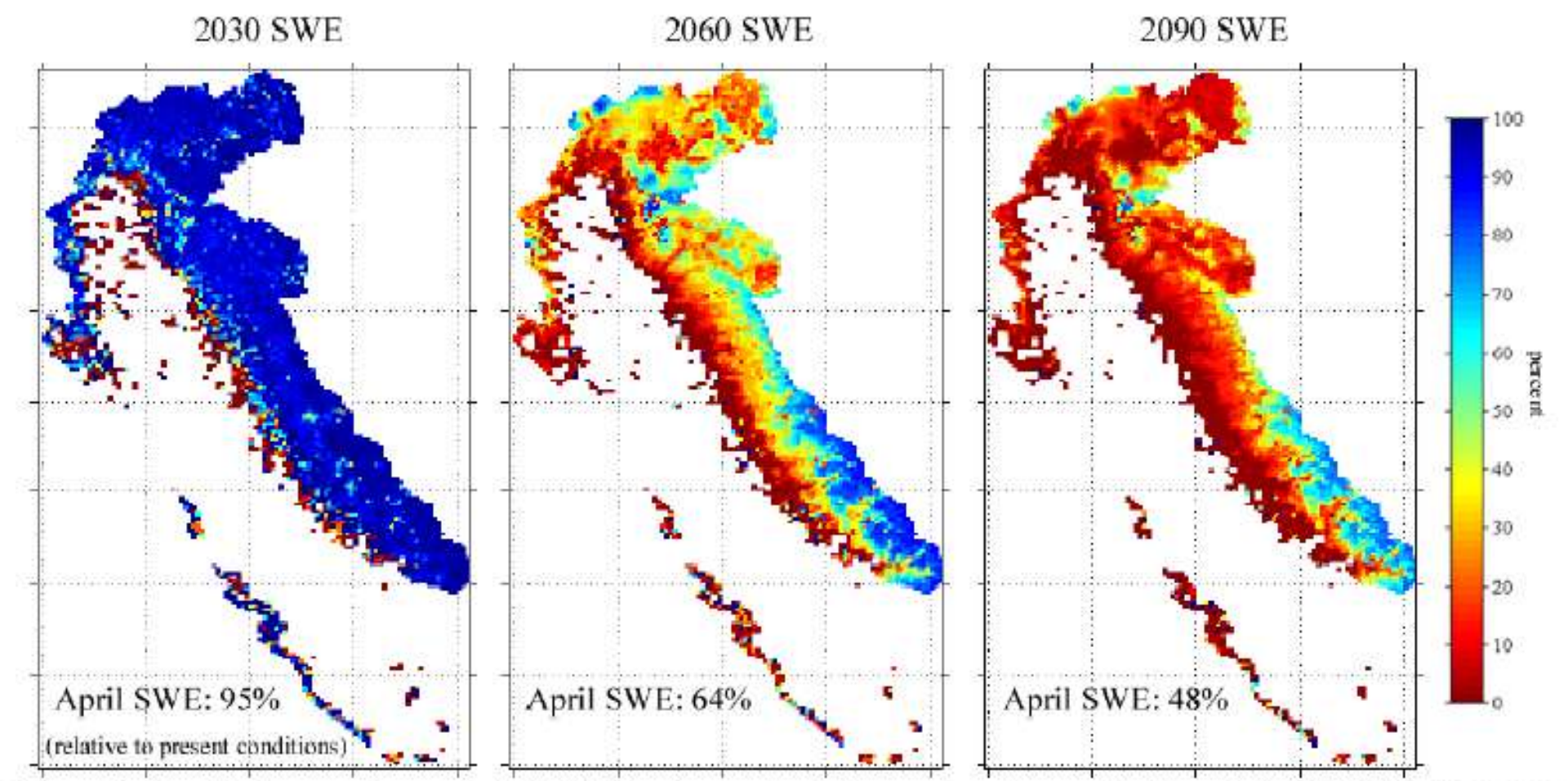


Figure 3. Simulated snow water equivalent (SWE) under a projected temperature increase for the periods 2020-2039, 2050-2069 and 2080-2099, expressed as a percentage of average present conditions.

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

P

T **6 C**

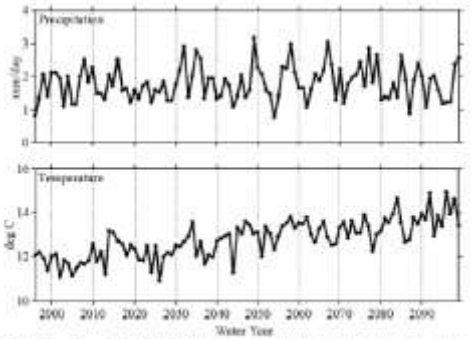


Figure 2. PCM-simulated watershed-averaged annual precipitation and temperature for WY 1995-2099.

Temperature and Precipitation and Elevation along I-80 in the Sierra Nevada

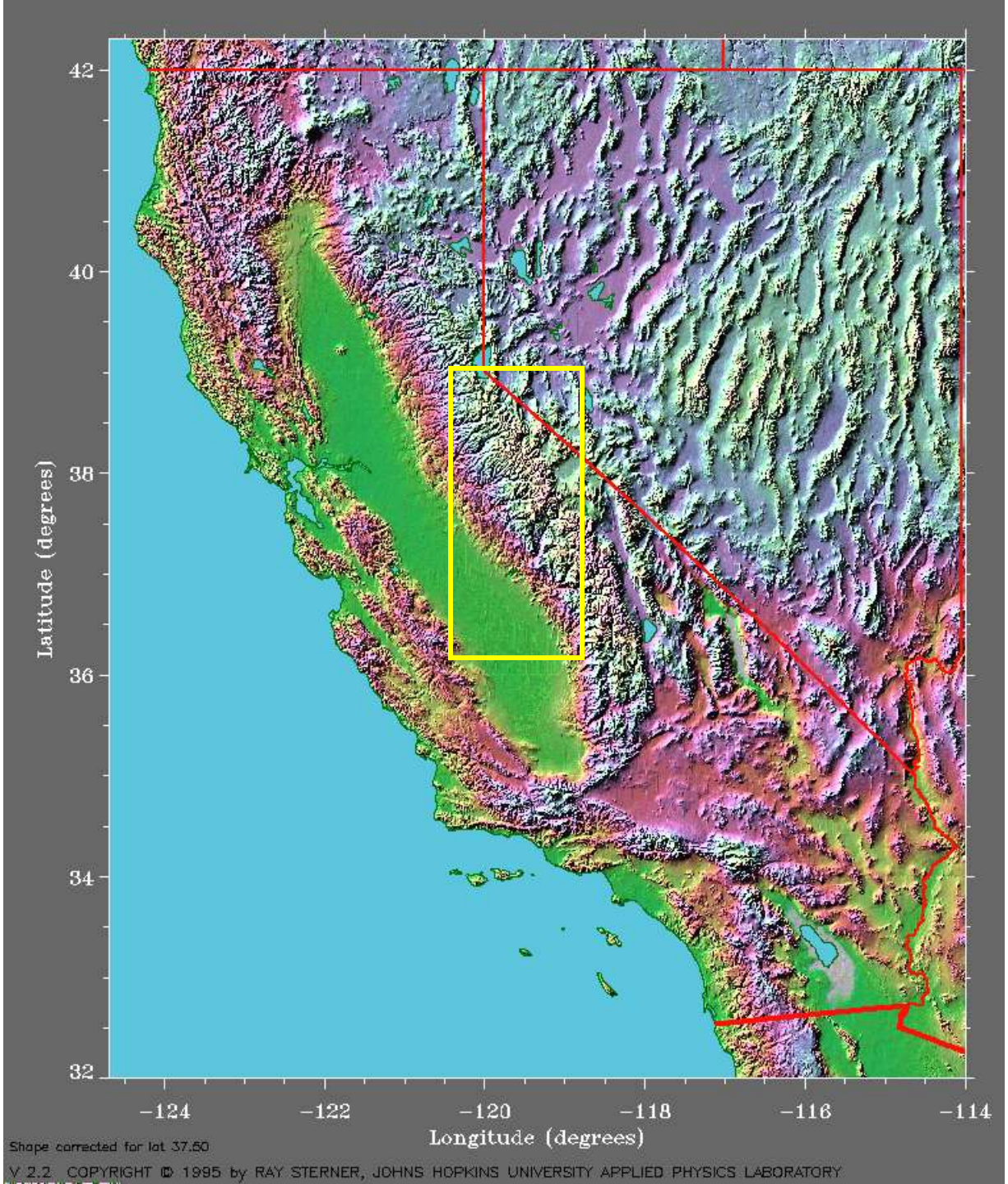
Blue Canyon 5280 ft
1949-2007 (approx)

Mean Seasonal Snowfall	610 cm	240 inches
Mean Winter Temperature DJF	+3.5 C	38.2 F
Mean Annual Precipitation	1780 mm	70.04 inches

Central Sierra Snow Lab 6900 ft
1949-2008 (approx)

Mean Seasonal Snowfall	1034cm	407 inches
Mean Winter Temperature DJF	-1.8C	28.8 F
Mean Annual Precipitation	1590 mm	62.56 inches
Mean DJF Temp 2002-2009	-1.4 C	29.5 F

Note.
This does not include a careful effort
to identify inhomogeneities in T or P time series.



Grids.

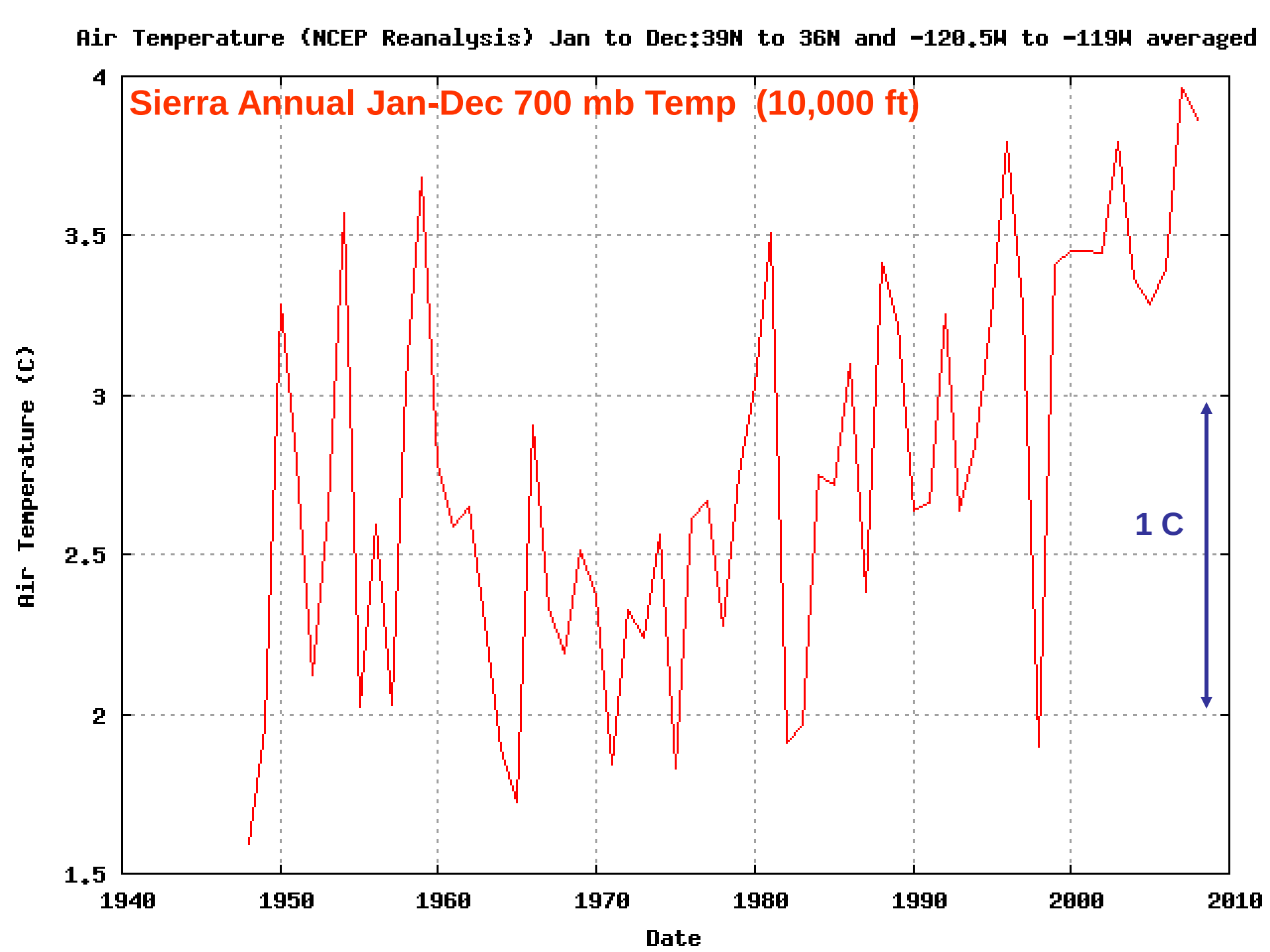
Reanalysis Resolution:

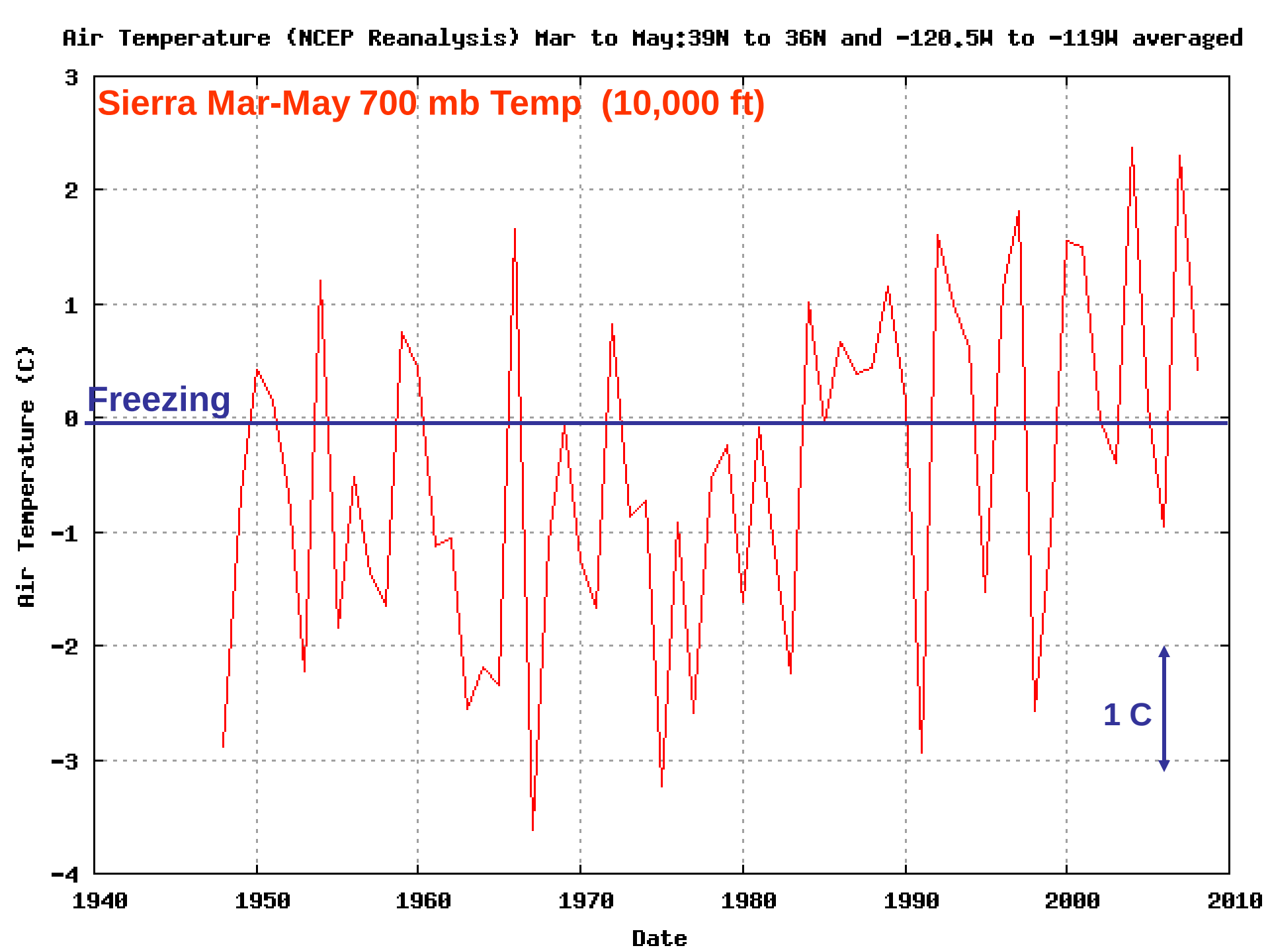
Global

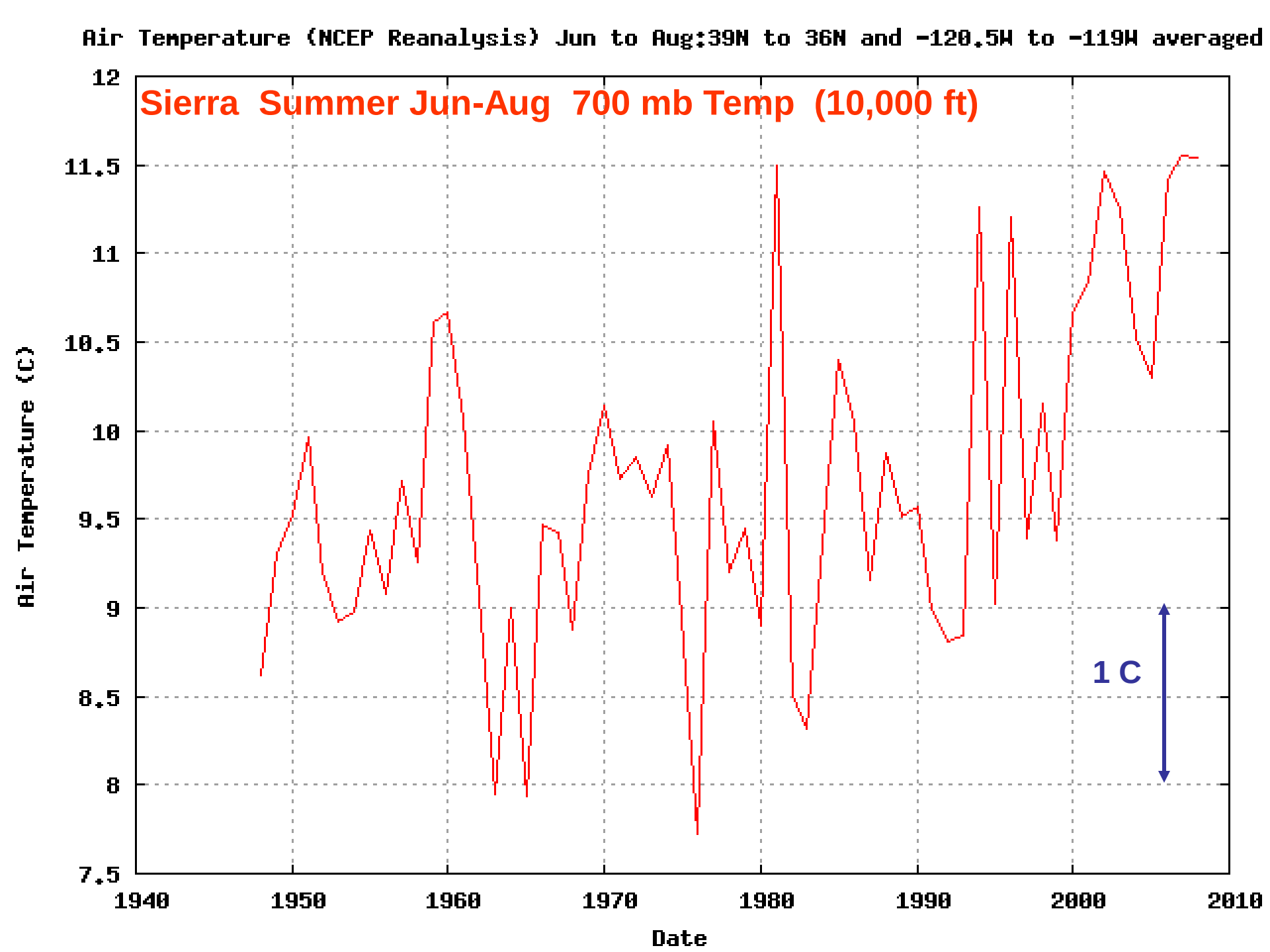
Regional
(slightly smaller; pixel resolution)

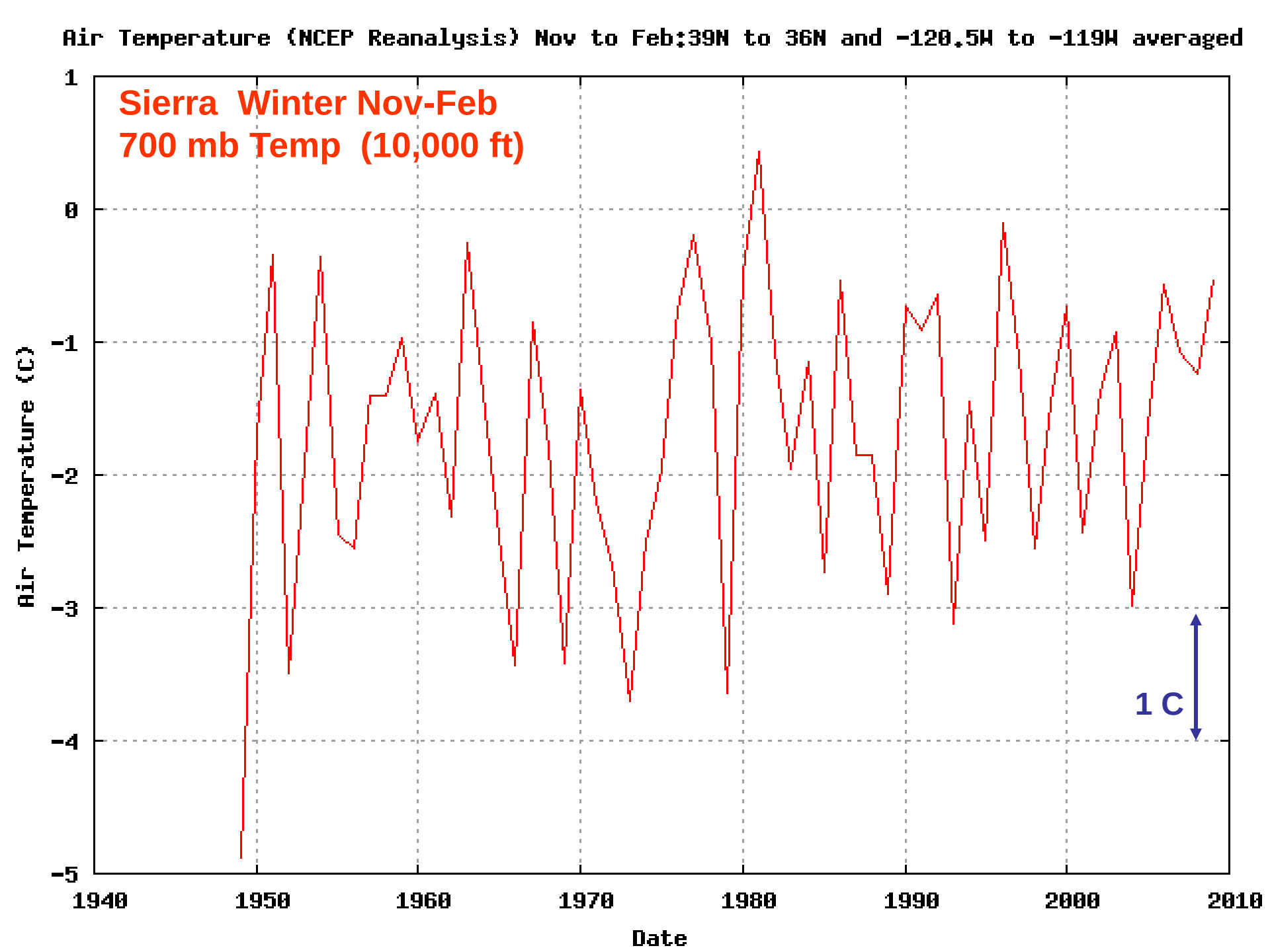
Desired Resolution

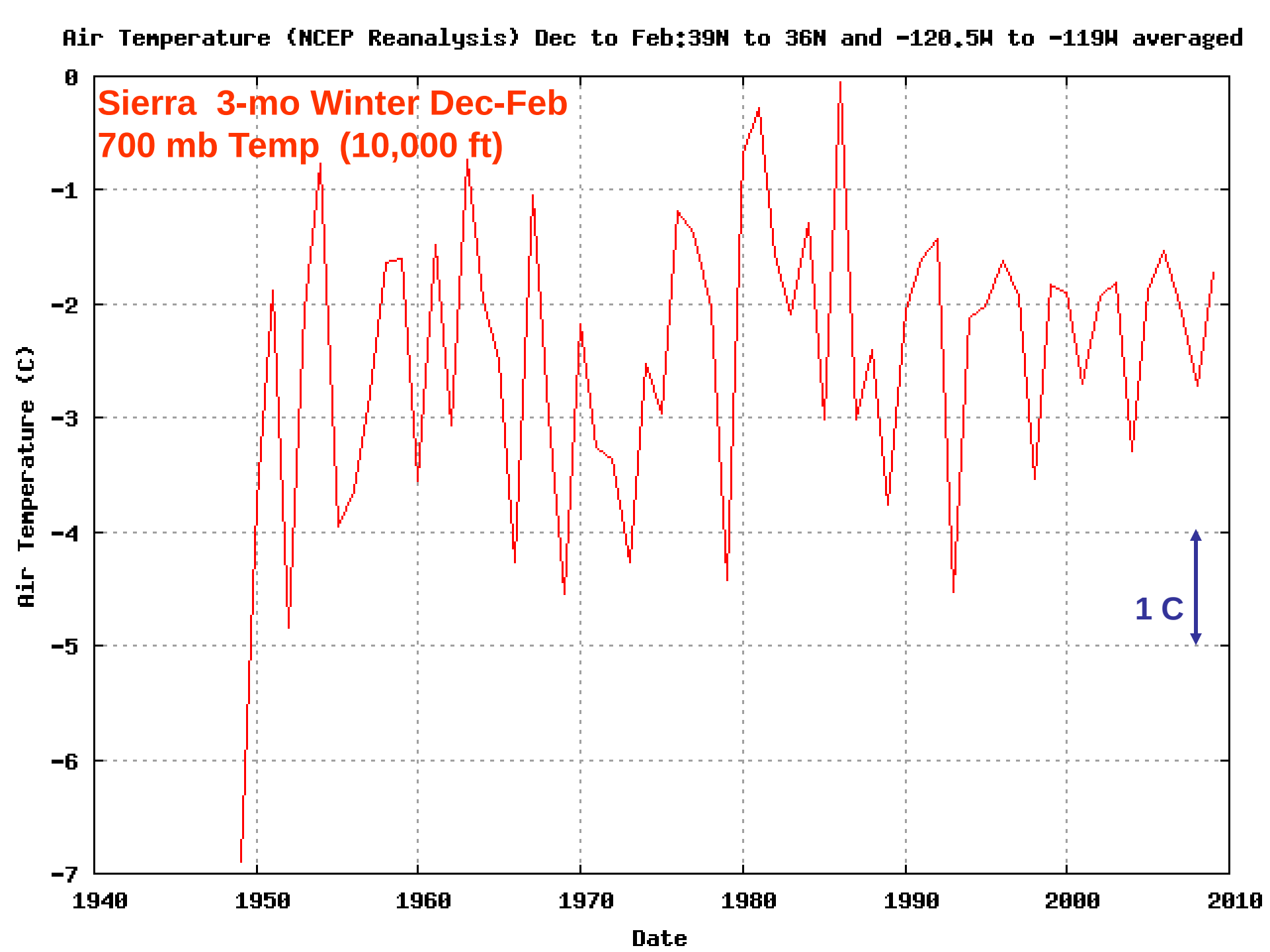
About 1 km


Air Temperature (NCEP Reanalysis) Jan to Dec:39N to 36N and -120.5W to -119W averaged
Sierra Annual Jan-Dec 700 mb Temp (10,000 ft)
Air Temperature (C)
4
3.5
3
2.5
2
1.5
1940
1950
1960
1970
1980
1990
2000
2010
Date
1 C

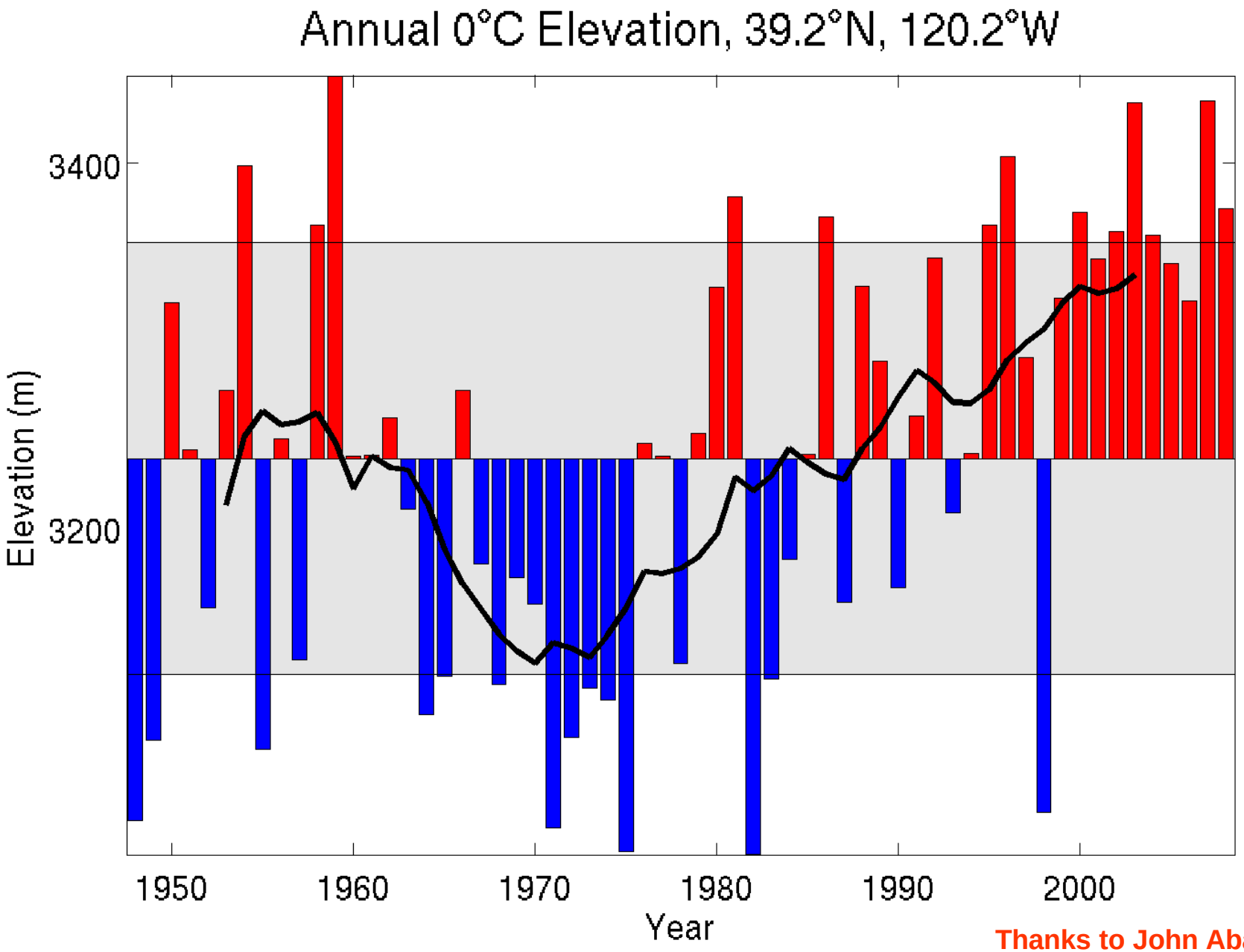

Air Temperature (NCEP Reanalysis) Mar to May:39N to 36N and -120.5W to -119W averaged
Sierra Mar-May 700 mb Temp (10,000 ft)
Freezing
1 C
Air Temperature (C)
Date
3
2
1
0
-1
-2
-3
-4
1940
1950
1960
1970
1980
1990
2000
2010


Air Temperature (NCEP Reanalysis) Jun to Aug:39N to 36N and -120.5W to -119W averaged
Sierra Summer Jun-Aug 700 mb Temp (10,000 ft)
Air Temperature (C)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
1940
1950
1960
1970
1980
1990
2000
2010
Date
1 C


Air Temperature (NCEP Reanalysis) Nov to Feb:39N to 36N and -120.5W to -119W averaged
Sierra Winter Nov-Feb
700 mb Temp (10,000 ft)
Air Temperature (C)
1
0
-1
-2
-3
-4
-5
1940
1950
1960
1970
1980
1990
2000
2010
Date
1 C

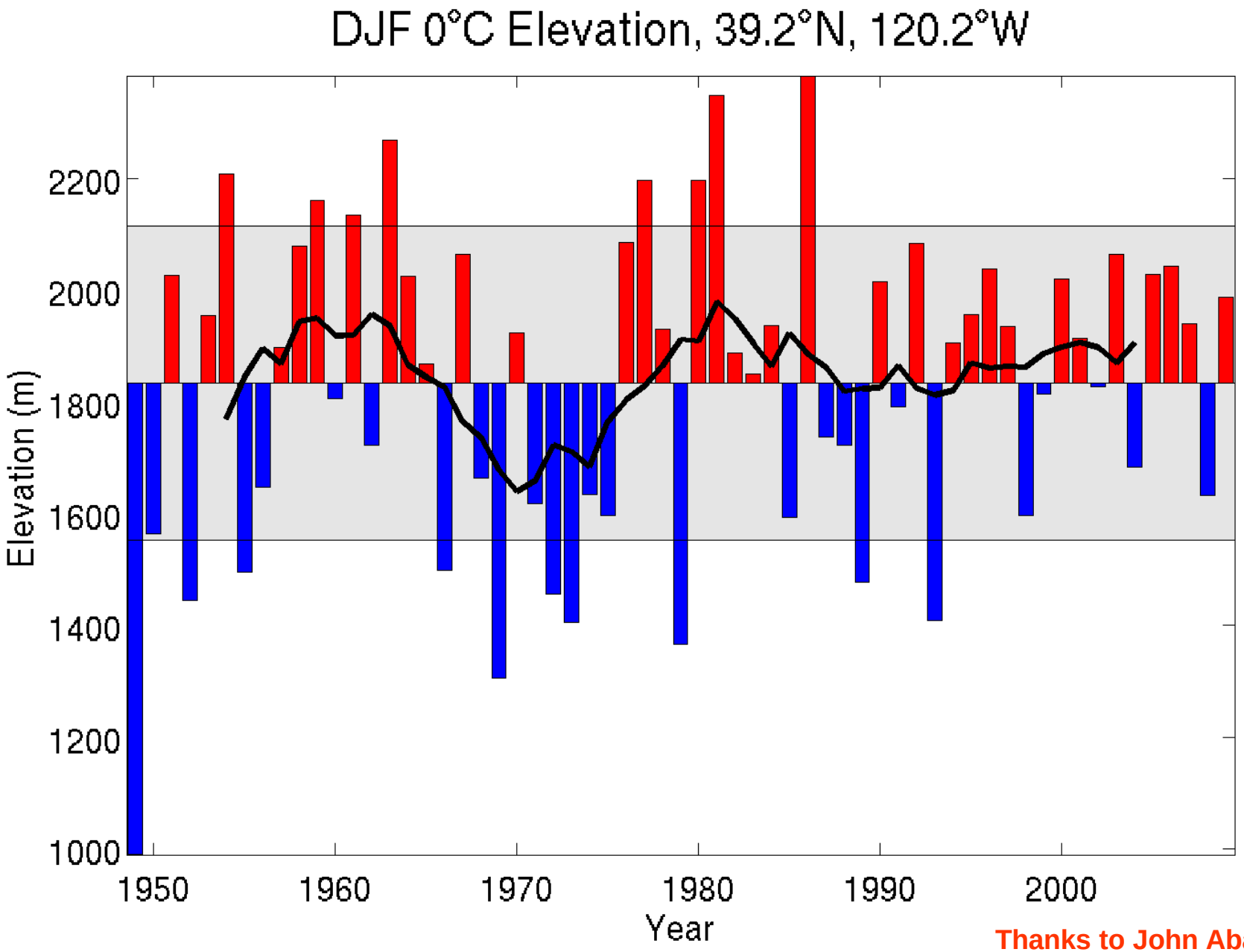

Air Temperature (NCEP Reanalysis) Dec to Feb:39N to 36N and -120.5W to -119W averaged
Sierra 3-mo Winter Dec-Feb
700 mb Temp (10,000 ft)
Air Temperature (C)
0
-1
-2
-3
-4
-5
-6
-7
1940
1950
1960
1970
1980
1990
2000
2010
Date
1 C

Elevation of Freezing Level over Lake Tahoe. Annual. From NCEP Reanalysis.



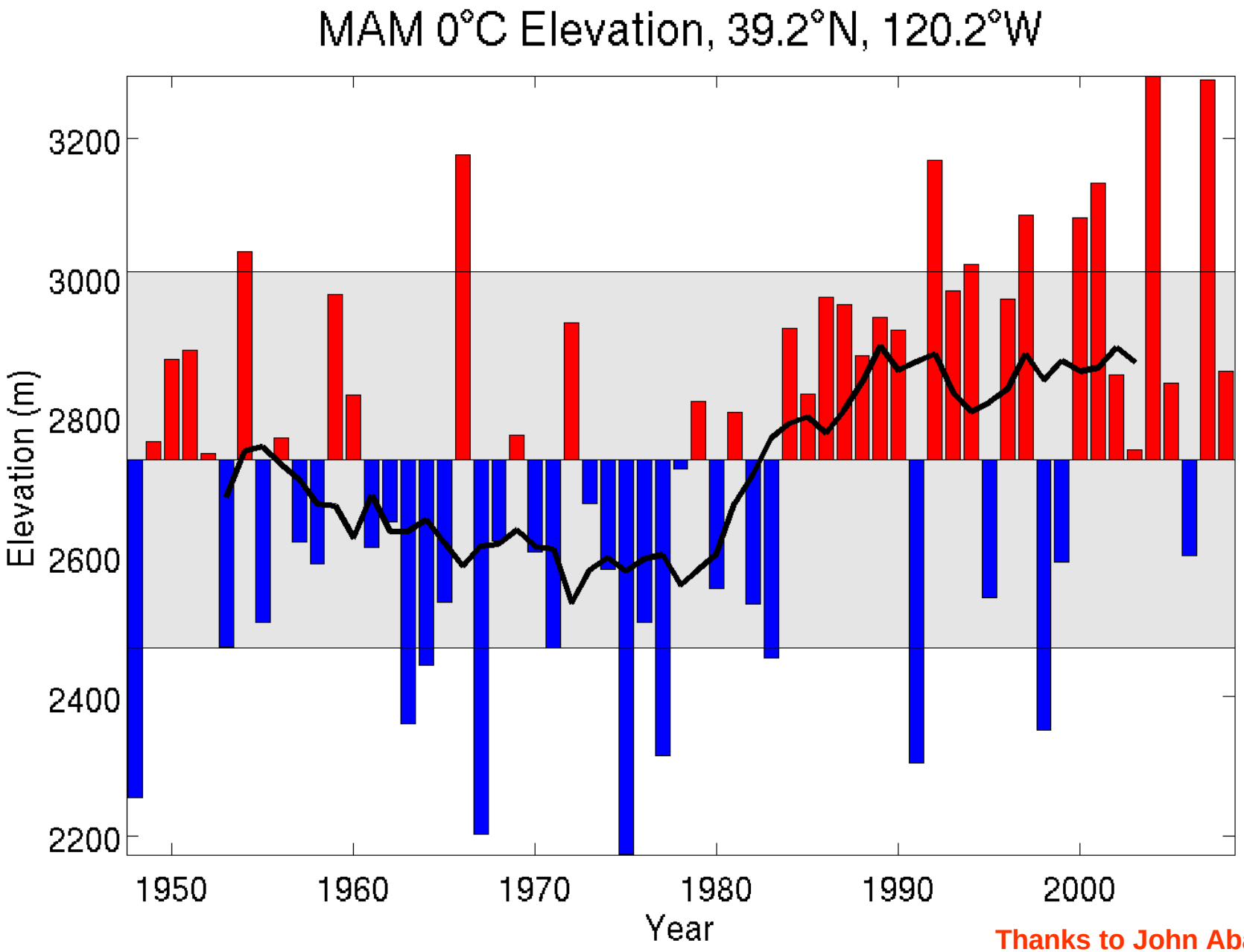
Thanks to John Abatzoglou

Elevation of Freezing Level over Lake Tahoe. Winter. From NCEP Reanalysis.



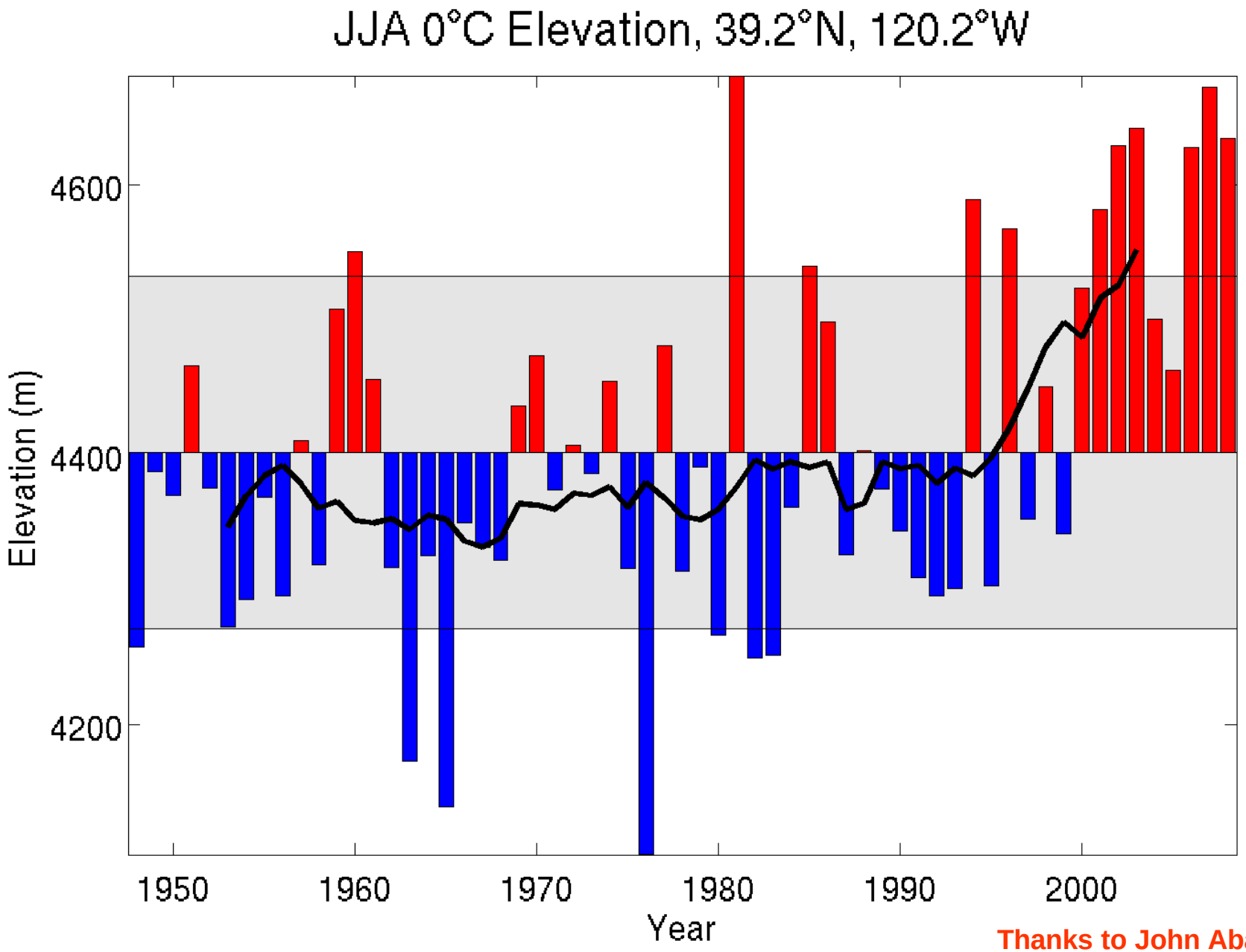
Thanks to John Abatzoglou

Elevation of Freezing Level over Lake Tahoe. Spring. From NCEP Reanalysis.



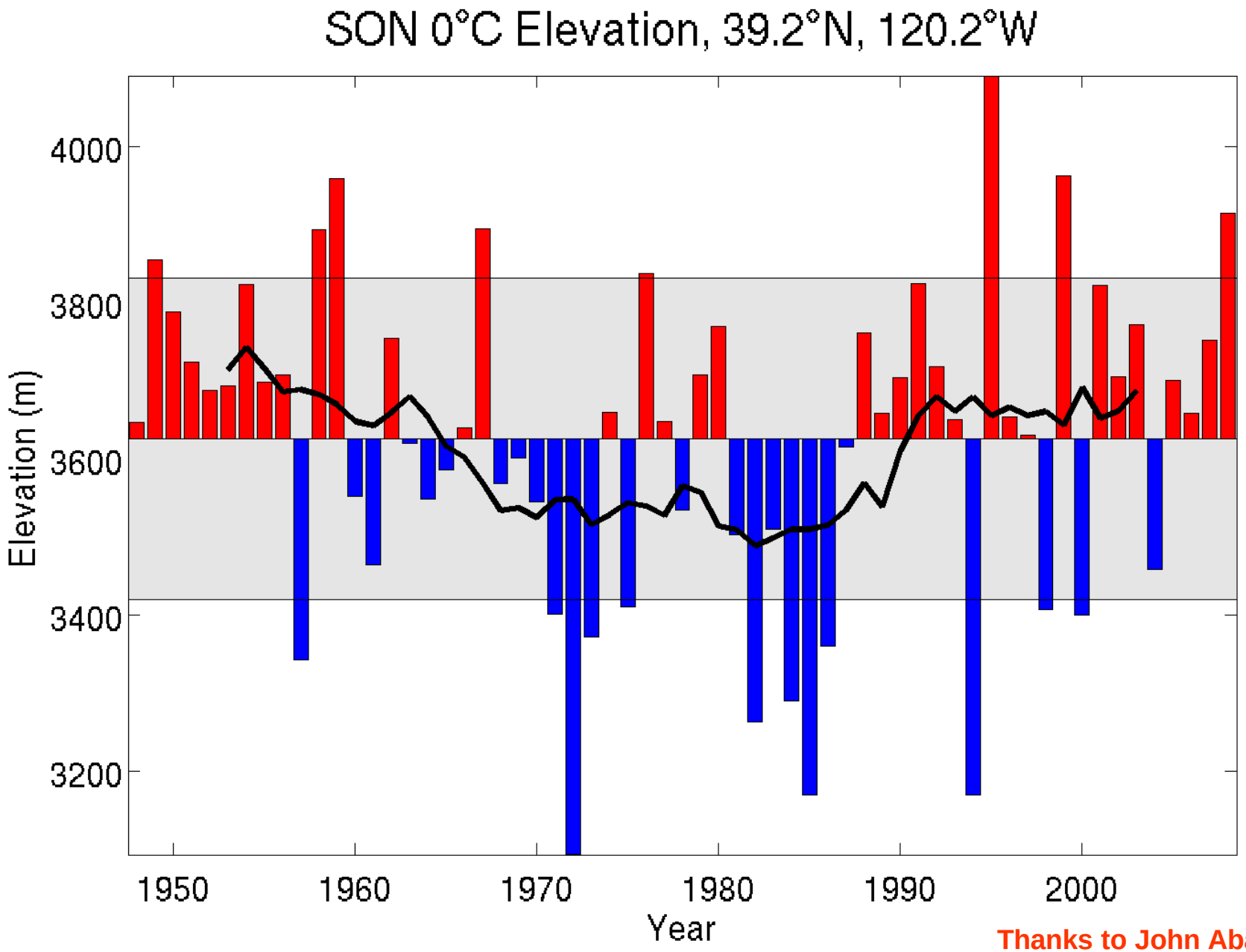
Thanks to John Abatzoglou

Elevation of Freezing Level over Lake Tahoe. Summer. From NCEP Reanalysis.



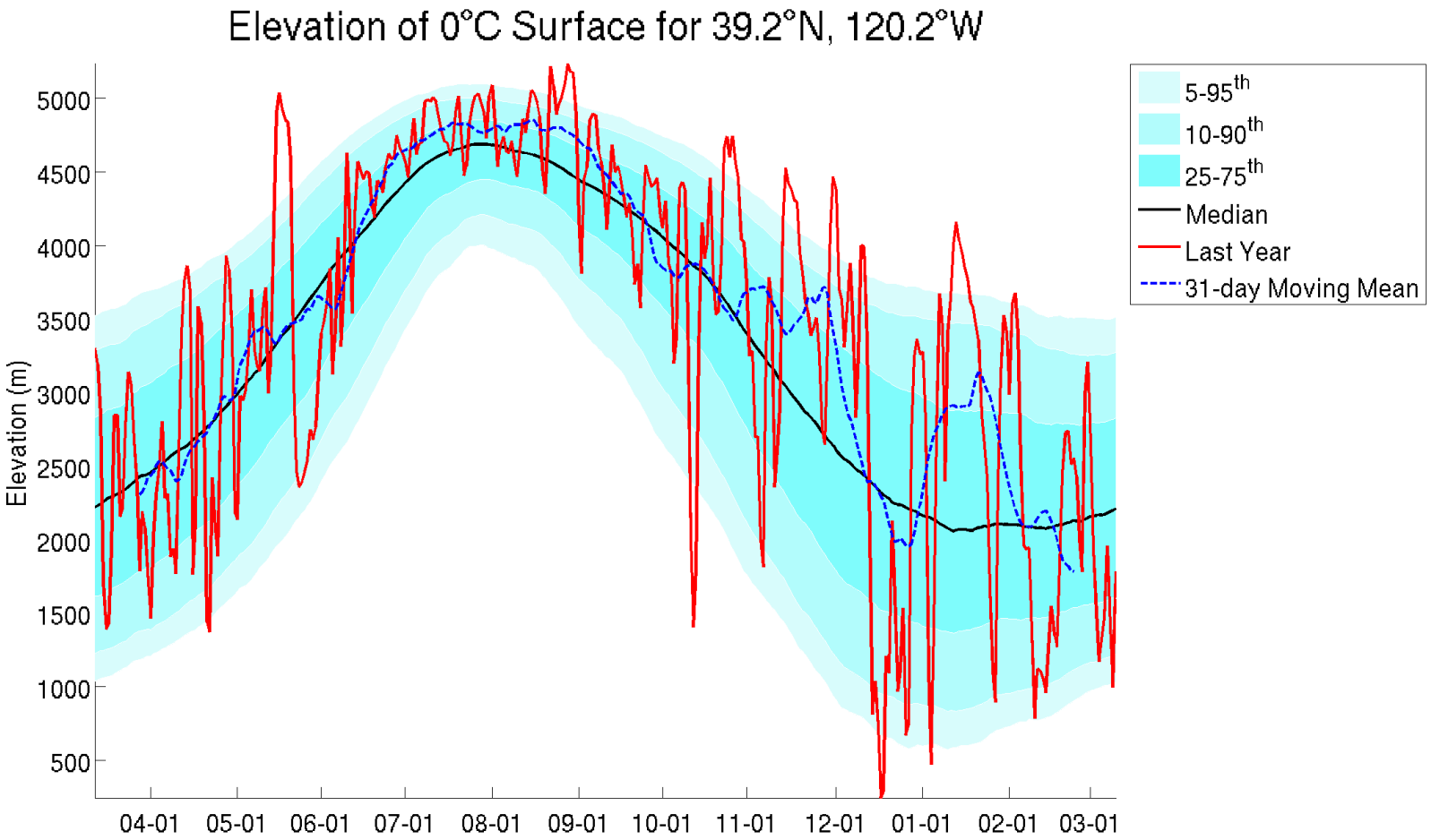
Thanks to John Abatzoglou

Elevation of Freezing Level over Lake Tahoe. Autumn. From NCEP Reanalysis.



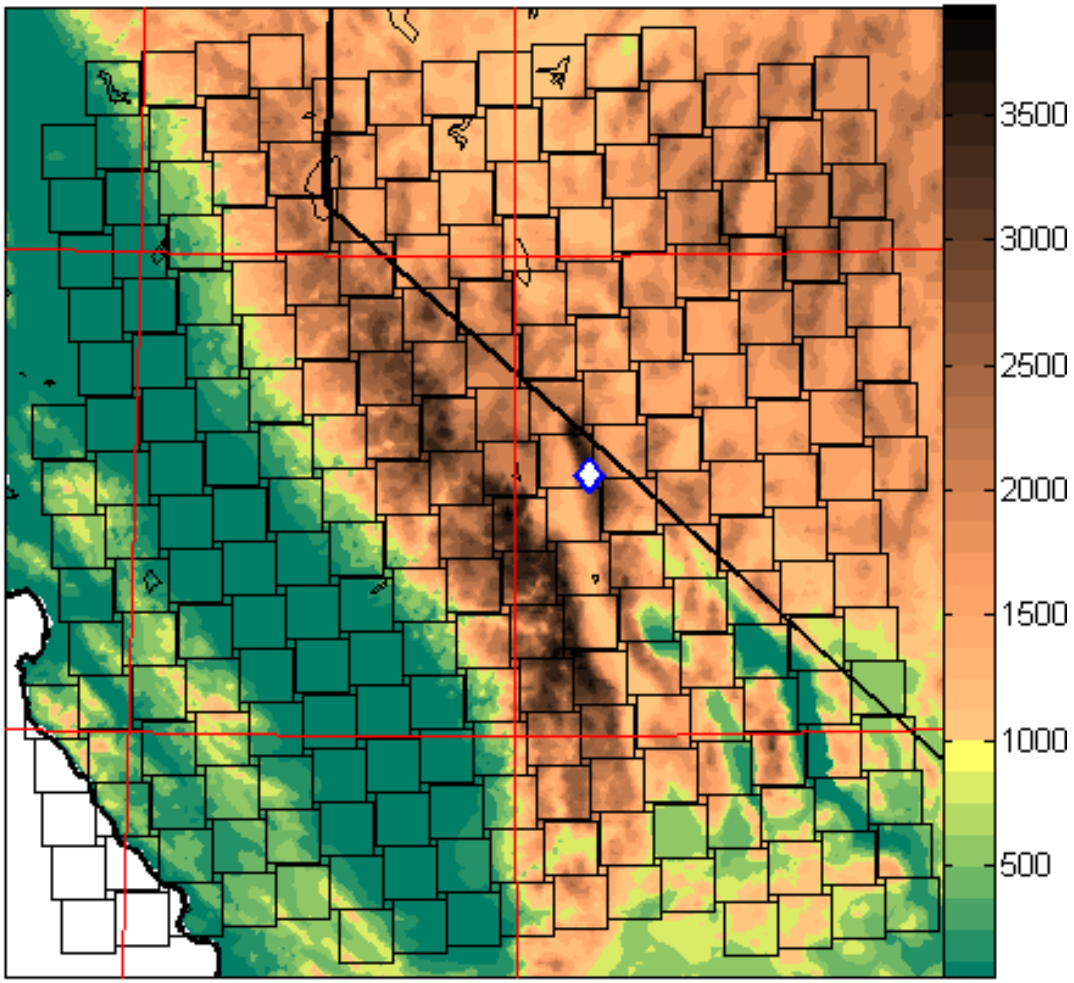
Thanks to John Abatzoglou

Elevation of Freezing Level over Lake Tahoe. 365 Days thru Feb 2009. From NCEP Reanalysis.



Thanks to John Abatzoglou

White Mountain Research Station Summit Station. 14,245 feet. White diamond.
North American Regional Reanalysis grid. 32 km, 3-hourly, 29 levels.



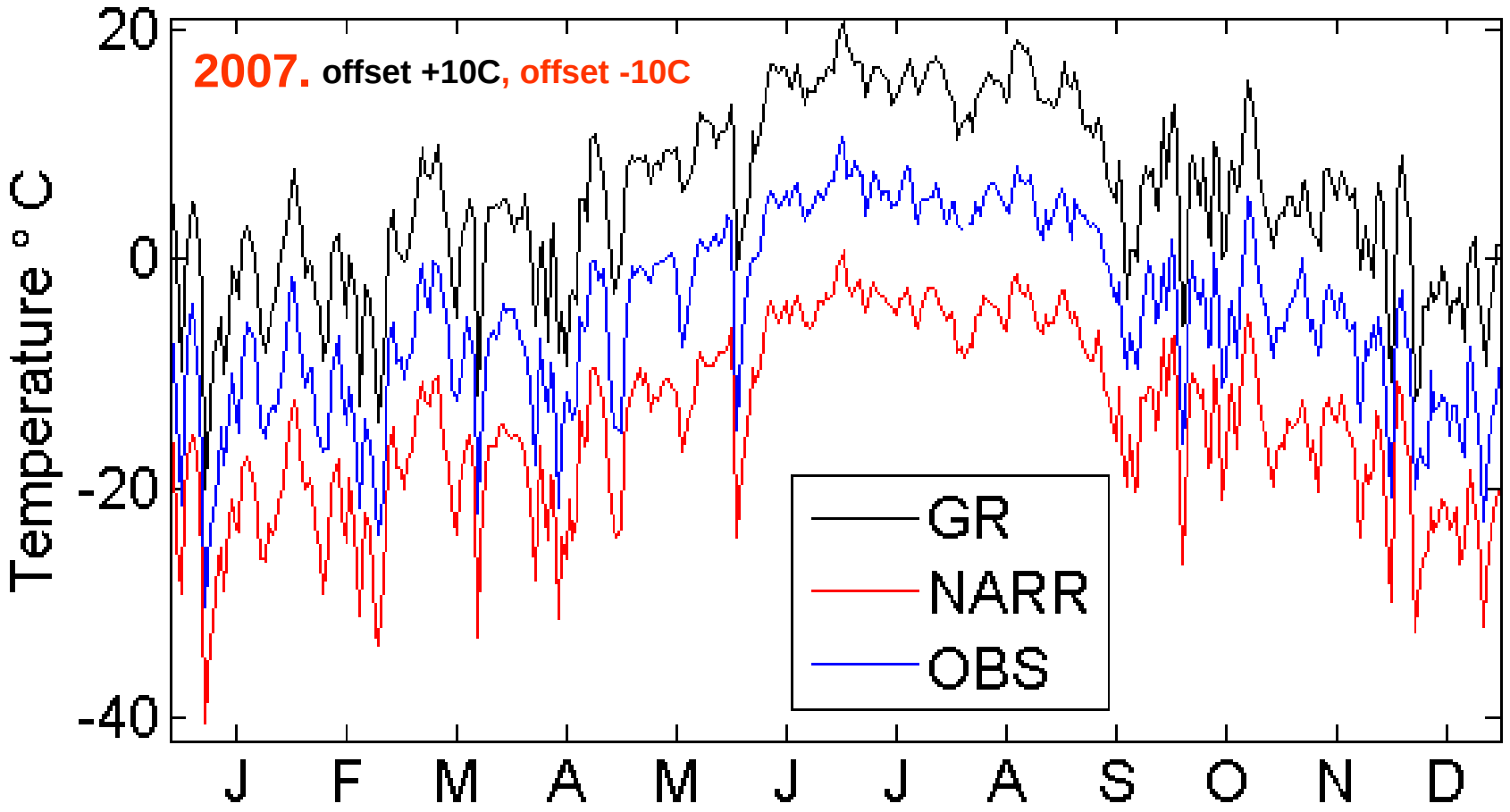
John Abatzoglou
Kelly Redmond

White Mountain Research Station Summit Station. 14,245 feet.

Mean Daily Temperature Observations. Complete days Sep 2003-May 2008. 70% of all days.

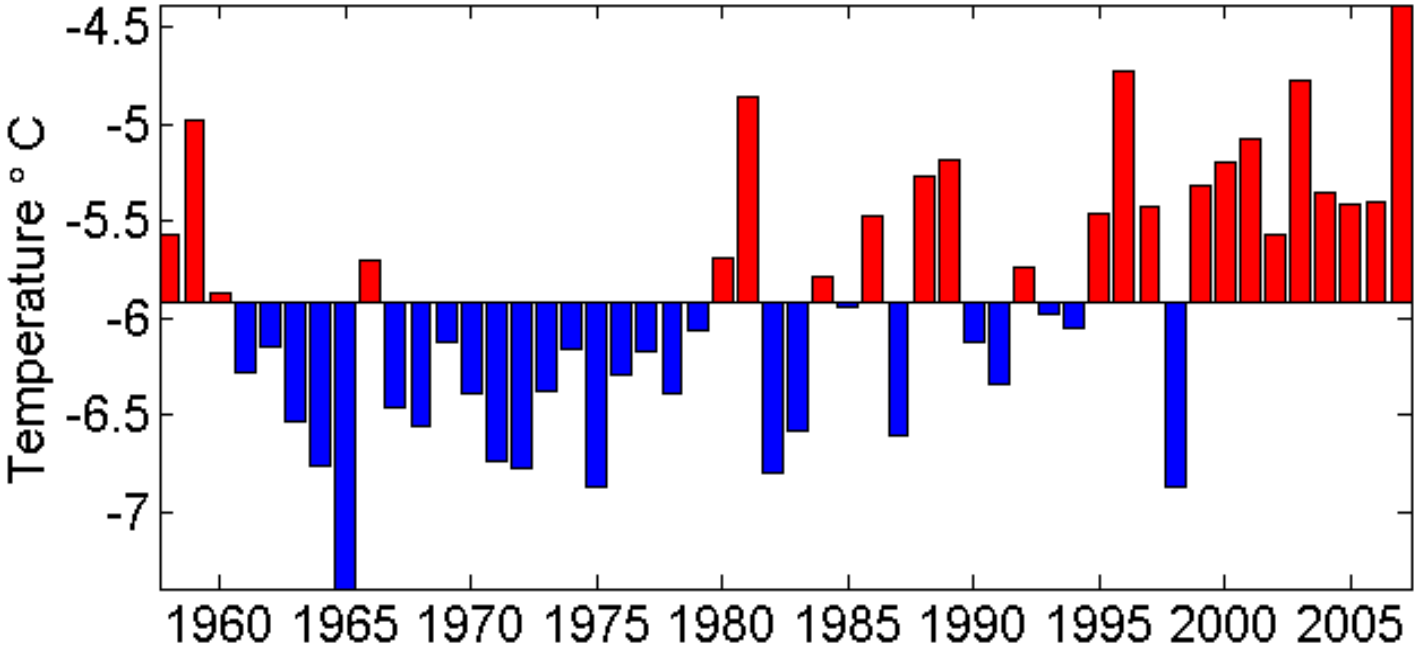
NARR. Reconstructed from North American Regional Reanalysis, 32 km, 29 levels. r = 0.985 (0.98 winter, 0.93 summer).

GR. Reconstructed from Global Reanalysis. r = 0.97



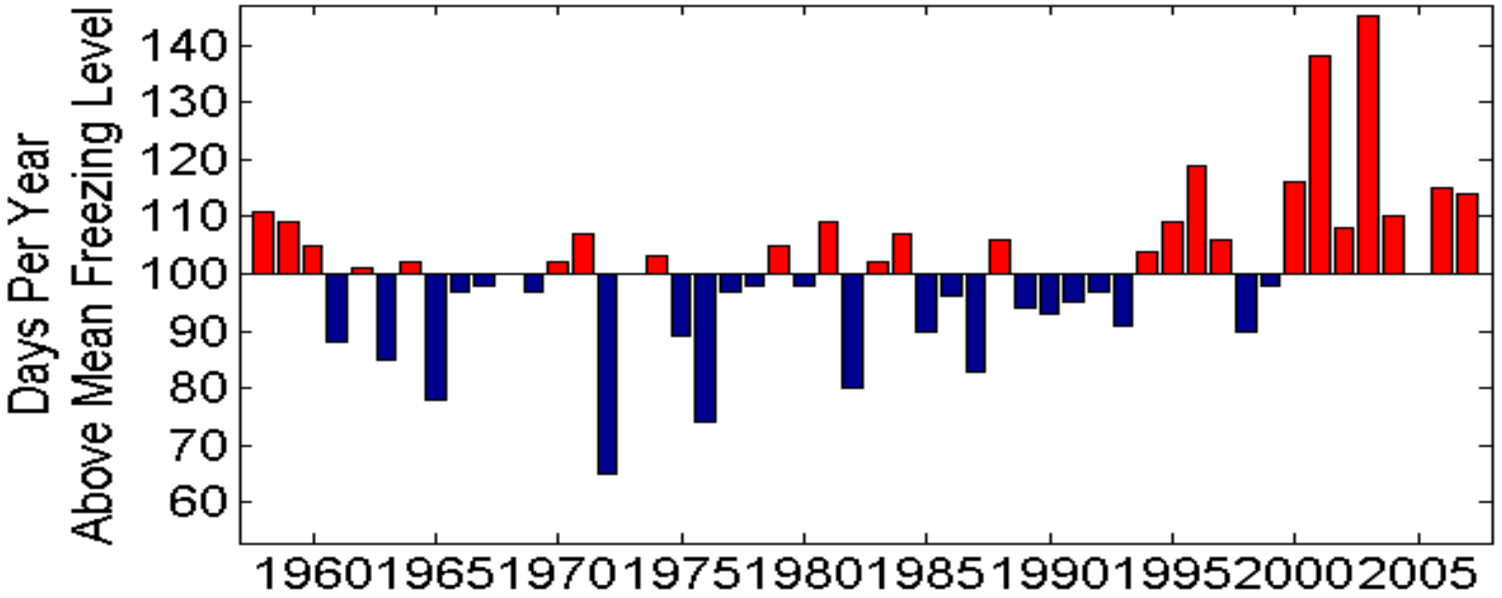
John Abatzoglou
Kelly Redmond

White Mountain Summit Temperature. 14,245 feet. Reconstructed from Global Reanalysis.
99 % of NARR-derived temperatures are within +/- 3 Deg C.



Mean Annual Temperature 1958-2007

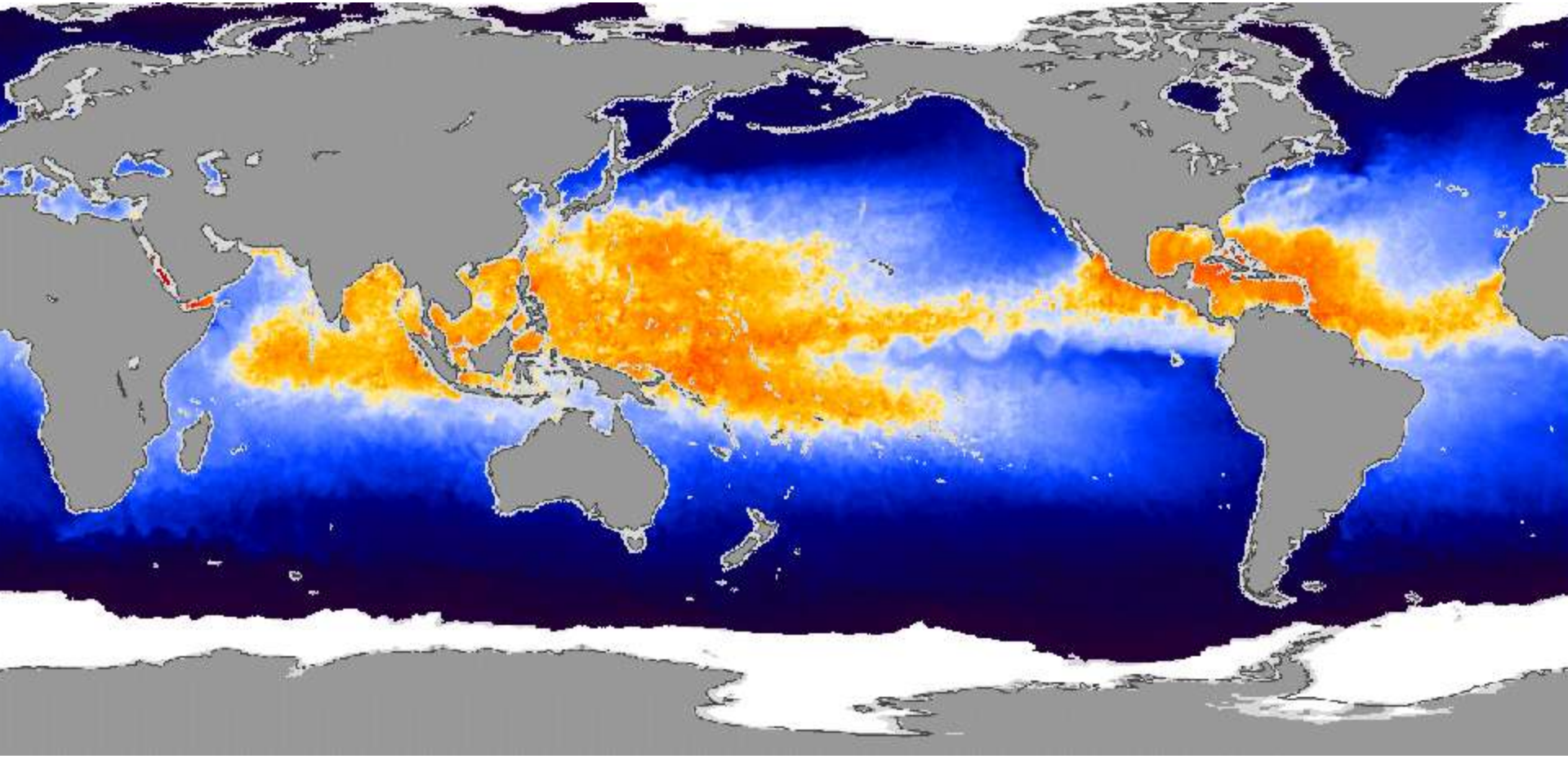
Trend 0.24 C/decade, 30% greater than California Statewide. Trends greatest above 6000 feet. Freezing level In spring: trend 1958-2008 170 ft/decade 52 m/decade



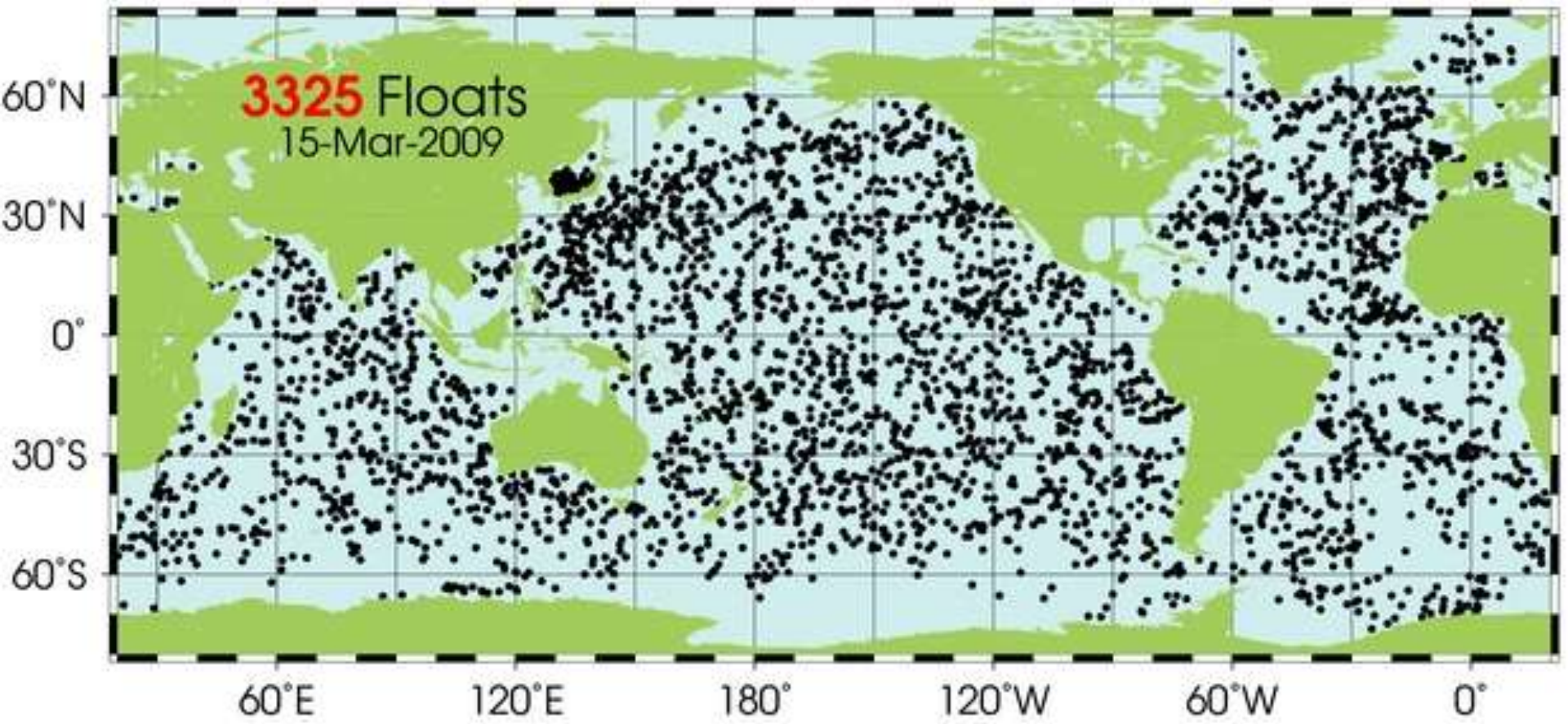
Days with Mean Daily Temperature Above Freezing (0 C)

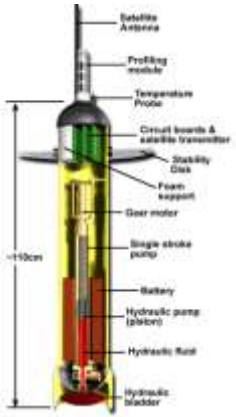
John Abatzoglou
Kelly Redmond

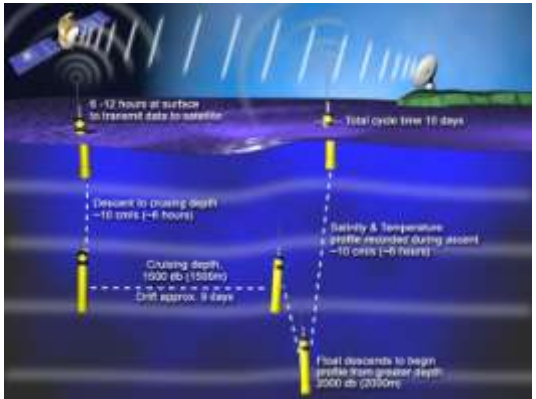
The World's Warm Oceans

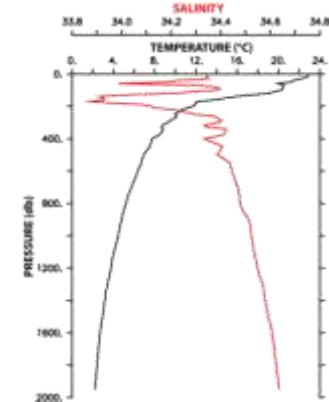


2009 March 15. 3325 Argo floats deployed.

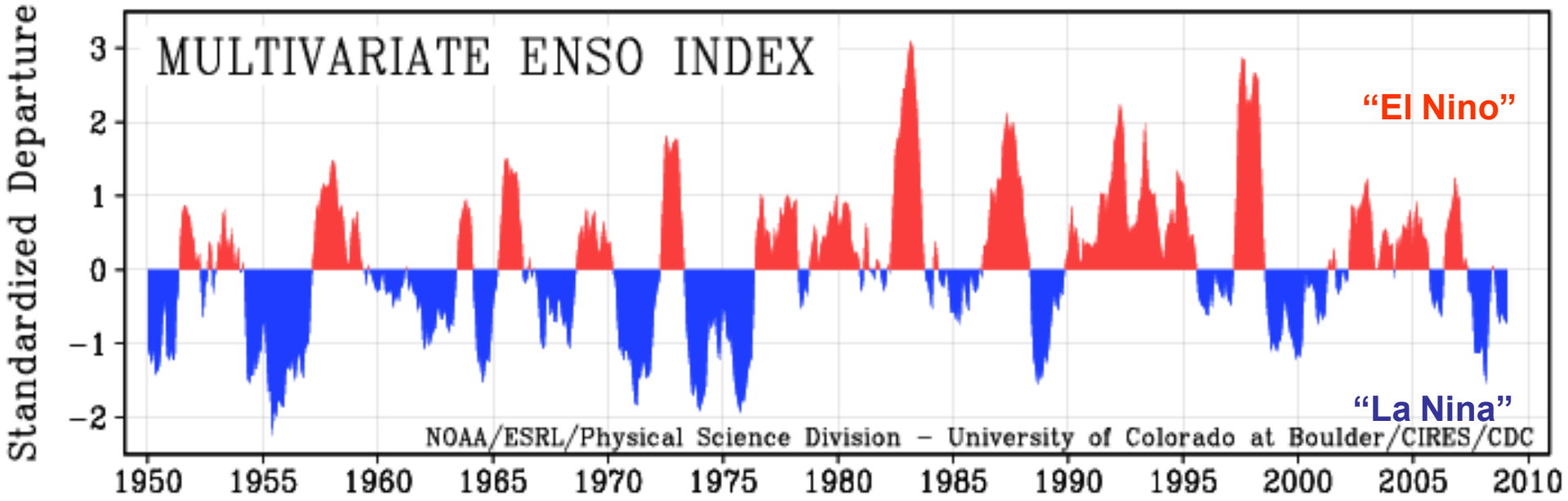






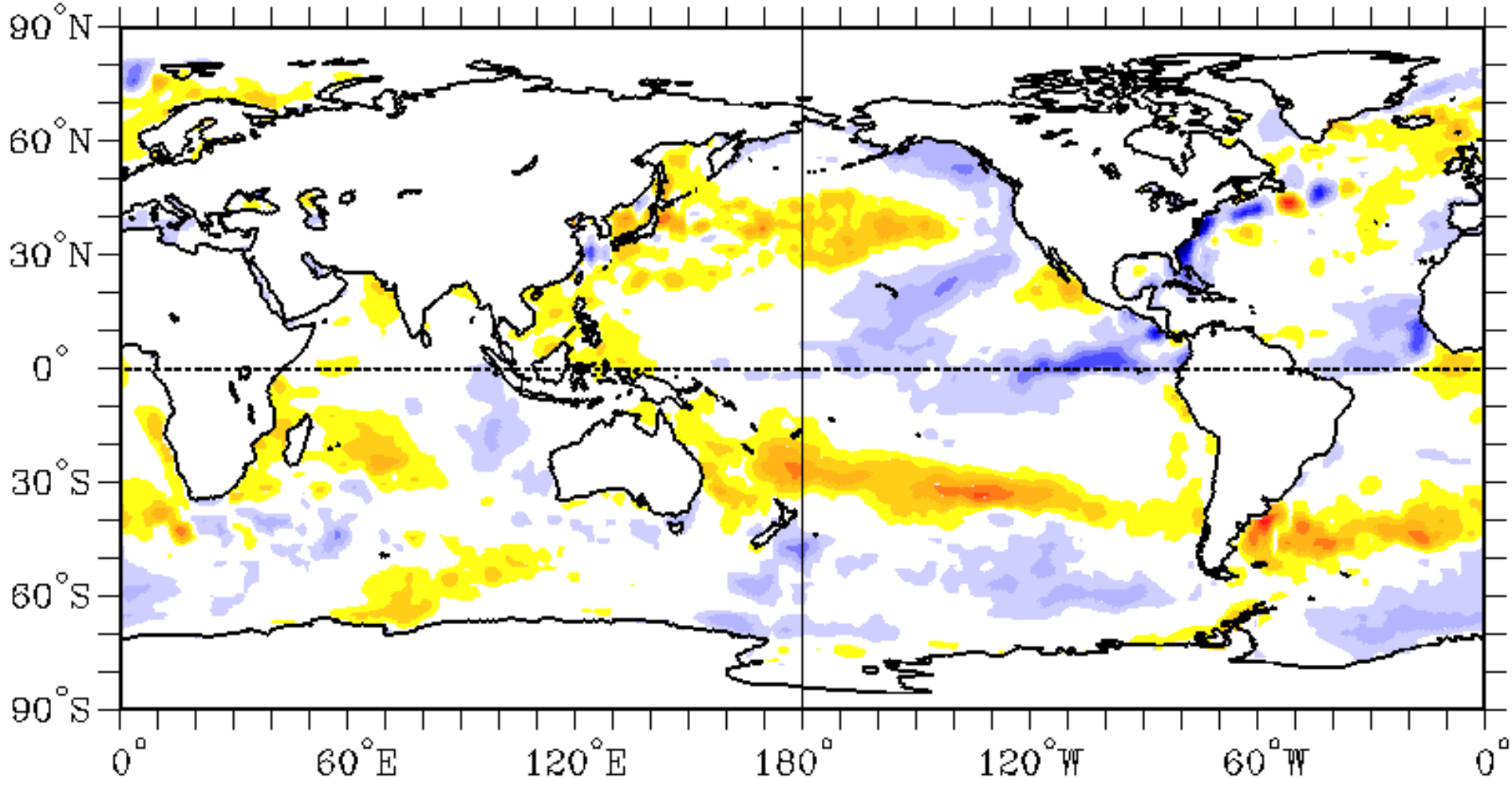


Through February 2009



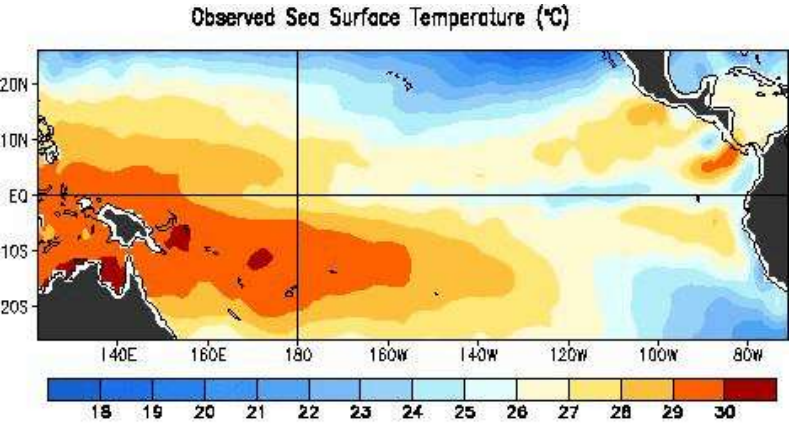
NOAA ESRL ("CDC"), Wolter and Timlin

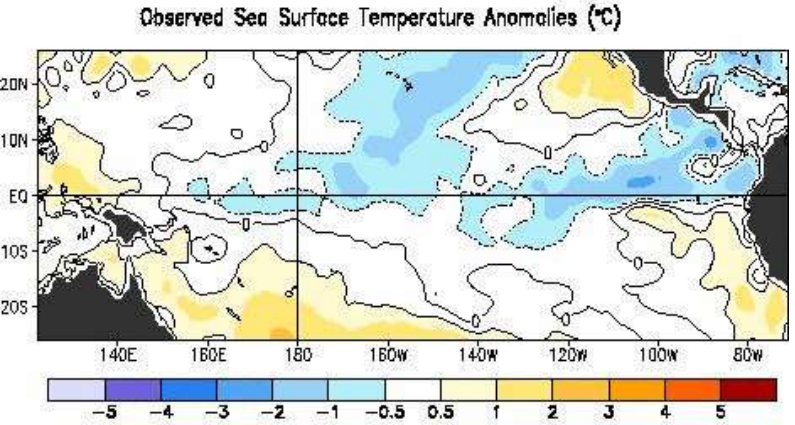
Global Sea Surface Temperature Anomalies (C) 2009 March 1-7

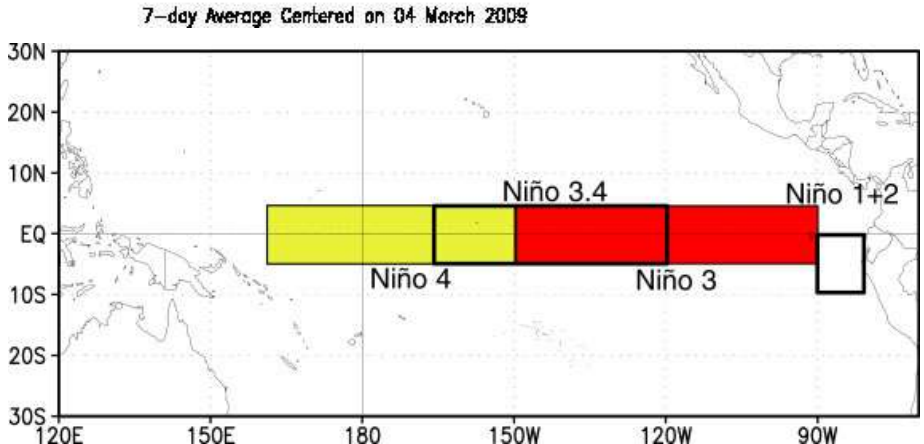


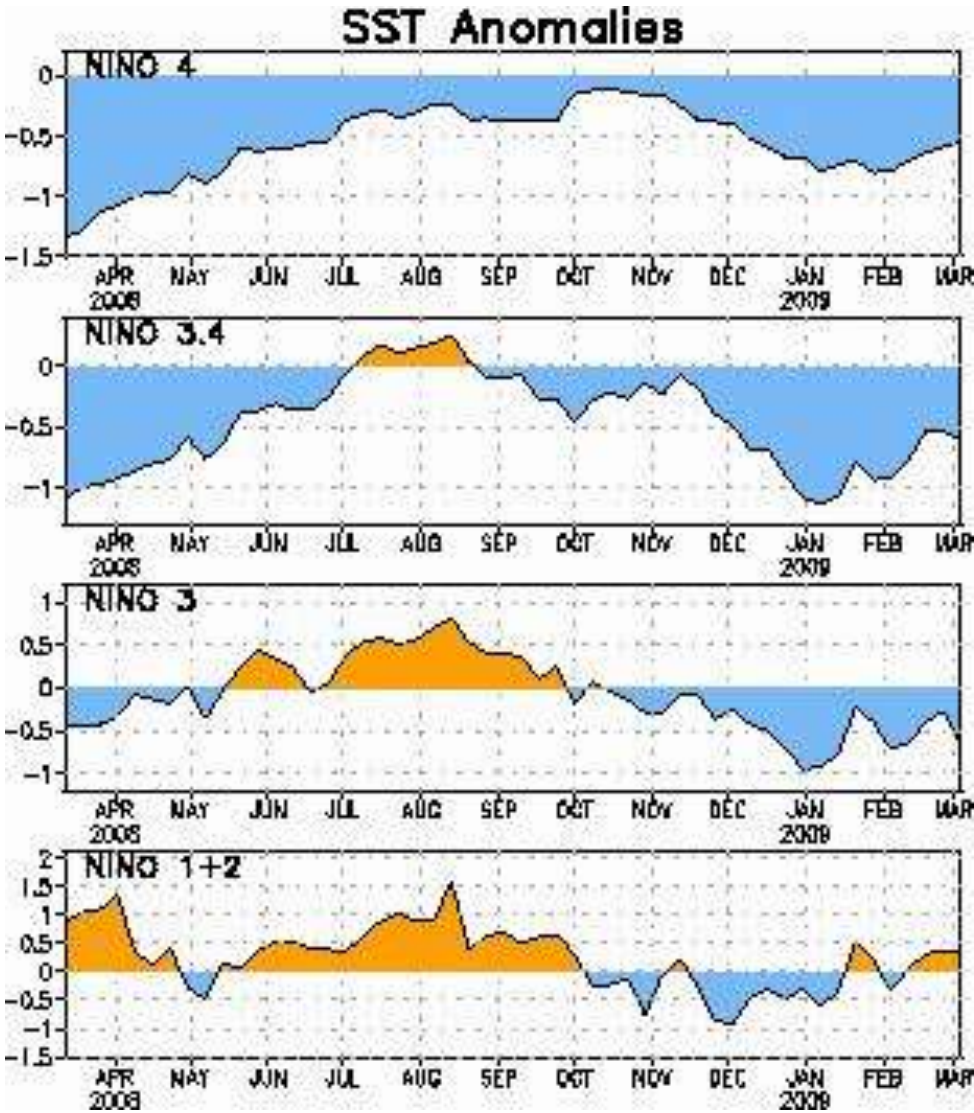
NOAA ESRL (“CDC”)

Recent Evolution of Equatorial Pacific SST Departures

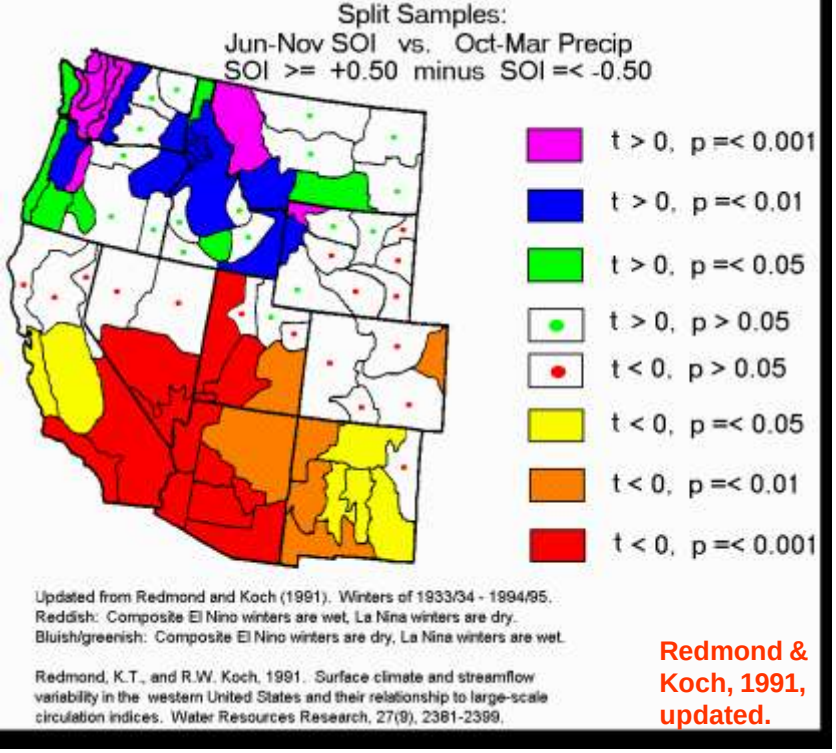




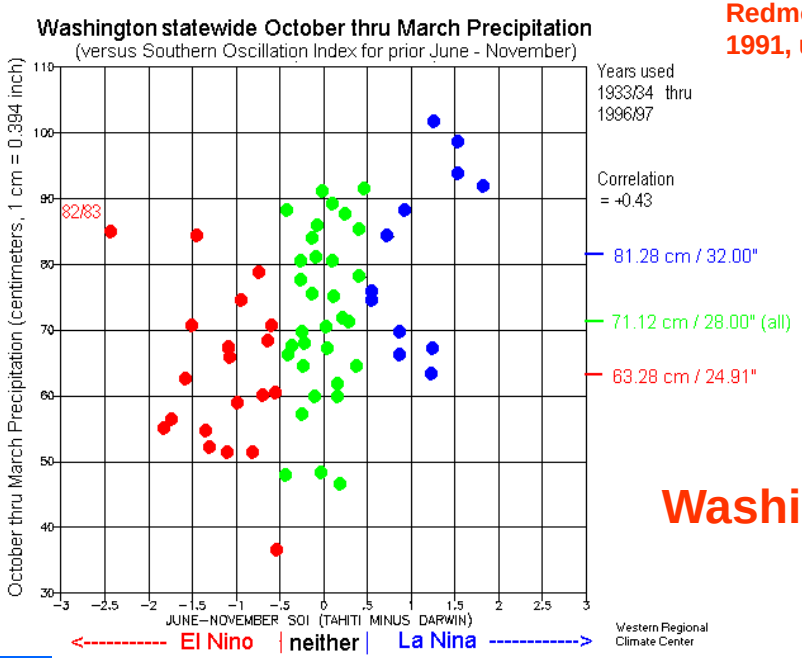




Updated through 2009 March 1-7



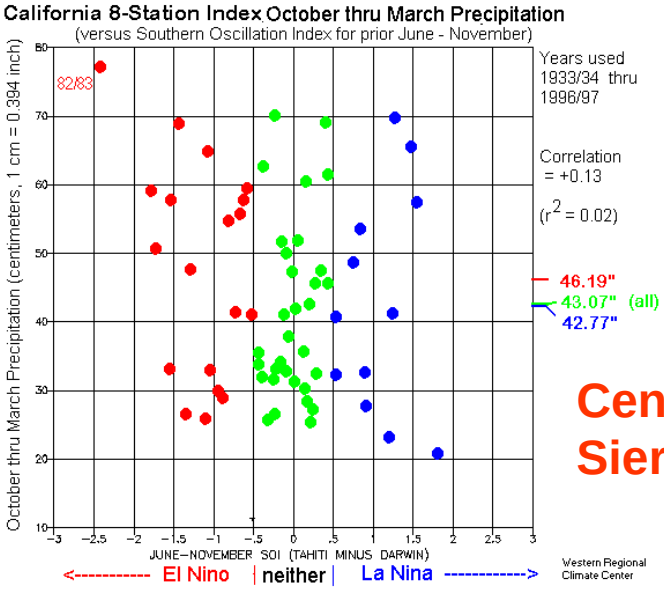
Redmond & Koch, 1991, updated.



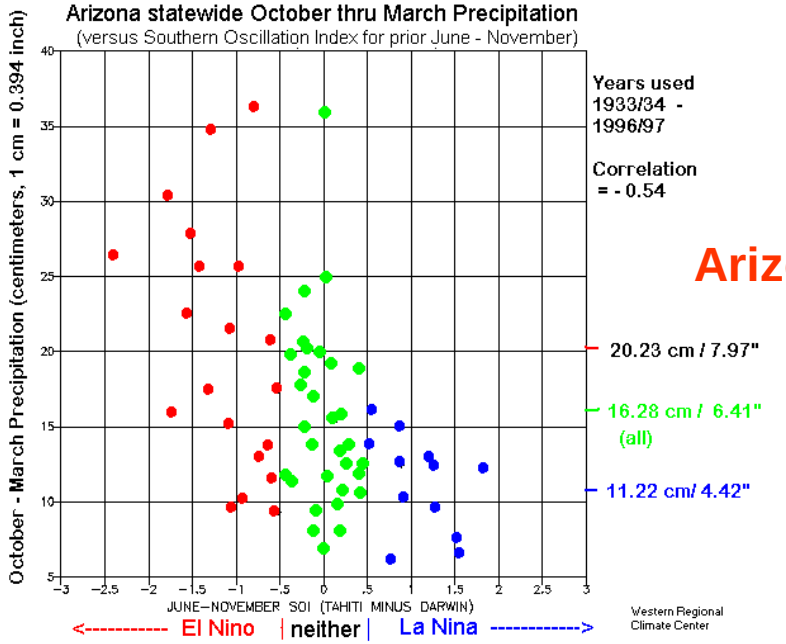
Redmond & Koch, 1991, updated.

Washington

ENSO



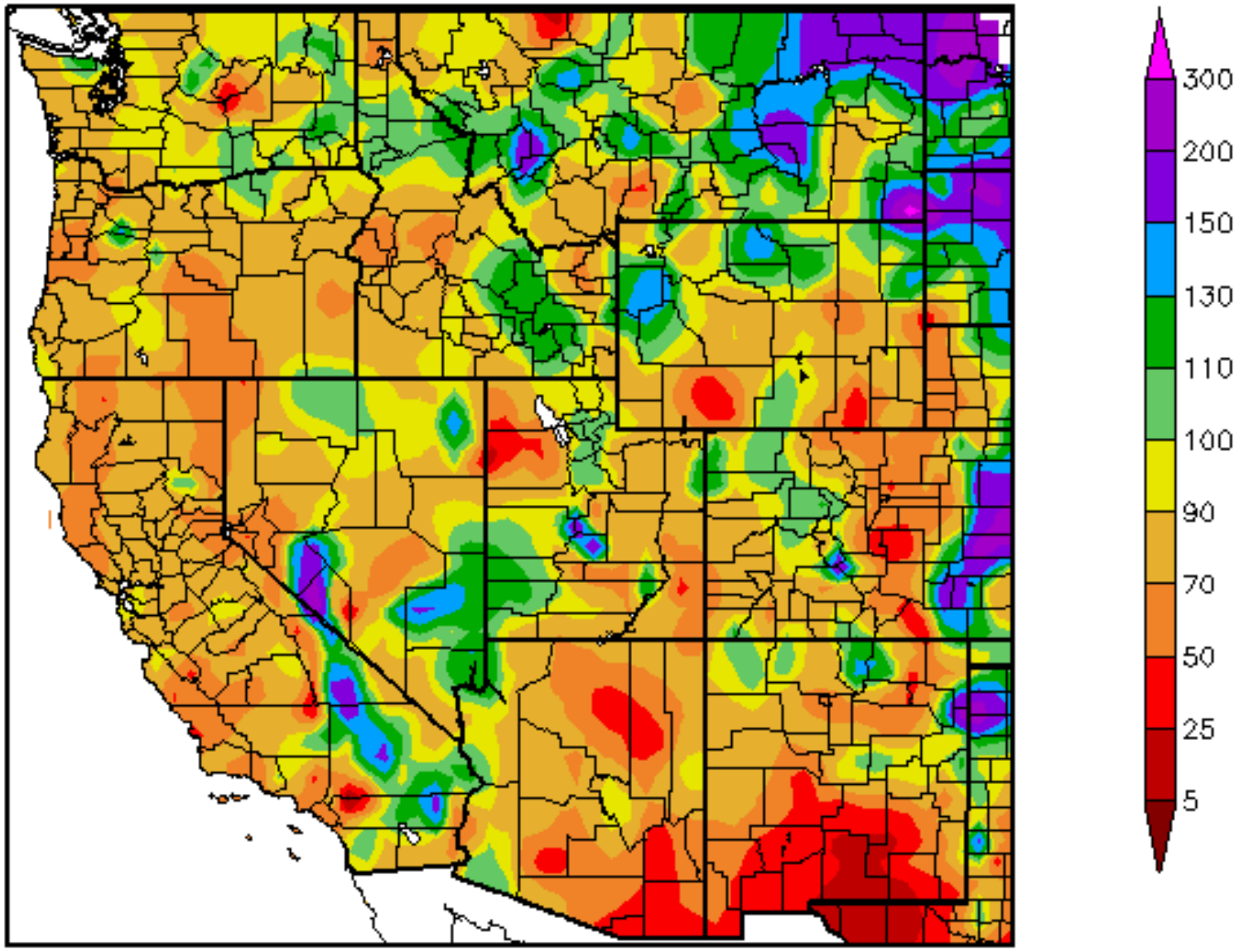
Central Sierra



Arizona

Water Year
2008 Oct 1
Thru
2009 Mar 14

Percent of Normal Precipitation (%)
10/1/2008 – 3/14/2009

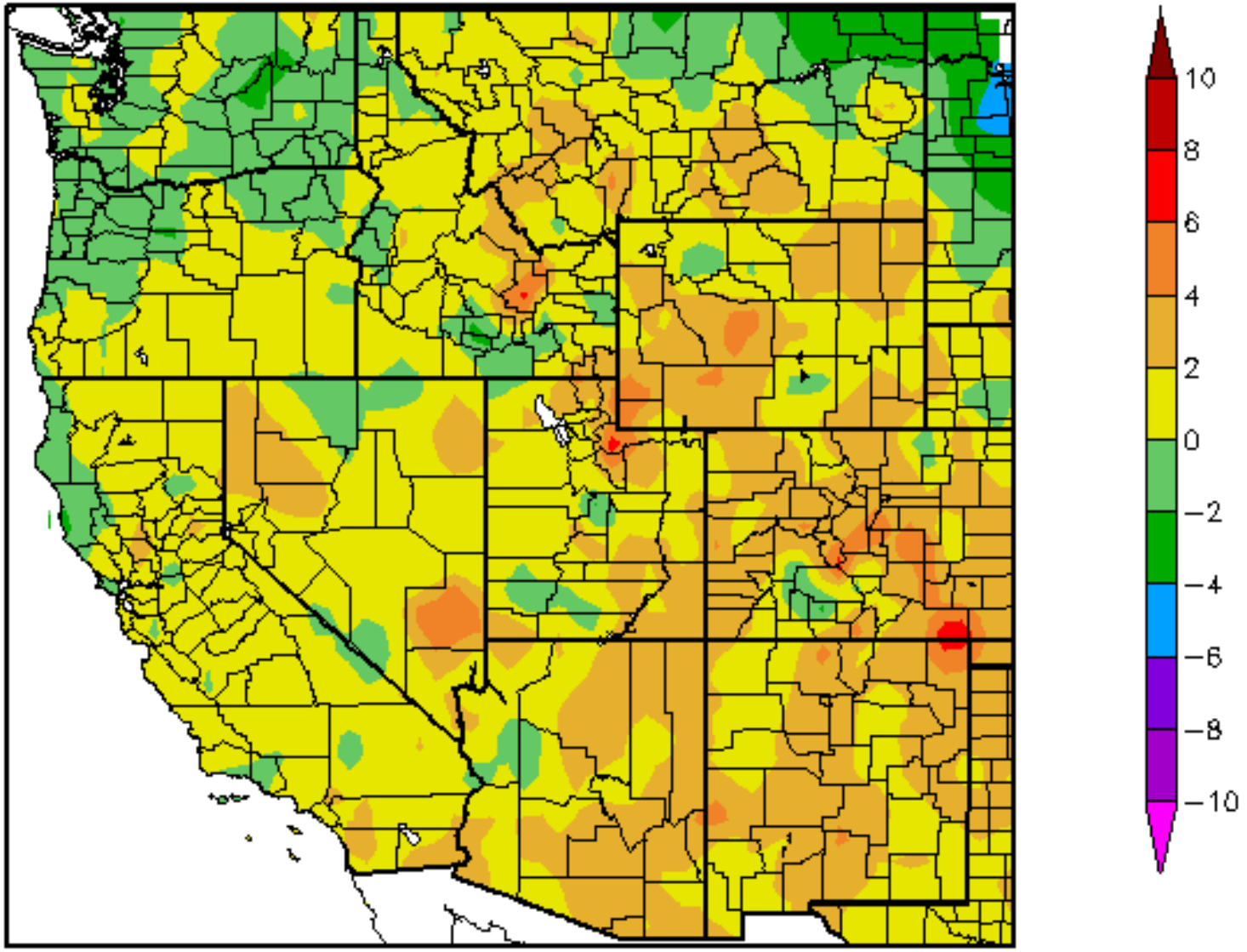


Generated 3/15/2009 at HPRCC using provisional data

NOAA Regional Climate Centers

Water Year
2008 Oct 01
Thru
2009 Mar 14

Departure from Normal Temperature (F)
10/1/2008 – 3/14/2009

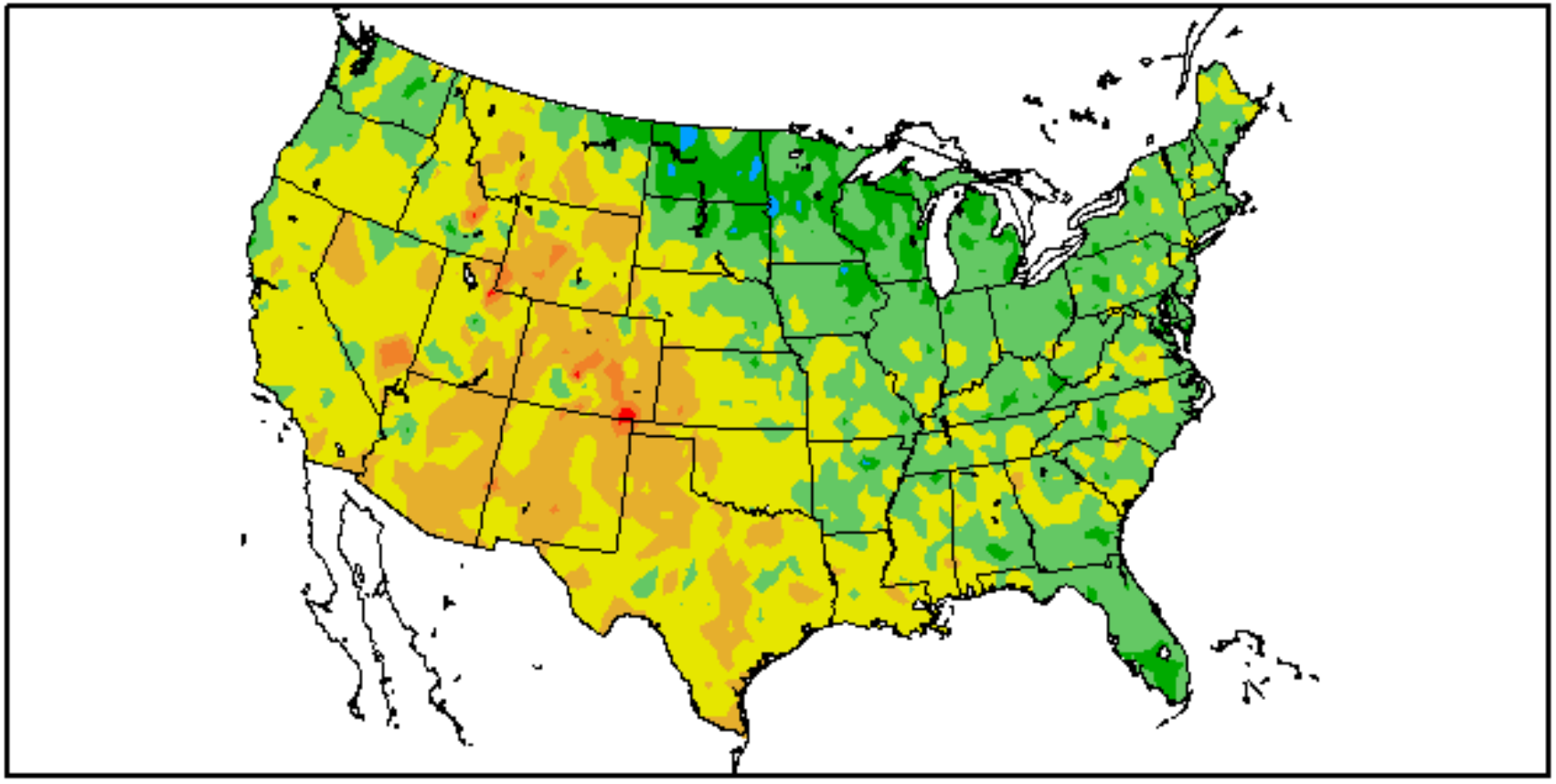


Generated 3/15/2009 at HPRCC using provisional data.

NOAA Regional Climate Centers

Water Year
2008 Oct 01
Thru
2009 Mar 14

Departure from Normal Temperature (F)
10/1/2008 – 3/14/2009



Generated 3/15/2009 at HPRCC using provisional data.

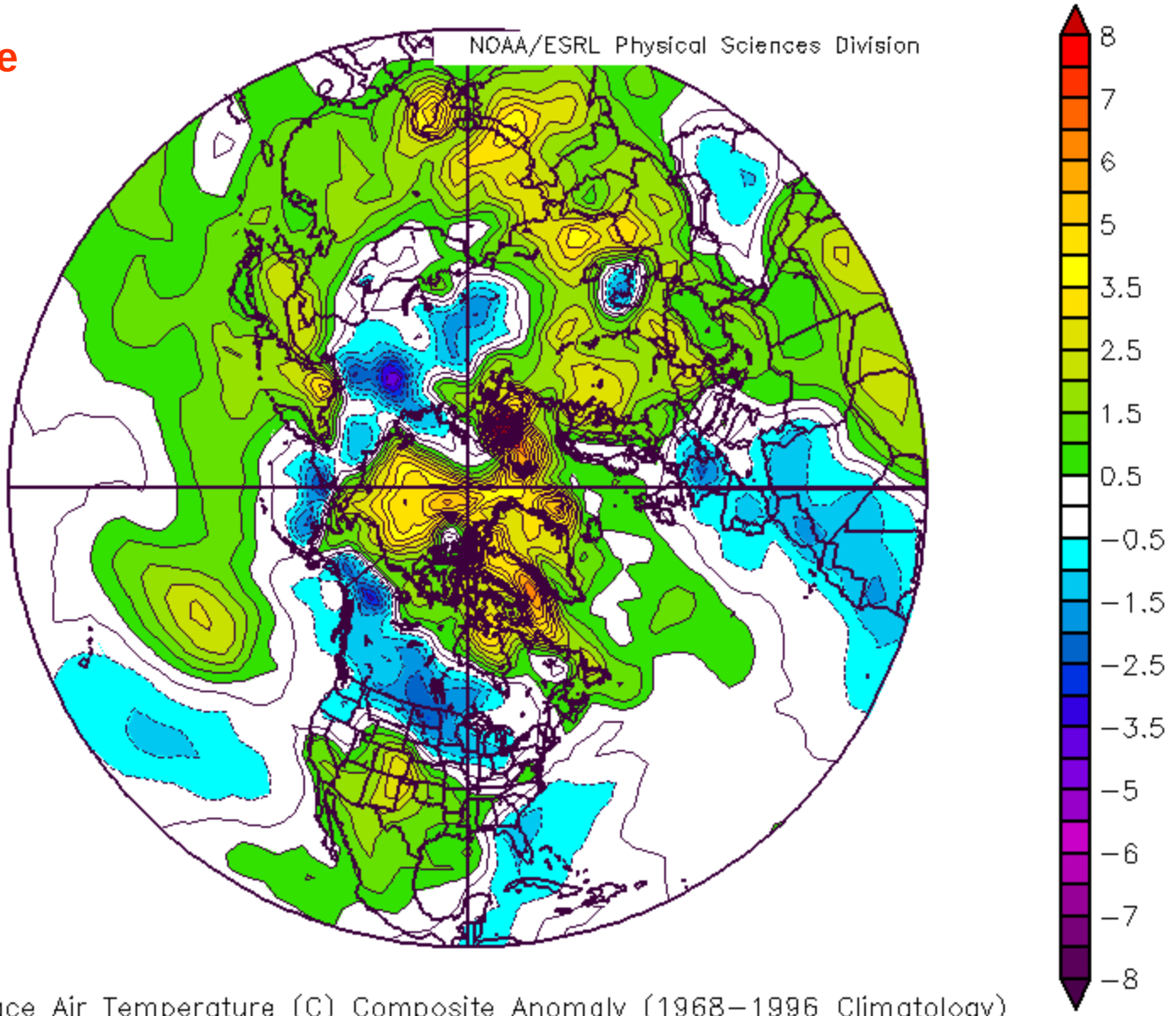
NOAA Regional Climate Centers

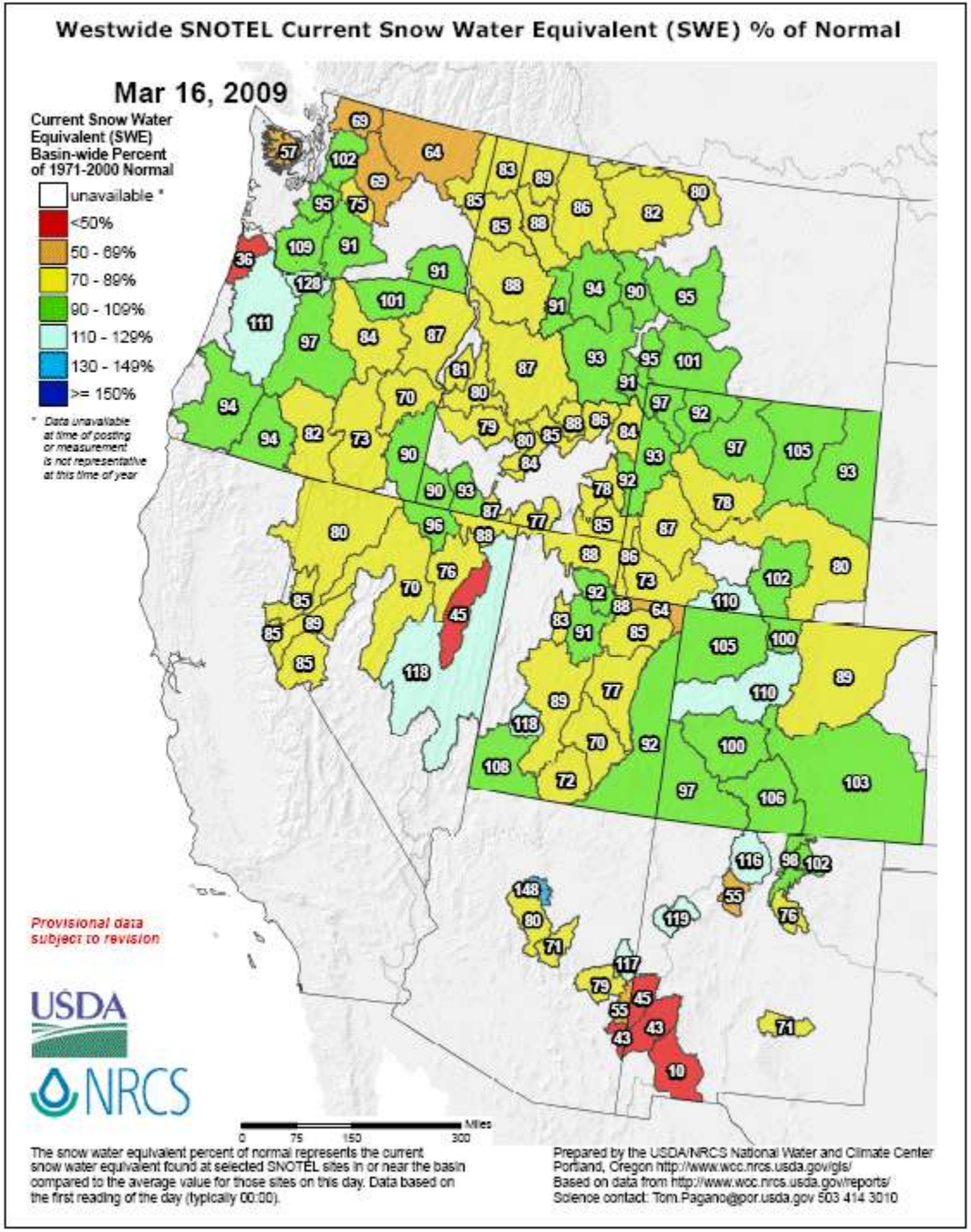
Winter 2008-2009
Dec 01 – Mar 12

Surface Temperature

Departure from Climatology (1968-1996)

Reanalysis Data





Western Basins

Snow Water Content

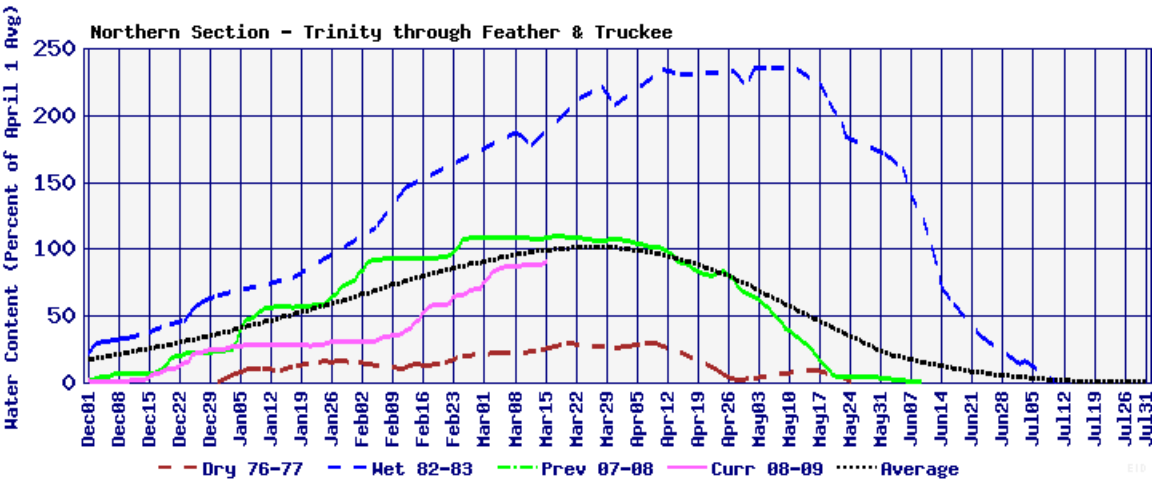
from
Snotel Stations

Percent of Average

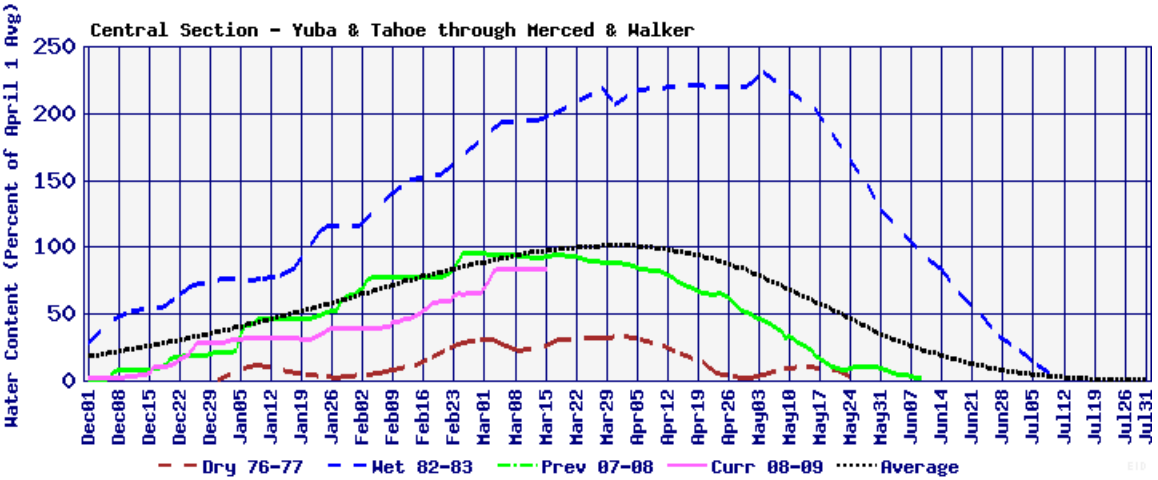
2009 March 16

Sierra Nevada Snowpack Conditions

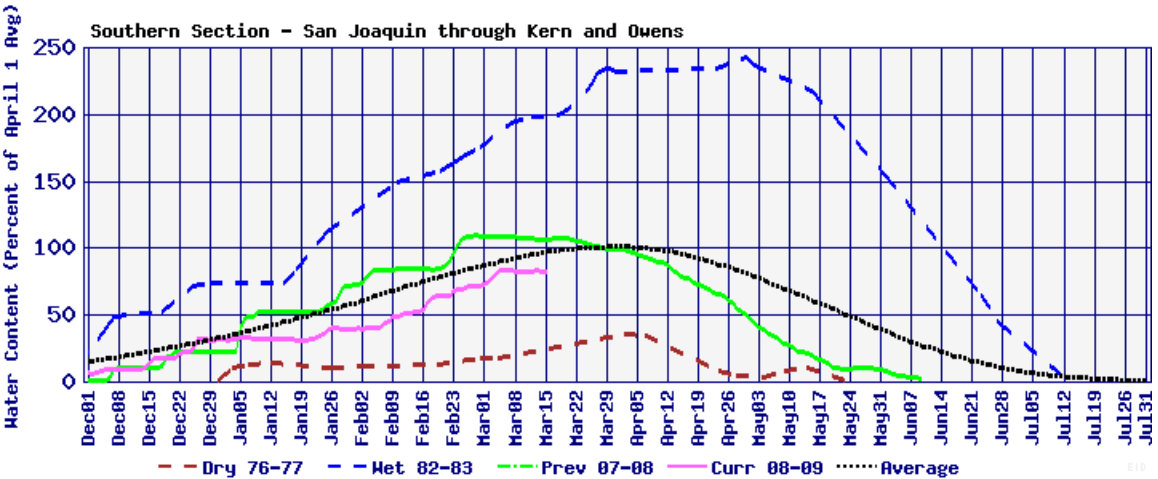
March 16, 2009



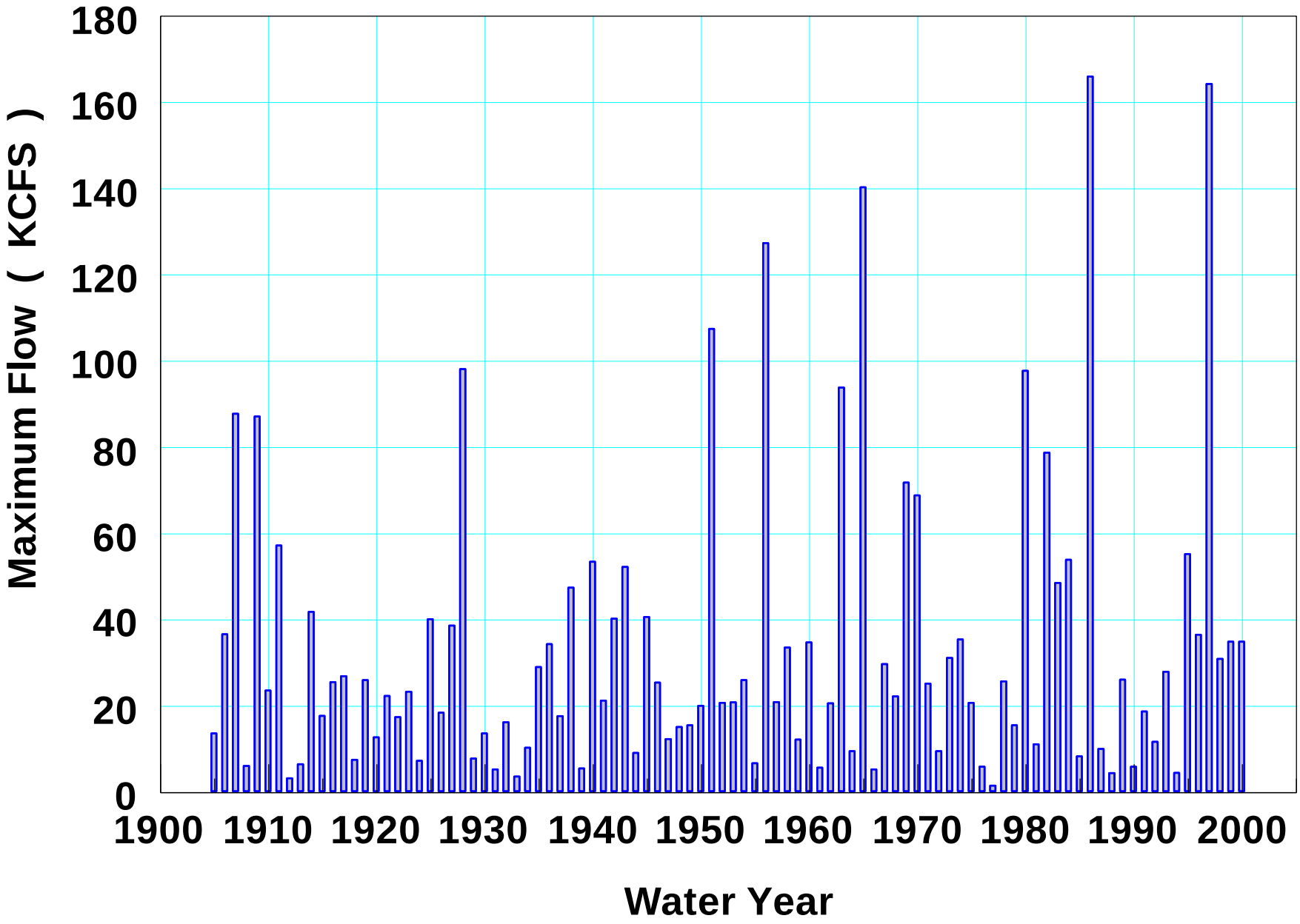
North

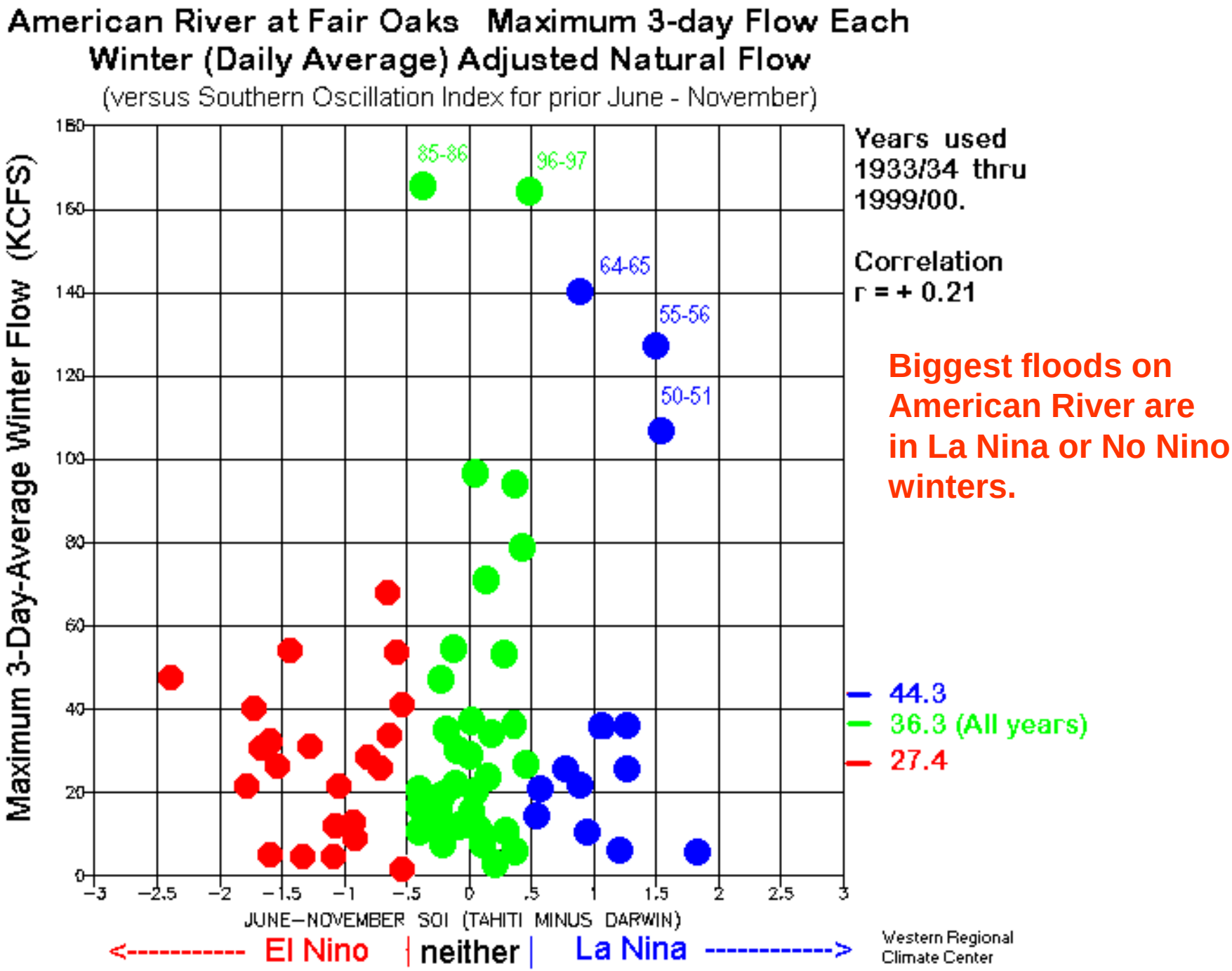


Central

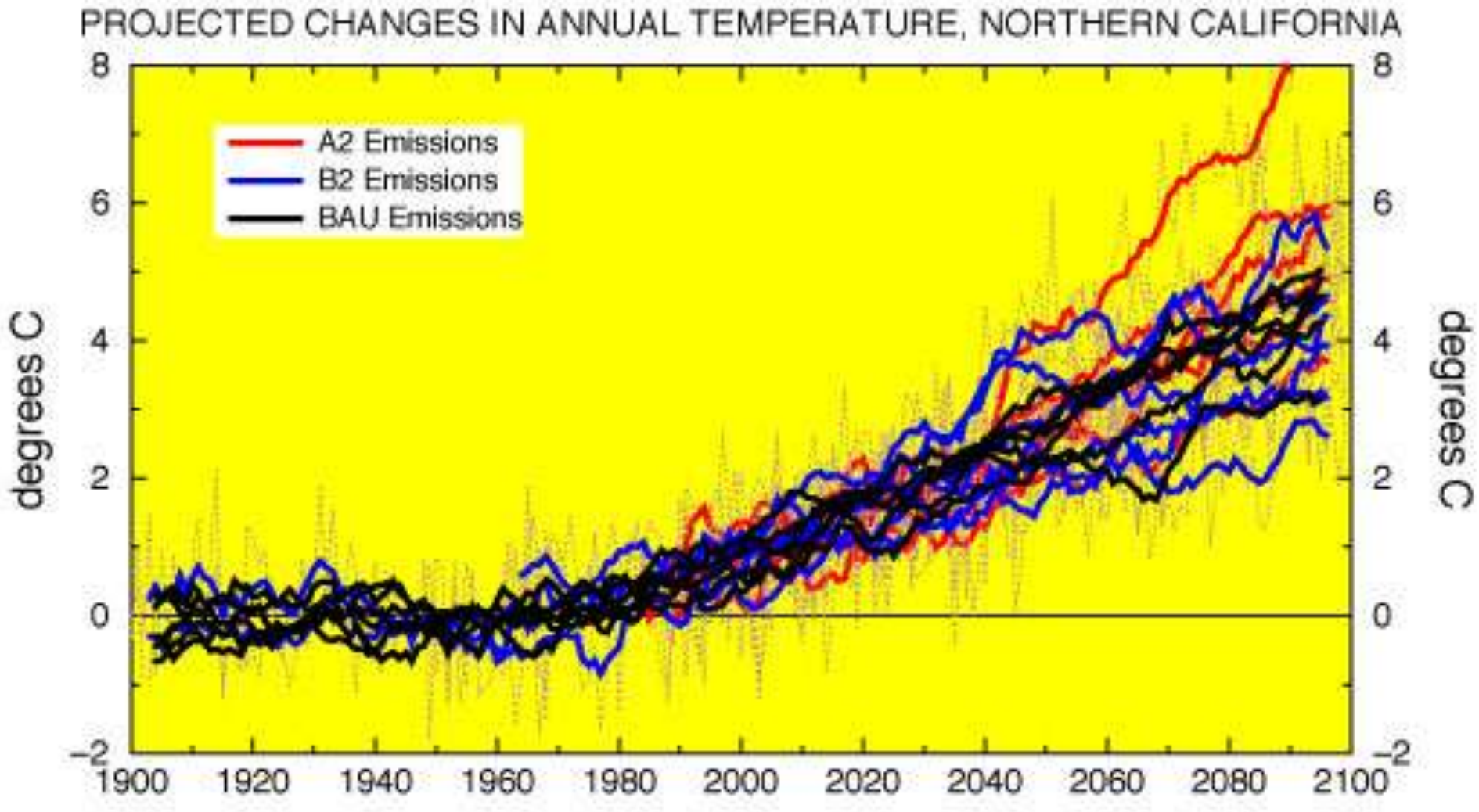


South

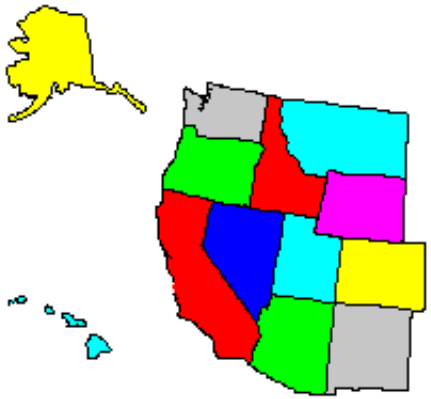

American River @ Fair Oaks (Sacramento CA)
Annual Maximum Three-Day Average Flow
Reconstructed Natural Flow below Folsom Reservoir
Maximum Flow (KCFS)
180
160
140
120
100
80
60
40
20
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Water Year


American River at Fair Oaks Maximum 3-day Flow Each Winter (Daily Average) Adjusted Natural Flow
(versus Southern Oscillation Index for prior June - November)
Maximum 3-Day-Average Winter Flow (KCFS)
180
160
140
120
100
80
60
40
20
0
85-86
96-97
64-65
55-56
50-51
Years used
1933/34 thru
1999/00.
Correlation
r = + 0.21
Biggest floods on American River are in La Nina or No Nino winters.
44.3
36.3 (All years)
27.4
−3
−2.5
−2
−1.5
−1
−.5
0
.5
1
1.5
2
2.5
3
JUNE–NOVEMBER SOI (TAHITI MINUS DARWIN)
<---------- El Nino | neither | La Nina ---------->
Western Regional Climate Center

So, is Nevada/California warming, … or not ???



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



Western Regional Climate Center

Historical Climate Information
Western U.S. Historical Summaries; Precipitation Maps; Station Inventories; Wind and Evaporation Data; Coastal Water Table; State Narratives; Station Descriptions; Anomalies.

Current Observations, Forecasts and Monitoring
Nat'l Weather Service Current and Past 24-hour Reports; Snotel; Climate Prediction Center Outlooks; Satellite and Radar Imagery; SPI; Anomalies; Divisional Climate Plots; ACIS; CoCoRaHS.

WRCC Projects
El Nino & La Nina; CEMP; WET; BLM RAWS; Yucca Mtn; Current Weather Plots; NSOE; Snotel; CoCoRaHS; California Climate Data Archive; Photo Gallery; Webcam; WxCoder

More Climate Information
Solar Radiation; Sunrise/Sunset Information (USNO); WGA data and information; Nat'l Climatic Data Center; Climate Prediction Center; CEFA; Nat'l Drought Mitigation Center.

Educational and Travel Pages
Terms; More about Weather and Climate - for teachers and kids! Climate for resorts and Nat'l parks around the West.

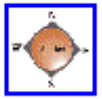
About the WRCC
Staff; Funding; Overview of WRCC; DRI Home Page; INTERNAL.

WRCC Supports a Three-Partner National Climate Services Program - the Partners Include:
National Climatic Data Center (NCDC), Regional Climate Centers (RCC's), and State Climate Offices.

Western Regional Climate Center

WRCC Projects


Community Environmental Monitoring Program (CEMP)
Data Monitoring Stations surrounding the NV test site.


Wind Energy Assesment for Nevada
Nevada Wind Study Towers.

RAWS Data (Remote Automated Weather Stations)
Summaries, Graphs, and other products for RAWS.

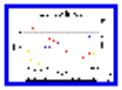
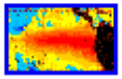
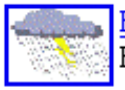

Current Weather Data Plots
Current Data Plots


Photo Galley of the Western States:
Landscapes; Sunrise, Sunset and Lunar; and Misc.


El Nino/La Nina and the Western US, Alaska and Hawaii
Information regarding El Nino and La Nina.

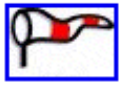

Yucca Mountain Climate Data Project
Climate Data from Yucca Mountain, Nevada.


Naval Air Warfare Center (NAWC) Pt. Mugu stations
Stations operated by the Naval Air Warfare Center. Pt. Mugu Handar stations.


Reno Area Weather Network
Reno Area weather/climate summaries

CoCoRaHS - Community Collaborative Rain, Hail and Snow Network

Washoe Evapotranspiration Project (WET)
Weather Stations that Monitor Evapotranspiration Rates.


NSOE - Anemometer Loan Program
Wind Resource Potential in Nevada


Snotel Data
Listings, Narratives, Maps and Station Conditions


National Parks RAWS page
RAWS Projects in the National Parks

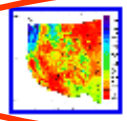

Current Webcam View from DRI-NNSC
View from the WRCC office


California Climate Data Archive
California Climate Information and Data (Scripps and CEC)

Nevada Test Site /NOAA/ARL/SORD/ MEDA Data Project
Climate Data from Nevada Test Site.


California Climate Tracker
Tracking Climate Variability and Change for the state of California.


Nevada Climate Tracker
Tracking Climate Variability and Change for the state of Nevada.
NEW


Westmap Climate Project
The Western Climate Mapping Initiative.
NEW

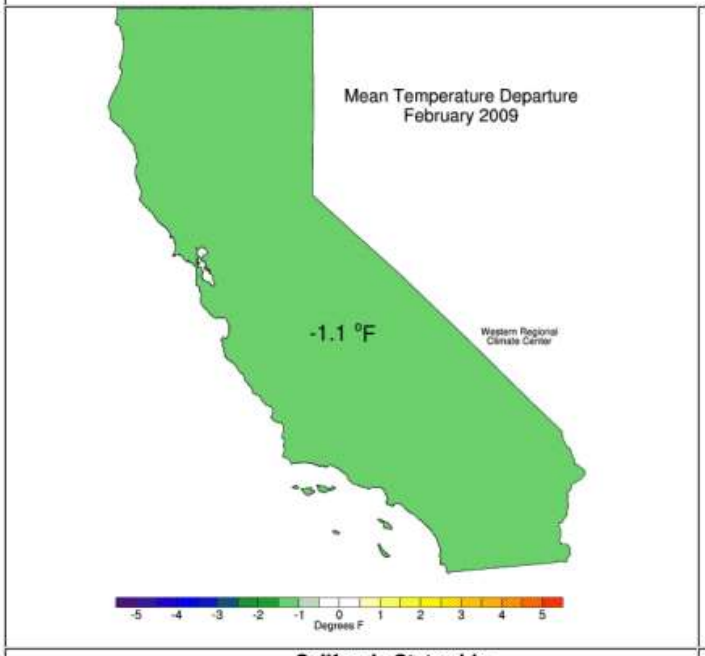
California Climate Tracker

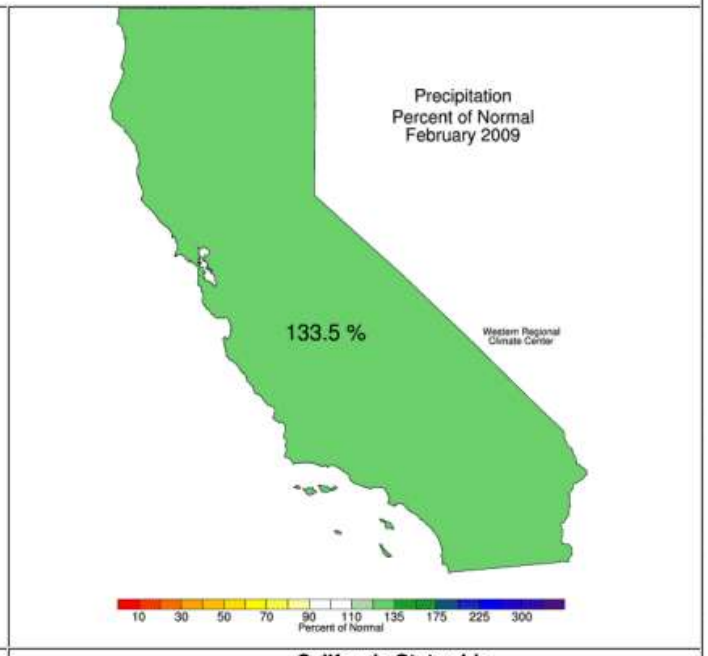
Tracking Climate Variability and Change for the State

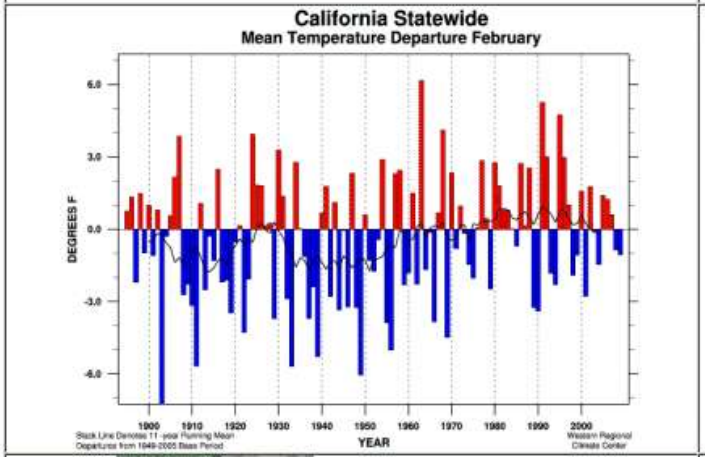
Much appreciation
to
John Abatzoglou

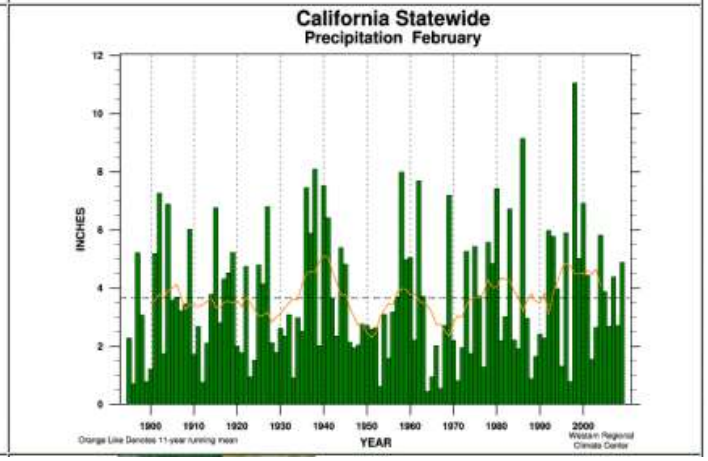
Explore Climate Products

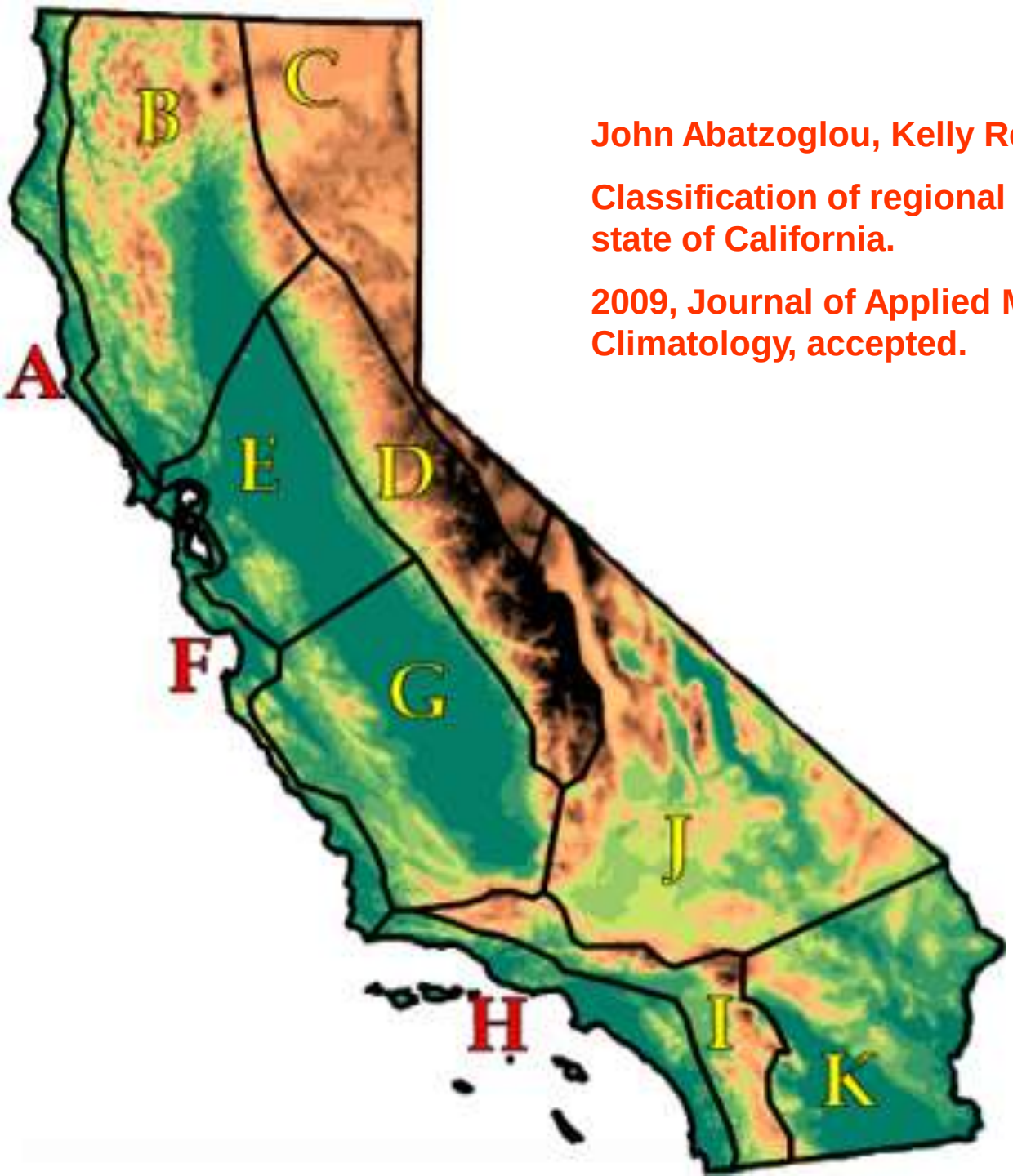
FEBRUARY 2009











John Abatzoglou, Kelly Redmond, Laura Edwards.

Classification of regional climate variability in the state of California.

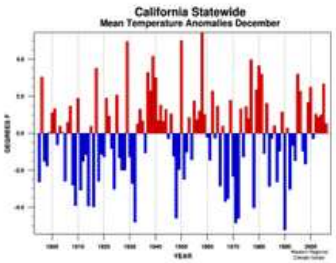
2009, Journal of Applied Meteorology and Climatology, accepted.

California Climate Tracker

Select from the Menu to the Right

Latest Graphics

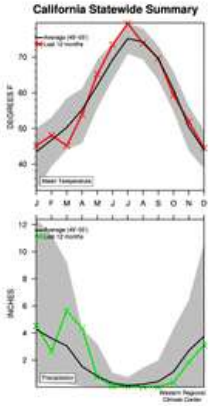
Time Series



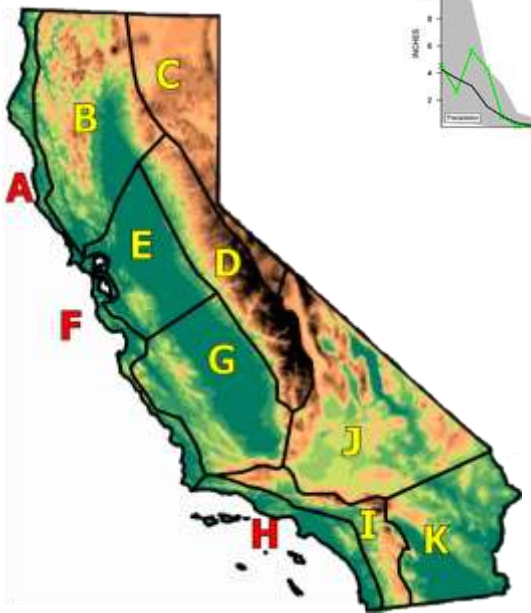
Latest Graphics
Select Region
Select Element
Select Data Type
Select Time Period
Select

Time Series
Select Region
Select Element
Select Time Period
Select

Last 12 Months



- Climate region data: 1895 to present
- Averages taken from: 1949-2005



Time Series
Sierra
Select Region
Statewide
Sierra
Northeast
North Central
Sacramento-Delta
San Joaquin Valley
North Coast
Central Coast
South Coast
South Interior
Mohave
Sonoran

Time Series
Select Region
Select Element
Select Element
Maximum Temperature
Minimum Temperature
Mean Temperature
Precipitation
Temperature Summary

Time Series
Select Region
Select Element
Select Time Period
March
April
May
June
July
August
September
October
November
December
Winter (DJF)
Spring (MAM)
Summer (JJA)
Autumn (SON)
Calendar Year (Jan-Dec)
Water Year (Oct-Sep)
Water Year (Jul-Jun)
January to Present
October To Present
July To Present

Summary of the Past 12 Months
Select Region
GO

Climate Regions
Plot Data

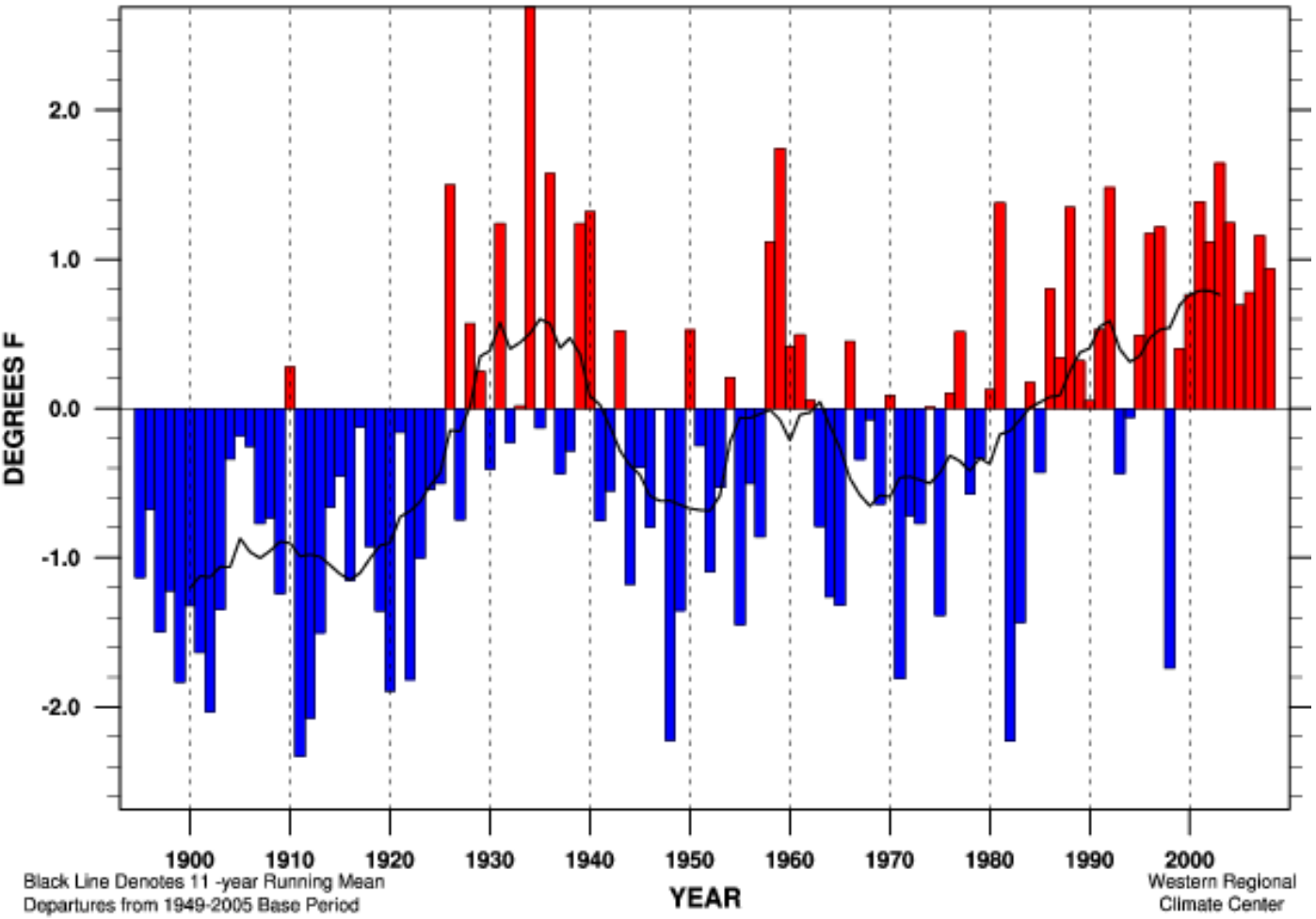
More Info
Retrieve Data

Back to the California Climate Tracker
Non-Frames Version

Western Regional Climate Center
DRI Desert Research Institute
Powered by ACIS NOAA Regional Climate Centers

Sierra Region

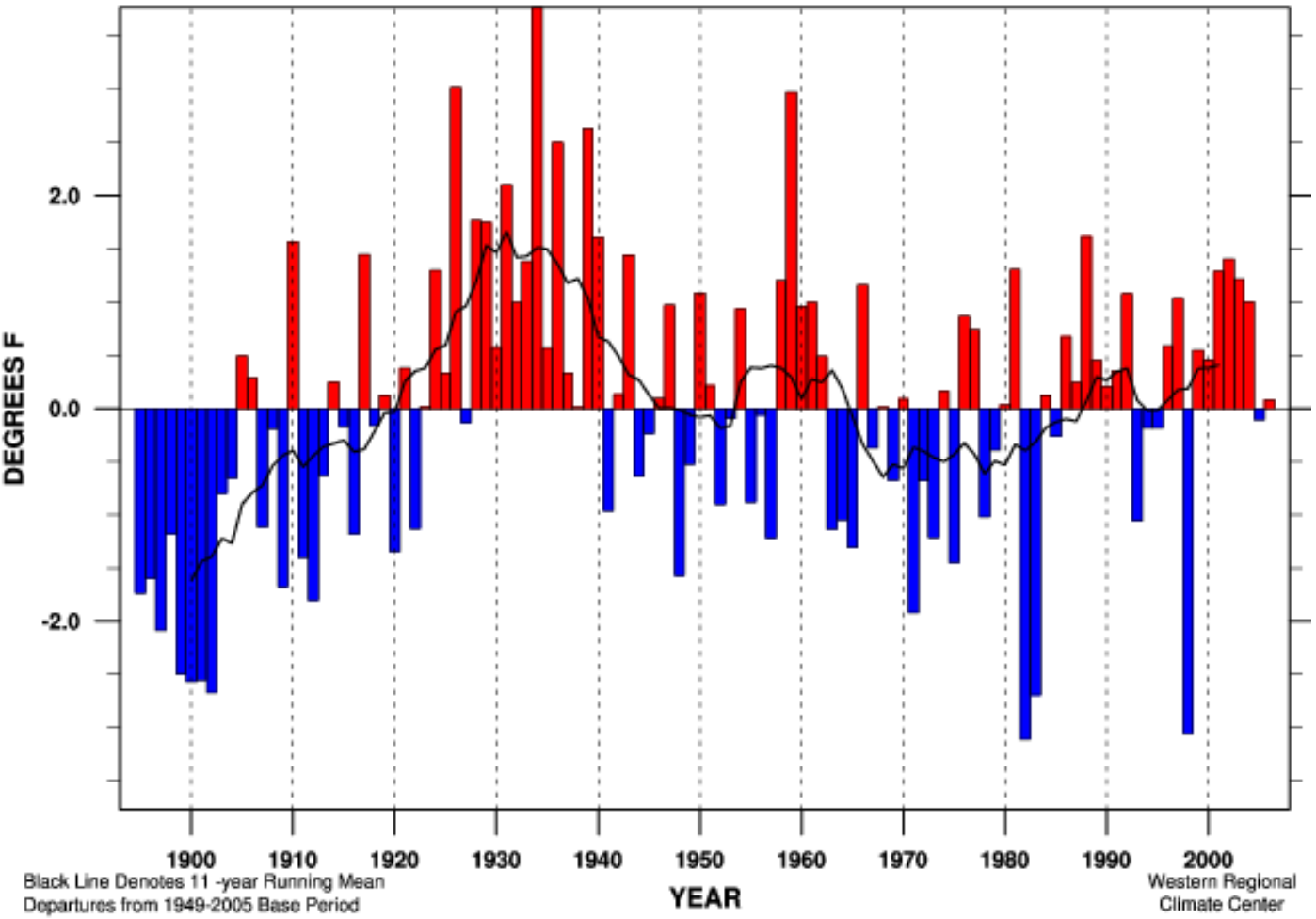
Mean Temperature Departure Jan-Dec



Linear Trend 1895-present		+ 1.44 ± 0.52 °F/100yr	
Linear Trend 1949-present		+ 2.46 ± 1.30 °F/100yr	
Linear Trend 1975-present		+ 4.83 ± 3.02 °F/100yr	
Warmest Year		51.7 °F (+ 2.7 °F) in 1934	MEAN 49.0 °F
Coldest Year		46.7 °F (- 2.3 °F) in 1911	STDEV 0.97 °F
Jan-Dec	2008	50.0 °F (+ 0.9 °F)	RANK 96 of 114

Sierra Region

Maximum Temperature Departure Jan-Dec



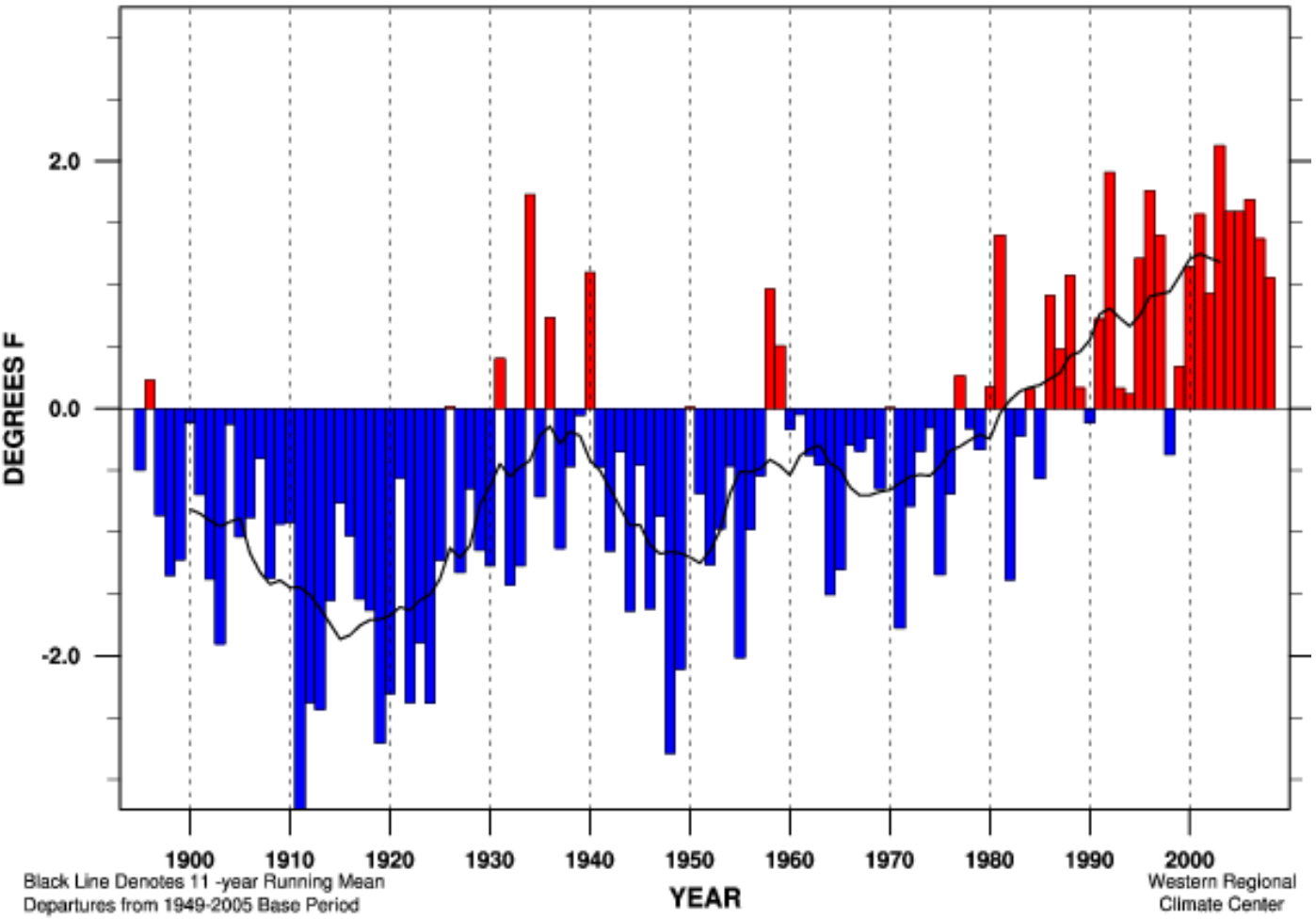
Black Line Denotes 11 -year Running Mean
Departures from 1949-2005 Base Period

Western Regional
Climate Center

Linear Trend 1895-present		+ 0.69 ± 0.77 °F/100yr	
Linear Trend 1949-present		+ 0.56 ± 1.82 °F/100yr	
Linear Trend 1975-present		+ 3.47 ± 4.72 °F/100yr	
Warmest Year		67.0 °F (+ 3.7 °F) in 1934	MEAN 63.2 °F
Coldest Year		60.1 °F (- 3.1 °F) in 1982	STDEV 1.33 °F
Jan-Dec	2006	63.3 °F (+ 0.1 °F)	RANK 56 of 112

Sierra Region

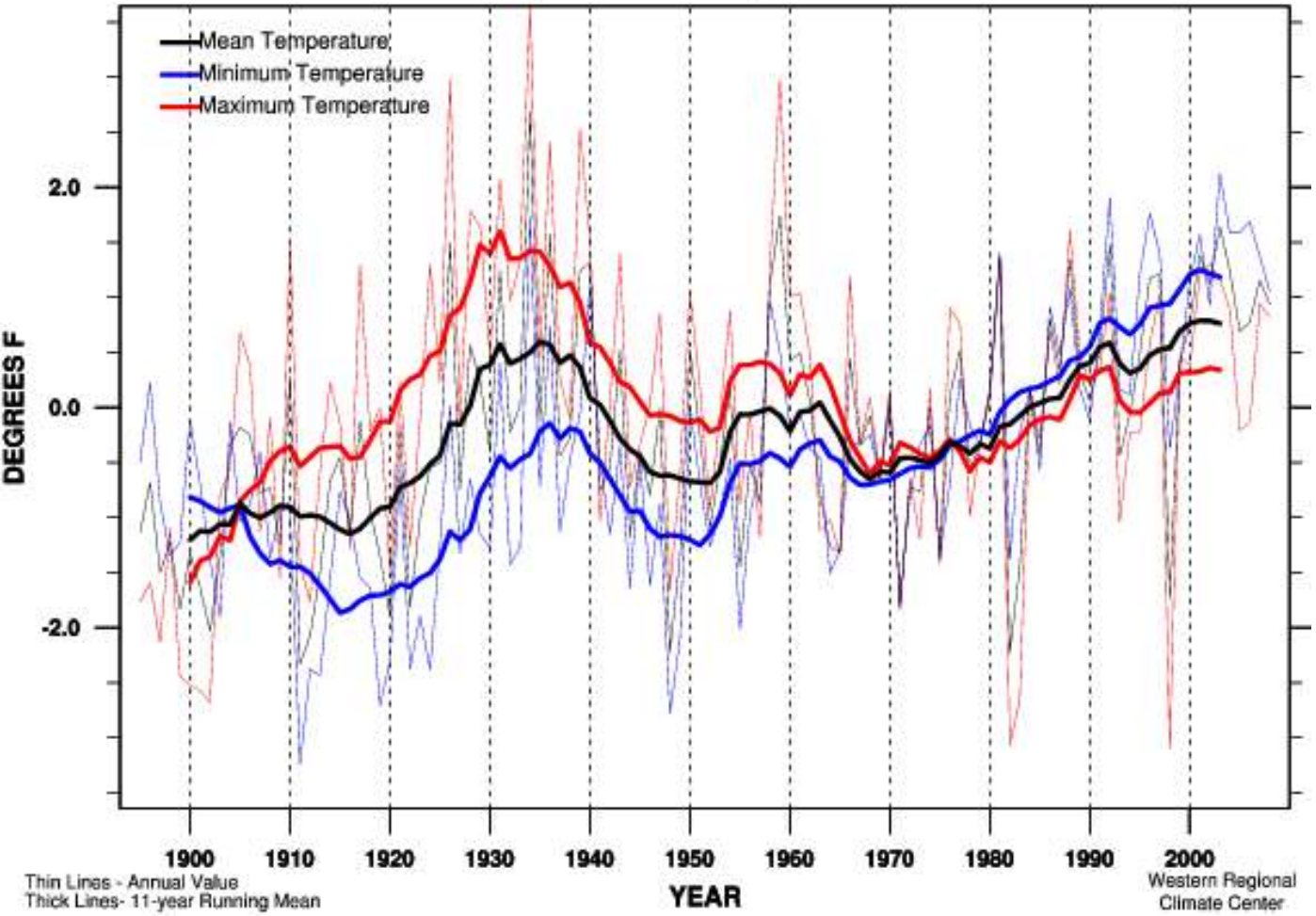
Miniumum Temperature Departure Jan-Dec



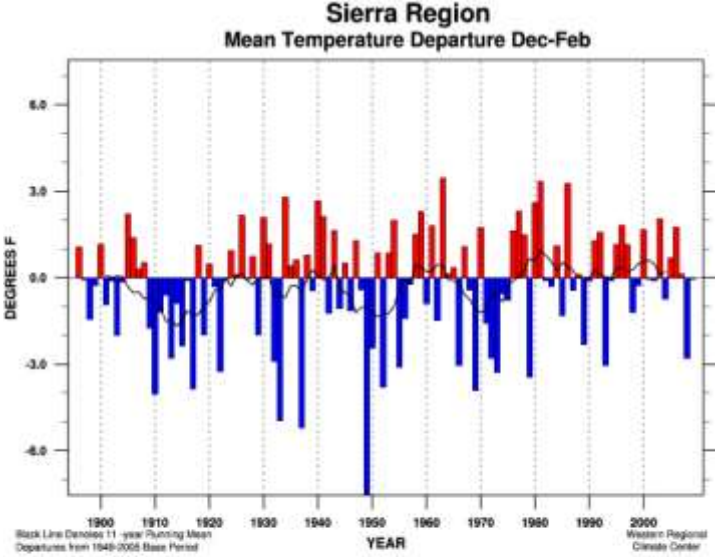
Linear Trend 1895-present		+ 2.15 ± 0.51°F/100yr	
Linear Trend 1949-present		+ 4.26 ± 1.07°F/100yr	
Linear Trend 1975-present		+ 6.40 ± 2.41°F/100yr	
Warmest Year		38.7 °F (+ 2.1°F) in 2003	MEAN 36.5 °F
Coldest Year		33.3 °F (- 3.2 °F) in 1911	STDEV 1.03 °F
Jan-Dec	2008	37.6 °F (+ 1.1°F)	RANK 99 of 114

Sierra Region

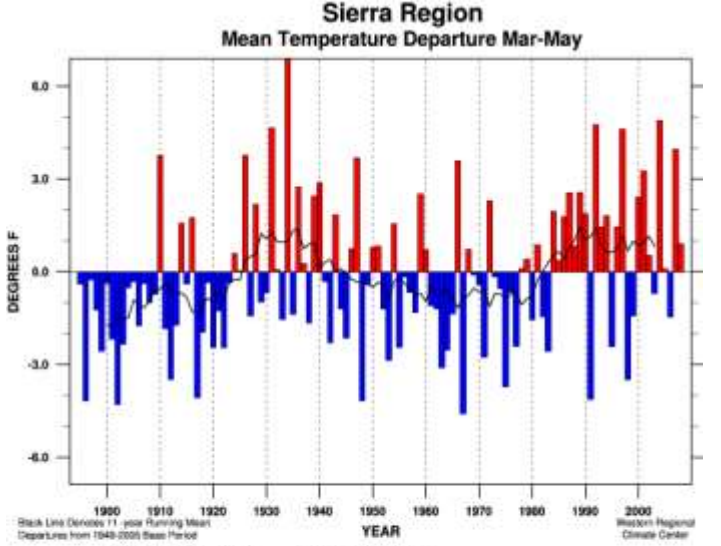
Temperature Departure Jan-Dec



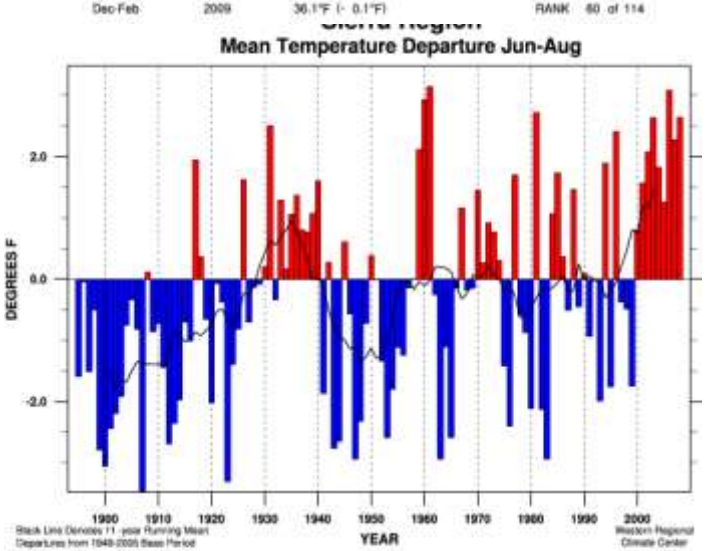
	Maximum Temperature	Minimum Temperature
Linear Trend 1895-present	+ 0.74 (± 0.73) °F/100yr	+ 2.15 (± 0.51) °F/100yr
Linear Trend 1949-present	+ 0.65 (± 1.70) °F/100yr	+ 4.26 (± 1.07) °F/100yr
Linear Trend 1975-present	+ 3.25 (± 4.13) °F/100yr	+ 6.40 (± 2.41) °F/100yr



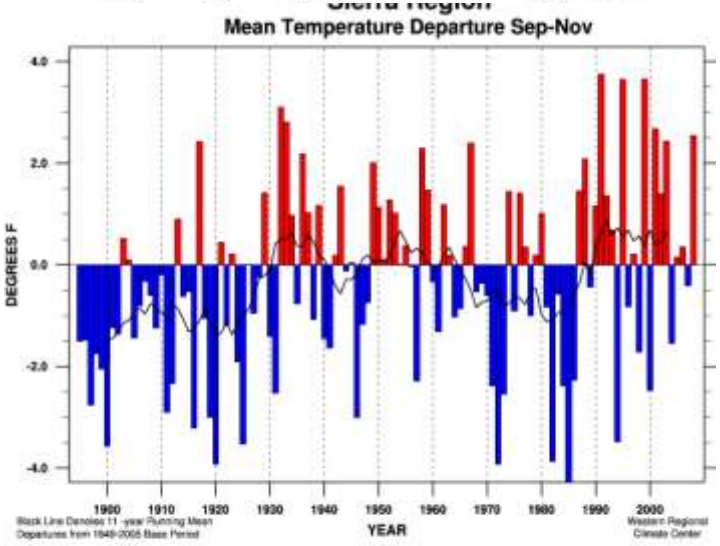
Winter



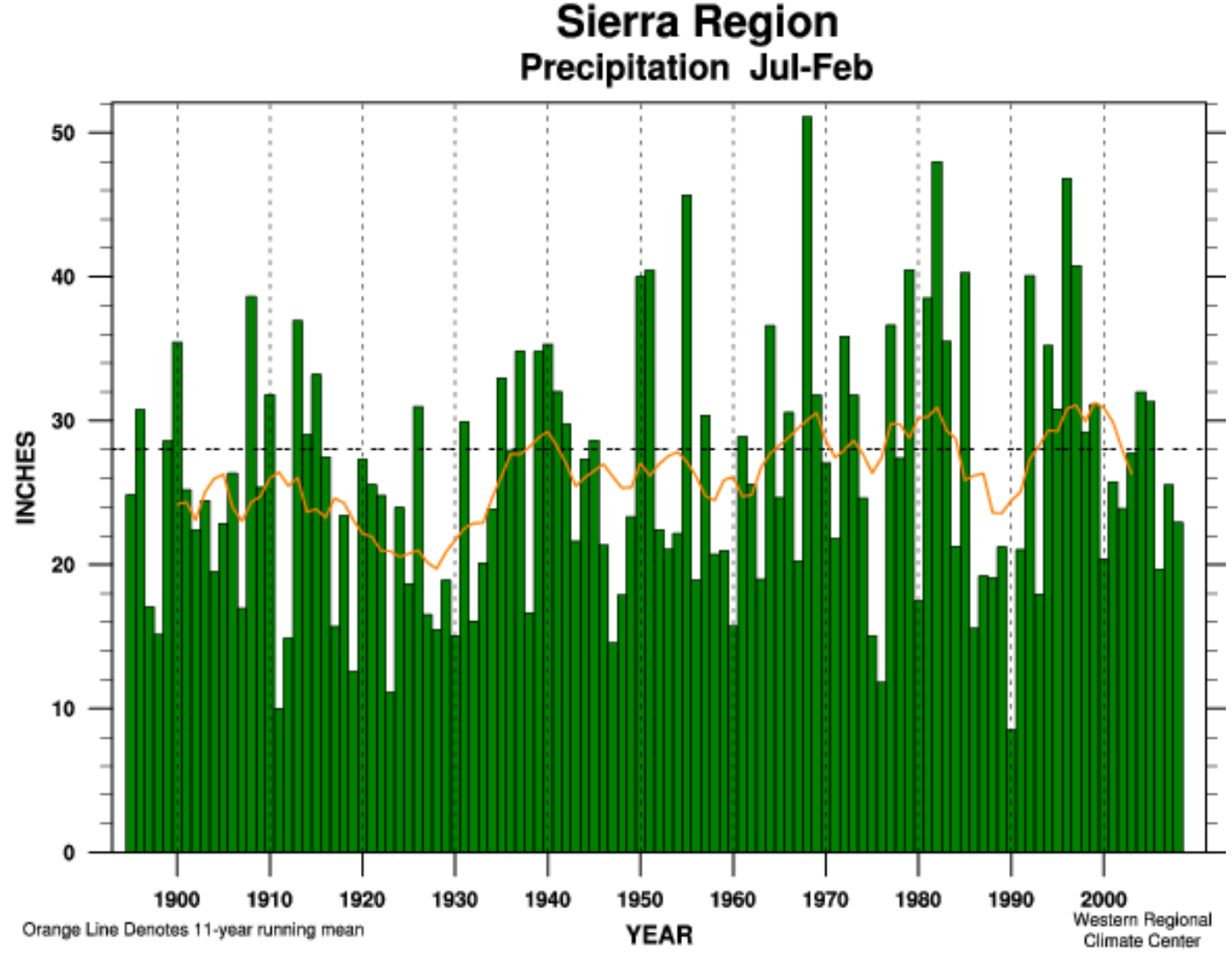
Spring



Summer



Autumn

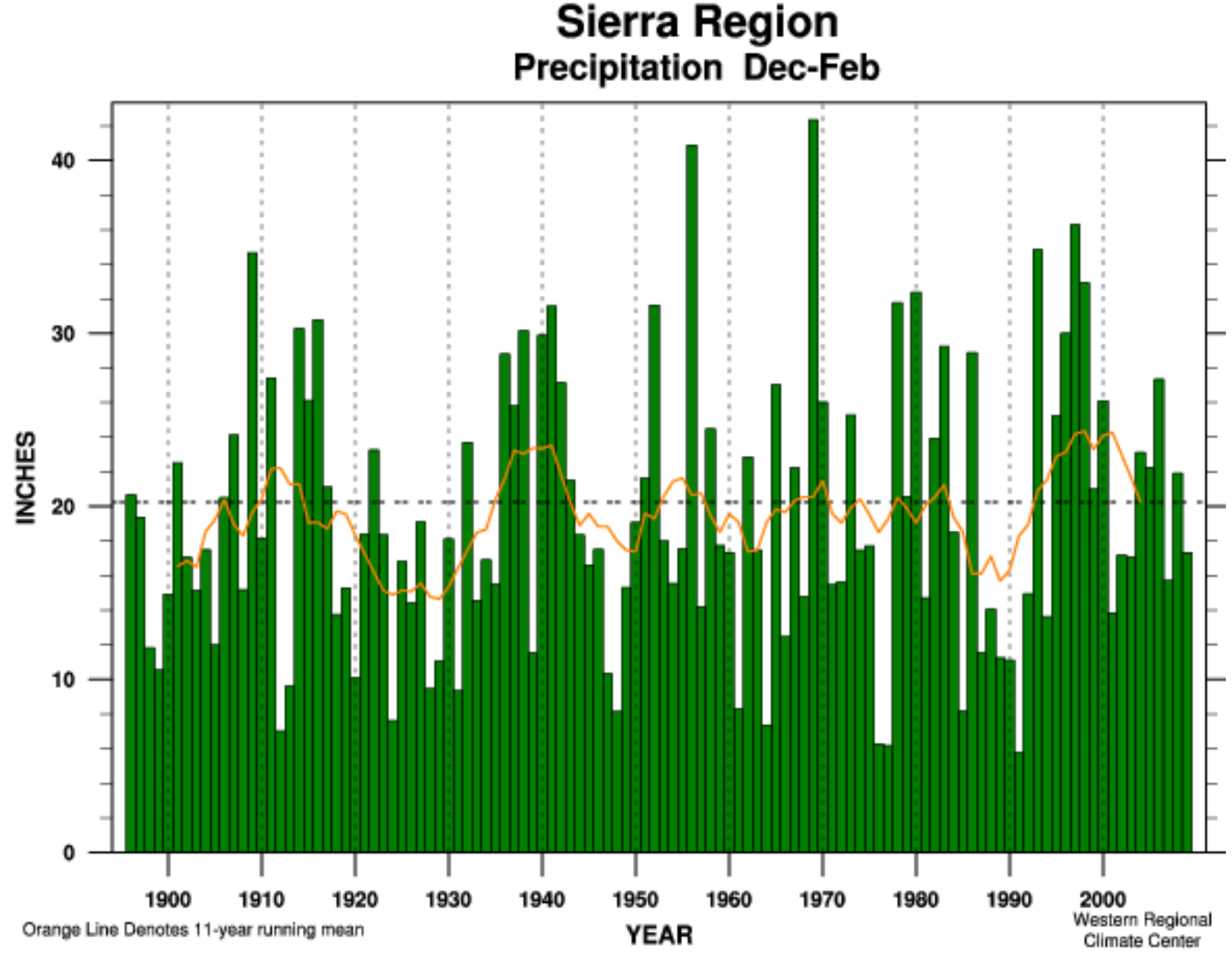


Linear Trend 1895-present	+ 4.79 ± 4.77 in.	(+ 17 ± 17%) per 100 yr	
Linear Trend 1949-present	- 0.63 ± 13.86 in.	(- 2 ± 49%) per 100 yr	
Linear Trend 1975-present	+ 0.99 ± 34.29 in.	(+ 3 ± 122%) per 100 yr	
Wettest Year	51.10 in. (182%)	in 1968	MEAN 28.03 in.
Driest Year	8.52 in. (30%)	in 1990	STDEV 9.69 in.
Jul-Feb 2008	22.92 in. (81%)		RANK 47 of 114

Precipitation Season To Date

July 1 to Feb 28

1895-96 Thru 2008-09



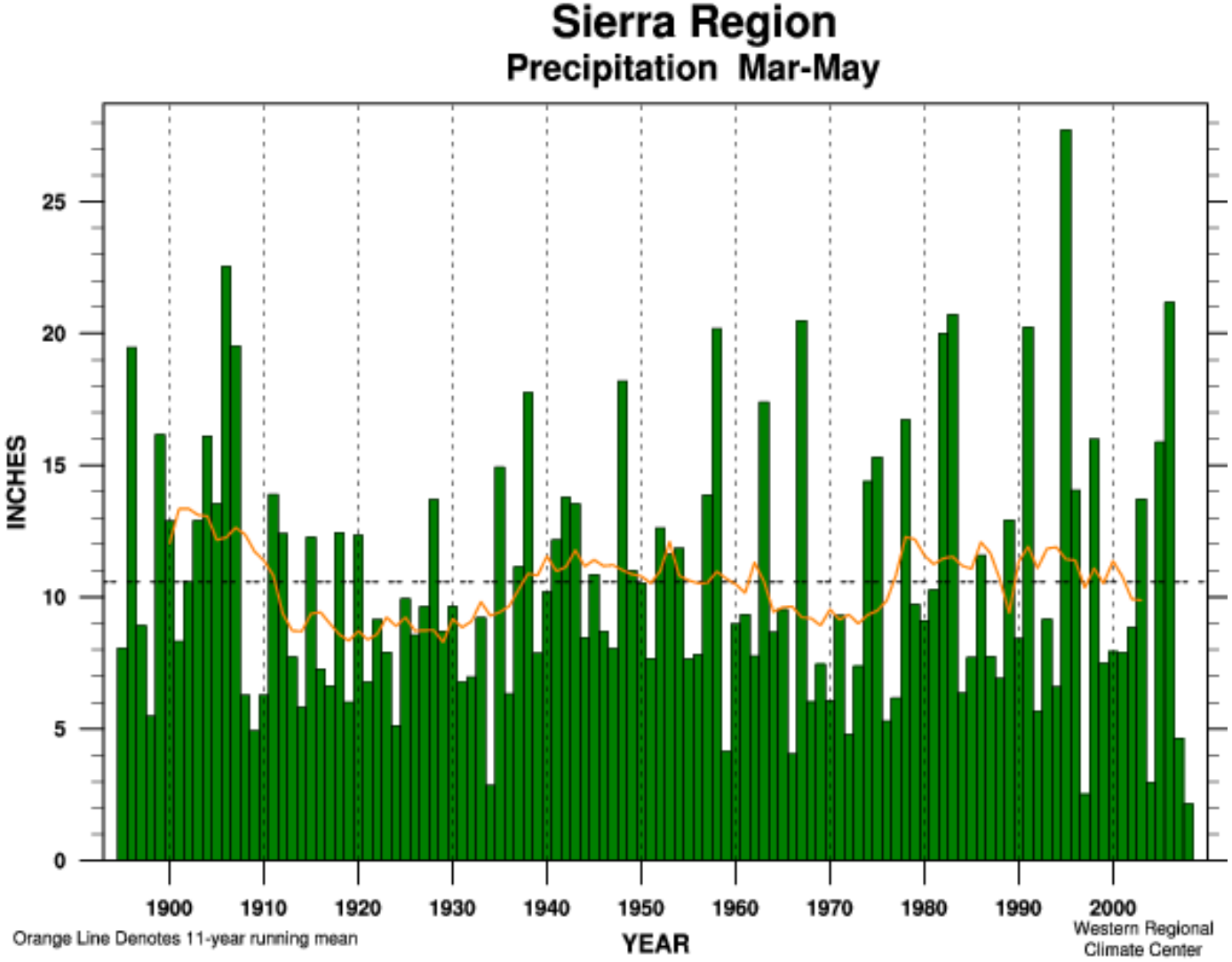
Linear Trend 1895-present	+ 2.78 ± 4.41 in.	(+ 13 ± 21%) per 100 yr	
Linear Trend 1949-present	+ 1.40 ± 12.76 in.	(+ 6 ± 63%) per 100 yr	
Linear Trend 1975-present	+13.81 ± 31.15 in.	(+ 68 ± 153%) per 100 yr	
Wettest Year	42.34 in. (209%)	in 1969	MEAN 20.23 in.
Driest Year	5.75 in. (28%)	in 1991	STDEV 8.68 in.
Dec-Feb 2009	17.34 in. (85%)		RANK 51 of 114

Sierra Nevada

Winter Precipitation

DJF

1895-96 Thru 2008-09



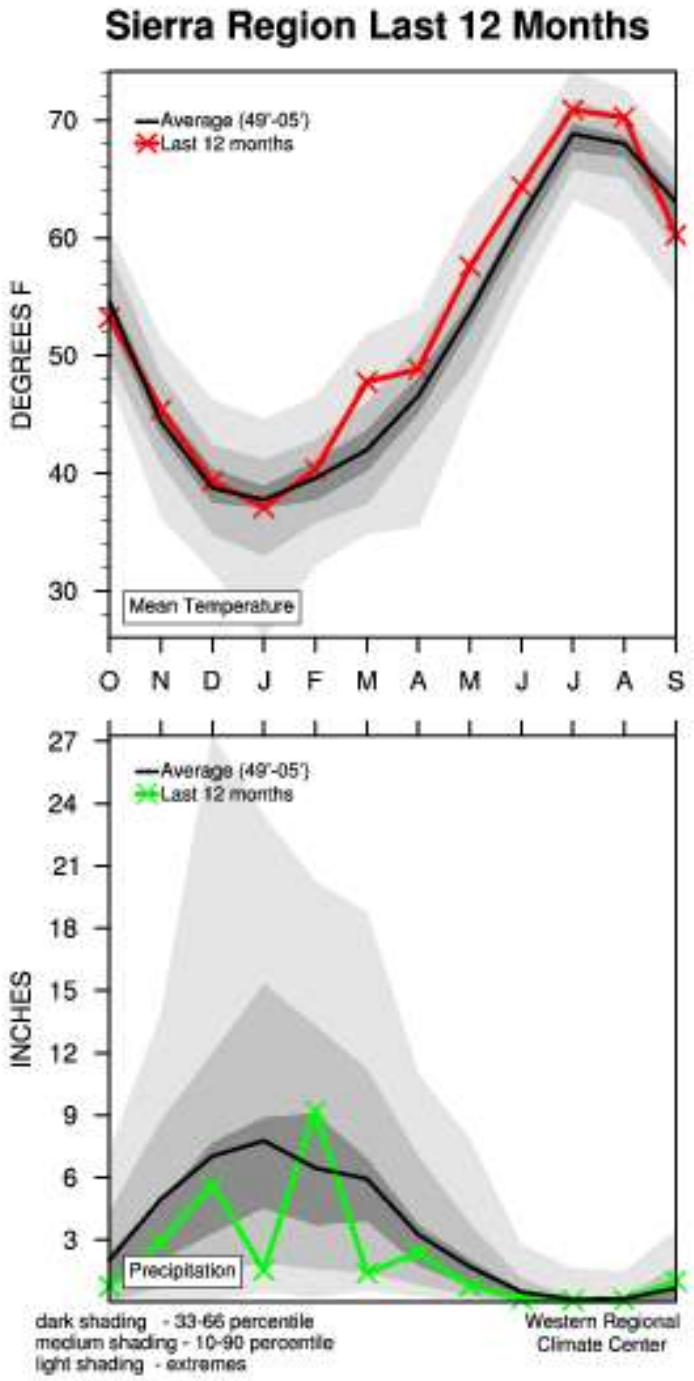
Linear Trend 1895-present	- 0.22 ± 2.75 in.	(- 2 ± 26%) per 100 yr	
Linear Trend 1949-present	+ 0.22 ± 8.14 in.	(+ 2 ± 77%) per 100 yr	
Linear Trend 1975-present	- 6.09 ± 21.96 in.	(- 57 ± 207%) per 100 yr	
Wettest Year	27.73 in. (262%)	in 1995	MEAN 10.57 in.
Driest Year	2.14 in. (20%)	in 2008	STDEV 5.20 in.
Mar-May 2008	2.14 in. (20%)		RANK 1 of 114

Sierra Nevada

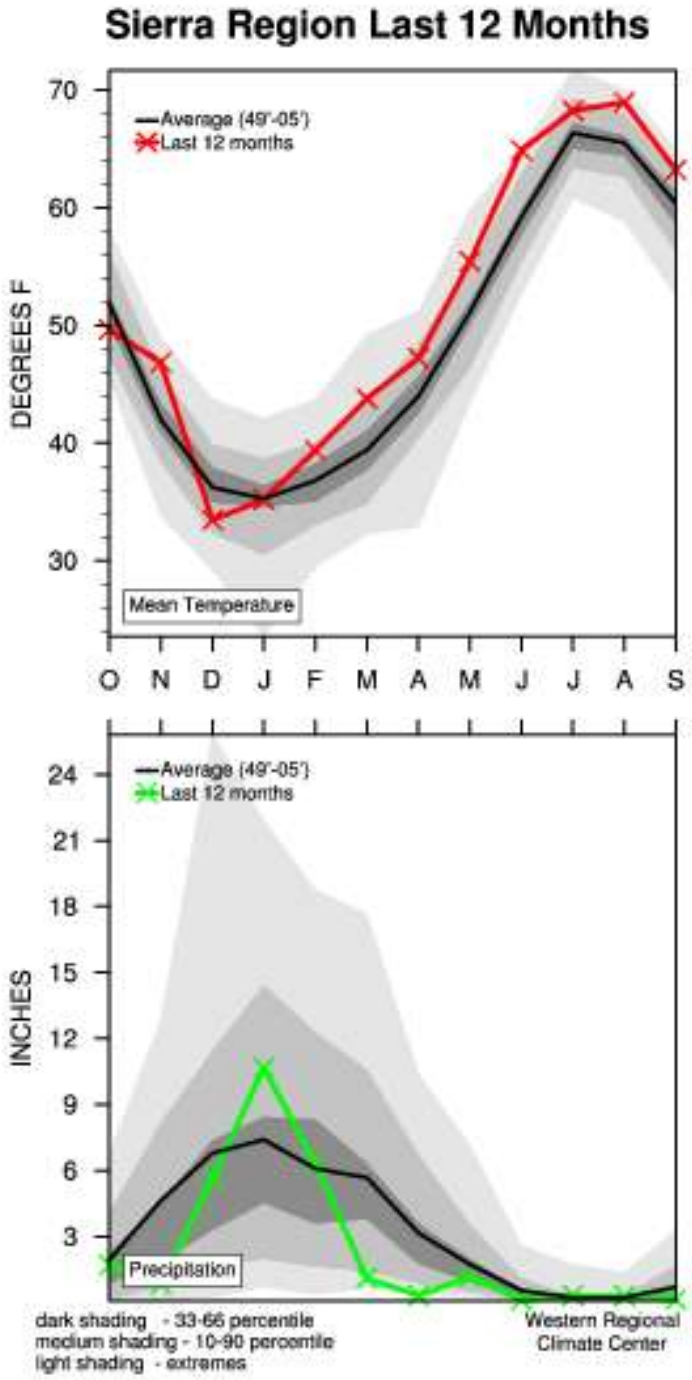
Spring Precipitation

MAM

1895 Thru 2009



Sierra Nevada Precipitation 12 Months Thru September 2007

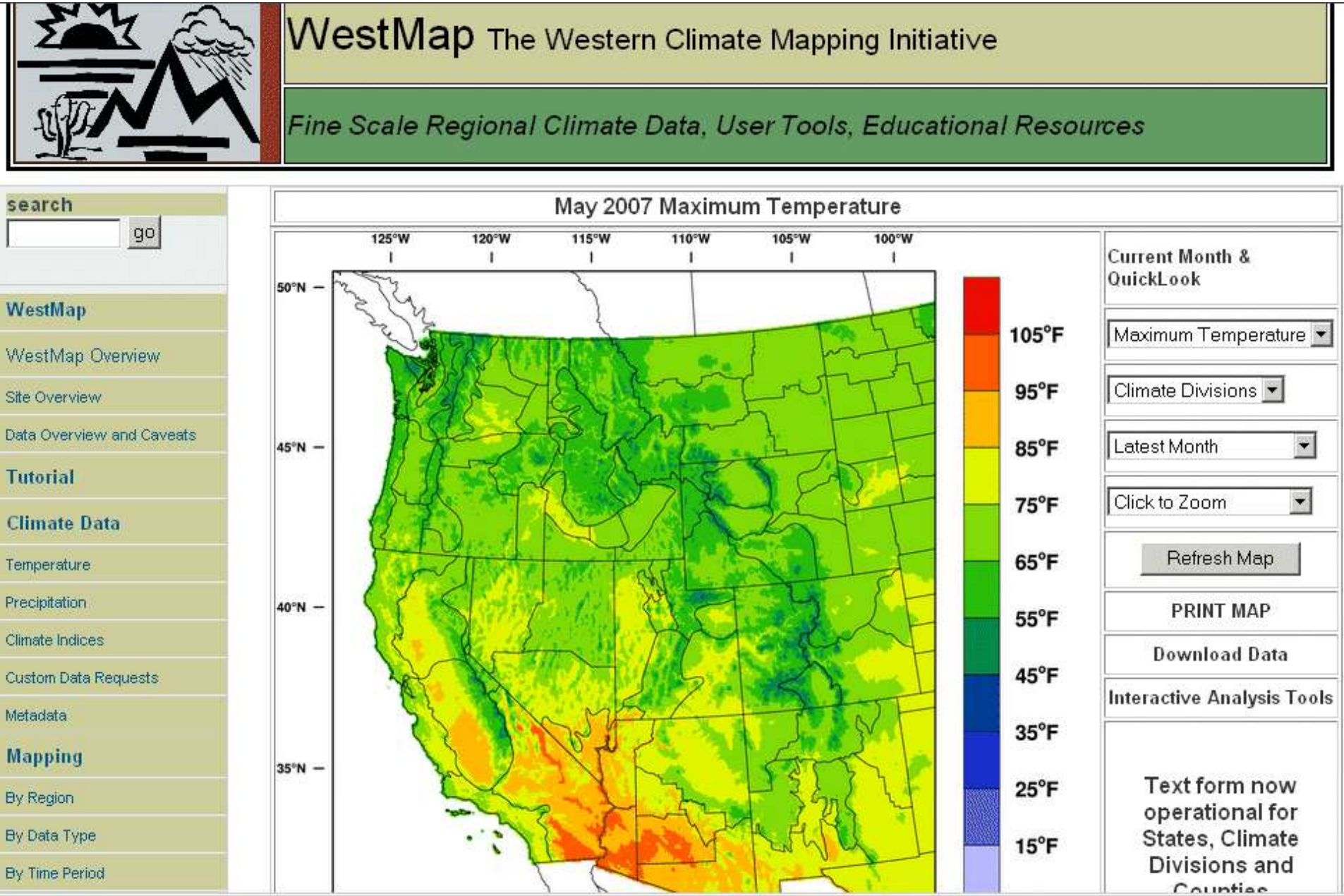


Sierra Nevada Precipitation 12 Months Thru September 2008

A possible analog for climate change ?

Westmap: U Arizona, DRI/WRCC, OSU NOAA – NCTP …CLIMAS/WRCC/CAP

Can be expanded to cover additional states www.wrcc.dri.edu/PROJECTS.html



States, counties, hydro basins, climate divisions, grid squares, stakeholder pixels

Uses 4 km (maybe soon 2 km) PRISM Monthly Time Series 1895 - last month

WestMap The Western Climate Mapping Initiative

Fine Scale Regional Climate Data, User Tools, Educational Resources

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go

WestMap

WestMap Overview

Site Overview

Data Overview and Caveats

Tutorial

Climate Data

Temperature

Precipitation

Climate Indices

Custom Data Requests

Metadata

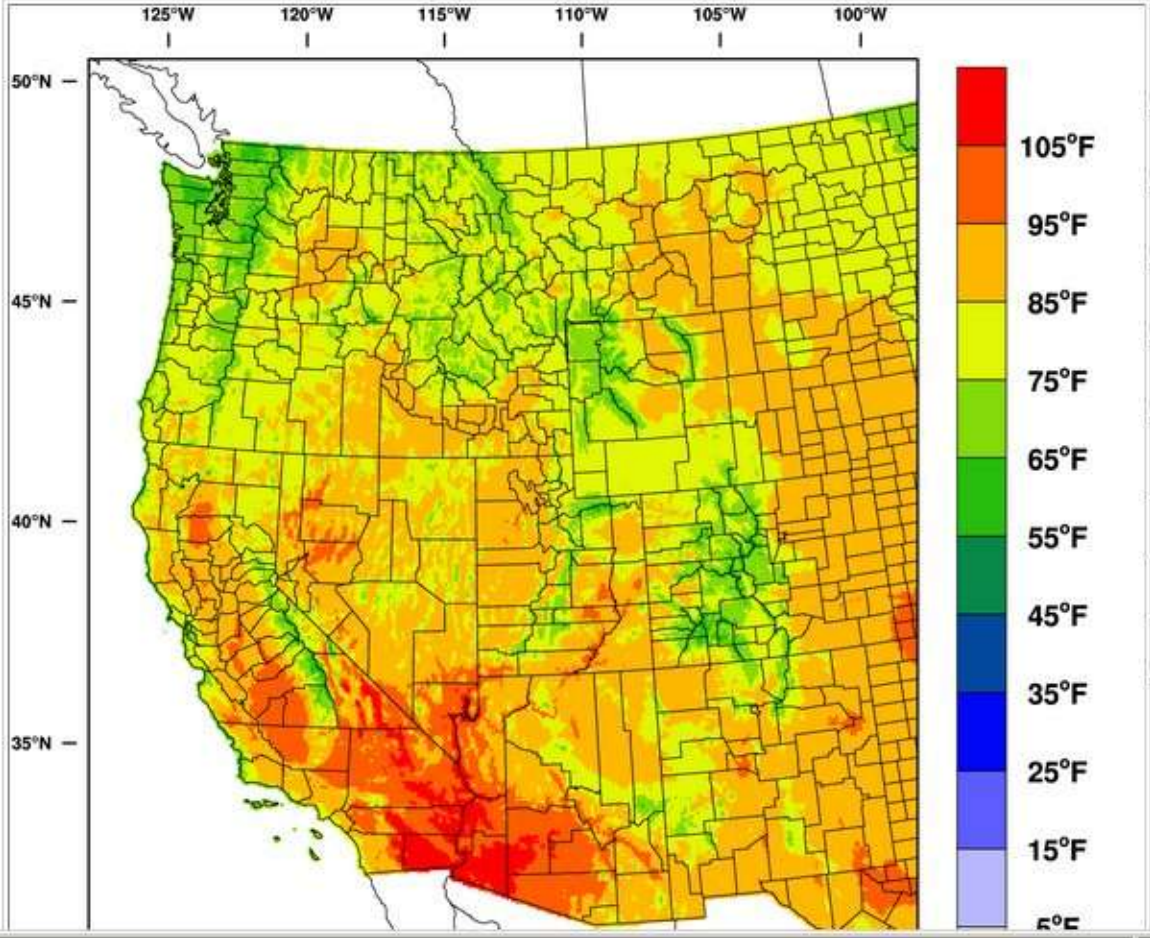
Mapping

By Region

By Data Type

By Time Period

August 2007 Maximum Temperature



Current Month & QuickLook

Maximum Temperature

County

Latest Month

Click to Zoom

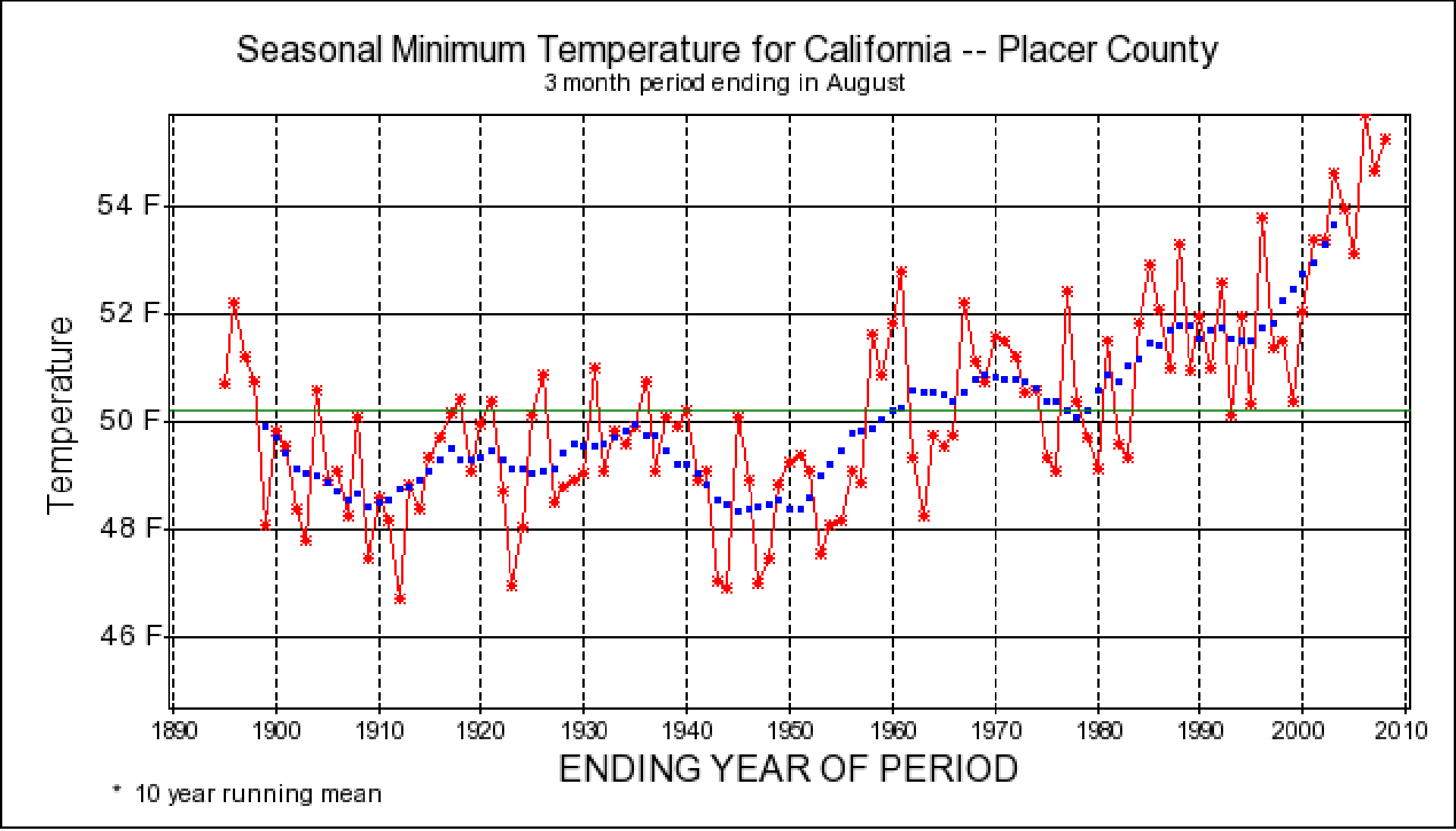
Refresh Map

PRINT MAP

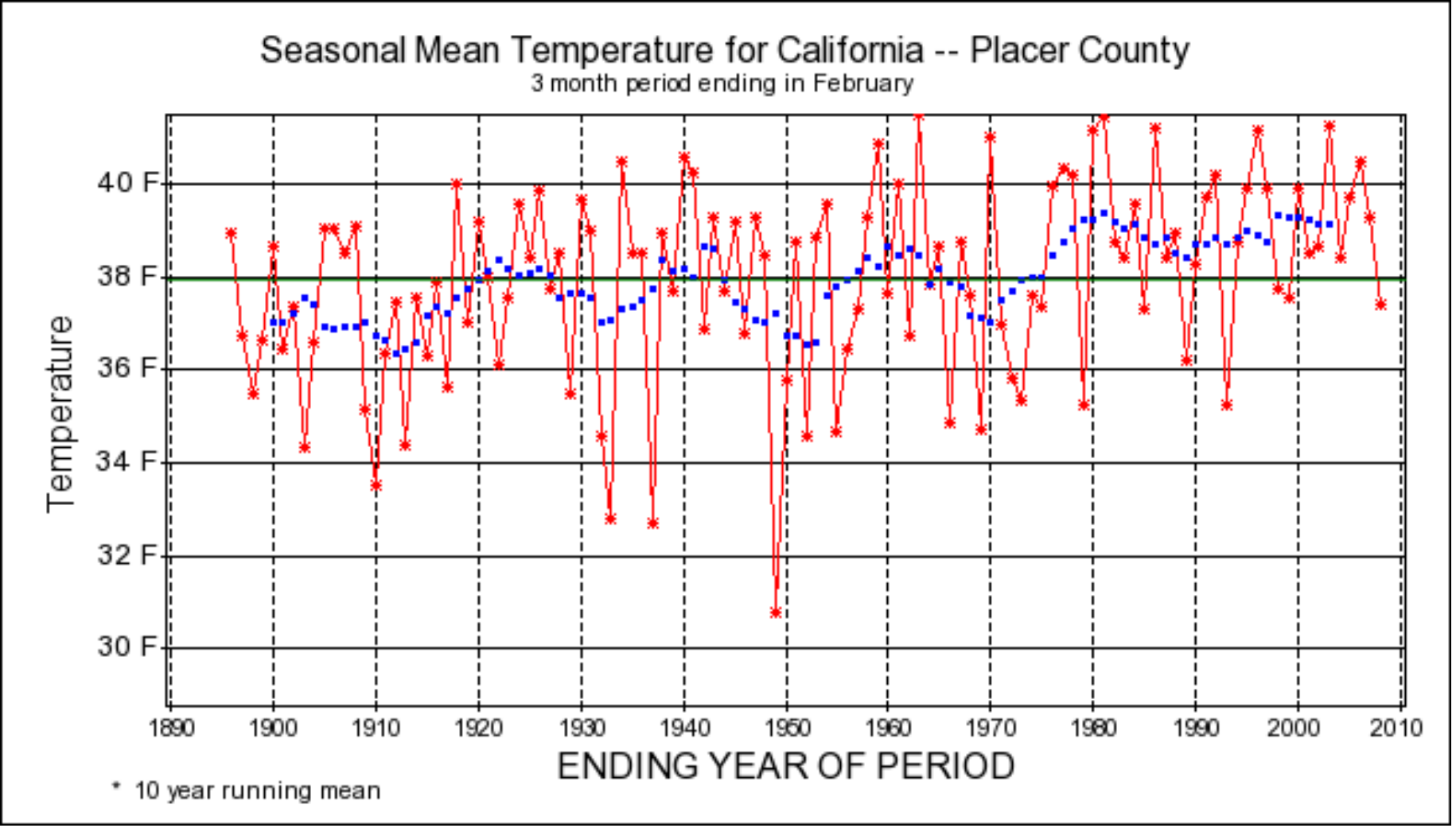
Download Data

Interactive Analysis Tools

Text form now operational for States, Climate Divisions and Counties

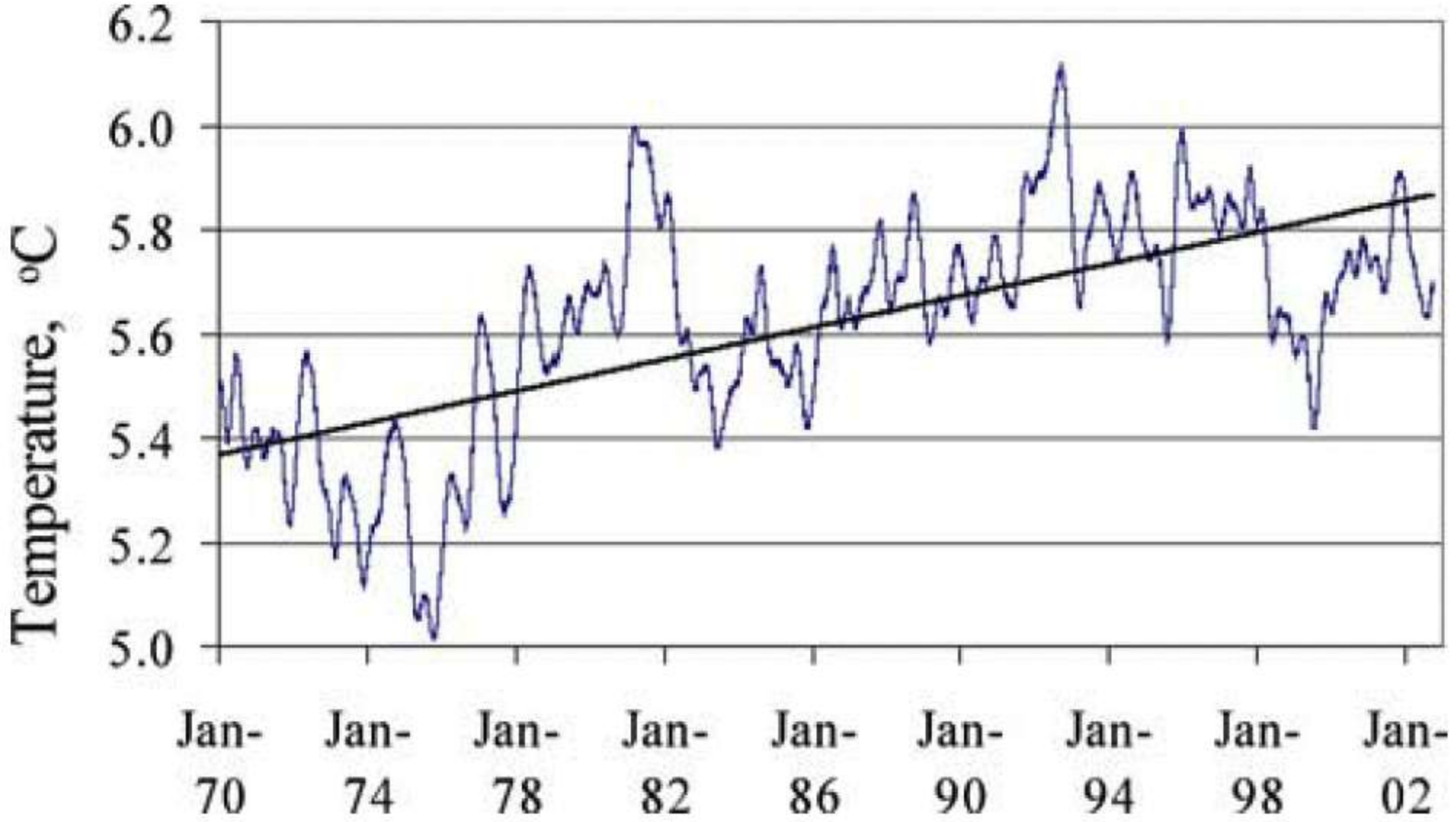


June-July-August 3-month Mean Minimum Temp
Placer County, California
With
10-Year Running Mean
Based on PRISM analysis



Dec-Jan-Feb 3-month Mean Temp
Placer County, California
Through 2009
With
10-Year Running Mean
Based on PRISM analysis

Lake Tahoe Depth-Averaged Temperature



Robert Coats, Joaquim Porez-Losada, Geoffrey Schladow, Robert Richards, Charles Goldman, 2006. The Warming of Lake Tahoe. Climate Change, 76, 121-148. DOI: 10.1007/s10584-005-9006-1

Concluding Comments - 1

Earth

- We are committed to a certain added amount of warming
- On our agenda: Adaptation as well as mitigation

West

- Warming began about middle 1970s (how much might be GHG?)
- Much of US warming is in the West
- Appears to be related to Indian Ocean and Indonesian Warm Pool

Sierra Nevada

- Temperature to rise thru century
  - Summer more than winter, especially later in century
- Precipitation to stay similar to now
  - More in winter, less in spring, summer, autumn
- Precipitation season more "compressed" than now
- Could lead to both more floods and droughts
- Freezing levels to increase
- Except at high elevations, more rain / less snow
- Temperature does matter for hydrology
- Shorter supply season, longer demand season

Concluding Comments - 2

Tahoe Basin

- Difficult to adequately track climate variability and trends
- Climate monitoring not coordinated or systematic
  - Much needed

Monitoring needs

- Adherence to climate monitoring guidelines (not just “weather”)
- Snow-capable precipitation measurements (not easy or cheap)
- Major features
  - The lake (surface and throughout its volume)
    - Lake temperature need not exactly track air temperature
  - The shoreline
  - Middle elevations
  - Around the mountain rim
- Systematic data repository

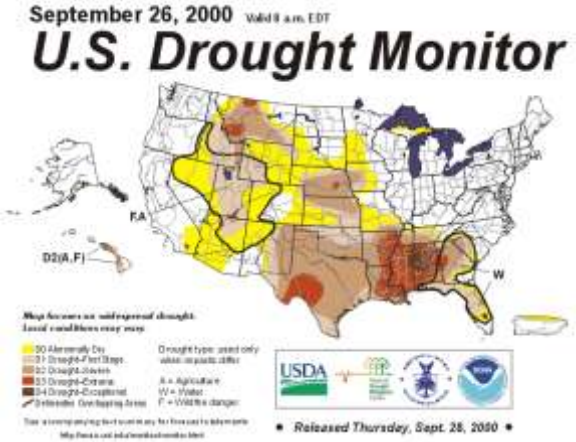
Purpose

- Description of variability, detection of trends
- Calibration of physical and environmental models
- Ground truth for environmental studies
- Assisting with attribution: effects from causes
- fundamental information in wide demand

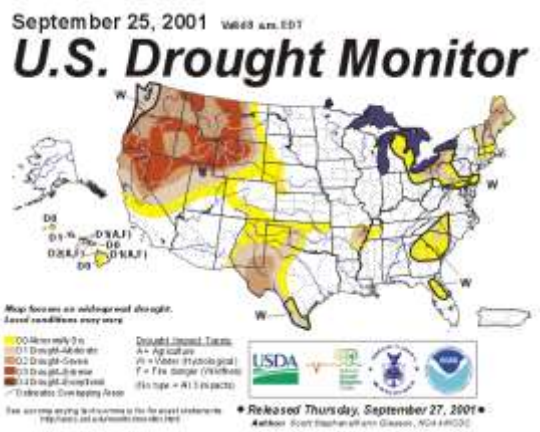

Thank You !

Discards

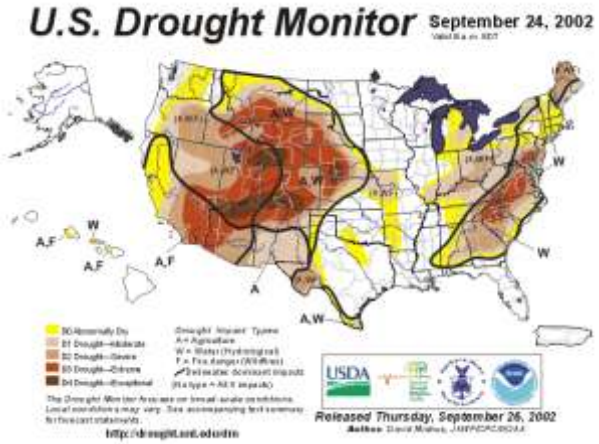
Sep 28, 1999



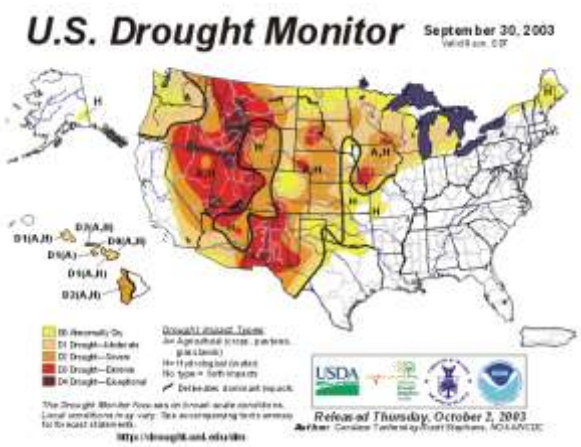
Sep 26, 2000



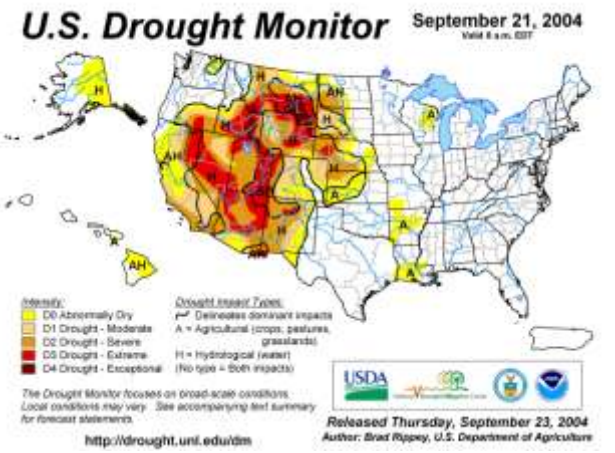
Sep 25, 2001



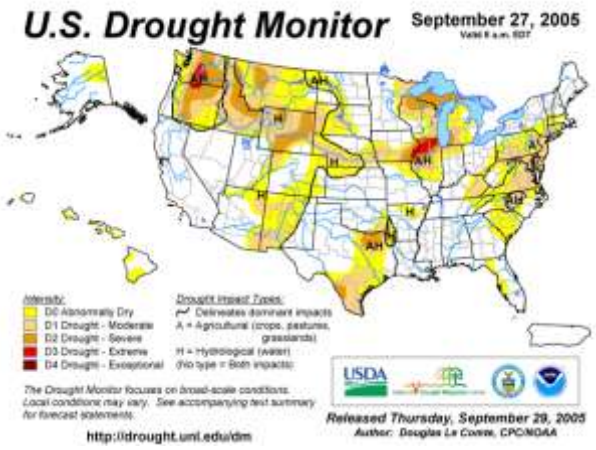
Sep 24, 2002



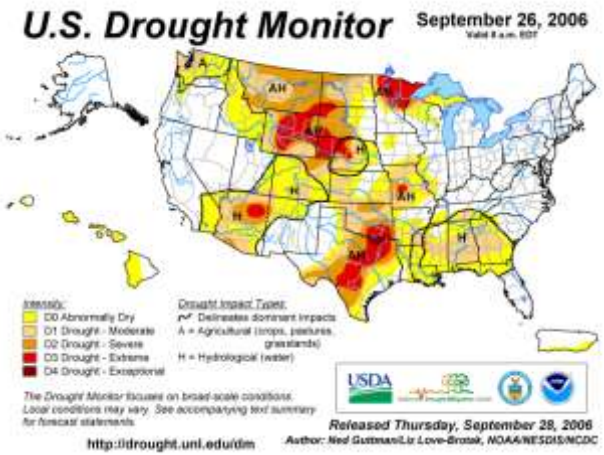
Sep 30, 2003



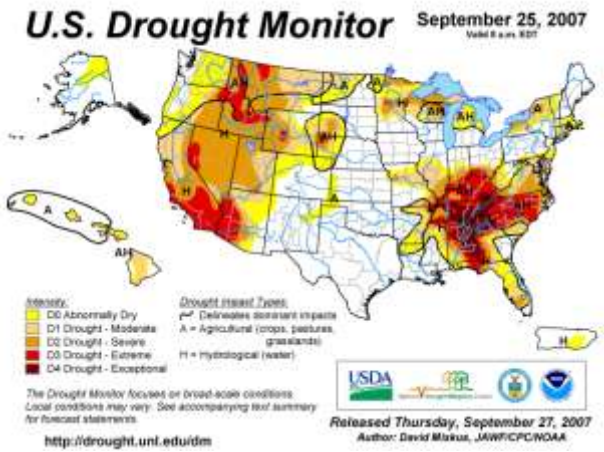
Sep 21, 2004



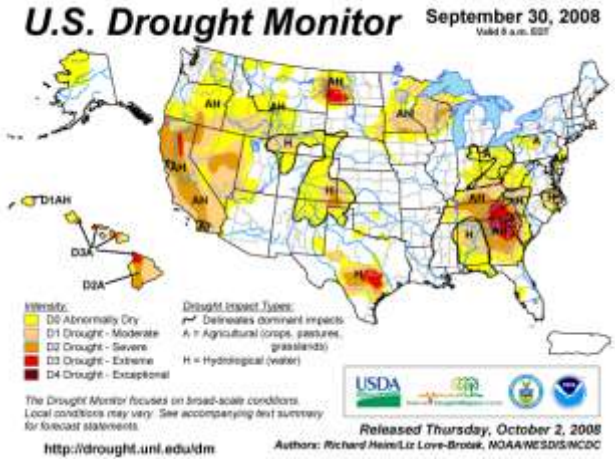
Sep 27, 2005



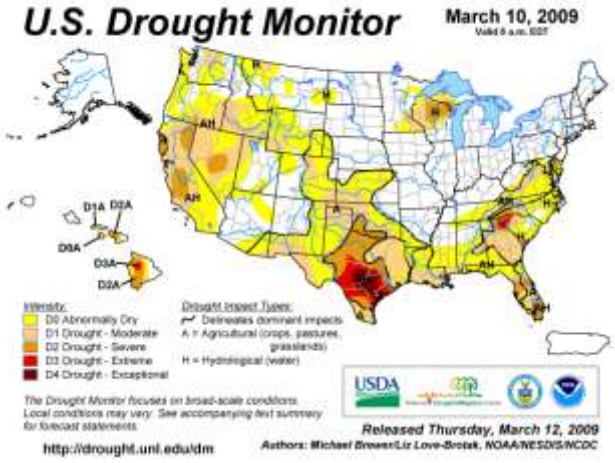
Sep 26, 2006



Sep 25, 2007



Sep 30, 2008

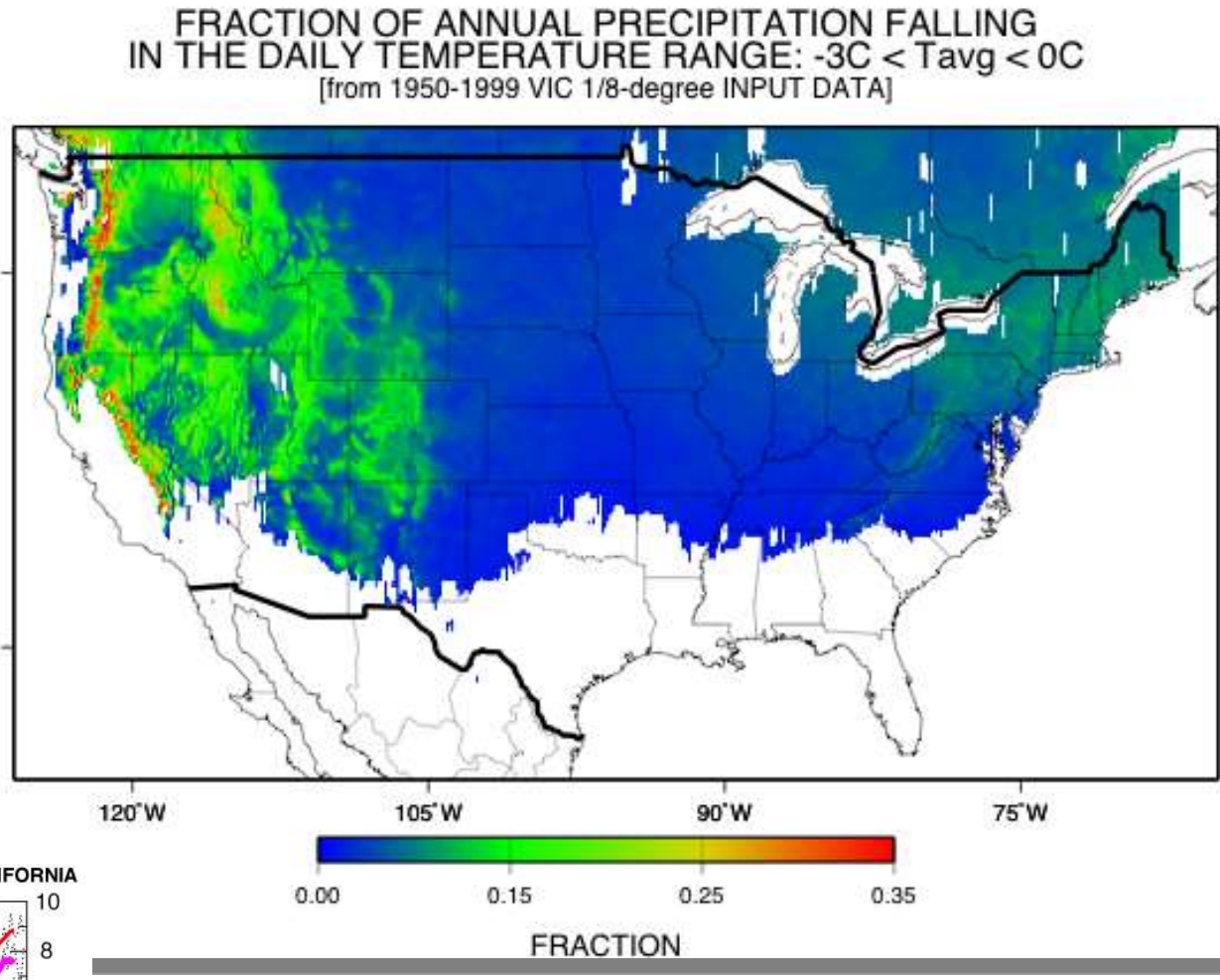


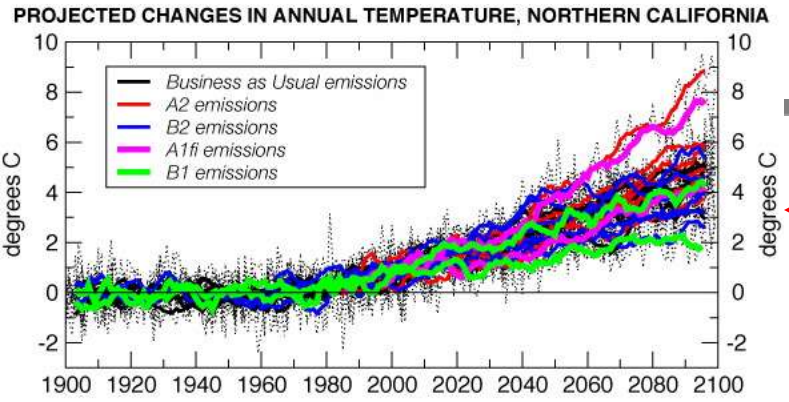
Mar 10, 2009

A SIMPLE INDEX OF SENSITIVITY OF SNOWFED HYDROCLIMATE TO A +3ºC WARMING … Rain? or Snow?

Vulnerability to warming:

What fraction of each year's precipitation historically fell on days with average temperatures just below freezing?





← +3 **Less vulnerable** **More vulnerable**

Computed from UW's VIC model daily INPUTS (Bales et al, in rev). Courtesy Mike Dettinger.

Temporal Variability of

Orographic Effect on Precipitation

Sacramento (10’)

Versus

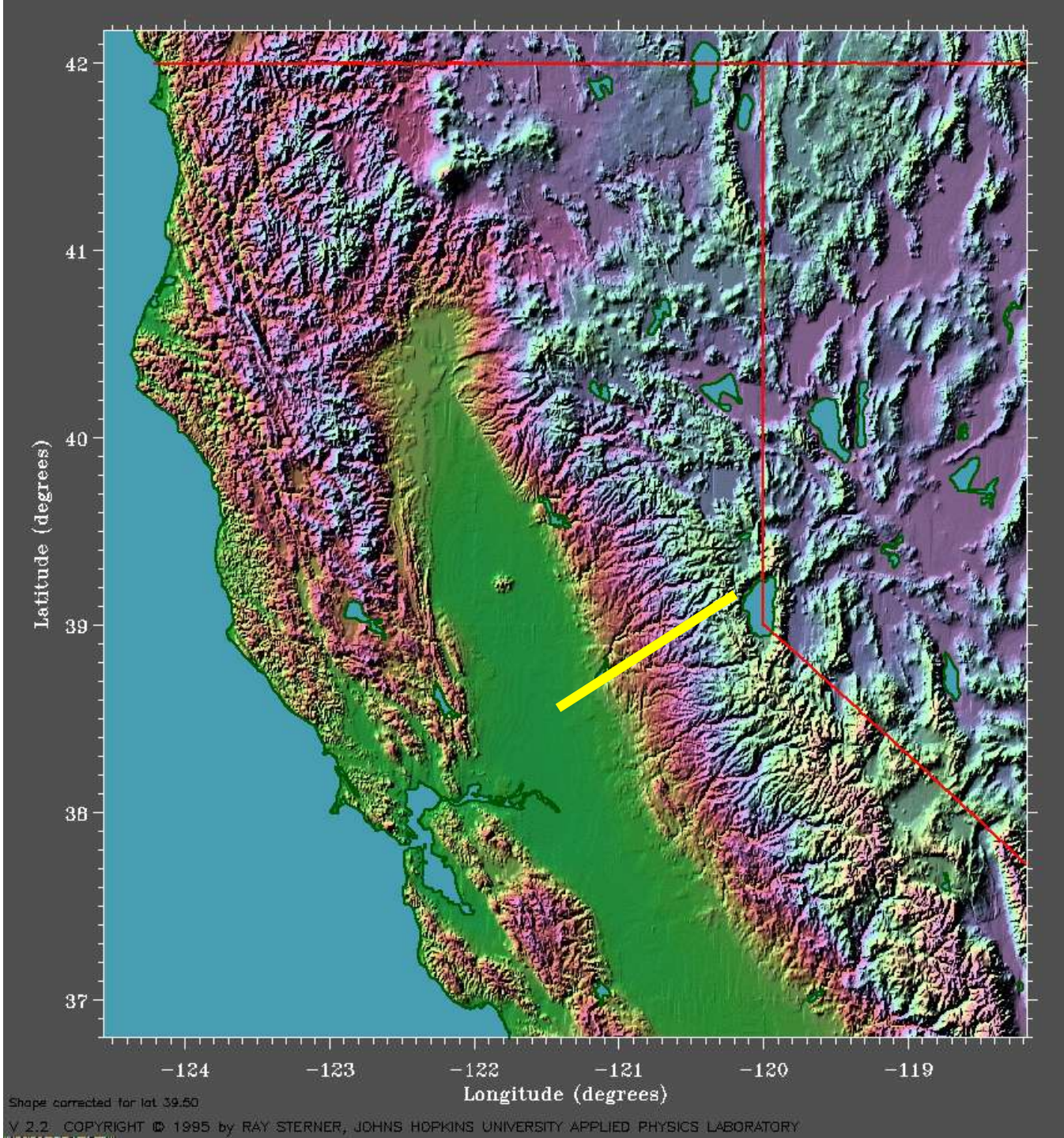
Tahoe City (6230’)

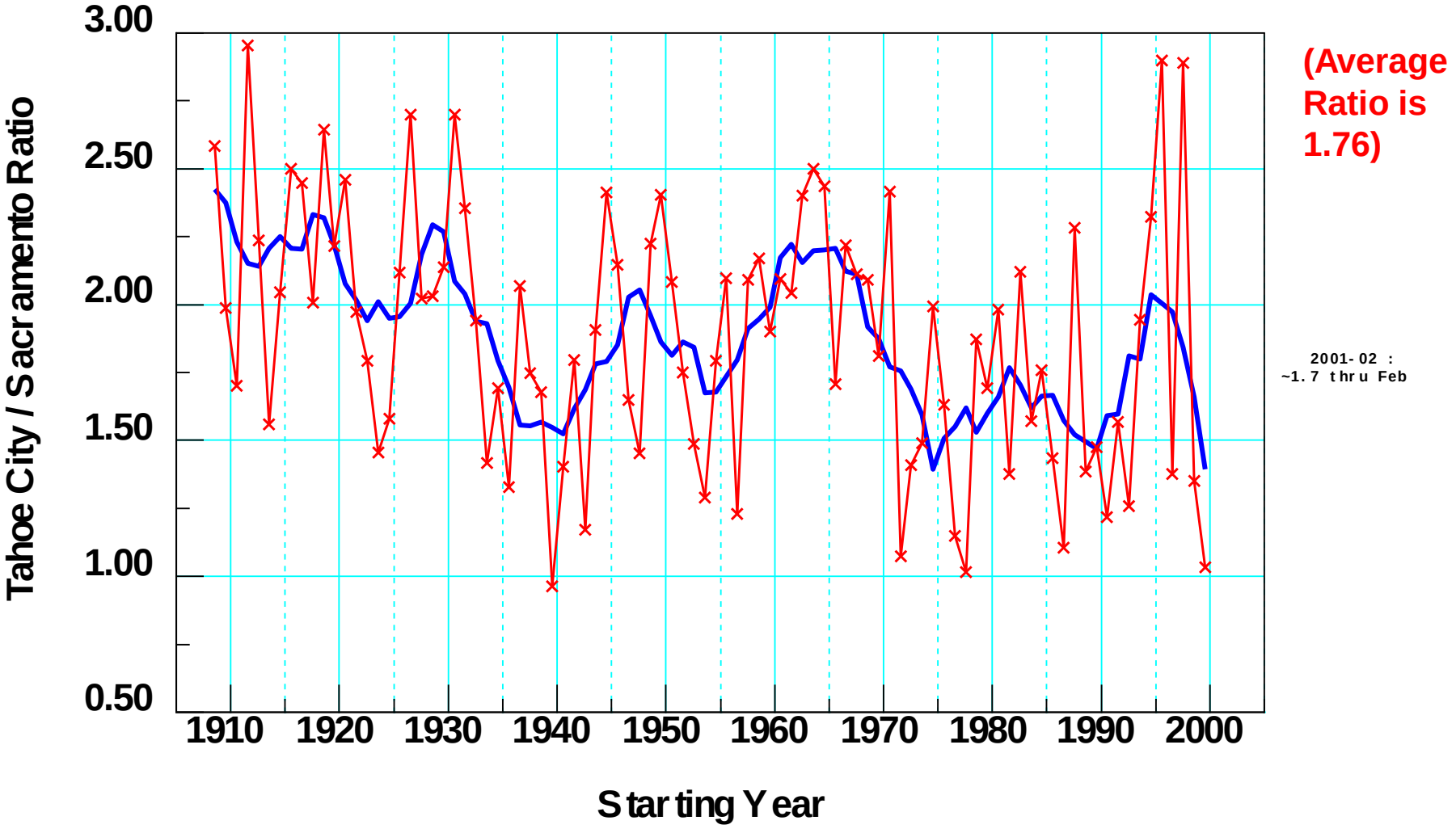
July thru June

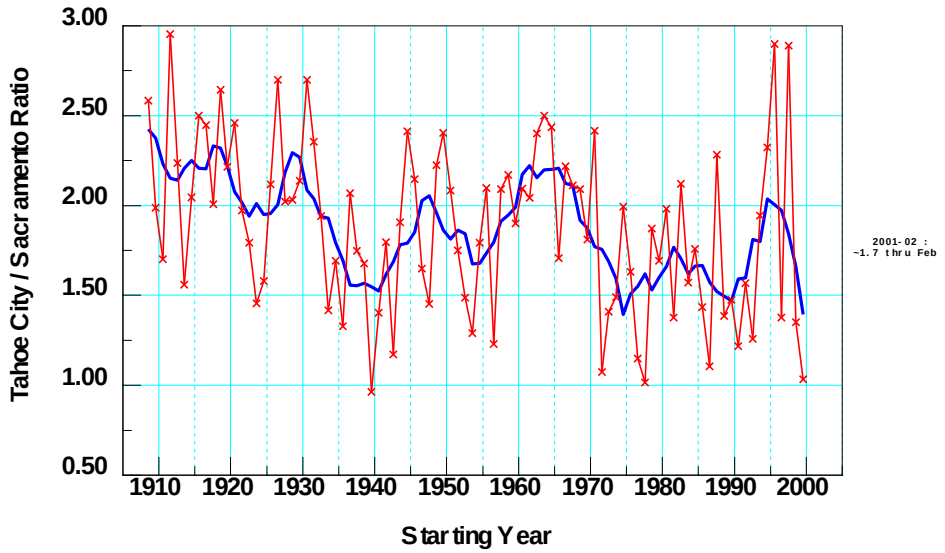
Oct-March Percent of Annual:

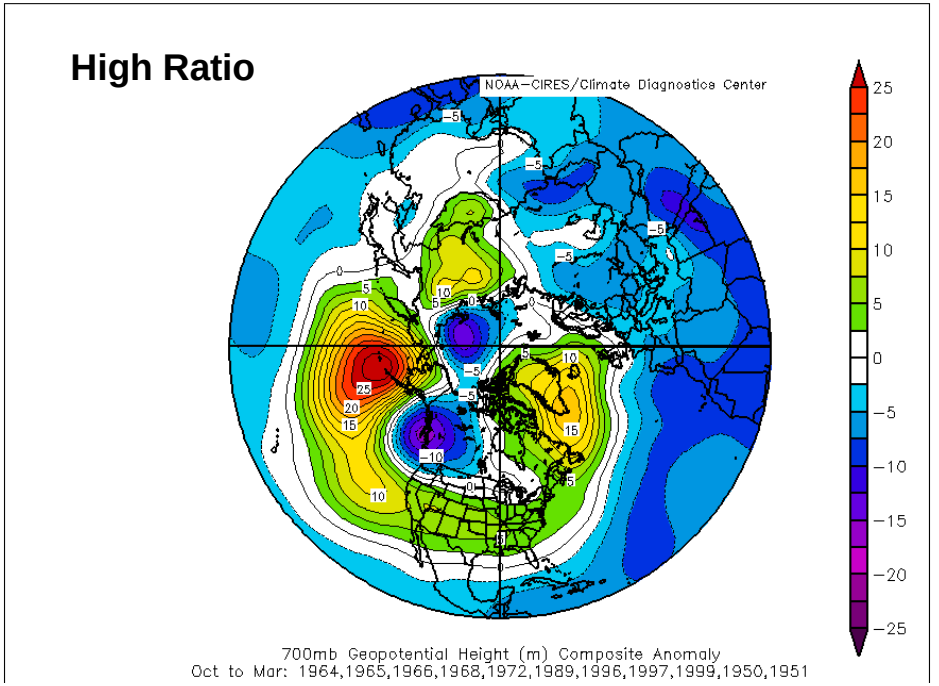
83% at Tahoe

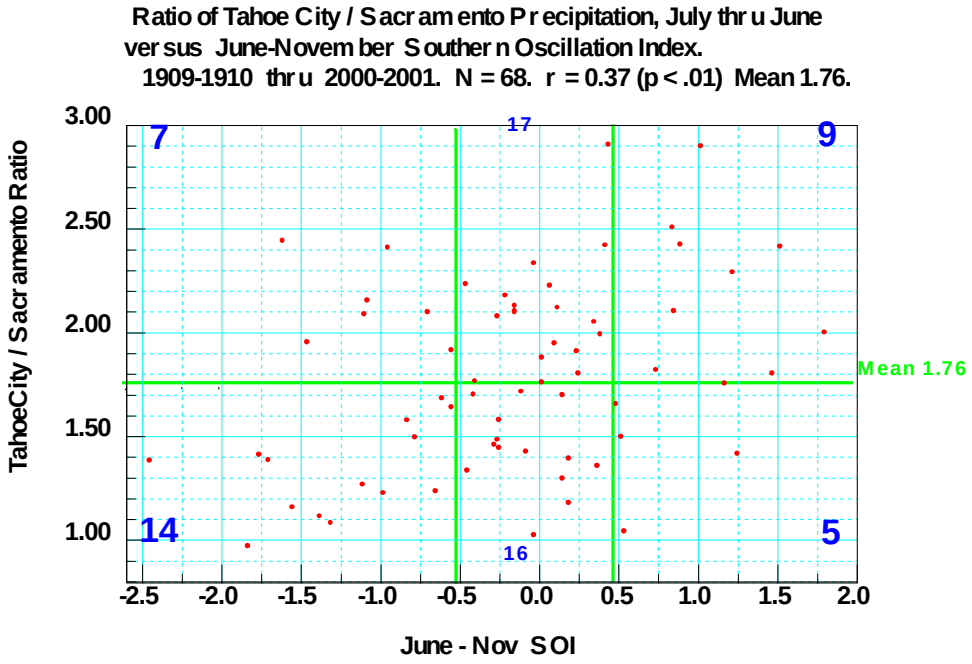
88% at Sacramento

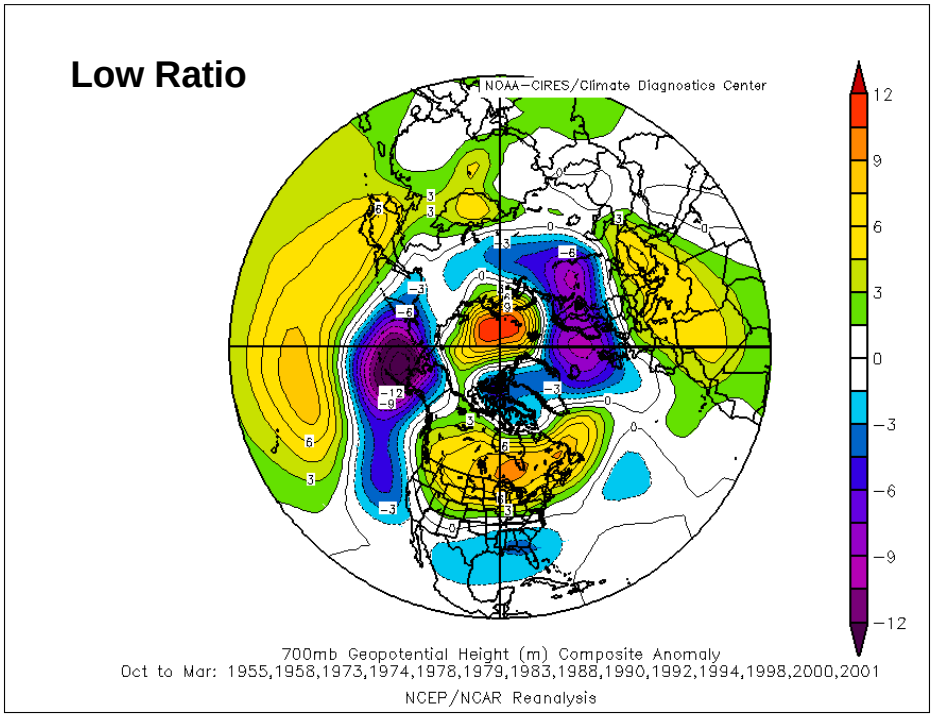



Ratio of June thru July Precipitation
Tahoe City / Sacramento. 1909-10 thru 2000-01.
Blue: 7-year running mean.
Tahoe City / Sacramento Ratio
3.00
2.50
2.00
1.50
1.00
0.50
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Starting Year
(Average Ratio is 1.76)
2001-02 : ~1.7 thru Feb



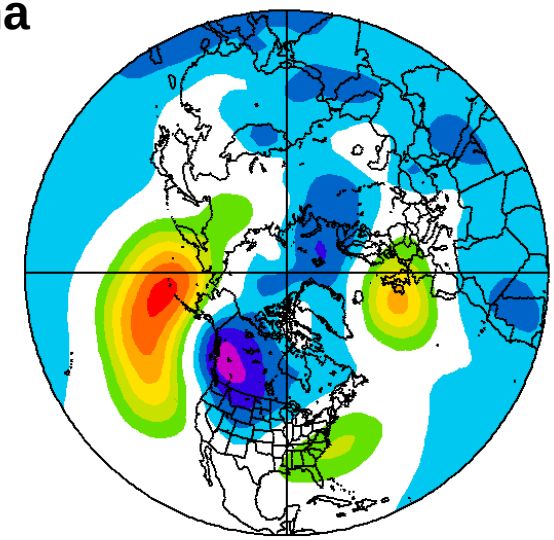


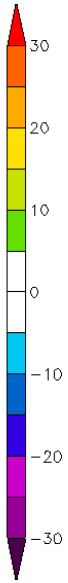




Kelly. Redmond, Western Regional Climate Center.

La Nina

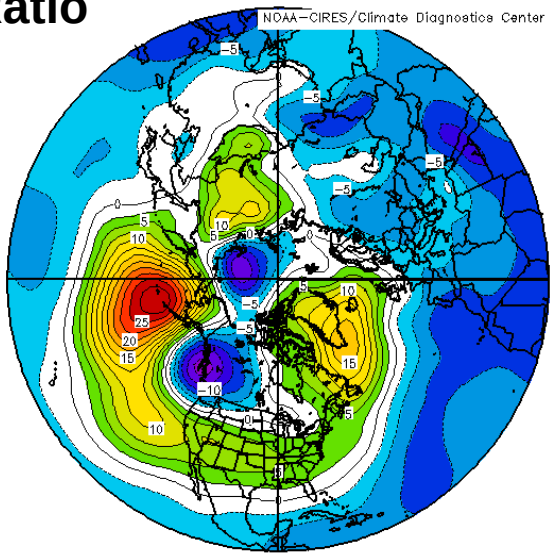




700mb Geopotential Heights (m) Composite Anomaly
Oct to Mar: 1965,71,72,74,75,76,89,97

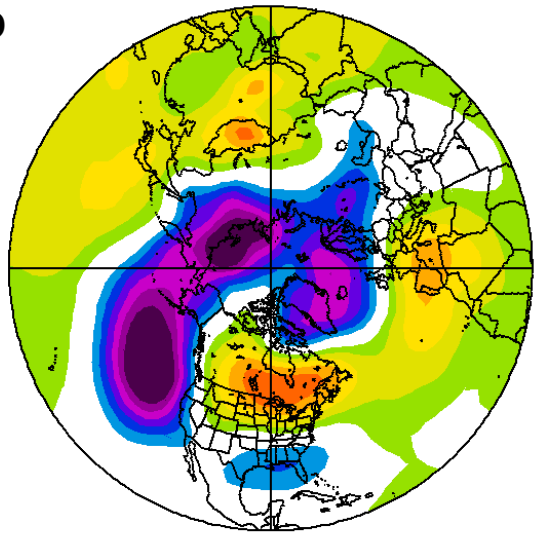
NOAA−CIRES/Climate Diagnostics Center

High Ratio



700mb Geopotential Height (m) Composite Anomaly
Oct to Mar: 1964,1965,1966,1968,1972,1989,1996,1997,1999,1950,1951

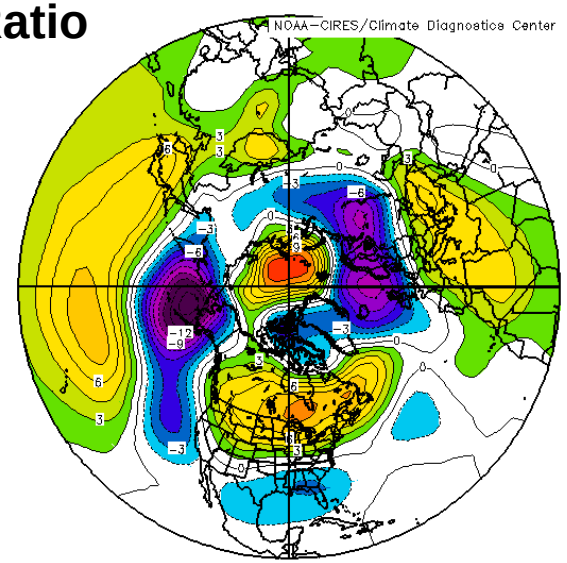
El Nino

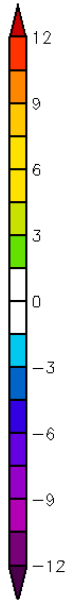


700mb Geopotential Heights (m) Composite Anomaly
Oct to Mar: 1966,73,78,83,88,92,93,94,95,98

NOAA−CIRES/Climate Diagnostics Center

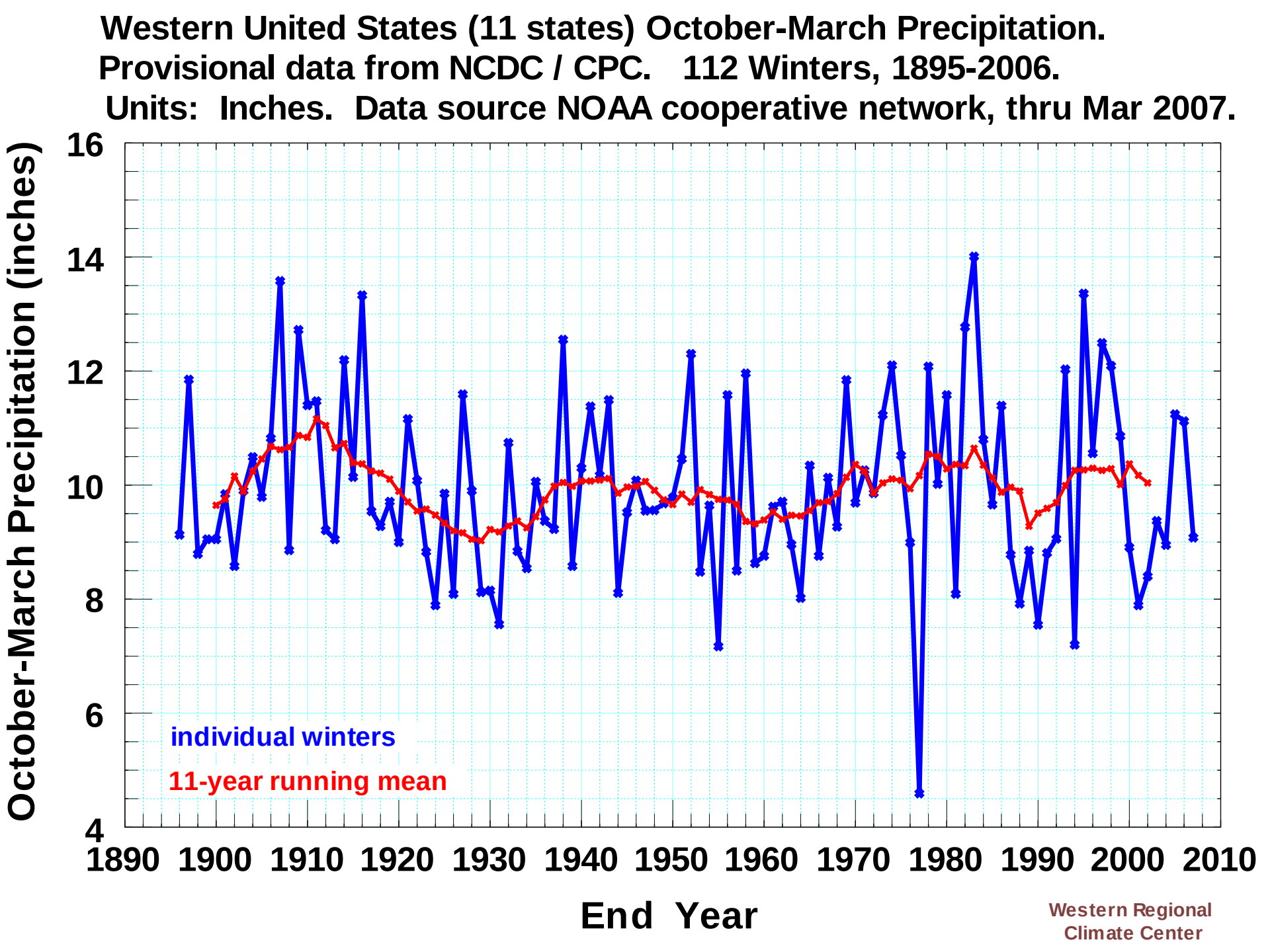
Low Ratio





700mb Geopotential Height (m) Composite Anomaly
Oct to Mar: 1955,1958,1973,1974,1978,1979,1983,1988,1990,1992,1994,1998,2000,2001

NCEP/NCAR Reanalysis


Western United States (11 states) October-March Precipitation.
Provisional data from NCDC / CPC. 112 Winters, 1895-2006.
Units: Inches. Data source NOAA cooperative network, thru Mar 2007.
October-March Precipitation (inches)
16
14
12
10
8
6
4
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
End Year
individual winters
11-year running mean
Western Regional
Climate Center