

Climate Impacts on Water Resources Of the West

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Western Regional Climate Center

Desert Research Institute

Reno Nevada

Pacific Northwest Section

American Water Works Association

Annual Spring Conference

May 6, 2009

Topics

Climate change drivers

Climate variability remains, with new source(s)

Projected changes, relevant to water and hydrology

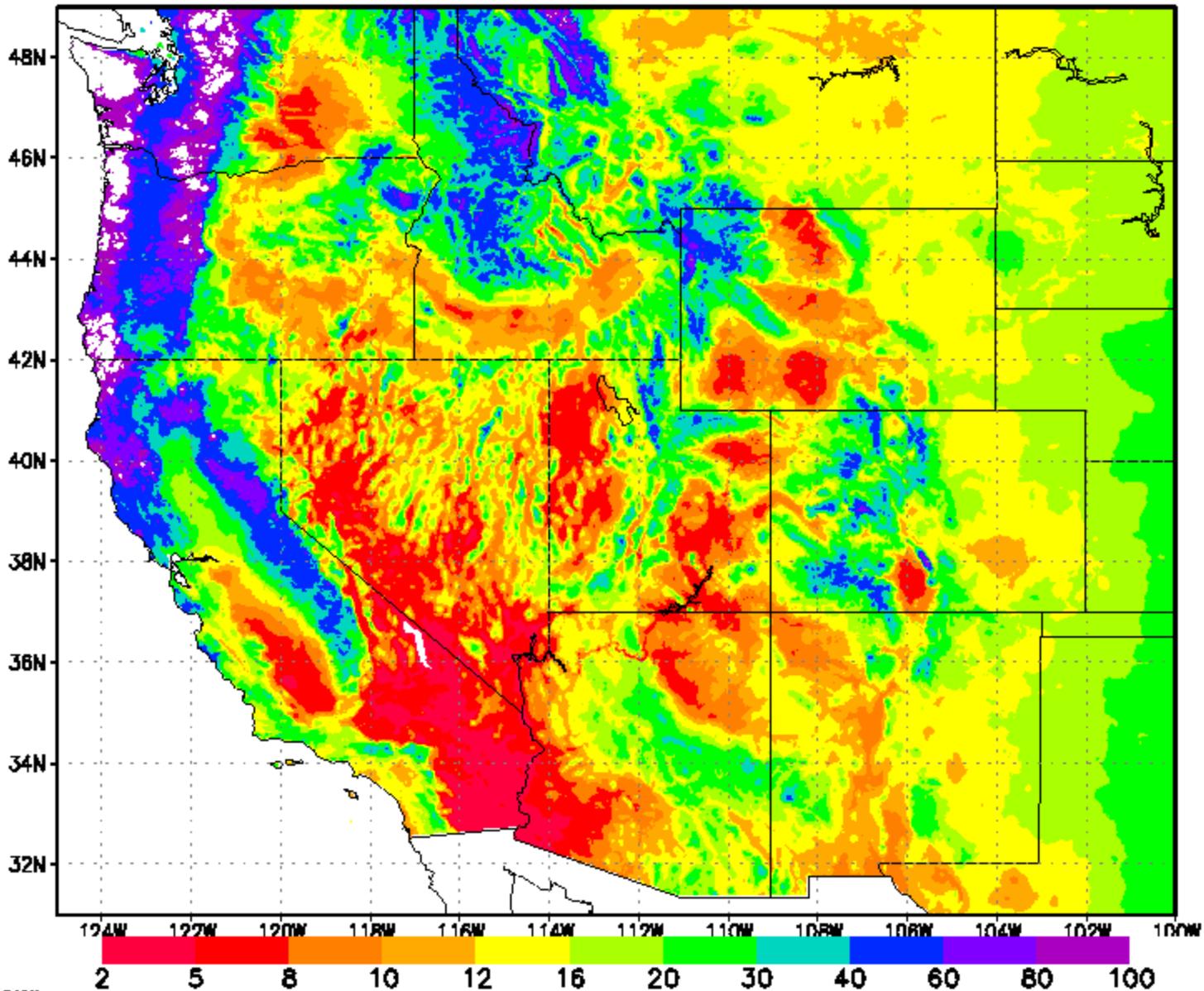
Is any of this happening? Can we tell?

Tools to watch climate unfold

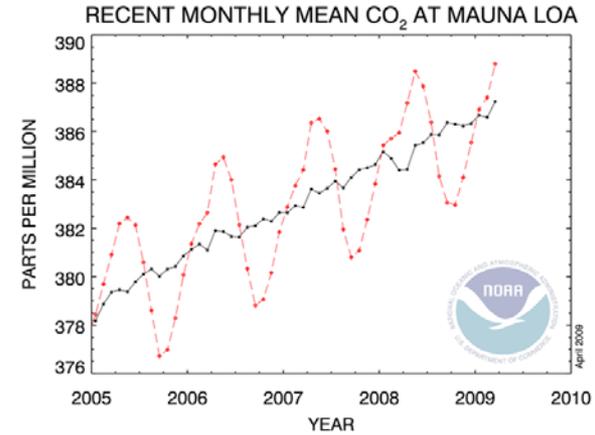
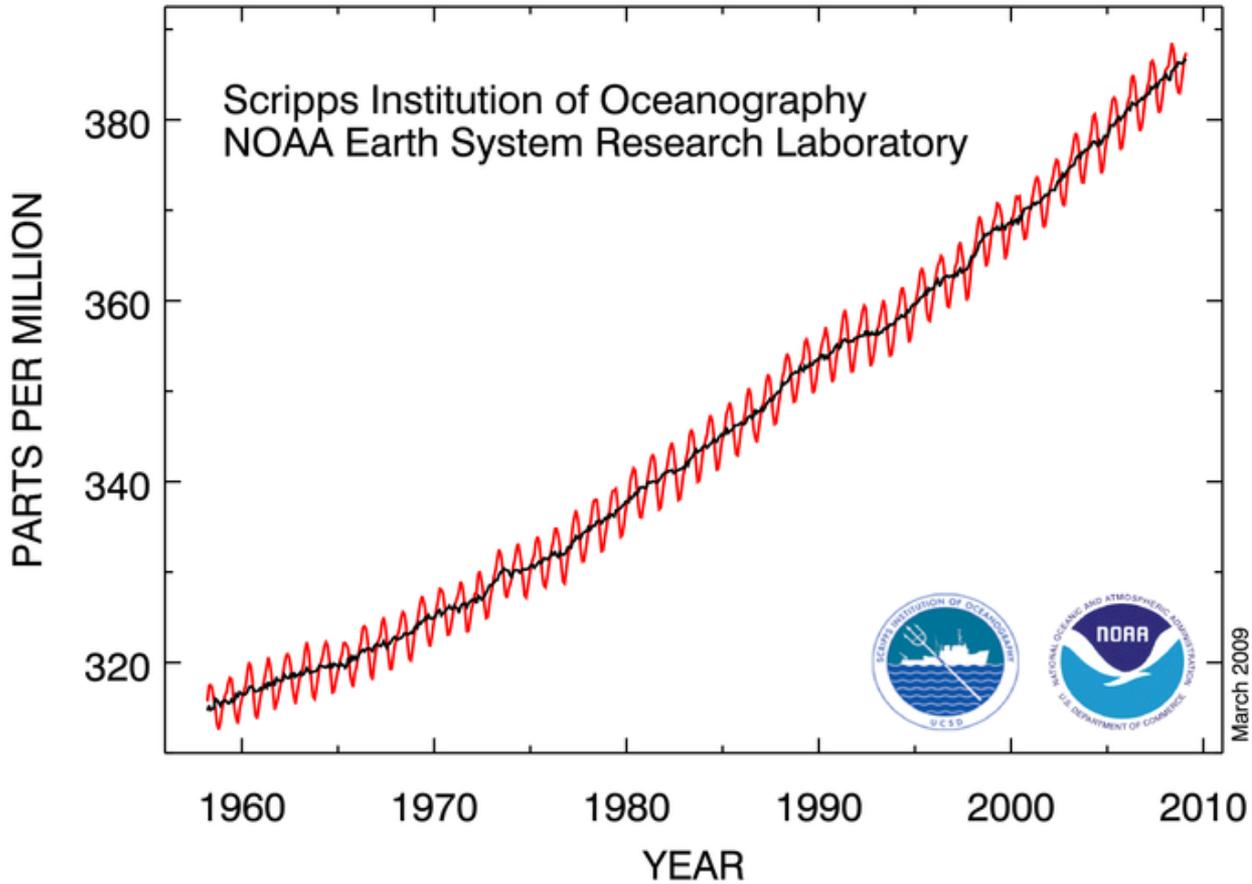
Recent climate

Summary

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



Atmospheric CO₂ at Mauna Loa Observatory



316 ppmv
1959

+22 %

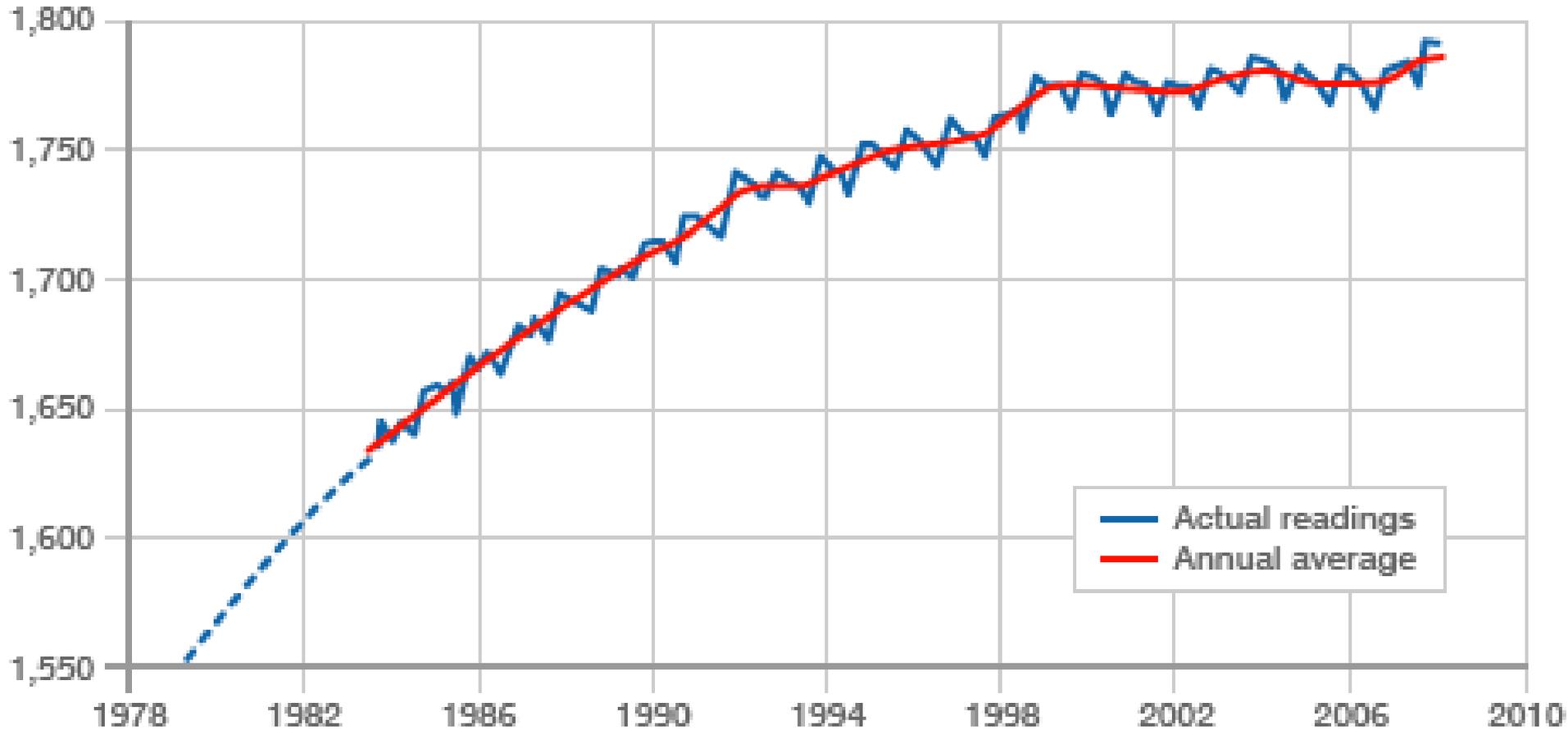
387
Mar 2009

Atmospheric Methane: Resumption of its Rise???

Methane is 23 times more potent as a greenhouse gas than CO2

RISING METHANE

Parts per billion

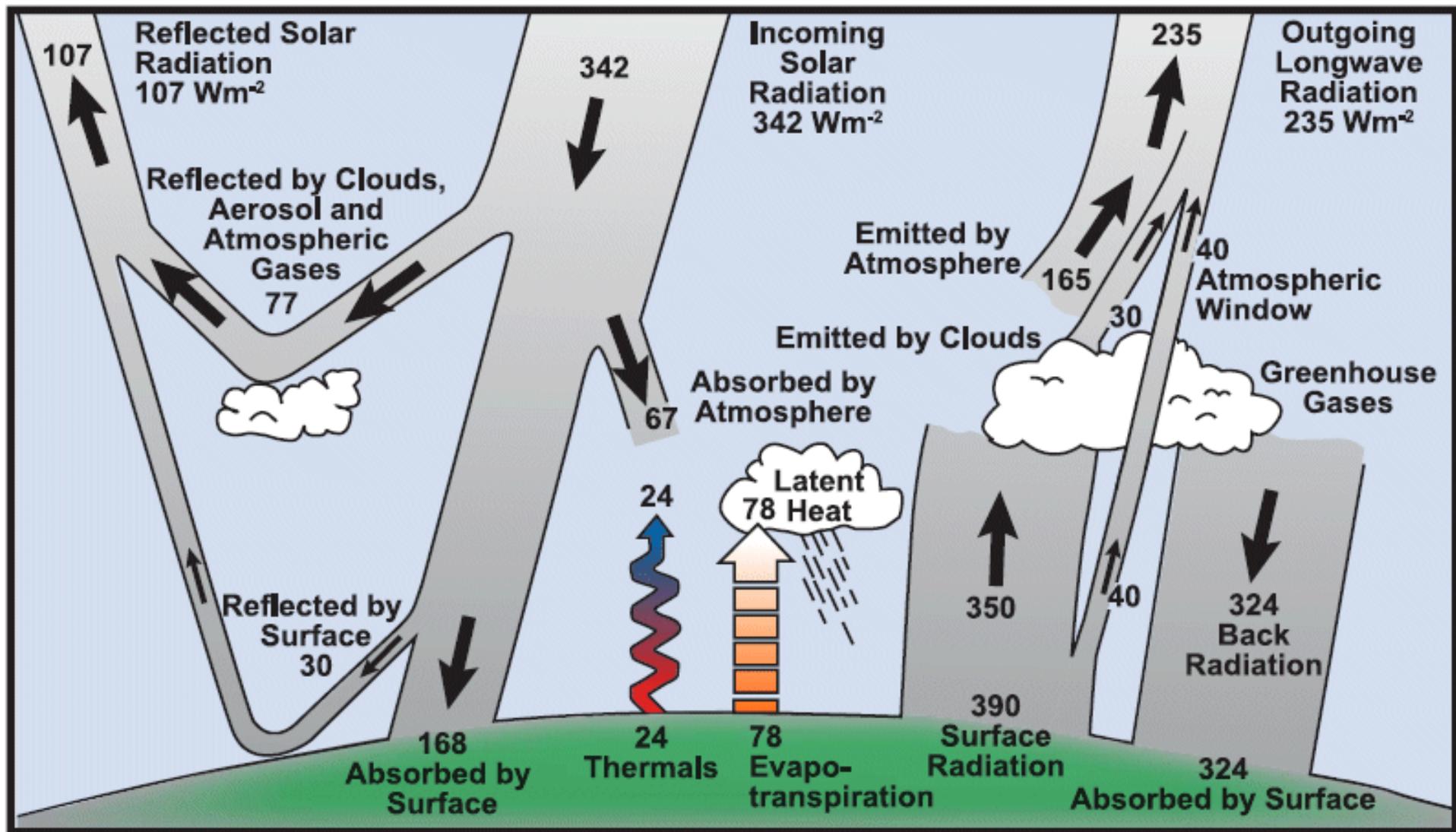


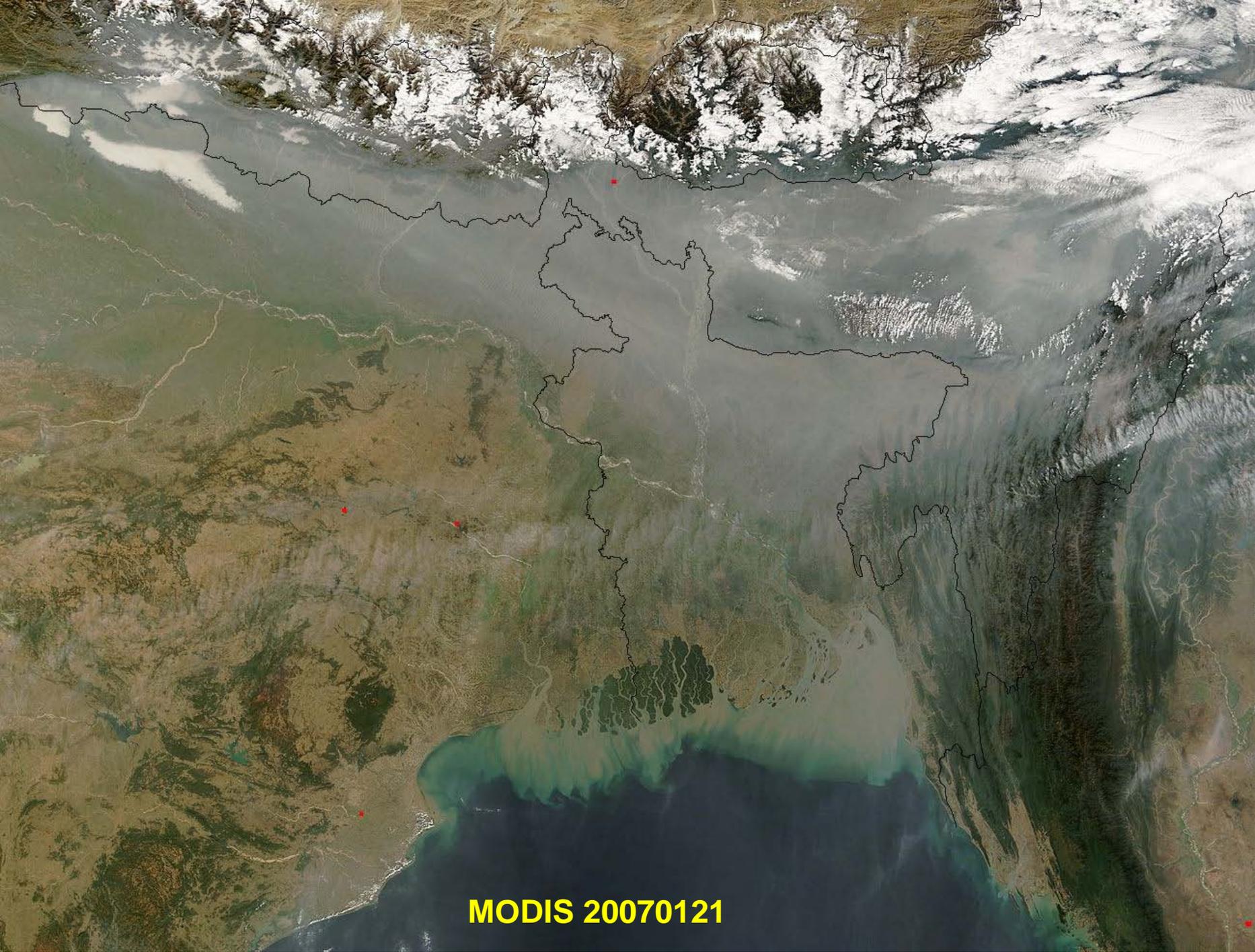
SOURCE: NOAA

The Planetary Radiation Budget

Net incoming $342 - 107 = 235 \text{ W/m}^2$

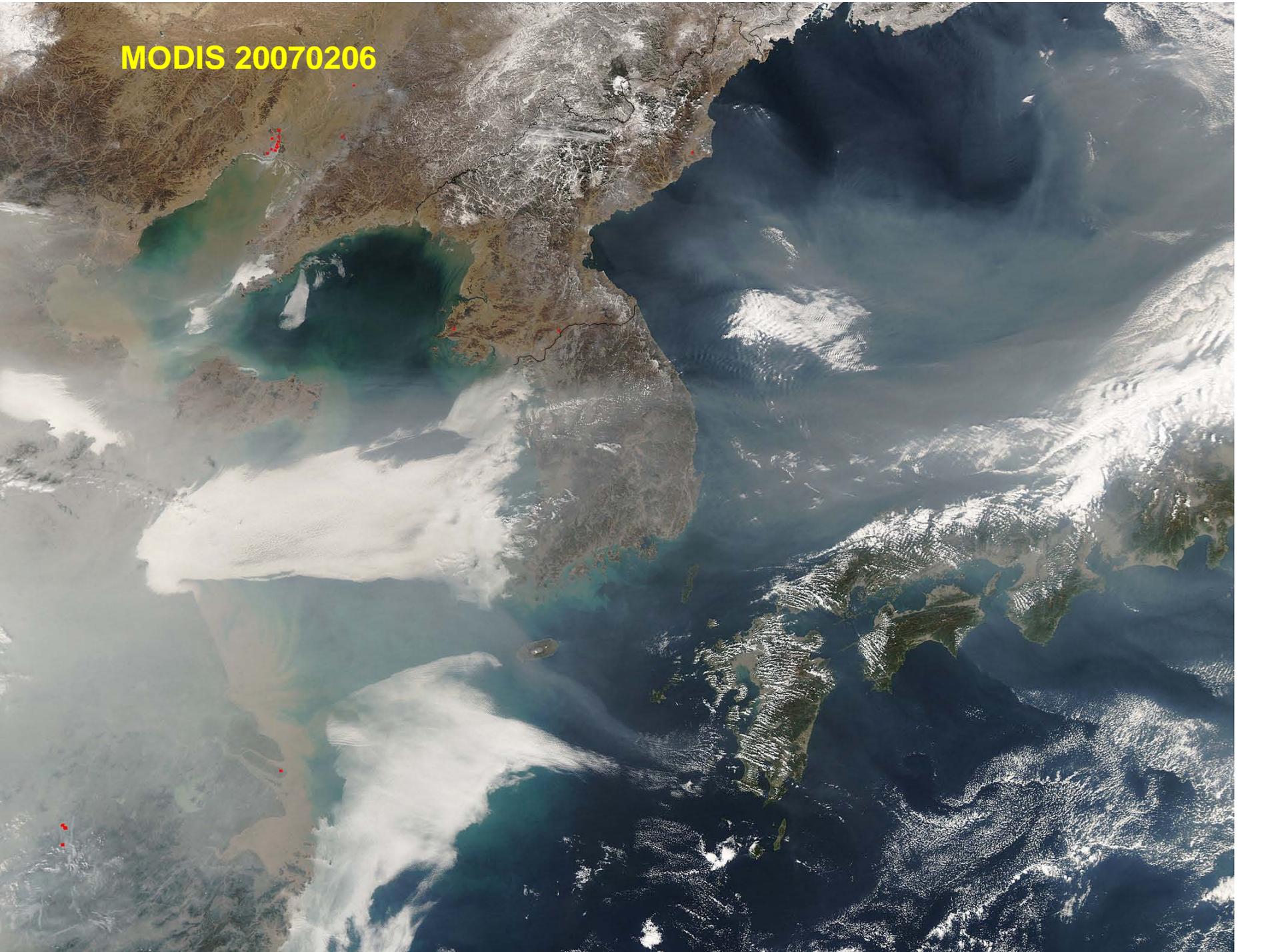
Net outgoing = 235 W/m^2



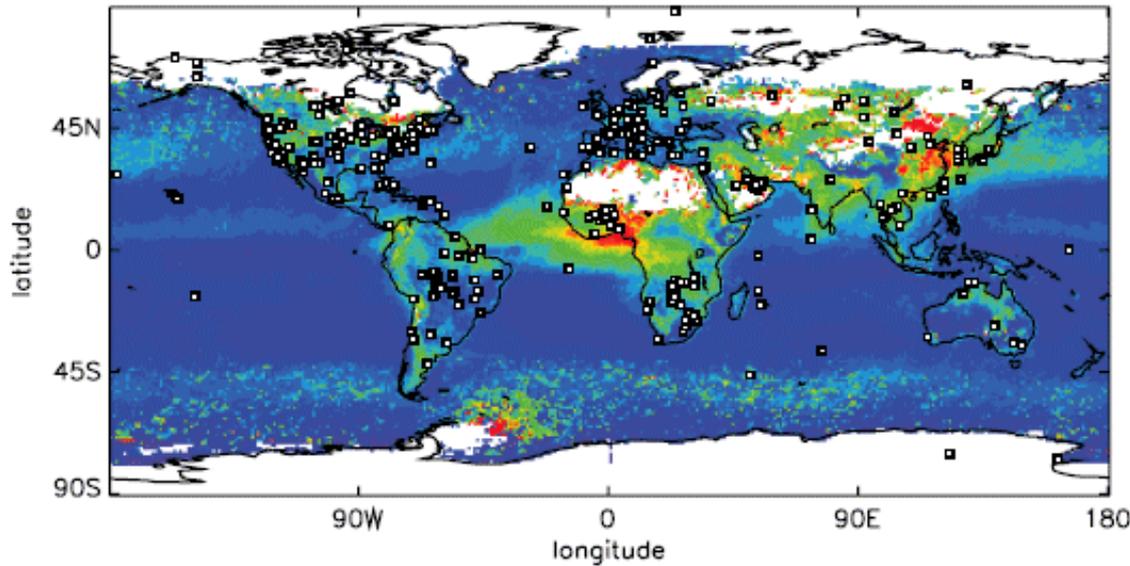


MODIS 20070121

MODIS 20070206



January to March 2001



Pollution is a global atmospheric concern

Obviously for health reasons

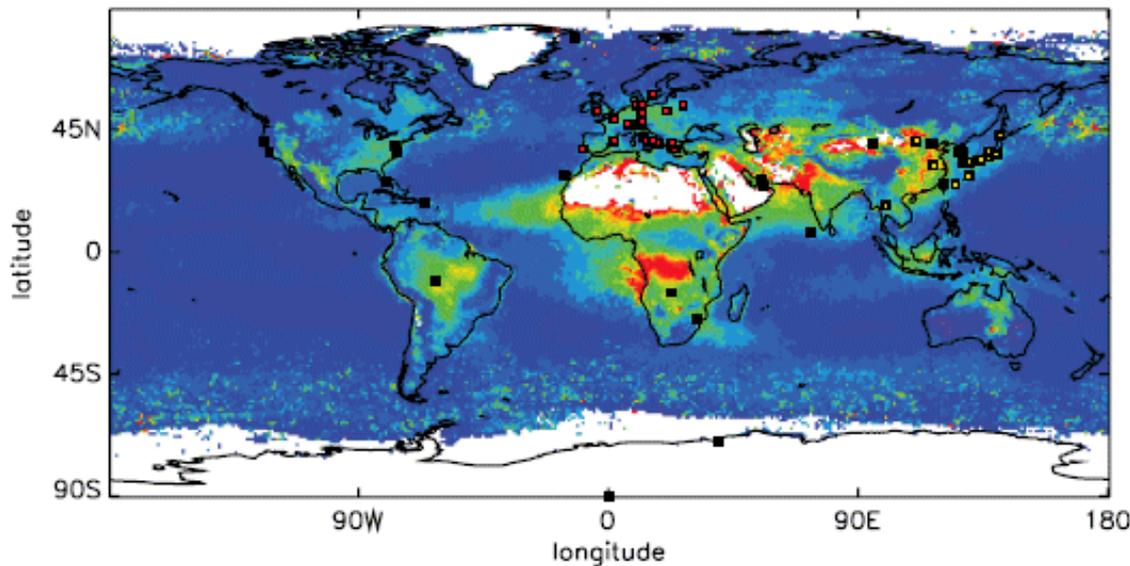
But, also,

Aerosols have effects on

**Temperature
And
Precipitation**

**Also note:
Aerosols are unequally
distributed around the earth**

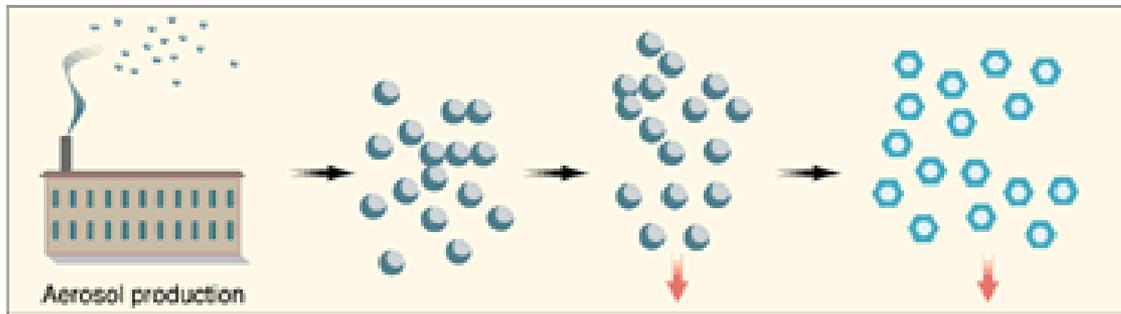
August to October 2001



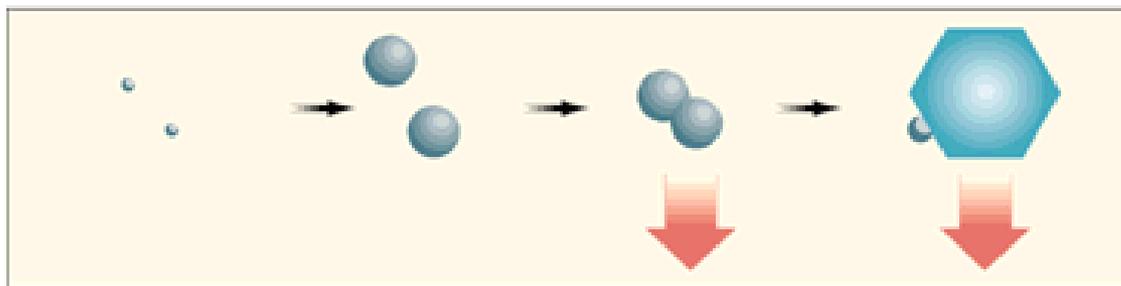
0.1 0.2 0.3 0.4 0.5 0.6 0.7

Total Aerosol Optical Depth

Polluted atmosphere



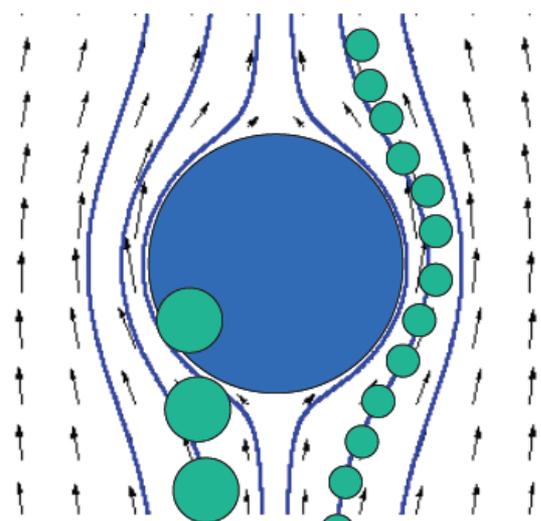
Natural atmosphere



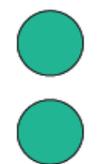
Cloud formation

Warm rain formation

Ice crystal rain formation



Large droplets collide with the falling drop



Small droplets follow the airflow streamlines and bypass the falling drop

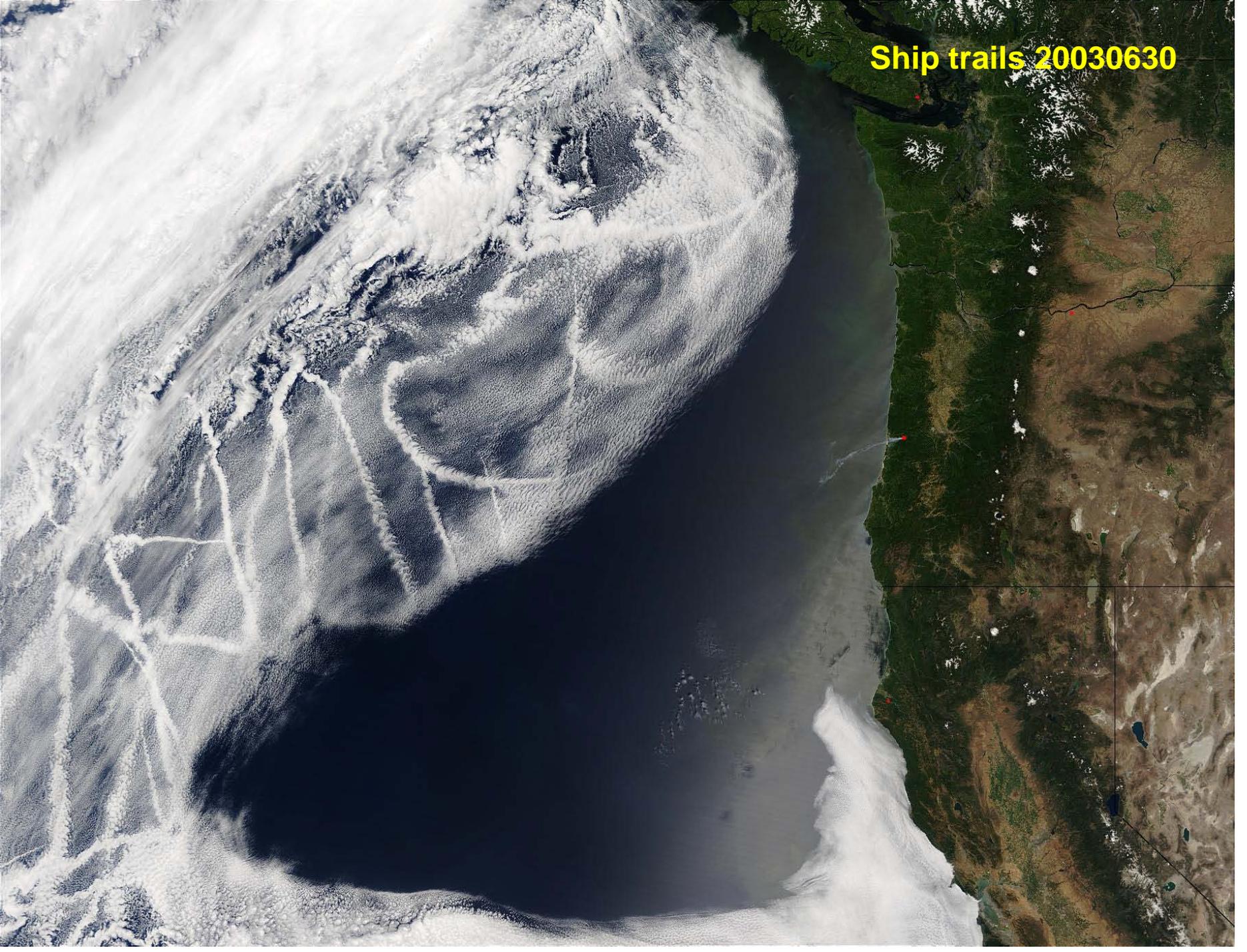
Owen B. Toon
How Pollution Suppresses Rain
Science Magazine,
10 March 2000
287 (5459), 1763-1765

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

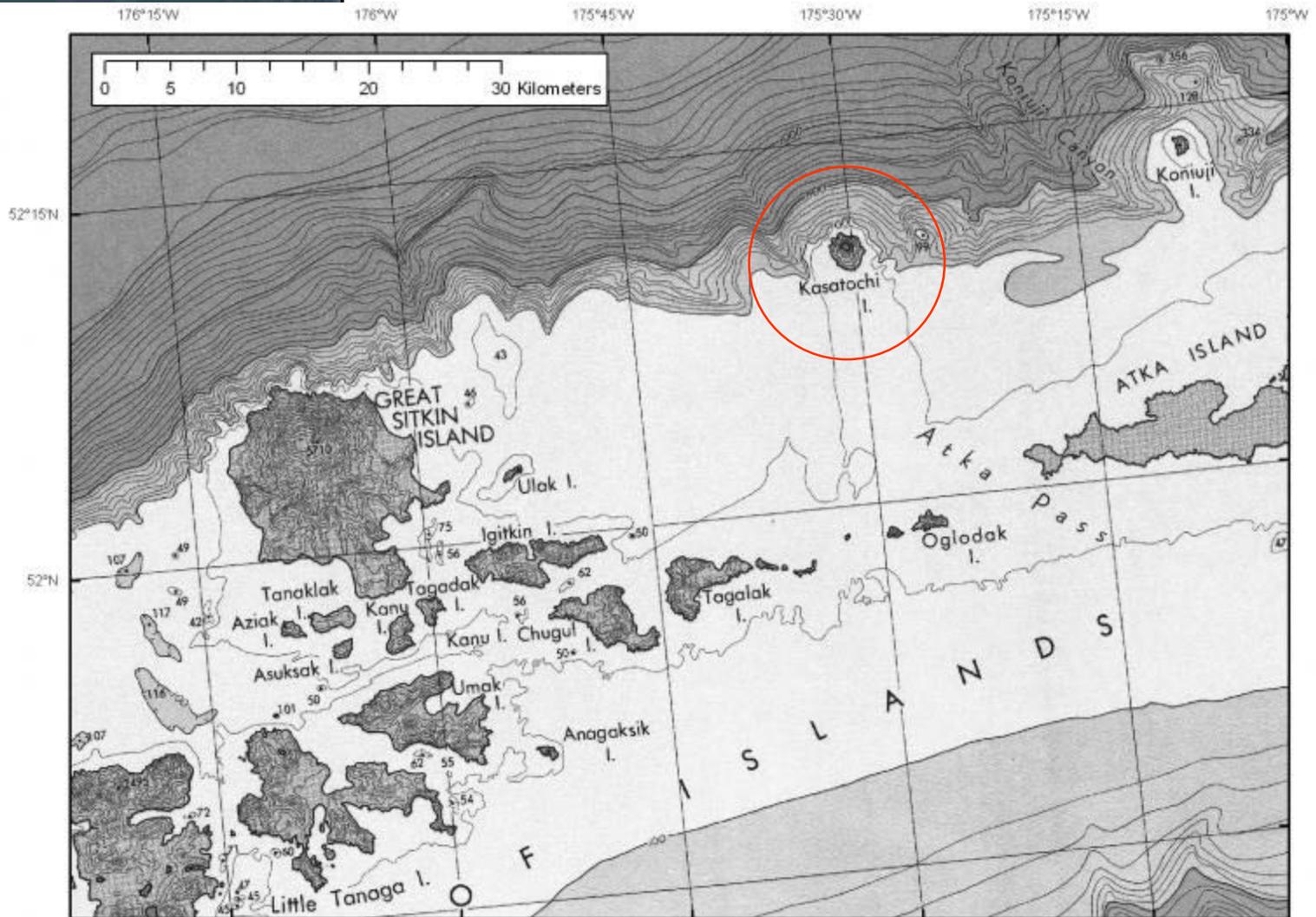
!4 Sep 2006. California Climate Change Research Conference.

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

Ship trails 20030630



Kasatochi

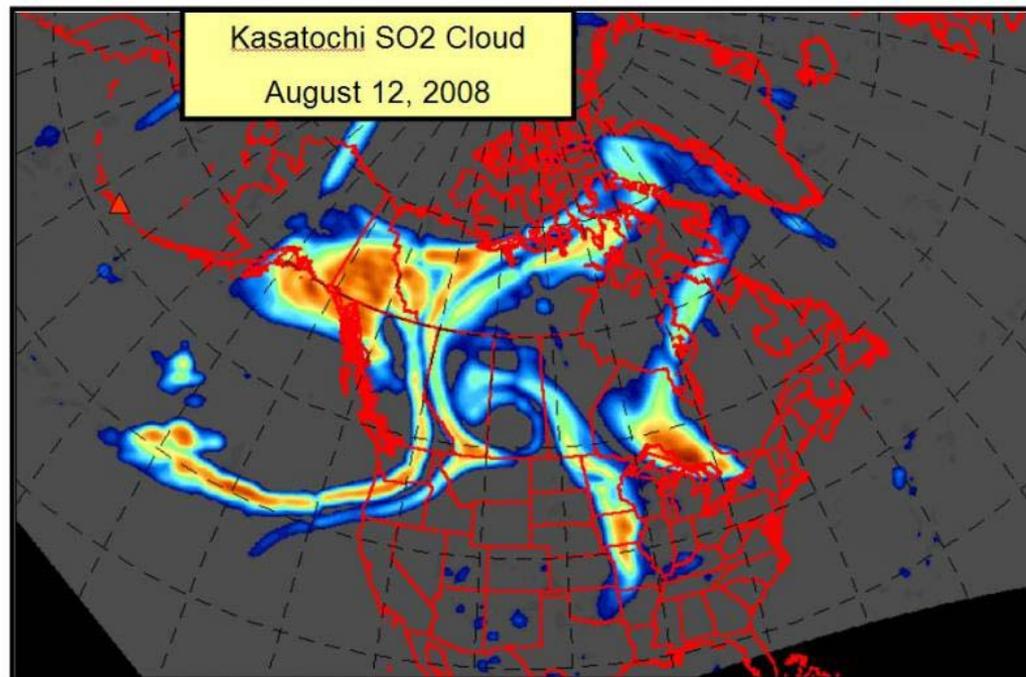
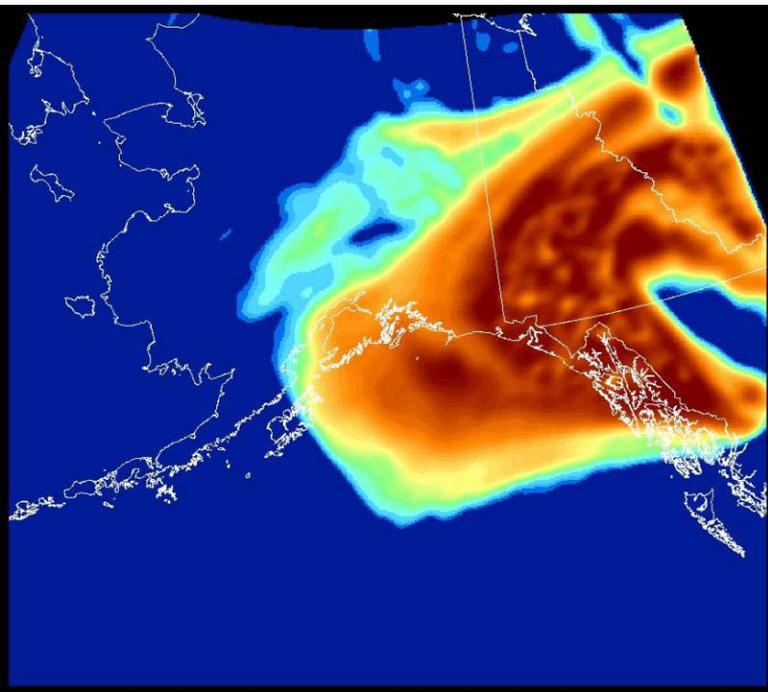


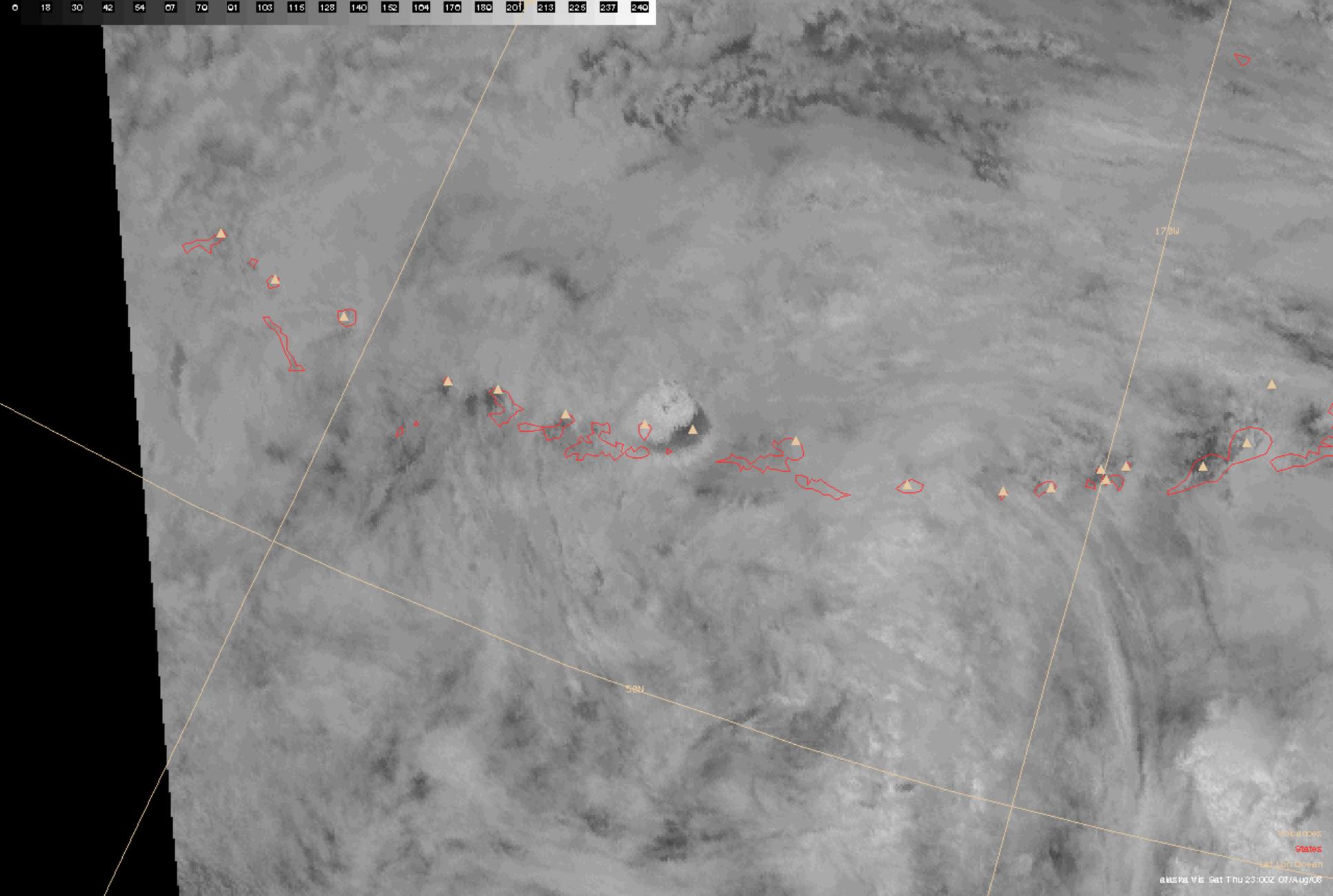
Nichols and Perry, 1966 Bathymetry
Contours in fathoms

080709 Jerry Morris



Kasatochi 20081023:1500ADT Jerry Morris





Kasatochi. August 07 eruption. Largest SO₂ input since Pinatubo.



Redoubt. Drift River lahar. 2009 March 23. Game McGimsey.

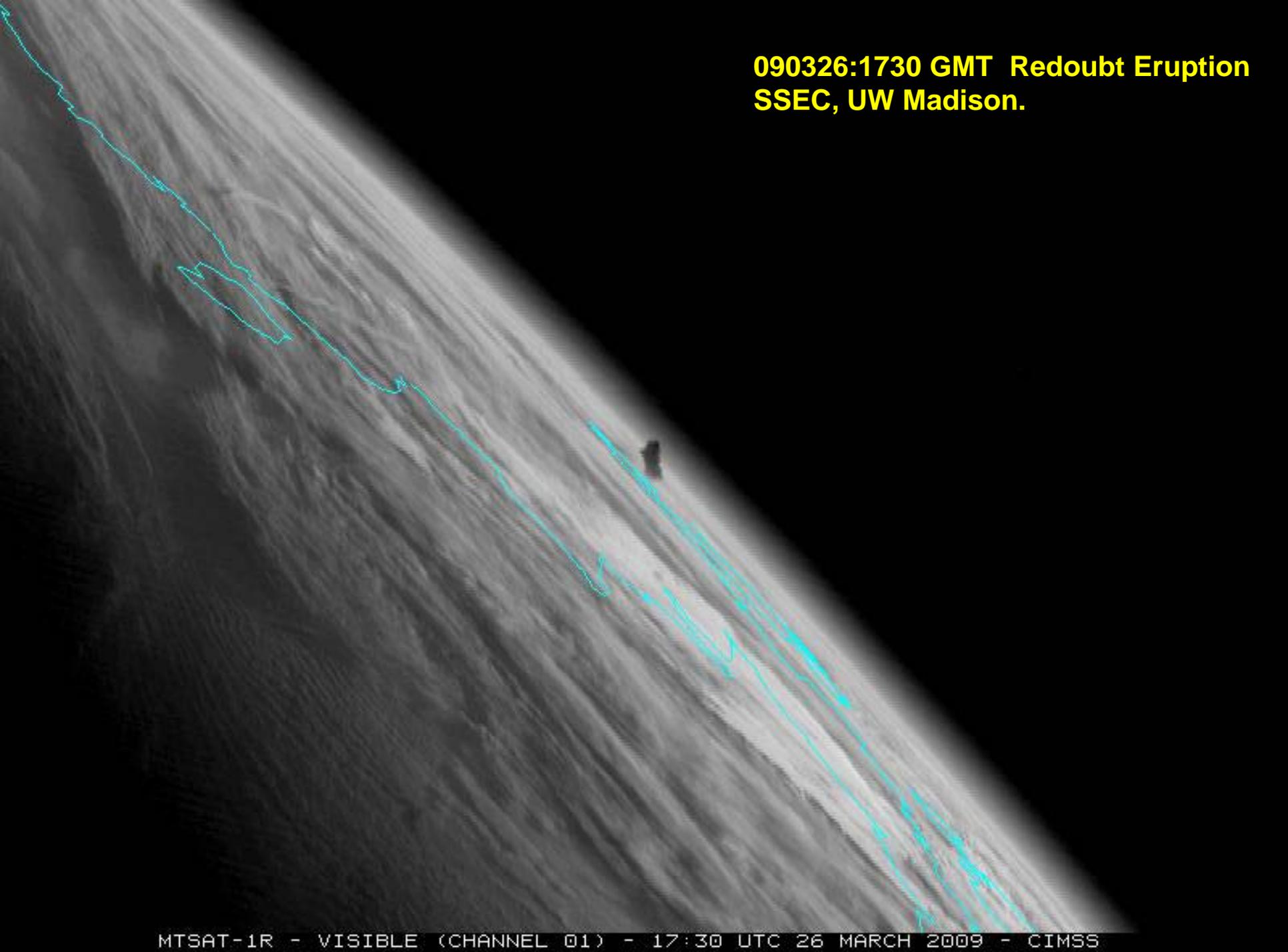


Redoubt. Mouth of Drift River. 2009 March 23. Cyrus Read.



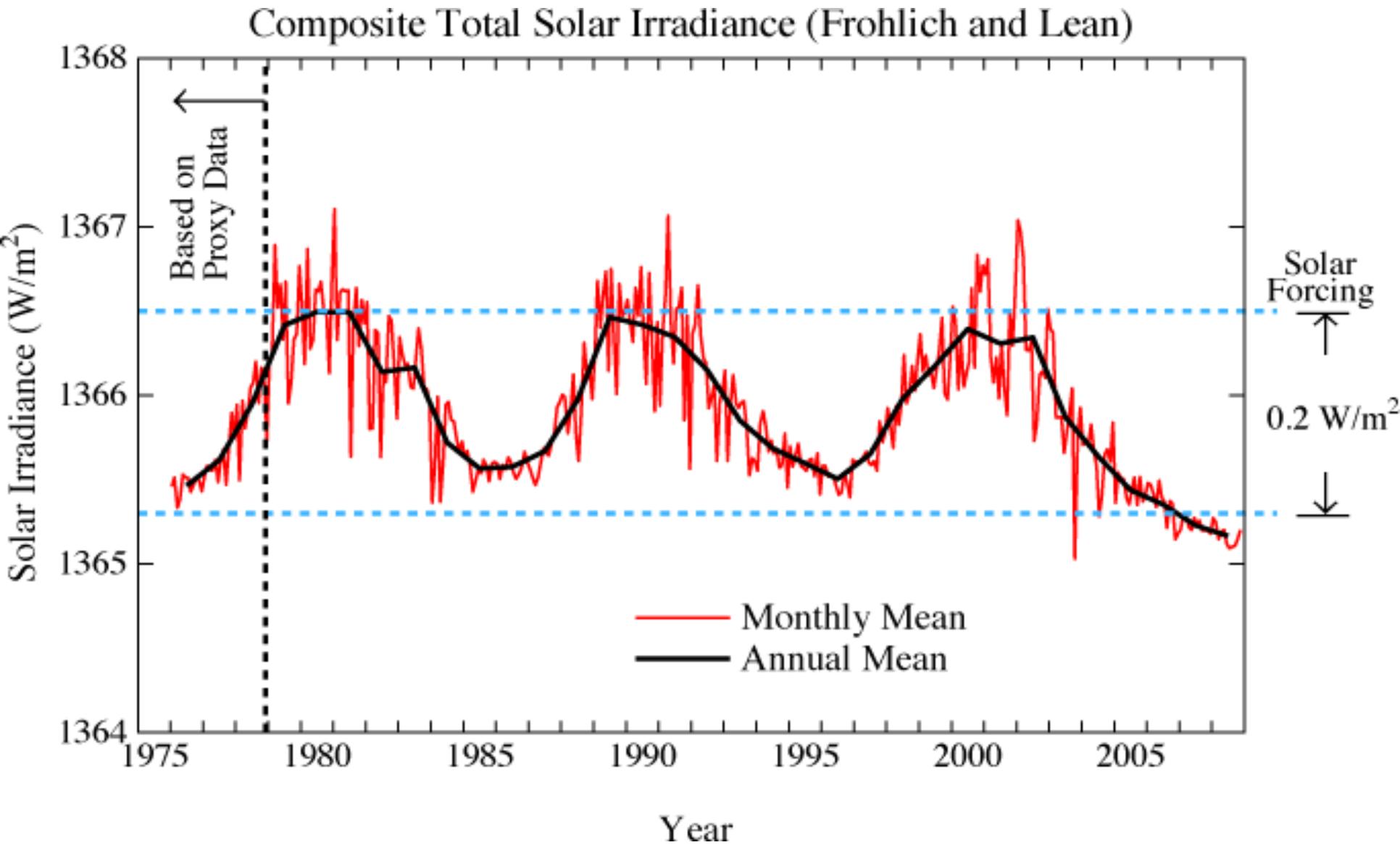
**090327:1925 GMT Redoubt Eruption
From Homer AK. Jonathan Dehn.**

**090326:1730 GMT Redoubt Eruption
SSEC, UW Madison.**

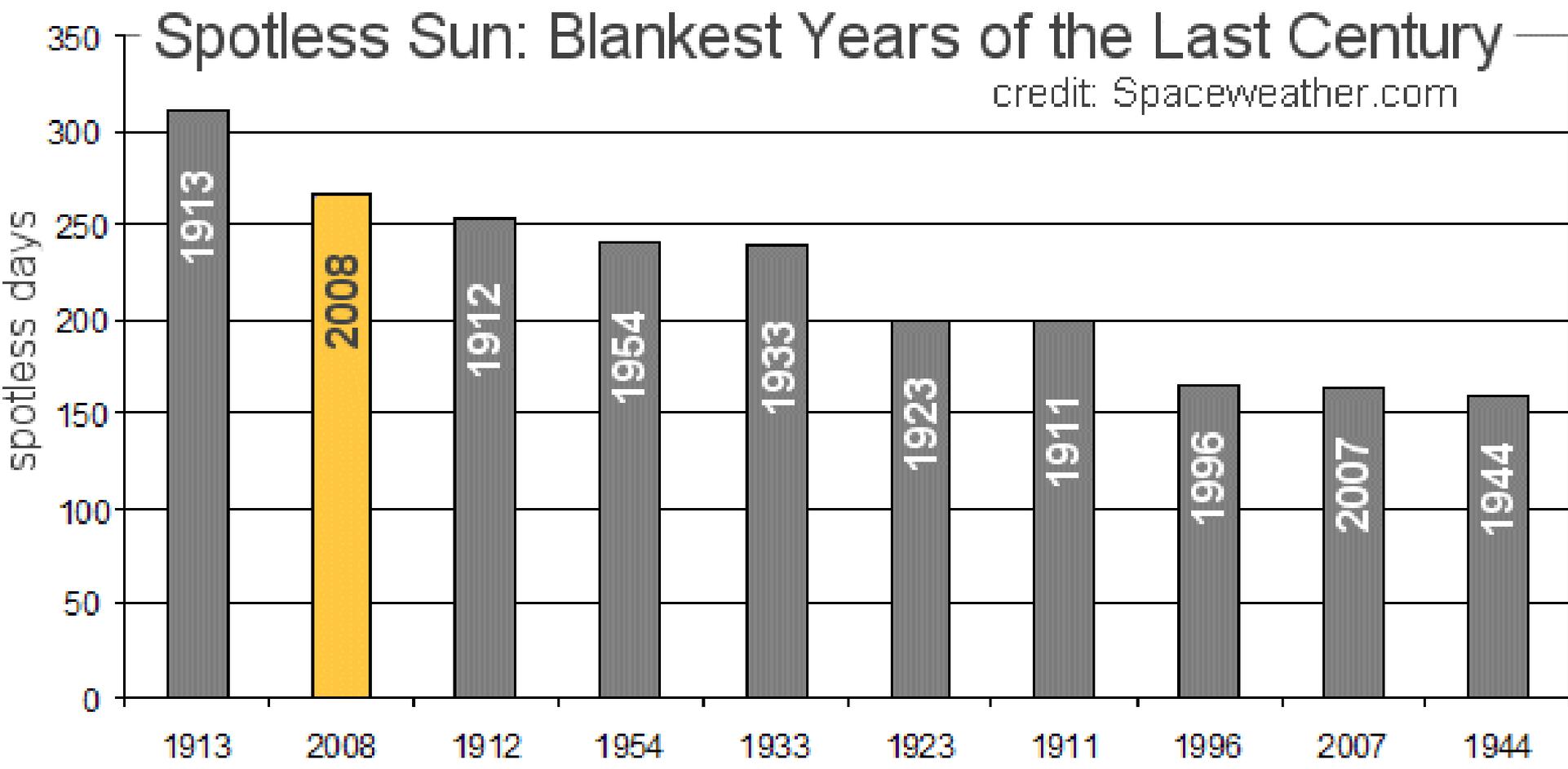


Solar Output During the Satellite Era

Through late December 2008

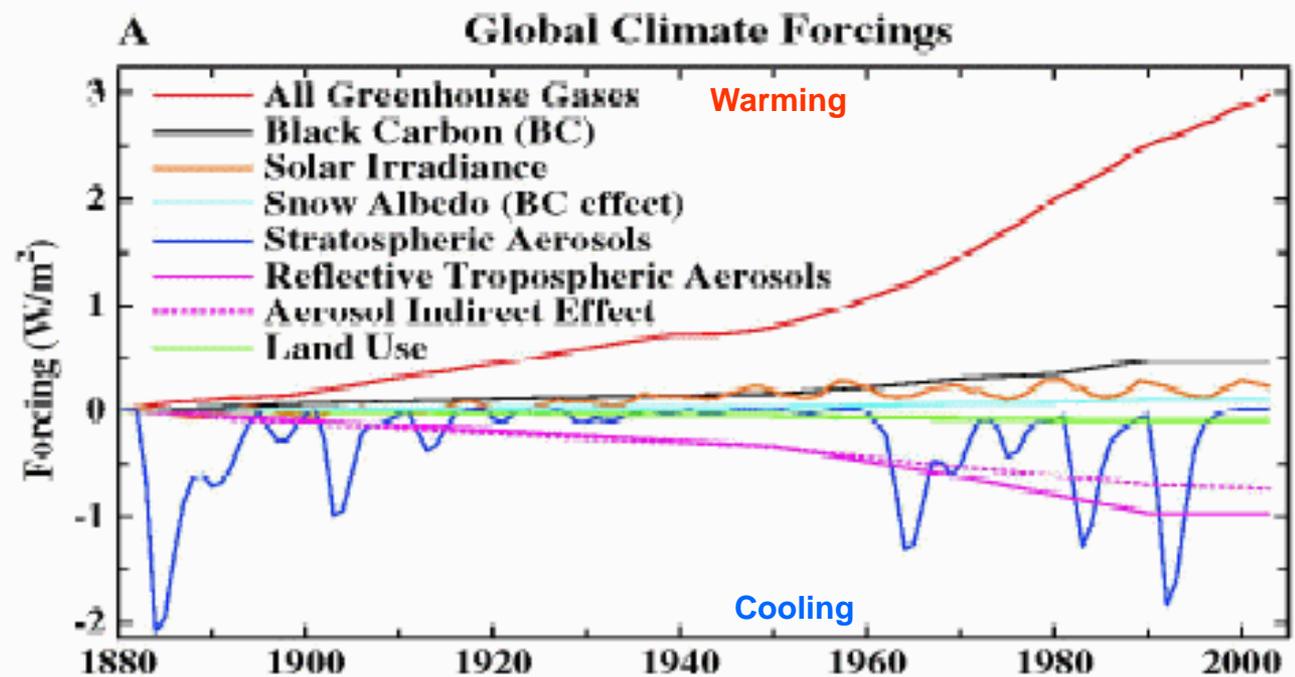


2008: 266 of 366 days, No sunspots. Most spotless days since 1913 with 311 days.
2009 through May 2: 117 days (87 pct of year).
Typical solar min: 485 spotless days. This solar min thru May 2: 617 spotless days.



History of Atmospheric Forcings

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



Annual Annual

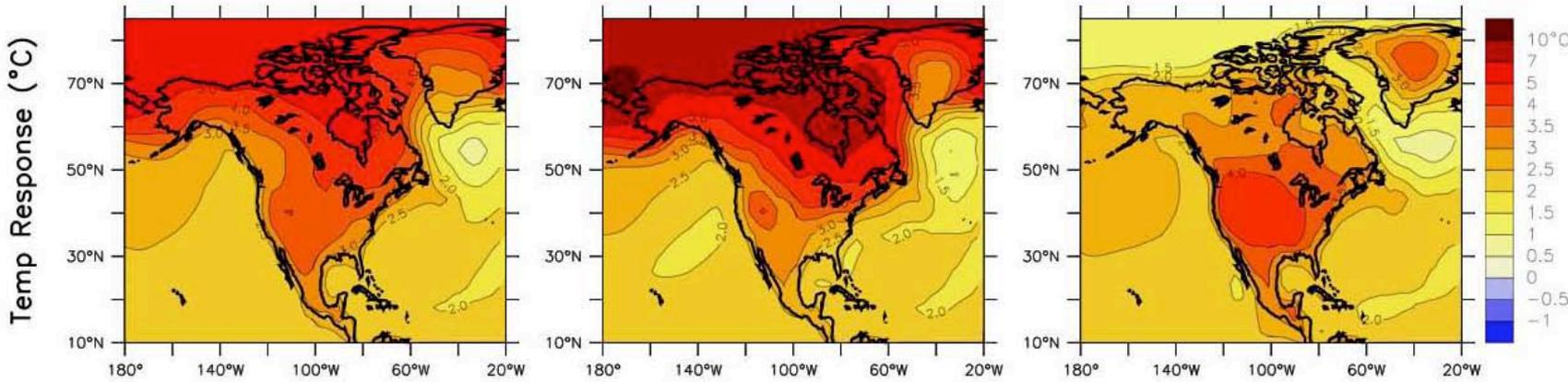
Winter DJF

Summer JJA

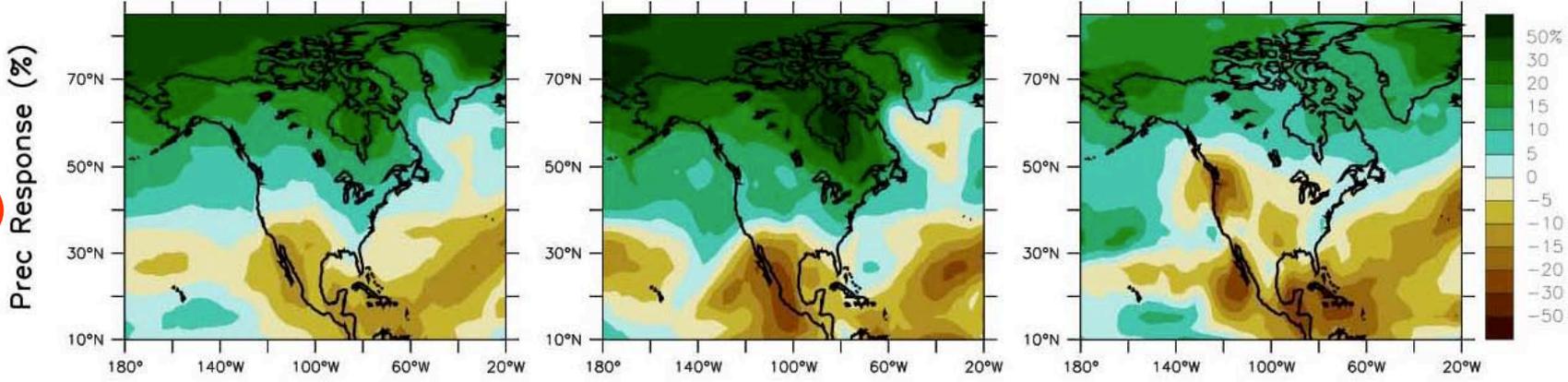
IPCC 2007

Late 21st

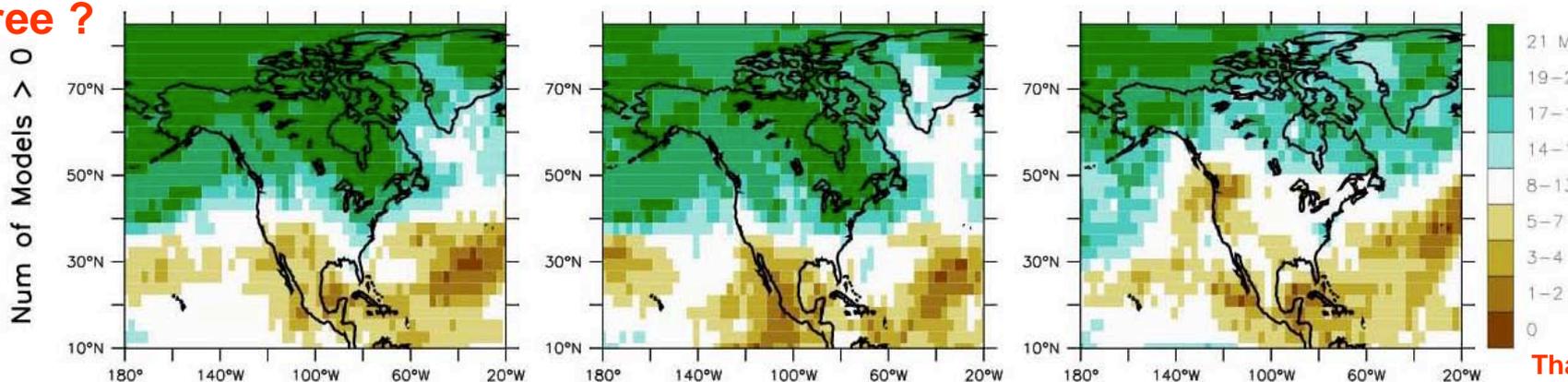
T
(°C)



P
(%)

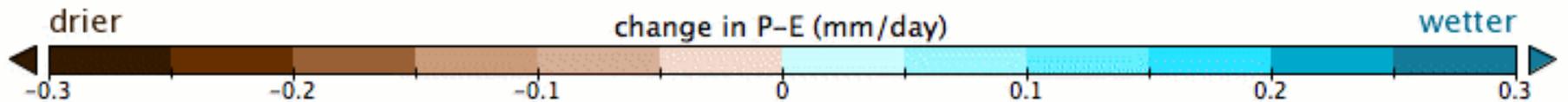
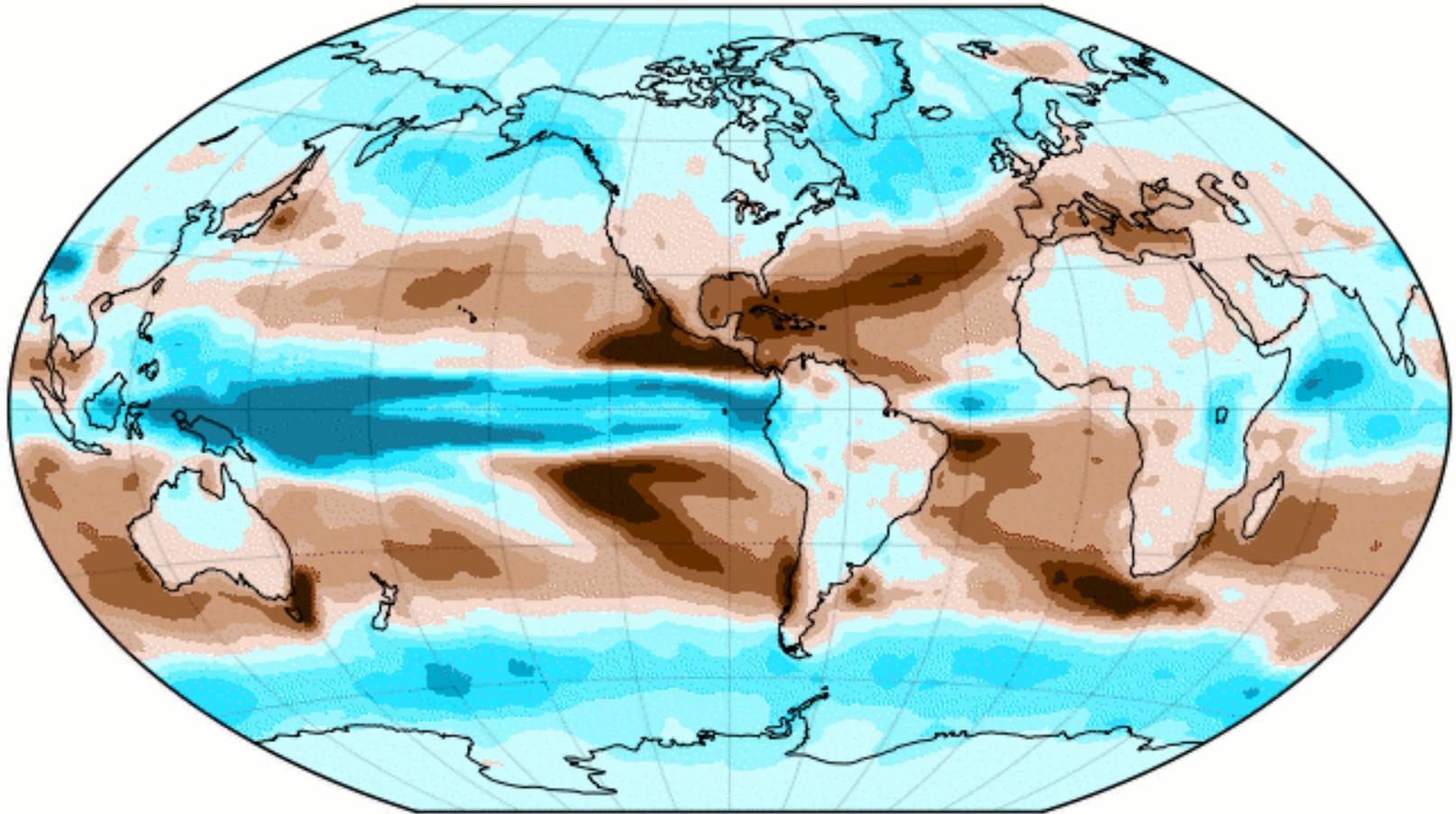


Agree ?



Thanks to Phil Mote

Change in P-E (2021-2040 minus 1950-2000)

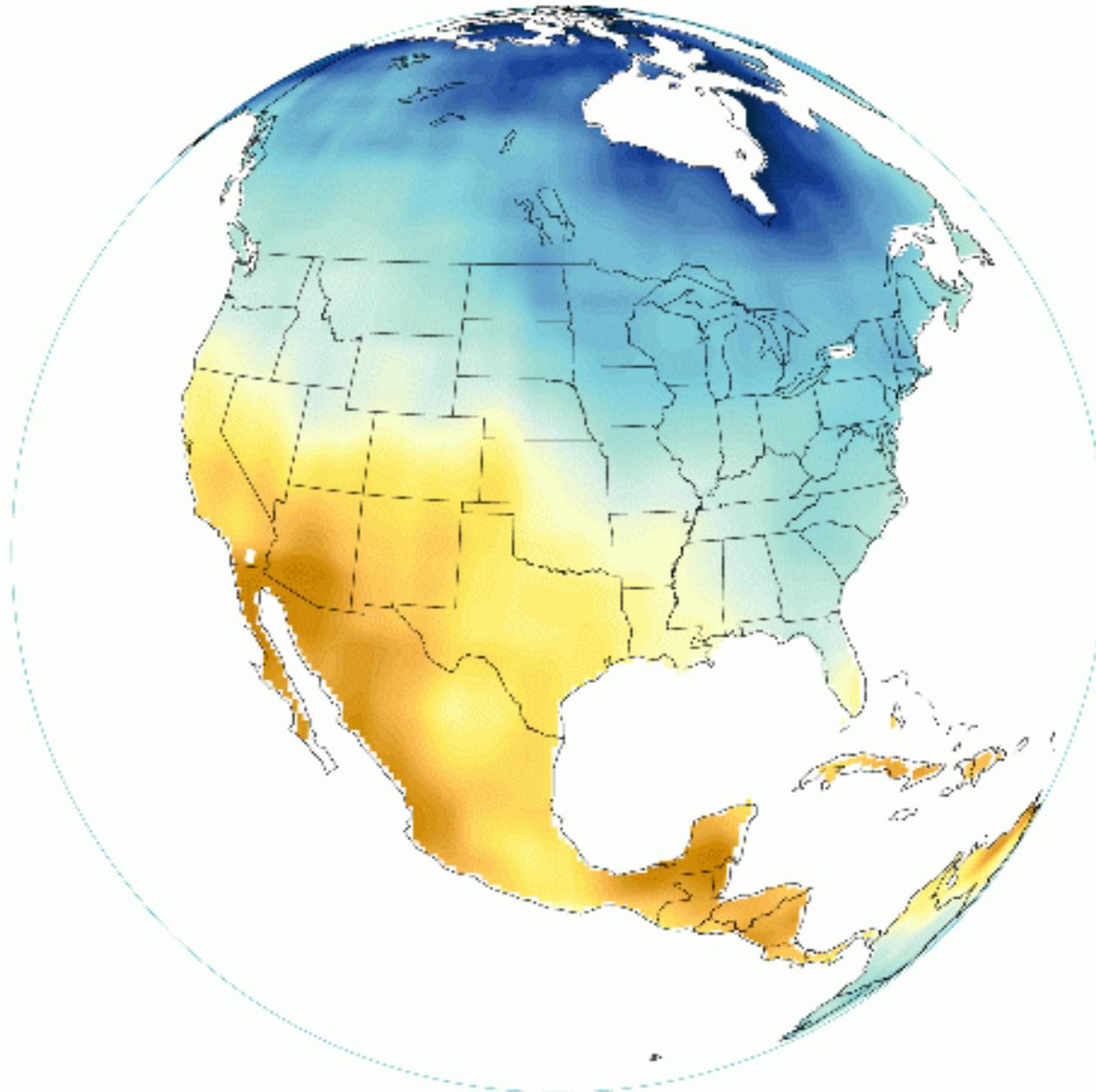


Winkel Tripel projection centered on -90.0°E

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

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

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



**Average of 19
climate models.
2007.**

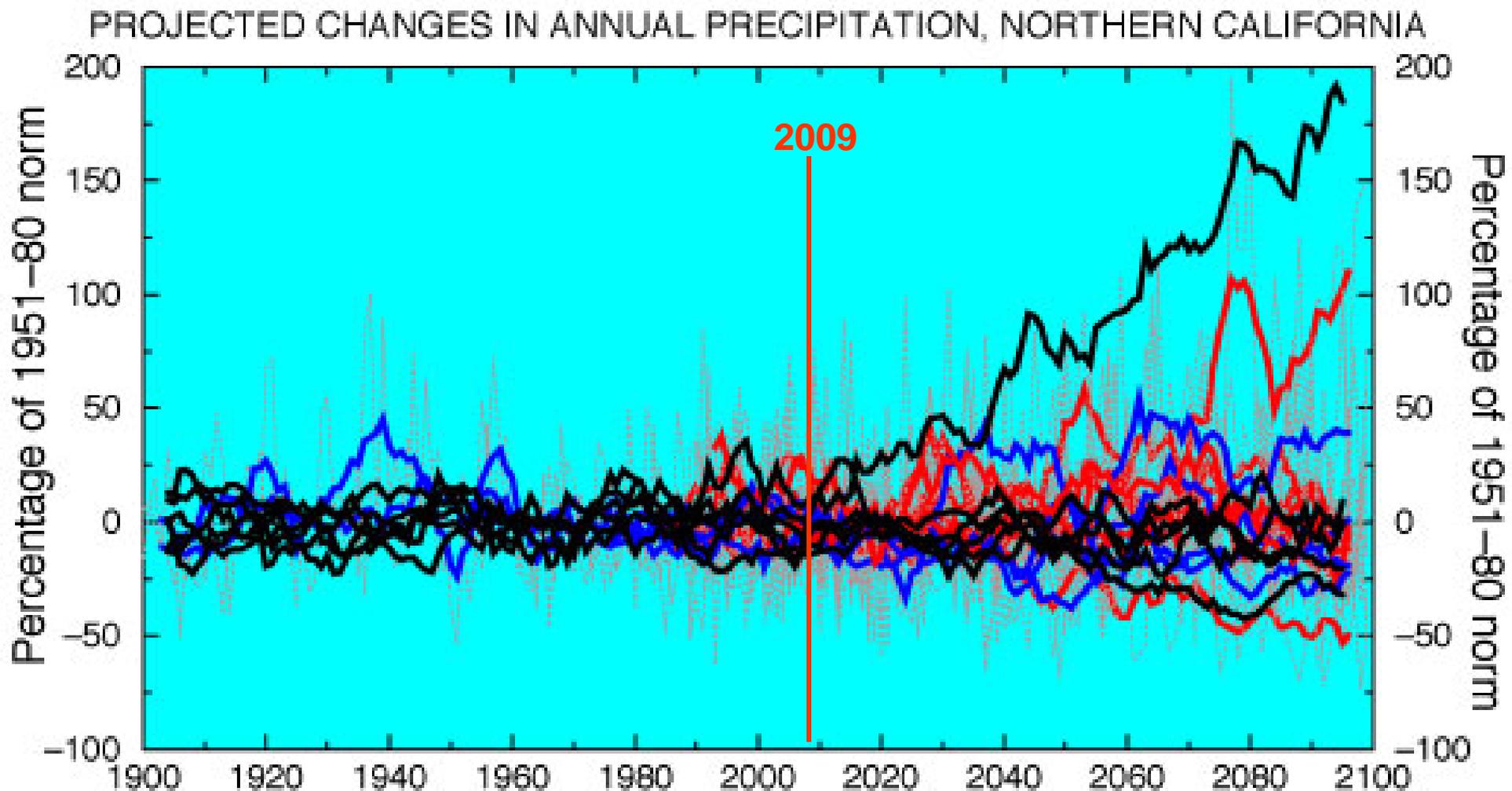
**Figure by
Gabriel Vecchi.**

[www.ideo.columbia.edu/
res/div/ocp/drought/science.shtml](http://www.ideo.columbia.edu/res/div/ocp/drought/science.shtml)

**21 Years
From 2009**

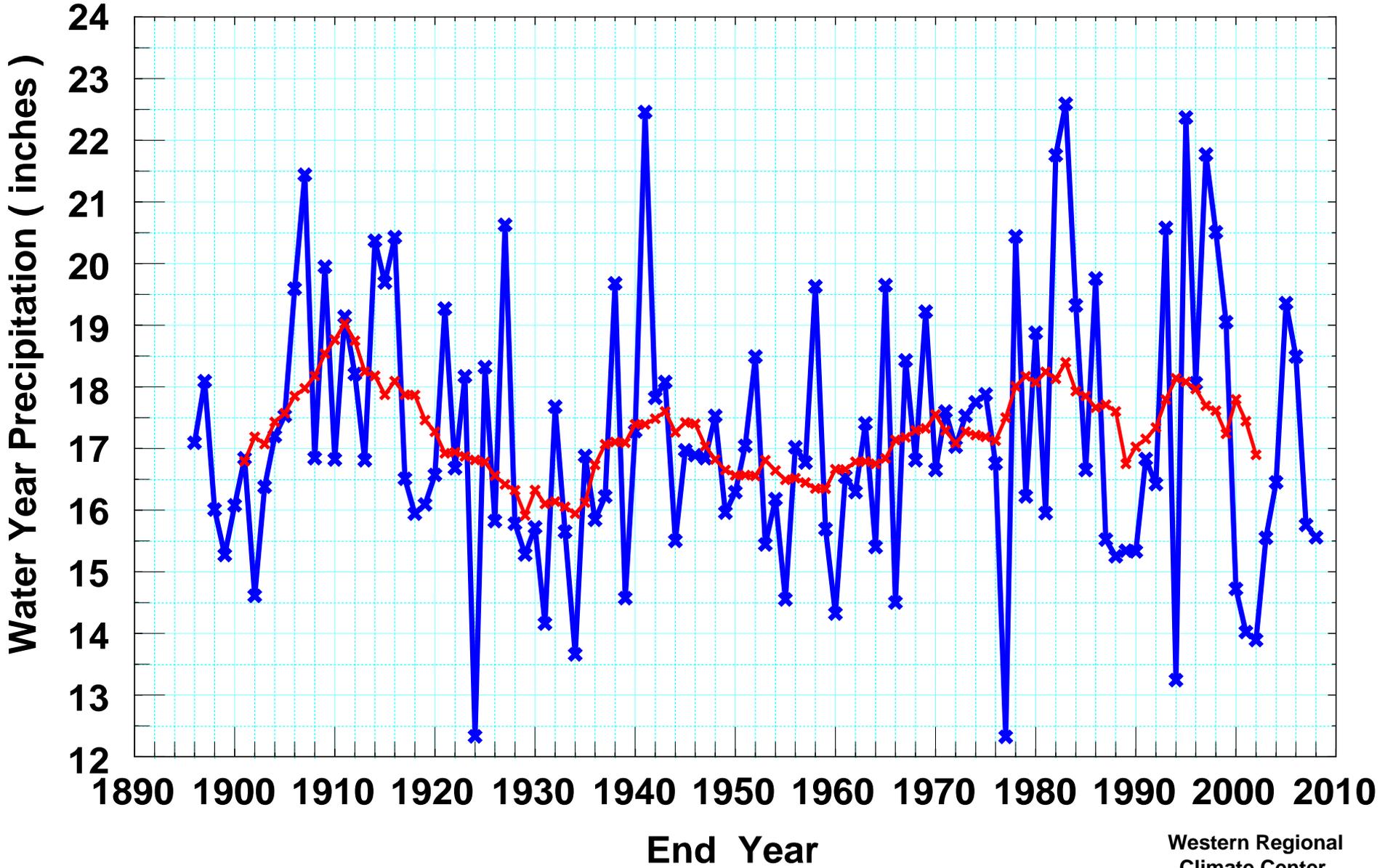
**R. Seager, M.F. Ting, I.M. Held,
Y. Kushnir, J. Lu, G. Vecchi,
H.-P. Huang, N. Harnik, A.
Leetmaa, N.-C. Lau, C. Li, J.
Velez, N. Naik, 2007. Model
Projections of an Imminent
Transition to a More Arid
Climate in Southwestern North
America. *Science*, DOI:
10.1126/science.1139601**

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>

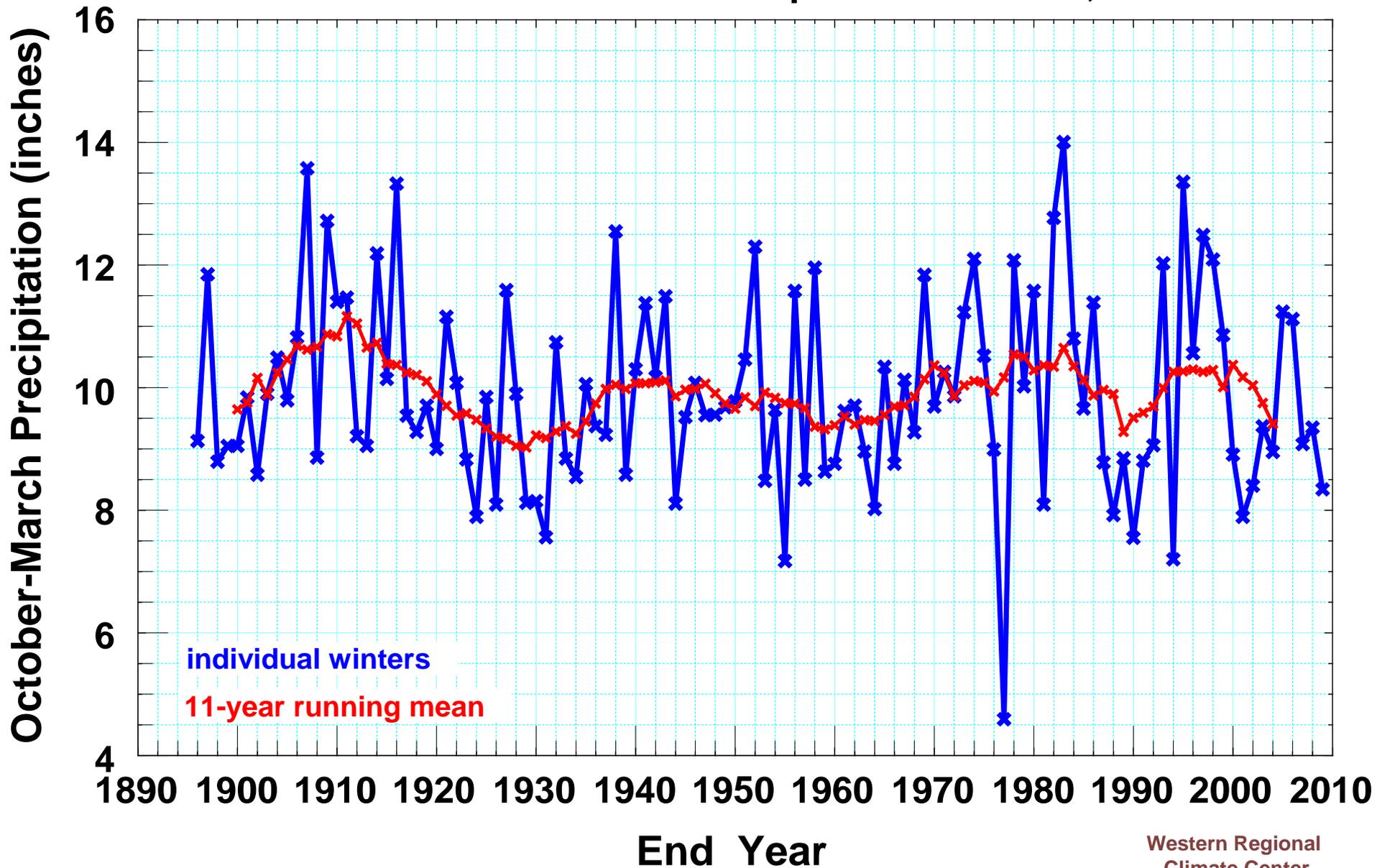
Western United States (11 states) Water Year (Oct-Sep) Precipitation.
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Inches. Data source NOAA cooperative network, thru Dec 2008.



Western United States (11 states) October-March Precipitation.

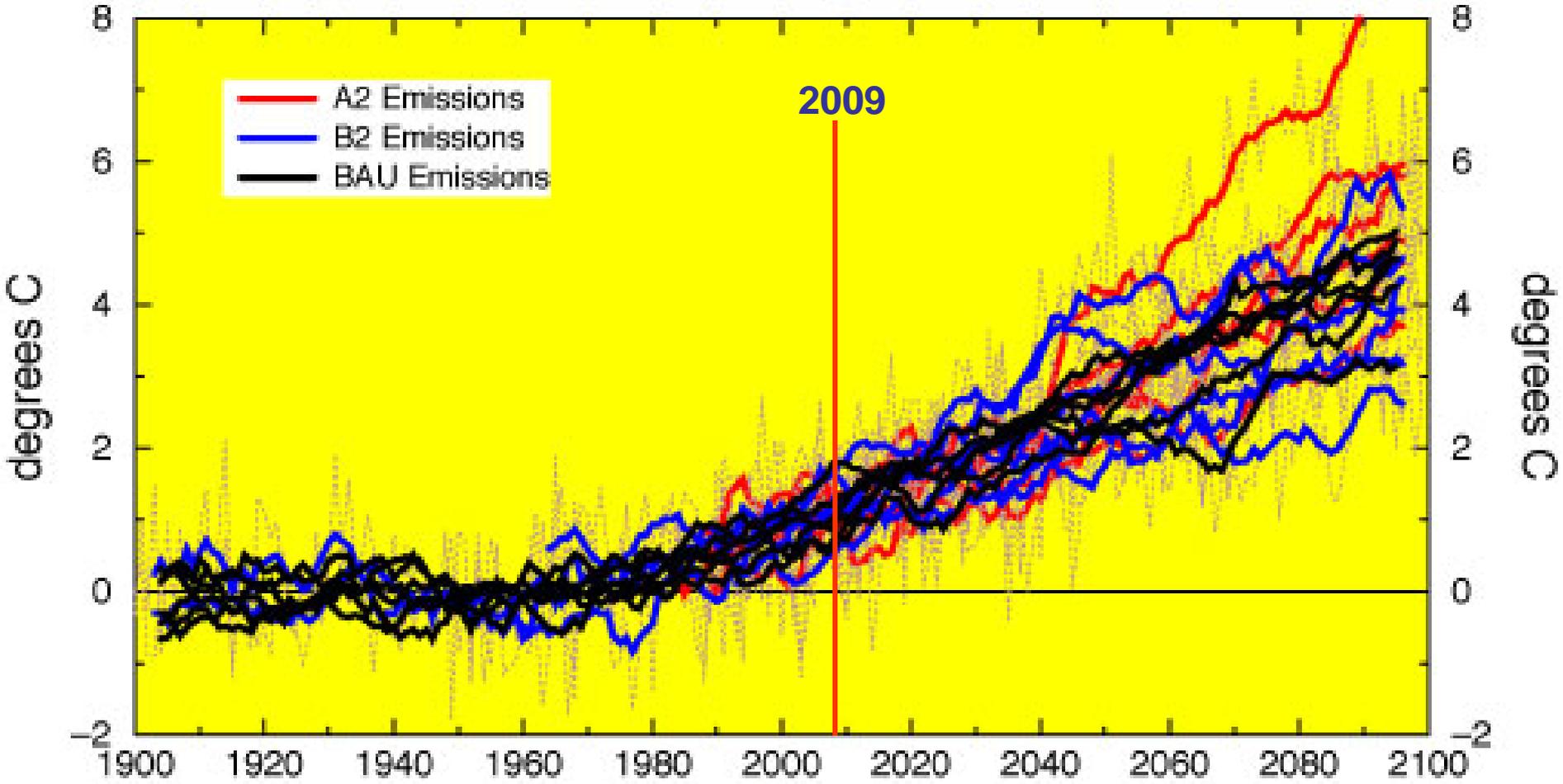
Provisional data from NCDC / CPC. 112 Winters, 1895-2006.

Units: Inches. Data source NOAA cooperative network, thru Mar 2009.

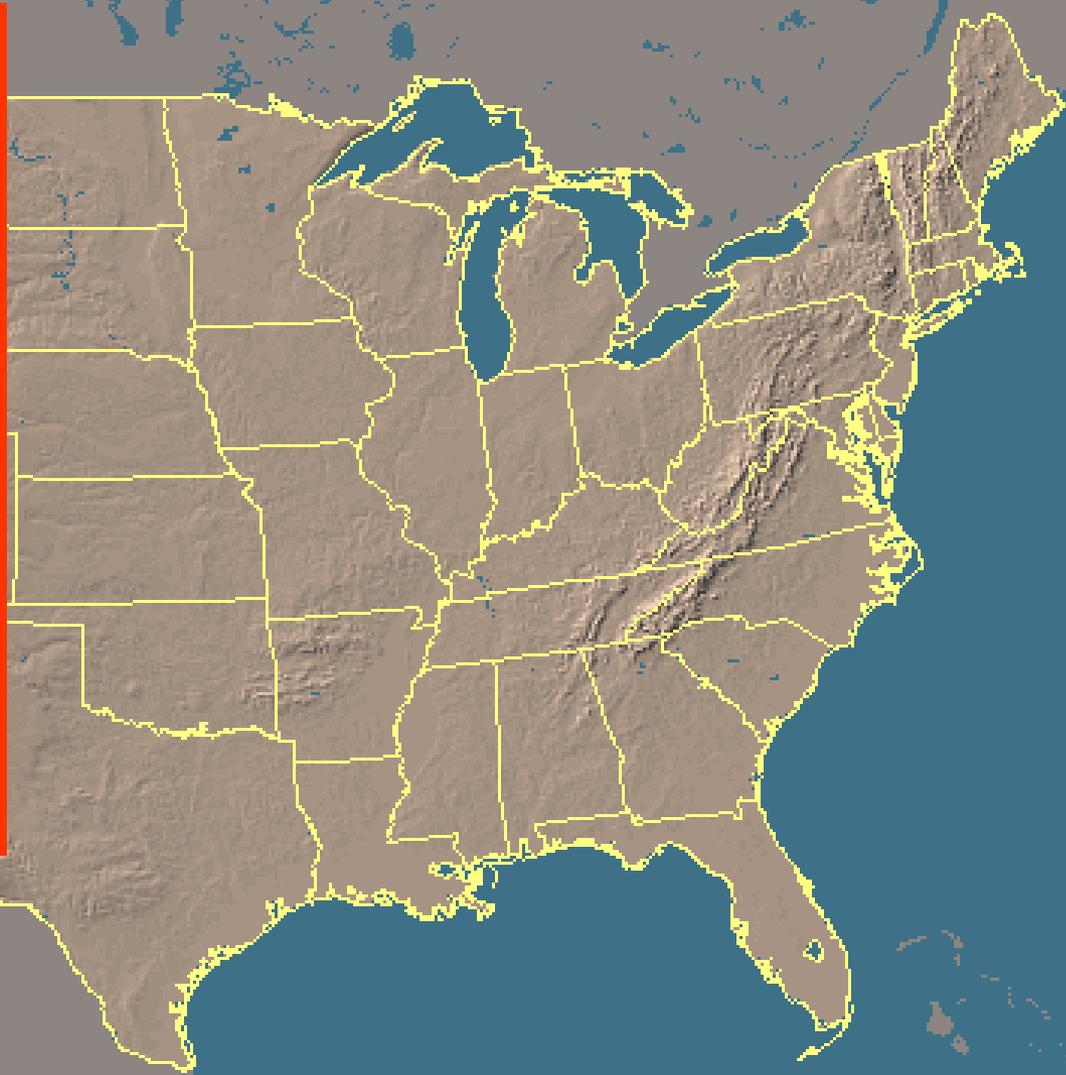


Courtesy of Mike Dettinger, USGS / Scripps.

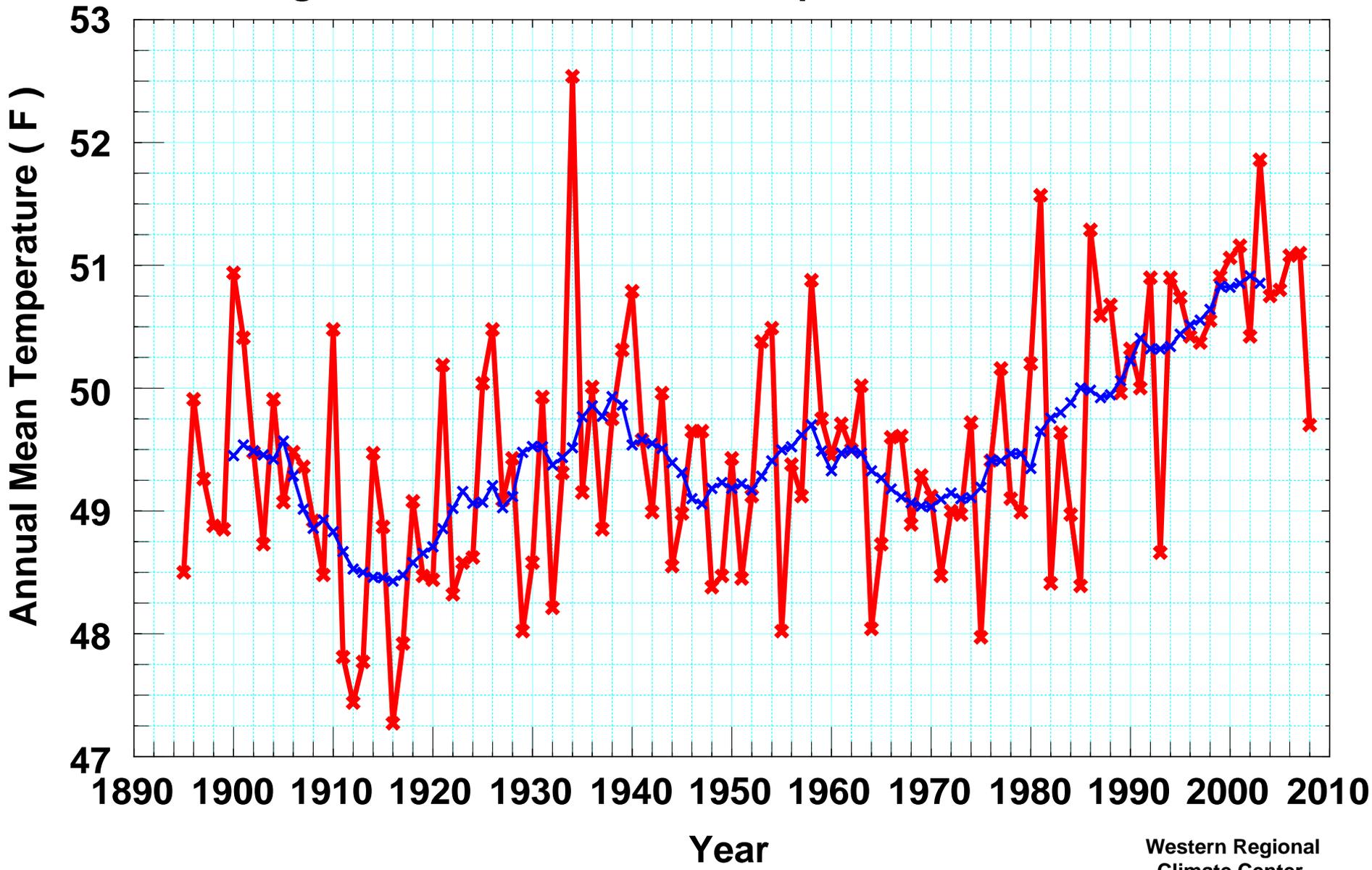
PROJECTED CHANGES IN ANNUAL TEMPERATURE, NORTHERN CALIFORNIA



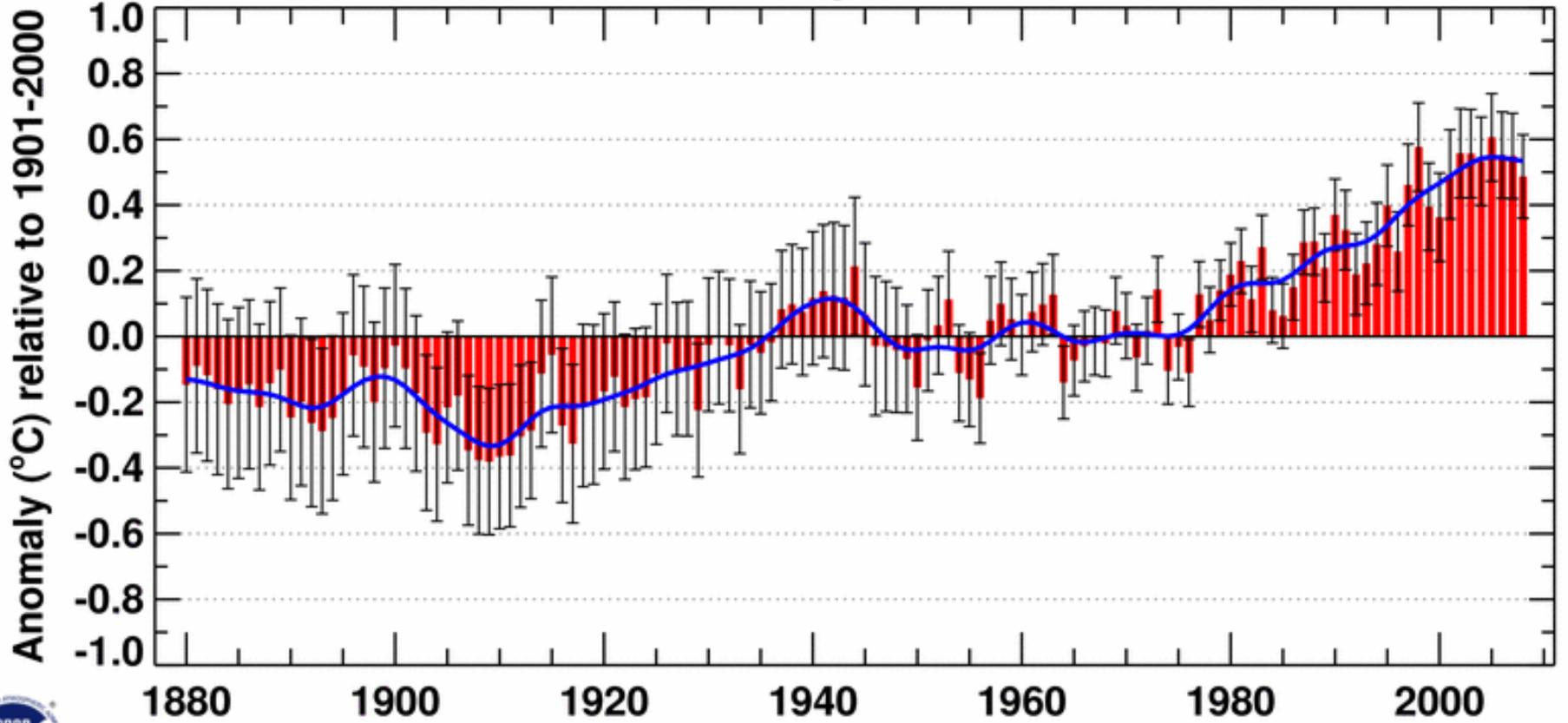
Dettinger MD. 2005. From climate change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science. Vol. 3, Issue 1, (March 2005), Article 4. <http://repositories.cdlib.org/jmie/sfew/s/vol3/iss1/art4>



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.



Jan-Dec Global Mean Temperature over Land & Ocean



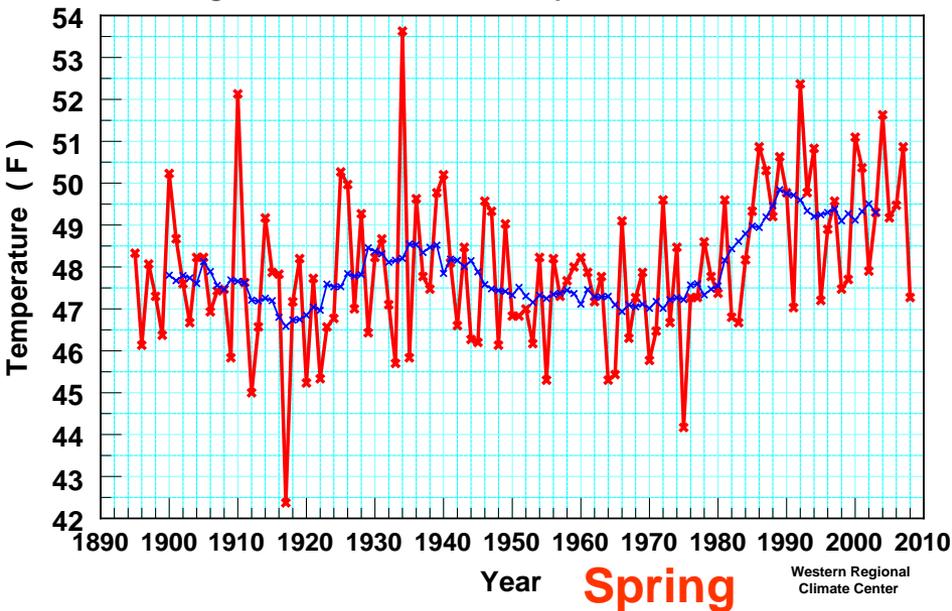
NCDC/NESDIS/NOAA

Thru Dec 2008

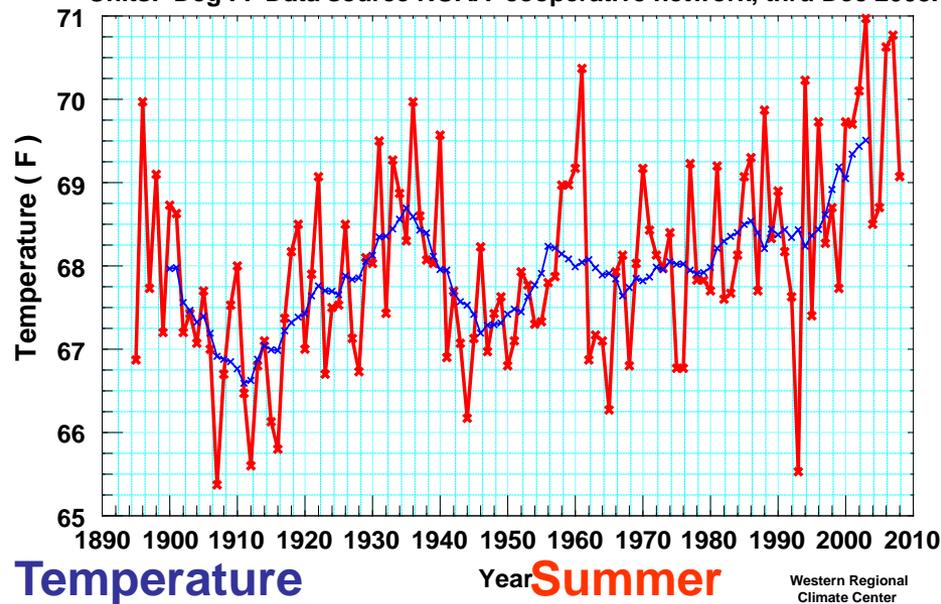
NOAA

National Climatic
Data Center

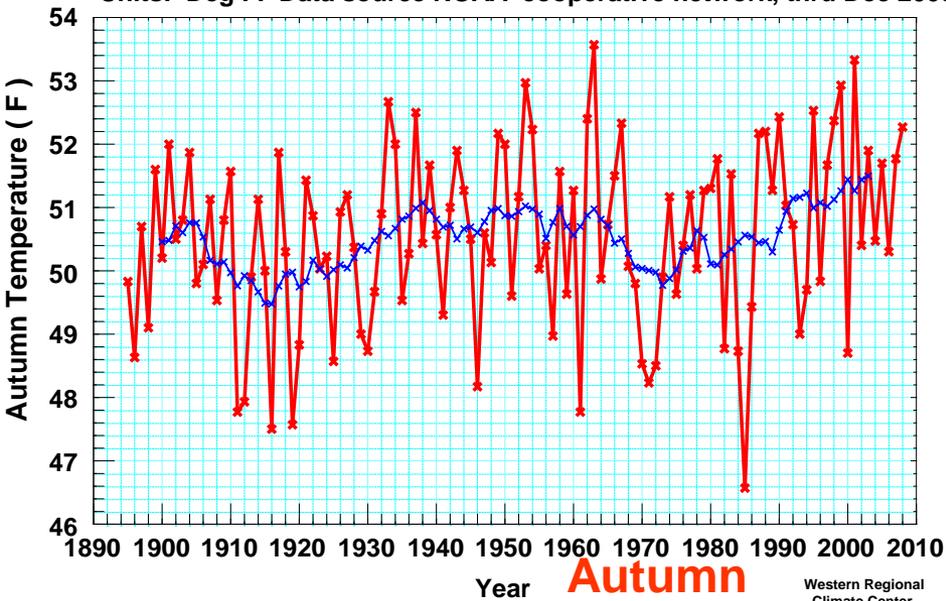
Western United States (11 states) Mar-Apr-May Temperature
 Provisional data from NCDC / CPC. Blue: 11-year running mean.
 Units: Deg F. Data source NOAA cooperative network, thru Dec 2008.



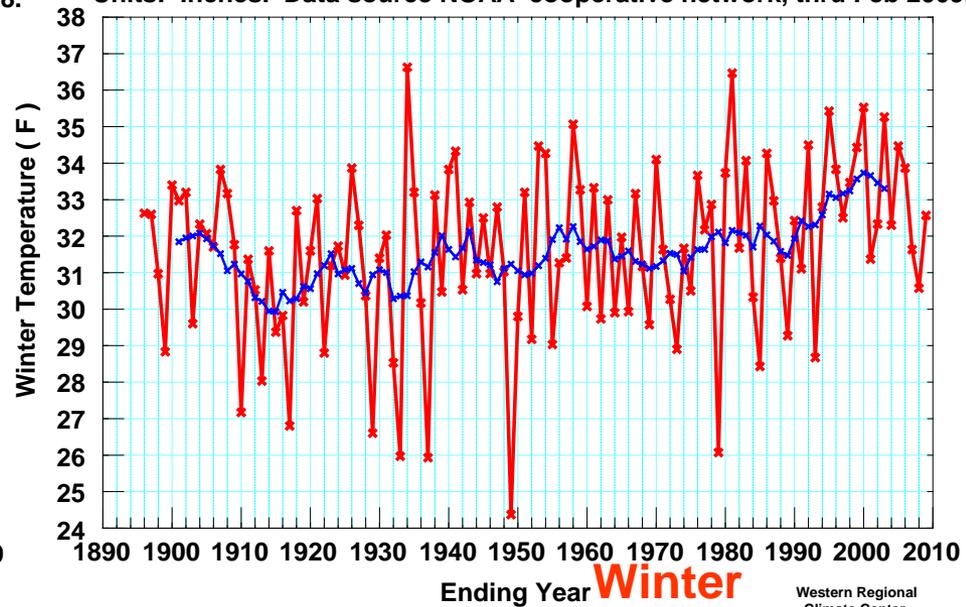
Western United States (11 states) June-July-August Temperature
 Provisional data from NCDC / CPC. Blue: 11-year running mean.
 Units: Deg F. Data source NOAA cooperative network, thru Dec 2008.



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 Dec 2008.



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.



IPCC Emissions Scenarios.

(observed trajectory in 2009 is above all of these)

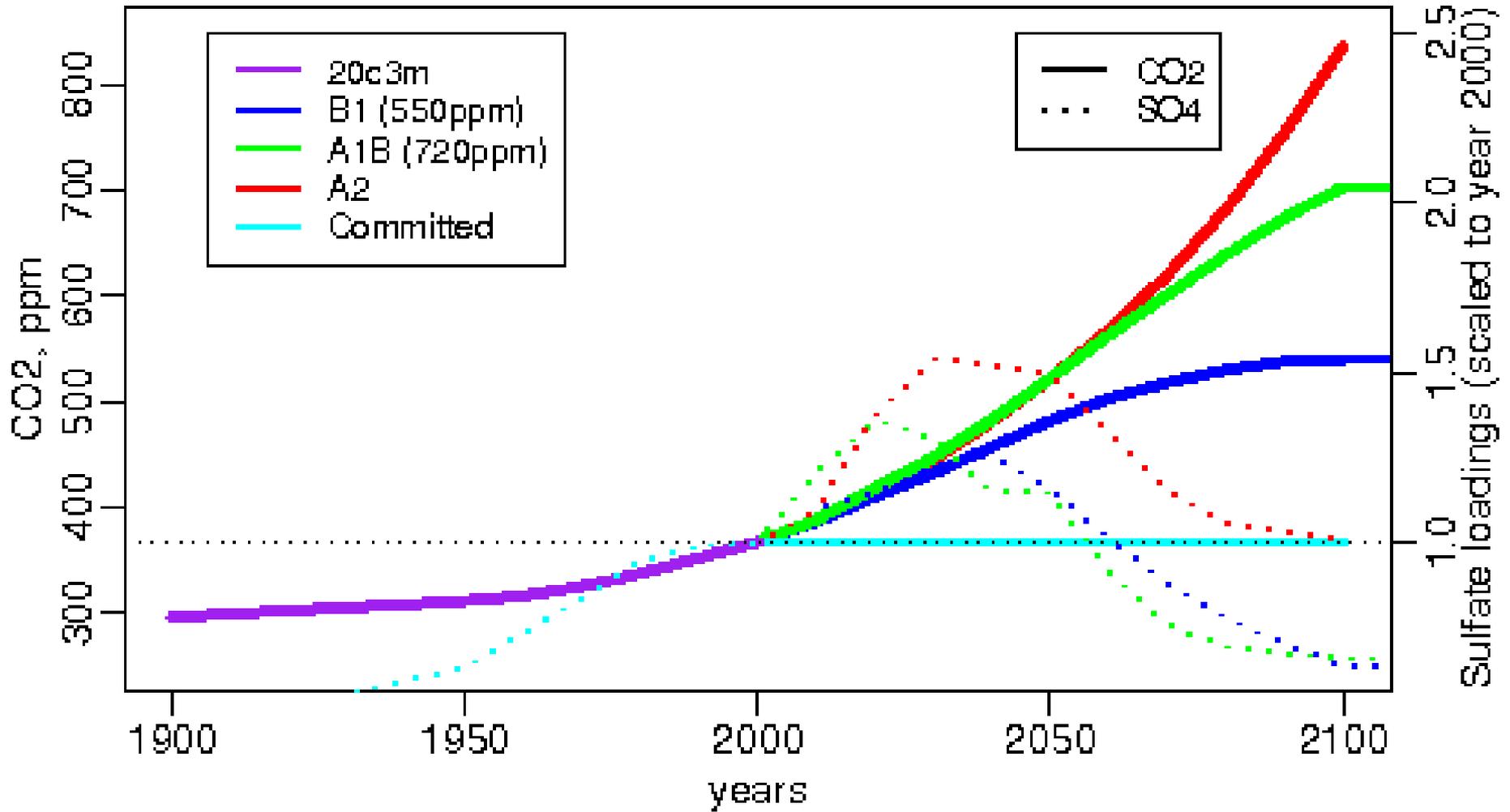
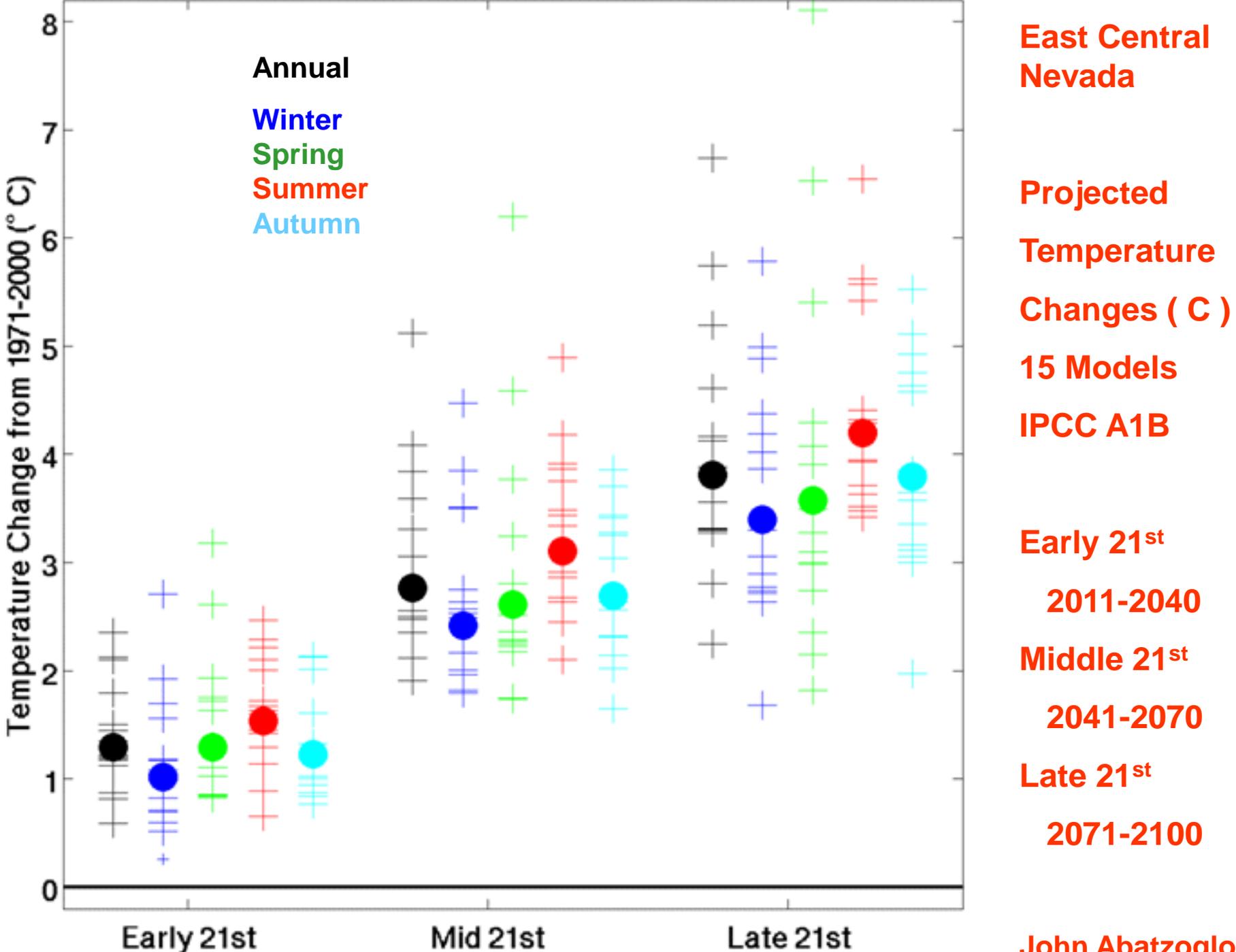
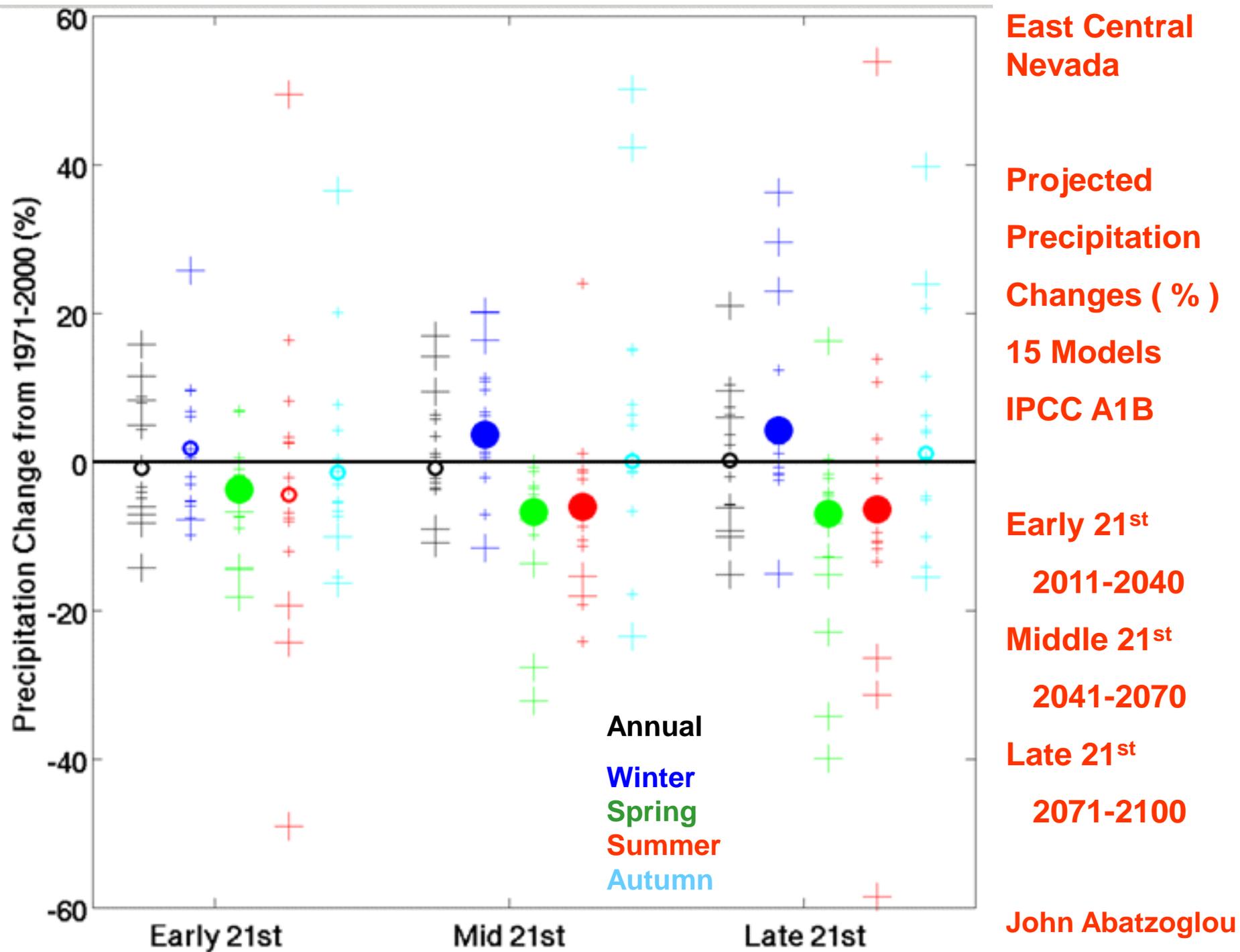
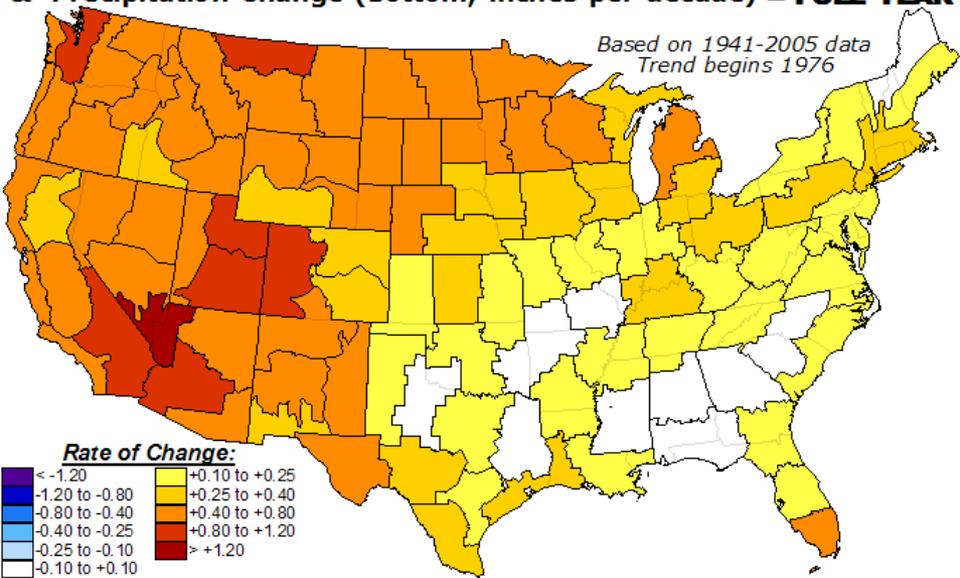


Figure from Environment Canada, 2005.



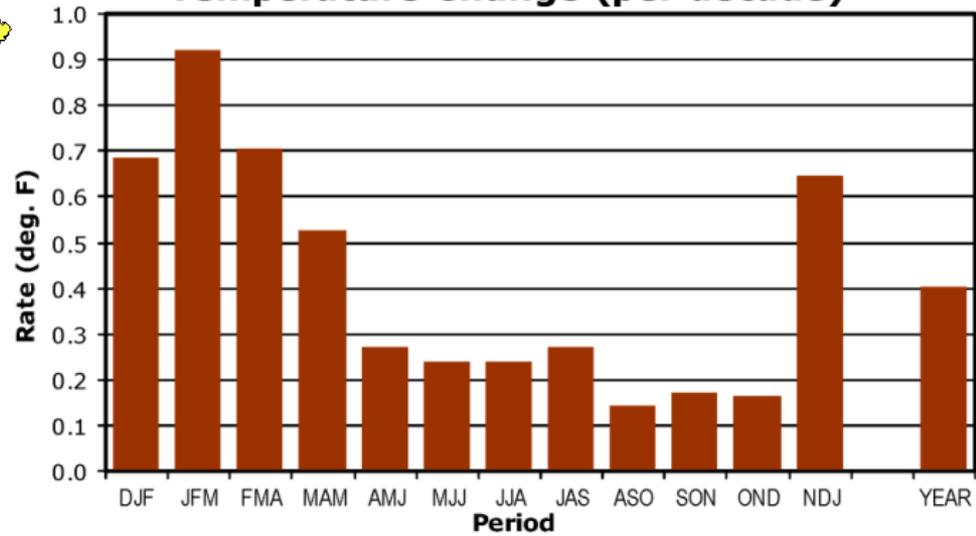


Rate of Long-Term Trend Temperature Change (top; °F per decade) & Precipitation Change (bottom; inches per decade) – FULL YEAR



Annual Temperature Trend 1976 - 2005

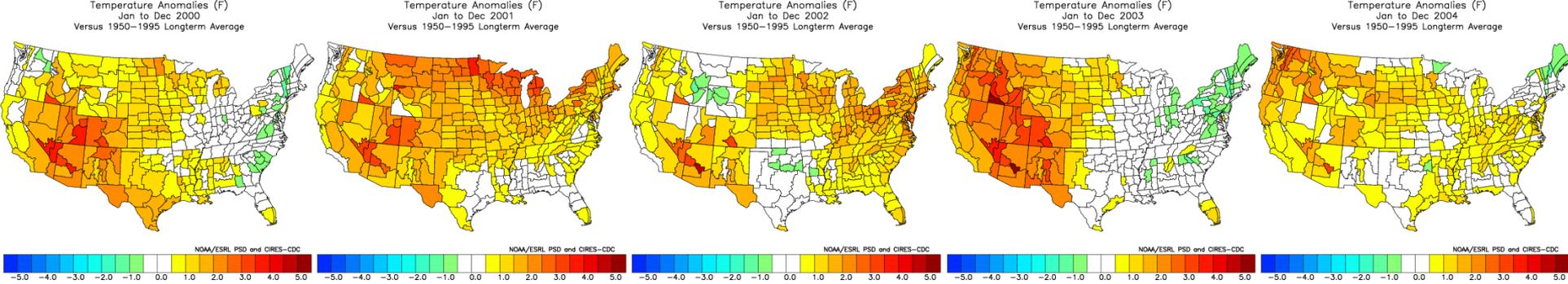
U.S. Average Rate of Long-Term Trend Temperature Change (per decade)



Winter Spring Summer Autumn Annual

National Temperature Trend by Season

The Last 30 Years



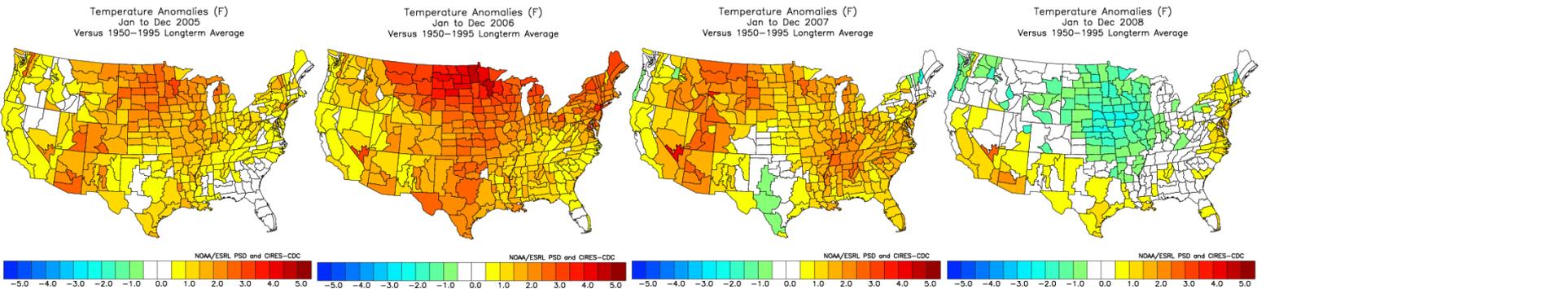
2000

2001

2002

2003

2004



2005

2006

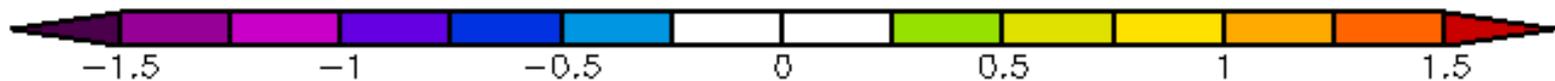
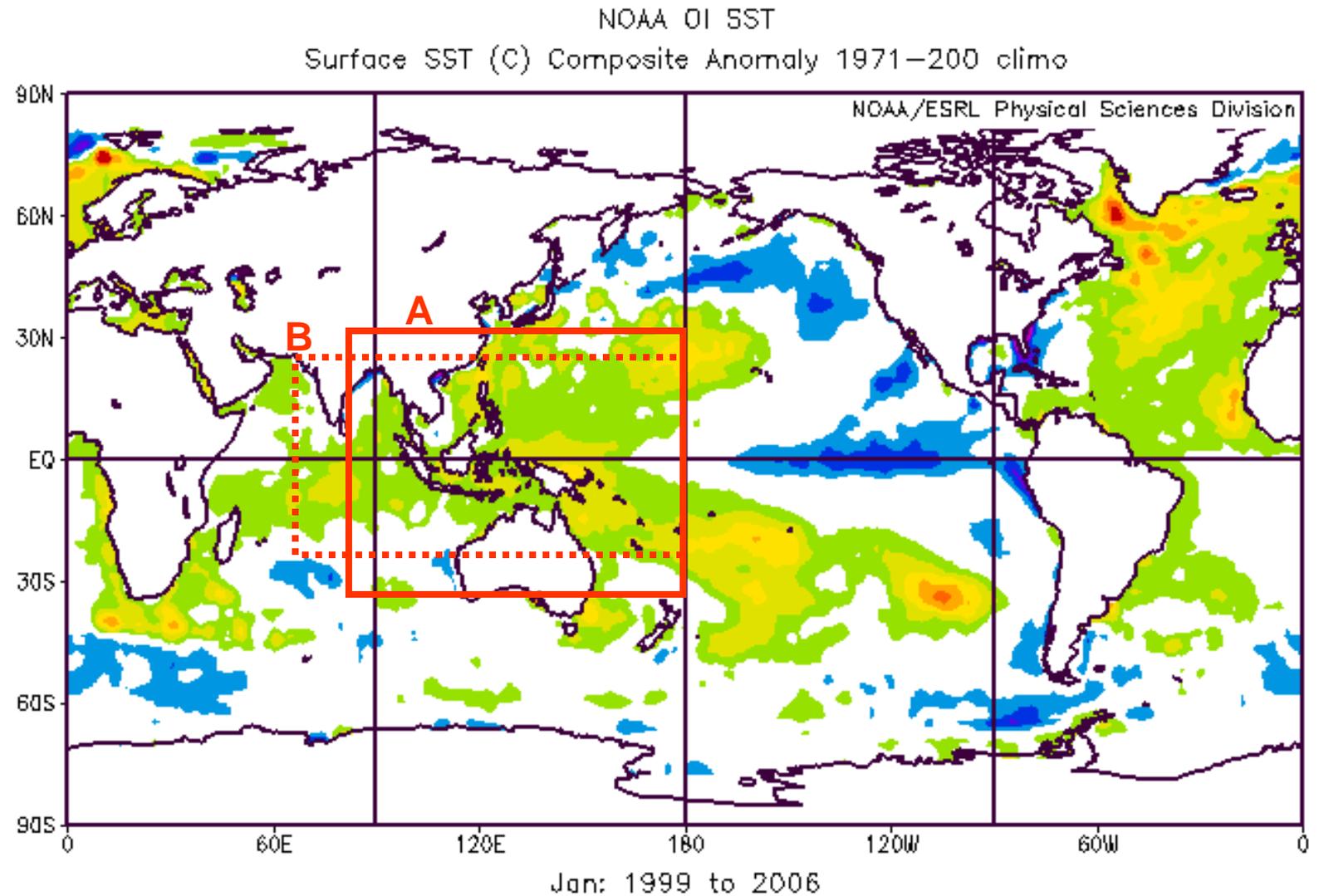
2007

2008

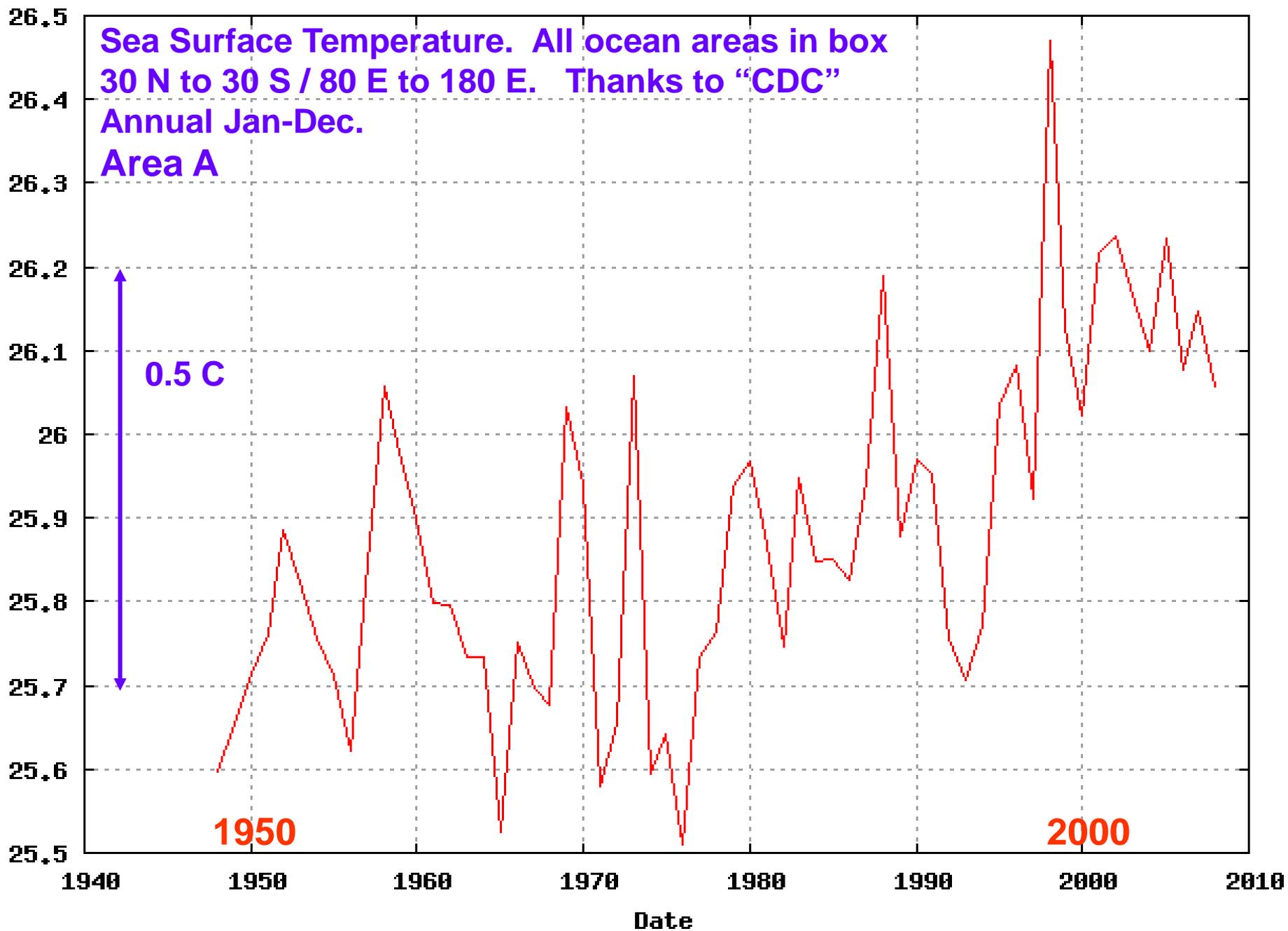
United States Annual Temperature Departure from 1950-1995 Mean

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

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

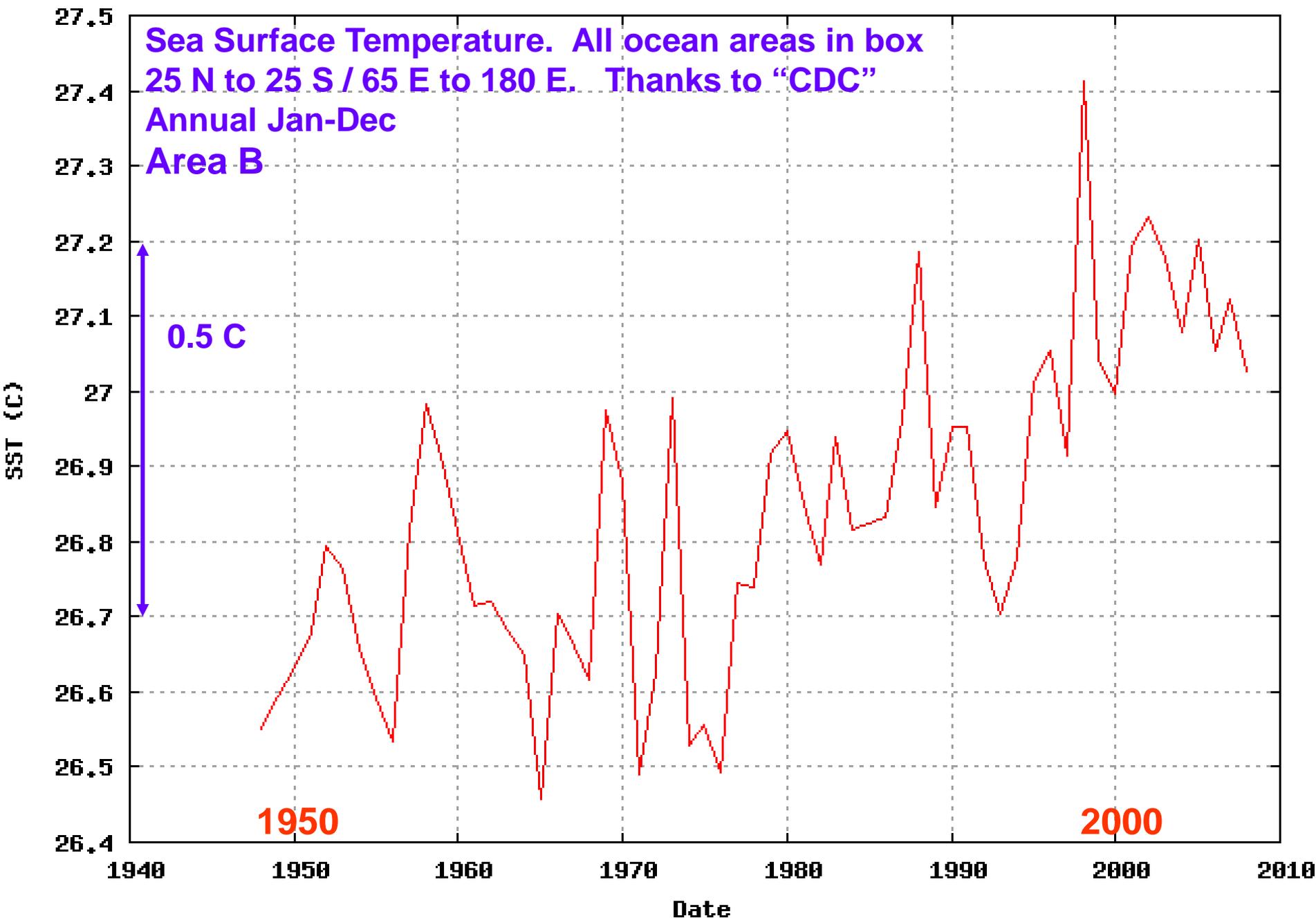


SST (NCEP Reanalysis) Jan to Dec; 30N to -30S and 80E to 180E averaged

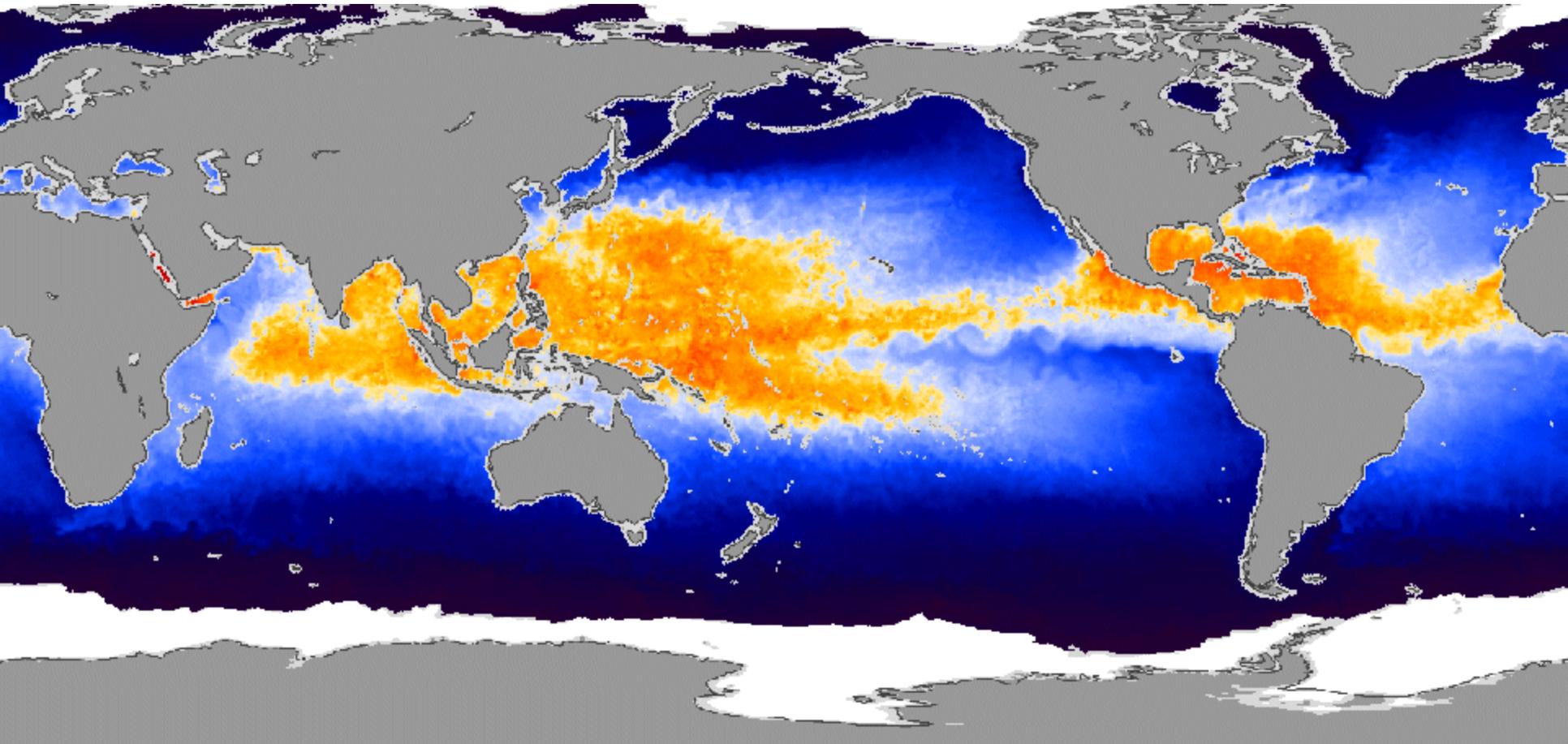


SST (NCEP Reanalysis) Jan to Dec; 25N to -25S and 65E to 180E averaged

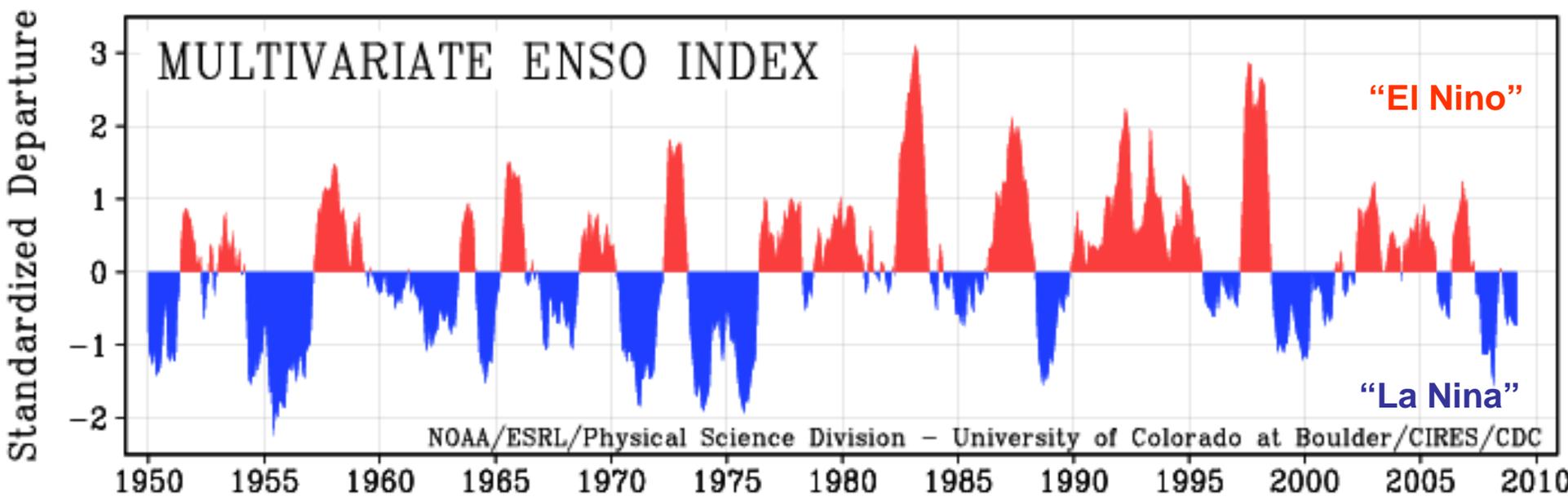
Sea Surface Temperature. All ocean areas in box
25 N to 25 S / 65 E to 180 E. Thanks to "CDC"
Annual Jan-Dec
Area B



The World's Warm Oceans

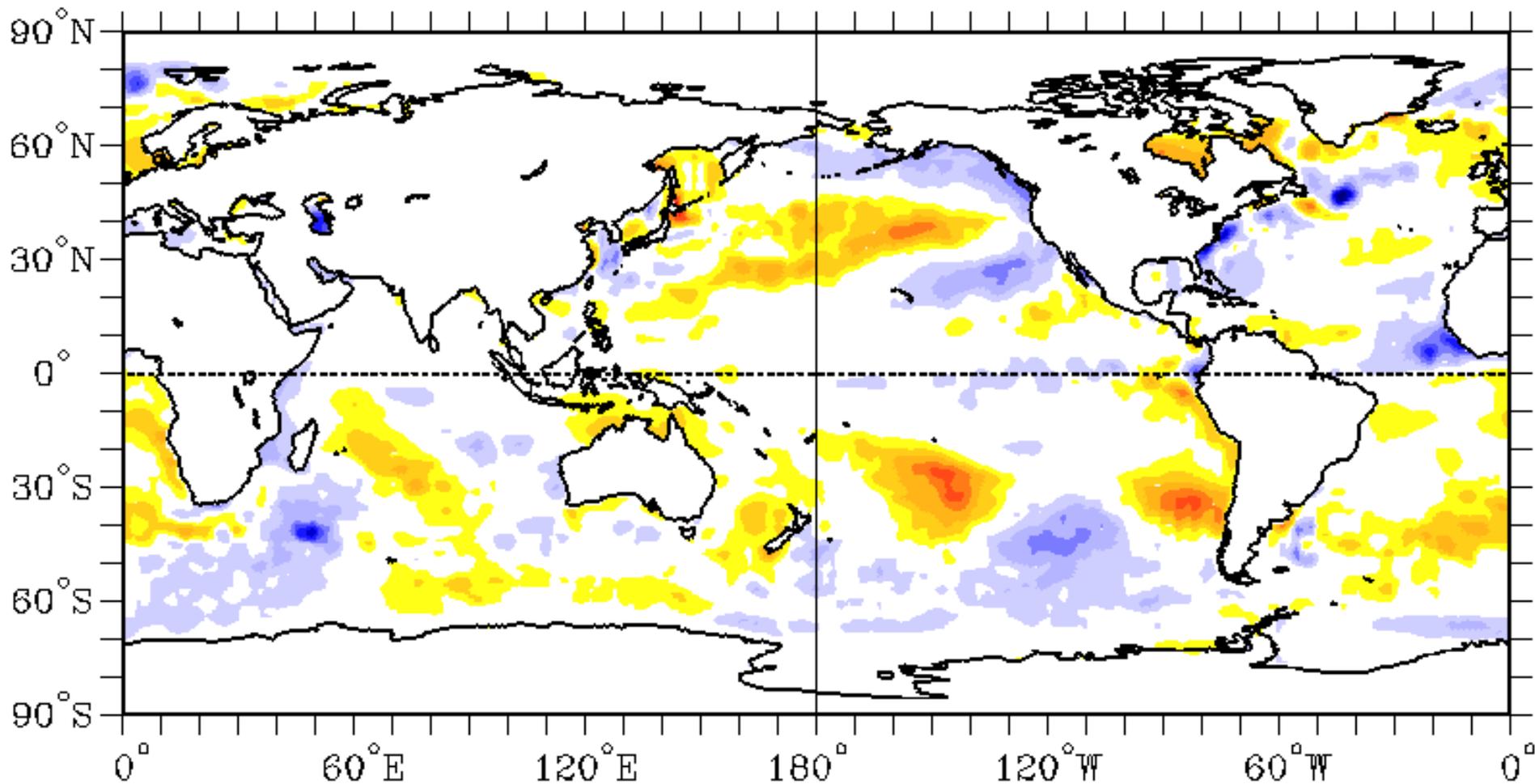


Through March 2009



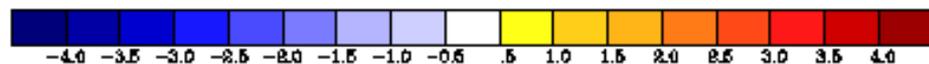
NOAA ESRL (“CDC”), Wolter and Timlin

Global Sea Surface Temperature Anomalies (C) 2009 April 19-25



SST ANOM 4/19/09- 4/25/09

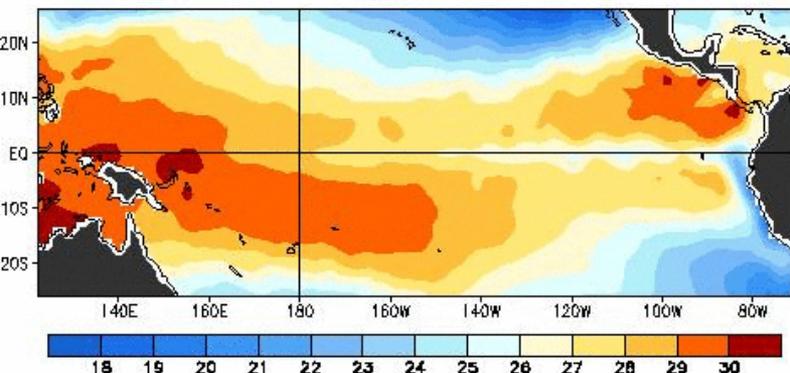
Base Period: 1982-96



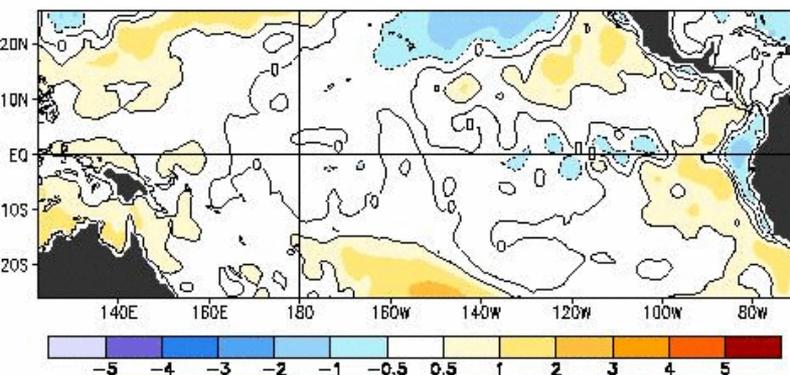
NOAA ESRL ("CDC")

Recent Evolution of Equatorial Pacific SST Departures

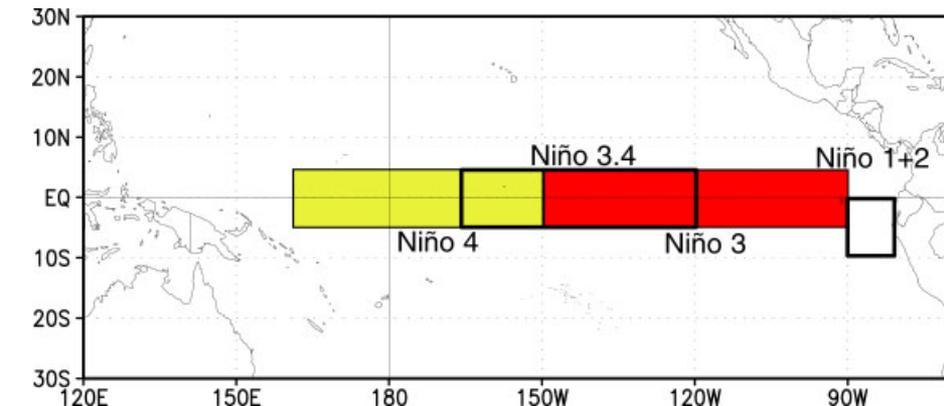
Observed Sea Surface Temperature (°C)



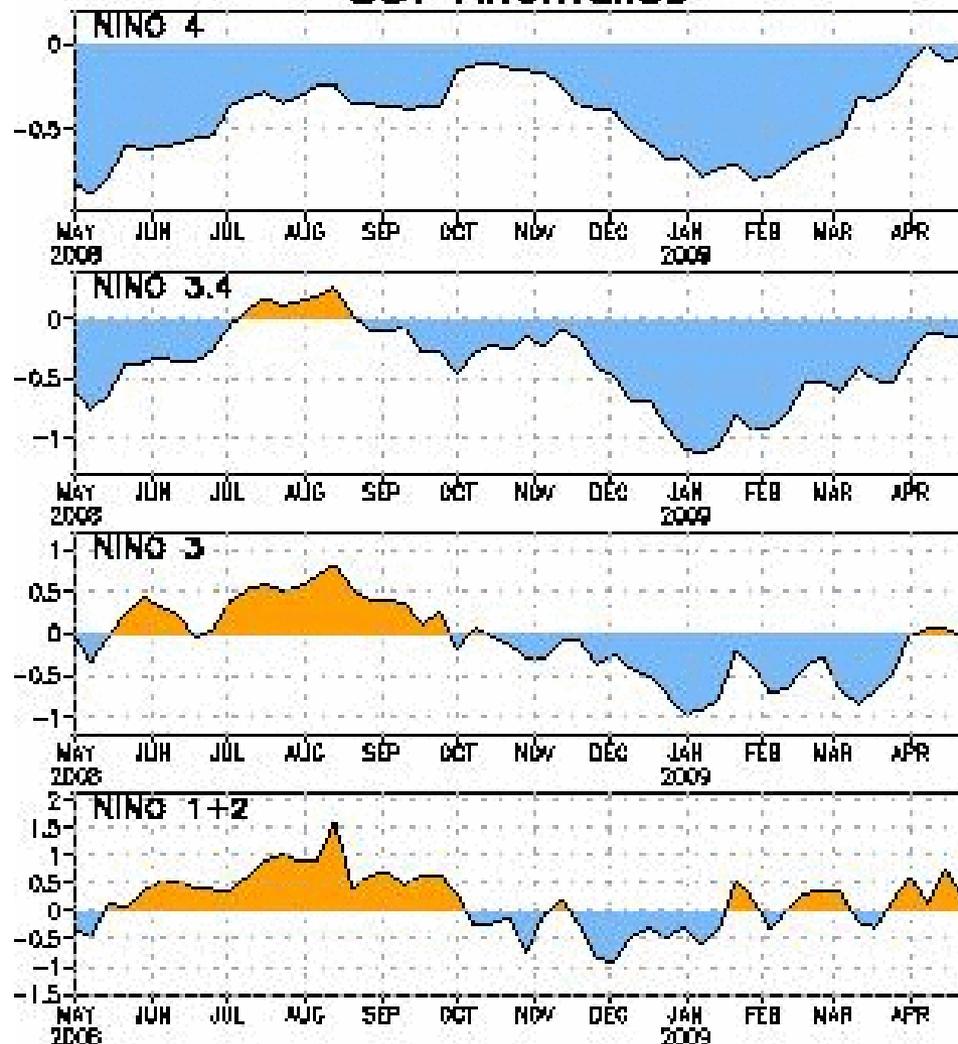
Observed Sea Surface Temperature Anomalies (°C)



7-day Average Centered on 22 April 2009



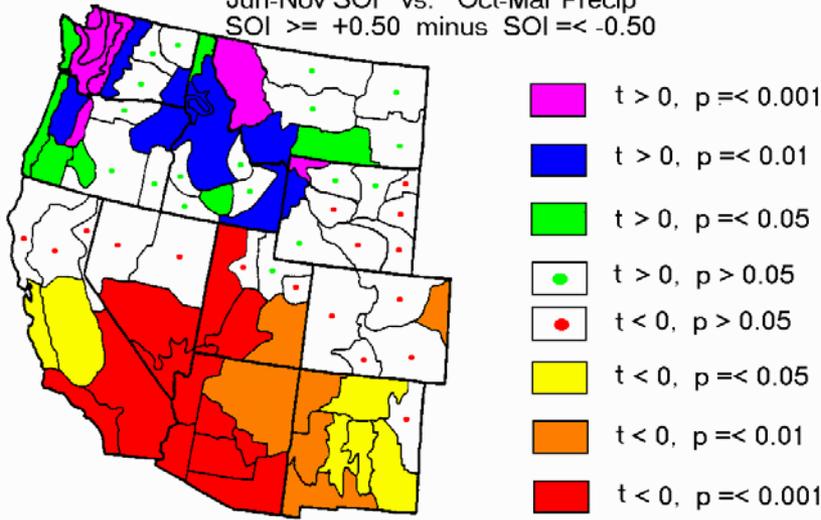
SST Anomalies



Updated through 2009 April 19-25

Split Samples:

Jun-Nov SOI vs. Oct-Mar Precip
 SOI $\geq +0.50$ minus SOI ≤ -0.50



Updated from Redmond and Koch (1991). Winters of 1933/34 - 1994/95.
 Reddish: Composite El Nino winters are wet, La Nina winters are dry.
 Bluish/greenish: Composite El Nino winters are dry, La Nina winters are wet.

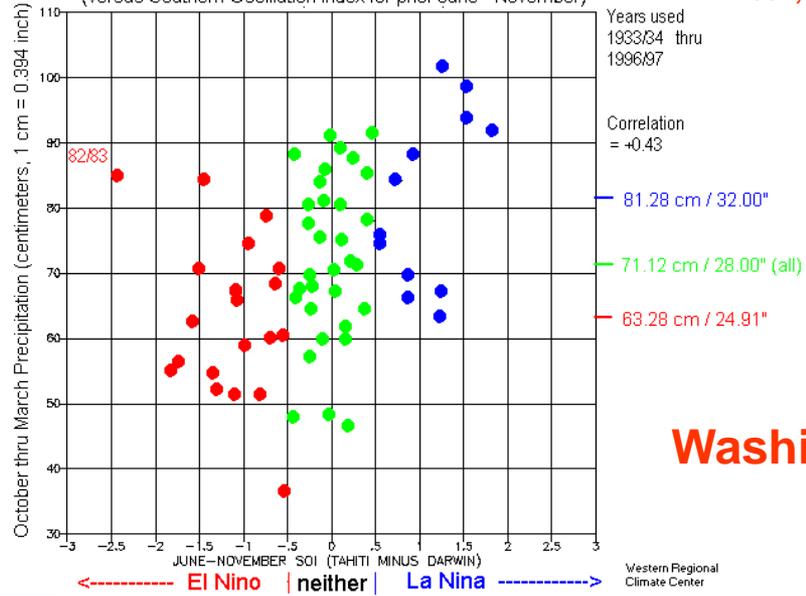
Redmond, K.T., and R.W. Koch, 1991. Surface climate and streamflow variability in the western United States and their relationship to large-scale circulation indices. Water Resources Research, 27(9), 2381-2399.

Redmond & Koch, 1991, updated.

ENSO

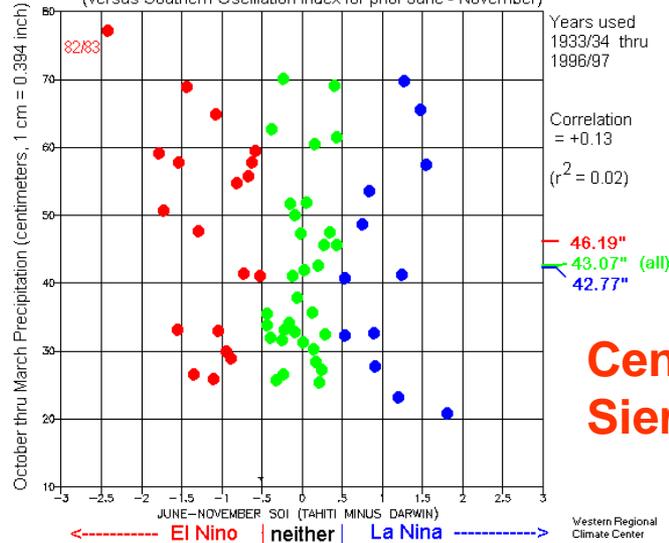
Redmond & Koch, 1991, updated.

Washington statewide October thru March Precipitation
 (versus Southern Oscillation Index for prior June - November)



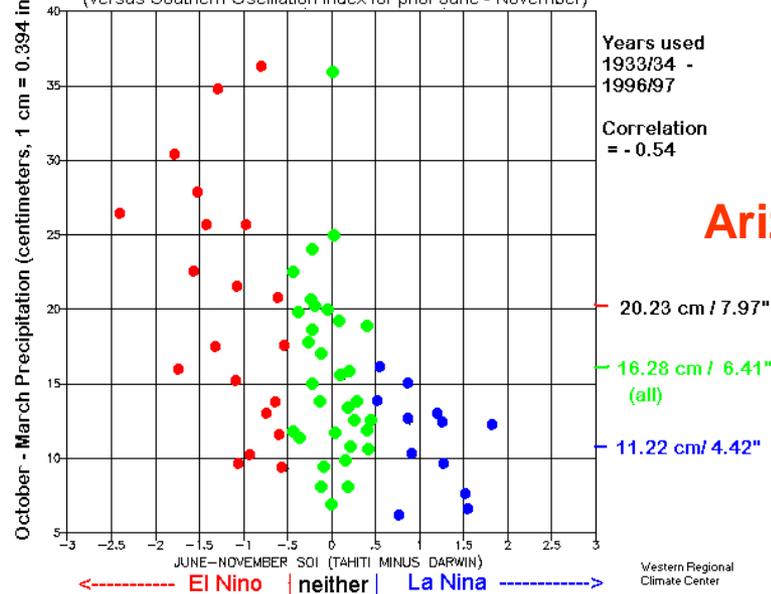
Washington

California 8-Station Index October thru March Precipitation
 (versus Southern Oscillation Index for prior June - November)

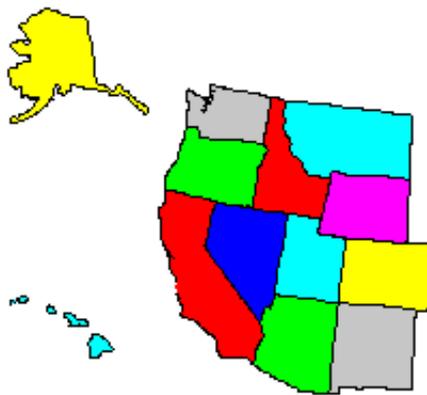


Central Sierra

Arizona statewide October thru March Precipitation
 (versus Southern Oscillation Index for prior June - November)



Arizona



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

[Climate Information](#) [Current Observations](#) [Projects](#) [Educational & Travel](#) [More Sources](#) [About Us](#) [HOME](#)



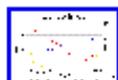
[Community Environmental Monitoring Program \(CEMP\)](#)
Data Monitoring Stations surrounding the NV test site.



[Wind Energy Assessment for Nevada](#)
Nevada Wind Study Towers.



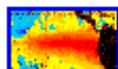
[RAWS Data \(Remote Automated Weather Stations\)](#)
Summaries, Graphs, and other products for RAWS.



[Current Weather Data Plots](#)
Current Data Plots



Photo Galley of the Western States:
[Landscapes](#), [Sunrise](#), [Sunset and Lunar](#), and [Misc.](#)



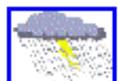
[El Nino/La Nina and the Western US, Alaska and Hawaii](#)
Information regarding El Nino and La Nina.



[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
Hadar 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.

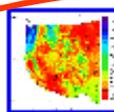


[California Climate Tracker](#)
Tracking Climate Variability and Change for the state of California.



[Nevada Climate Tracker](#)
Tracking Climate Variability and Change for the state of Nevada.

NEW



[Westmap Climate Project](#)
The Western Climate Mapping Initiative.

NEW



WestMap

Climate Analysis & Mapping Toolbox

[WestMap Home](#)

TOOLBOX

Map & Graph

[Create Time Series](#)

[Create Map](#)

[Tutorial](#)

[Custom Requests](#)

Climate 101

[Local Climate](#)

[Educational Resources](#)

[Climate Links](#)

WestMap

[Overview](#)

[About PRISM](#)

[About Us](#)

User Feedback

[Survey!](#)

[Publications](#)

[Applications](#)

Select Element

Precipitation

Select Region By

States

Select Record

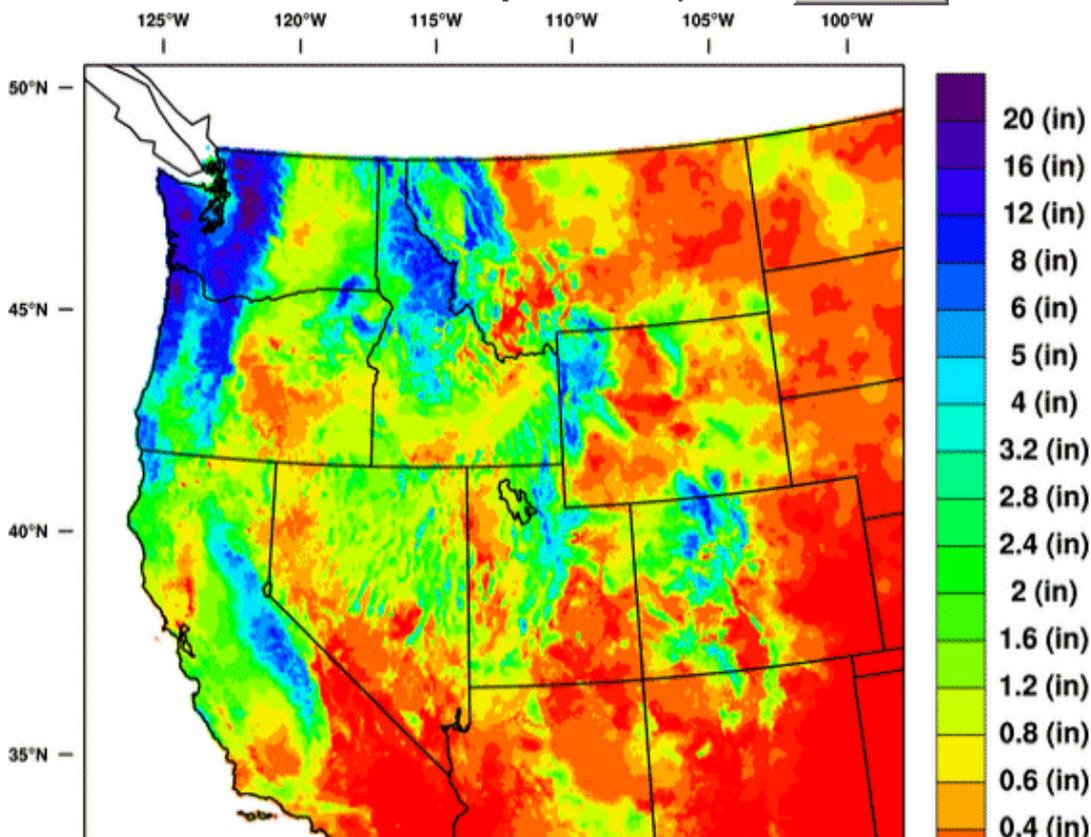
Most Recent

Map Click

Show Time Series

January 2009 Precipitation

PRINT MAP



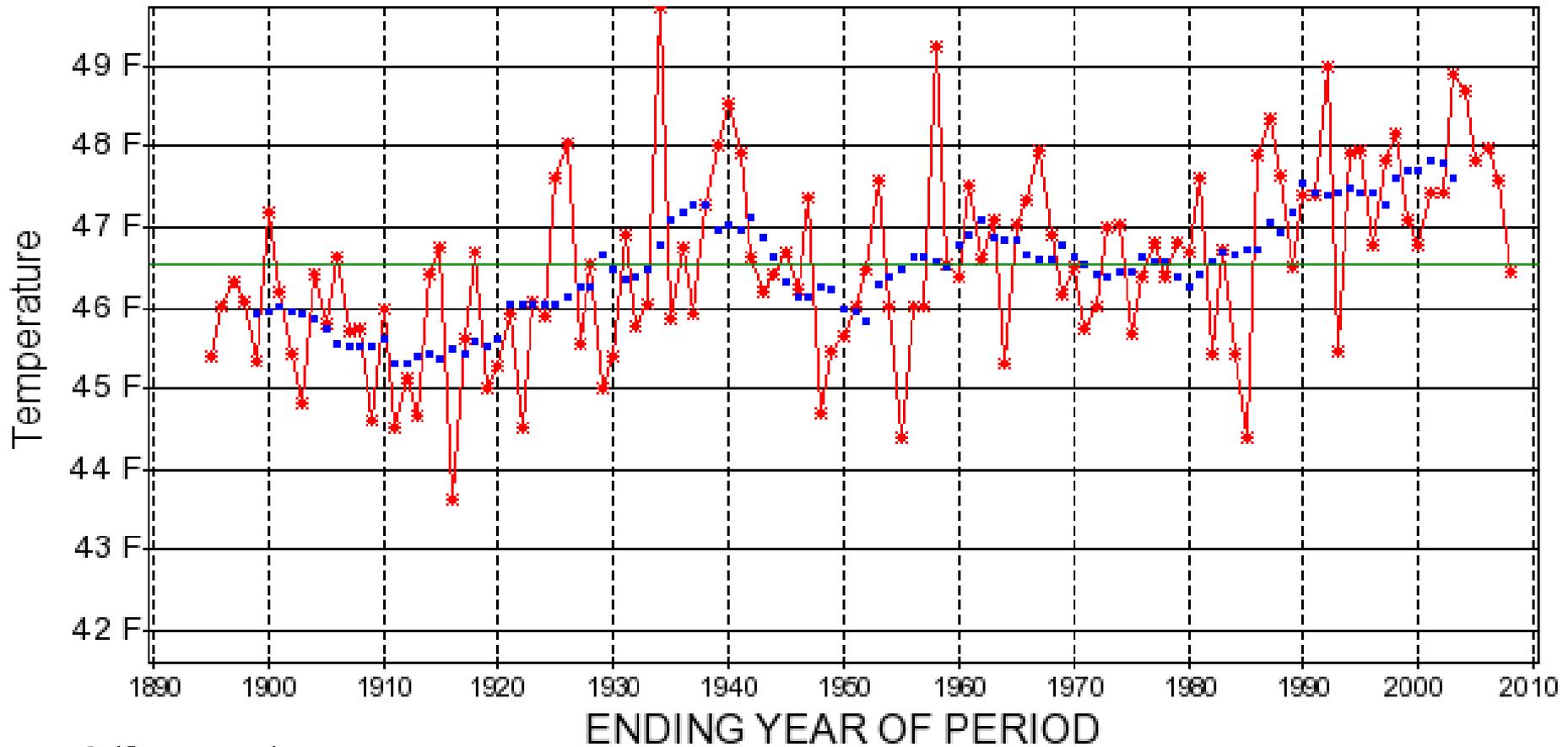
www.cefa.dri.edu/Westmap

or www.wrcc.dri.edu/Projects (select Westmap)

Mean Annual Temperature for Oregon + Washington

Total Mean Temperature for OR-WA Statewide

12 month period ending in December



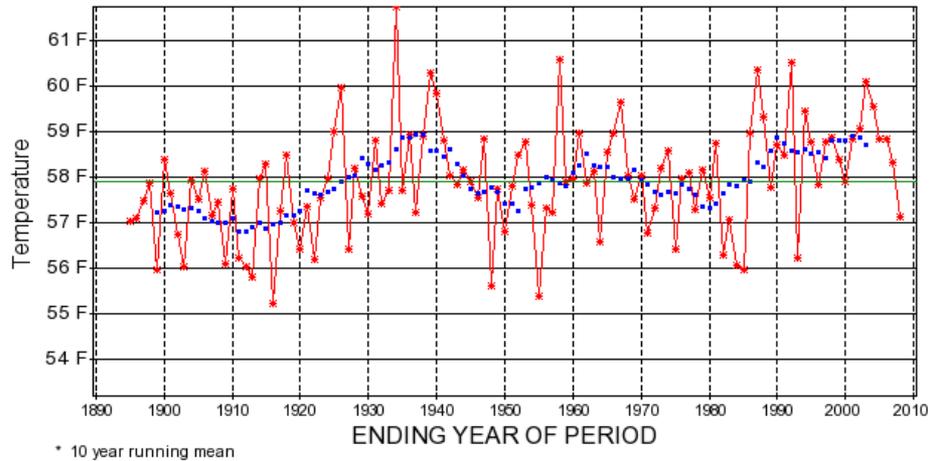
* 10 year running mean

Mean Annual Temperature for Oregon + Washington

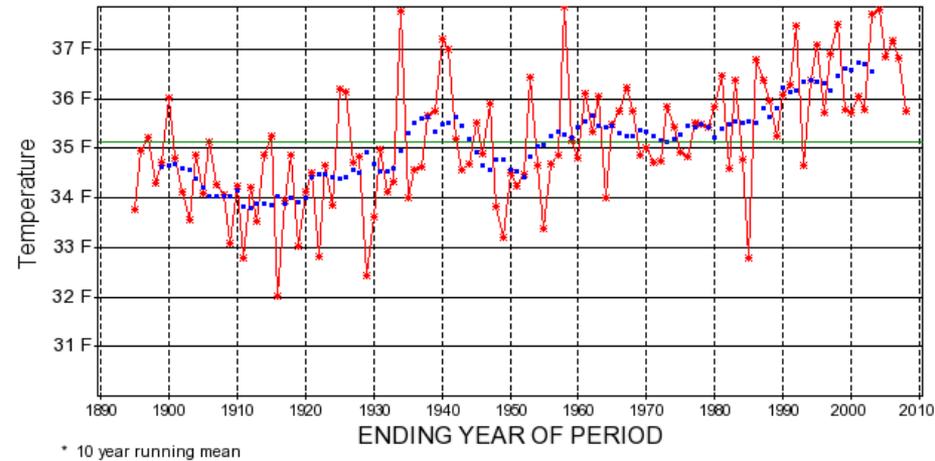
Maximum Temp

Minimum Temp

Total Maximum Temperature for OR-WA Statewide
12 month period ending in December

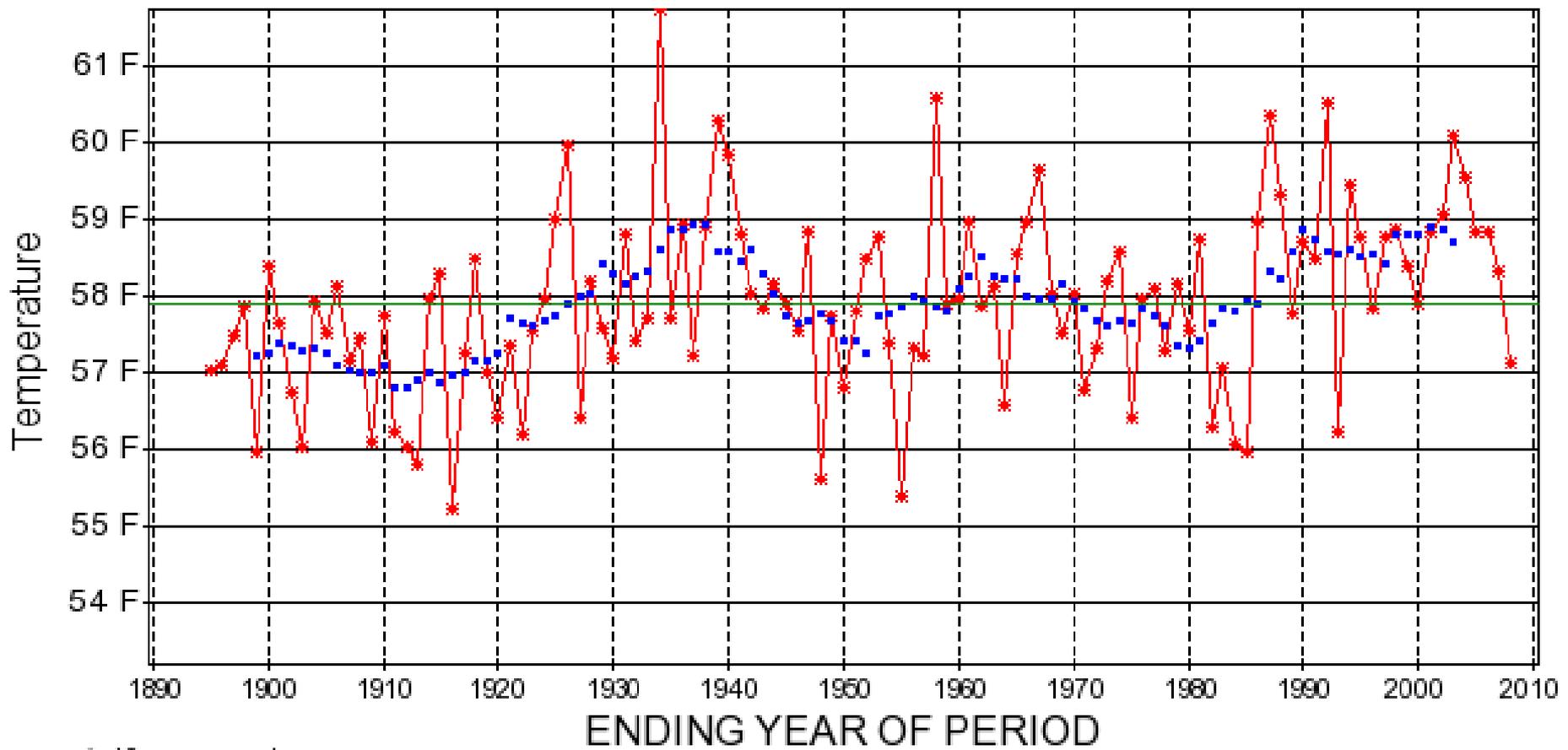


Total Minimum Temperature for OR-WA Statewide
12 month period ending in December



Total Maximum Temperature for OR-WA Statewide

12 month period ending in December

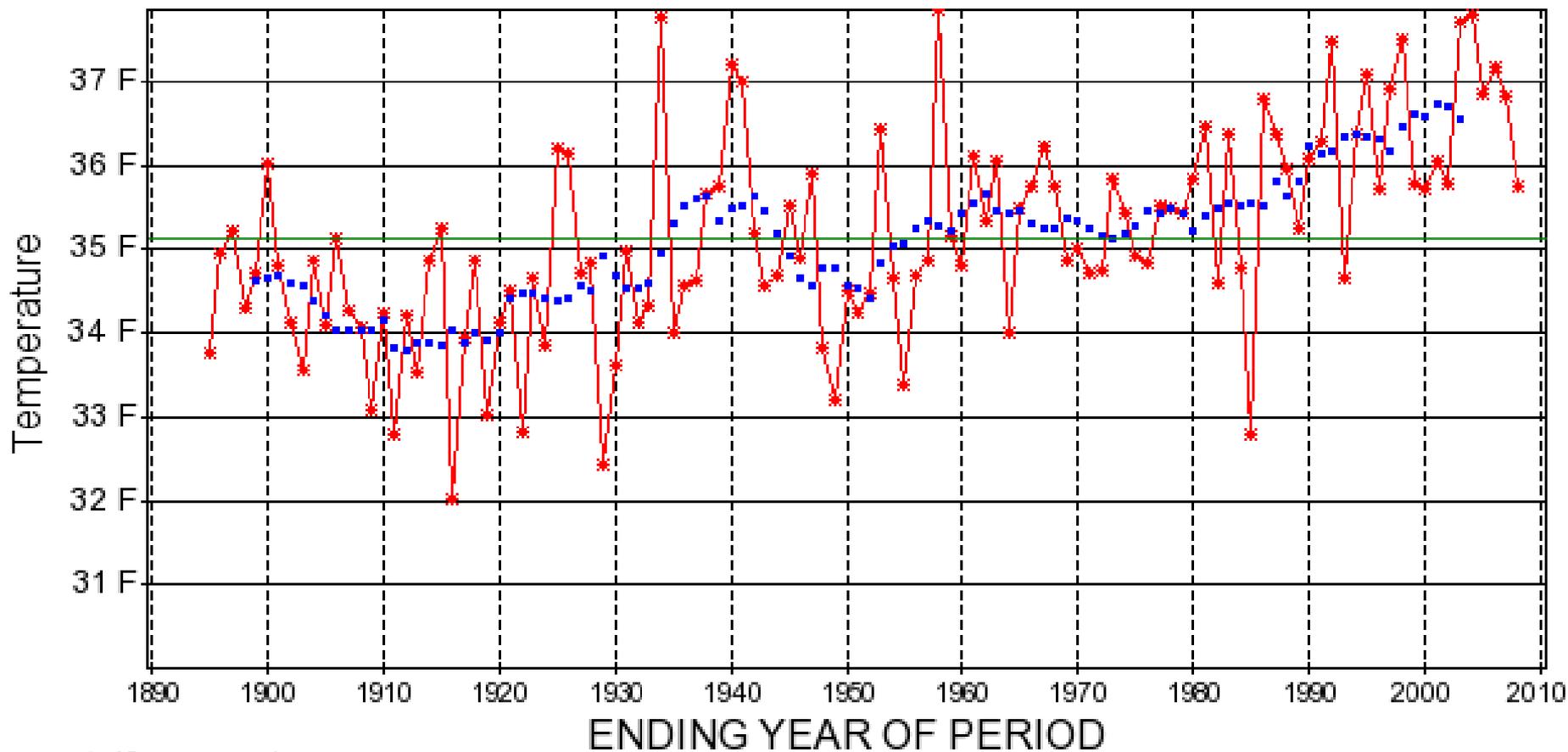


* 10 year running mean

T Max

Total Minimum Temperature for OR-WA Statewide

12 month period ending in December

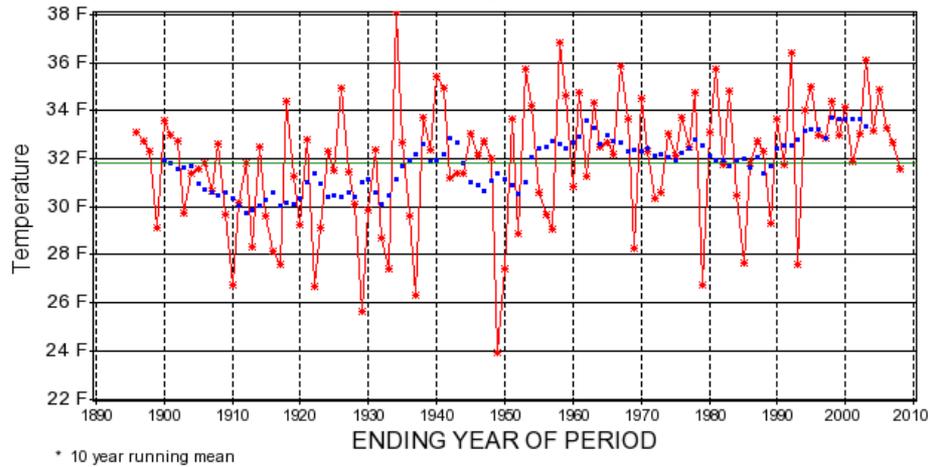


* 10 year running mean

T Min

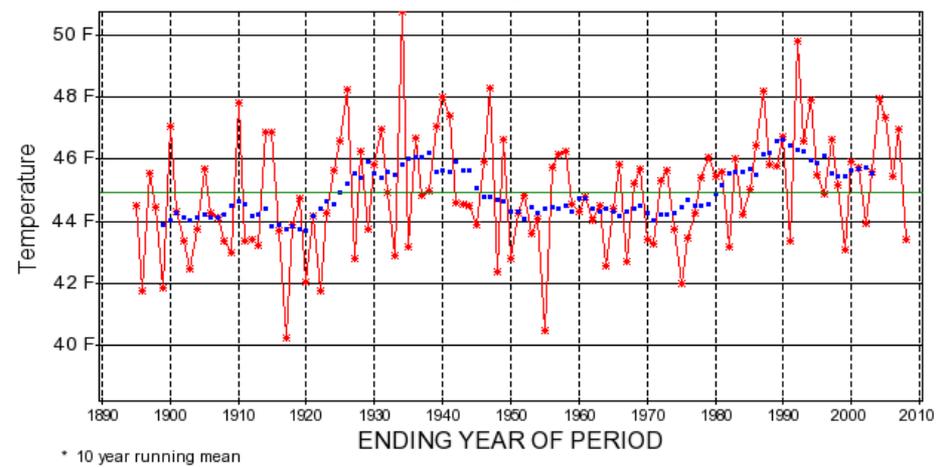
Mean Seasonal Temperature for Oregon + Washington

Seasonal Mean Temperature for OR-WA Statewide
3 month period ending in February



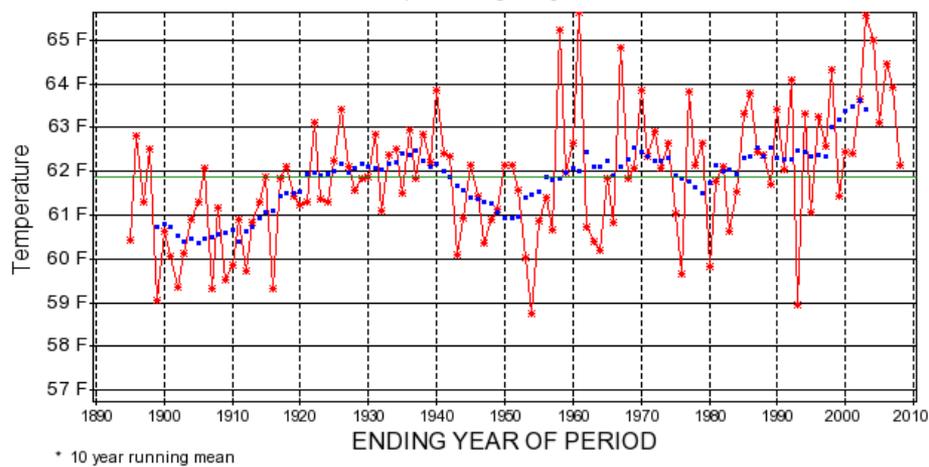
Winter DJF

Seasonal Mean Temperature for OR-WA Statewide
3 month period ending in May



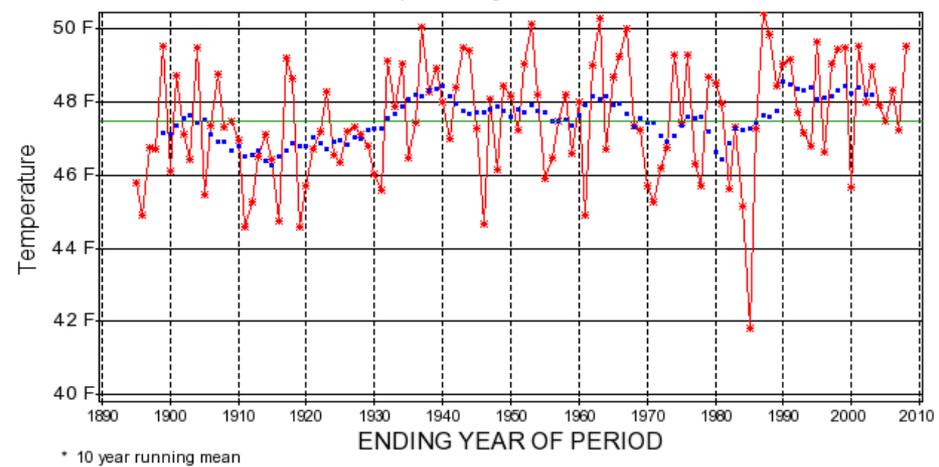
Spring MAM

Seasonal Mean Temperature for OR-WA Statewide
3 month period ending in August



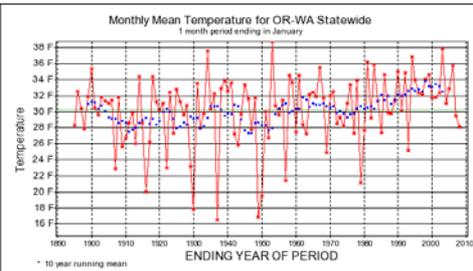
Summer JJA

Seasonal Mean Temperature for OR-WA Statewide
3 month period ending in November

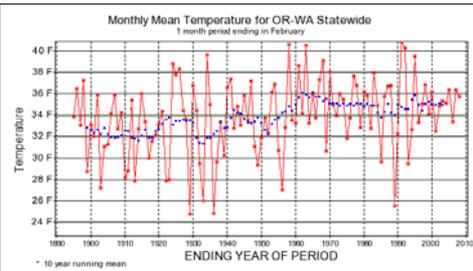


Autumn SON

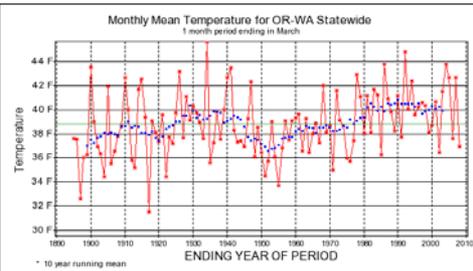
Mean Monthly Temperature for Oregon + Washington



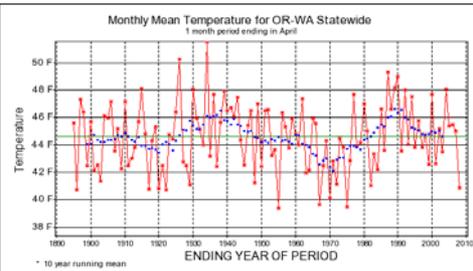
Jan



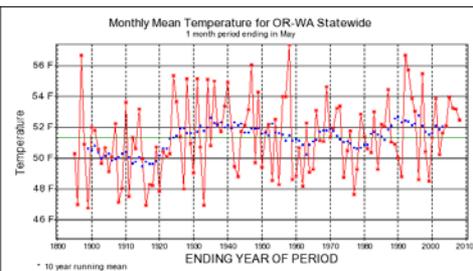
Feb



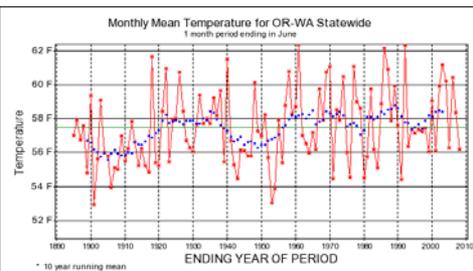
Mar



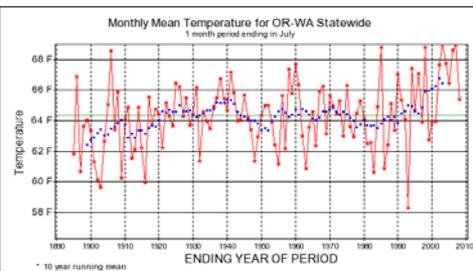
Apr



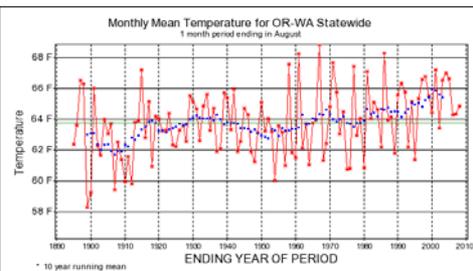
May



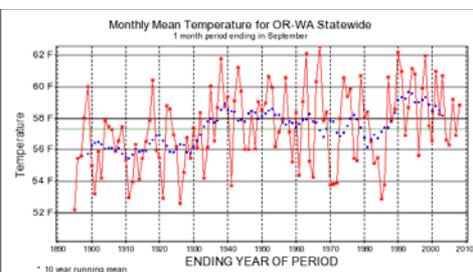
Jun



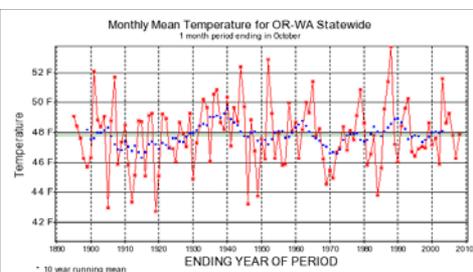
Jul



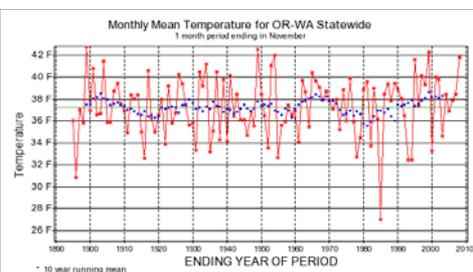
Aug



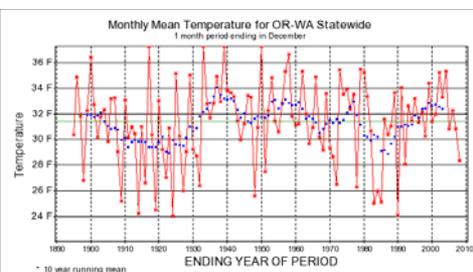
Sep



Oct



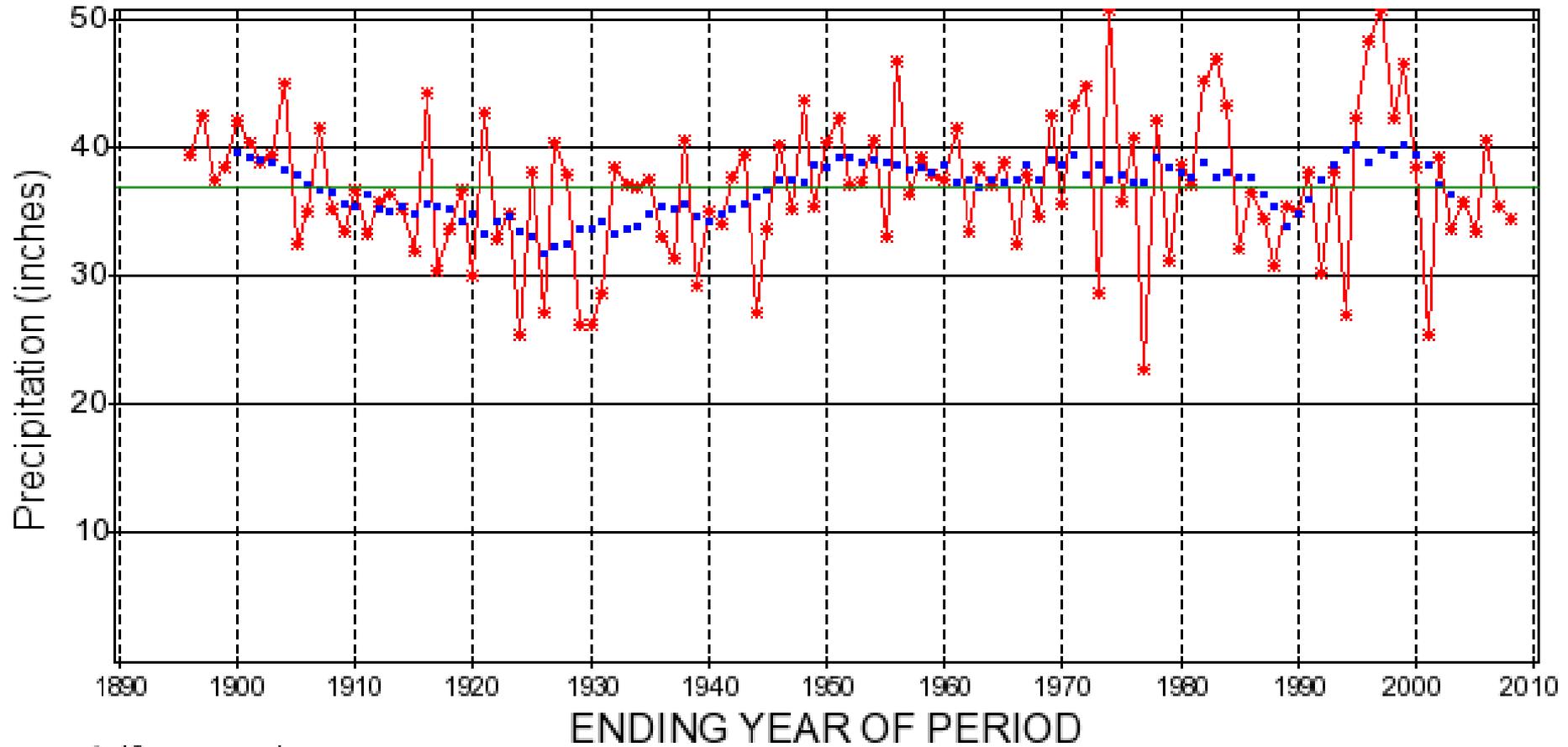
Nov



Dec

Total Winter-Centered Precipitation for Oregon + Washington

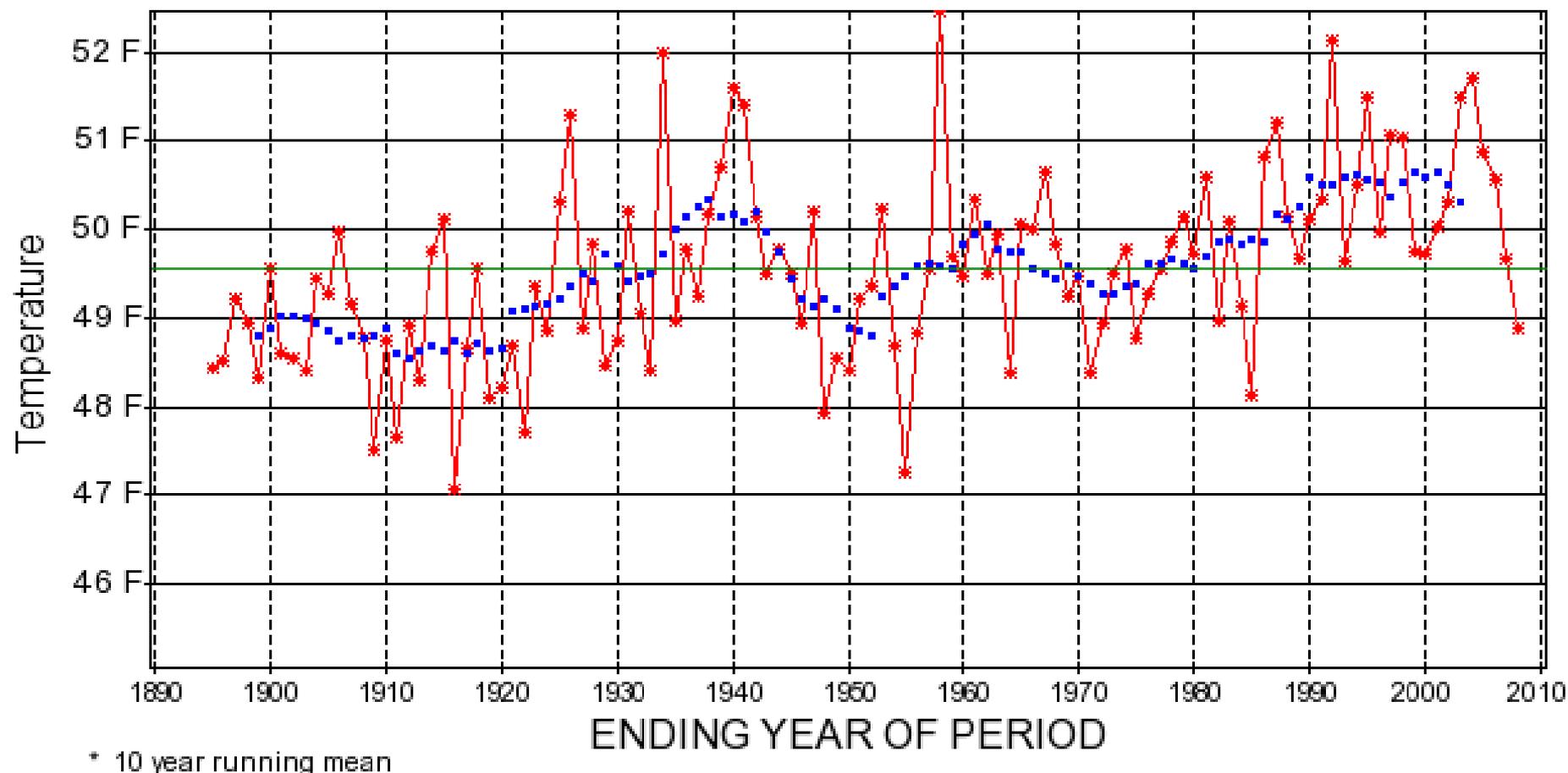
Total Precipitation for OR-WA Statewide
12 month period ending in July



* 10 year running mean

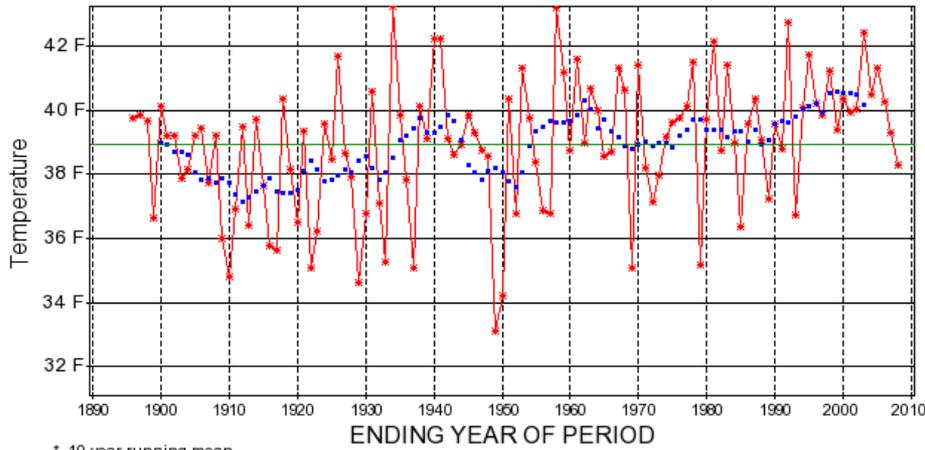
Mean Annual Temperature for Coastal / Interior OR-WA

Total Mean Temperature for Clim Divs WA-1,2,3,4 OR 1,2
12 month period ending in December



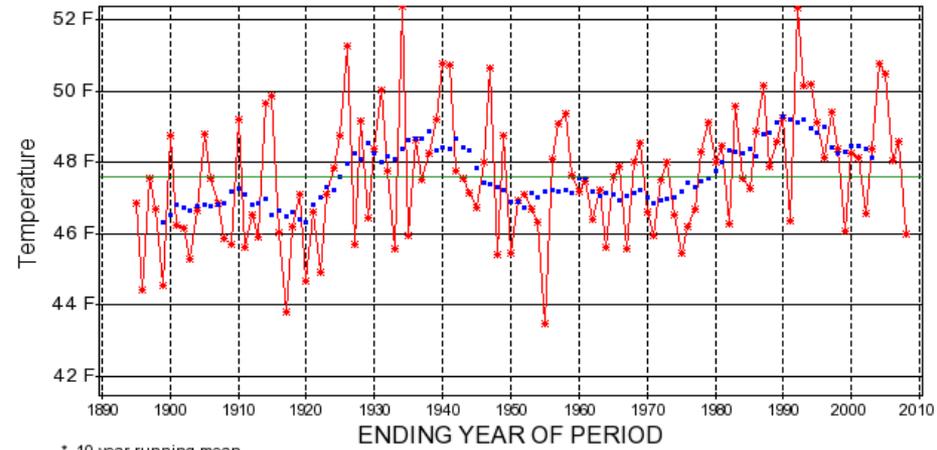
Mean Seasonal Temperature for Coastal / Interior OR-WA

Seasonal Mean Temperature for Clim Divs WA-1,2,3,4 OR 1,2
3 month period ending in February



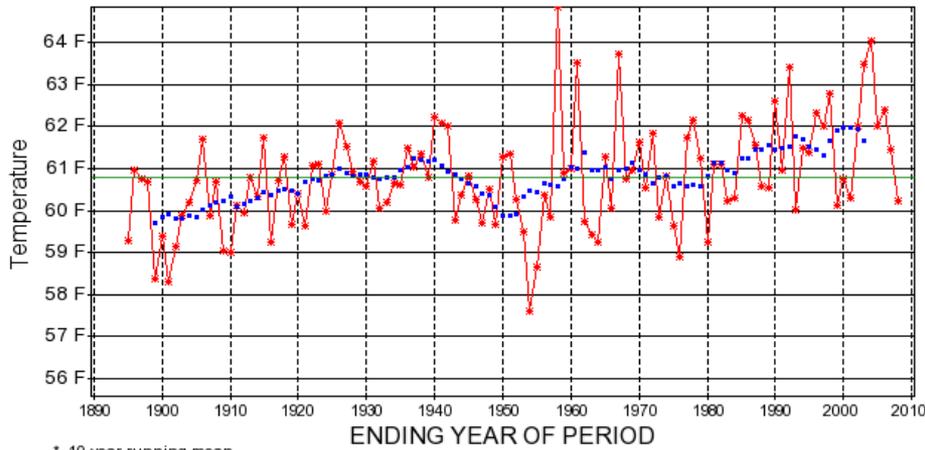
Winter DJF

Seasonal Mean Temperature for Clim Divs WA-1,2,3,4 OR 1,2
3 month period ending in May



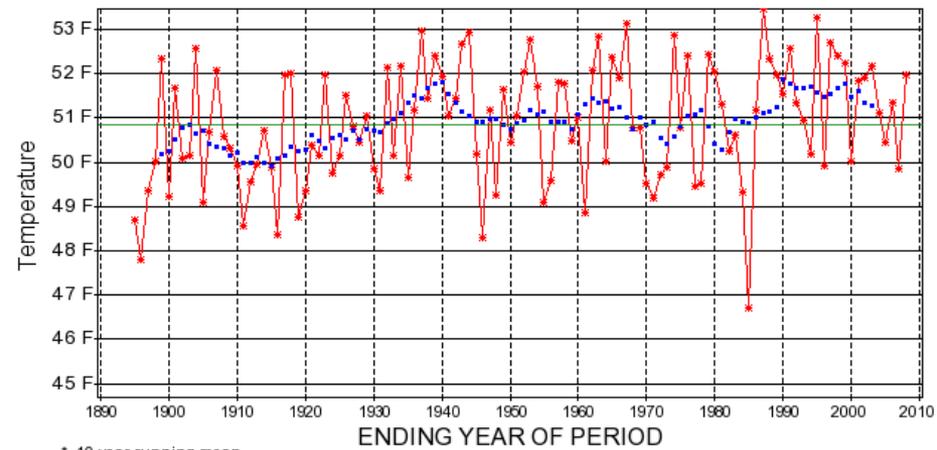
Spring MAM

Seasonal Mean Temperature for Clim Divs WA-1,2,3,4 OR 1,2
3 month period ending in August



Summer JJA

Seasonal Mean Temperature for Clim Divs WA-1,2,3,4 OR 1,2
3 month period ending in November



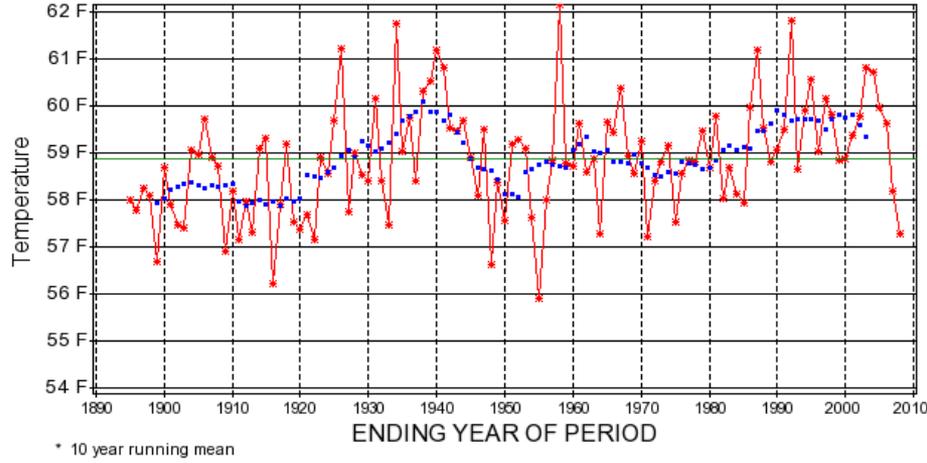
Autumn SON

Mean Annual Temperature for Coastal / Interior OR-WA

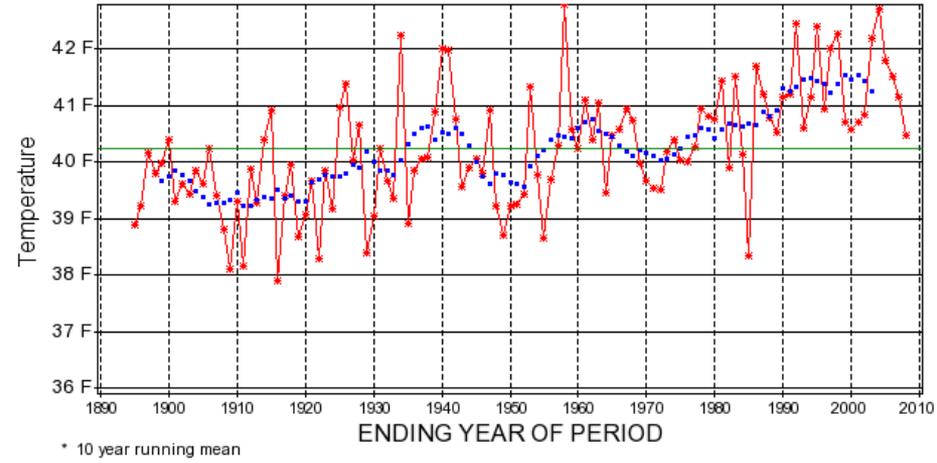
Maximum Temp

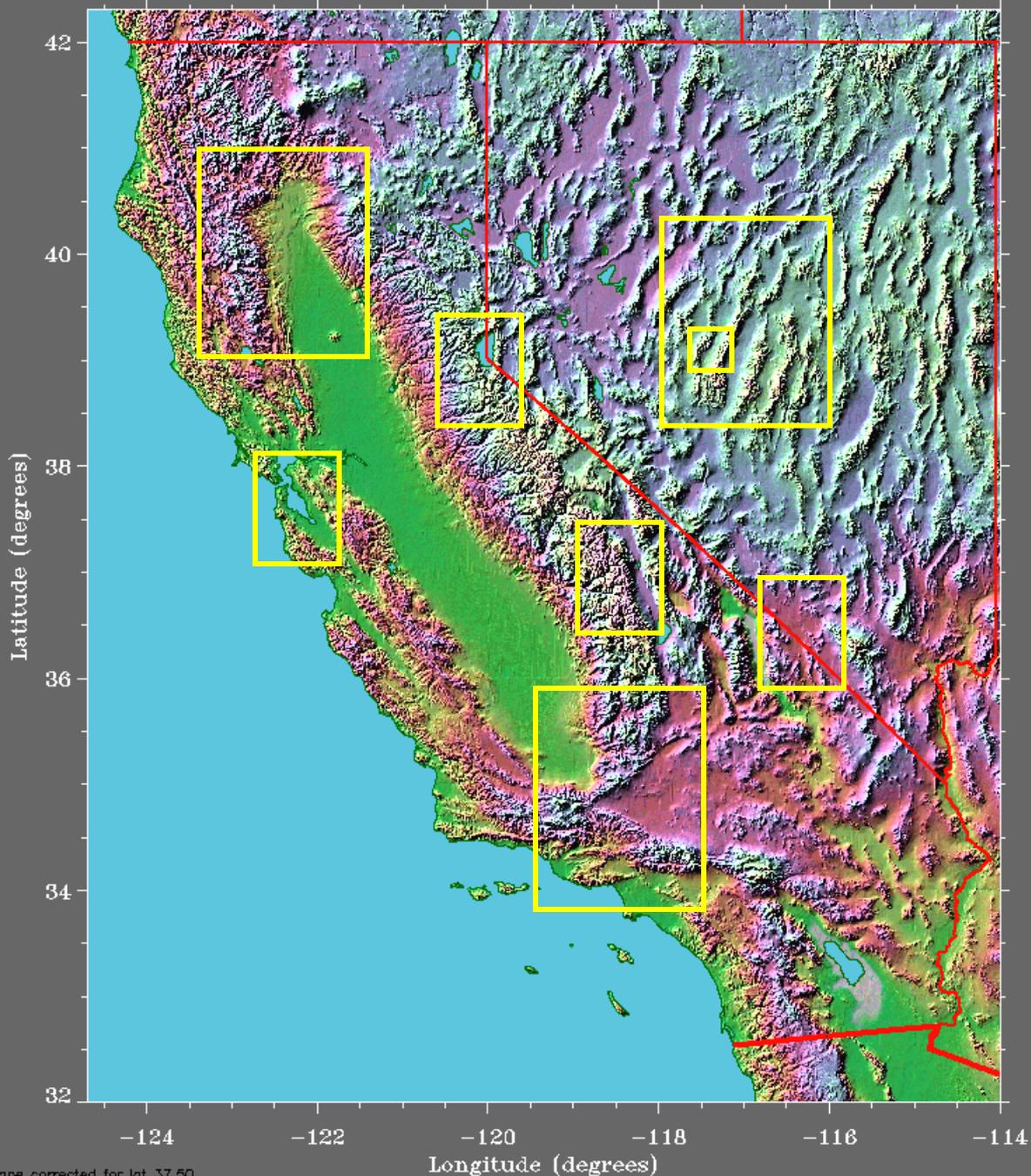
Minimum Temp

Total Maximum Temperature for Clim Divs WA-1,2,3,4 OR 1,2
12 month period ending in December



Total Minimum Temperature for Clim Divs WA-1,2,3,4 OR 1,2
12 month period ending in December





**Grid
resolution:**

**Global
Climate Model
and
Reanalysis**

Global



**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
(CIRMOLINT)

July 2006

2030 SWE

2060 SWE

2090 SWE

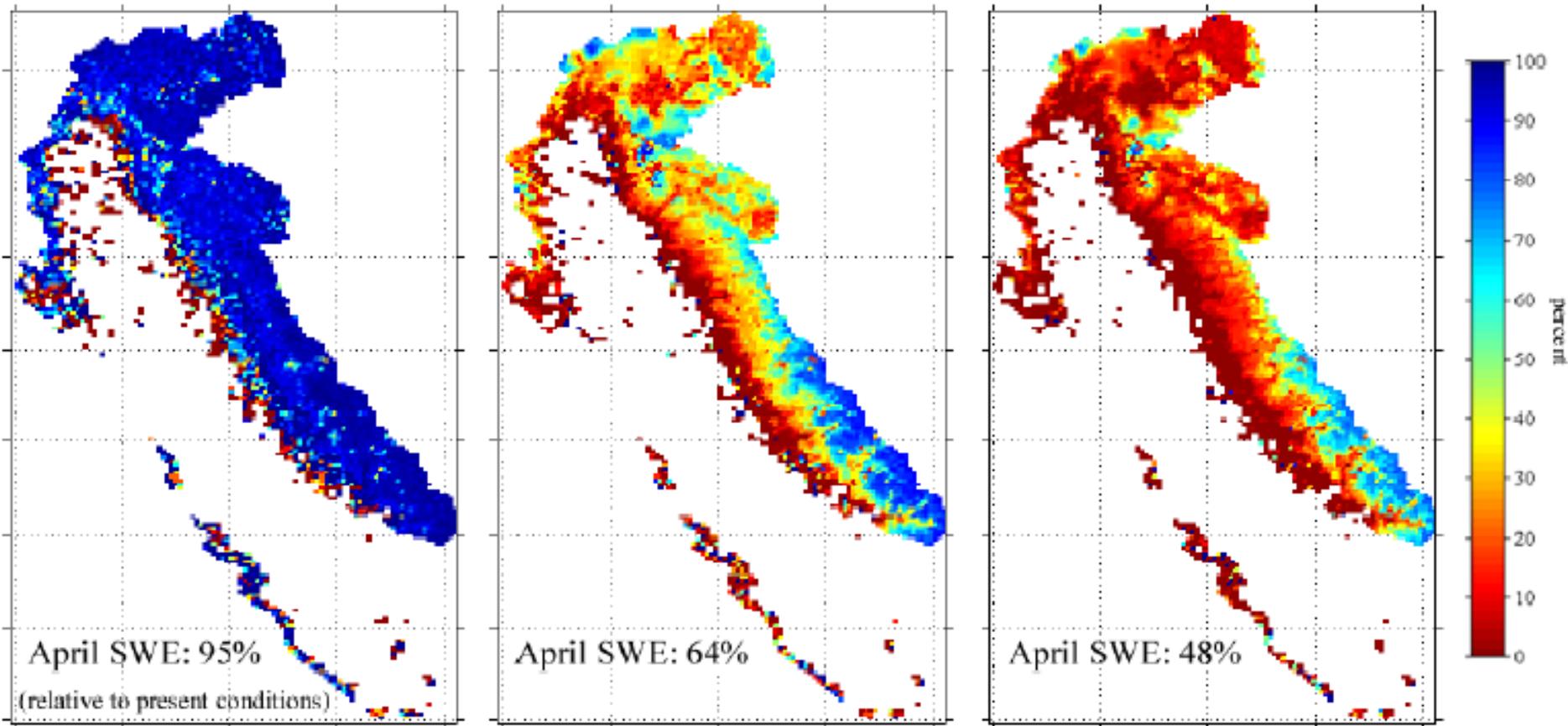


Figure 3. Simulated snow water equivalent (SWE) under a projected temperature increase for the periods 2020-2039, 2050-2069 and 2080-2099, expressed as a percentage of average present conditions.

P

T

6°C

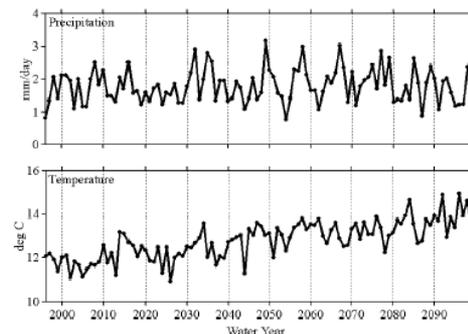


Figure 2. PCM-simulated watershed-averaged annual precipitation and temperature for WY 1995-2099.

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

Select type of product, set up display parameters, select location for time series or domain for map.

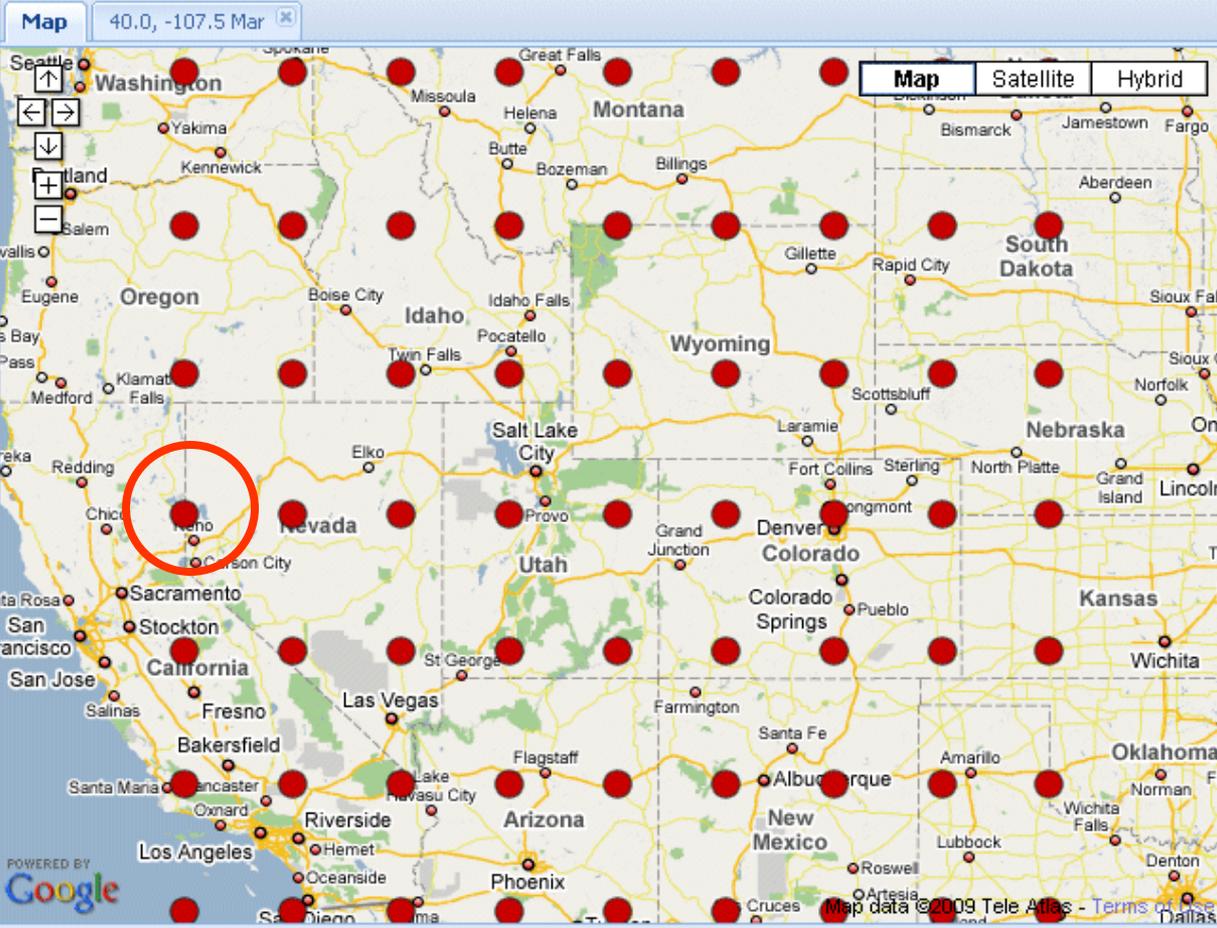
North American Freezing Level Tracker

West

Navigation

Hi. I'm the west panel.

- Time Series**
- Monthly
- Fixed temperature
- Fixed height
- Pct precip as snow
- Daily
- Fixed temperature
- Fixed height
- Maps**
- Monthly / Daily
- Fixed temperature.
- Mean / departure
- Fixed height
- Mean / departure



East Side

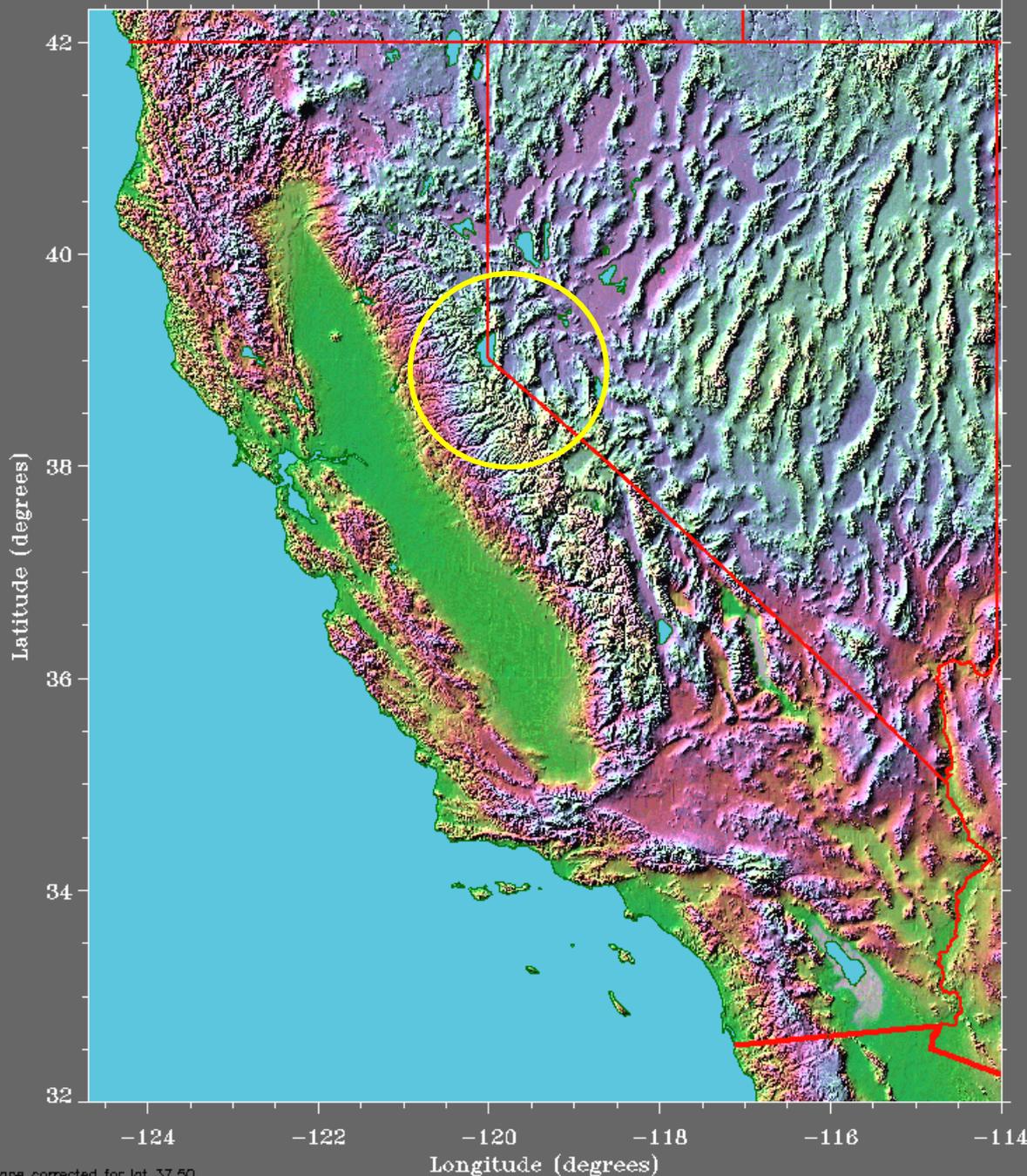
Month: Mar

- Product Setup**
- Graph parameters
- Period / duration
- Color scheme
- Absolute vs departure

Options Property Grid

South

south - generally for informational stuff, also could be for status bar



North American Freezing Level Tracker

Example for

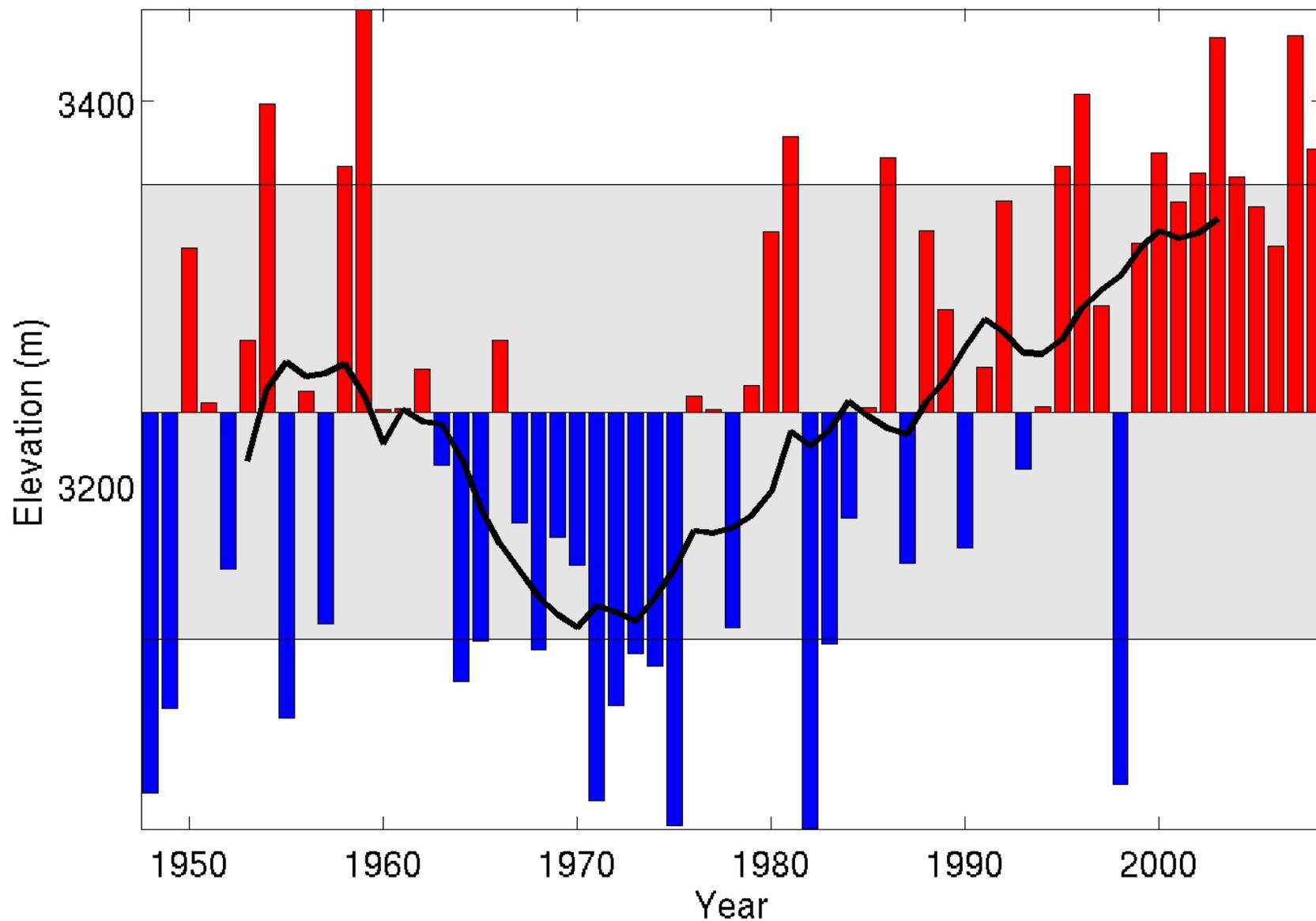
Tahoe Climate Change
Symposium

held on
St Patricks Day 2009

John Abatzoglou

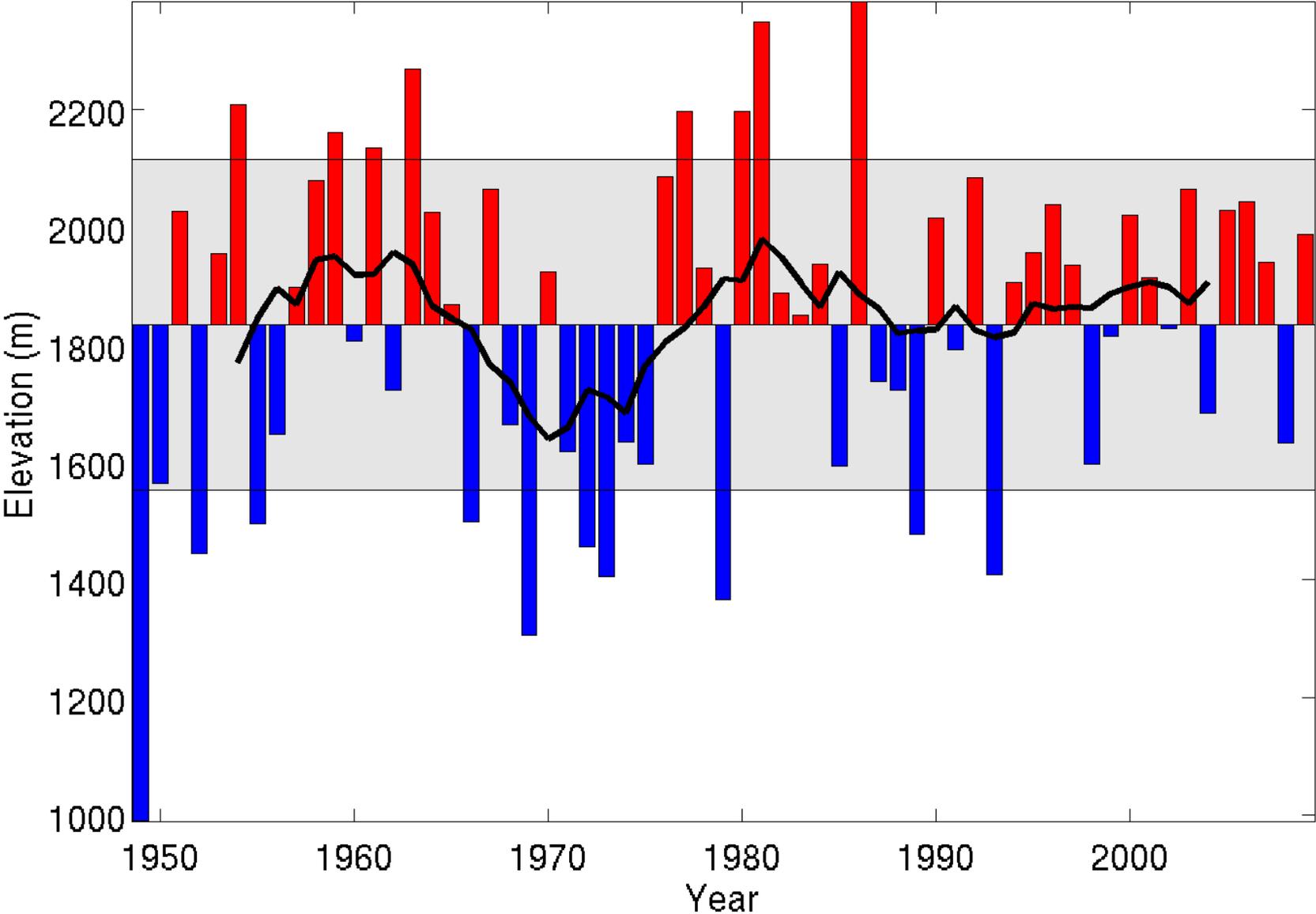
Elevation of Freezing Level over Lake Tahoe. Annual. From NCEP Reanalysis.

Annual 0°C Elevation, 39.2°N, 120.2°W



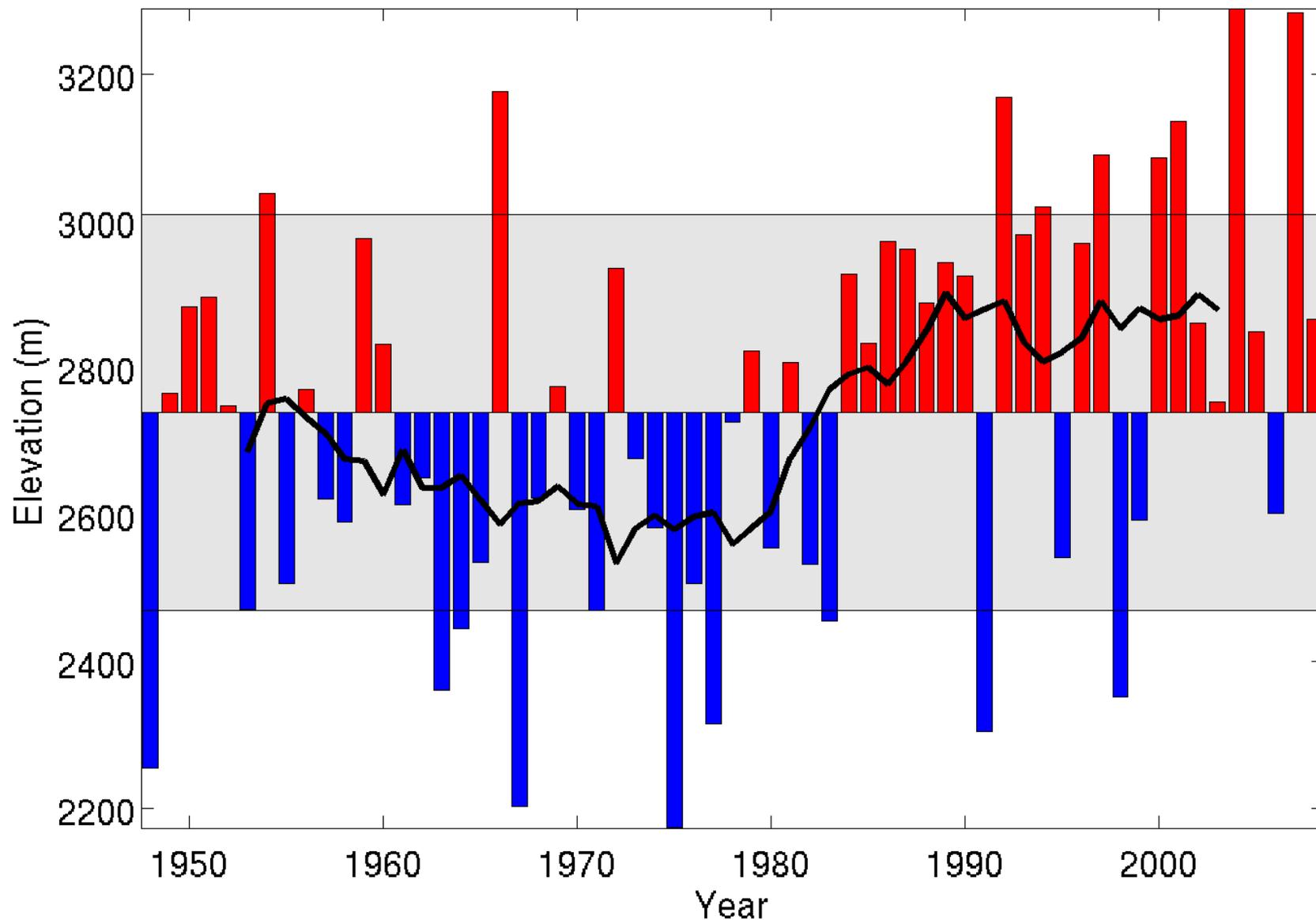
Elevation of Freezing Level over Lake Tahoe. Winter. From NCEP Reanalysis.

DJF 0°C Elevation, 39.2°N, 120.2°W



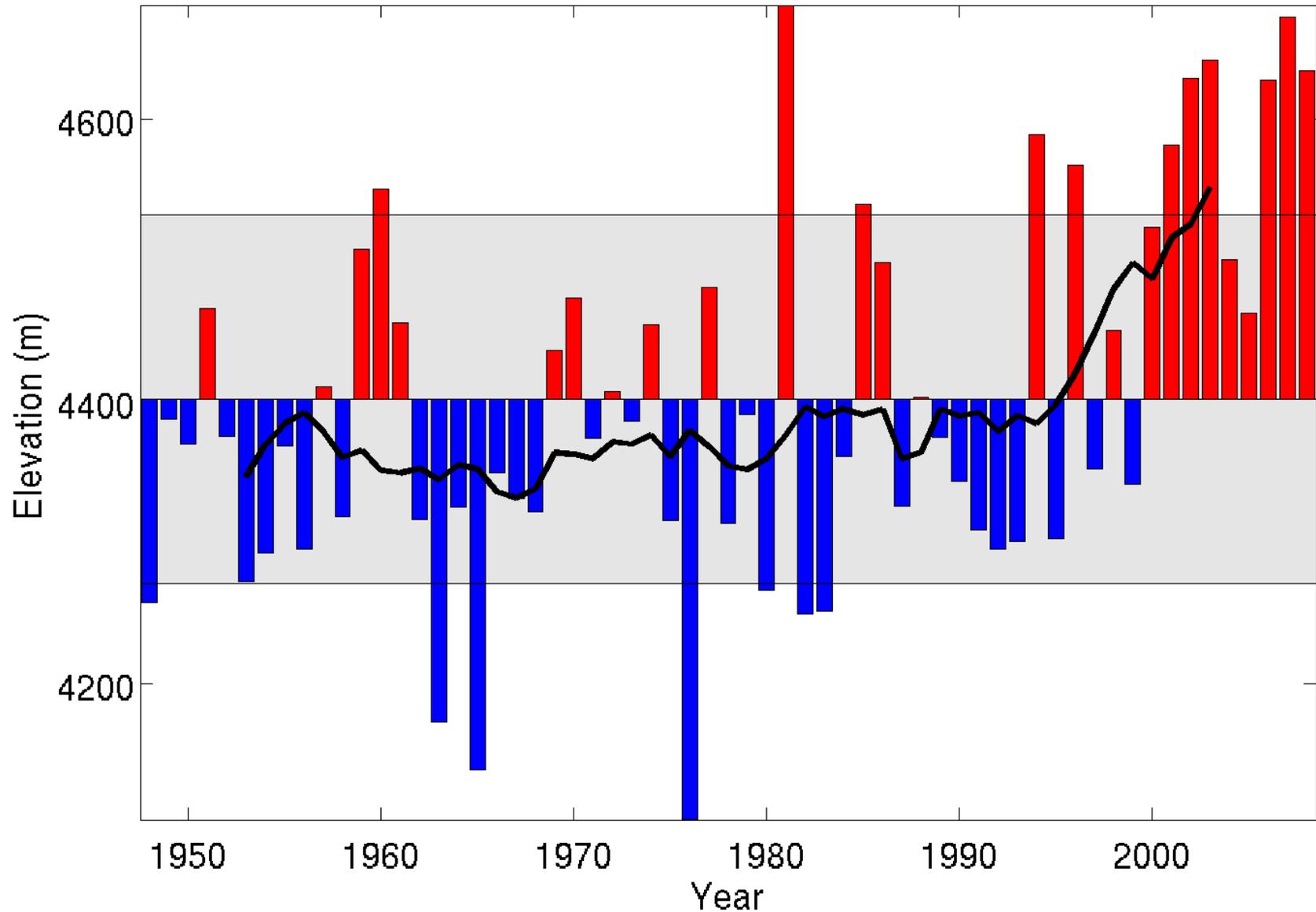
Elevation of Freezing Level over Lake Tahoe. Spring. From NCEP Reanalysis.

MAM 0°C Elevation, 39.2°N, 120.2°W



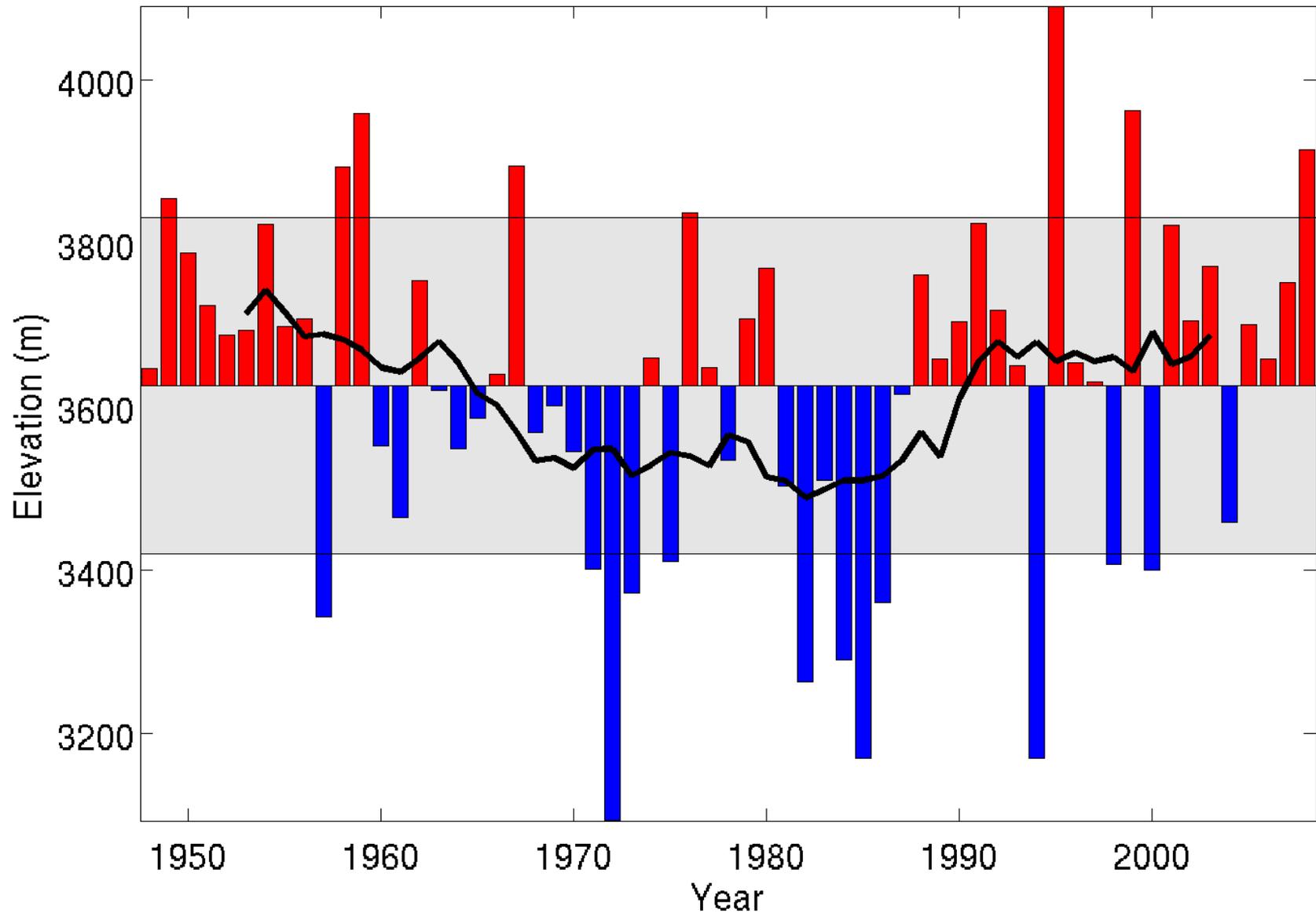
Elevation of Freezing Level over Lake Tahoe. Summer. From NCEP Reanalysis.

JJA 0°C Elevation, 39.2°N, 120.2°W

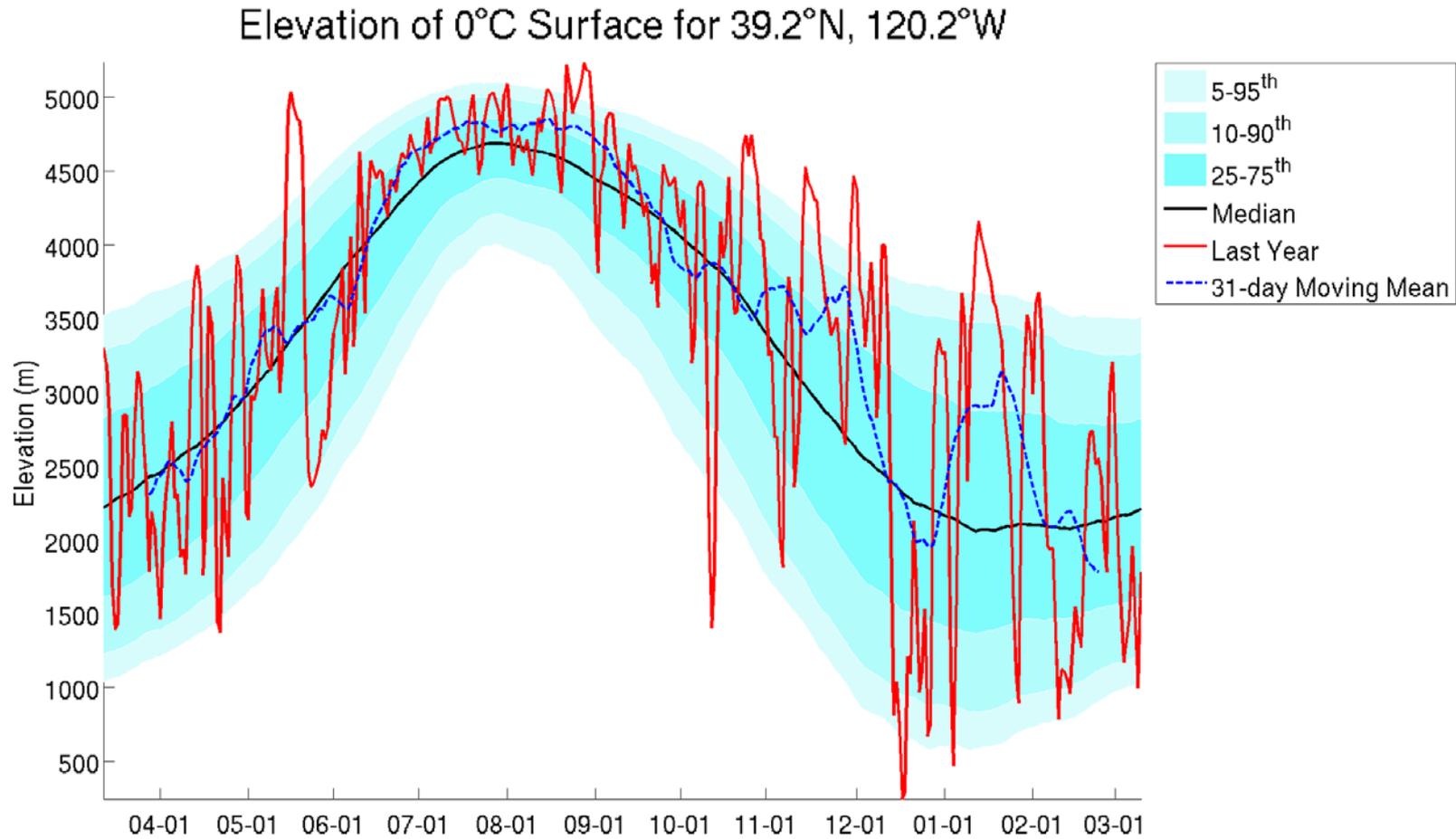


Elevation of Freezing Level over Lake Tahoe. Autumn. From NCEP Reanalysis.

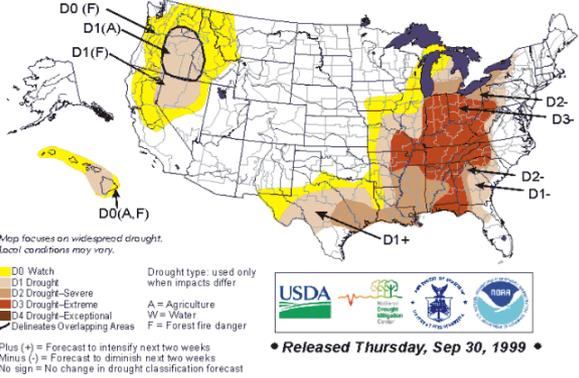
SON 0°C Elevation, 39.2°N, 120.2°W



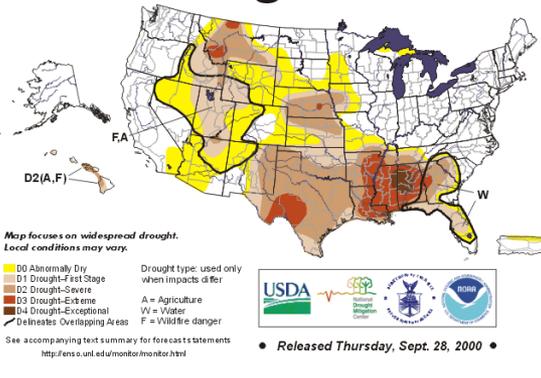
**Elevation of Freezing Level over Lake Tahoe. 365 Days into early March 2009.
Climatology 1948-2009: black line median and blue percentiles.**



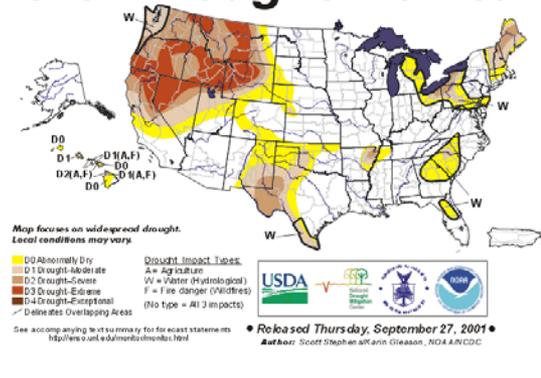
September 28, 1999
U.S. Drought Monitor



September 26, 2000 Valid 8 a.m. EDT
U.S. Drought Monitor



September 25, 2001 Valid 8 a.m. EDT
U.S. Drought Monitor

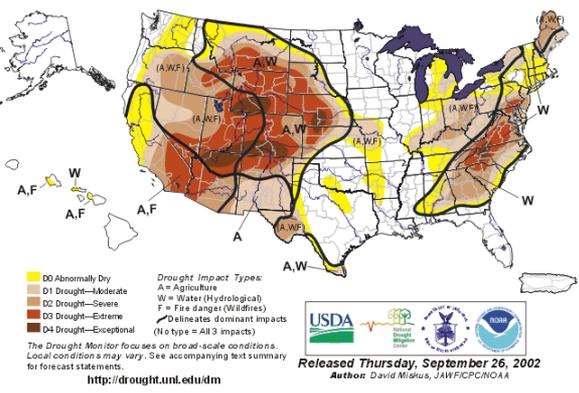


Sep 28, 1999

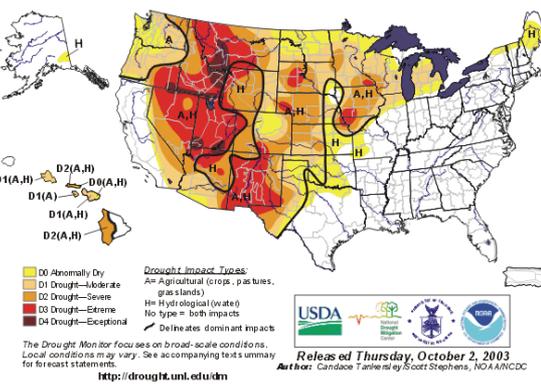
Sep 26, 2000

Sep 25, 2001

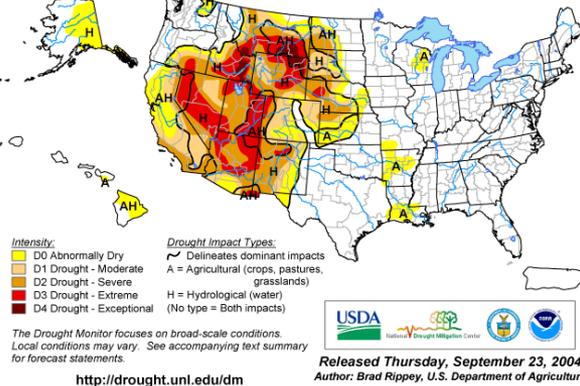
September 24, 2002 Valid 8 a.m. EDT
U.S. Drought Monitor



September 30, 2003 Valid 8 a.m. EDT
U.S. Drought Monitor



September 21, 2004 Valid 8 a.m. EDT
U.S. Drought Monitor



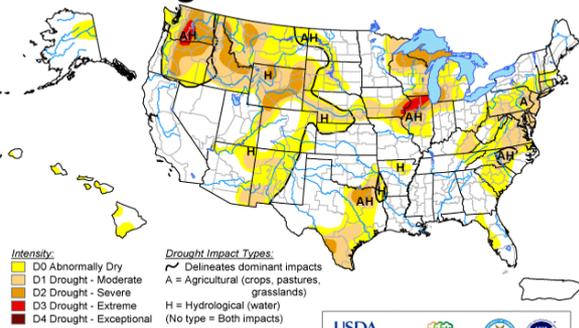
Sep 24, 2002

Sep 30, 2003

Sep 21, 2004

U.S. Drought Monitor September 27, 2005

Valid 6 a.m. EDT



Intensity:
 D0 Abnormally Dry
 D1 Drought - Moderate
 D2 Drought - Severe
 D3 Drought - Extreme
 D4 Drought - Exceptional

Drought Impact Types:
 ~ Delineates dominant impacts
 A = Agricultural (crops, pastures, grasslands)
 H = Hydrological (water)
 (No type = Both impacts)



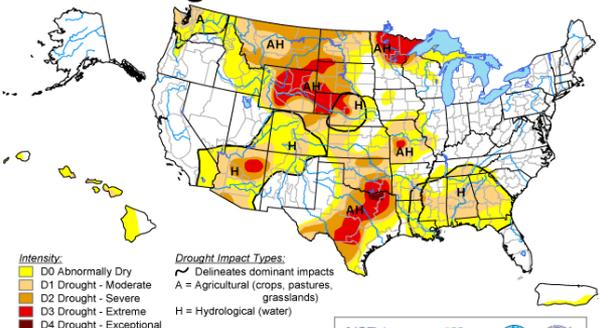
Released Thursday, September 29, 2005
 Author: Douglas Le Comte, CPC/NOAA

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
<http://drought.unl.edu/dm>

Sep 27, 2005

U.S. Drought Monitor September 26, 2006

Valid 9 a.m. EDT



Intensity:
 D0 Abnormally Dry
 D1 Drought - Moderate
 D2 Drought - Severe
 D3 Drought - Extreme
 D4 Drought - Exceptional

Drought Impact Types:
 ~ Delineates dominant impacts
 A = Agricultural (crops, pastures, grasslands)
 H = Hydrological (water)



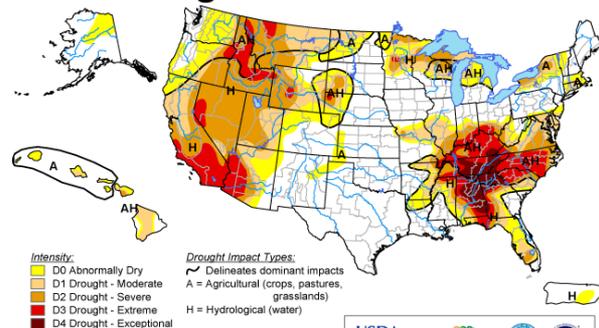
Released Thursday, September 28, 2006
 Author: Ned Guttman/Liz Love-Brotak, NOAA/NESDIS/NCDC

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
<http://drought.unl.edu/dm>

Sep 26, 2006

U.S. Drought Monitor September 25, 2007

Valid 6 a.m. EDT



Intensity:
 D0 Abnormally Dry
 D1 Drought - Moderate
 D2 Drought - Severe
 D3 Drought - Extreme
 D4 Drought - Exceptional

Drought Impact Types:
 ~ Delineates dominant impacts
 A = Agricultural (crops, pastures, grasslands)
 H = Hydrological (water)



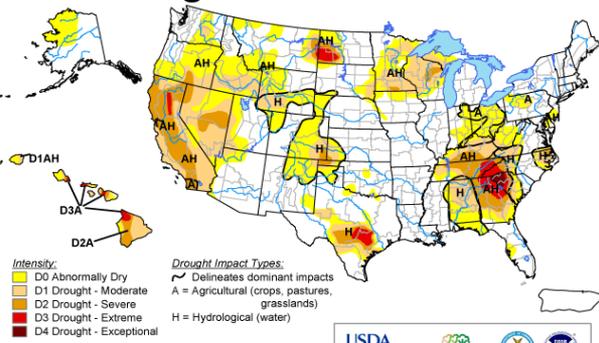
Released Thursday, September 27, 2007
 Author: David Miskus, JAWF/CPC/NOAA

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
<http://drought.unl.edu/dm>

Sep 25, 2007

U.S. Drought Monitor September 30, 2008

Valid 6 a.m. EDT



Intensity:
 D0 Abnormally Dry
 D1 Drought - Moderate
 D2 Drought - Severe
 D3 Drought - Extreme
 D4 Drought - Exceptional

Drought Impact Types:
 ~ Delineates dominant impacts
 A = Agricultural (crops, pastures, grasslands)
 H = Hydrological (water)



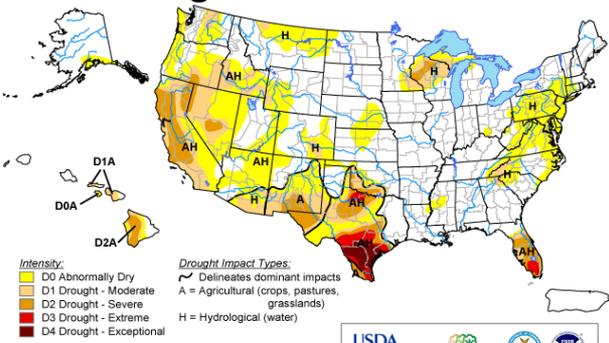
Released Thursday, October 2, 2008
 Authors: Richard Heim/Liz Love-Brotak, NOAA/NESDIS/NCDC

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
<http://drought.unl.edu/dm>

Sep 30, 2008

U.S. Drought Monitor April 28, 2009

Valid 6 a.m. EDT



Intensity:
 D0 Abnormally Dry
 D1 Drought - Moderate
 D2 Drought - Severe
 D3 Drought - Extreme
 D4 Drought - Exceptional

Drought Impact Types:
 ~ Delineates dominant impacts
 A = Agricultural (crops, pastures, grasslands)
 H = Hydrological (water)

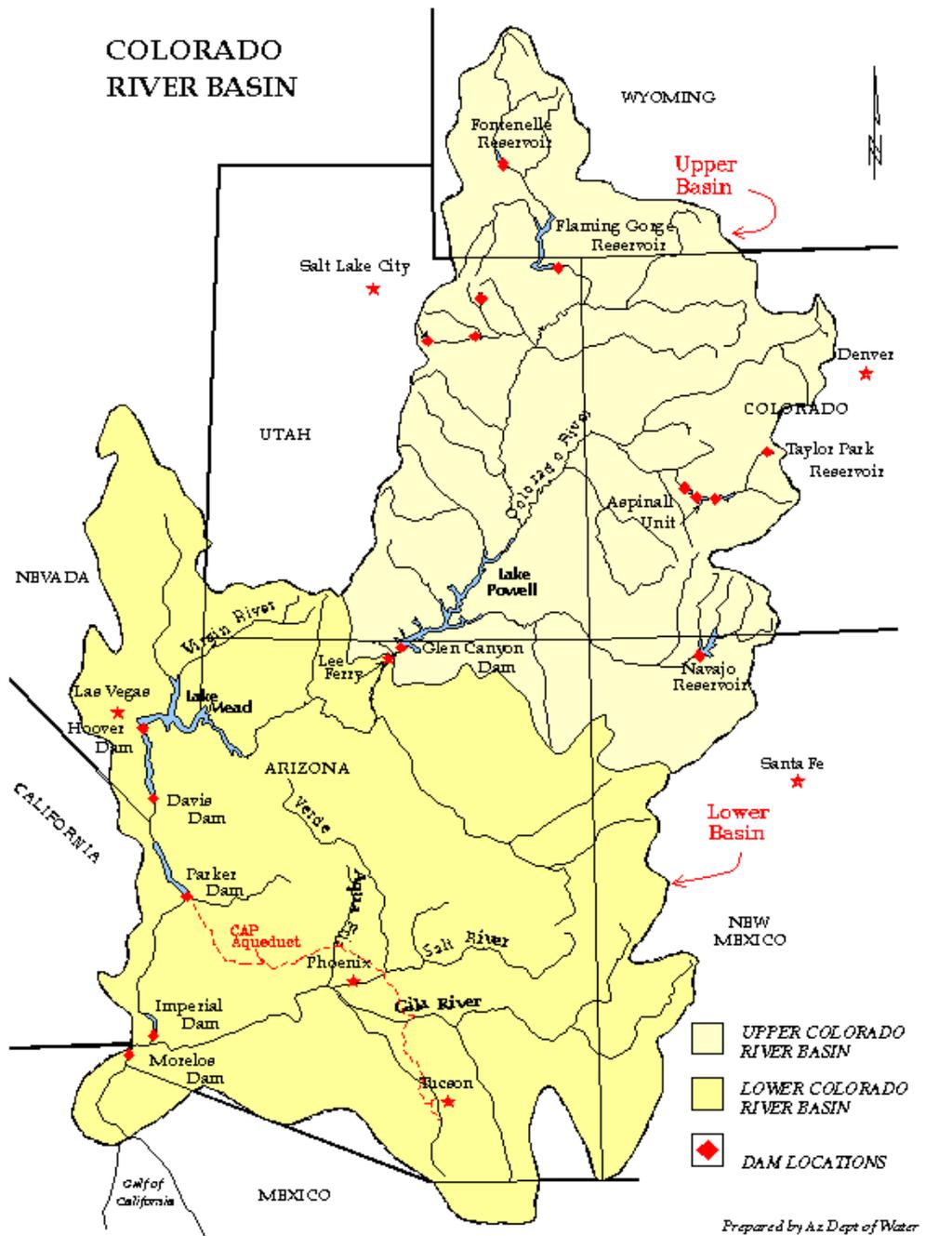


Released Thursday, April 30, 2009
 Author: Brad Rippey, U.S. Department of Agriculture

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
<http://drought.unl.edu/dm>

Apr 28, 2009

COLORADO RIVER BASIN

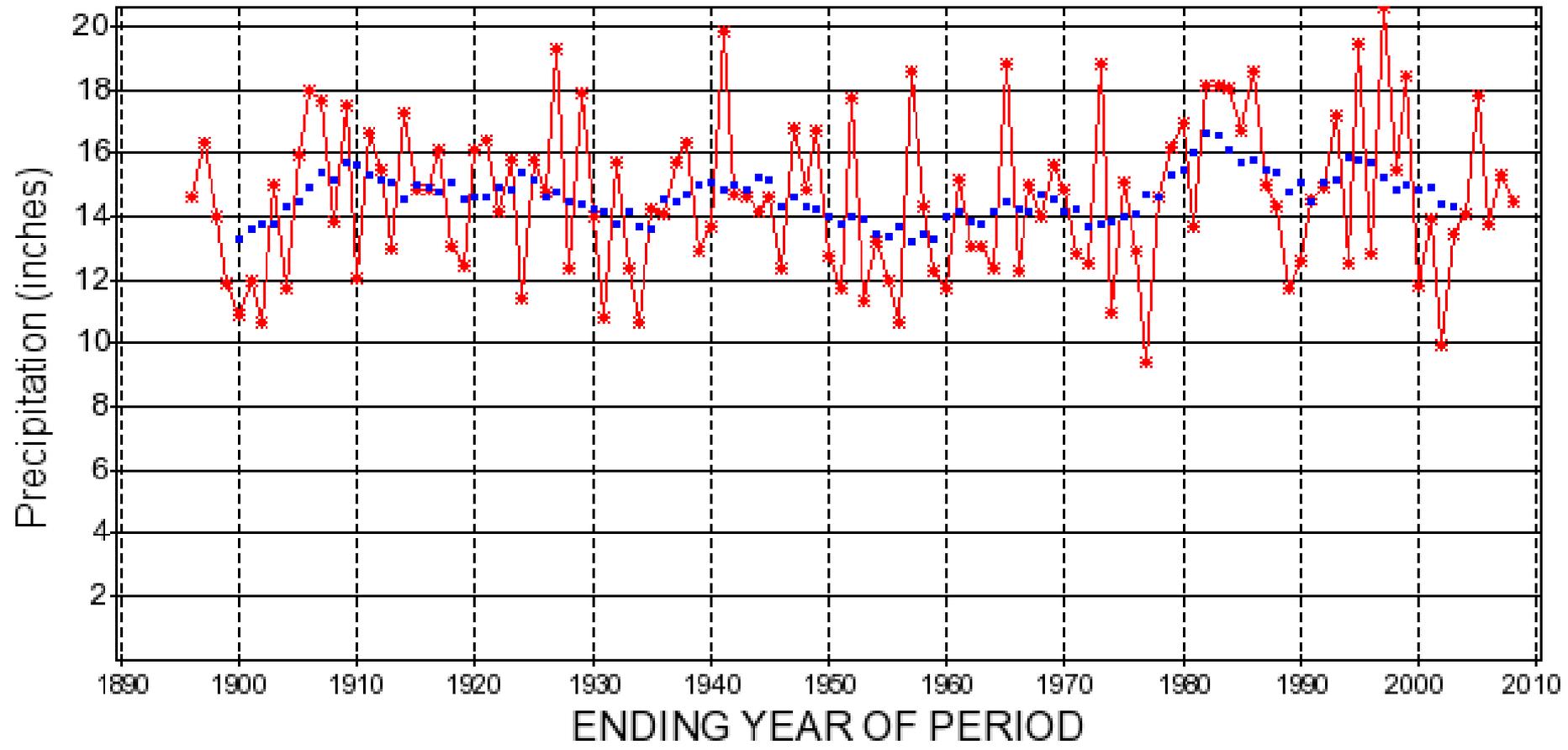


- UPPER COLORADO RIVER BASIN
- LOWER COLORADO RIVER BASIN
- DAM LOCATIONS

Prepared by Az Dept of Water Resources, Colorado River Mgmt
Phyllis Andrews June 12, 1997

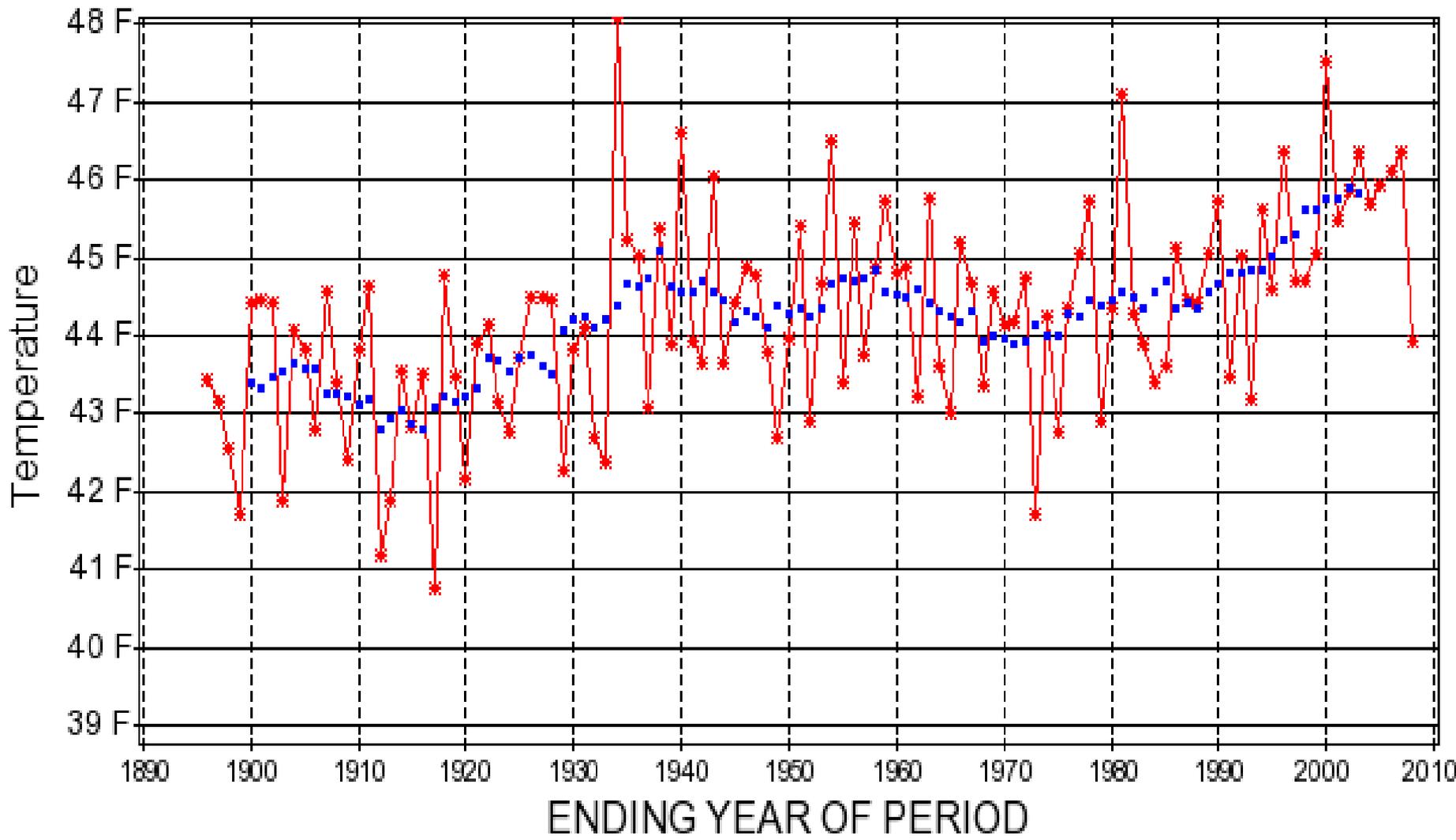
Water Year Precipitation (Oct-Sep) thru Sep 2008. Upper Colorado River Basin.

Monthly Mean Precipitation for Upper Colorado River Basin
12 month period ending in September



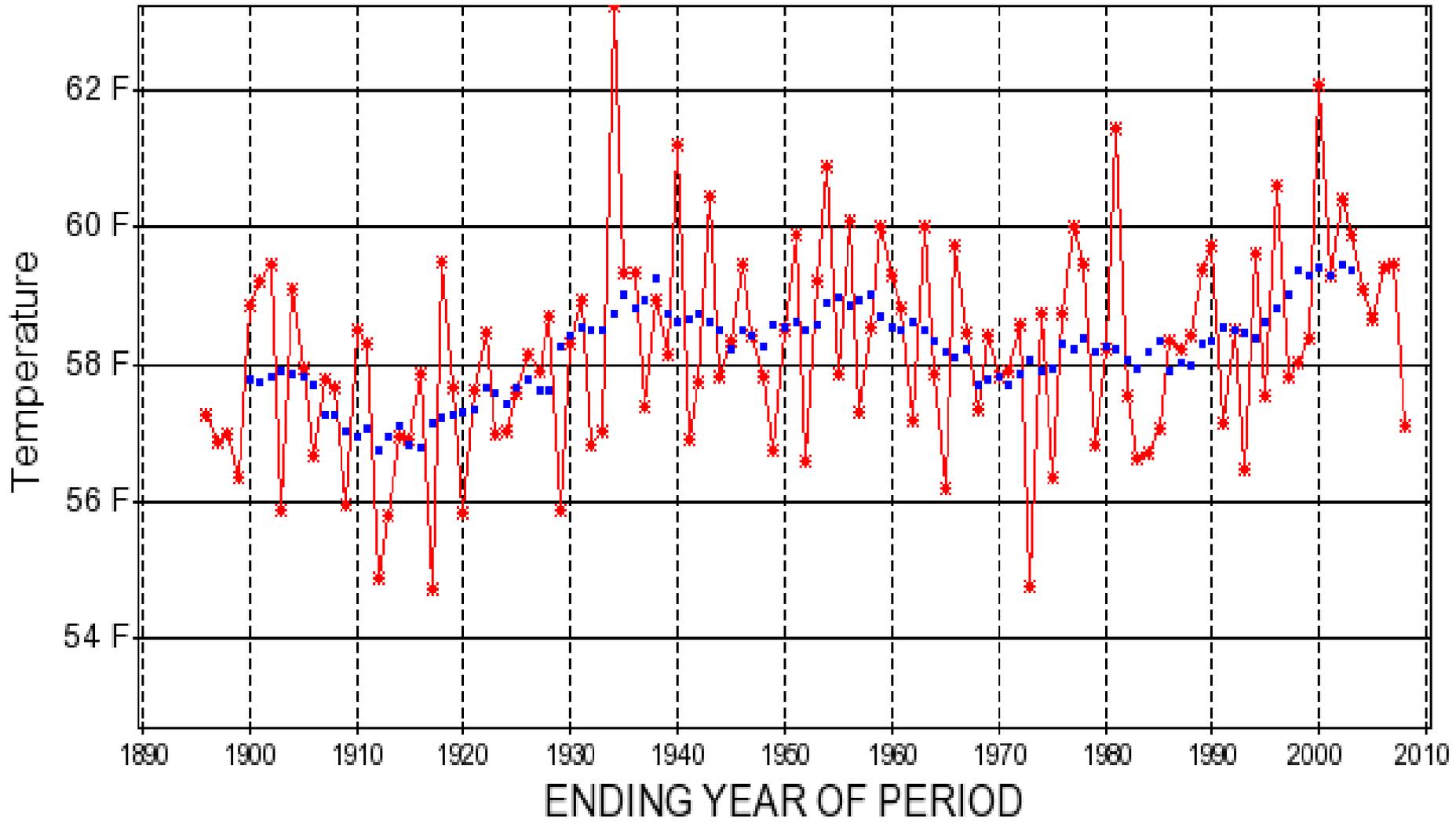
Water Year Mean Temperature (Oct-Sep) thru 2008. Upper Colorado River Basin.

Monthly Mean Mean Temperature for Upper Colorado River Basin
12 month period ending in September



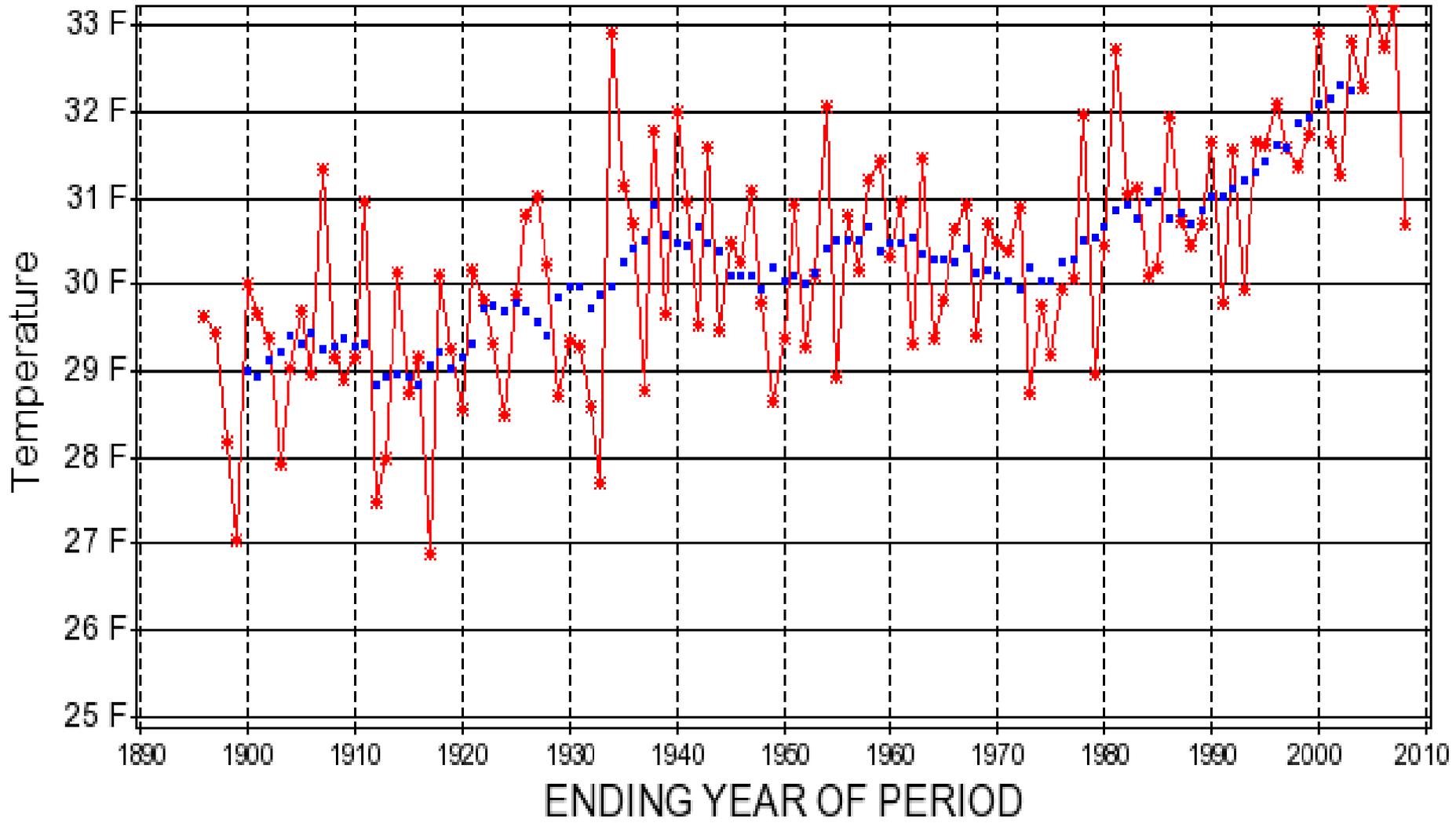
Water Year MAX Temperature (Oct-Sep) thru 2008. Upper Colorado River Basin.

Monthly Mean Maximum Temperature for Upper Colorado River Basin
12 month period ending in September

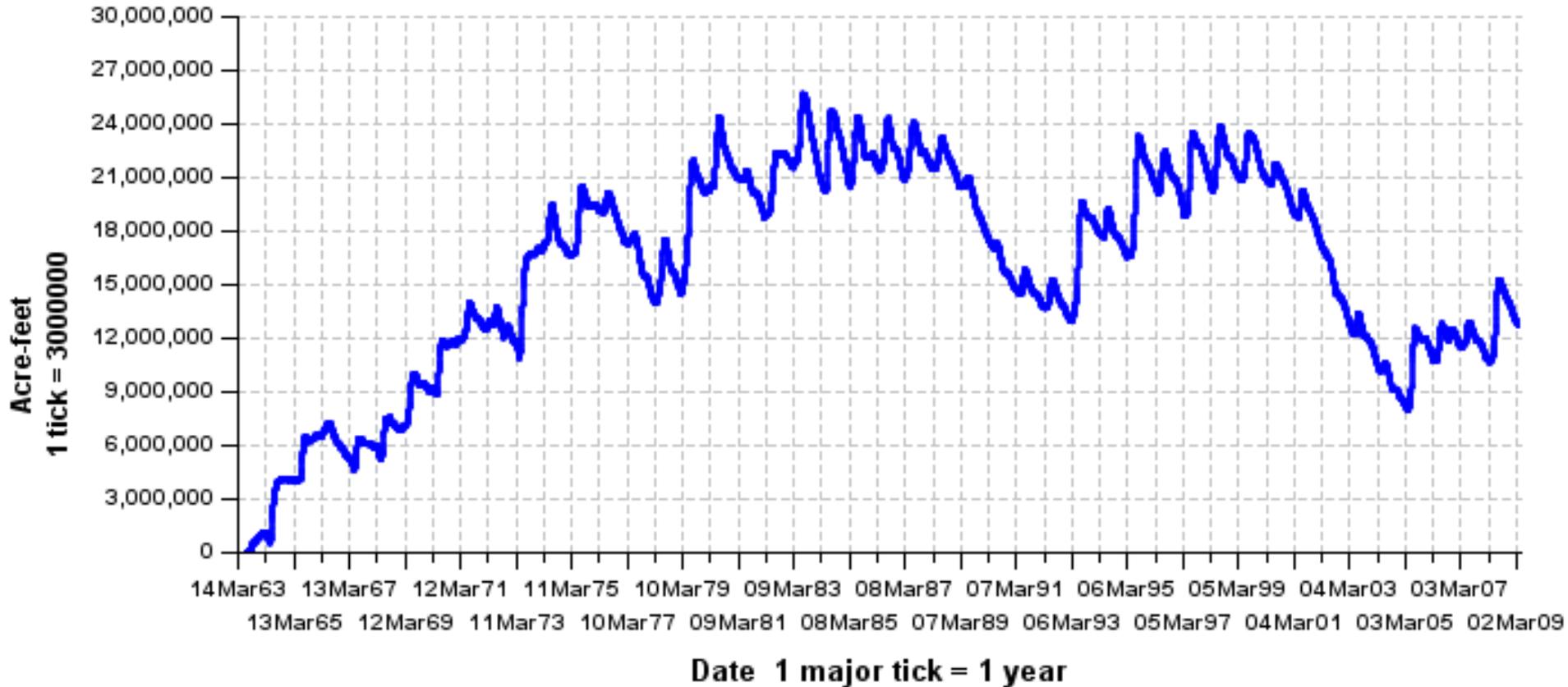


Water Year MIN Temperature (Oct-Sep) thru 2008. Upper Colorado River Basin.

Monthly Mean Minimum Temperature for Upper Colorado River Basin
12 month period ending in September

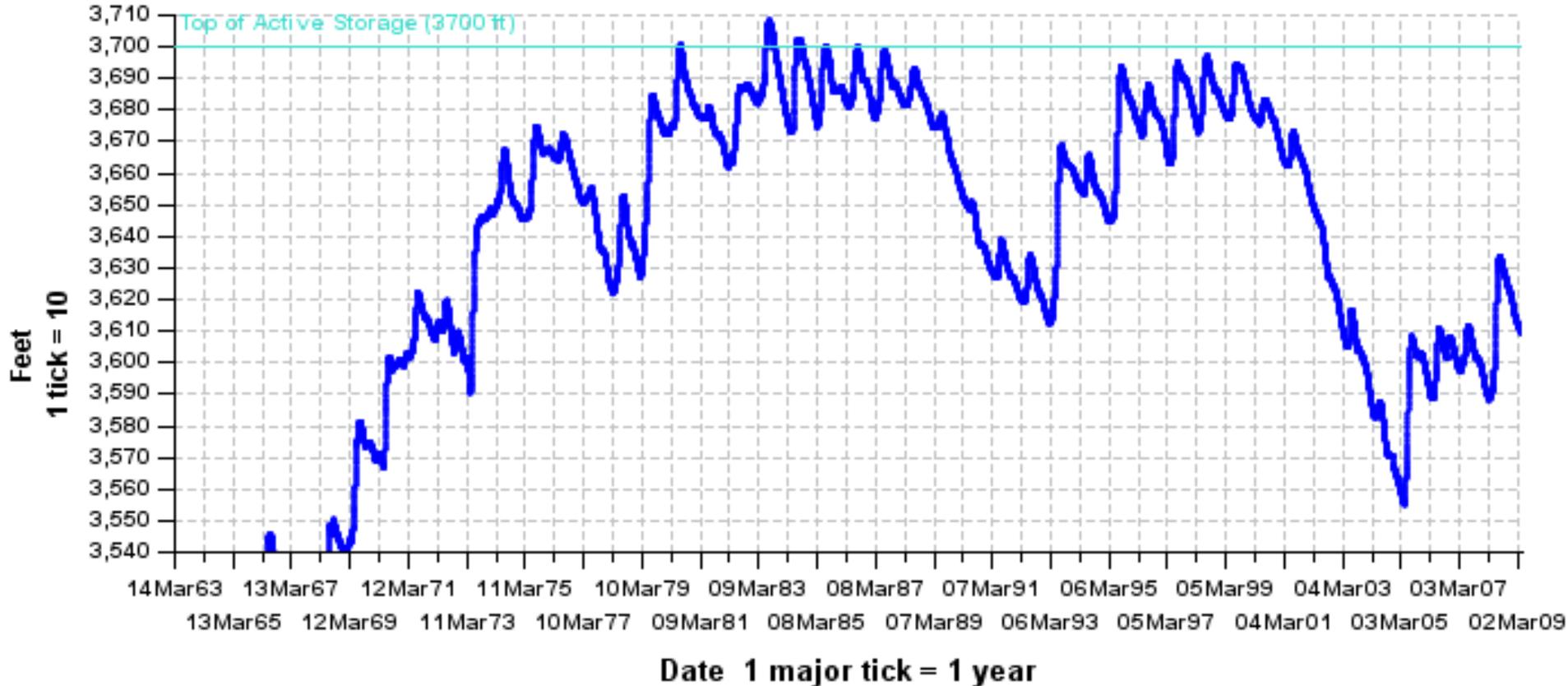


Lake Powell Storage Through May 2, 2009



Currently 53 % full (capacity 24.17 MAF)
Minimum: 33 % full on April 8, 2005

Lake Powell Elevation Through May 2, 2009



Water level on Apr 17, 2009 was 3611.80 ft, - 88 ft below full.

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

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



Is the current Southwest drought a once-or-twice-a-century drought like those of the past 500 years ...



... or ...



a harbinger of things to come, a different type of drought that we have not observed before ?



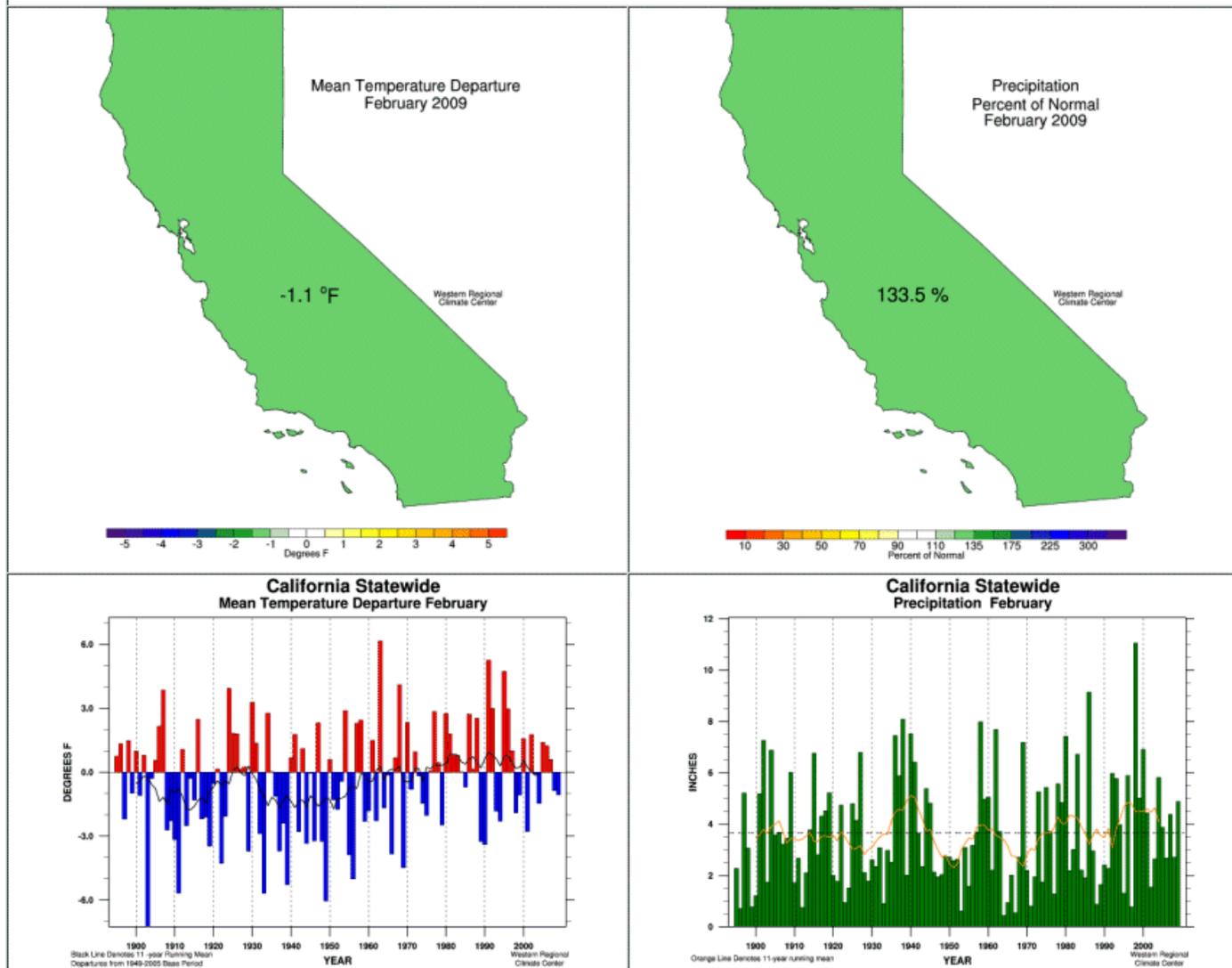
California Climate Tracker

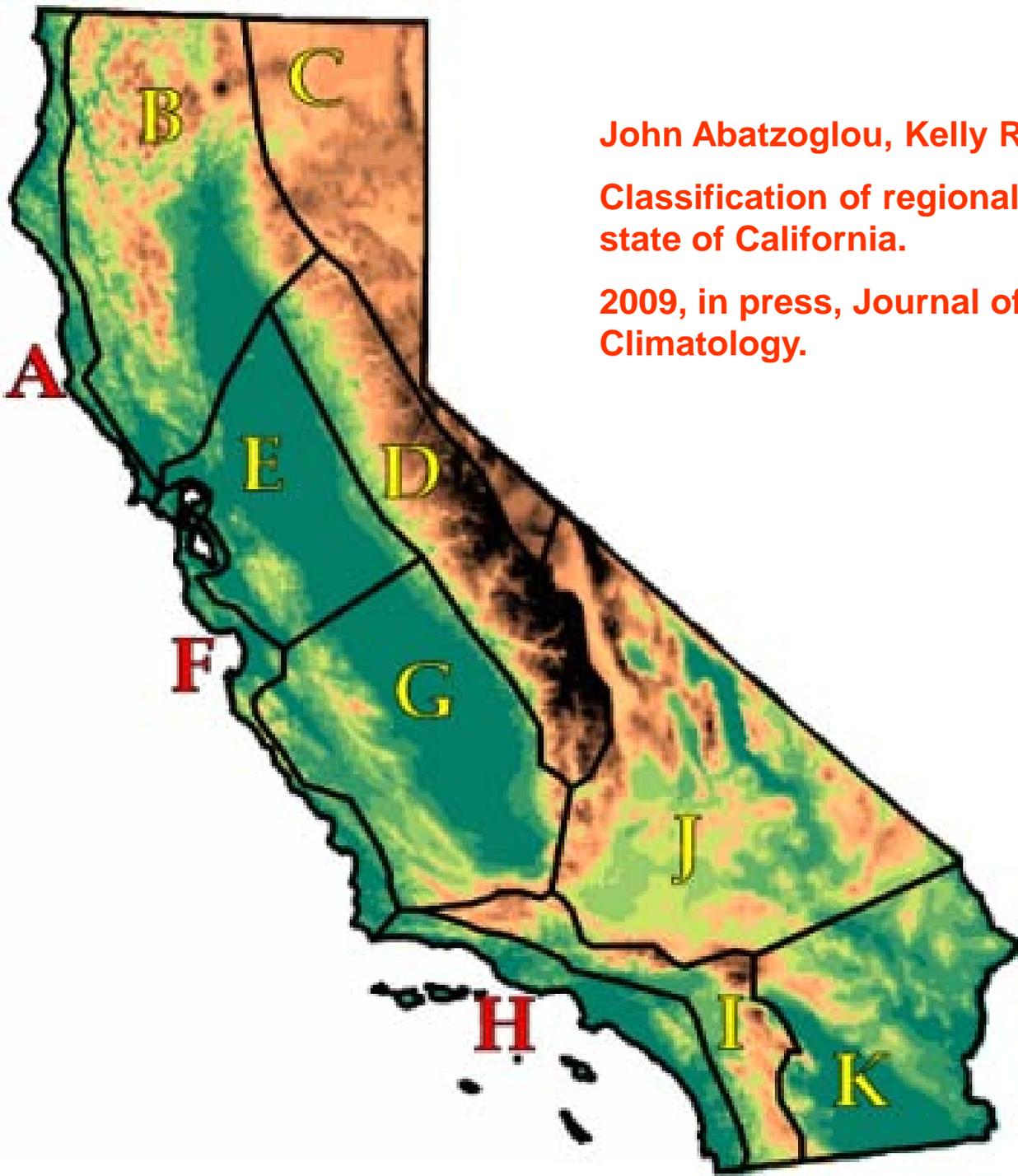
Tracking Climate Variability and Change for the State

[Explore Climate Products](#)

Updated by
John Abatzoglou

FEBRUARY 2009





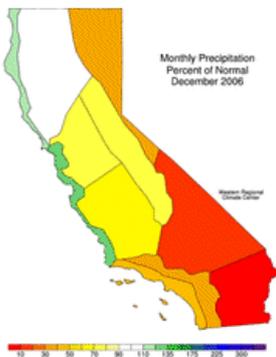
John Abatzoglou, Kelly Redmond, Laura Edwards.

Classification of regional climate variability in the state of California.

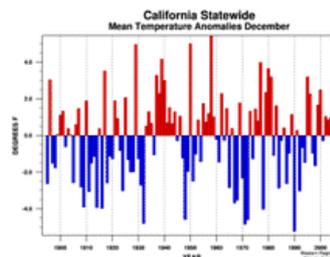
2009, in press, Journal of Applied Meteorology and Climatology.

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

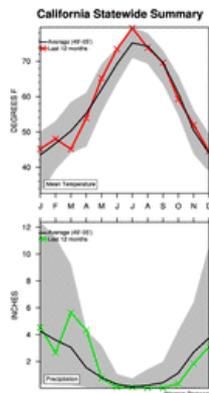
Select Element

Select Time Period

Select



Last 12 Months



Summary of the Past 12 Months

Select Region GO

[Climate Regions](#) [More Info](#)
[Plot Data](#) [Retrieve Data](#)

[Back to the California Climate Tracker](#)
[Non-Frames Version](#)

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

Time Series

Select Region

Select Element

Select Element

- Maximum Temperature
- Minimum Temperature
- Mean Temperature
- Precipitation
- Temperature Summary

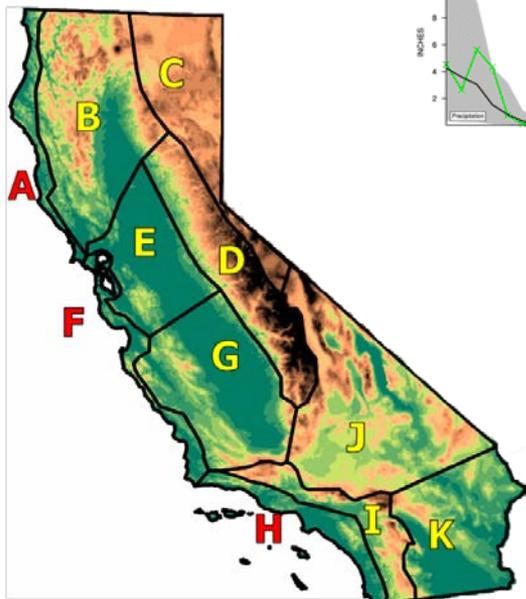
Time Series

Sierra

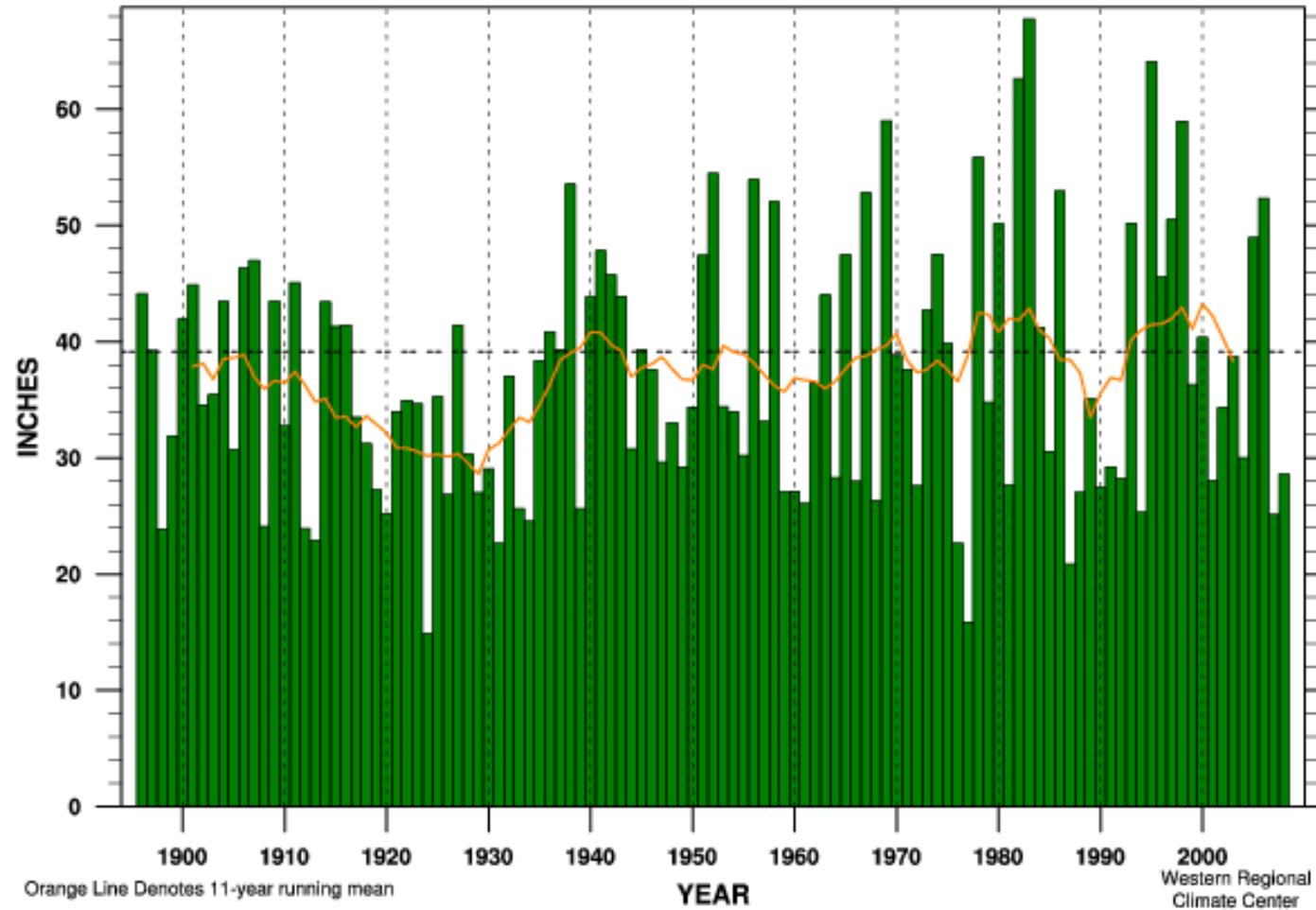
Select Region

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

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



Sierra Region Precipitation Oct-Sep



**Water Year
Oct-Sep
Precip**

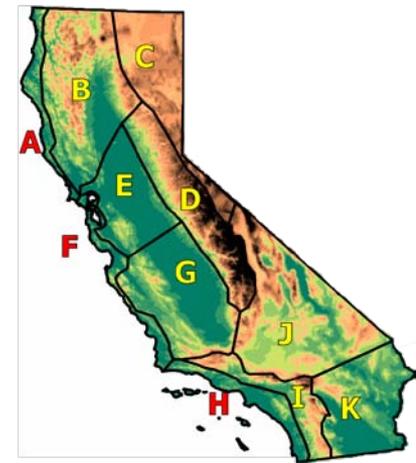
**Sierra
Nevada**

**1895/96
thru
2007/08**

Orange Line Denotes 11-year running mean

Western Regional
Climate Center

Linear Trend 1895-present	+ 4.88 ± 6.09 in.	(+ 12 ± 15%) per 100 yr	
Linear Trend 1949-present	+ 0.58 ± 19.02 in.	(+ 1 ± 48%) per 100 yr	
Linear Trend 1975-present	+ 0.11 ± 52.49 in.	(+ 0 ± 134%) per 100 yr	
Wettest Year	67.79 in. (173%)	in 1983	MEAN 39.15 in.
Driest Year	14.89 in. (38%)	in 1924	STDEV 12.33 in.
Oct-Sep 2008	28.61 in. (73%)		RANK 31 of 113

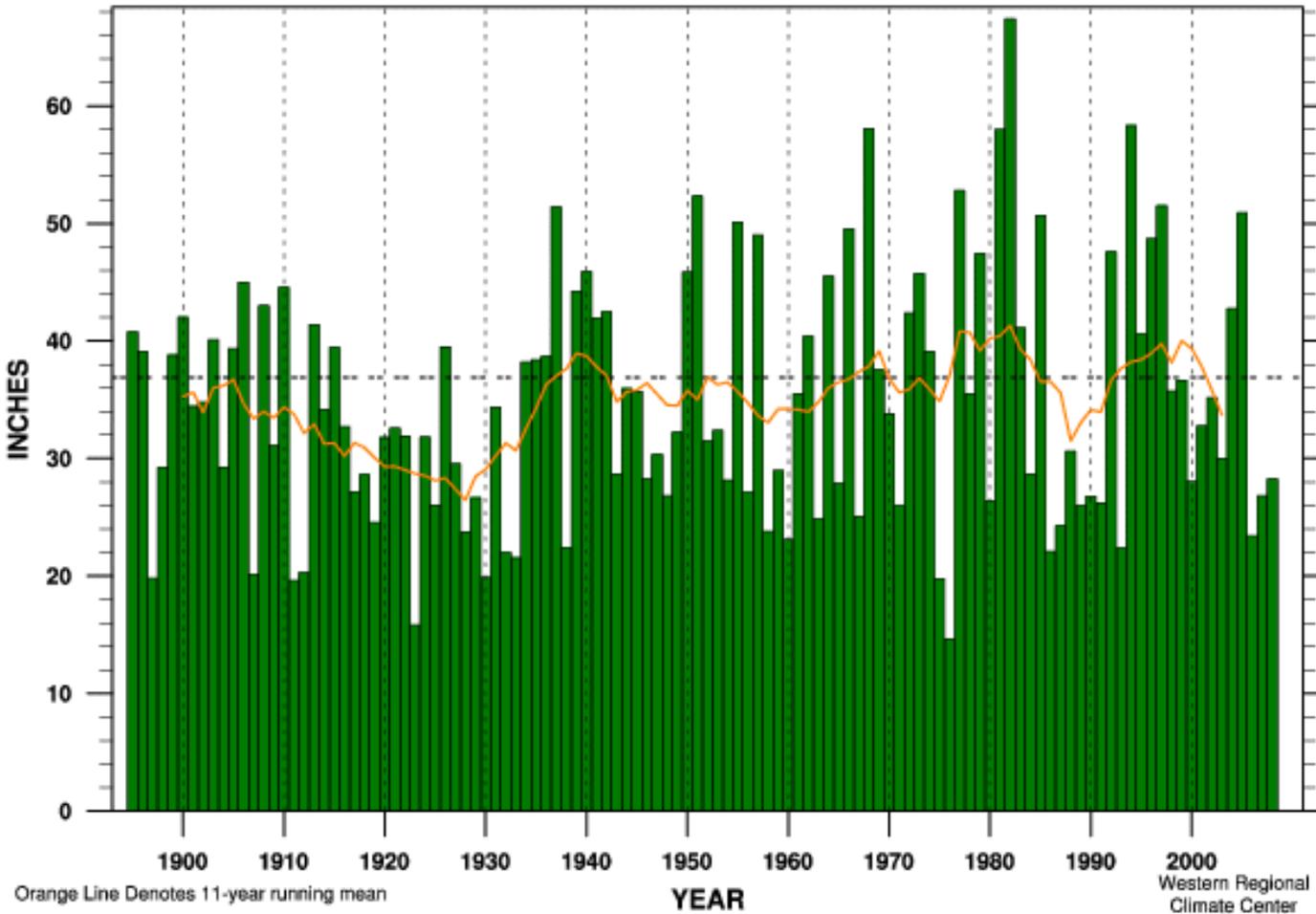


Sierra Region Precipitation Jul-Apr

**Precipitation
Season
To Date**

**July 01
to
April 30**

**1895-96
Thru
2008-09**



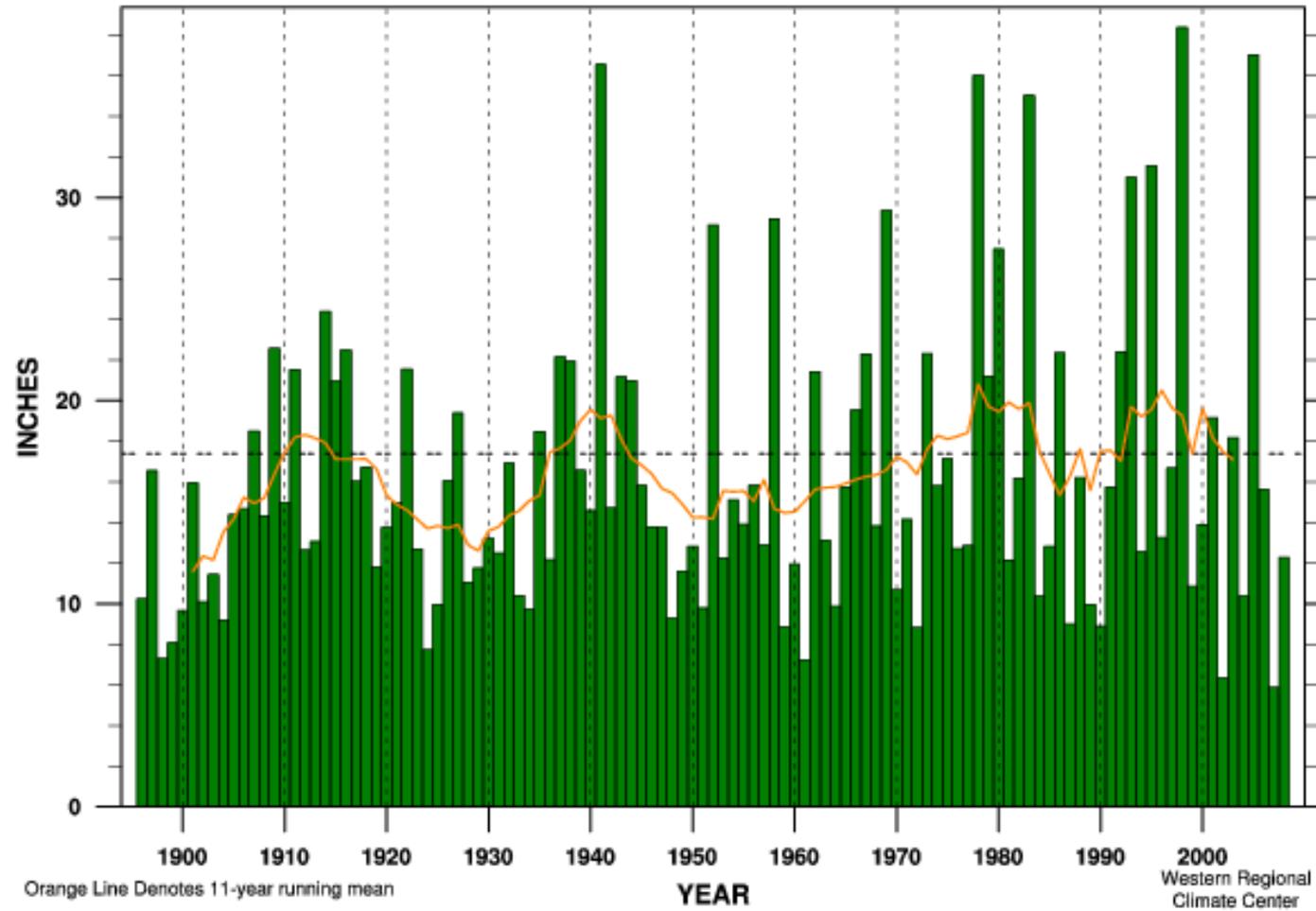
Linear Trend 1895-present	+ 4.41 ± 5.73 in.	(+ 11 ± 15%) per 100 yr	
Linear Trend 1949-present	- 1.51 ± 17.10 in.	(- 4 ± 46%) per 100 yr	
Linear Trend 1975-present	- 7.06 ± 44.04 in.	(- 19 ± 119%) per 100 yr	
Wettest Year	67.41 in. (182%)	in 1982	MEAN 36.87 in.
Driest Year	14.64 in. (39%)	in 1976	STDEV 11.81 in.
Jul-Apr	2008	28.27 in. (76%)	RANK 37 of 114

South Coast Region Precipitation Oct-Sep

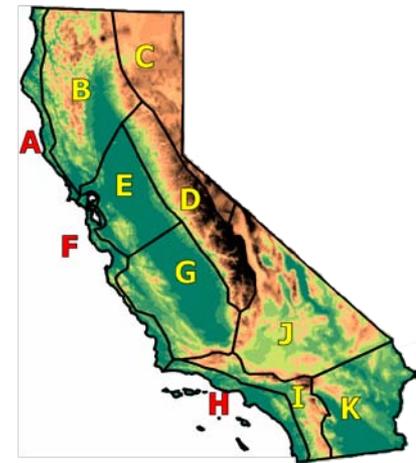
**Water Year
Oct-Sep
Precip**

**South
Coastal
California**

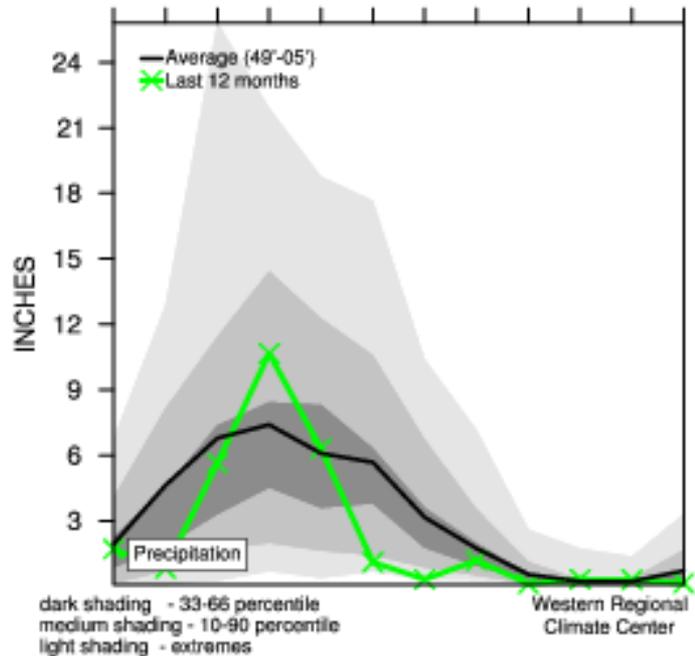
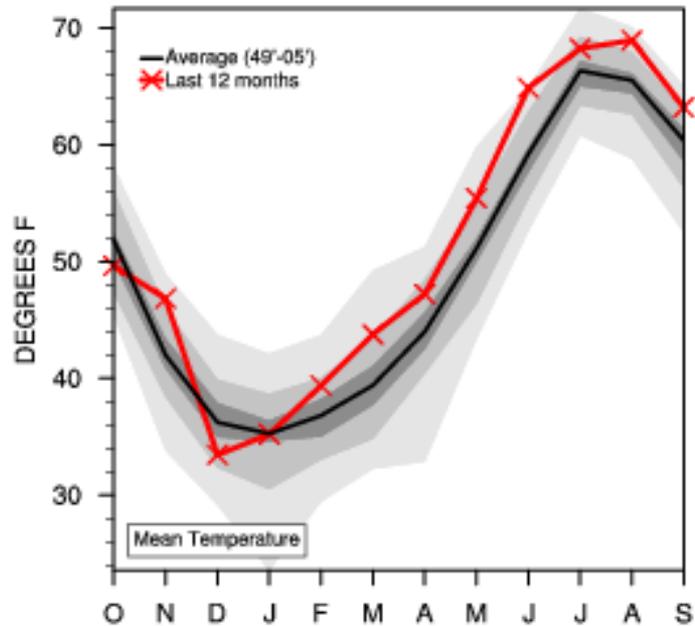
**1895/96
thru
2007/08**



Linear Trend 1895-present	+ 3.75 ± 3.93 in.	(+ 21 ± 22%) per 100 yr	
Linear Trend 1949-present	+ 3.96 ± 12.53 in.	(+ 22 ± 72%) per 100 yr	
Linear Trend 1975-present	-11.58 ± 35.10 in.	(- 66 ± 201%) per 100 yr	
Wettest Year	38.39 in. (220%) in 1998	MEAN	17.38 in.
Driest Year	5.87 in. (33%) in 2007	STDEV	8.13 in.
Oct-Sep 2008	12.29 in. (70%)	RANK	35 of 113



Sierra Region Last 12 Months



Sierra Nevada

**Temperature
and
Precipitation**

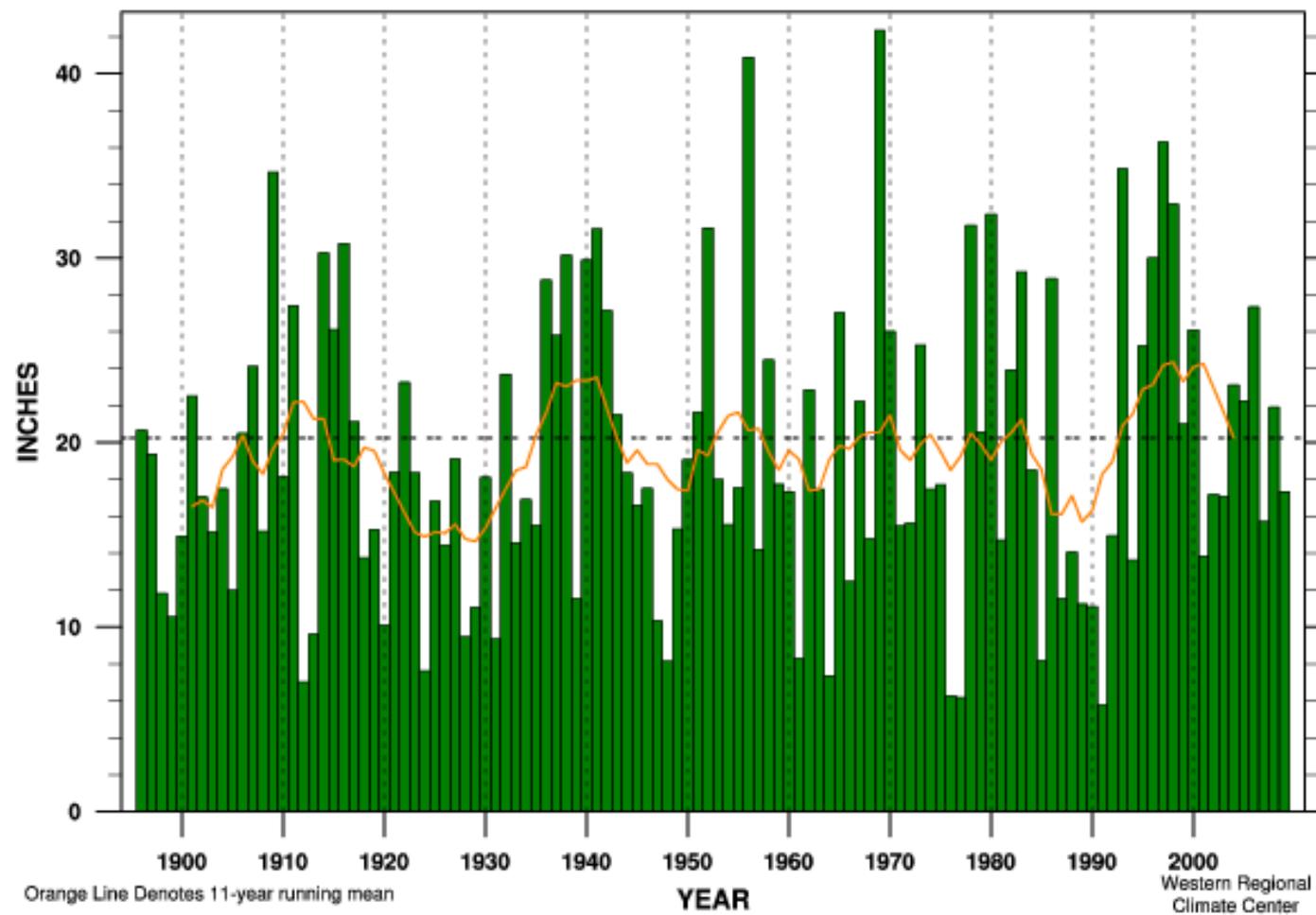
**Oct 2007
Thru
Sep 2008**

**A possible
analog for
climate
change ?**

**California Climate
Tracker**

Sierra Region Precipitation Dec-Feb

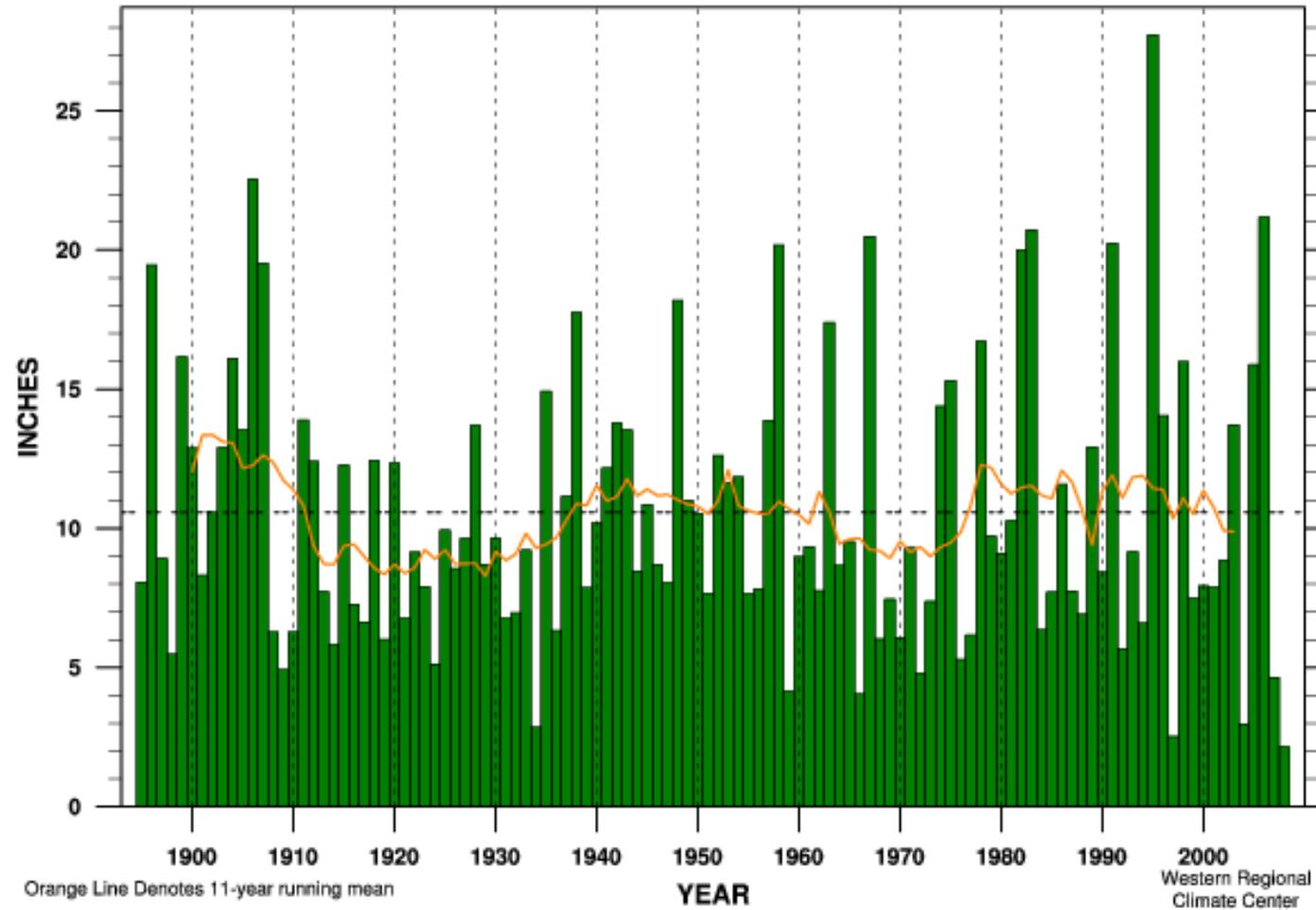
**Sierra
Nevada
Winter
Precipitation
DJF
1895-96
Thru
2008-09**



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 Region Precipitation Mar-May

**Sierra
Nevada
Spring
Precipitation
MAM
1895
Thru
2009**

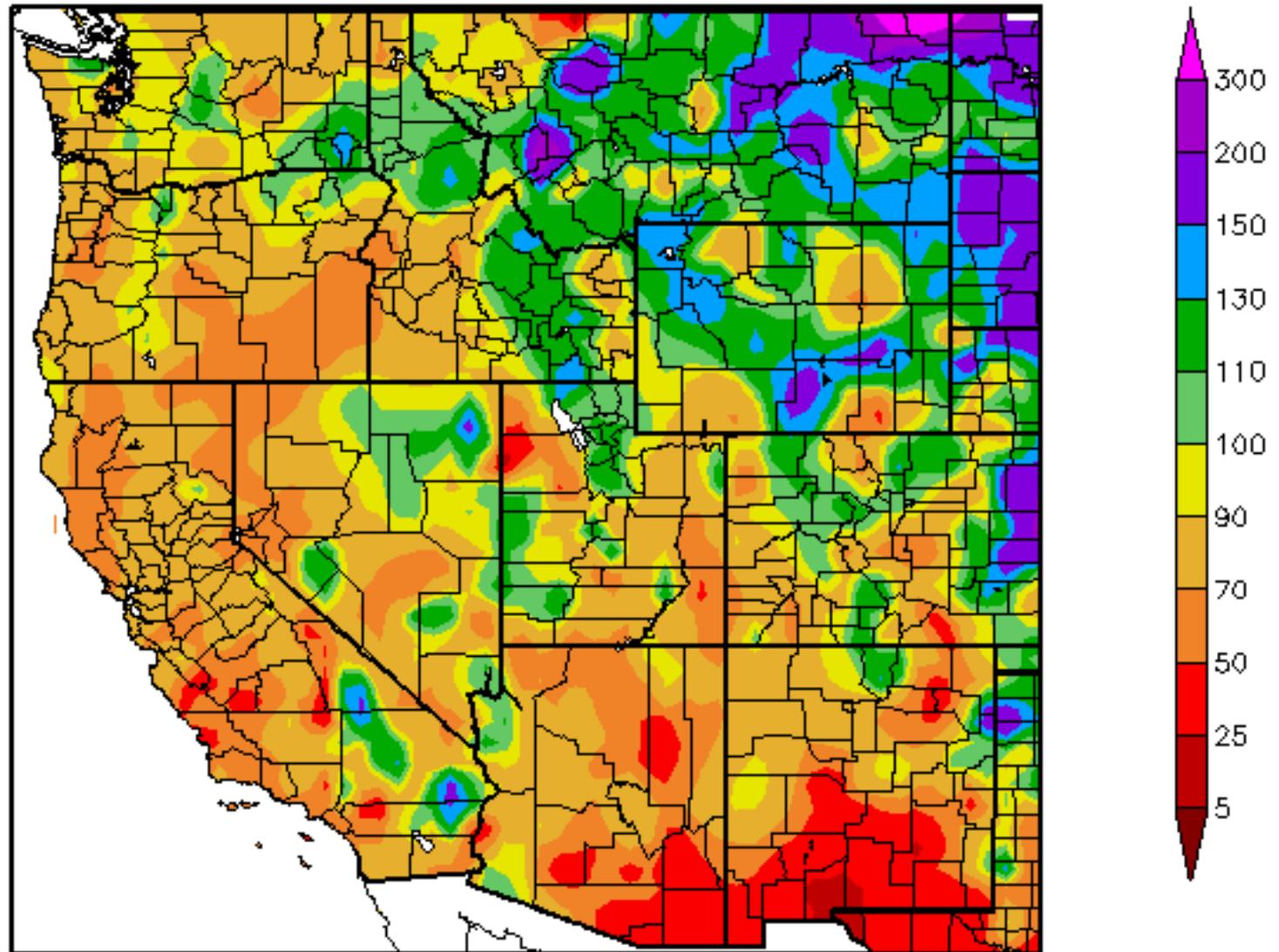


Linear Trend 1895-present	- 0.22 ± 2.75 in.	(- 2 ± 26%) per 100 yr	
Linear Trend 1949-present	+ 0.22 ± 8.14 in.	(+ 2 ± 77%) per 100 yr	
Linear Trend 1975-present	- 6.09 ± 21.96 in.	(- 57 ± 207%) per 100 yr	
Wettest Year	27.73 in. (262%) in 1995	MEAN	10.57 in.
Driest Year	2.14 in. (20%) in 2008	STDEV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

Water Year
2008 Oct 1
Thru
2009 May 01

Percent of Normal Precipitation (%)

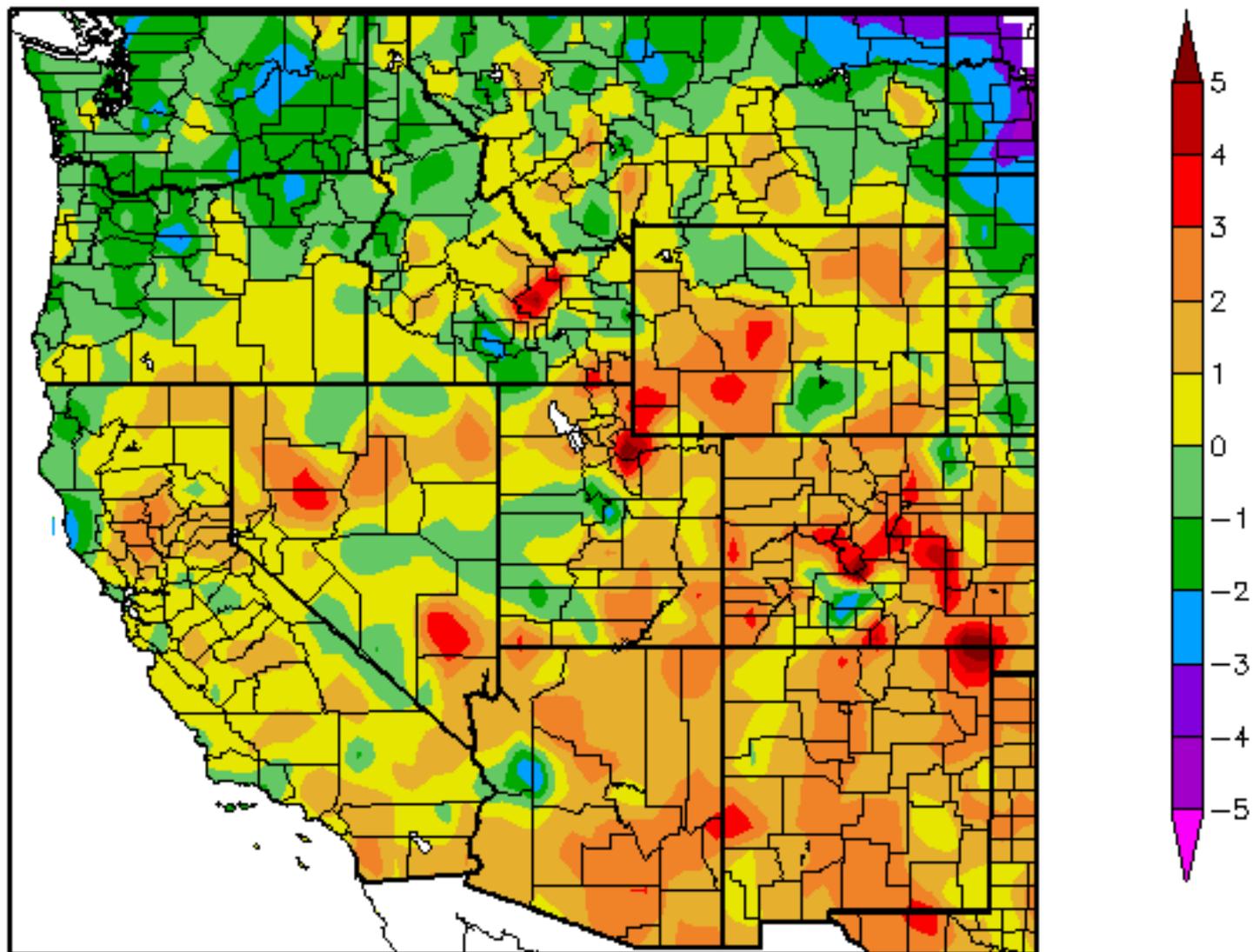
10/1/2008 - 5/1/2009



Departure from Normal Temperature (F)

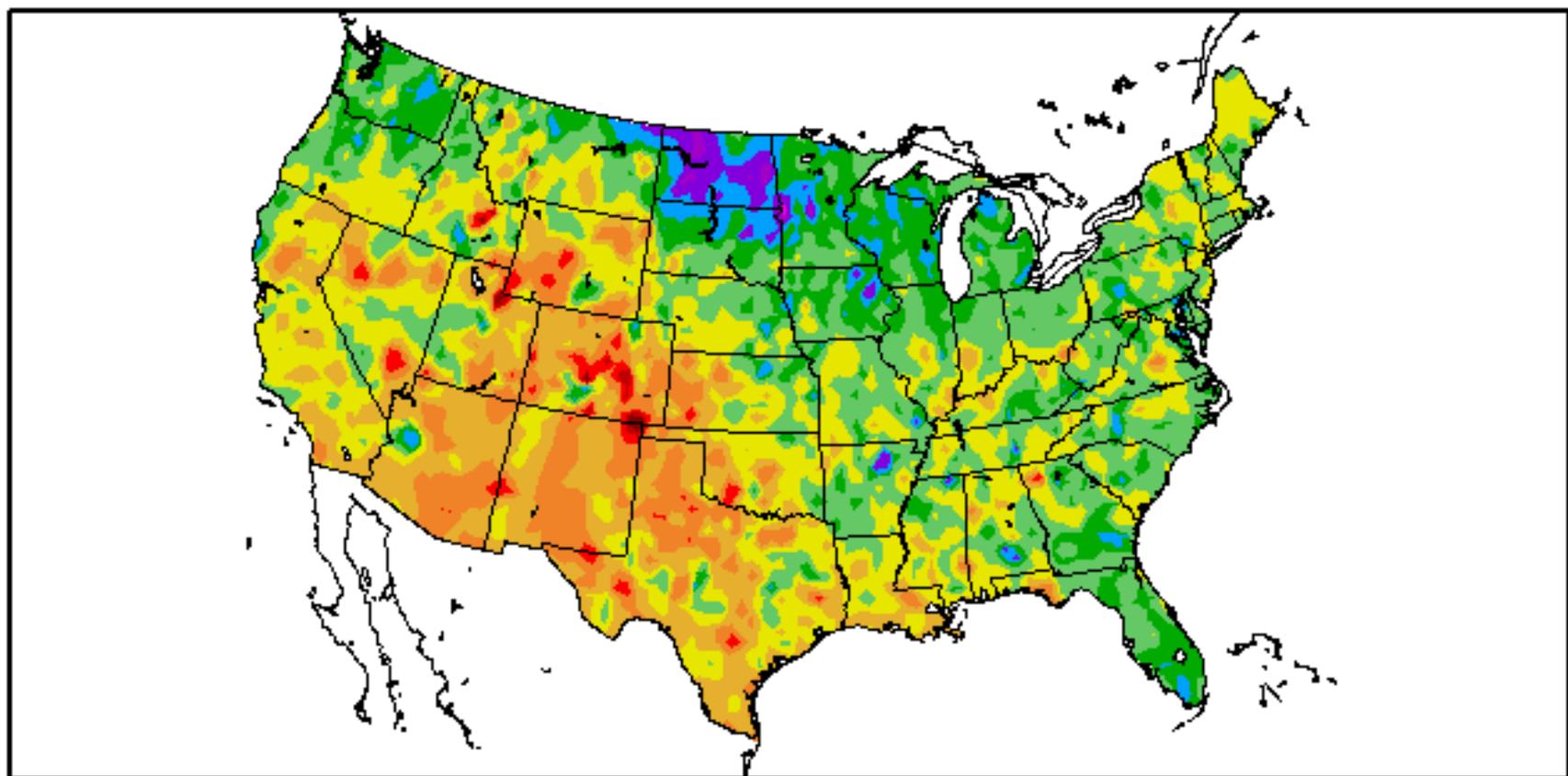
10/1/2008 - 5/1/2009

Water Year
2008 Oct 01
Thru
2009 May 01



Water Year
2008 Oct 01
Thru
2009 May 01

Departure from Normal Temperature (F)
10/1/2008 – 5/1/2009



Winter 2008-2009

Dec thru Mar

NCEP/NCAR Reanalysis

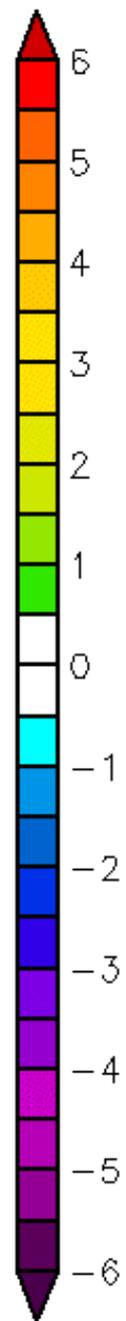
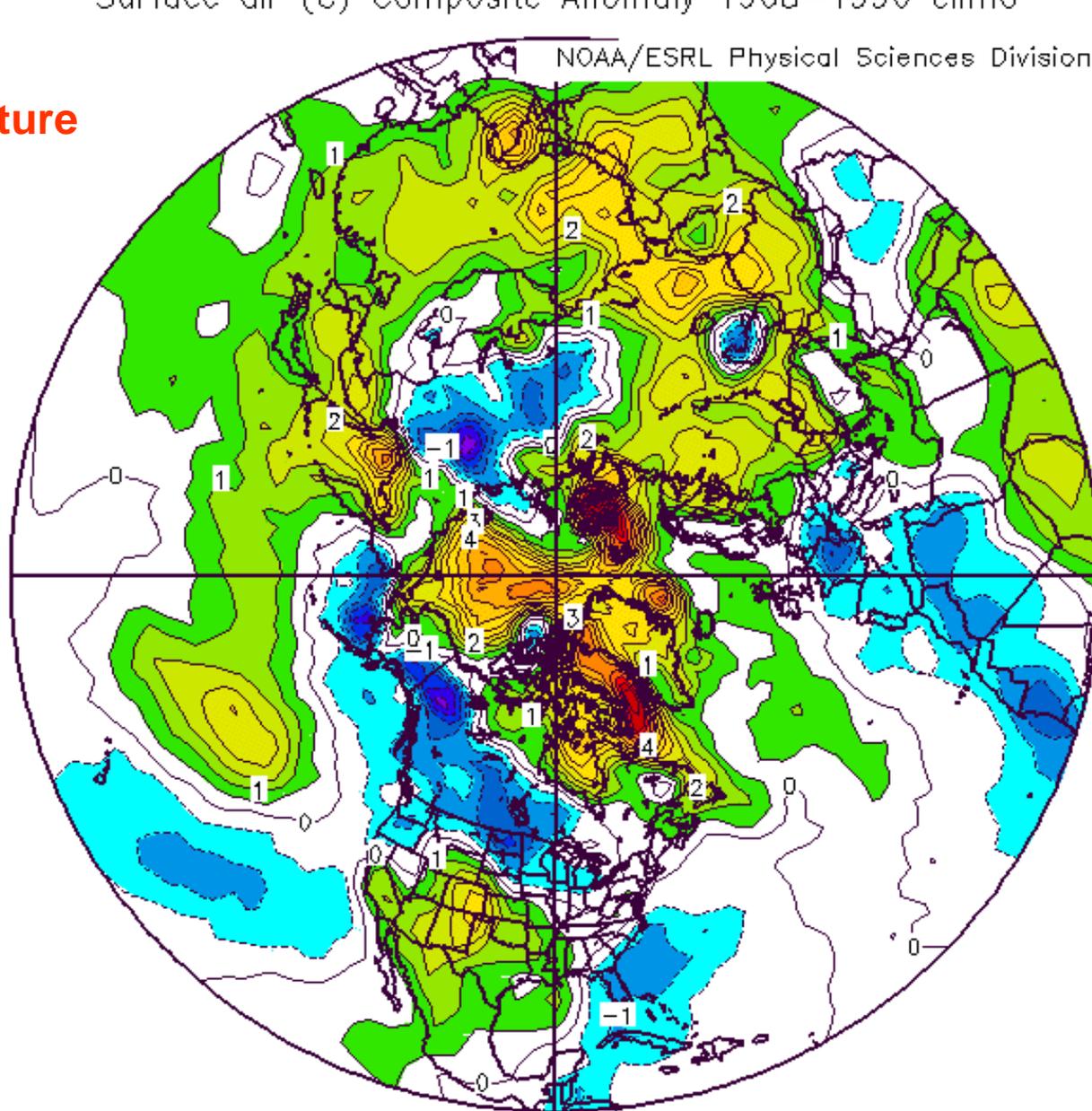
Surface air (C) Composite Anomaly 1968-1996 climo

NOAA/ESRL Physical Sciences Division

Surface Temperature

Departure from
Climatology
(1968-1996)

Reanalysis
Data

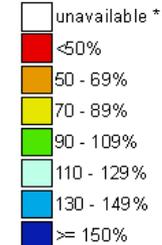


Dec to Mar: 2009

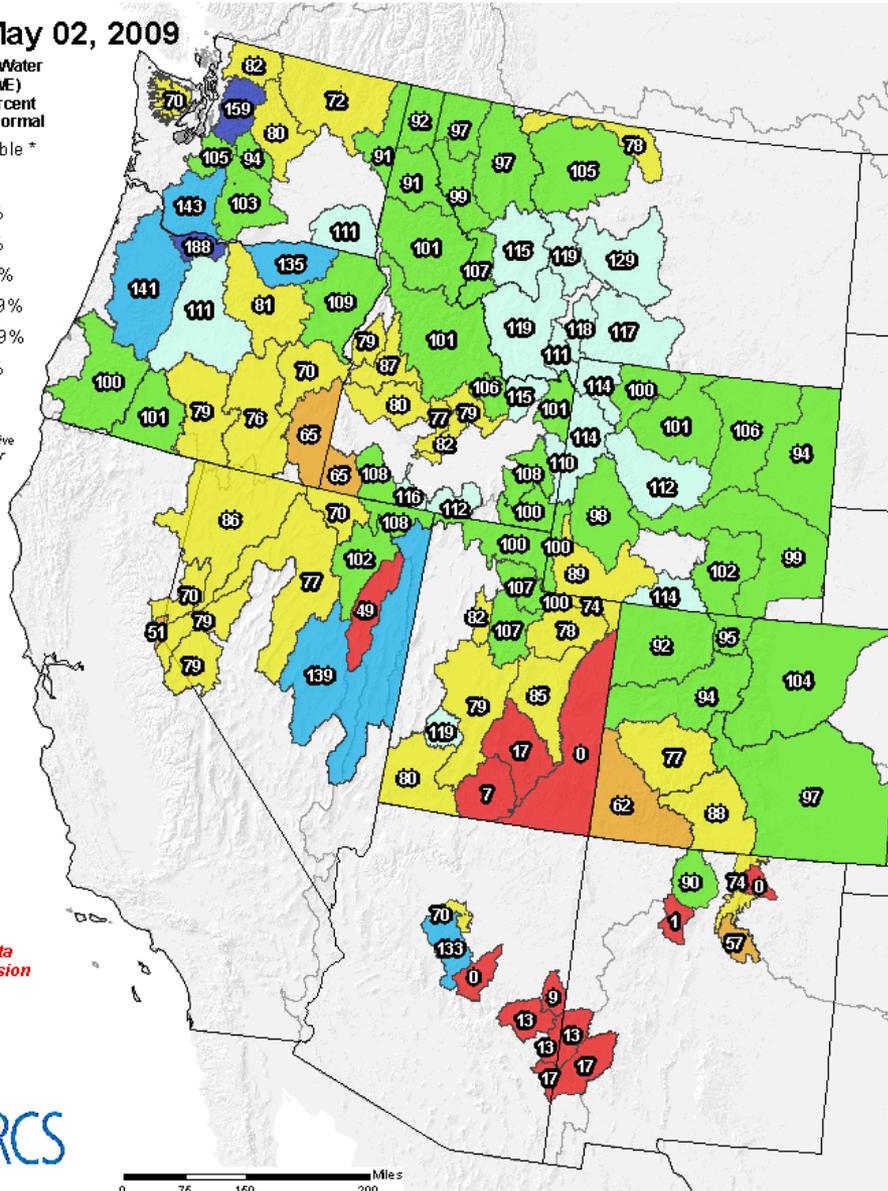
Westwide SNOTEL Current Snow Water Equivalent (SWE) % of Normal

May 02, 2009

Current Snow Water Equivalent (SWE) Basin-wide Percent of 1971-2000 Normal



* Data unavailable at time of posting or measurement is not representative at this time of year



Provisional data subject to revision



The snow water equivalent percent of normal represents the current snowwater equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by the USDA/NRCS National Water and Climate Center Portland, Oregon <http://www.wcc.nrcs.usda.gov/gis/>
Based on data from <http://www.wcc.nrcs.usda.gov/reports/>
Science contact: Tom.Pagano@por.usda.gov 503 414 3010

Western Basins

Snow Water Content

from Snotel Stations

Percent of Average

2009May 02

Above L Powell 83%

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**

Anticipated changes in Western USA next several decades:

Increased temperatures everywhere. Temperature is a hydrologic element.

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

Precipitation increases during the mid-winter months in relation to rest of year

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, more north, less south

Same precipitation with higher temperatures is “like” less precipitation

This is all not necessarily straightforward.

Thank You



Bishop Creek, CA

Discards