Climate Change and Western Deserts

An Overview

Kelly T. Redmond

Western Regional Climate Center

Desert Research Institute

Reno Nevada

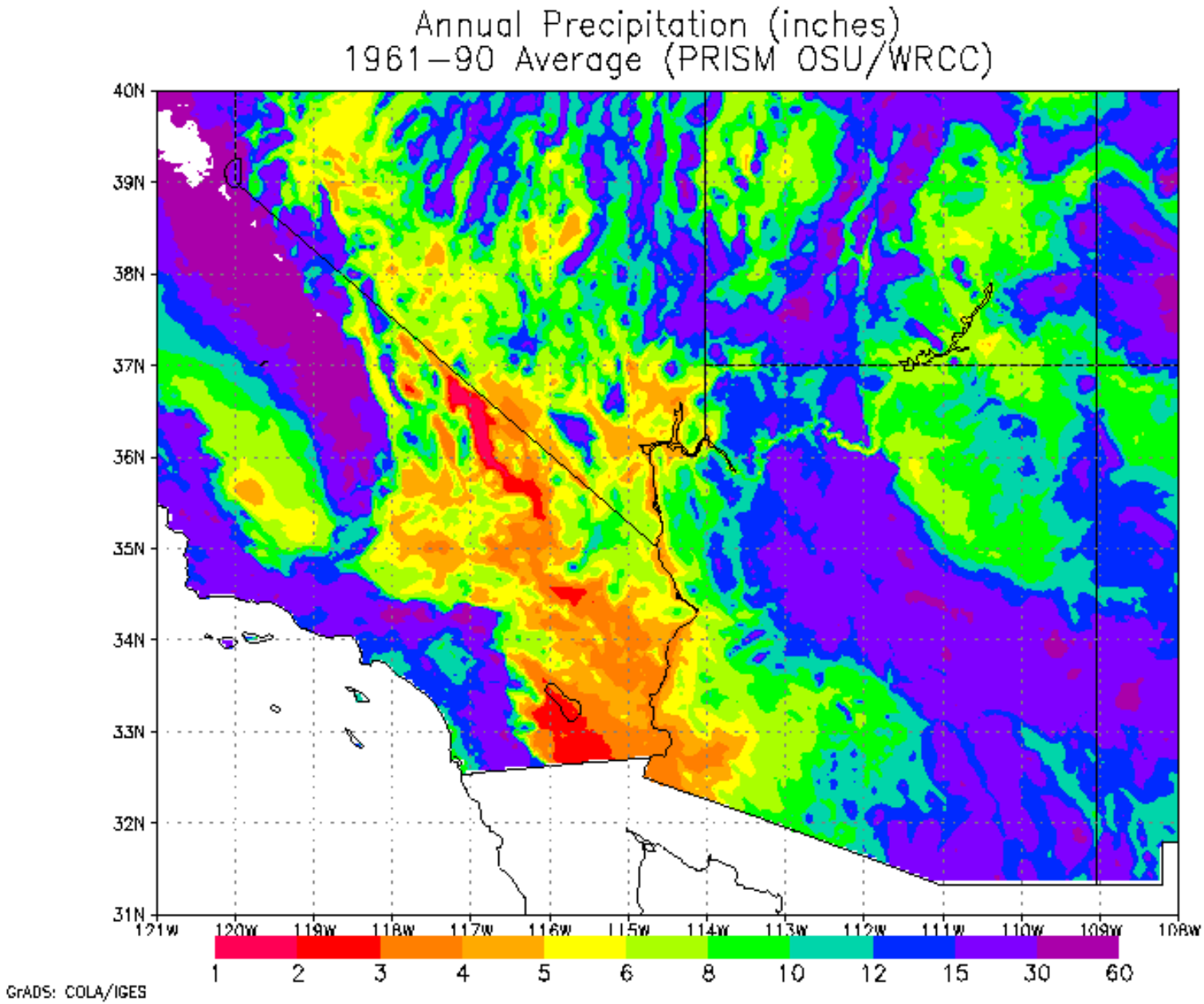
The Climate and Desert Workshop

Adaptive Management of Desert Ecosystems

in a Changing Environment

Laughlin, Nevada 2008 April 9-10

Western Regional
Climate Center


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

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)

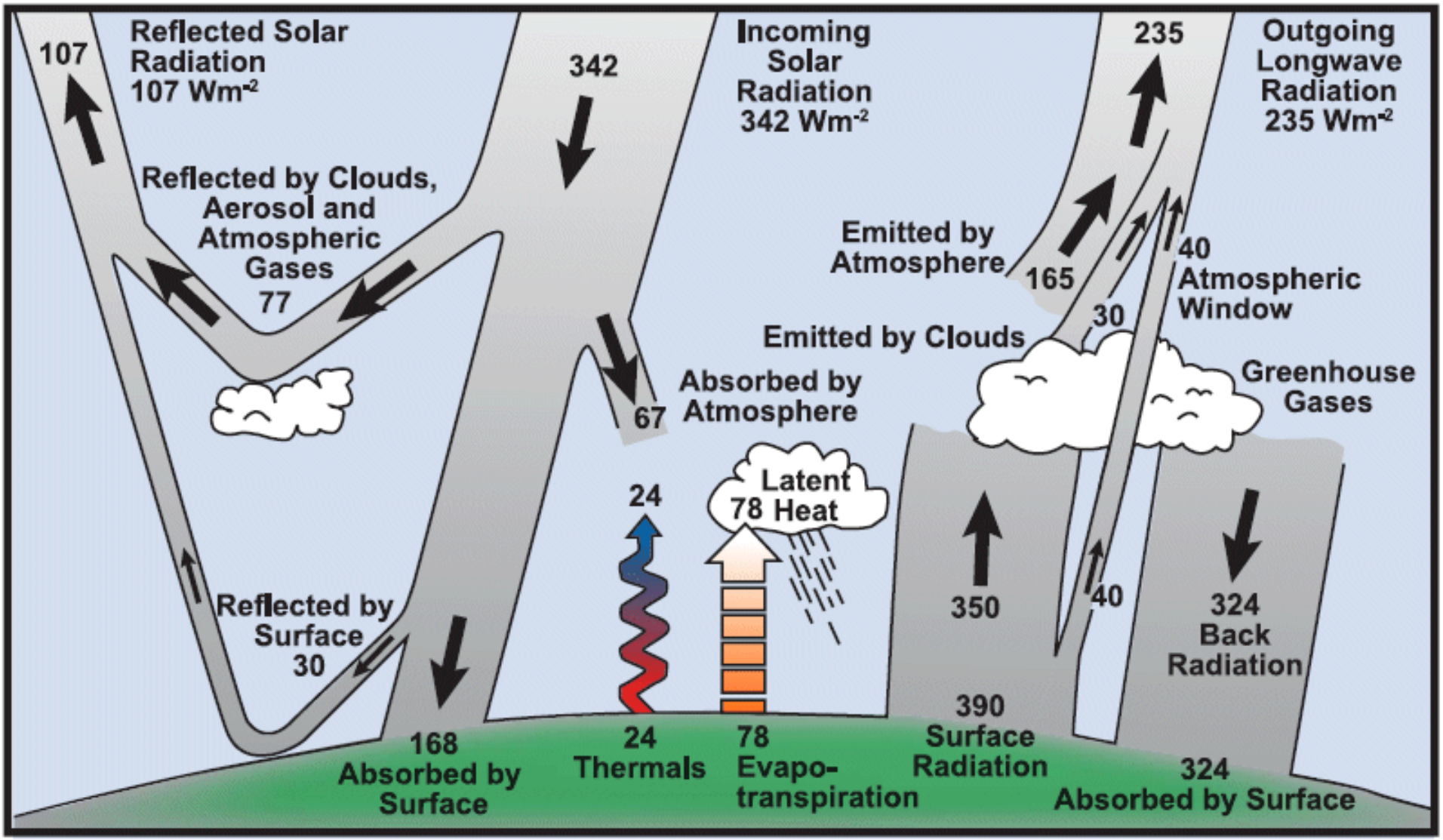
Land use / land cover changes
- Changes in albedo
- Changes in water vapor
- Changes in vegetative influence / participation in energy and mass flows

Natural

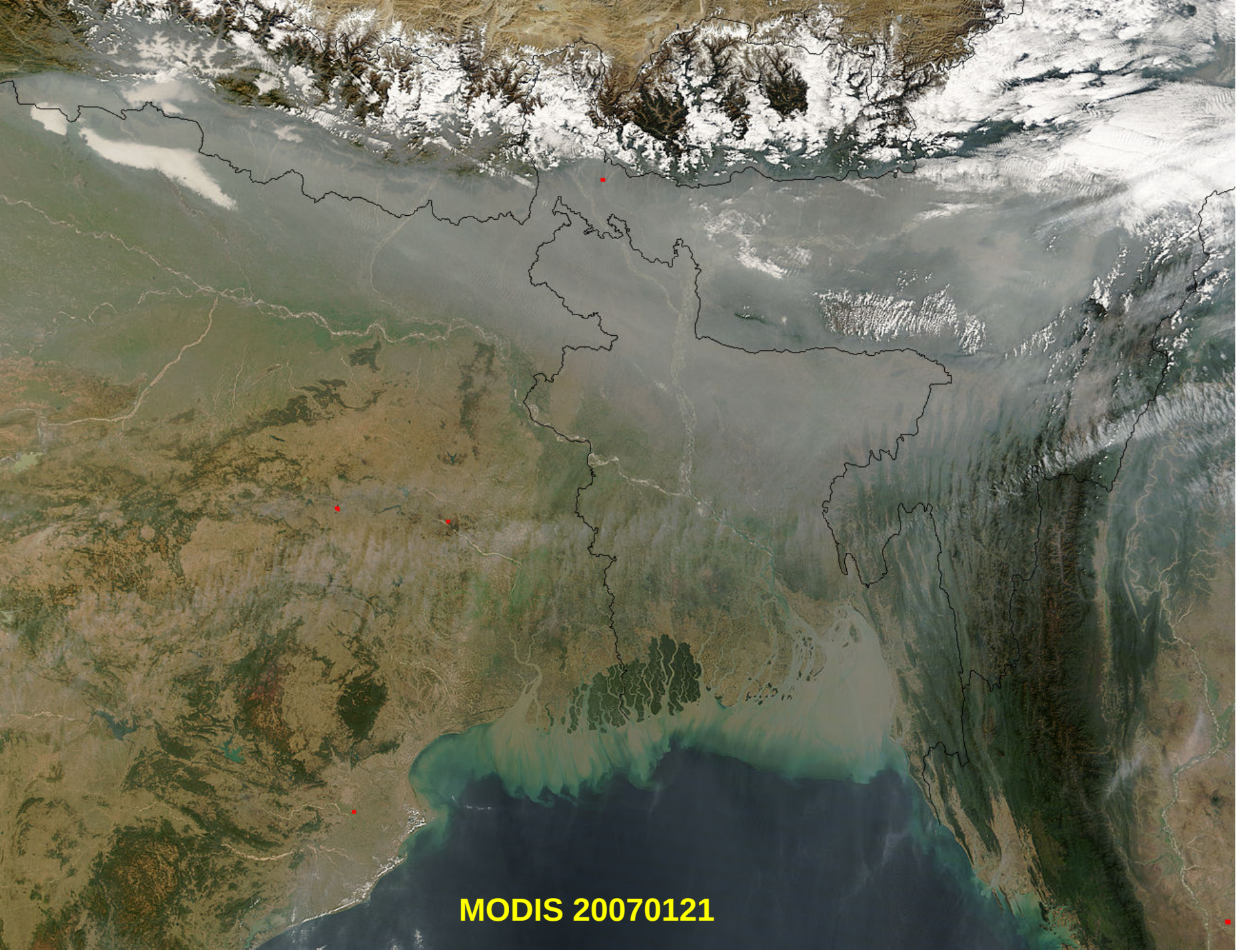
Astronomical radiation forcing
Solar variations
Volcanoes

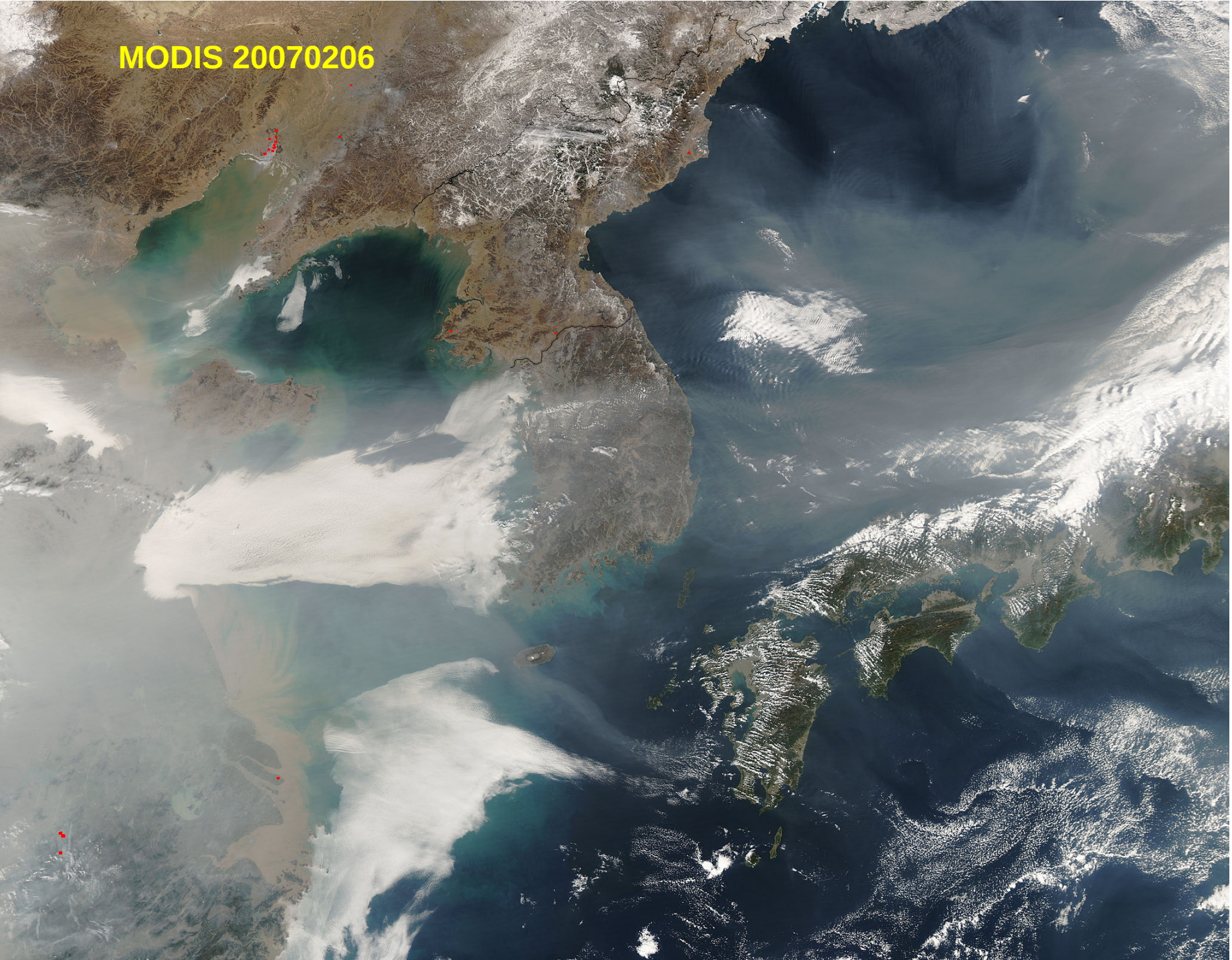
The Planetary Radiation Budget

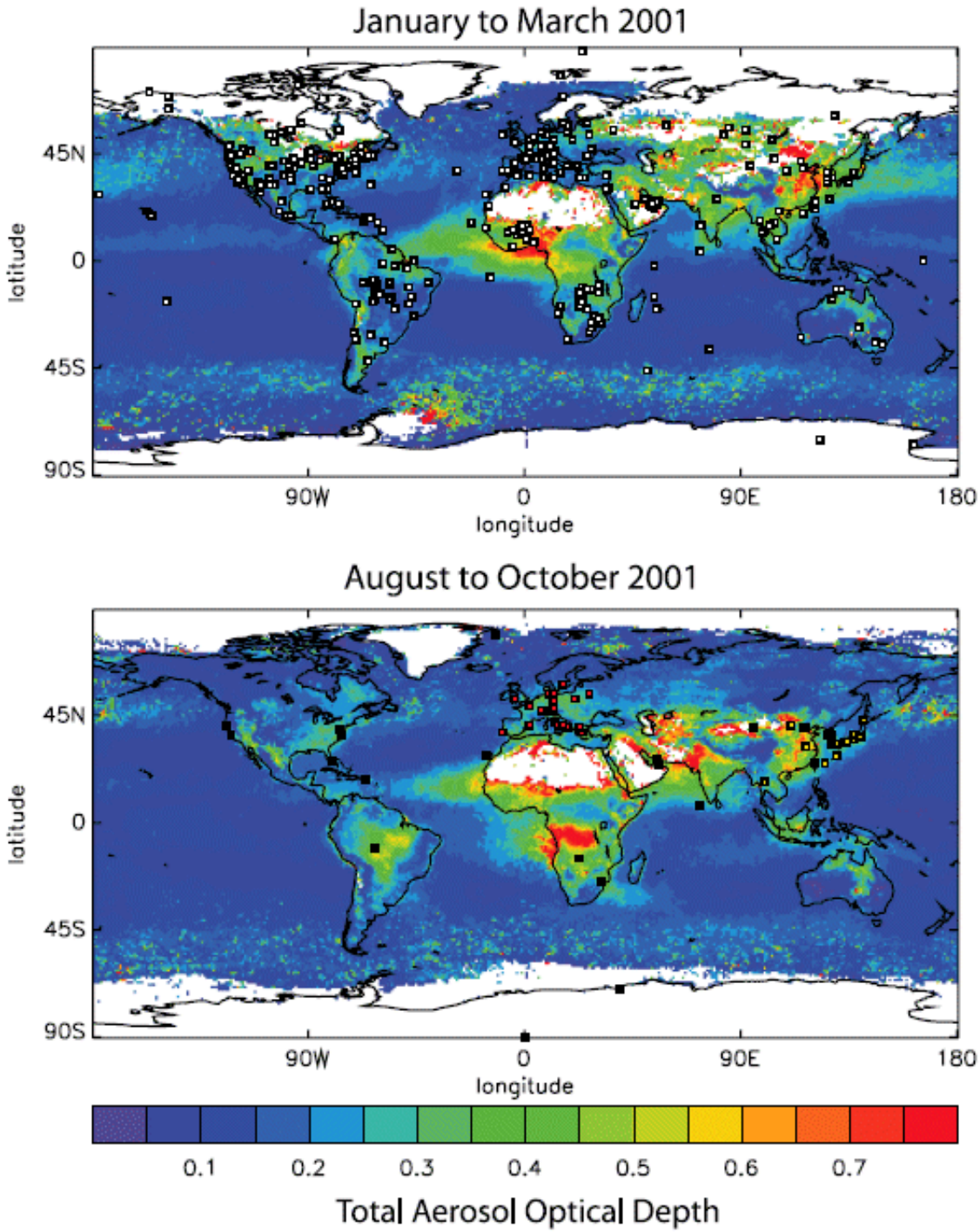
Net incoming 342 – 107 = 235 W/m² **Net outgoing = 235 W / m²**



IPCC AR4, Kiehl and Trenberth (1997)


MODIS 20070121


MODIS 20070206



Pollution is a global atmospheric concern

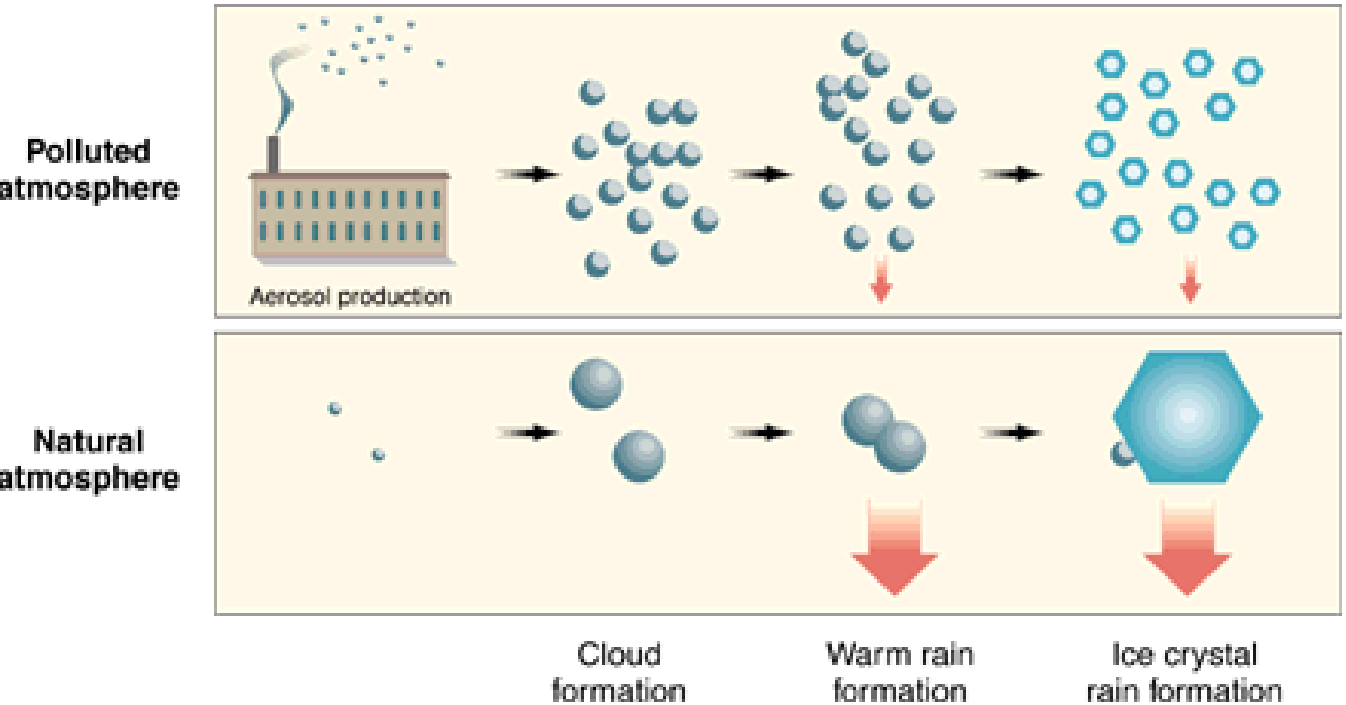
Obviously for health reasons

But, also,

Aerosols have effects on

Temperature
And
Precipitation

Also note:
Aerosols are unequally distributed around the earth



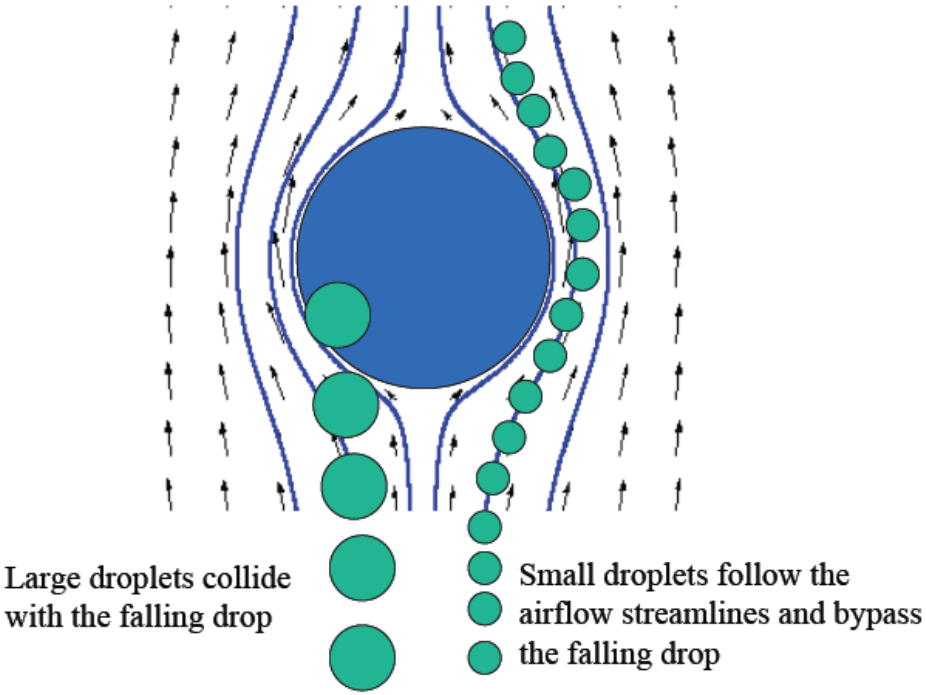
Owen B. Toon

How Pollution Suppresses Rain

Science Magazine,

10 March 2000

287 (5459), 1763-1765

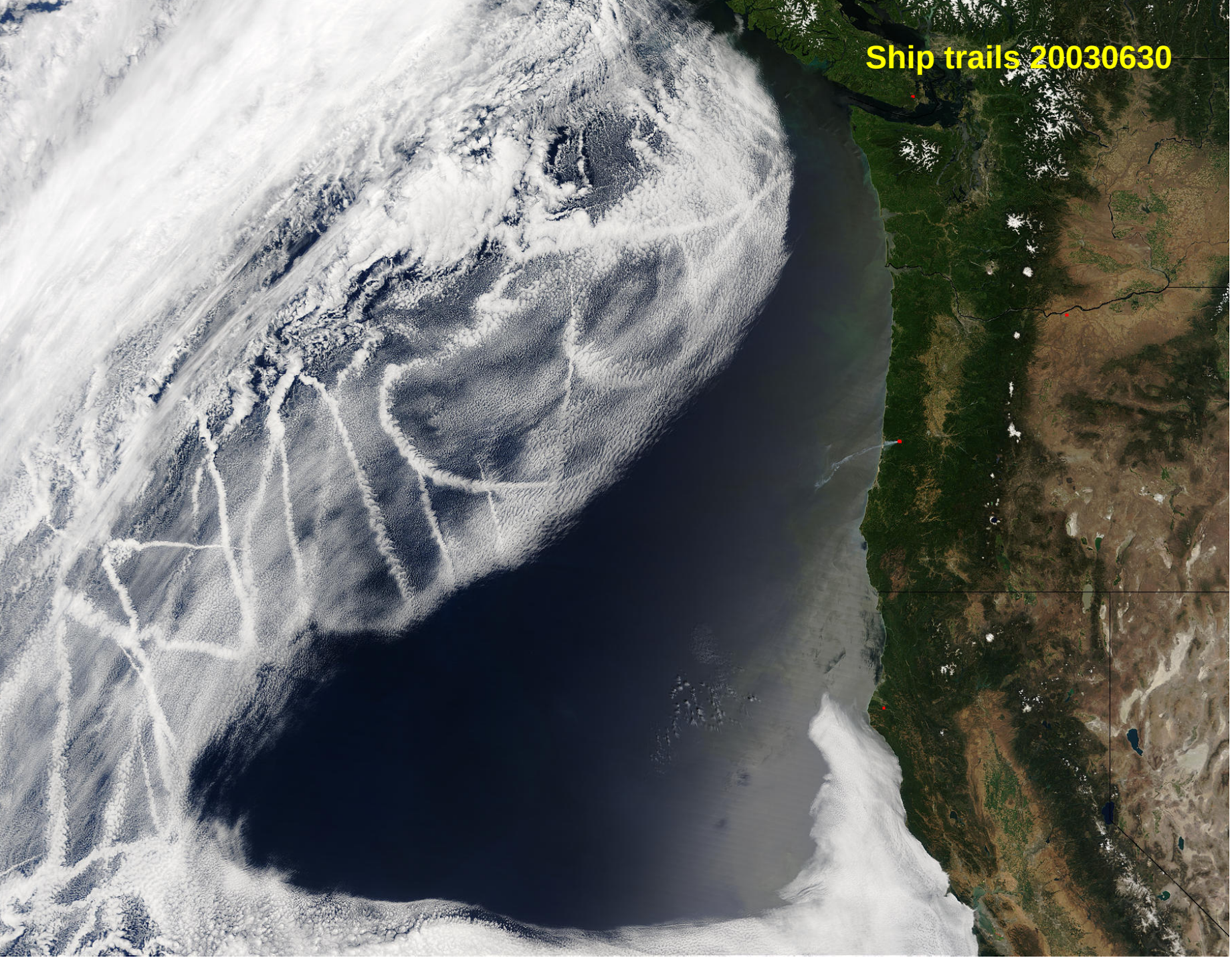


Daniel Rosenfeld

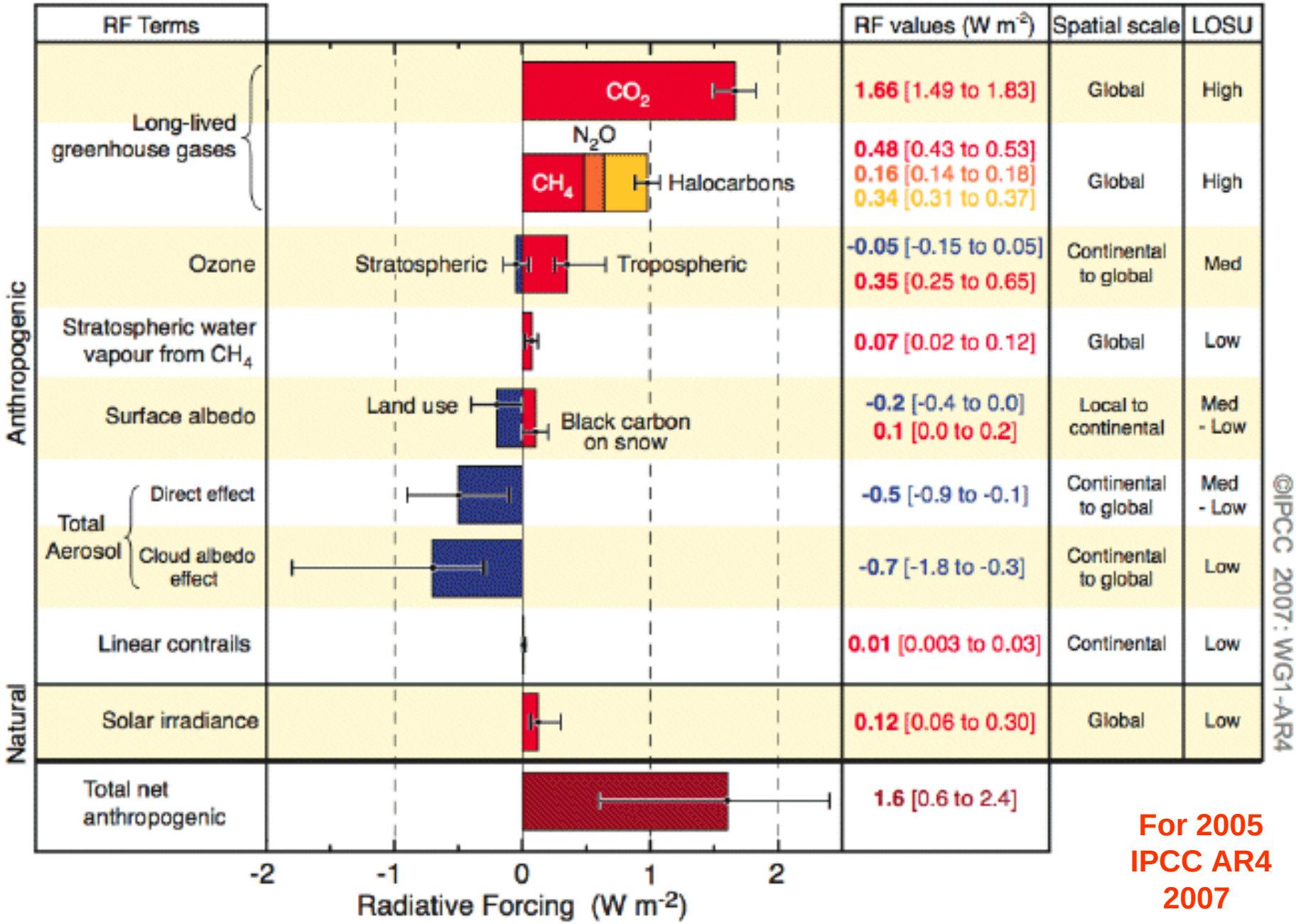
Aerosols Suppressing Precipitation in the Central Sierra: Results of the 2006 Winter Field Campaign

!4 Sep 2006. California Climate Change Research Conference.

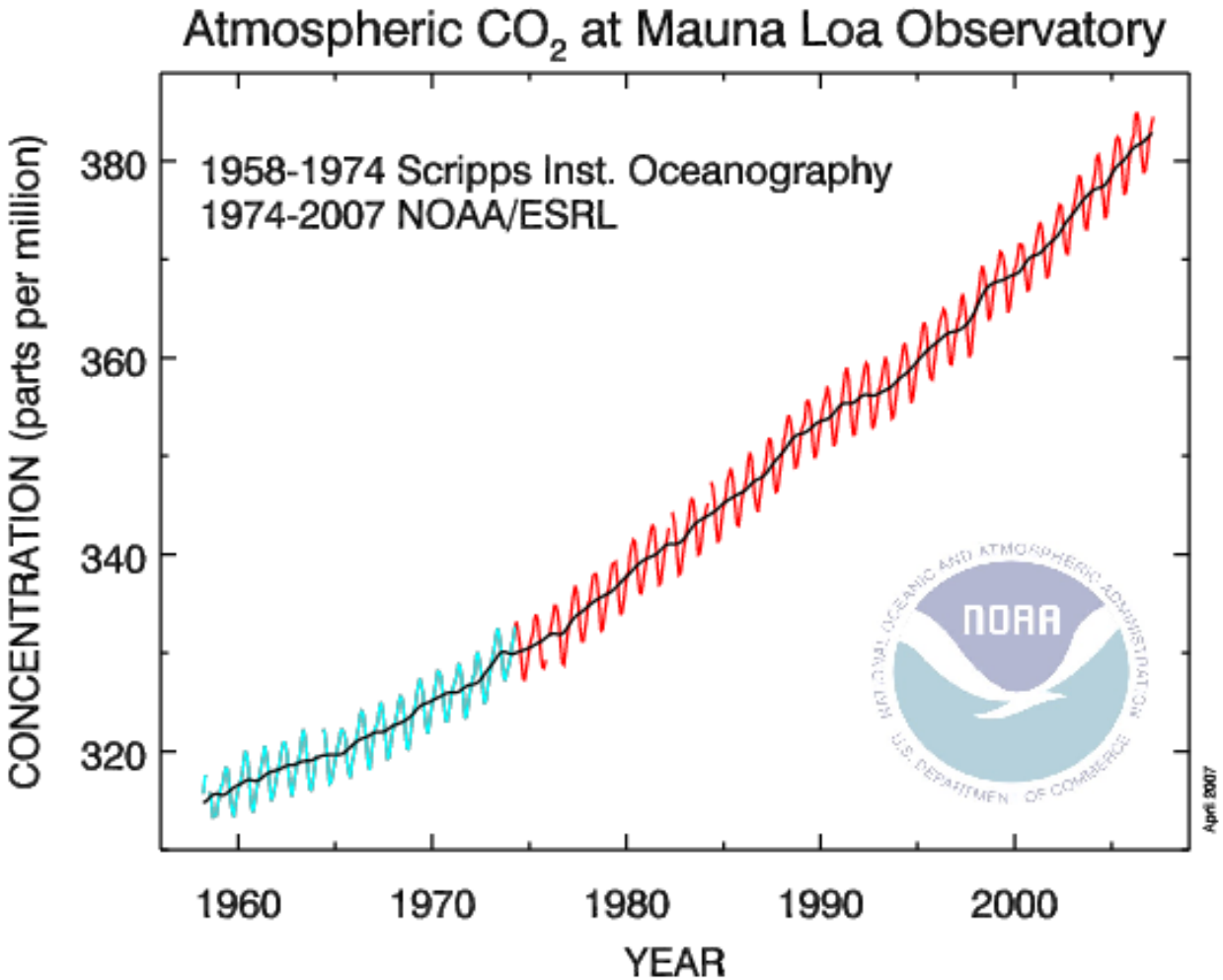
Suppression of Rain and Snow by Industrial and Urban Air Pollution. Science, 2000, March 10, 287, 1793-1796.


Ship trails 20030630

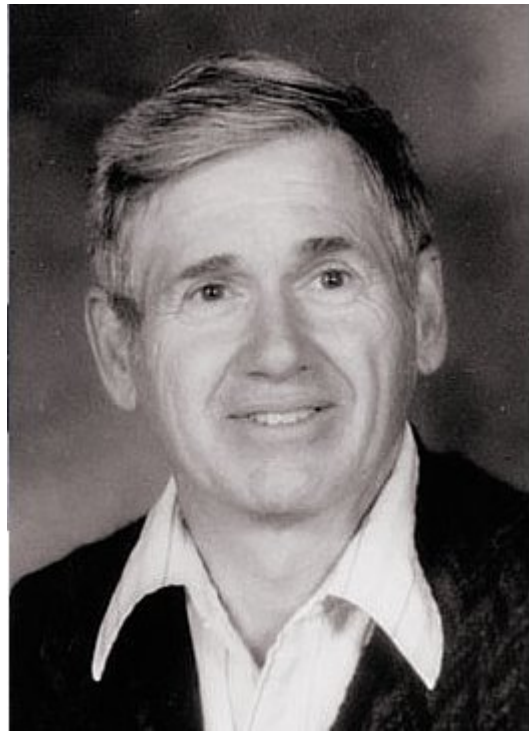
Global Radiative Forcing Components



For 2005
IPCC AR4
2007



Dave Keeling, Scripps

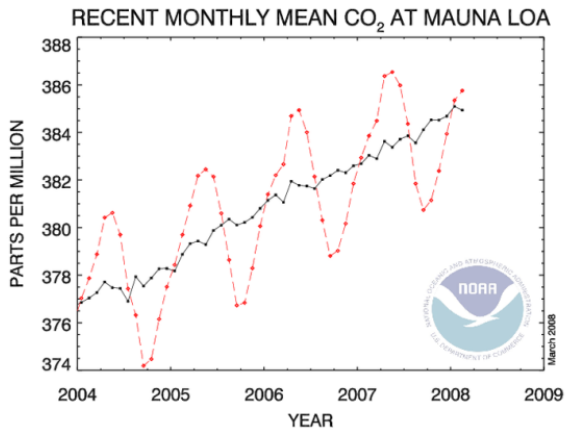


1928 April 20 - 2005 June 20

1959: 316 ppmv

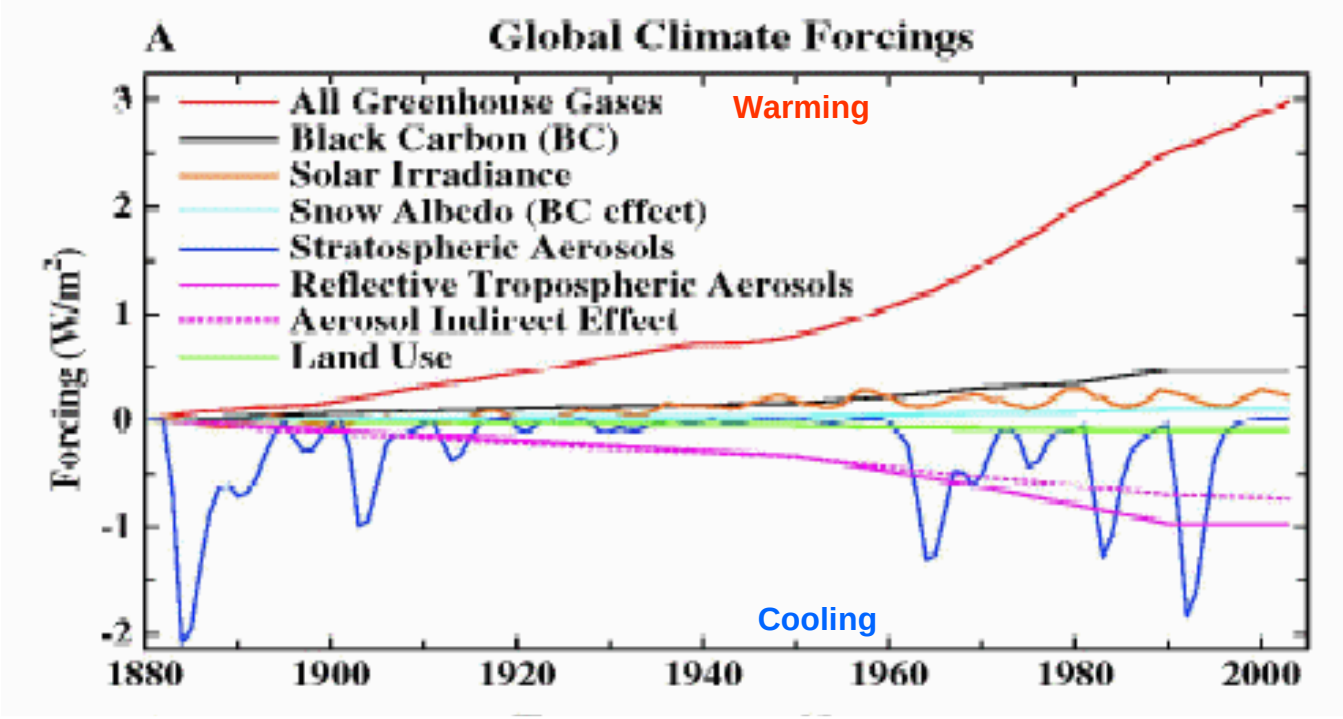
+21.8 %

385
Feb 2008



History of Atmospheric Forcings

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



Projections for Utah

6 climate models
3 emissions scenarios

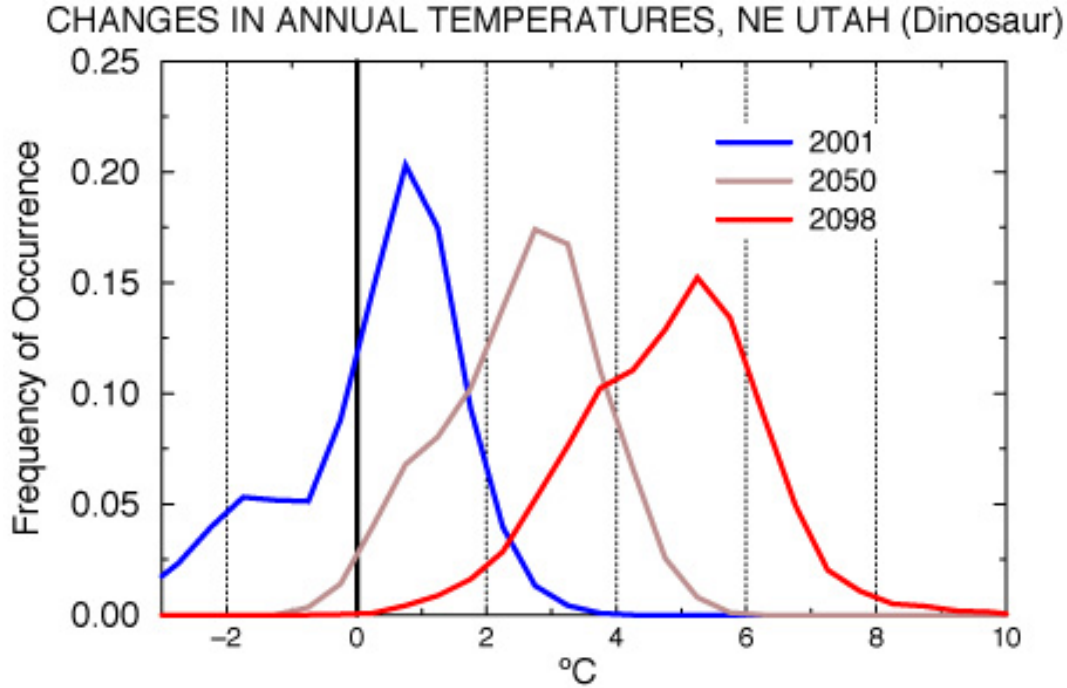
Projections for interior West not very different from those for California

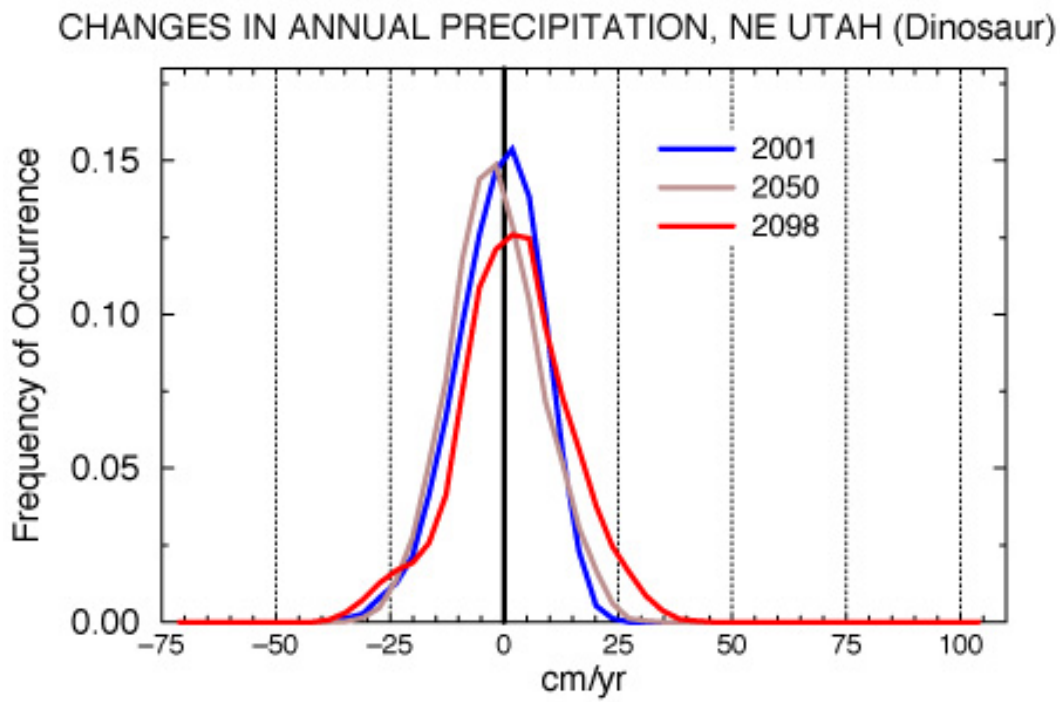
Warming
- **2001: +1 C**
- **2050: +3 C**
- **2098: +5 C**

Strong indication of no precipitation change

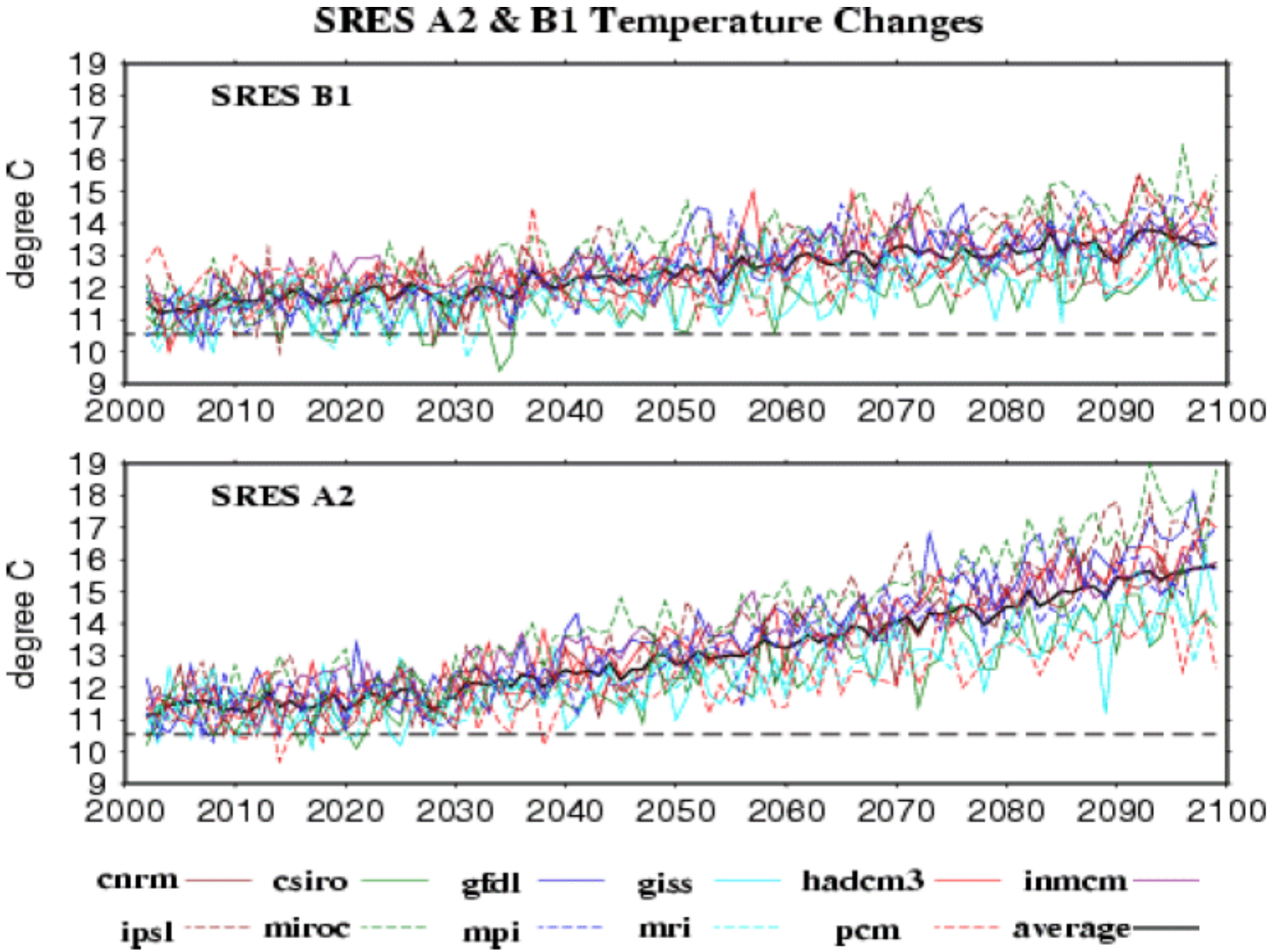
Resampling used.

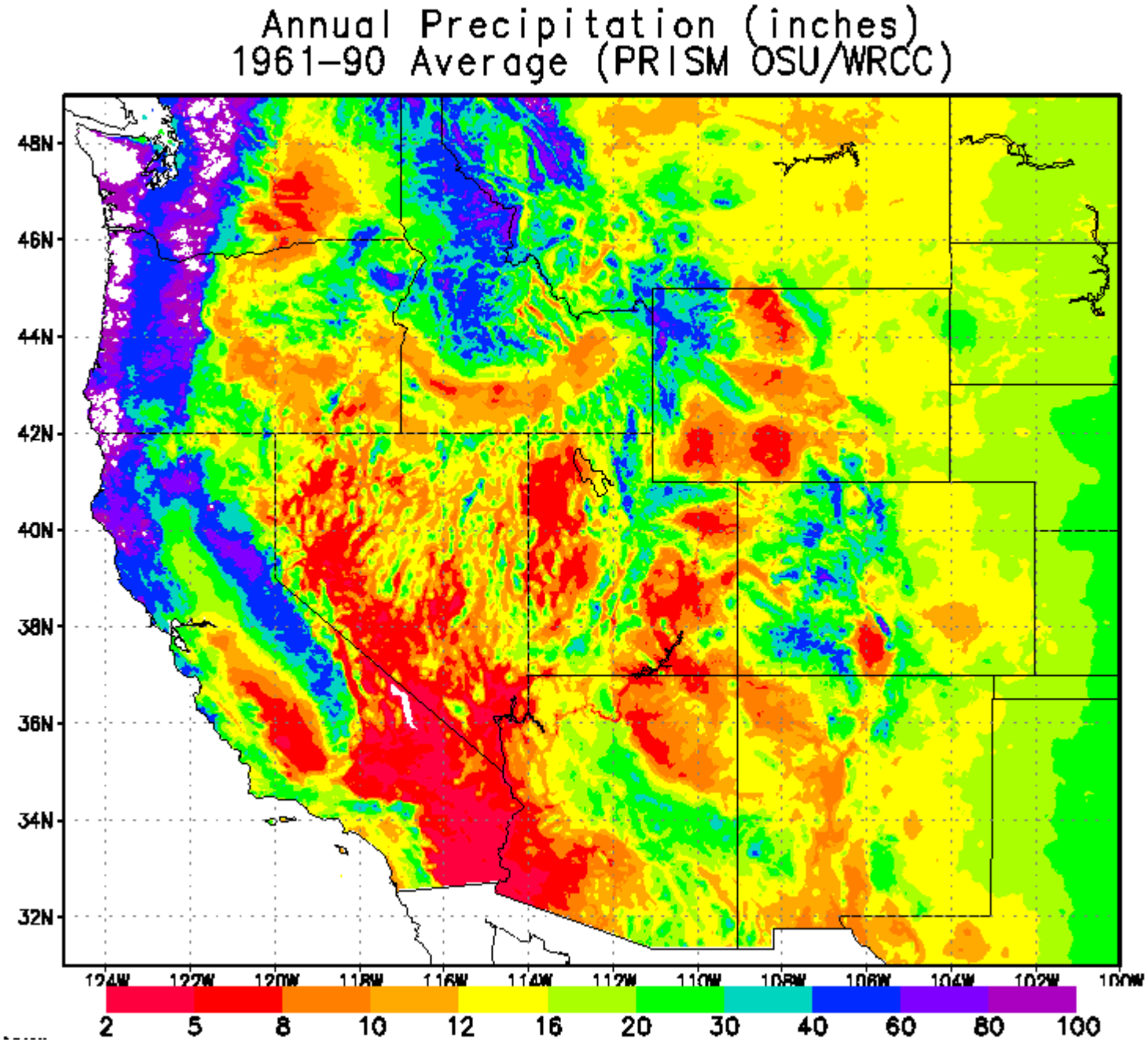
Thanks to
Mike Dettinger
USGS / Scripps



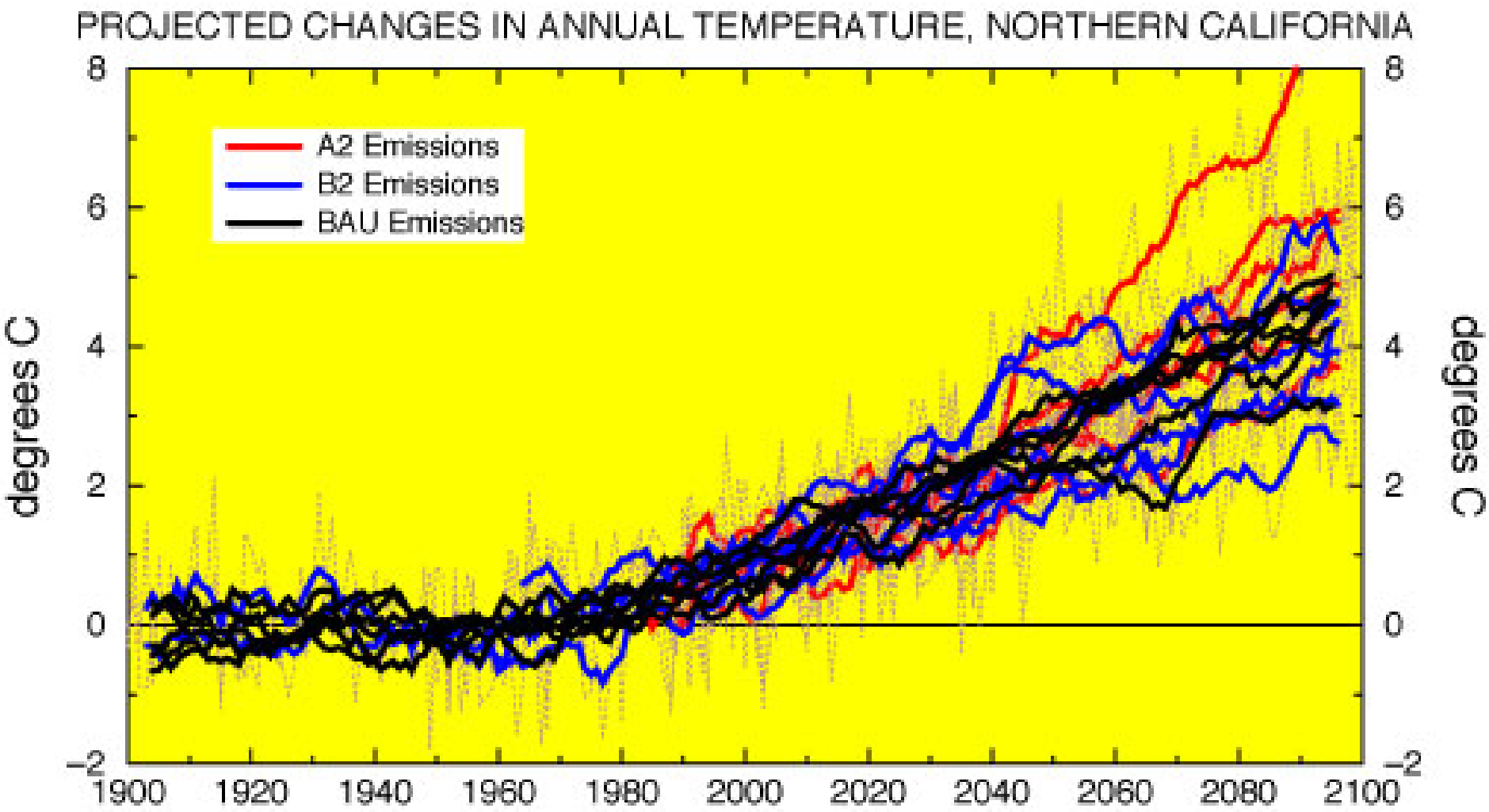


11 Models, 2 CO2 Scenarios, Colorado River Basin (from Christensen and Lettenmaier, 2007)

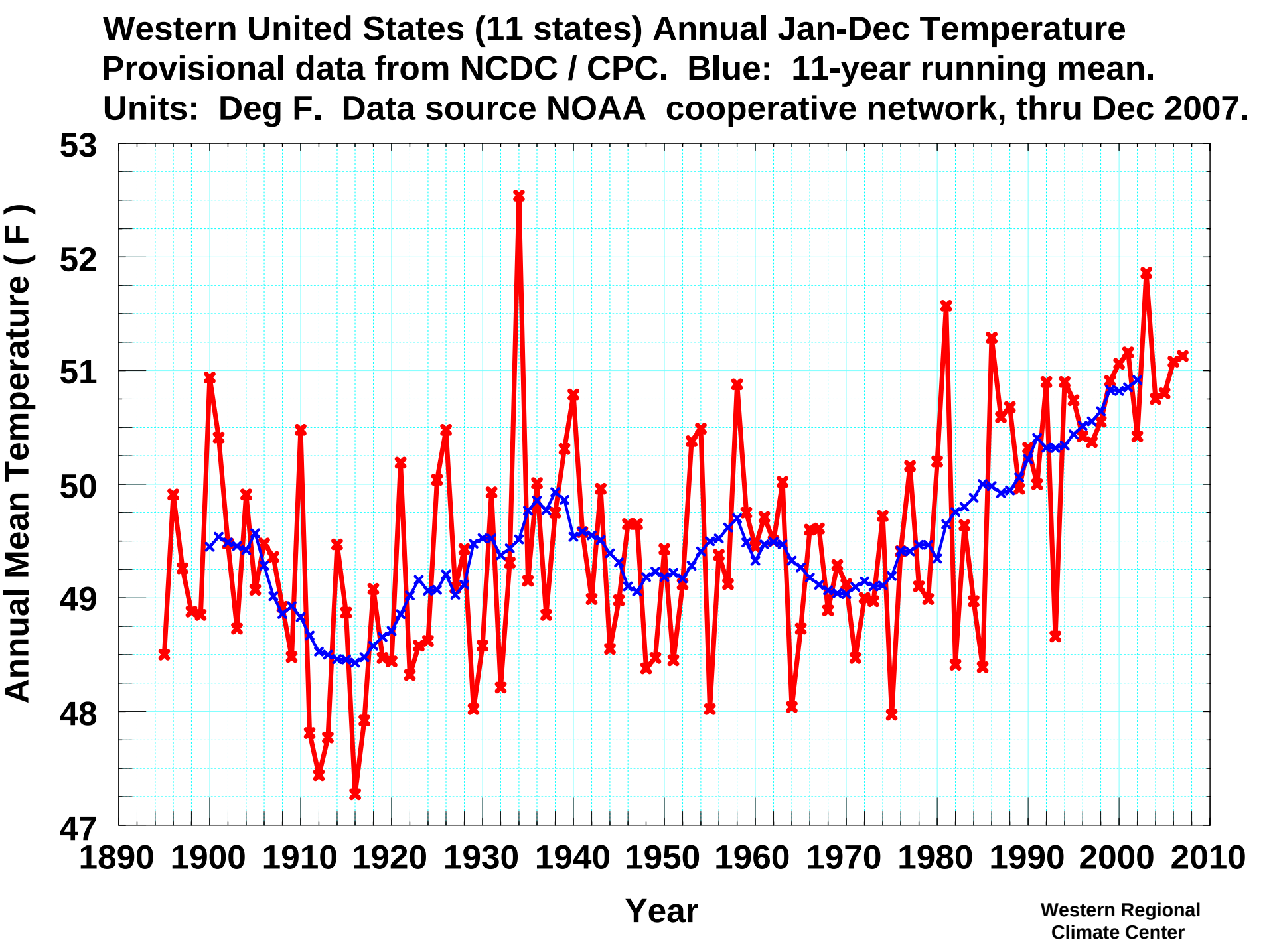



Annual Precipitation (inches)
1961–90 Average (PRISM OSU/WRCC)
48N
46N
44N
42N
40N
38N
36N
34N
32N
124W
122W
120W
118W
116W
114W
112W
110W
108W
106W
104W
102W
100W
2
5
8
10
12
16
20
30
40
60
80
100

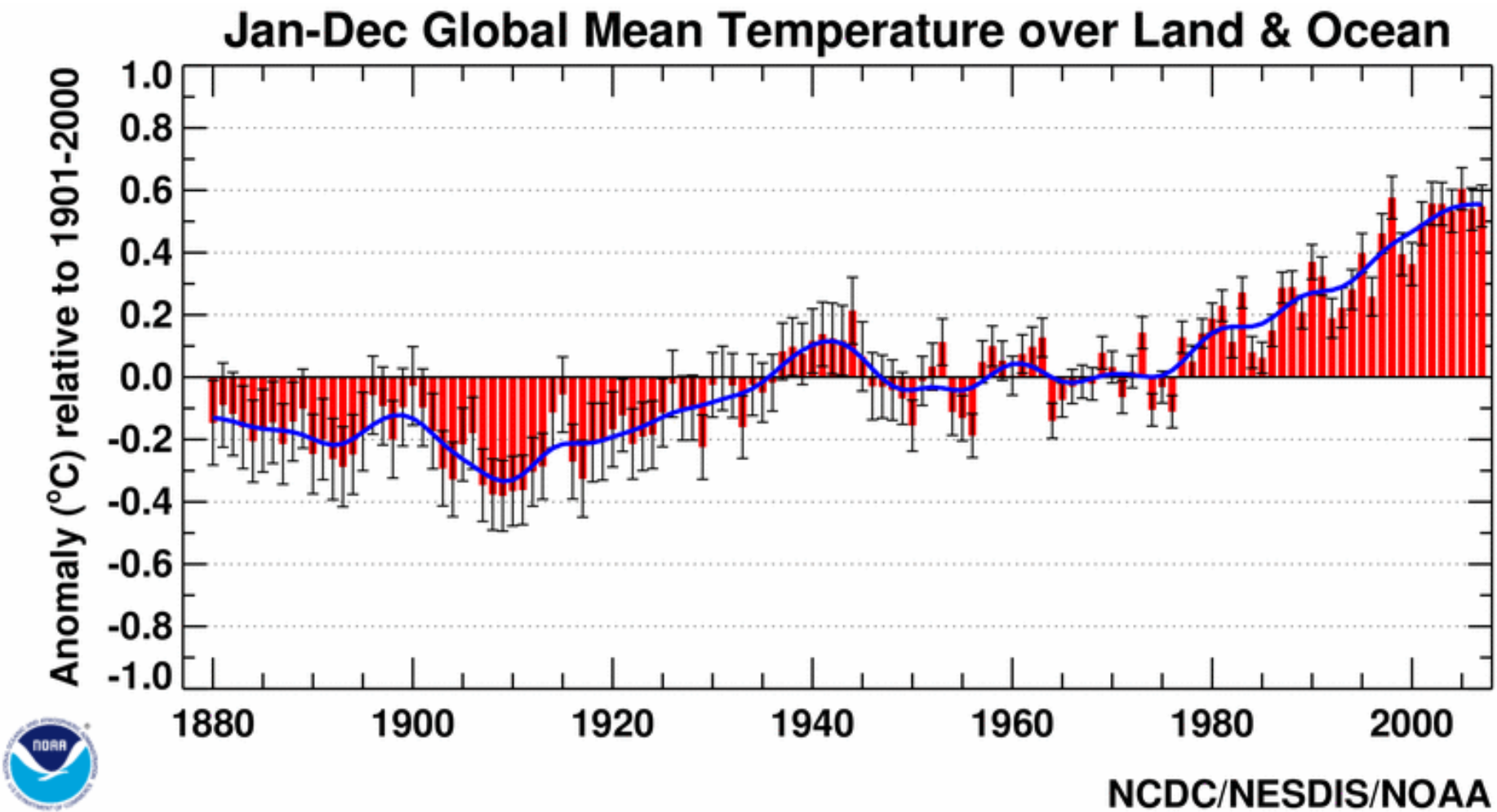
Courtesy of Mike Dettinger, USGS / Scripps.

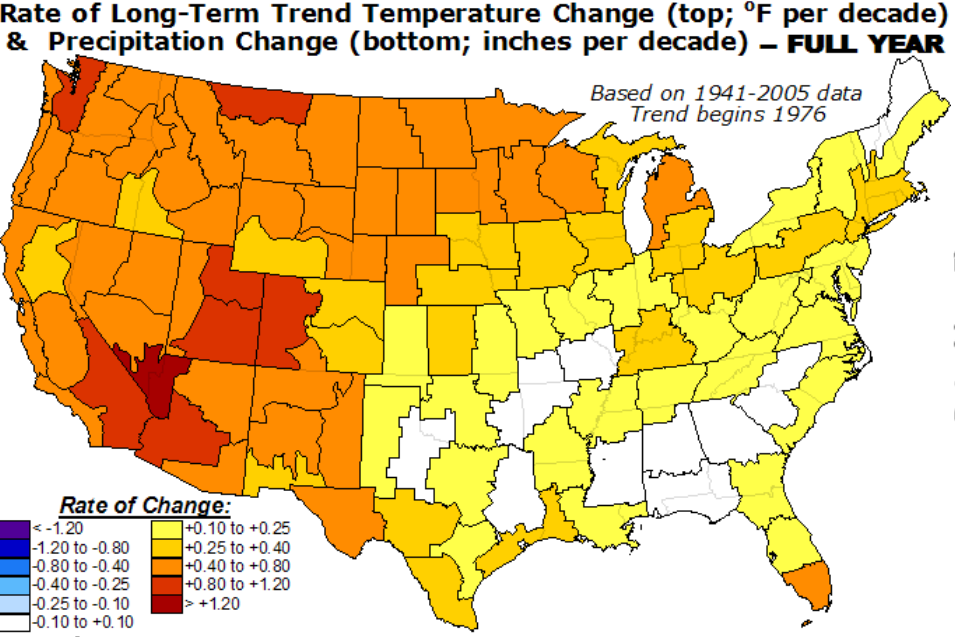


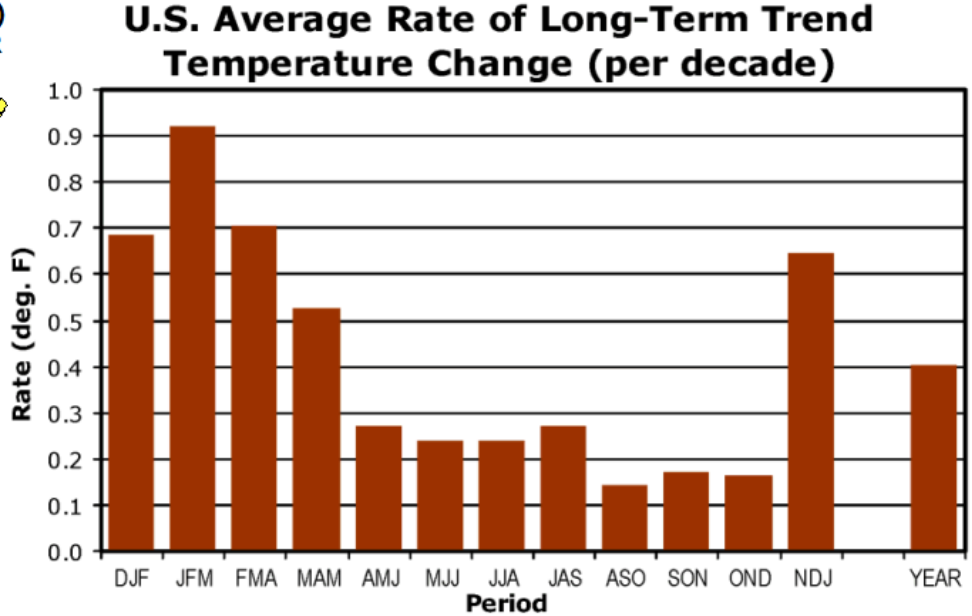
Dettinger MD. 2005. From climate change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science. Vol. 3, Issue 1, (March 2005), Article 4. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4


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 2007.
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

Through 2007







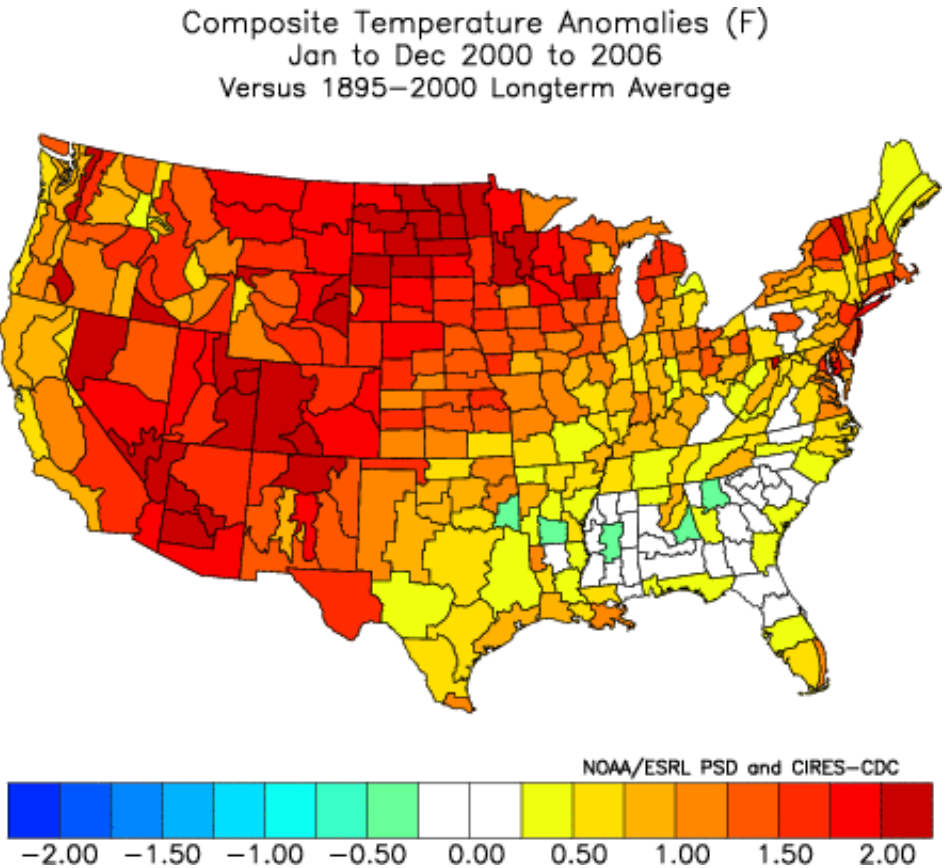
Winter Spring Summer Autumn Annual

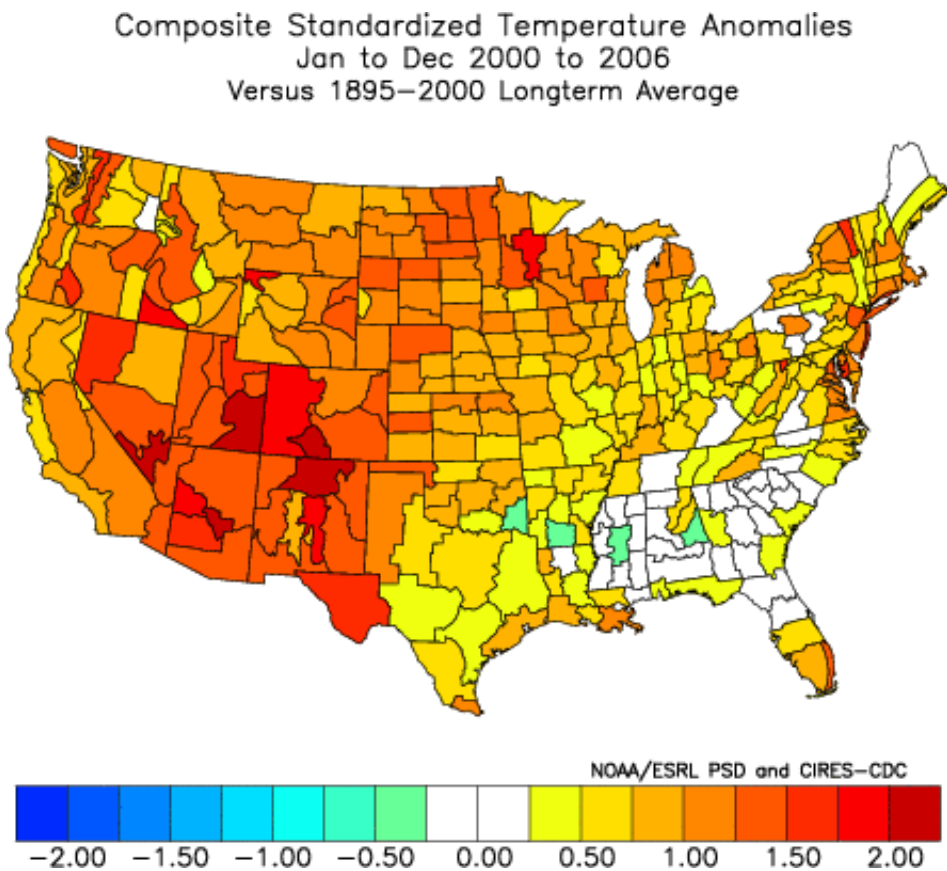
Annual Temperature Trend 1976 - 2005

National Temperature Trend by Season

The Last 30 Years

Annual Mean Temperatures, 2000-2006.
Departures from 1895-2000 Mean.

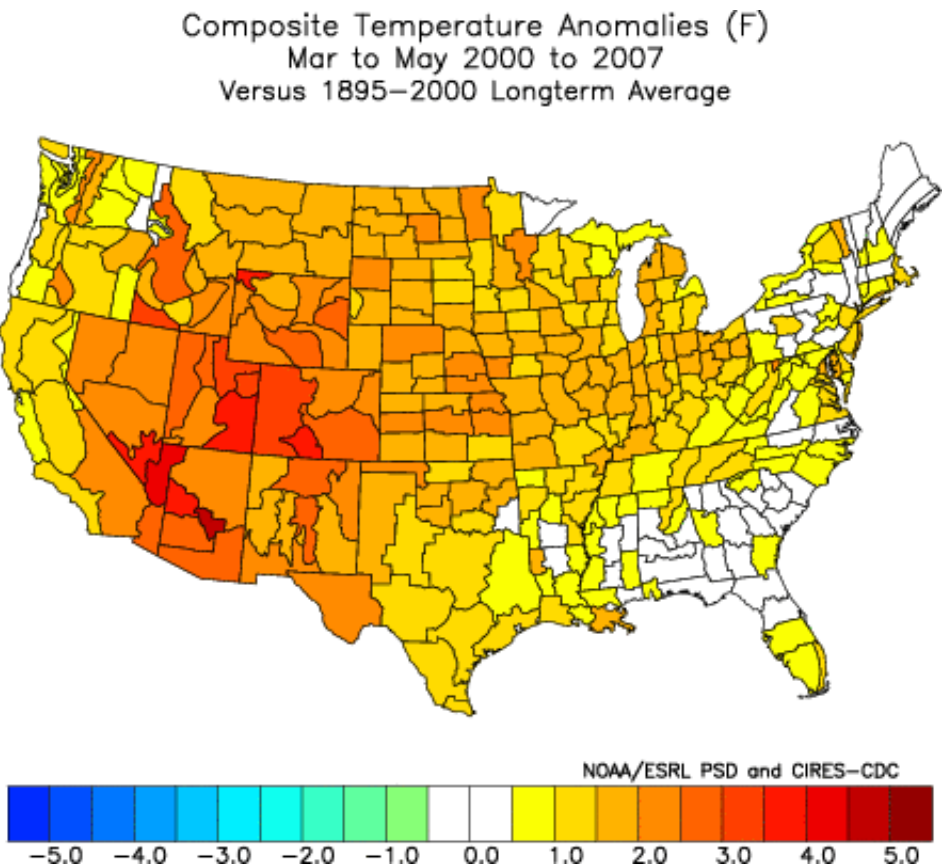


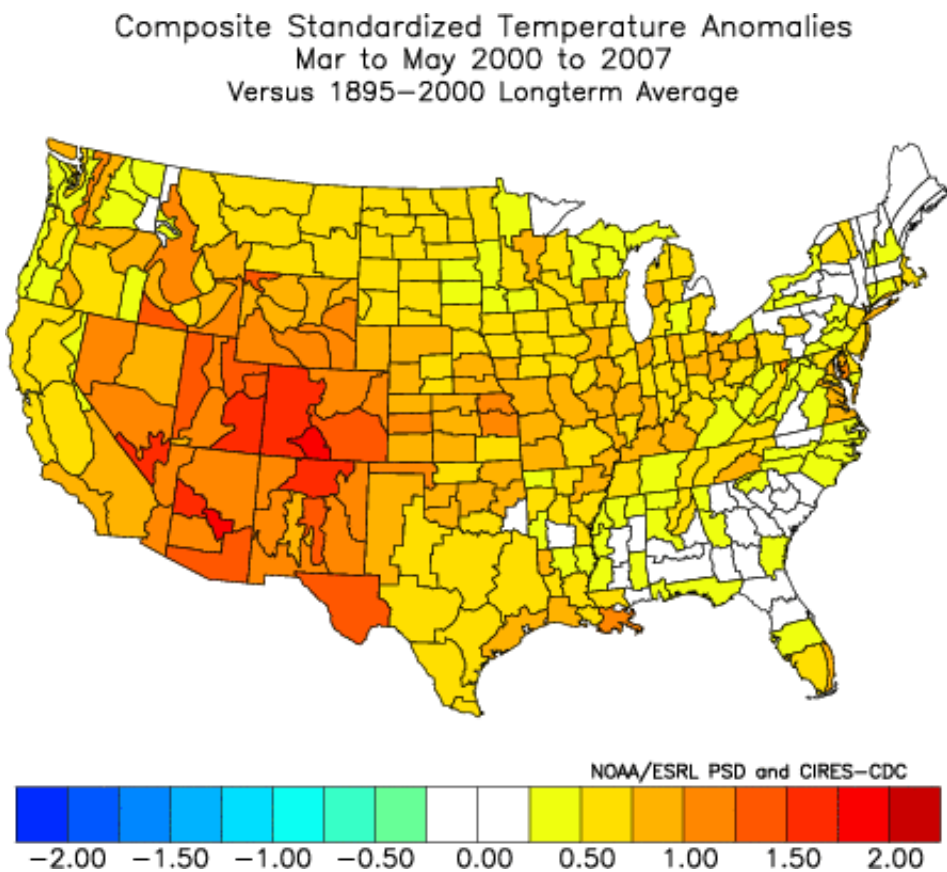


Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

The West dominates recent U.S. warming.

Spring (Mar-Apr-May) Mean Temperatures, 2000-2007. Departures from 1895-2000 Mean.

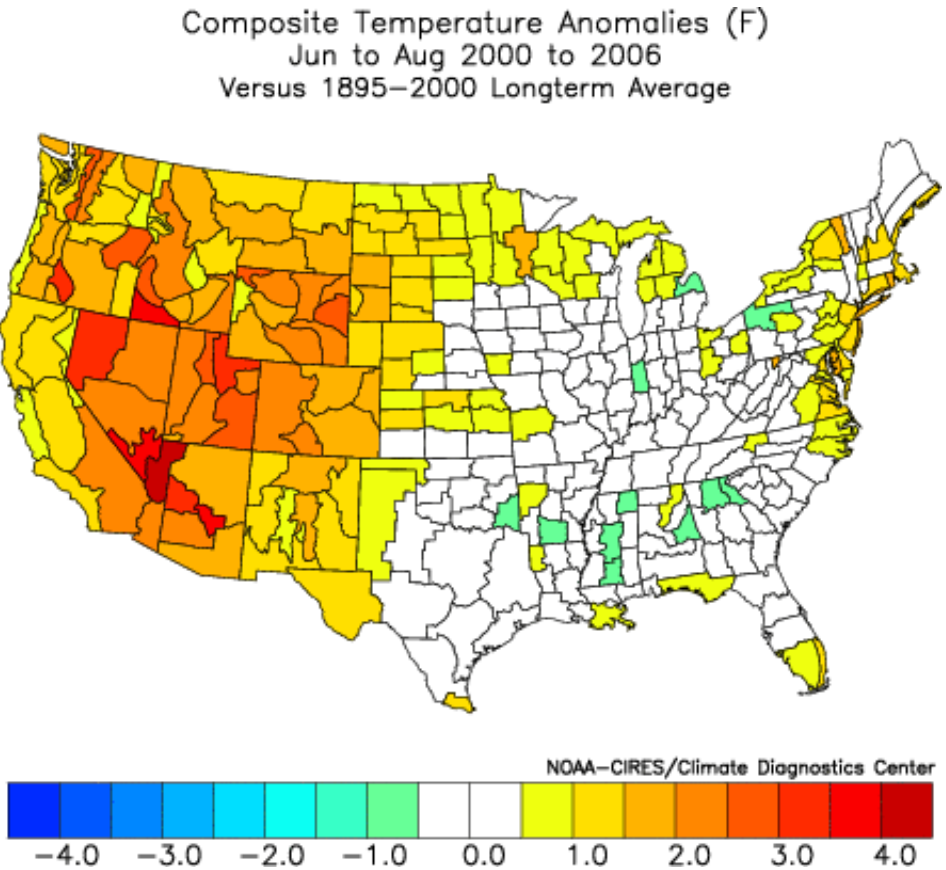


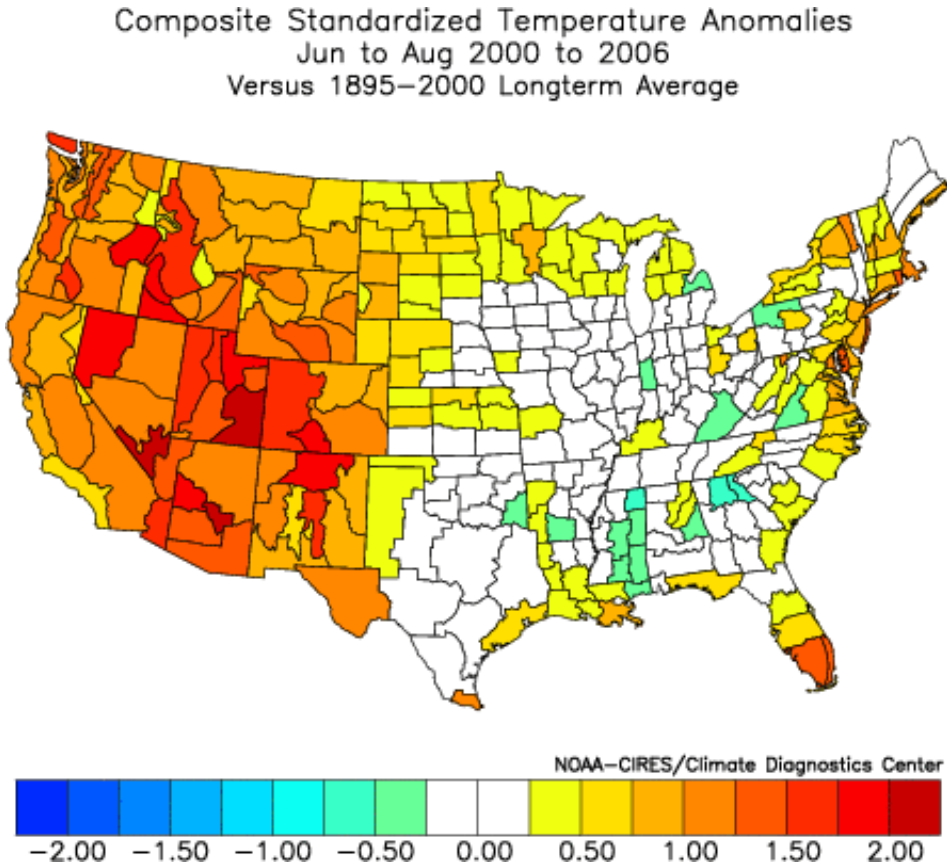


Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

The West dominates recent U.S. warming.

Summer (Jun-Jul-Aug) Mean Temperatures, 2000-2006. Departures from 1895-2000 Mean.

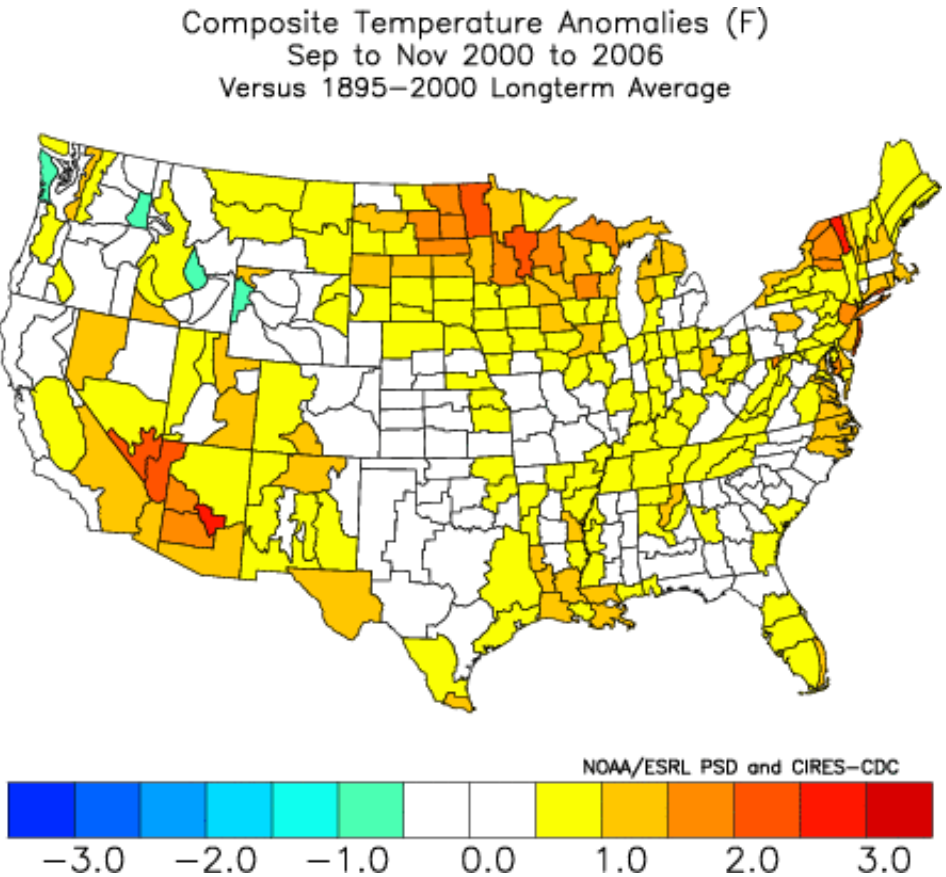


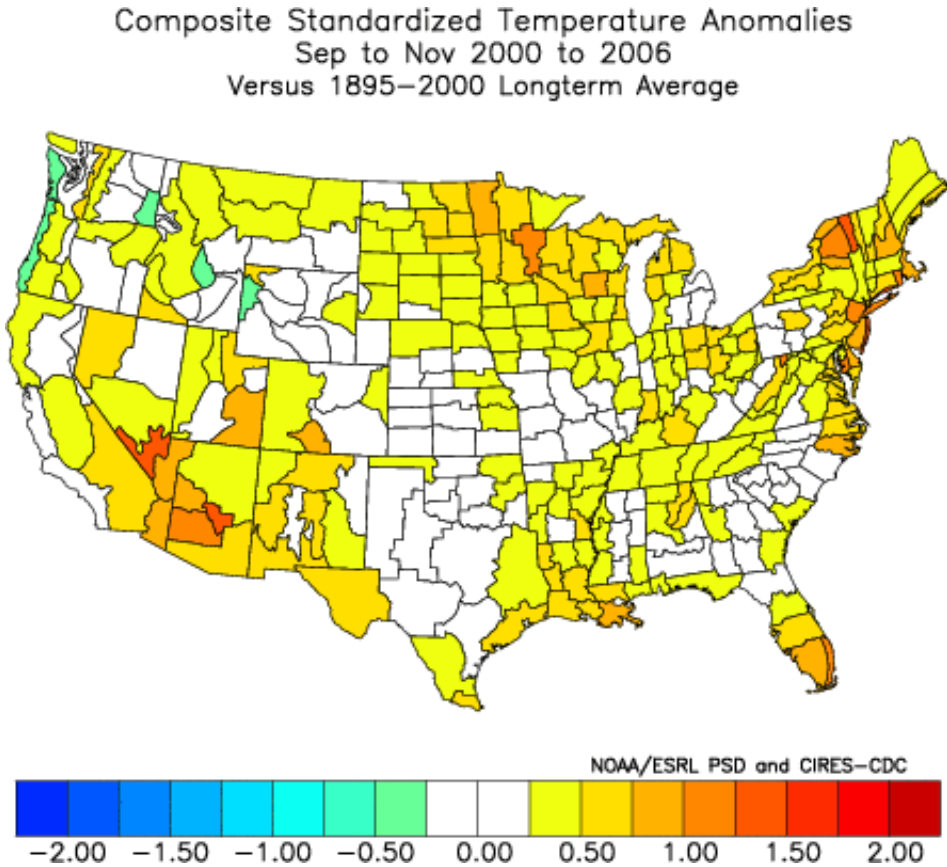


Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

The West dominates recent U.S. warming.

Autumn (Sep-Oct-Nov) Mean Temperatures, 2000-2006. Departures from 1895-2000 Mean.

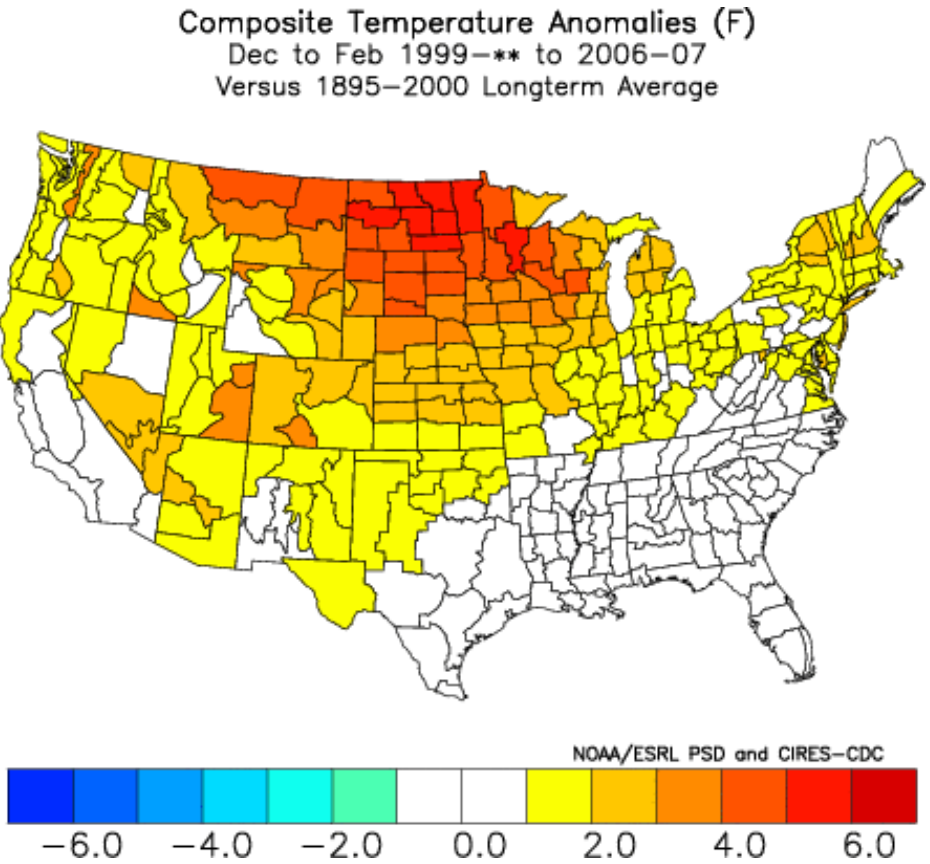


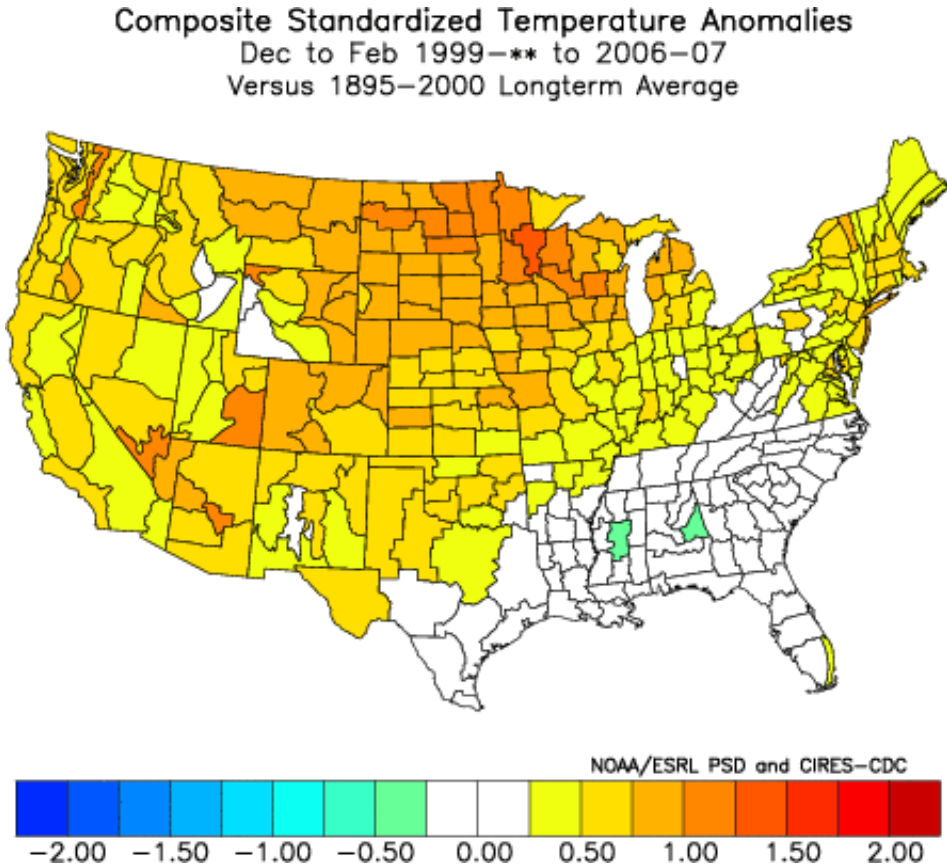


Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

No particular pattern, scattered mild warming.

Winter (Dec-Jan-Feb) Mean Temperatures, 1999/2000-2006/2007. Departures from 1895-2000 Mean.

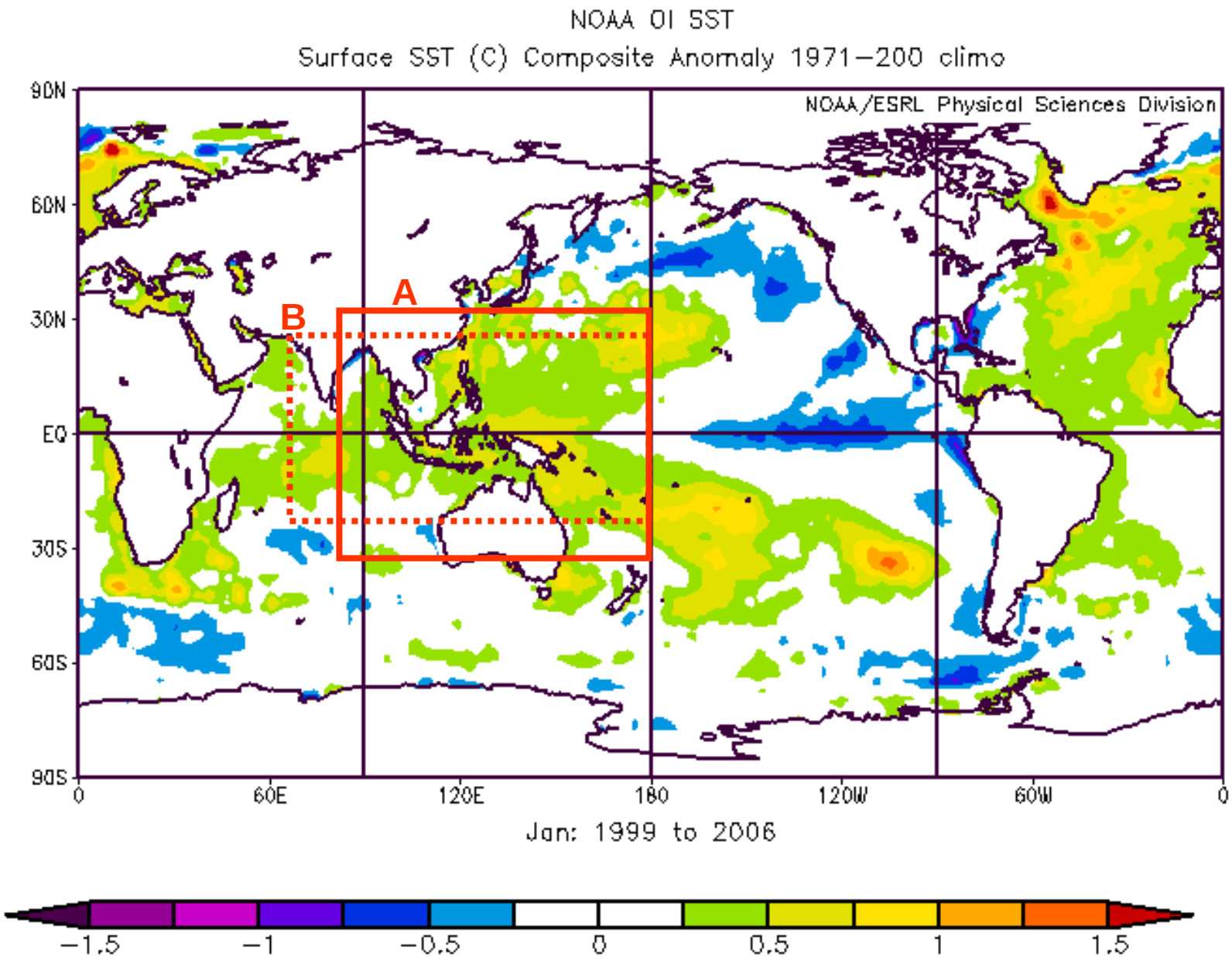


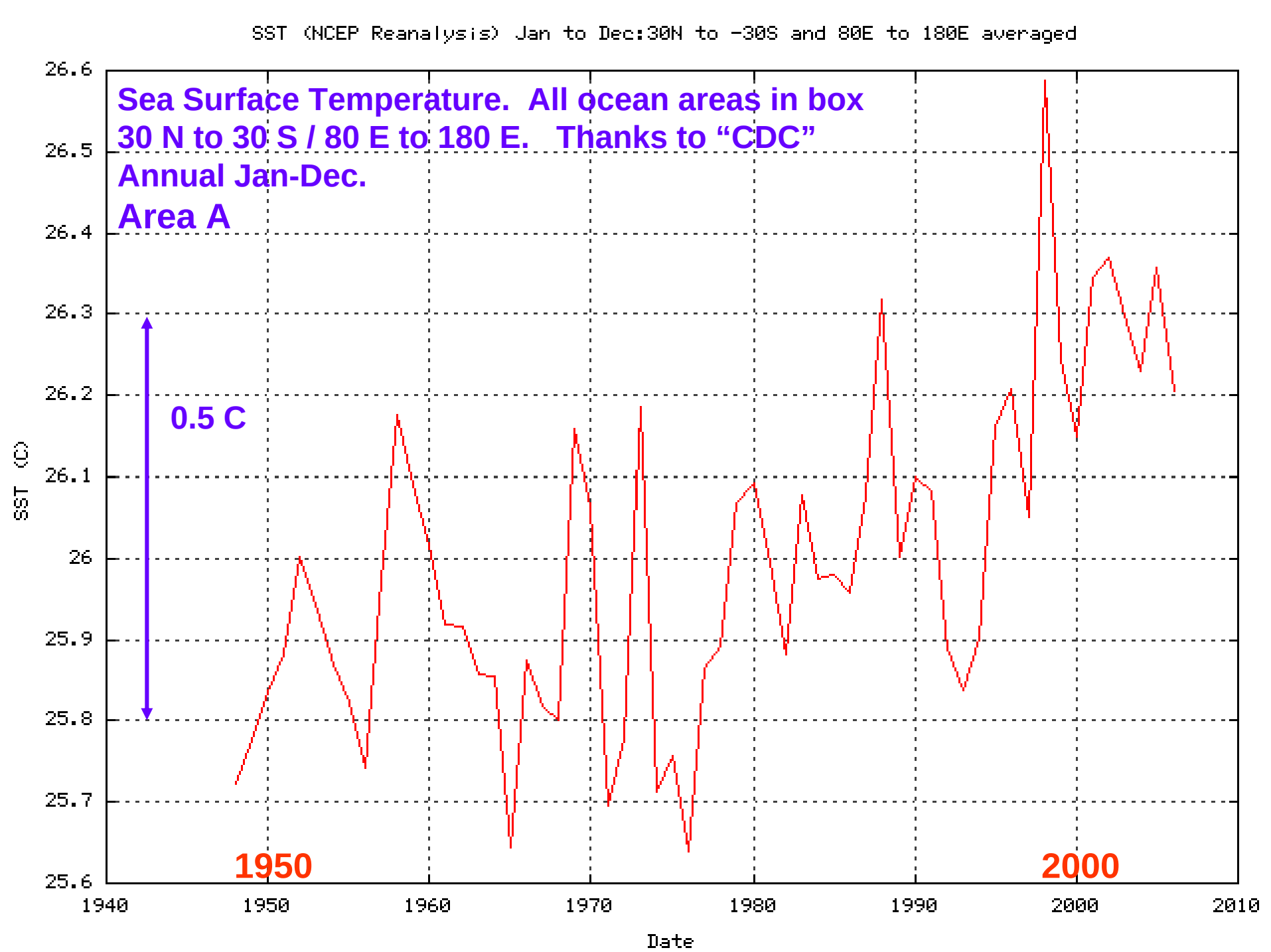


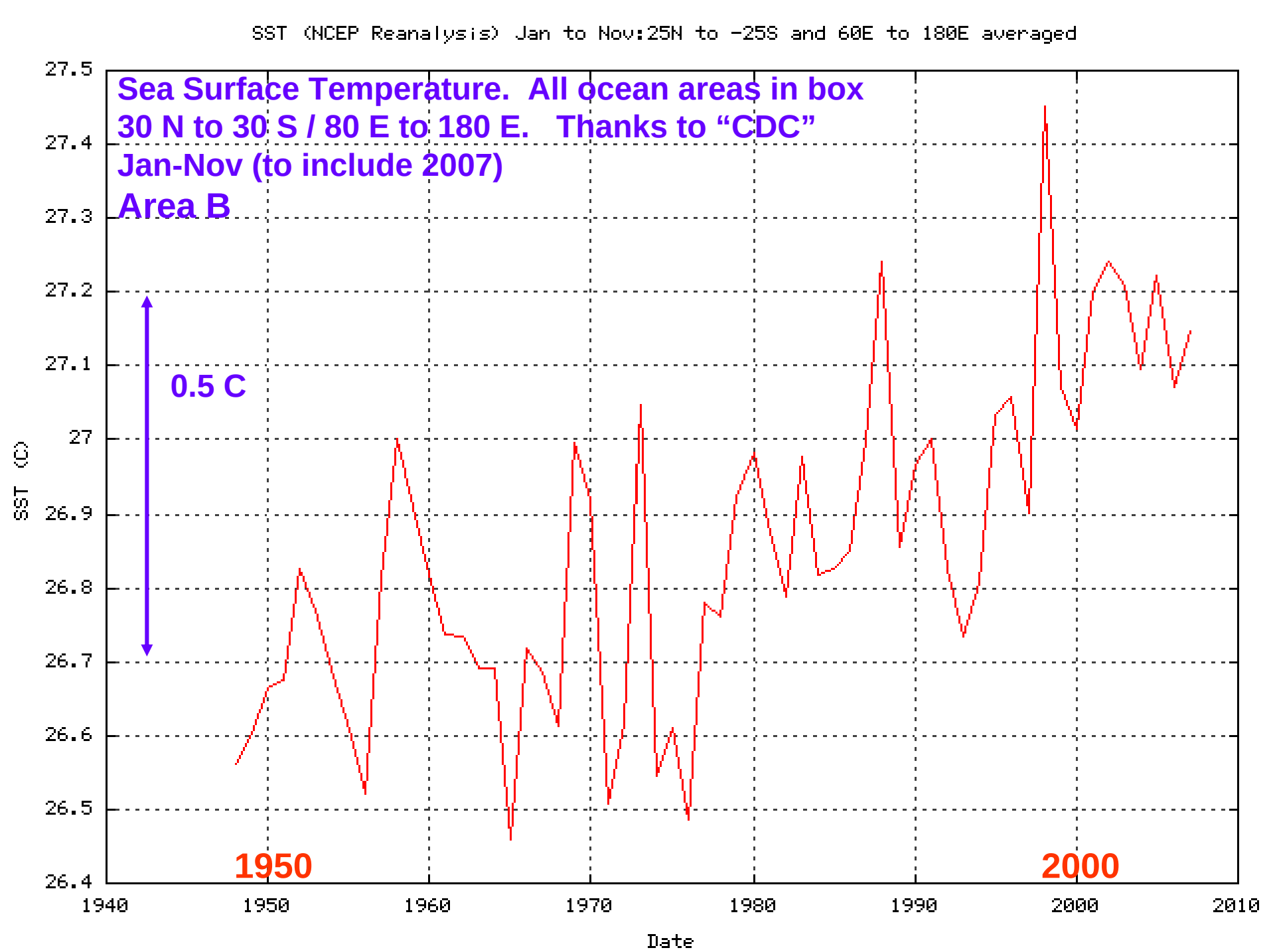
Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

The West and North dominate recent U.S. warming.

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



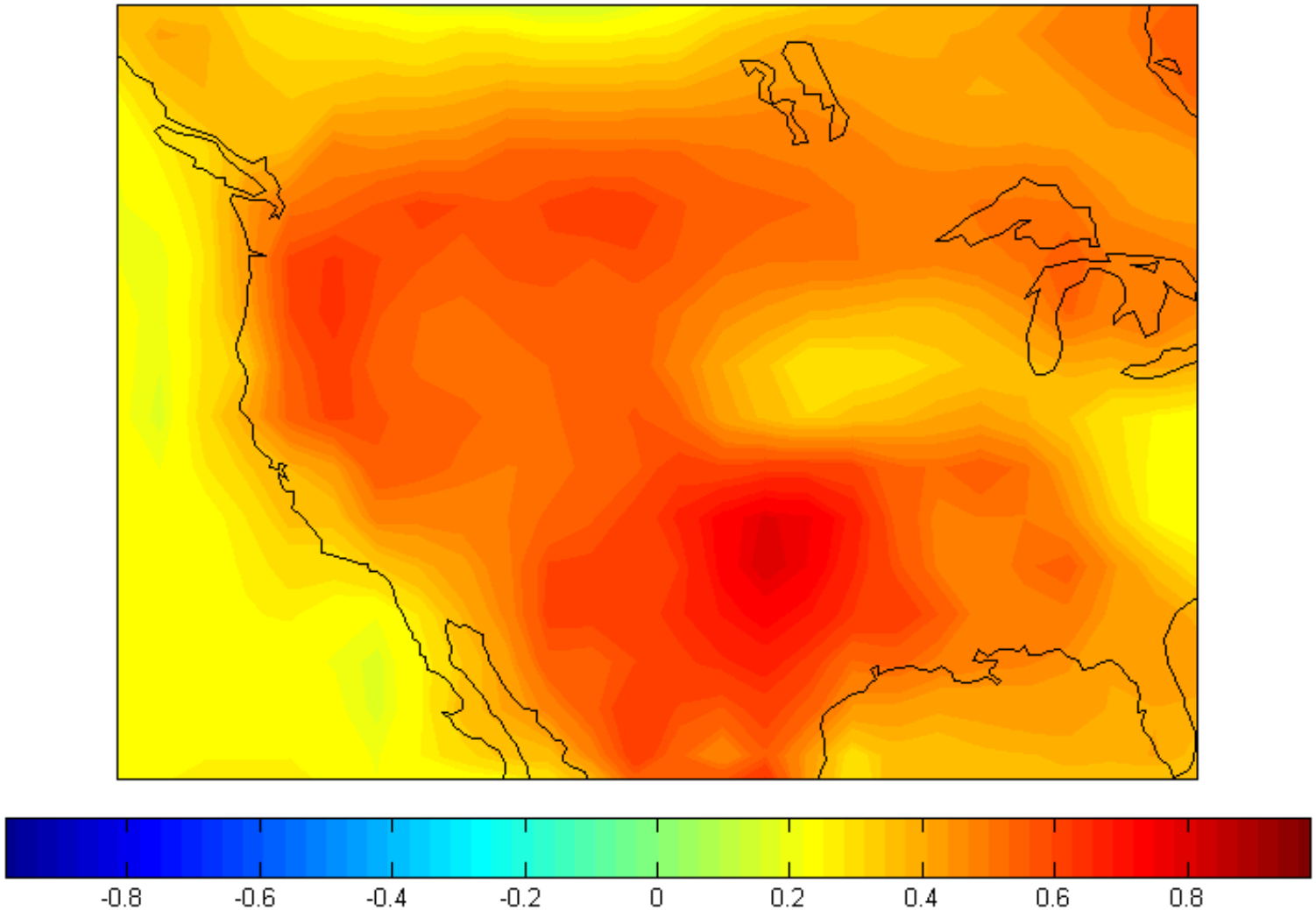

SST (NCEP Reanalysis) Jan to Dec:30N to -30S and 80E to 180E averaged
Sea Surface Temperature. All ocean areas in box
30 N to 30 S / 80 E to 180 E. Thanks to "CDC"
Annual Jan-Dec.
Area A
0.5 C
1950
2000
SST (C)
Date
26.6
26.5
26.4
26.3
26.2
26.1
26
25.9
25.8
25.7
25.6
1940
1950
1960
1970
1980
1990
2000
2010


SST (NCEP Reanalysis) Jan to Nov:25N to -25S and 60E to 180E averaged
Sea Surface Temperature. All ocean areas in box
30 N to 30 S / 80 E to 180 E. Thanks to "CDC"
Jan-Nov (to include 2007)
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

9 models x 3 scenarios = 27 “opinions”

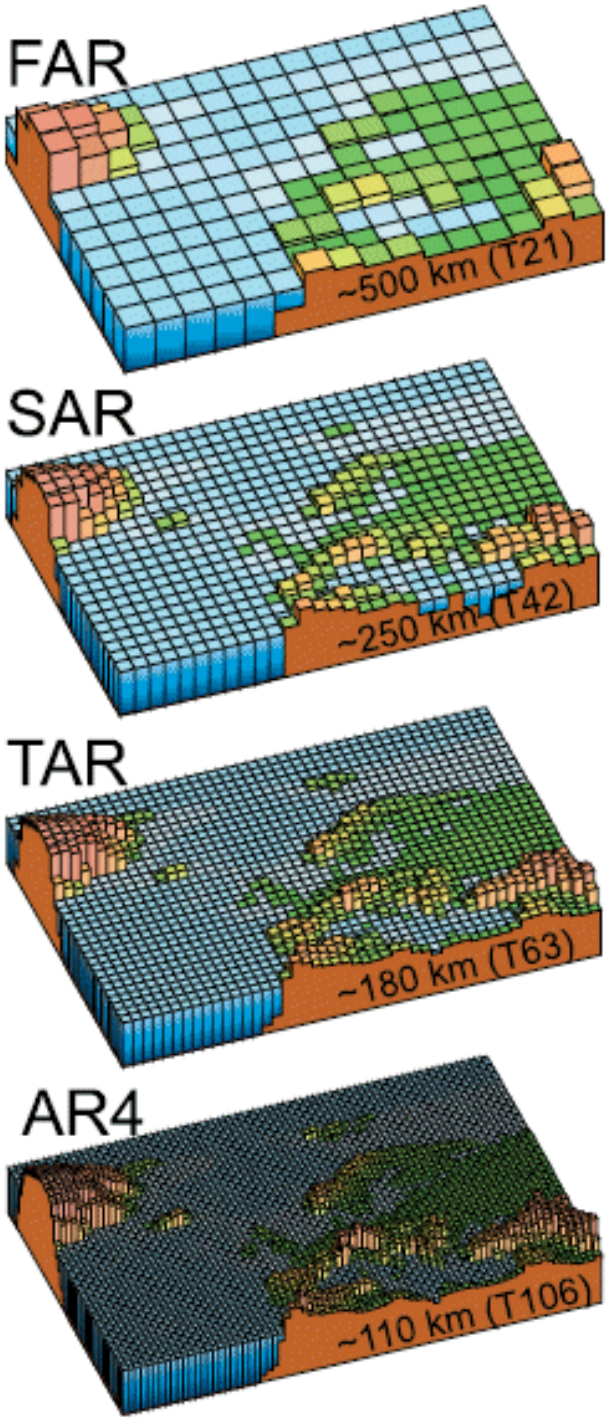
Anomaly expectations for recent years. Summer.

MultiModel Ensemble JJA Temperature difference 2000-2007 minus 1971-2000



Degrees C

Thanks to John Abatzoglou



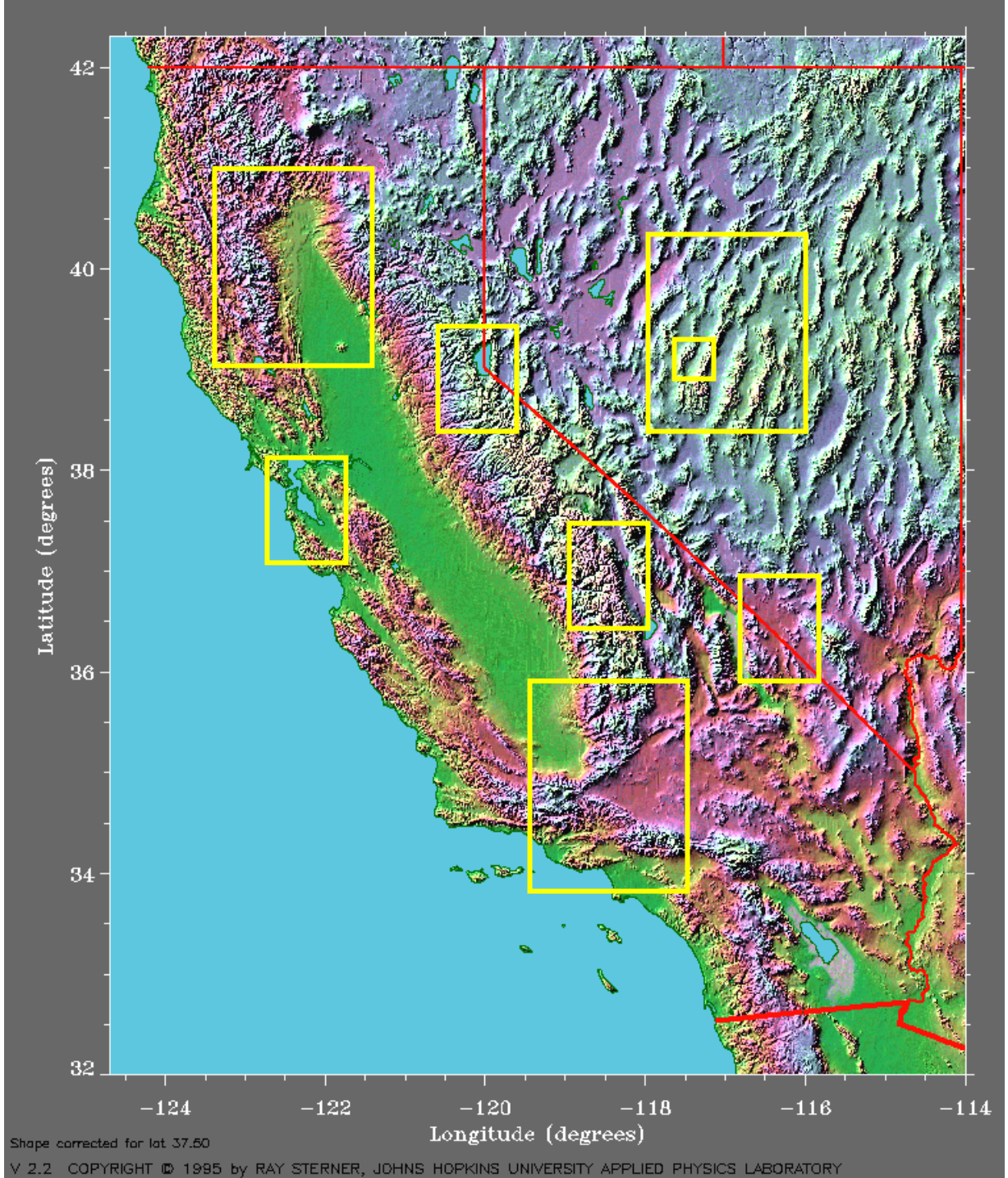
Model Resolution
IPCC Reports
(Intergovernmental Panel on Climate Change)

First Assessment Report

Second Assessment Report

Third Assessment Report

Fourth Assessment Report



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

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

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

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;

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

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.

Address:
WRCC
2215 Raggio Parkway
Reno, NV 89512
(775) 674-7010 - phone
(775) 674-7016 - fax

wrcc@dri.edu

Disclaimer
Site Map

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

ACIS - Applied Climate Information System

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

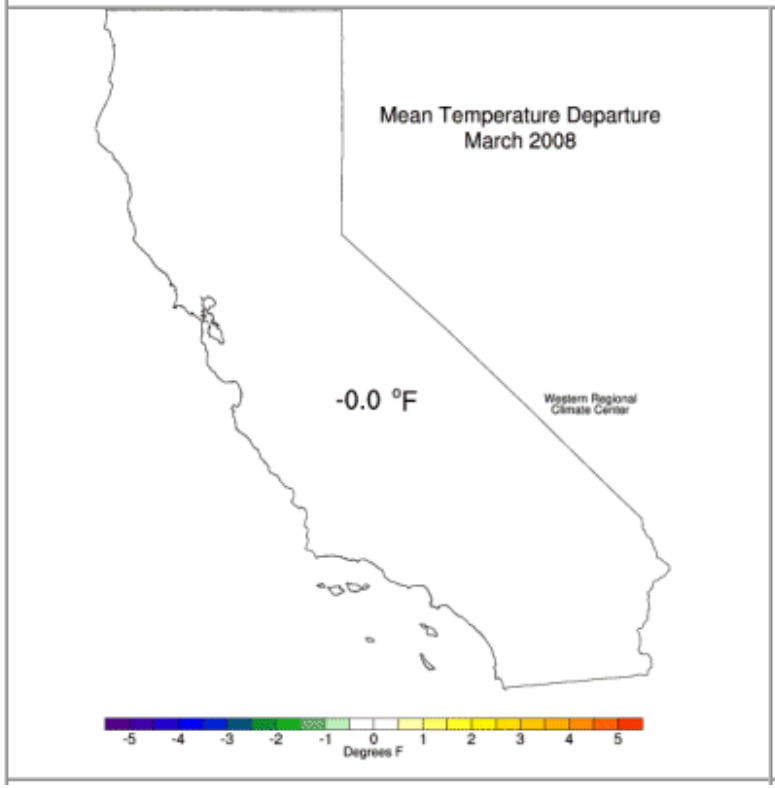
WxCoder
Data entry system for NWS COOP Observers.

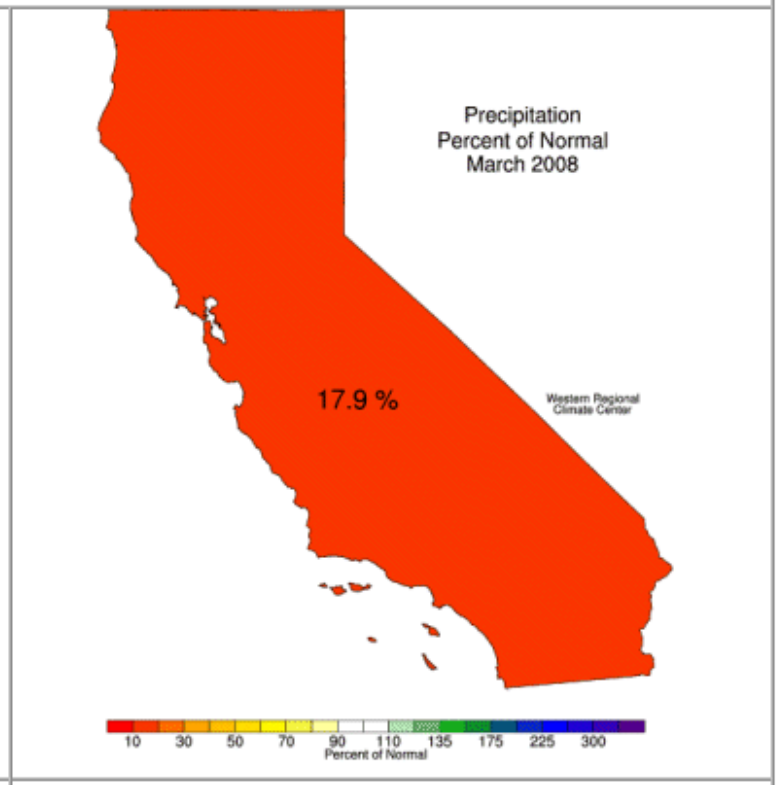
California Climate Tracker

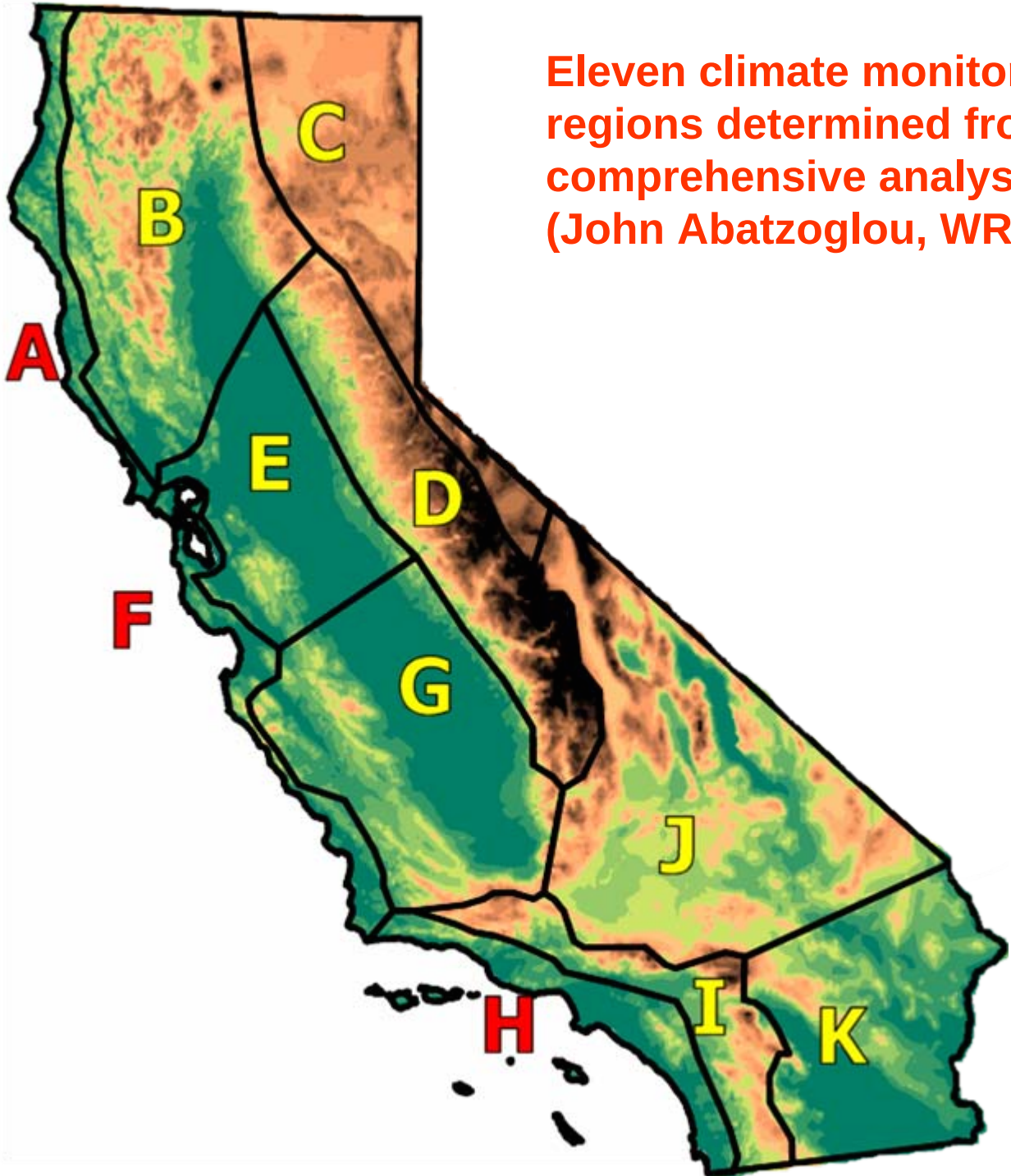
Tracking Climate Variability and Change for the State

Climate Products Frames Version

MARCH 2008



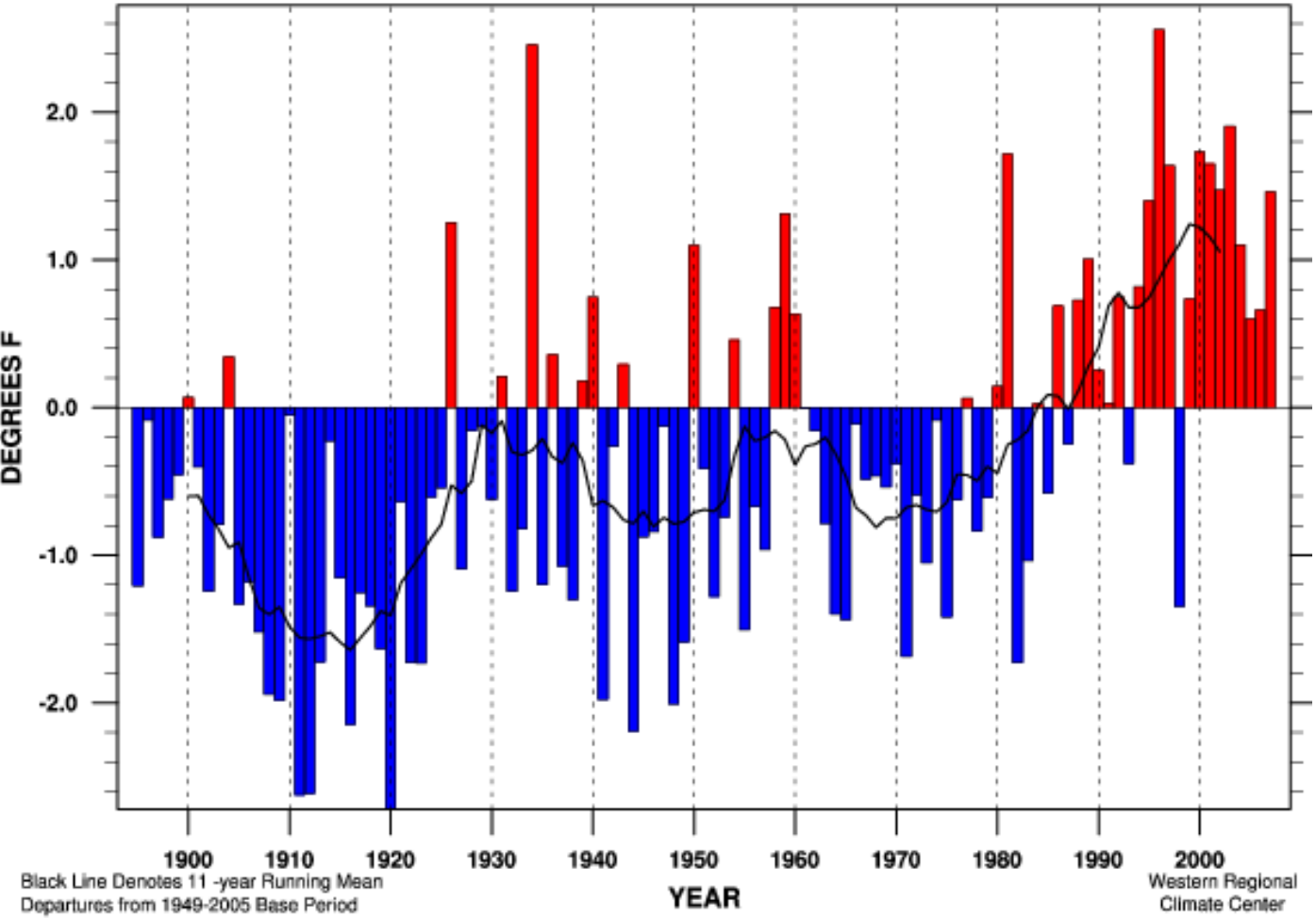




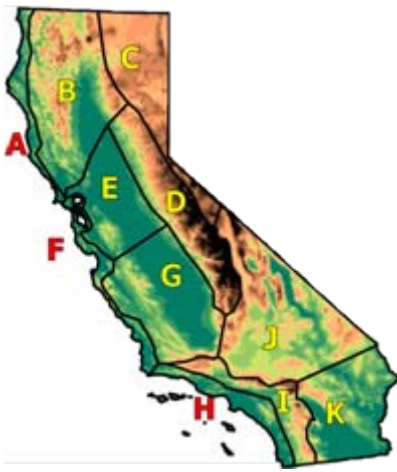
Eleven climate monitoring regions determined from a comprehensive analysis. (John Abatzoglou, WRCC)

Mohave Desert Region

Mean Temperature Departure Jan-Dec

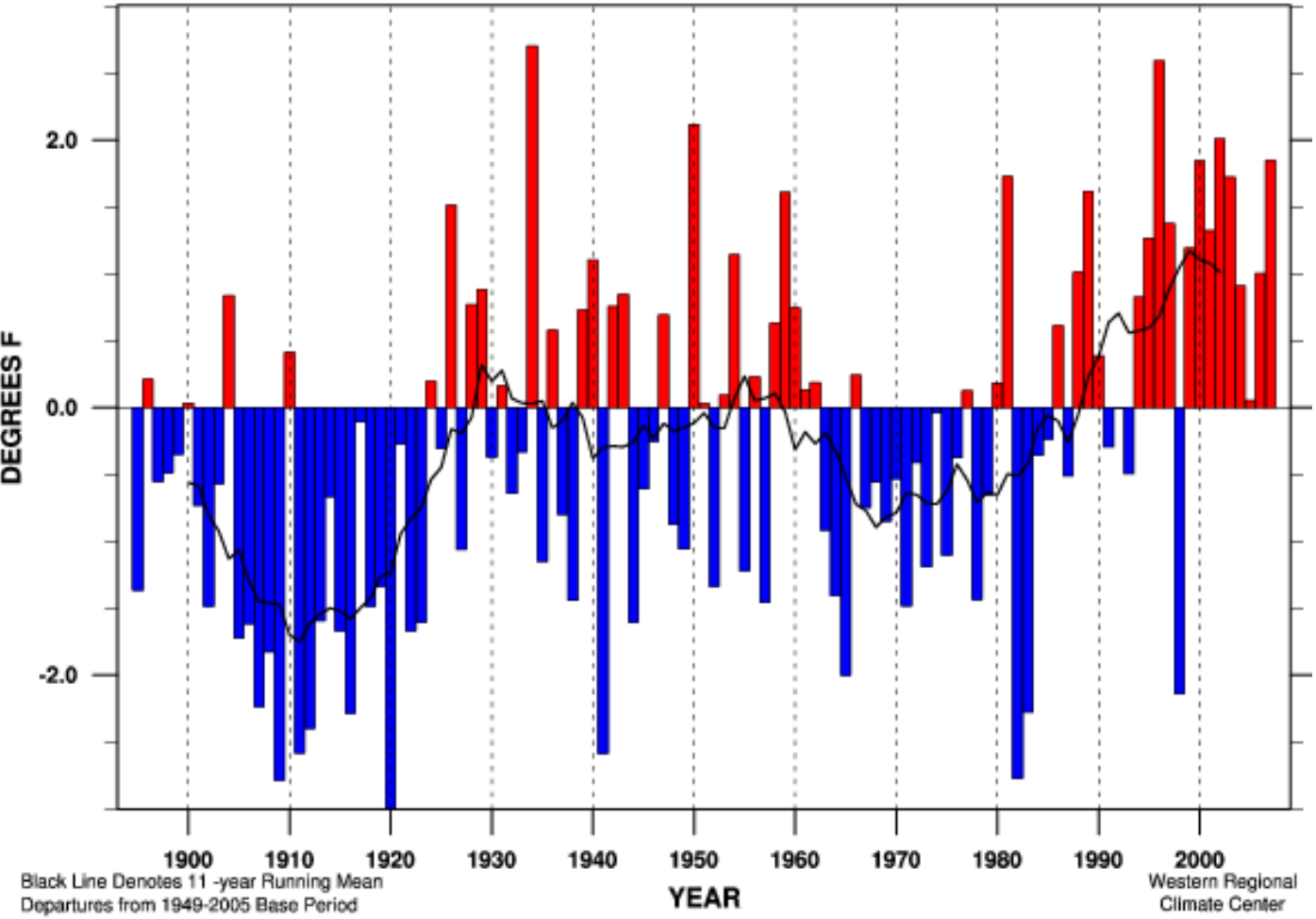


Linear Trend 1895-present		+ 1.76 ± 0.55 °F/100yr	
Linear Trend 1949-present		+ 3.33 ± 1.38 °F/100yr	
Linear Trend 1975-present		+ 6.85 ± 3.22 °F/100yr	
Warmest Year		64.0 °F (+ 2.6 °F) in 1996	MEAN 61.5 °F
Coldest Year		58.8 °F (- 2.7 °F) in 1920	STDEV 1.06 °F
Jan-Dec	2007	62.9 °F (+ 1.5 °F)	RANK 105 of 113

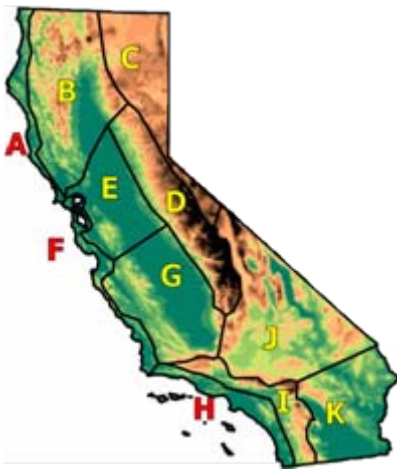


Mohave Desert Region

Maximum Temperature Departure Jan-Dec

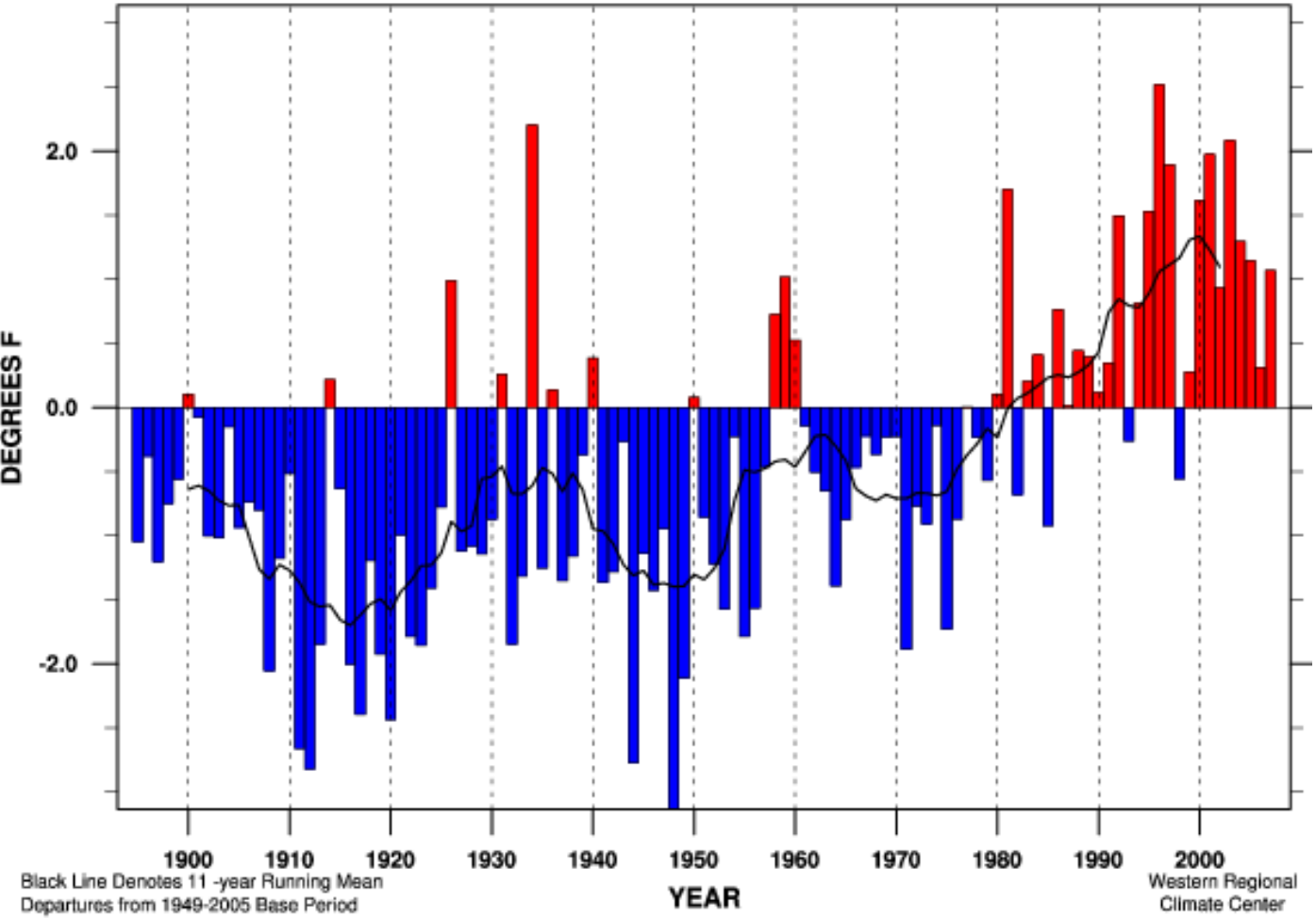


Linear Trend 1895-present	+ 1.54 ± 0.66 °F/100yr		
Linear Trend 1949-present	+ 2.52 ± 1.77 °F/100yr		
Linear Trend 1975-present	+ 7.36 ± 4.17 °F/100yr		
Warmest Year	77.8 °F (+ 2.7 °F) in 1934	MEAN	75.1 °F
Coldest Year	72.1 °F (- 3.0 °F) in 1920	STDEV	1.21 °F
Jan-Dec 2007	77.0 °F (+ 1.8 °F)	RANK	109 of 113

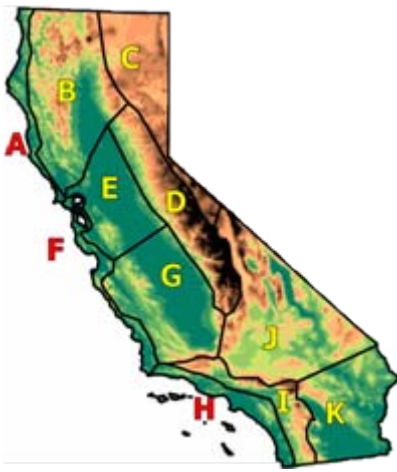


Mohave Desert Region

Miniumum Temperature Departure Jan-Dec

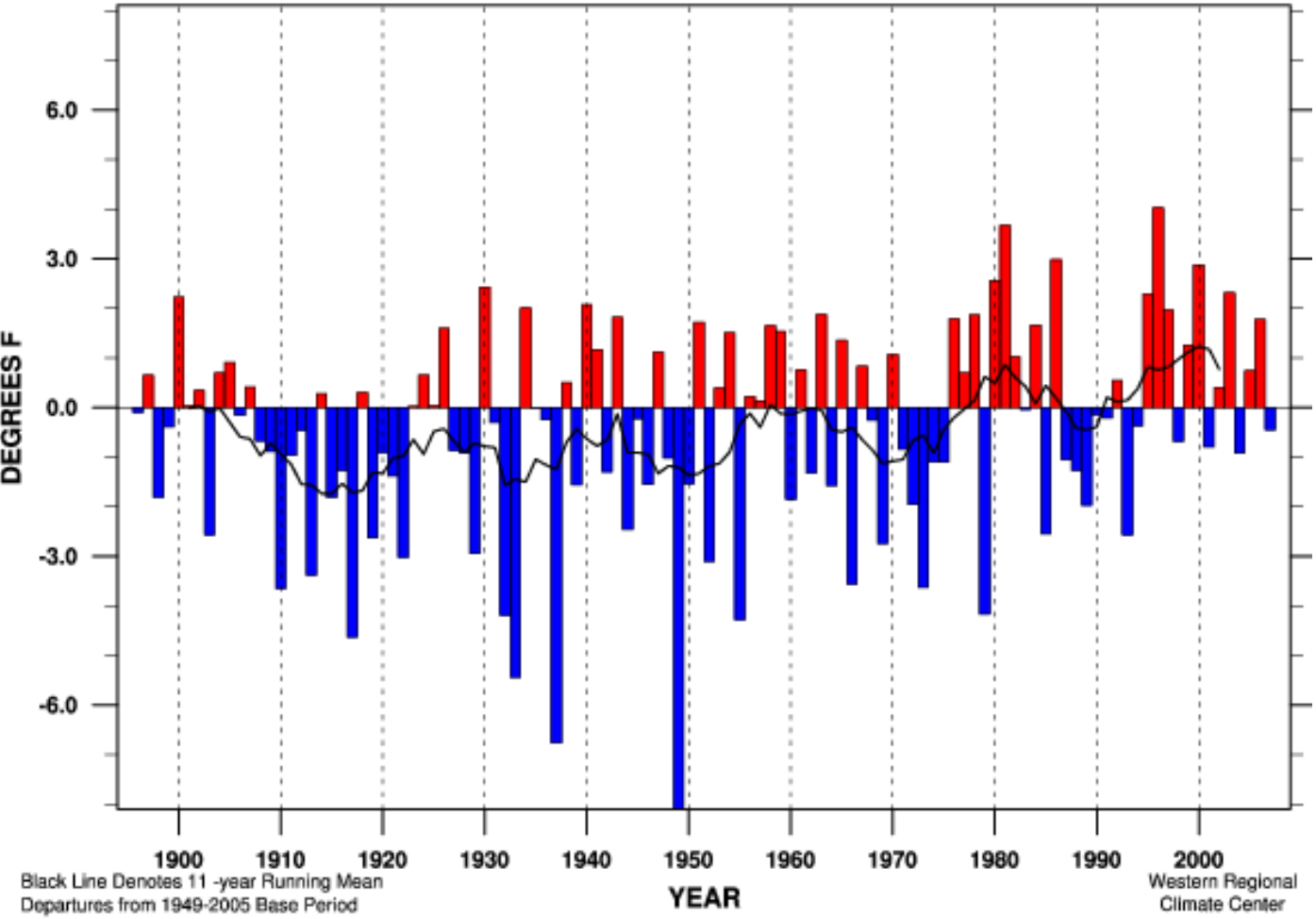


Linear Trend 1895-present		+ 1.97 ± 0.55 °F/100yr	
Linear Trend 1949-present		+ 4.14 ± 1.24 °F/100yr	
Linear Trend 1975-present		+ 6.33 ± 2.97 °F/100yr	
Warmest Year		50.4 °F (+ 2.5 °F) in 1996	MEAN 47.8 °F
Coldest Year		44.7 °F (- 3.1 °F) in 1948	STDEV 1.08 °F
Jan-Dec	2007	48.9 °F (+ 1.1 °F)	RANK 102 of 113

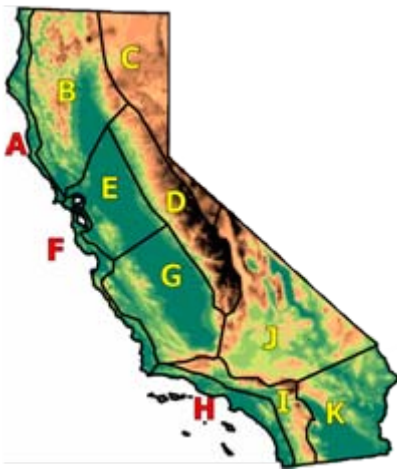


Mohave Desert Region

Mean Temperature Departure Dec-Feb

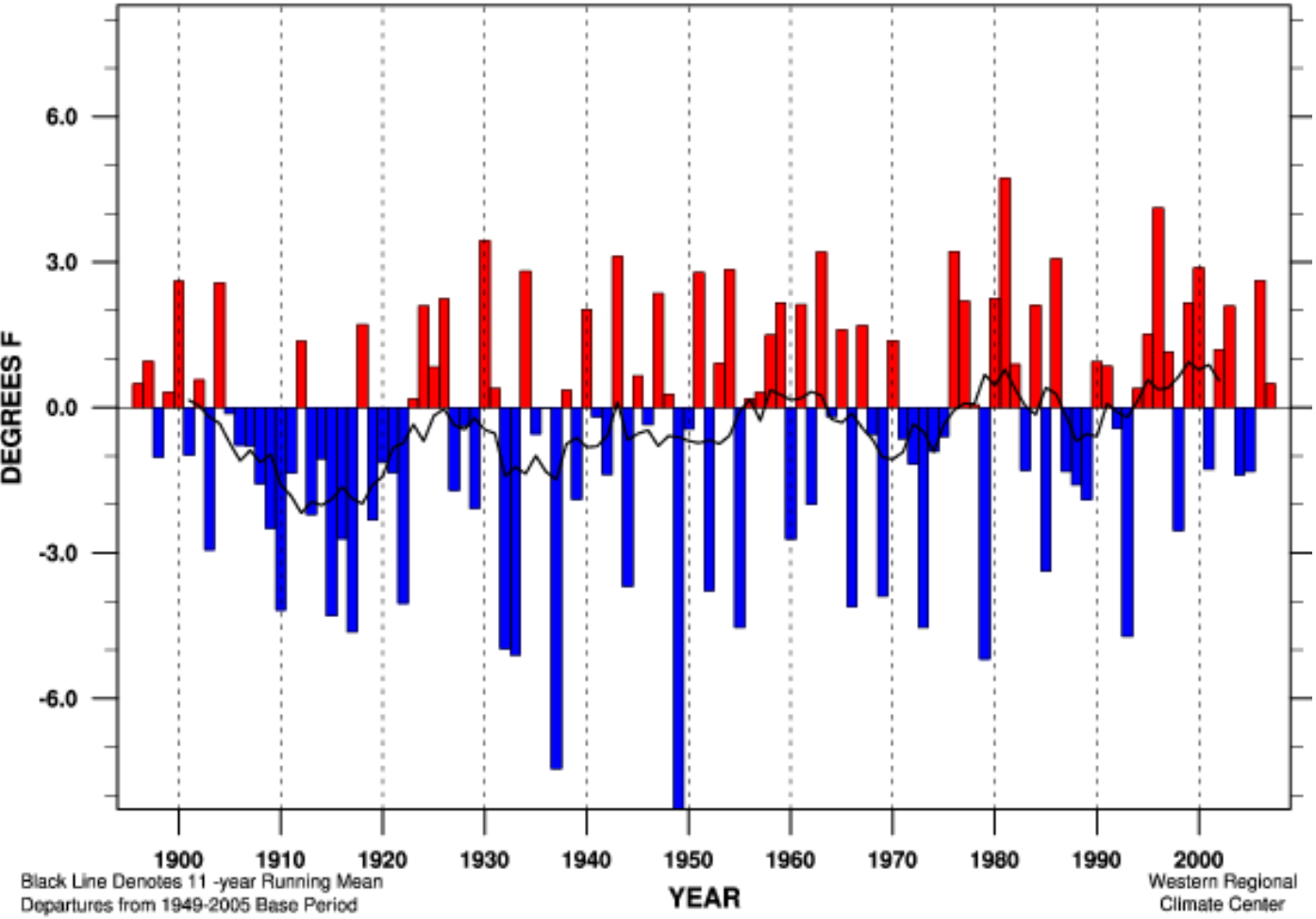


Linear Trend 1895-present		+ 1.39 ± 1.20 °F/100yr		
Linear Trend 1949-present		+ 2.60 ± 3.03 °F/100yr		
Linear Trend 1975-present		+ 0.60 ± 7.62 °F/100yr		
Warmest Year		48.9 °F (+ 4.0 °F) in 1996	MEAN	44.9 °F
Coldest Year		36.8 °F (- 8.1 °F) in 1949	STDEV	1.97 °F
Dec-Feb	2007	44.4 °F (- 0.4 °F)	RANK	50 of 112

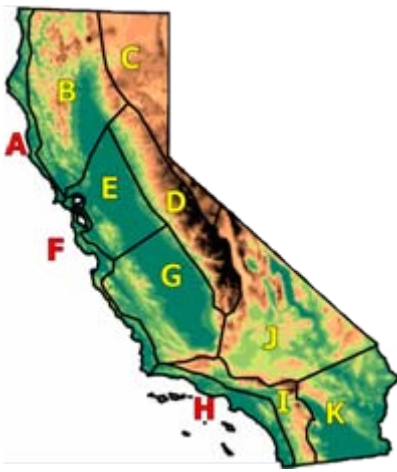


Mohave Desert Region

Maximum Temperature Departure Dec-Feb

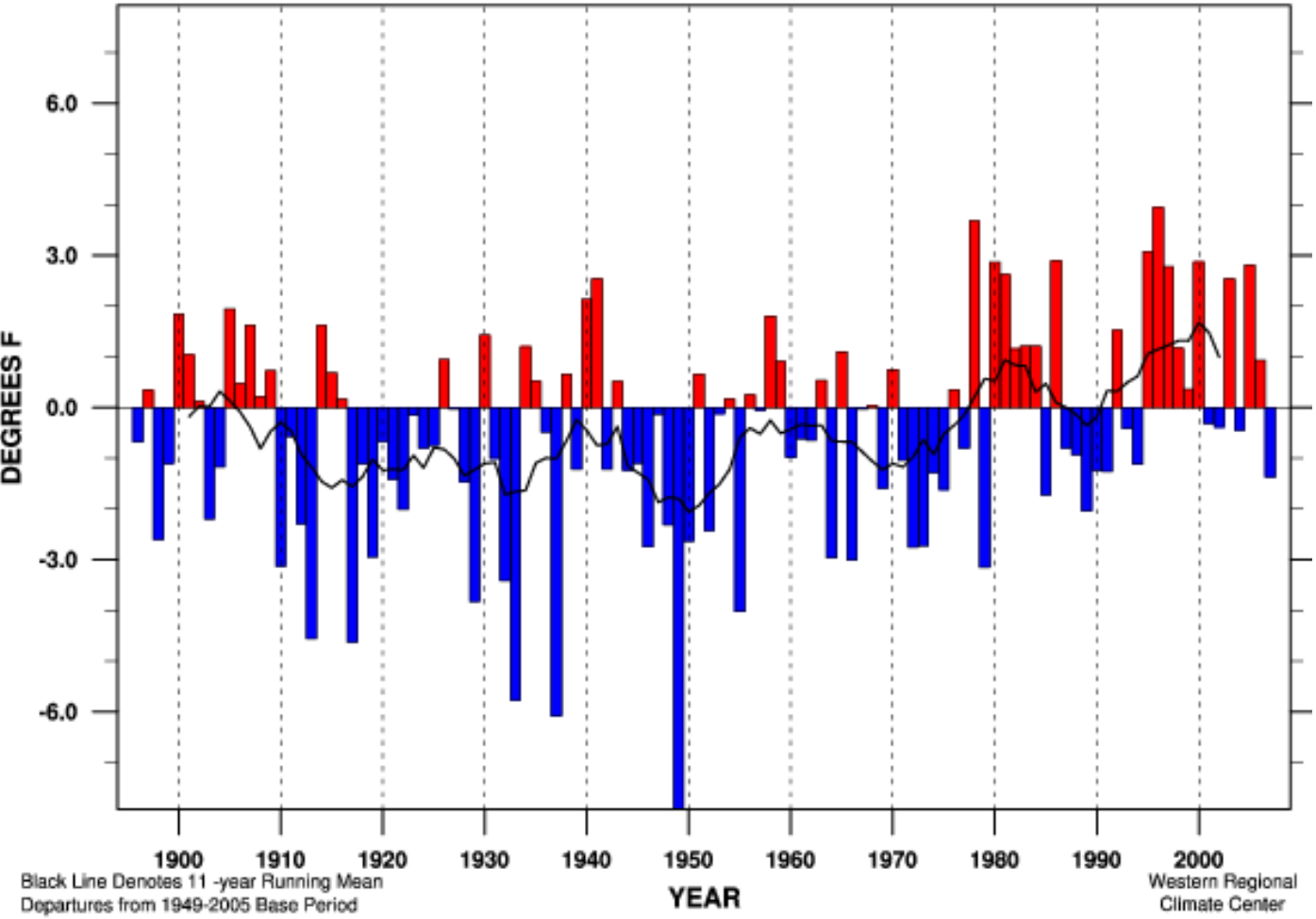


Linear Trend 1895-present		+ 1.27 ± 1.44 °F/100yr		
Linear Trend 1949-present		+ 1.28 ± 3.82 °F/100yr		
Linear Trend 1975-present		- 0.15 ± 9.61 °F/100yr		
Warmest Year		61.5 °F (+ 4.7 °F) in 1981	MEAN	56.8 °F
Coldest Year		48.5 °F (- 8.3 °F) in 1949	STDEV	2.43 °F
Dec-Feb	2007	57.3 °F (+ 0.5 °F)	RANK	70 of 112

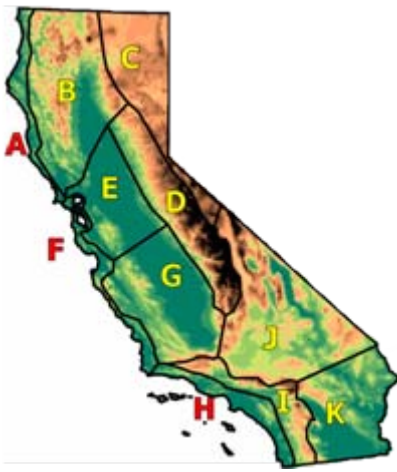


Mohave Desert Region

Miniumum Temperature Departure Dec-Feb

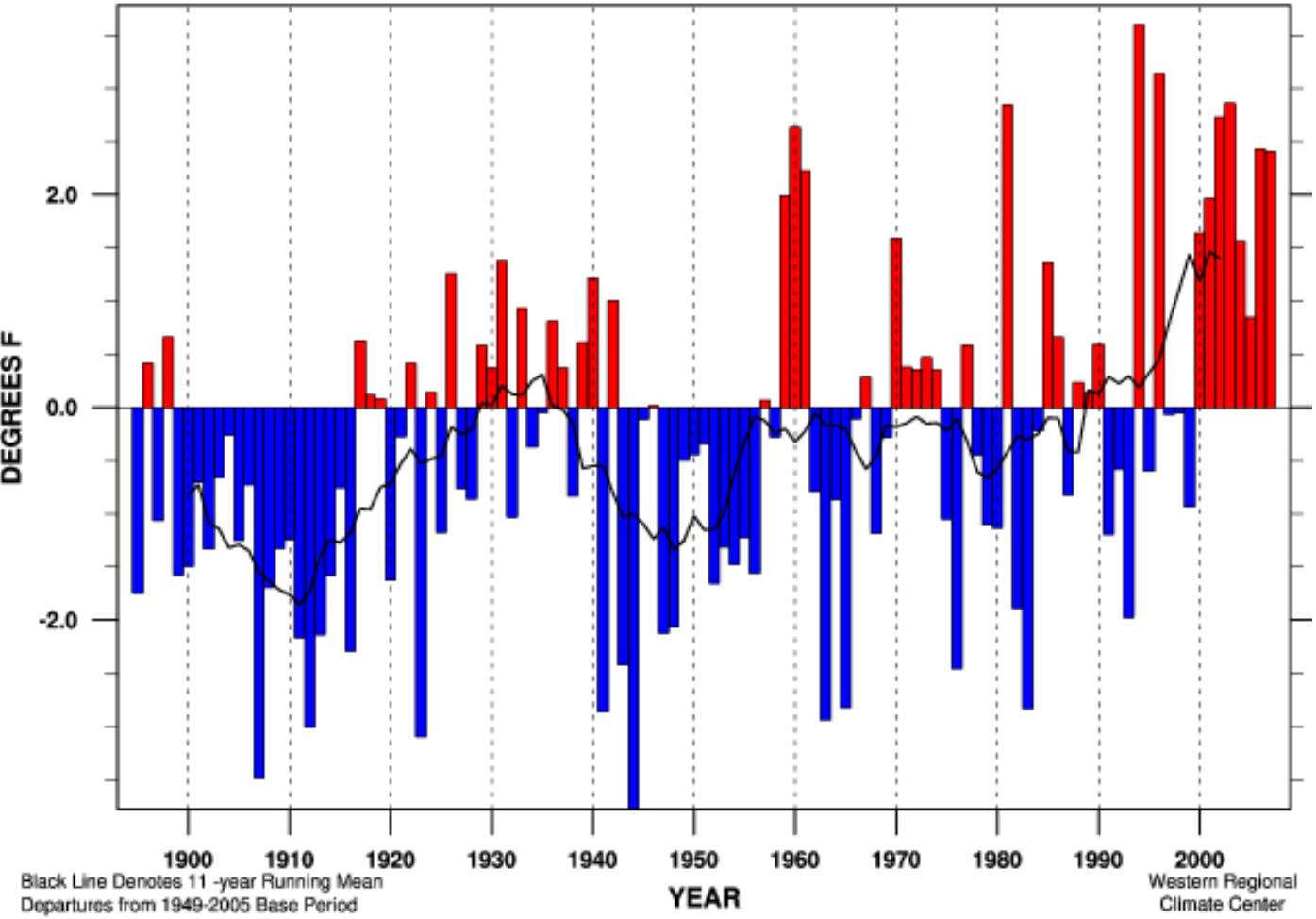


Linear Trend 1895-present		+ 1.50 ± 1.18 °F/100yr		
Linear Trend 1949-present		+ 3.91 ± 2.82 °F/100yr		
Linear Trend 1975-present		+ 1.36 ± 7.53 °F/100yr		
Warmest Year		36.9 °F (+ 3.9 °F) in 1996	MEAN	33.0 °F
Coldest Year		25.1 °F (- 7.9 °F) in 1949	STDEV	1.90 °F
Dec-Feb	2007	31.6 °F (- 1.4 °F)	RANK	30 of 112

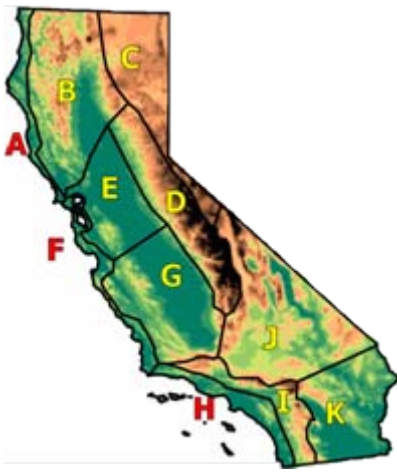


Mohave Desert Region

Mean Temperature Departure Jun-Aug

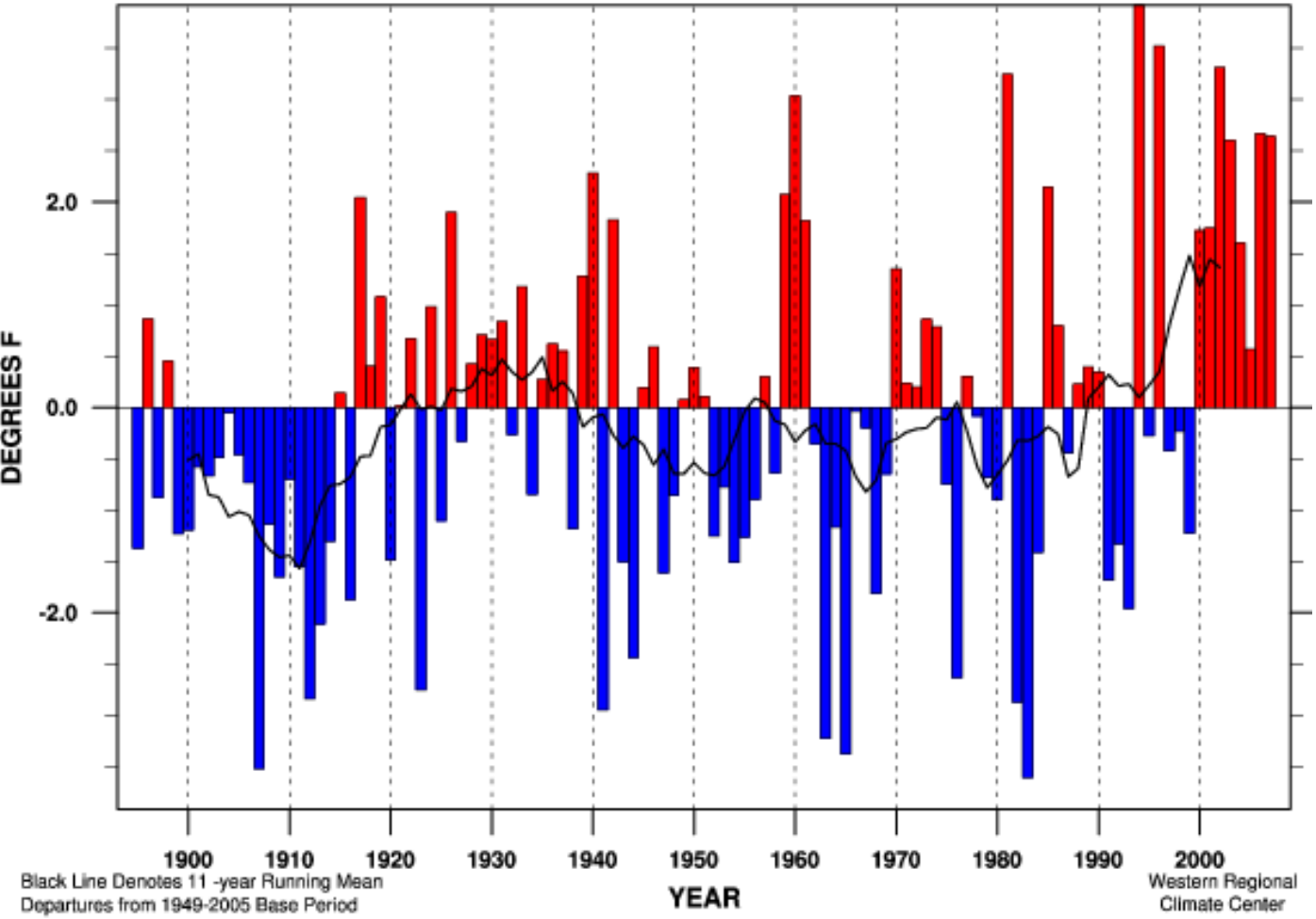


Linear Trend 1895-present		+ 1.83 ± 0.80 °F/100yr	
Linear Trend 1949-present		+ 3.76 ± 2.26 °F/100yr	
Linear Trend 1975-present		+ 9.92 ± 5.42 °F/100yr	
Warmest Year		82.9 °F (+ 3.6 °F) in 1994	MEAN 79.3 °F
Coldest Year		75.5 °F (- 3.8 °F) in 1944	STDEV 1.59 °F
Jun-Aug	2007	81.7 °F (+ 2.4 °F)	RANK 106 of 113

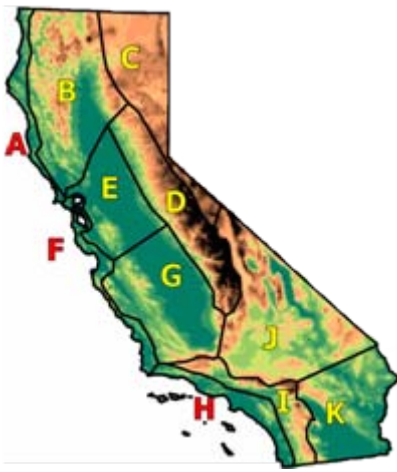


Mohave Desert Region

Maximum Temperature Departure Jun-Aug

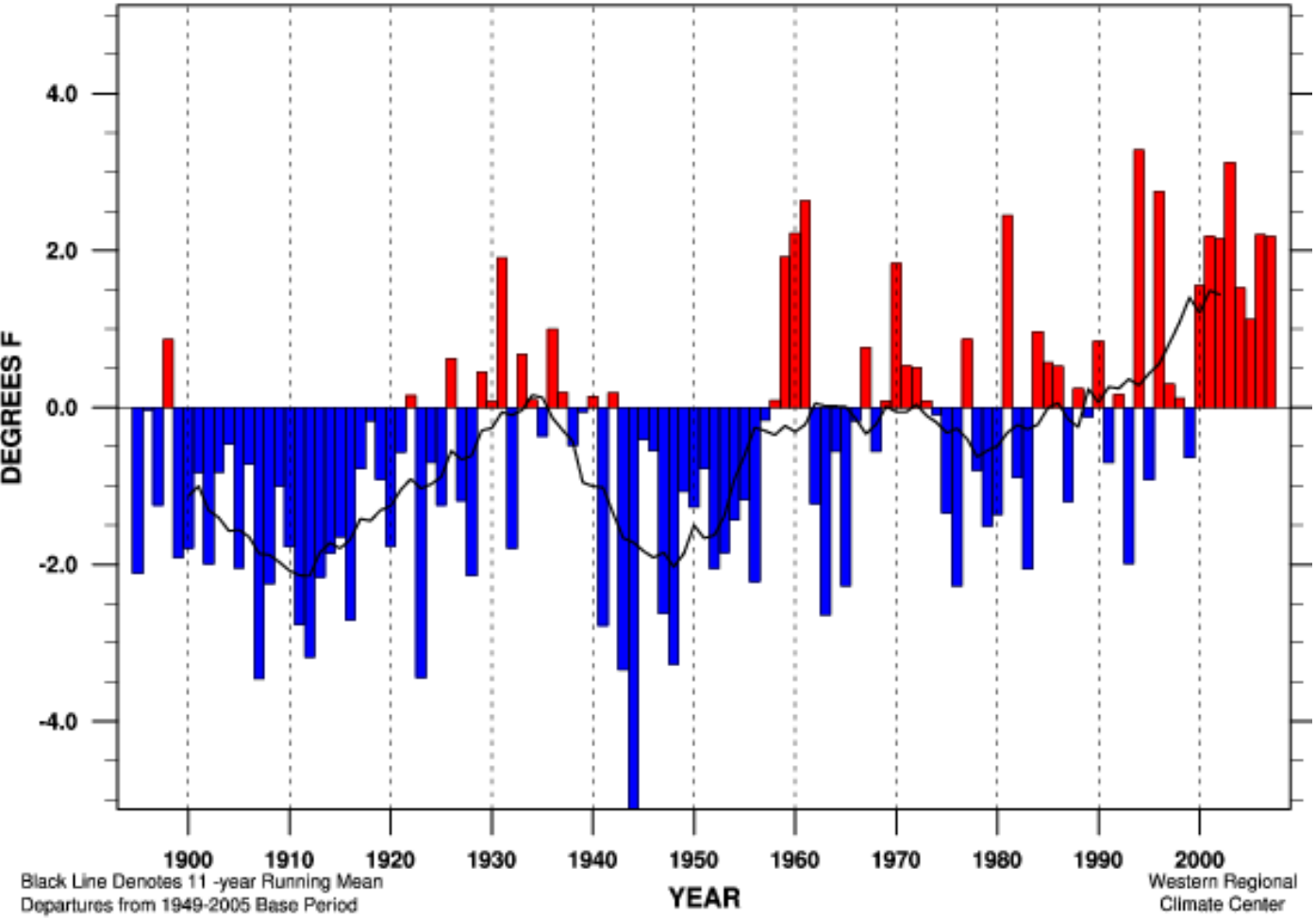


Linear Trend 1895-present	+ 1.32 ± 0.87 °F/100yr		
Linear Trend 1949-present	+ 3.33 ± 2.57 °F/100yr		
Linear Trend 1975-present	+10.10 ± 6.43 °F/100yr		
Warmest Year	98.3 °F (+ 3.9 °F) in 1994	MEAN	94.4 °F
Coldest Year	90.8 °F (- 3.6 °F) in 1983	STDEV	1.75 °F
Jun-Aug 2007	97.0 °F (+ 2.6 °F)	RANK	107 of 113

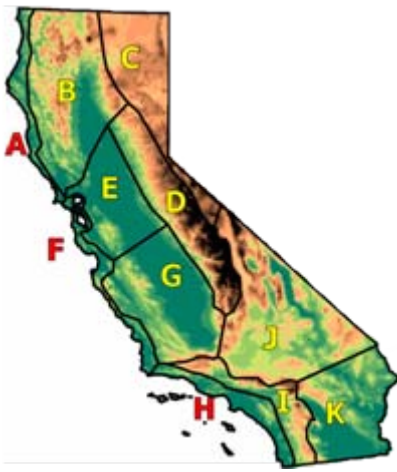


Mohave Desert Region

Miniumum Temperature Departure Jun-Aug

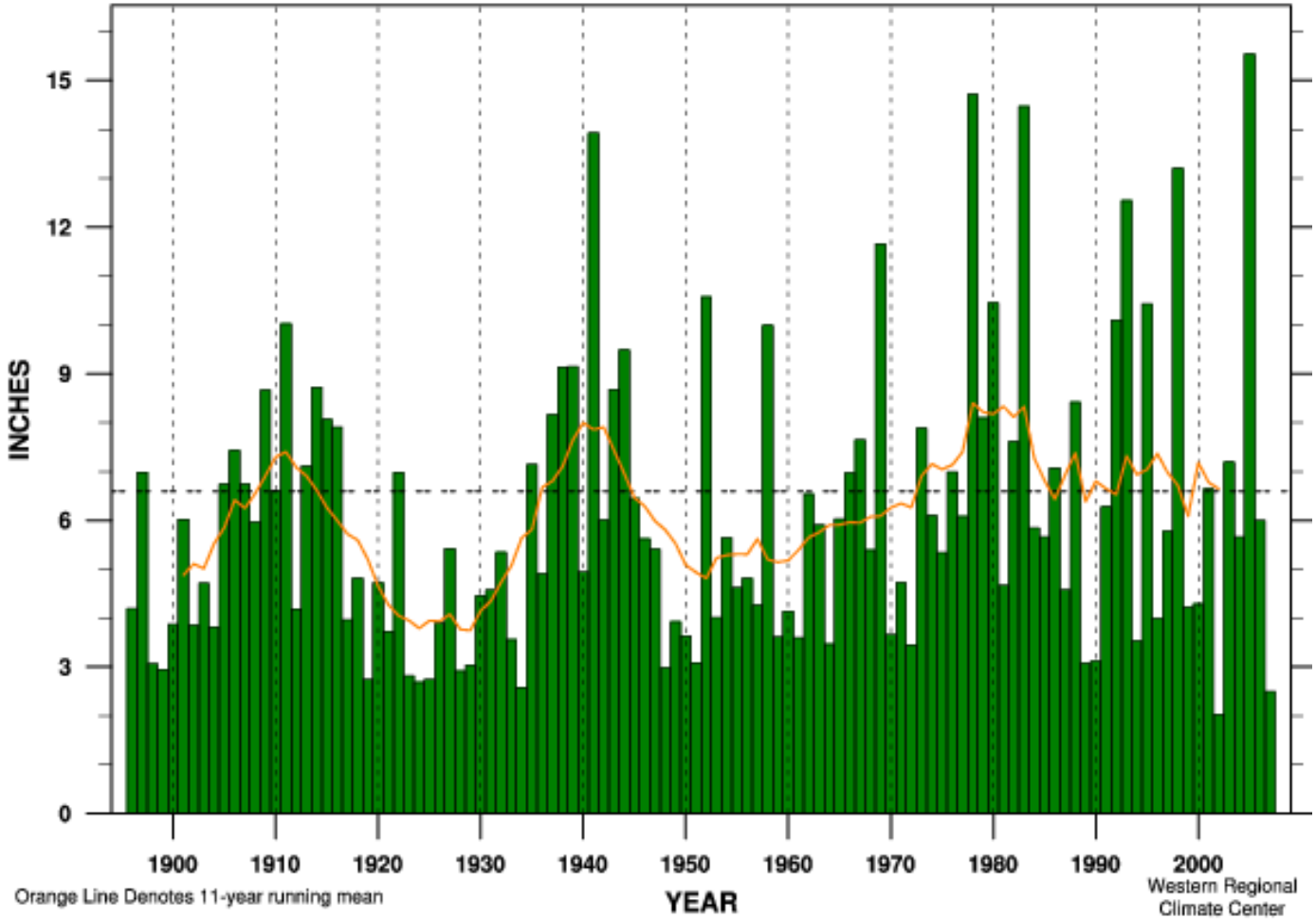


Linear Trend 1895-present	+ 2.34 ± 0.80 °F/100yr		
Linear Trend 1949-present	+ 4.18 ± 2.12 °F/100yr		
Linear Trend 1975-present	+ 9.74 ± 4.83 °F/100yr		
Warmest Year	67.5 °F (+ 3.3 °F) in 1994	MEAN	64.2 °F
Coldest Year	59.1 °F (- 5.1 °F) in 1944	STDEV	1.54 °F
Jun-Aug 2007	66.4 °F (+ 2.2 °F)	RANK	105 of 113

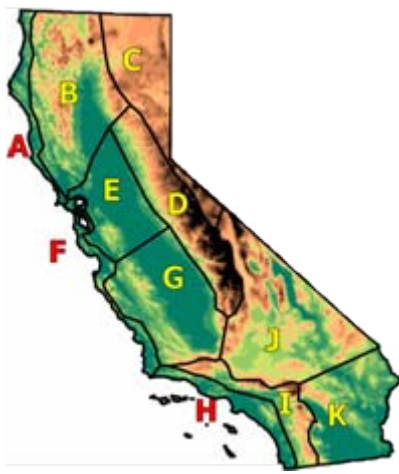


Mohave Desert Region

Precipitation Oct-Sep

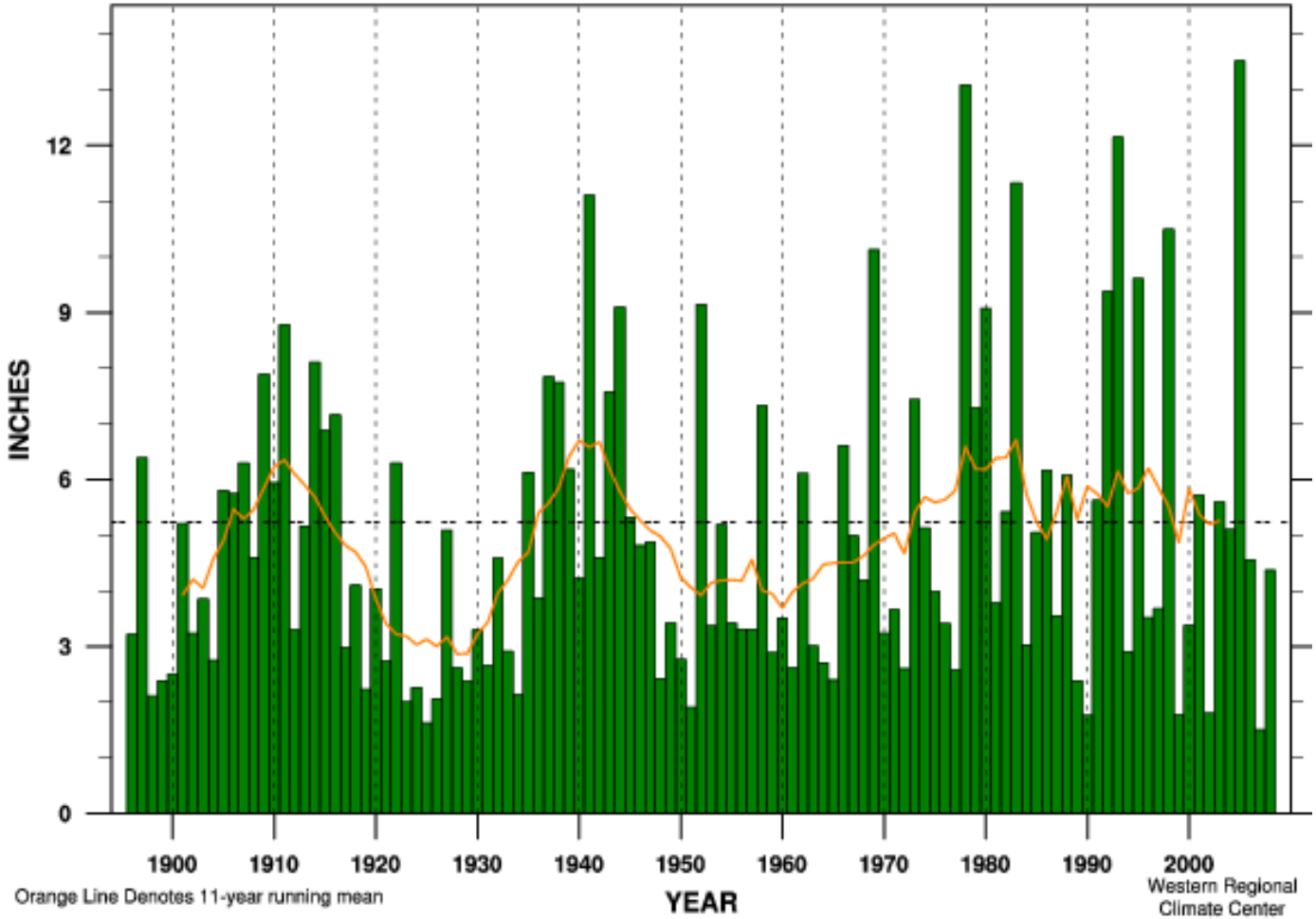


Linear Trend 1895-present	+ 1.83 ± 1.63 in.	(+ 27 ± 24%) per 100 yr	
Linear Trend 1949-present	+ 3.17 ± 5.04 in.	(+ 48 ± 76%) per 100 yr	
Linear Trend 1975-present	- 7.31 ± 14.42 in.	(-110 ± 218%) per 100 yr	
Wettest Year	15.54 in. (235%) in 2005	MEAN	6.59 in.
Driest Year	2.03 in. (30%) in 2002	STDEV	3.21 in.
Oct-Sep 2007	2.50 in. (37%)	RANK	2 of 112

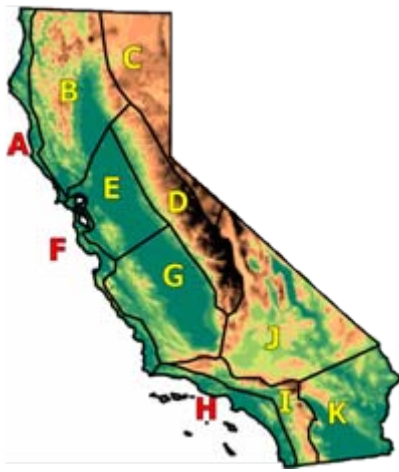


Mohave Desert Region

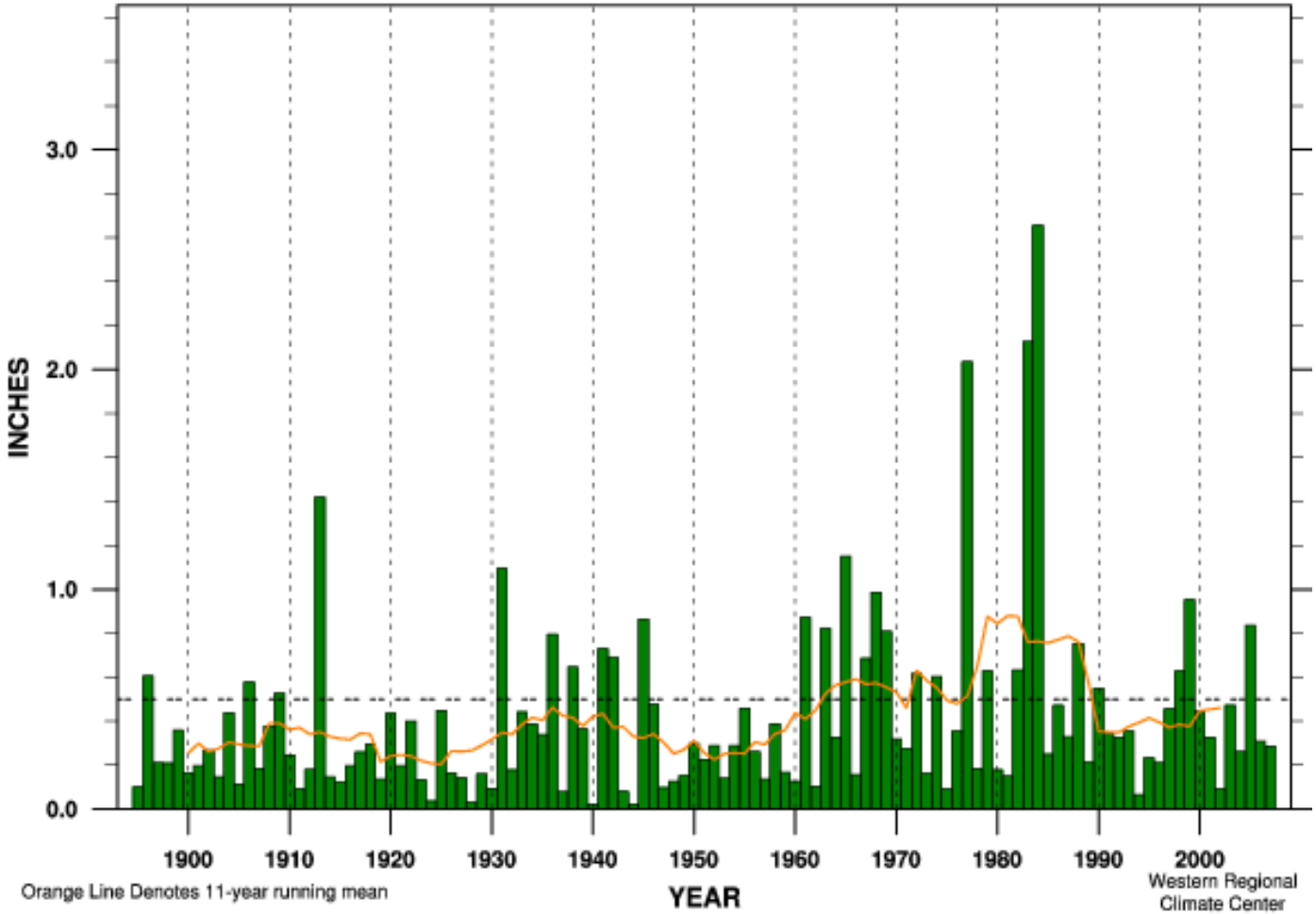
Precipitation Oct-Mar



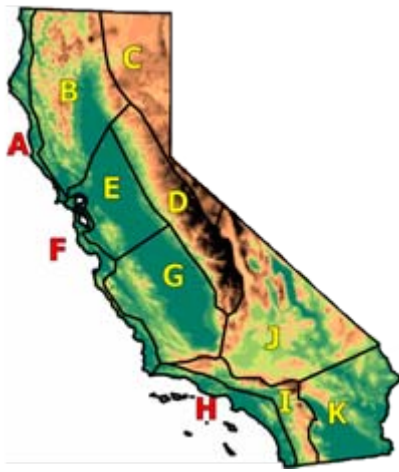
Linear Trend 1895-present	+ 1.22 ± 1.50 in.	(+ 23 ± 28%) per 100 yr	
Linear Trend 1949-present	+ 2.86 ± 4.58 in.	(+ 54 ± 87%) per 100 yr	
Linear Trend 1975-present	- 4.22 ± 13.03 in.	(- 80 ± 248%) per 100 yr	
Wettest Year	13.52 in. (258%)	in 2005	MEAN 5.24 in.
Driest Year	1.51 in. (28%)	in 2007	STDEV 3.02 in.
Oct-Mar 2008	4.37 in. (83%)		RANK 59 of 113



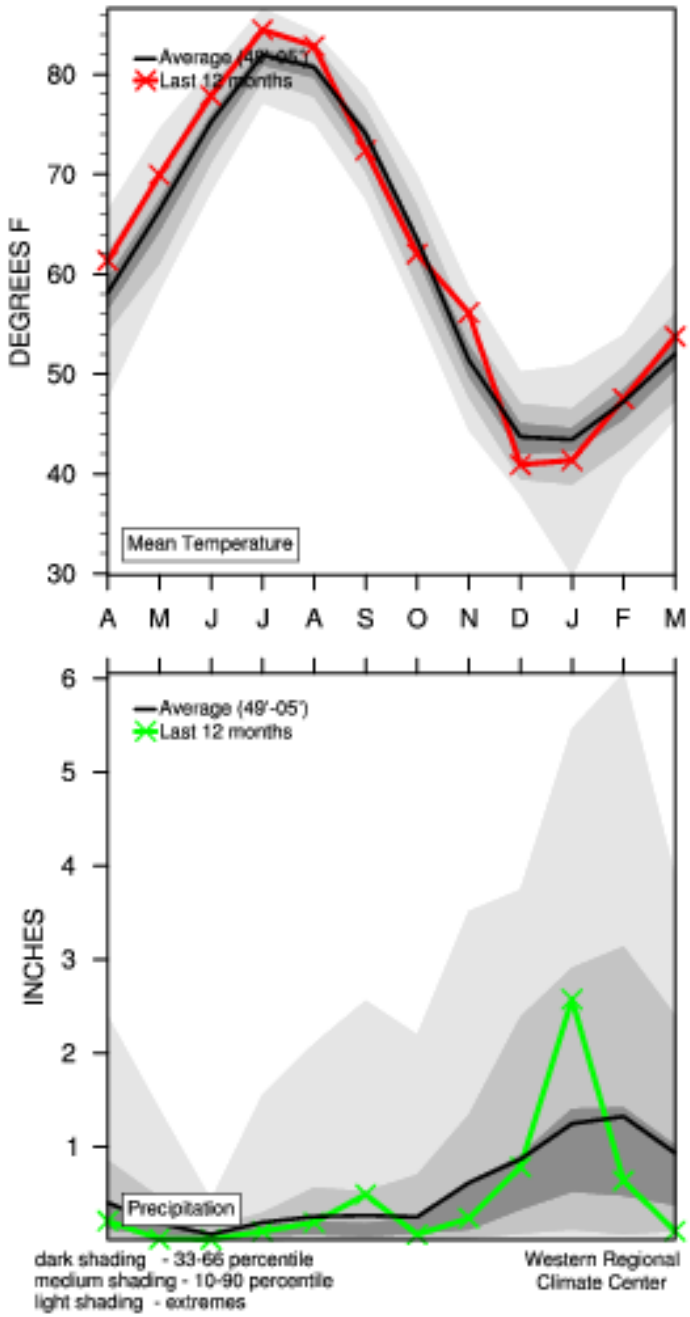
Mohave Desert Region
Precipitation Jun-Aug



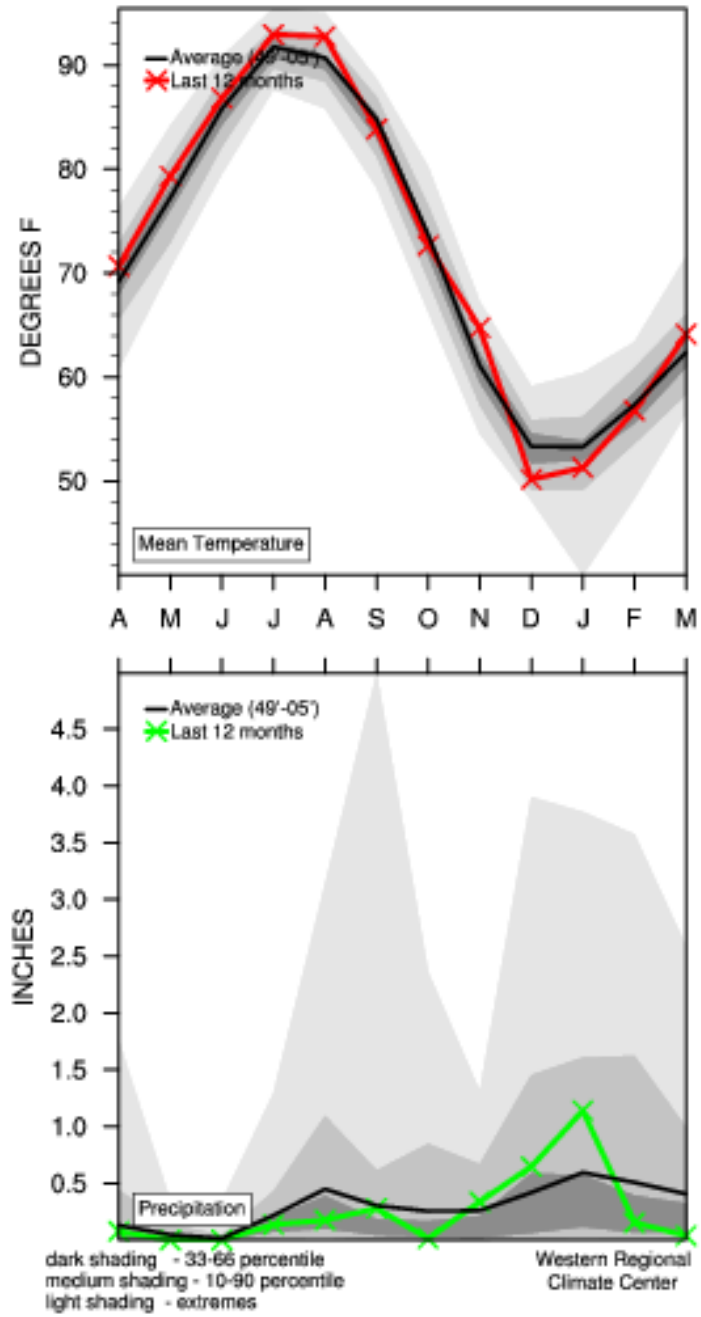
Linear Trend 1895-present	+ 0.27 ± 0.23 in.	(+ 54 ± 46%) per 100 yr	
Linear Trend 1949-present	+ 0.22 ± 0.75 in.	(+ 44 ± 150%) per 100 yr	
Linear Trend 1975-present	- 1.40 ± 2.20 in.	(-280 ± 441%) per 100 yr	
Wettest Year	2.66 in. (532%)	in 1984	MEAN 0.50 in.
Driest Year	0.03 in. (6%)	in 1928	STDEV 0.50 in.
Jun-Aug 2007	0.29 in. (57%)		RANK 55 of 113



Mohave Desert Region Last 12 Months



Sonoran Desert Region Last 12 Months



Address http://www.cefa.dri.edu/Westmap/

WestMap
Climate Analysis & Mapping Toolbox

TOOLBOX

Access & Analysis
- QUICK PLOT
- Mapping
- Metadata
- Tutorial
- Custom Requests

Climate 101
- Local Climate
- Educational Resources
- Climate Links

User Feedback
- Publications
- Applications
- Survey

WestMap Overview
- What is WestMap?
- PRISM 101
- About Us

Help
- FAQs
- Ask Us!

CONTENTS UNDER CONSTRUCTION

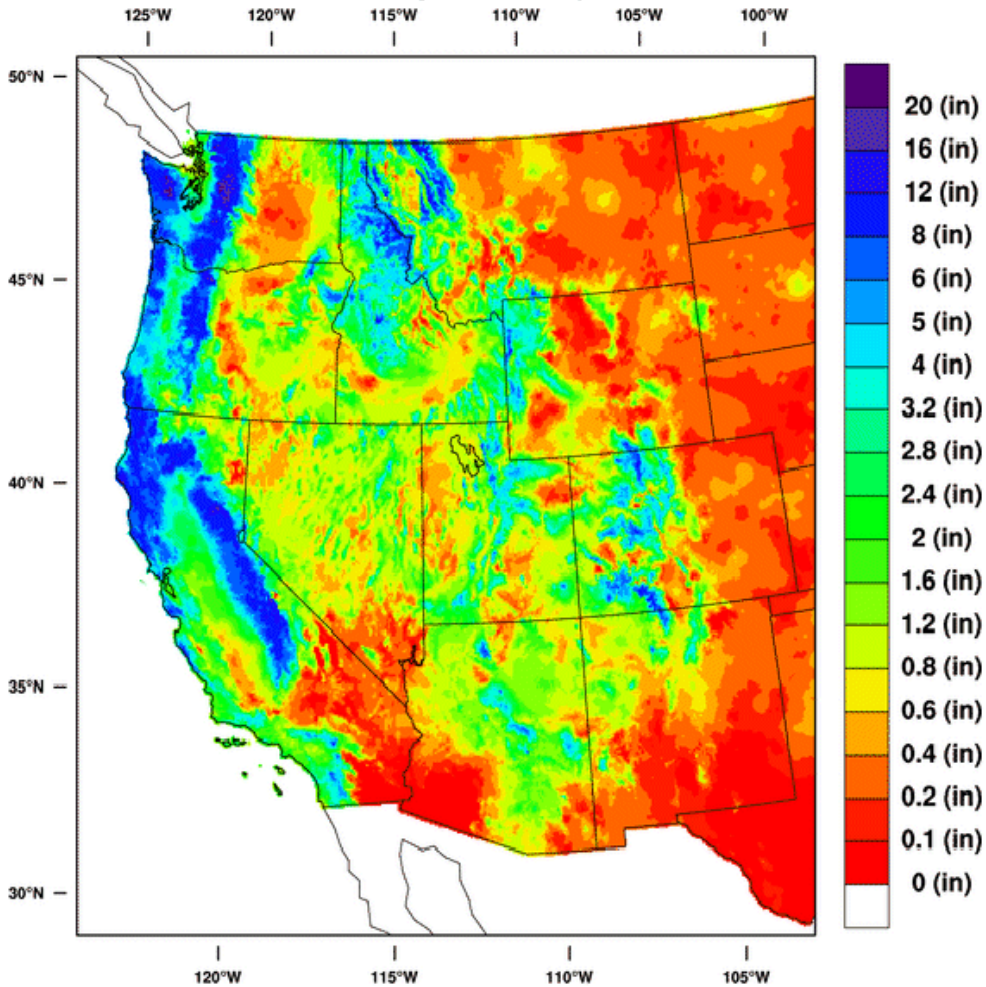
PRINT MAP

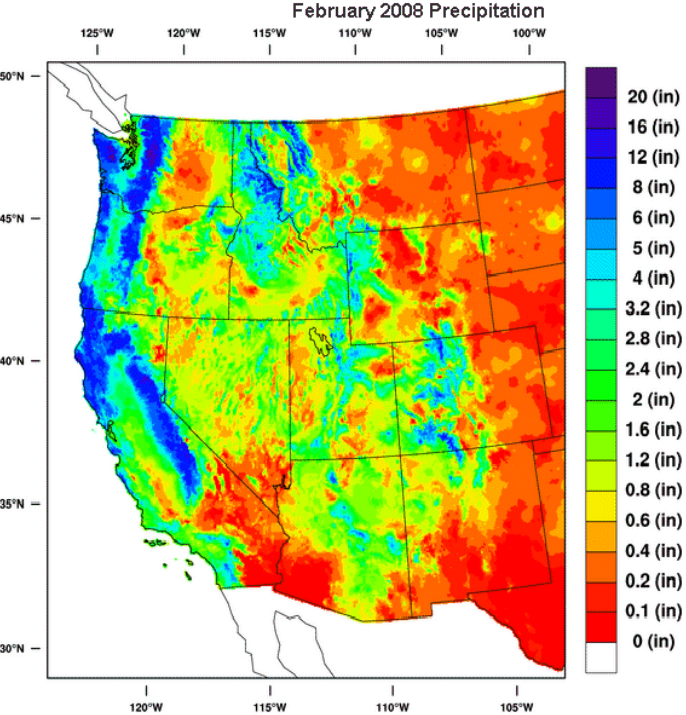
Select Element: Precipitation

Select Region: States

Map Click: Show Time Series

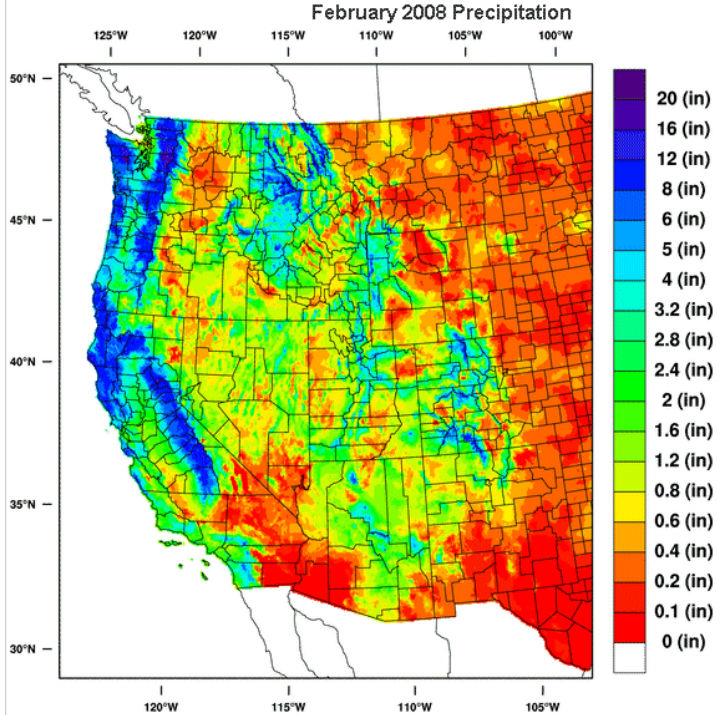
February 2008 Precipitation

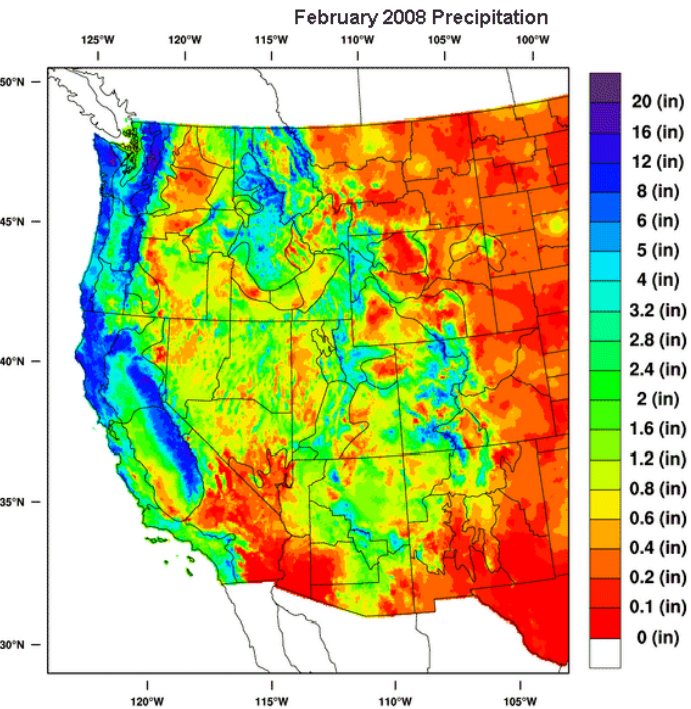




States

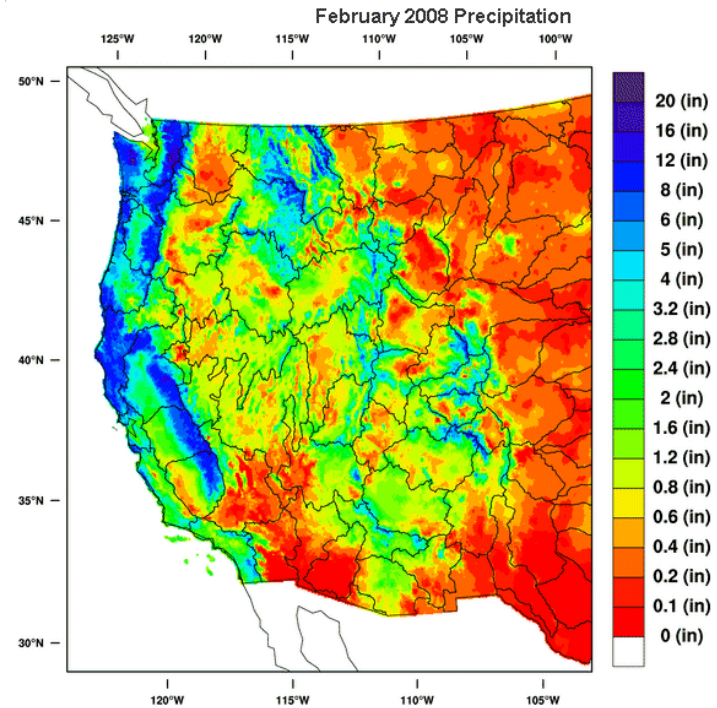
Counties





Climate Divisions

Hydro Basins



Plot time series history of monthly divisional precipitation or temperature.

More details about this program

Boundaries: Climate Divisions

To access state-wide averages, use the division pull-down.

Nevada | 04 - Extreme Southern | Get Timeseries

Select the quantity you wish to plot

- (•) Precipitation
- ( ) Mean Temperature
- ( ) Max Temperature
- ( ) Min Temperature

Enter the Beginning year: 1895 Enter the Ending year: 2008

Enter the period of months each data poin will represent (1-72): 1

Select the last month of the period. February

Would you like a running mean? (blue) (•) Yes ( ) No

Enter the number of years in the running mean (2-30) 10

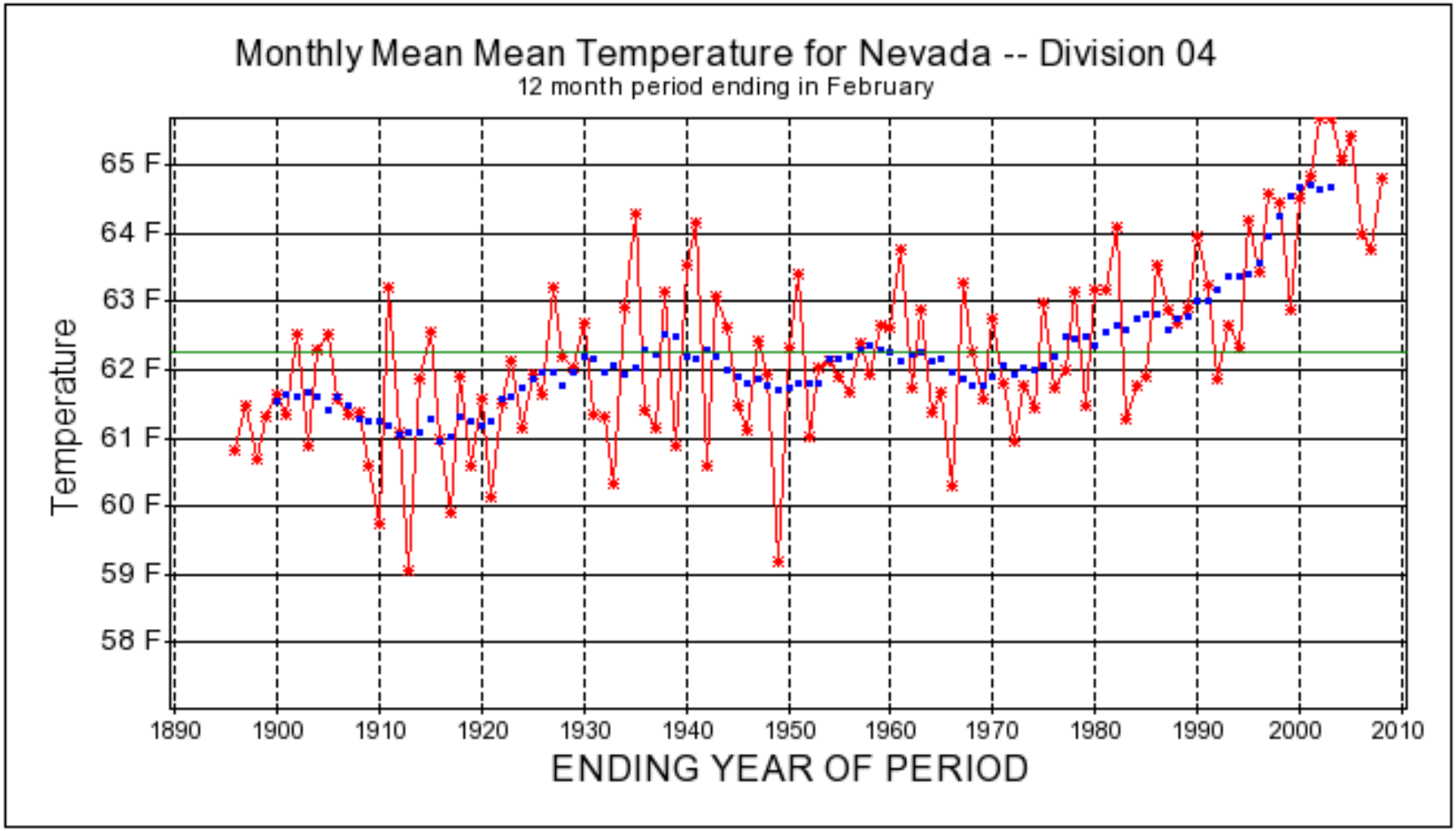
Show the average? (green) (•) Yes ( ) No

Select the image size of the plot.

- ( ) Small (510x290)
- (•) Medium (650x370)
- ( ) Large (850x480)

List the data for the points plotted? ( ) Yes (•) No

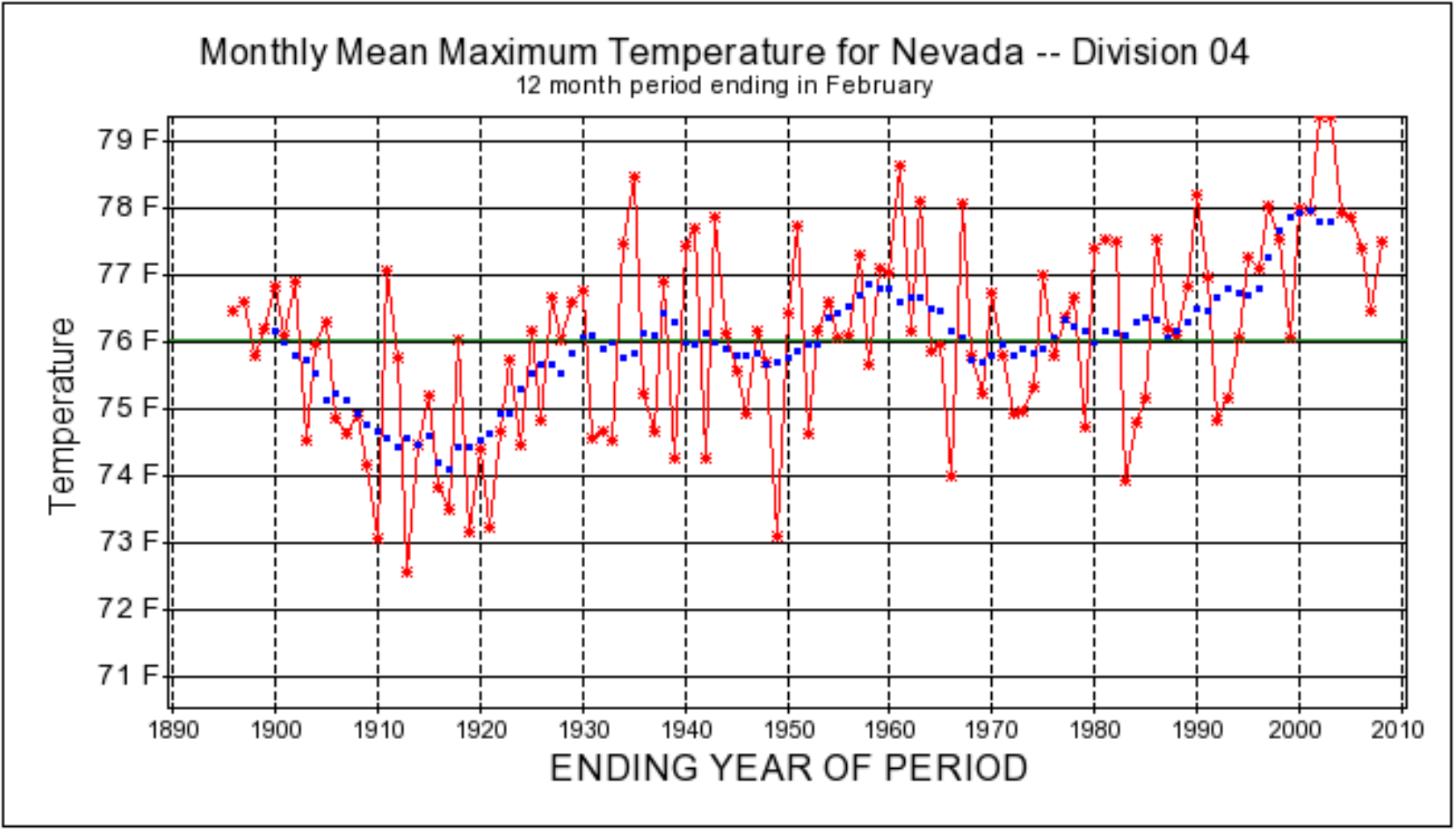
Western Regional Climate Center, wrcc@dri.edu



12-Month Period Ending in February

AVERAGE	62.267
MEDIAN	62.017
MINIMUM	59.050
MAXIMUM	65.725
SKEWNESS	0.385
COEFF OF VAR	0.021
SIGMA (RMS)	62.281
NUMBER OBS	113.000

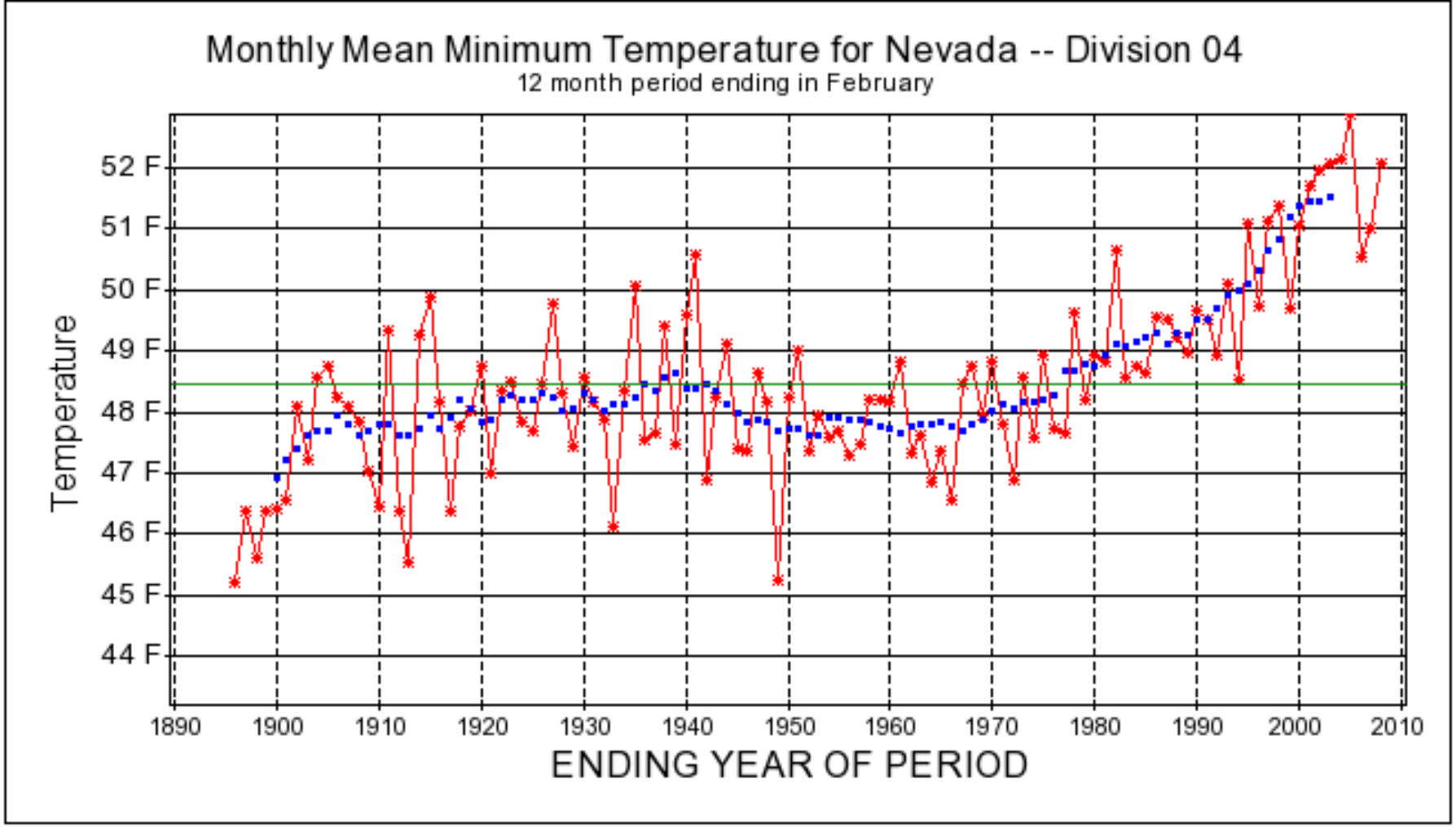
Southern Nevada Climate Division 4
12-Month March thru February
Mean Temperature



12-Month Period Ending in February

AVERAGE	76.059
MEDIAN	76.108
MINIMUM	72.567
MAXIMUM	79.408
SKEWNESS	-0.115
COEFF OF VAR	0.019
SIGMA (RMS)	76.072
NUMBER OBS	113.000

Southern Nevada Climate Division 4
12-Month March thru February
Mean Max Temperature



12-Month Period Ending in February

AVERAGE	48.476
MEDIAN	48.258
MINIMUM	45.217
MAXIMUM	52.917
SKEWNESS	0.589
COEFF OF VAR	0.031
SIGMA (RMS)	48.500
NUMBER OBS	113.000

Southern Nevada Climate Division 4
12-Month March thru February
Mean Min Temperature

WestMap
Climate Analysis & Mapping Toolbox

TOOLBOX

Access & Analysis

QUICK PLOT

Mapping

Metadata

Tutorial

Custom Requests

Climate 101

Local Climate

Educational Resources

Climate Links

User Feedback

Publications

Applications

Survey

WestMap Overview

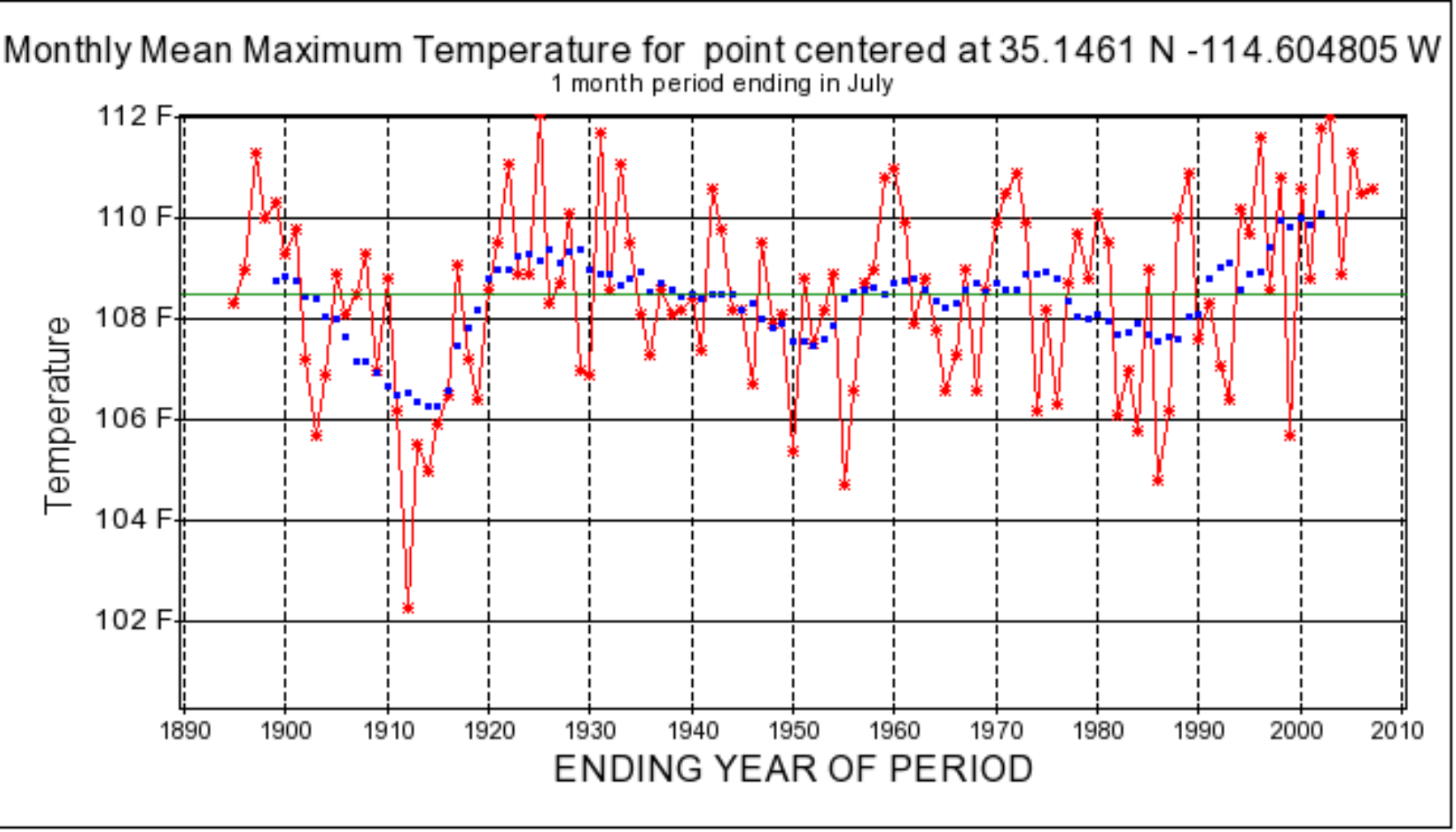
What is WestMap?

Please click map or enter Latitude and Longitude to get PRISM pixel

Single PRISM pixel

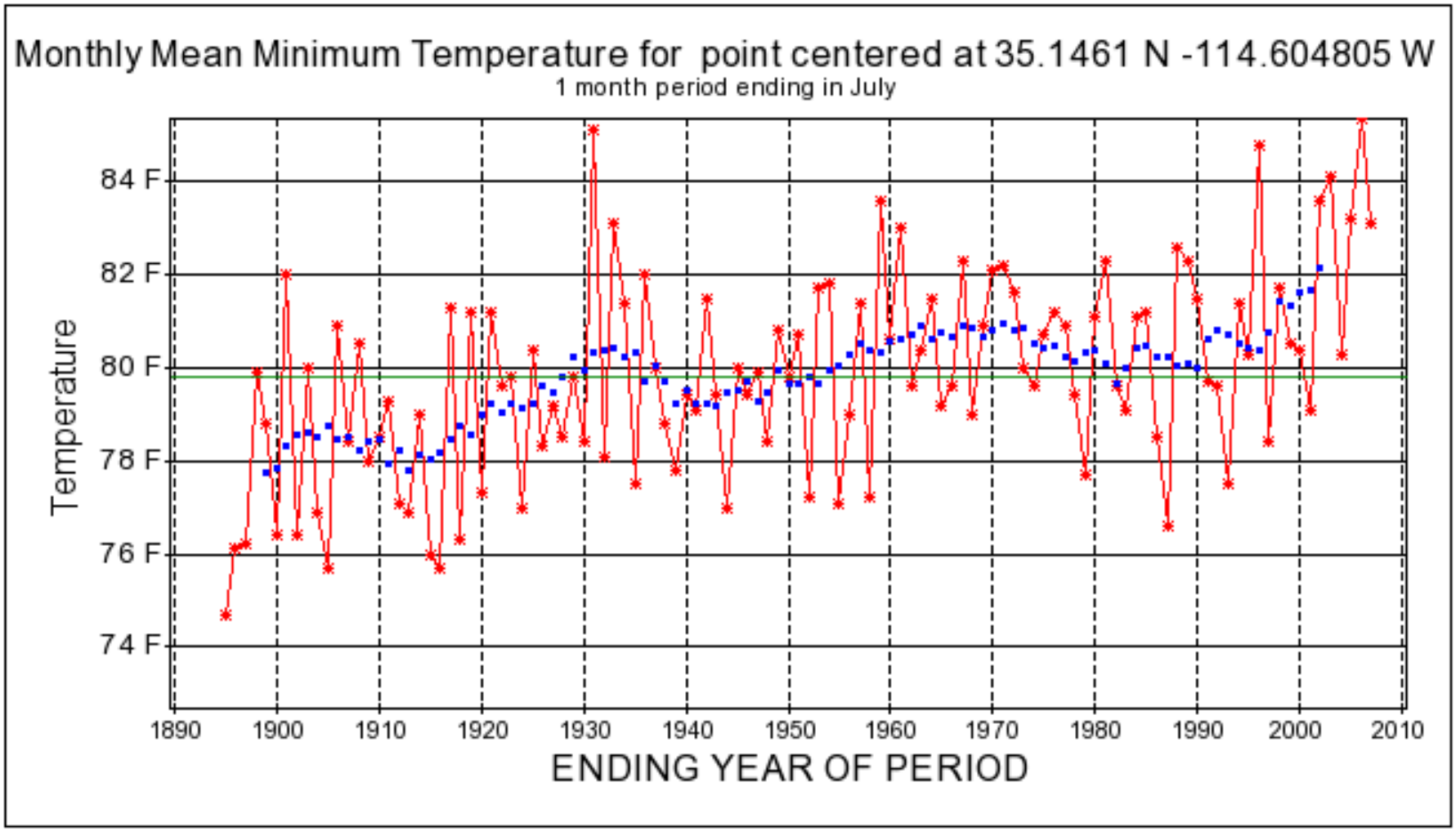
Select Element	Select Region	Latitude:	Longitude:	
Precipitation	By Pixel	35.13787911	-114.5901489	Get Timeseries

This page uses Google Maps



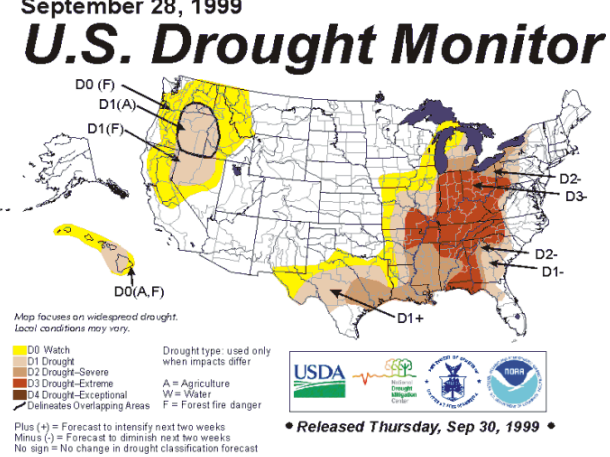

```
1-Month Period Ending in July
AVERAGE        108.493
MEDIAN         108.600
MINIMUM        102.300
MAXIMUM        112.100
SKEWNESS        -0.354
COEFF OF VAR     0.017
SIGMA (RMS)    108.508
NUMBER OBS     113.000
```

Laughlin Nevada PRISM pixel
July
Mean Max Temperature

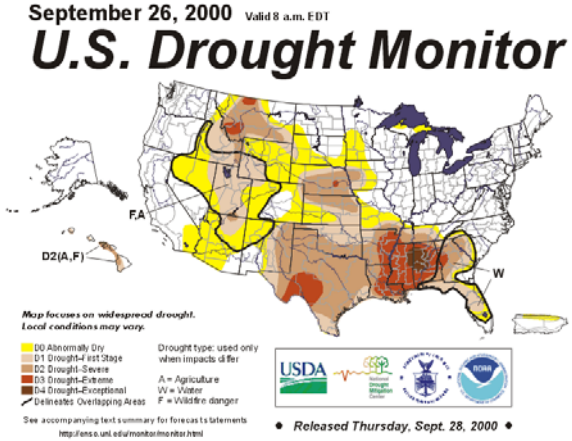



```
1-Month Period Ending in July
AVERAGE        79.827
MEDIAN         79.800
MINIMUM        74.700
MAXIMUM        85.400
SKEWNESS        0.088
COEFF OF VAR    0.027
SIGMA (RMS)    79.856
NUMBER OBS    113.000
```

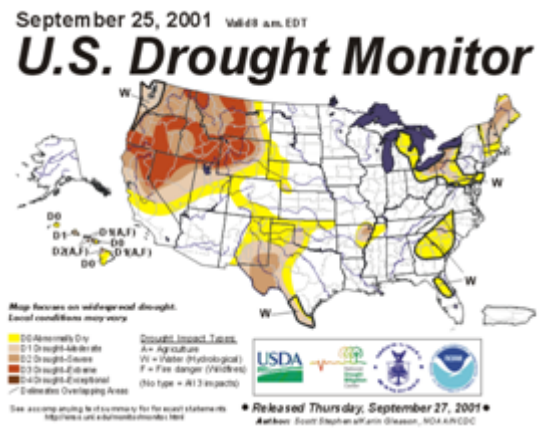
Laughlin Nevada PRISM pixel
July
Mean Min Temperature



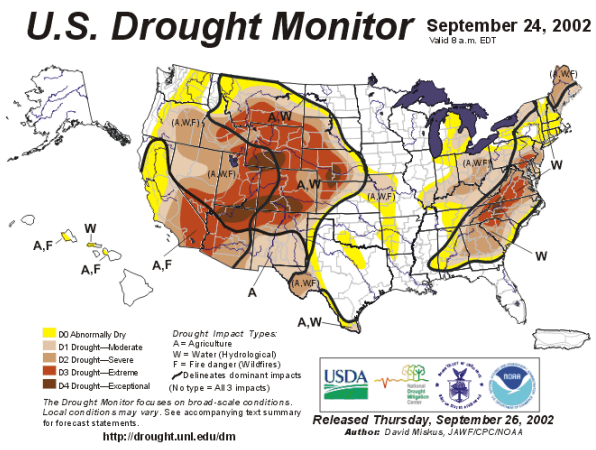
Sep 28, 1999



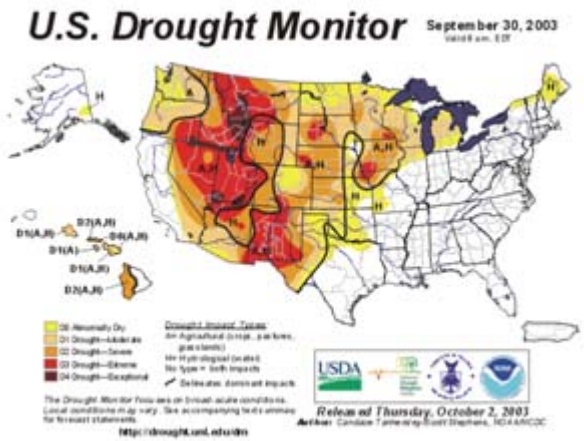
Sep 26, 2000



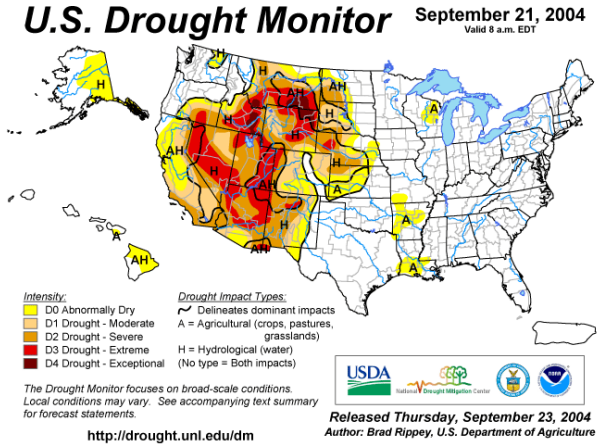
Sep 25, 2001



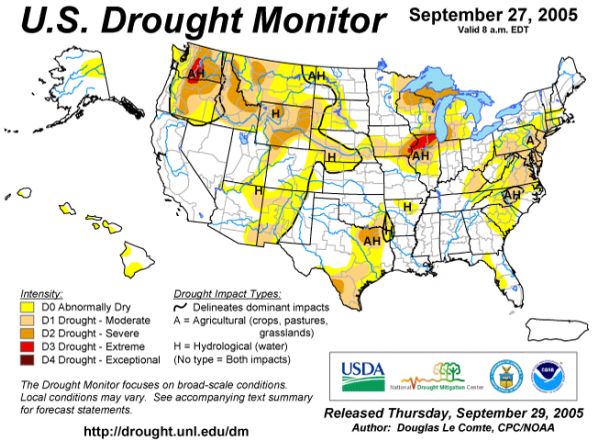
Sep 24, 2002



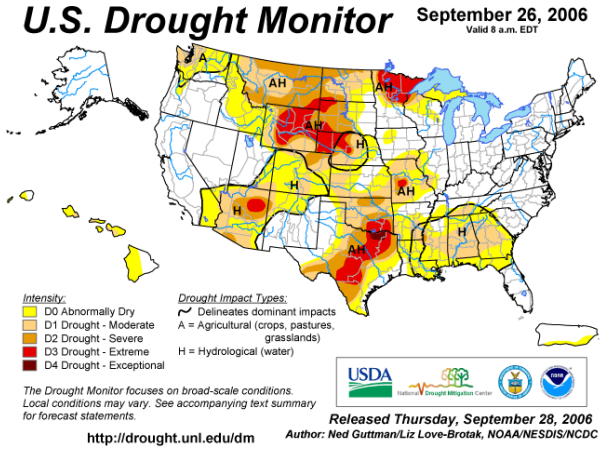
Sep 30, 2003



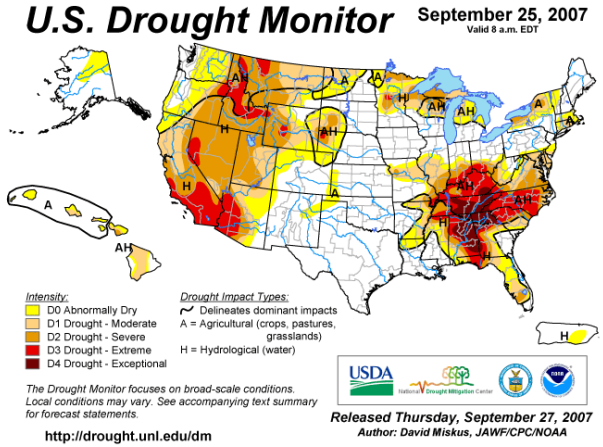
Sep 21, 2004



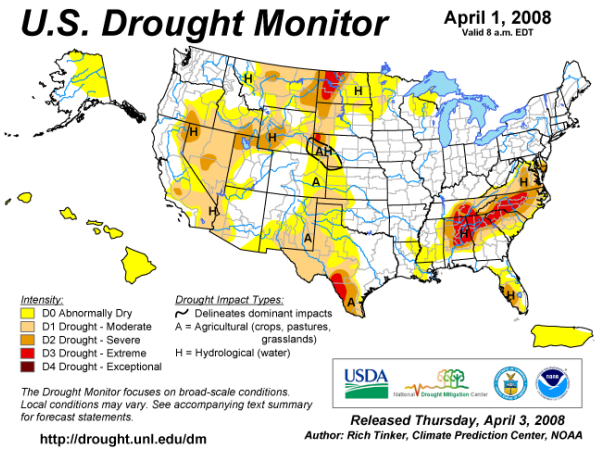
Sep 27, 2005



Sep 26, 2006



Sep 25, 2007



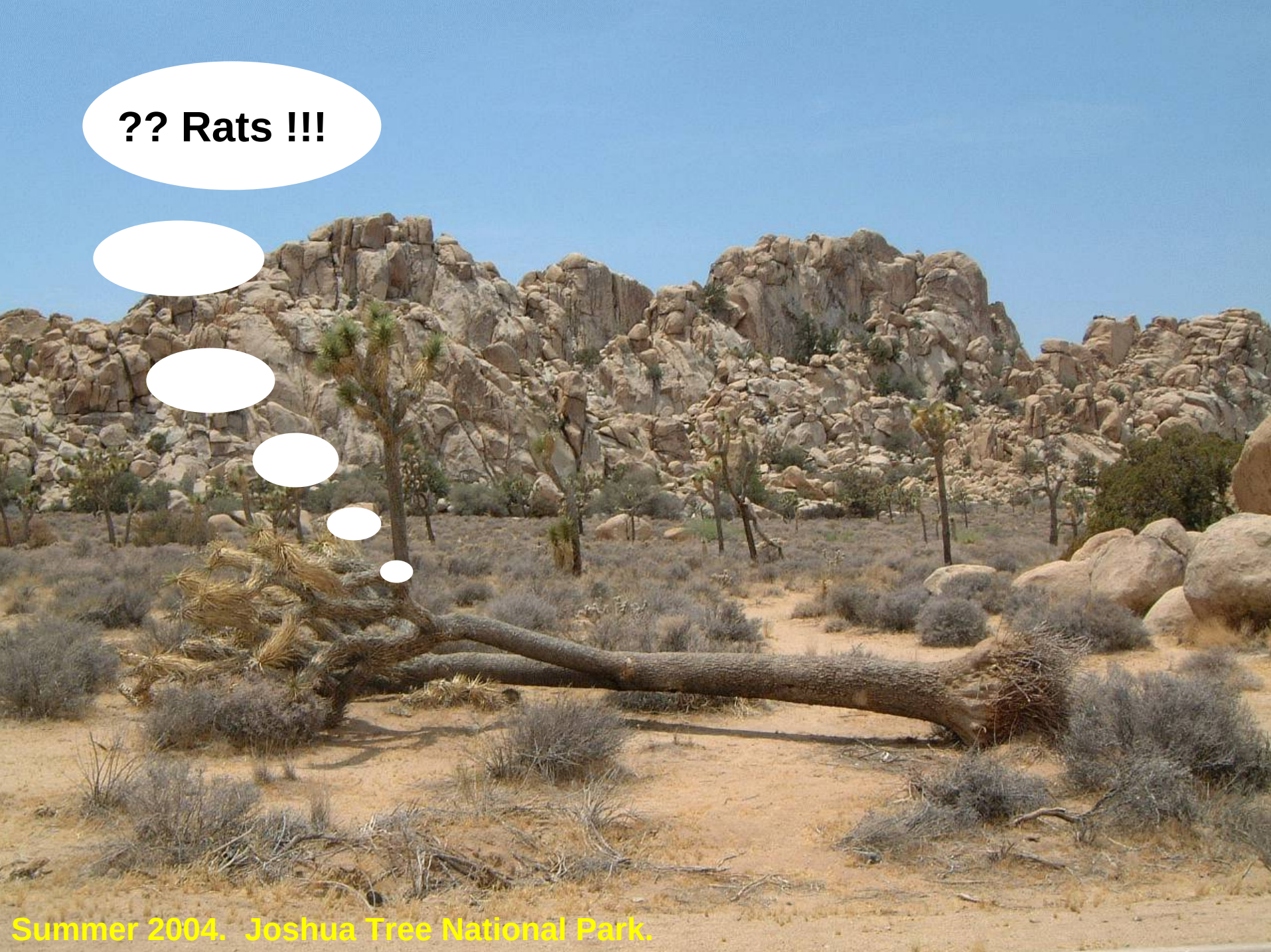
Apr 1, 2008

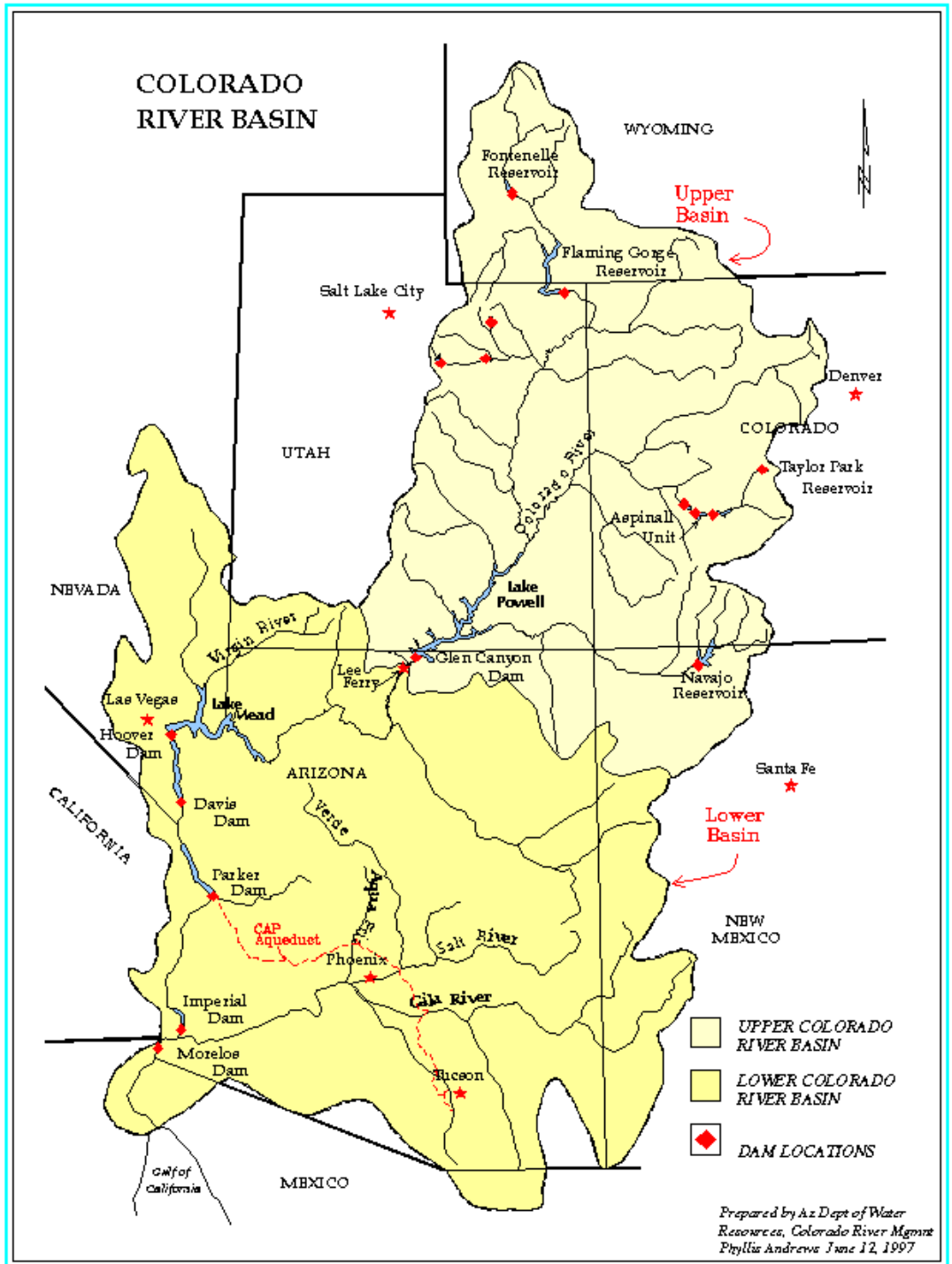
2004

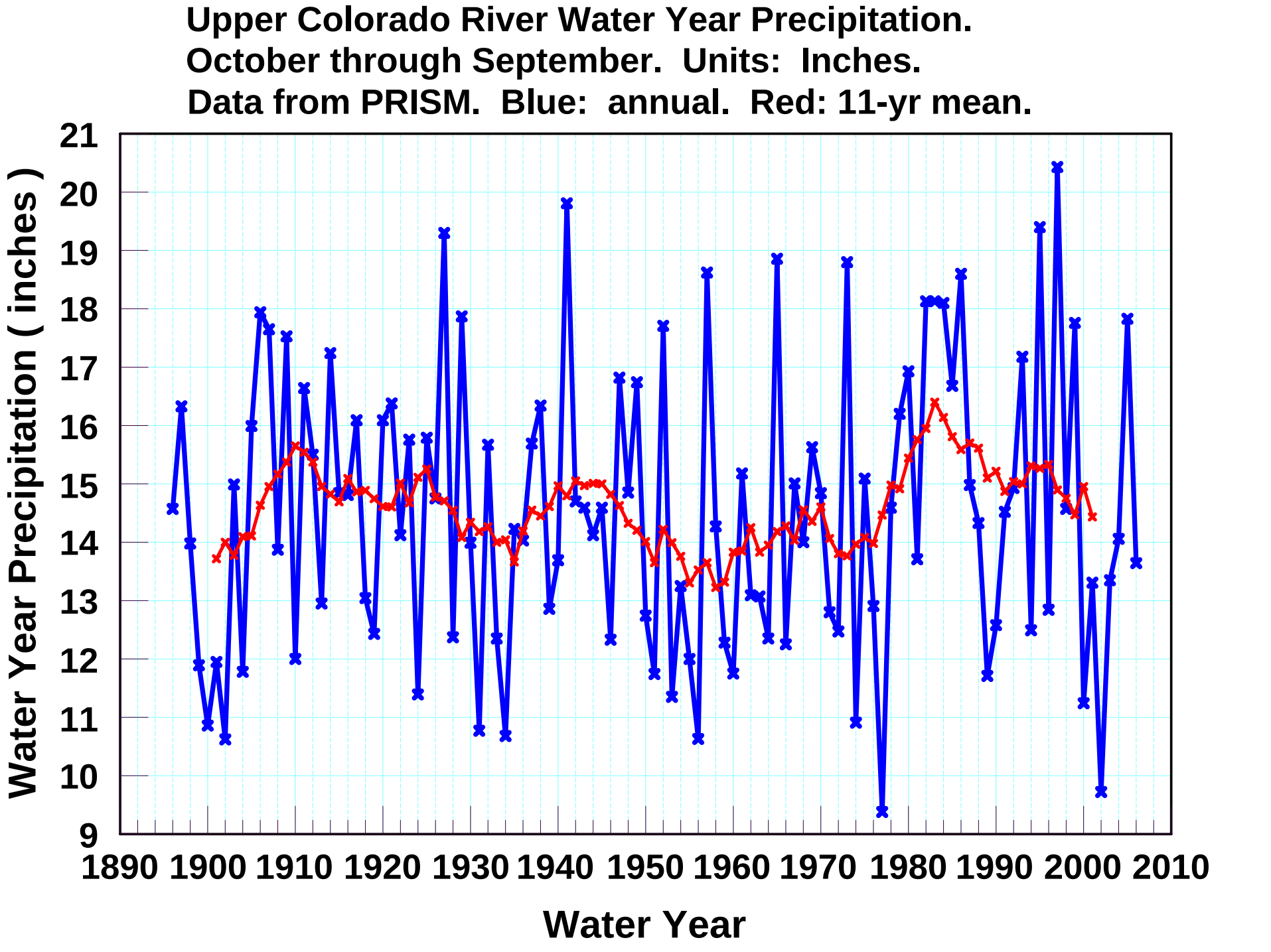
If a natural system experiences dry conditions,

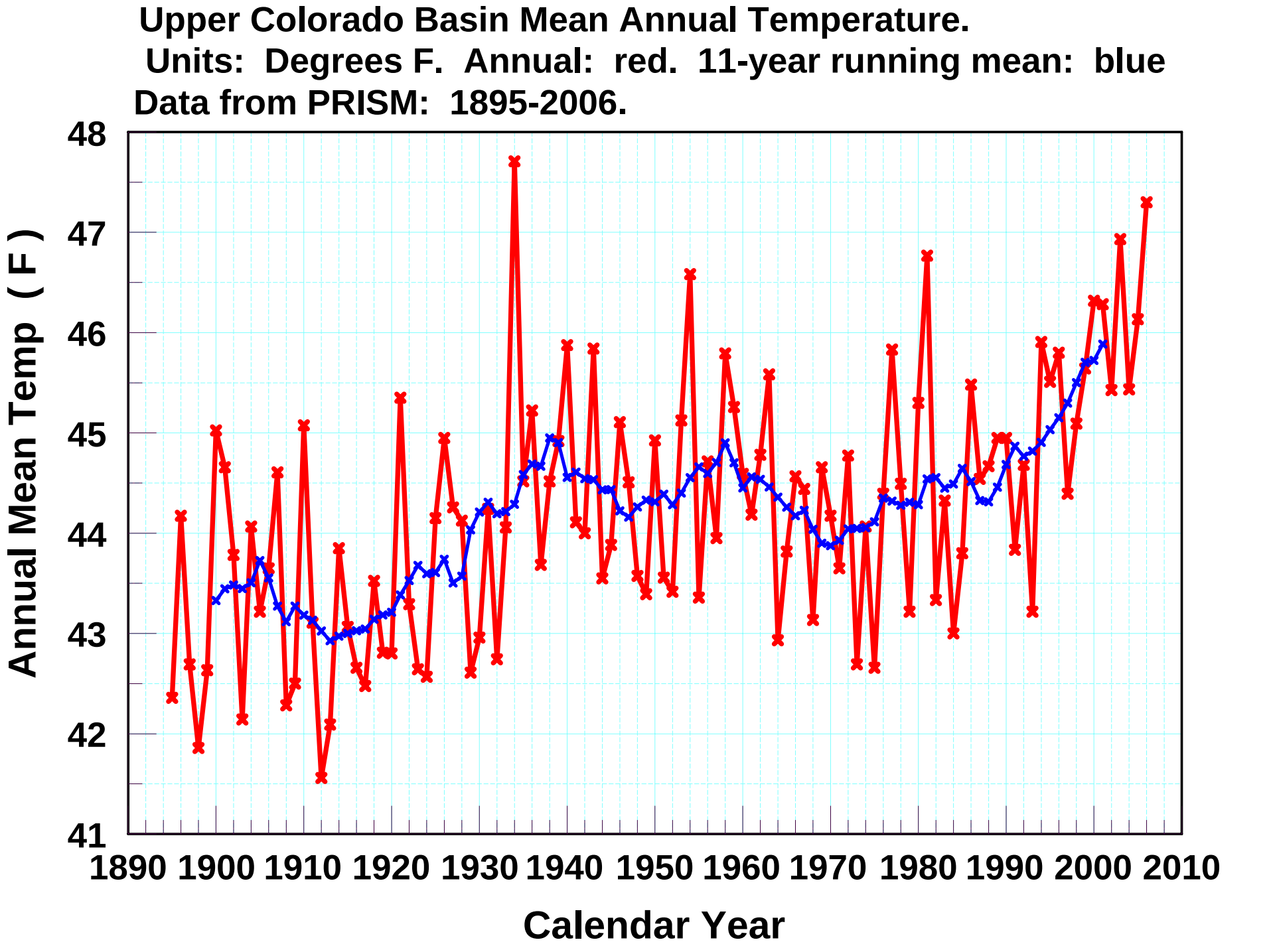
and no one is there to record it,

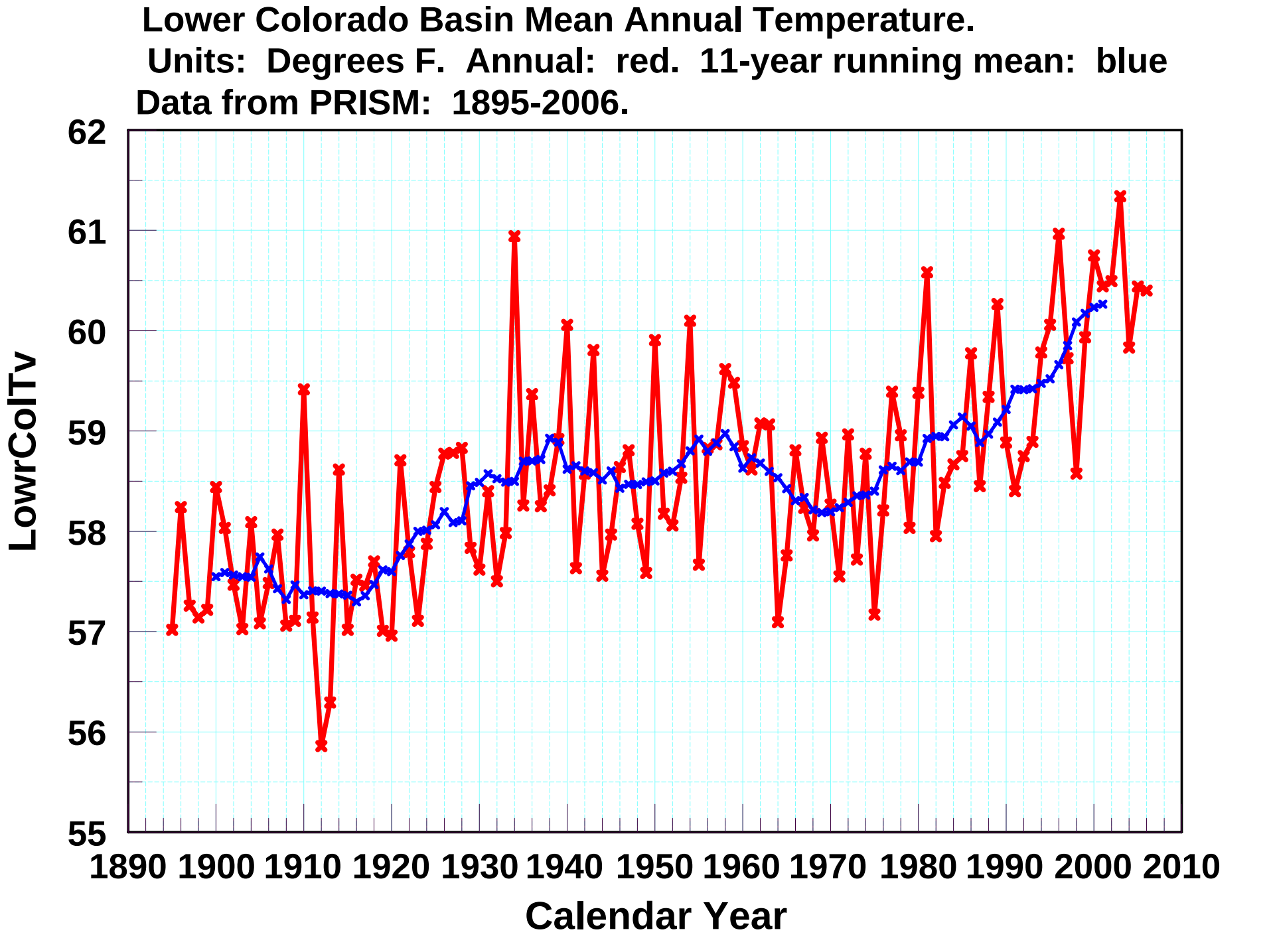
is there drought?


?? Rats !!!
Summer 2004. Joshua Tree National Park.

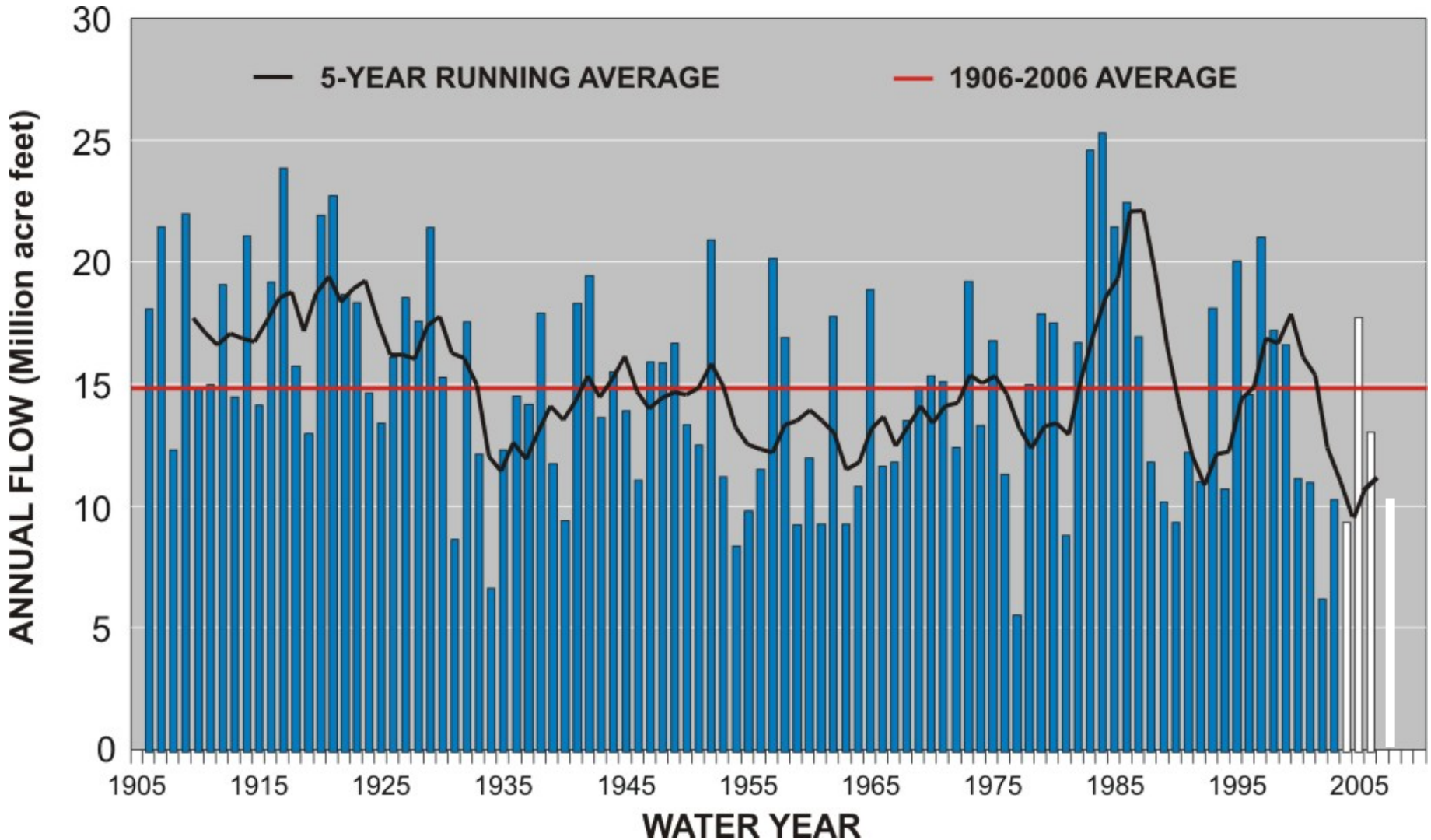

COLORADO
RIVER BASIN
WYOMING
Fontenelle Reservoir
Upper Basin
Flaming Gorge Reservoir
Salt Lake City
Denver
COLORADO
UTAH
Colorado River
Taylor Park Reservoir
Aspinall Unit
NEVADA
Lake Powell
Virgin River
Glen Canyon Dam
Lee Ferry
Navajo Reservoir
Las Vegas
Lake Mead
Hoover Dam
ARIZONA
Santa Fe
Davis Dam
Verde
Lower Basin
CALIFORNIA
Parker Dam
Gila River
CAP Aqueduct
Salt River
NEW MEXICO
Phoenix
Gila River
Imperial Dam
Morelos Dam
Tucson
UPPER COLORADO RIVER BASIN
LOWER COLORADO RIVER BASIN
DAM LOCATIONS
Gulf of California
MEXICO
Prepared by Az Dept of Water Resources, Colorado River Mgmnt
Phyllis Andrews June 12, 1997


Upper Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Water Year Precipitation (inches)
21
20
19
18
17
16
15
14
13
12
11
10
9
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Water Year

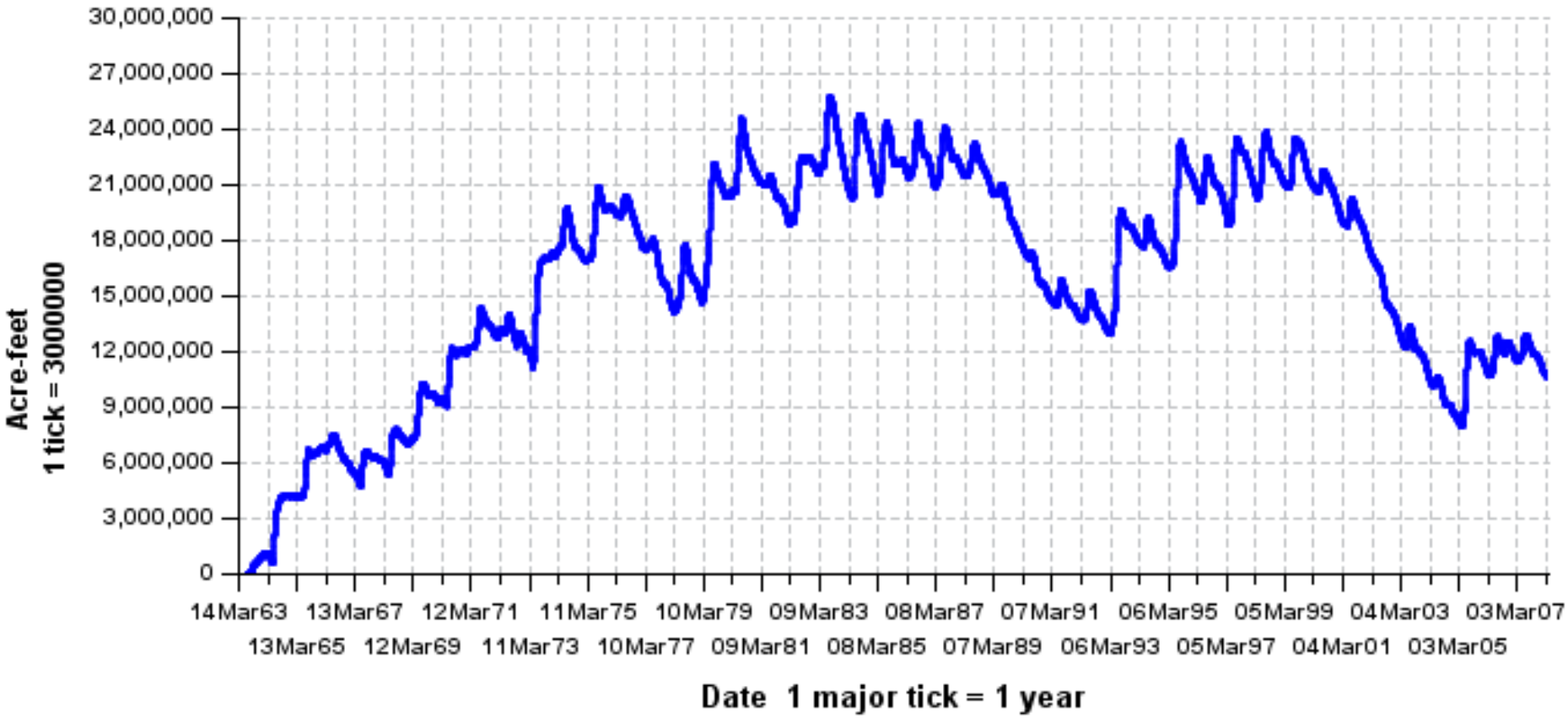

Upper Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2006.
Annual Mean Temp (F)
48
47
46
45
44
43
42
41
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Calendar Year


Lower Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2006.
LowrColTv
62
61
60
59
58
57
56
55
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Calendar Year

Reconstructed natural flow at Lees Ferry. Water Years 1906-2006. White: preliminary estimates.
Running mean plotted at end of 5-year period.
WY 2006-07 estimate (Aug 07) approx 69 percent



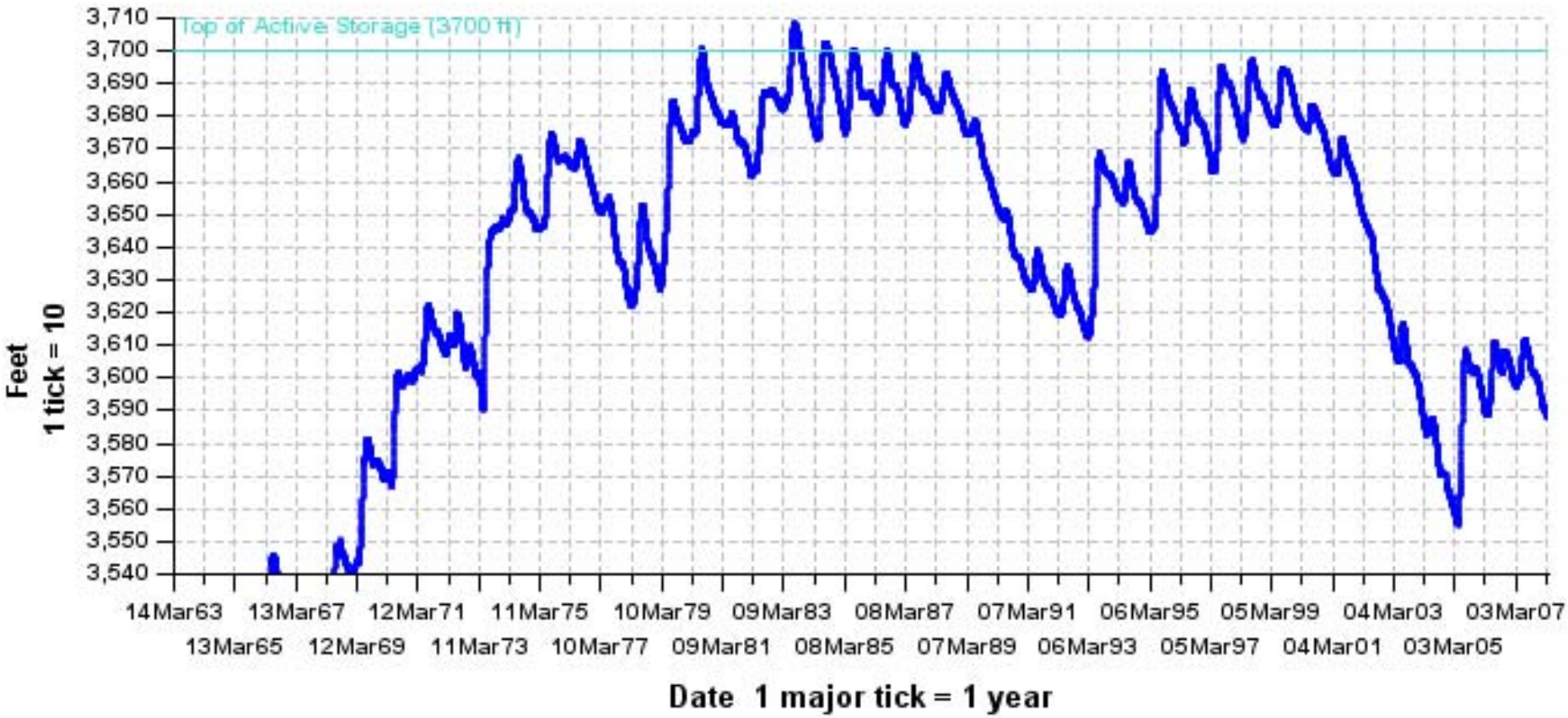
Lake Powell Storage Through Apr 3, 2008



Currently 45 % full

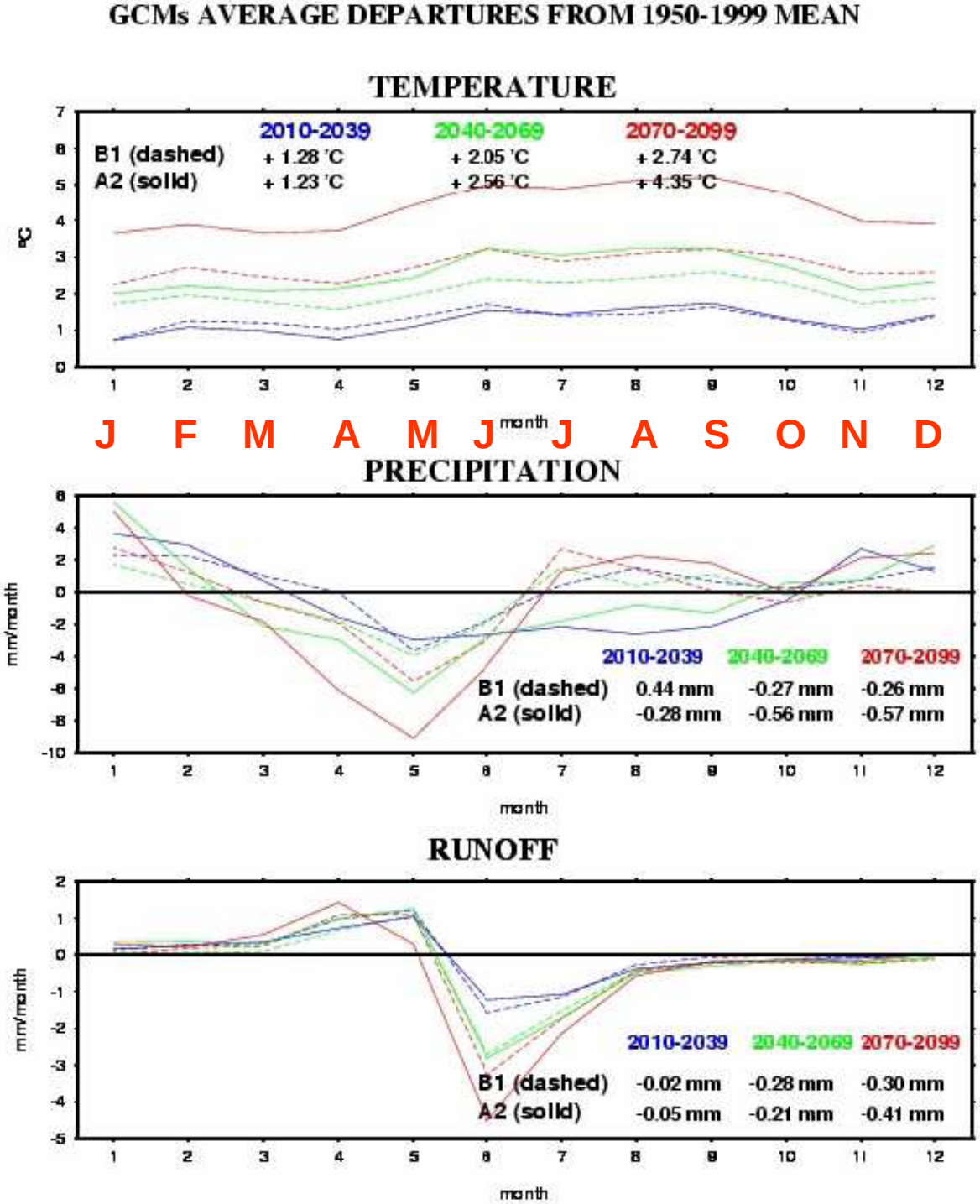
Minimum: 33 % full on April 8, 2005

Lake Powell Elevation Through Apr 5, 2008



Water level on Apr 5, 2008 was 3590.34 ft, -109.66 ft below full.
Minimum level on April 8, 2005 was 3555 ft, -145 ft below full.

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



11-Model Consensus
2 Scenarios

Colorado River Basin

By Month

3 Future Periods

From Christensen and Lettenmaier, in review, 2007

PER 1: 2010-2039 PER 2: 2040-2069 PER 3: 2070-2099

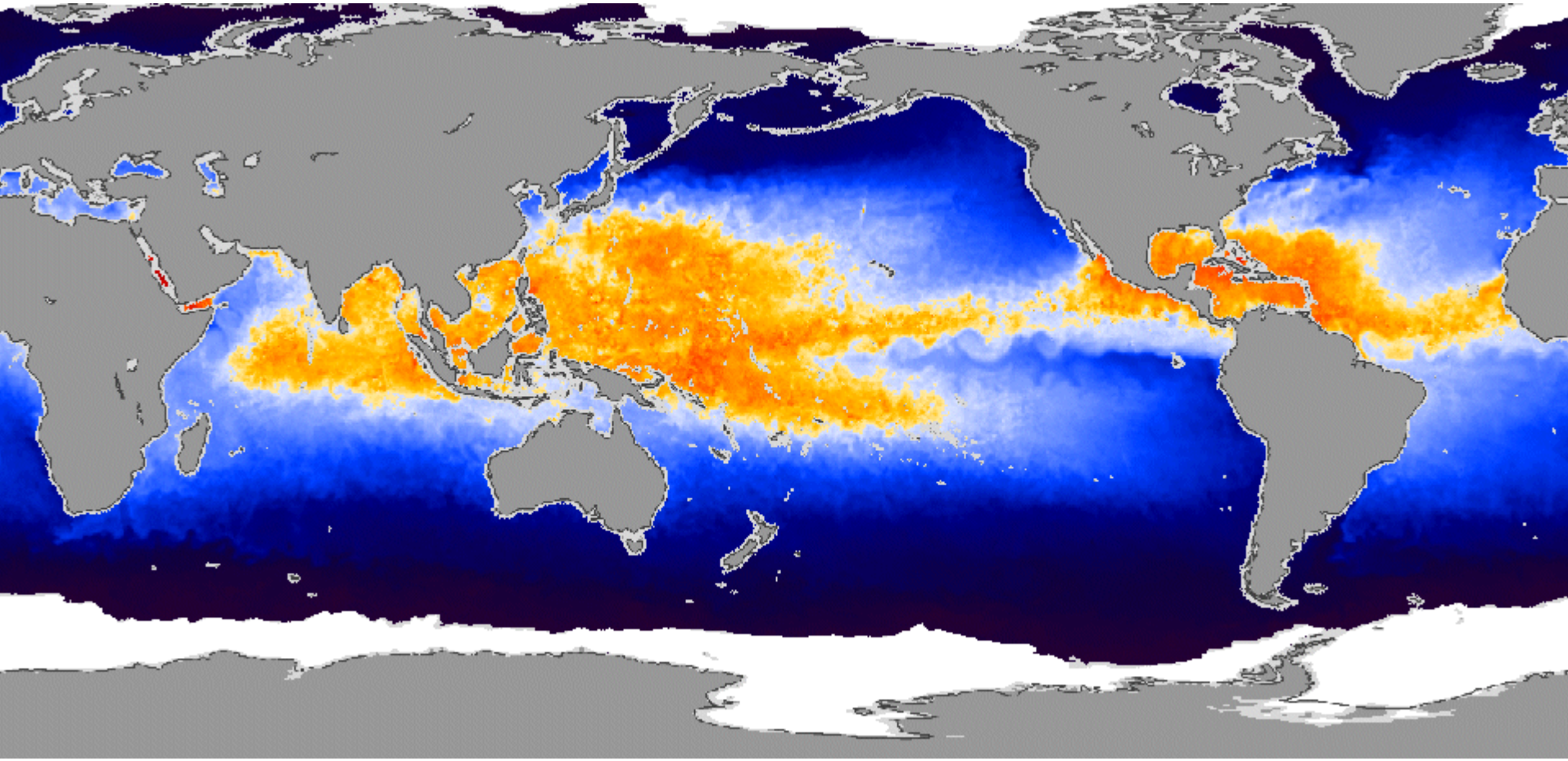
2020 2050 2080

Table 2. Annual average precipitation, evaporation, and runoff (in mm/year), runoff ratio, and basin average temperature (°C).

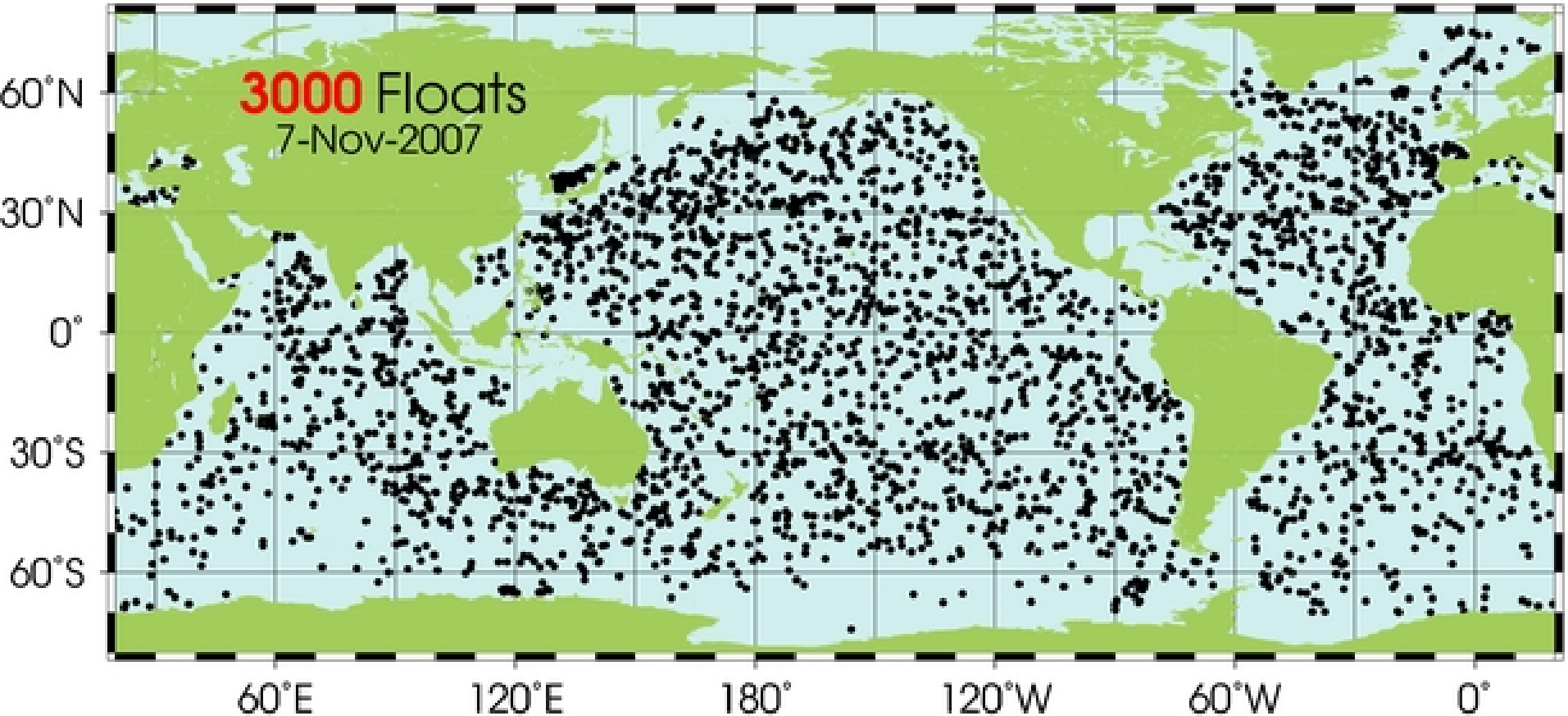
Scenario, Per	Precip. (percent change relative to historic)	Evap. (percent change relative to historic)	Runoff (percent change relative to historic)	Runoff Ratio (percent change relative to historic)	Temp (°C relative to historic)
HISTORIC	354 mm/yr.	309 mm/yr.	45.2 mm/yr.	12.8 %	10.5 °C
B1 / PER 1	360 (+1%)	315 (+2%)	45.0 (0%)	12.5 (-2%)	11.8 (+ 1.3°C)
B1 / PER 2	351 (-1%)	310 (0%)	41.8 (-7%)	11.9 (-7%)	12.6 (+ 2.1°C)
B1 / PER 3	351 (-1%)	309 (0%)	41.6 (-8%)	11.8 (-8%)	13.2 (+ 2.7°C)
A2 / PER 1	351 (-1%)	307 (-1%)	44.6 (-1%)	12.7 (-1%)	11.8 (+ 1.2°C)
A2 / PER 2	348 (-2%)	305 (-1%)	42.7 (-6%)	12.2 (-5%)	13.1 (+ 2.6°C)
A2 / PER 3	347 (-2%)	306 (-1%)	40.3 (-11%)	11.6 (-10%)	14.9 (+ 4.4°C)

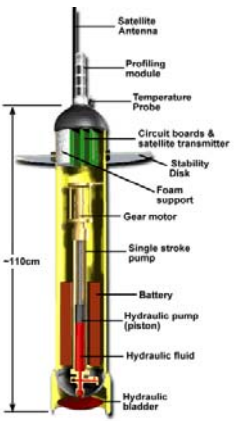
Niklas Christensen and Dennis Lettenmaier, A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. Hydrology and Earth System Sciences, in review period, 2007, online journal: http://www.hydro.washington.edu/SurfaceWaterGroup/Publications/hessd-2006-0147-tx.pdf

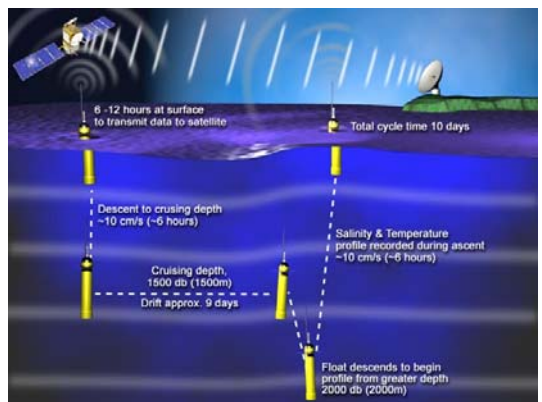
The World’s Warm Oceans

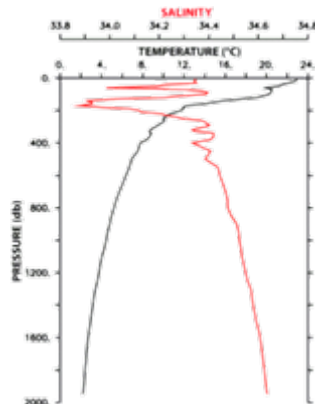


2007 November. 3000-th Argo float deployed.

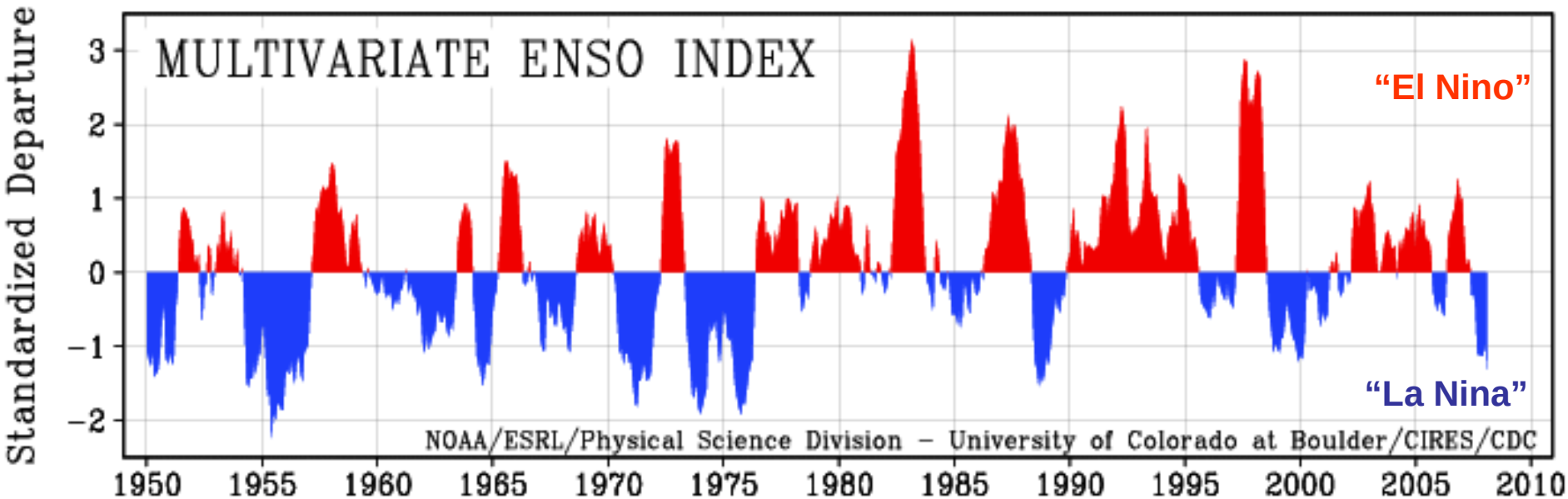






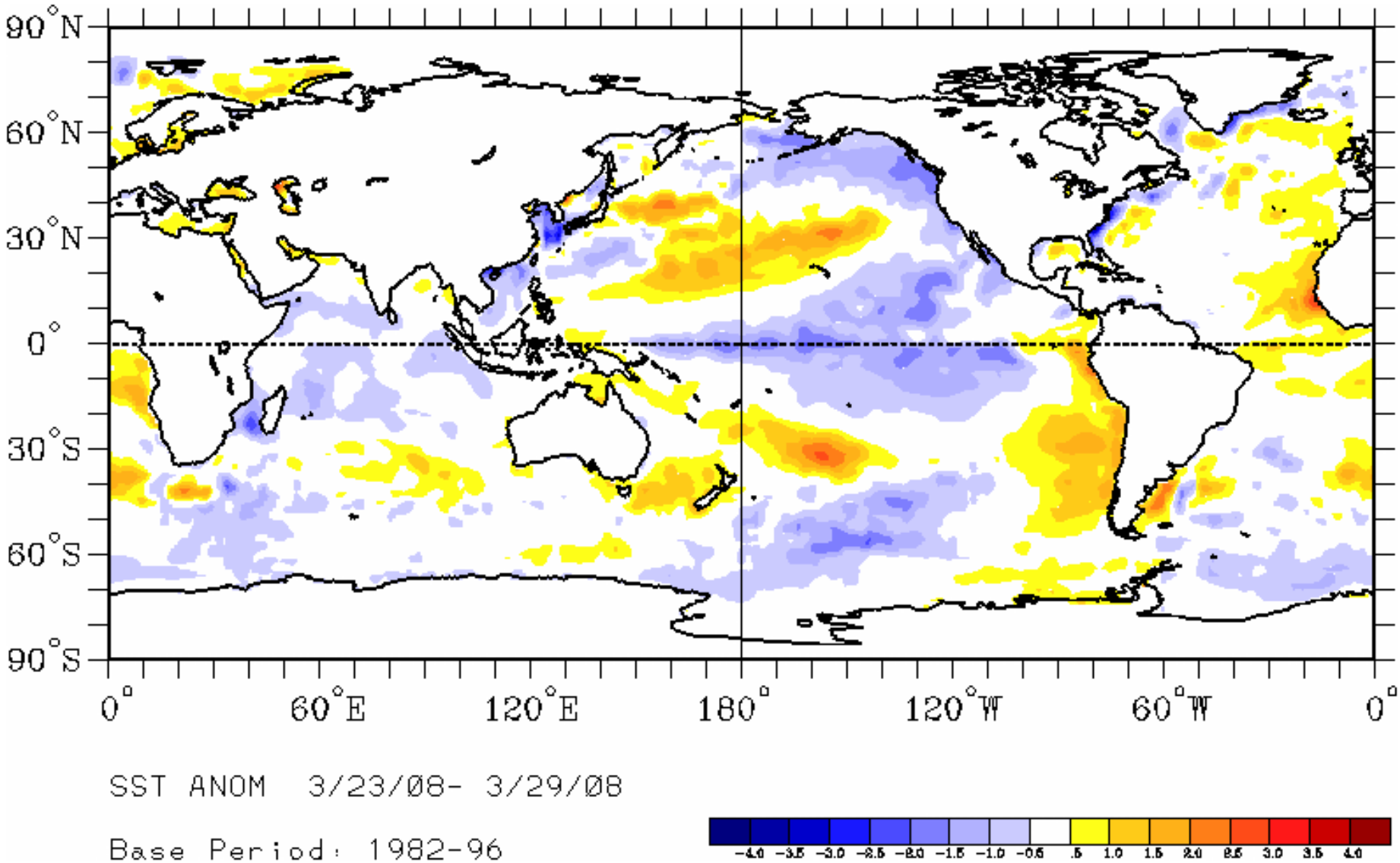


Through February 2008



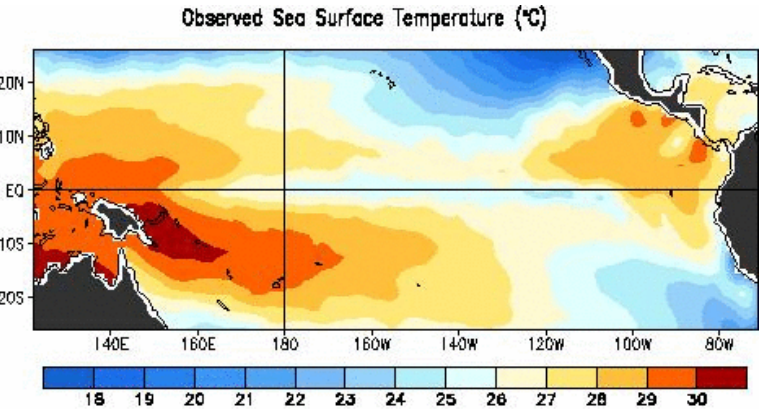
NOAA ESRL ("CDC"), Wolter and Timlin

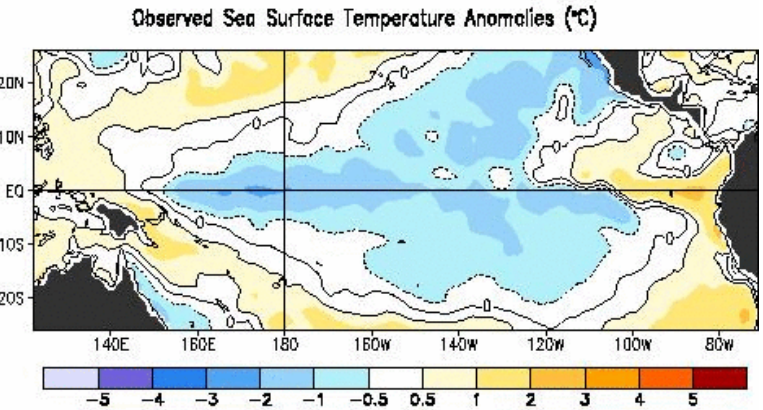
Global Sea Surface Temperature Anomalies (C) 2008 March 23-29

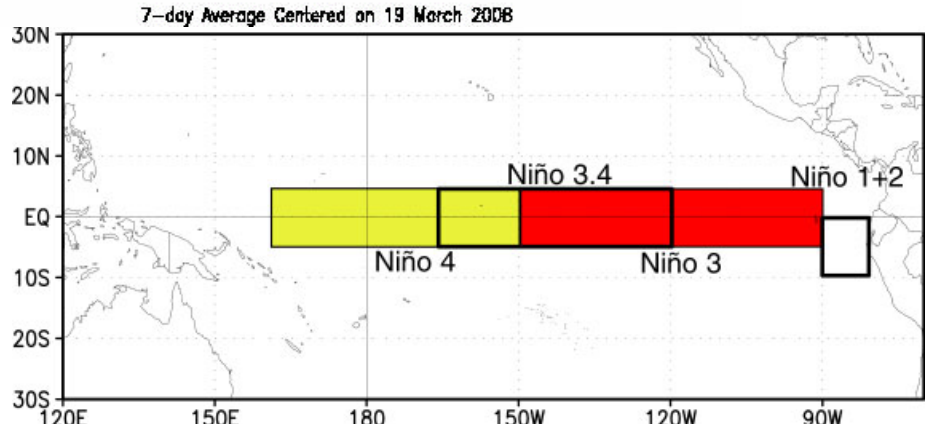


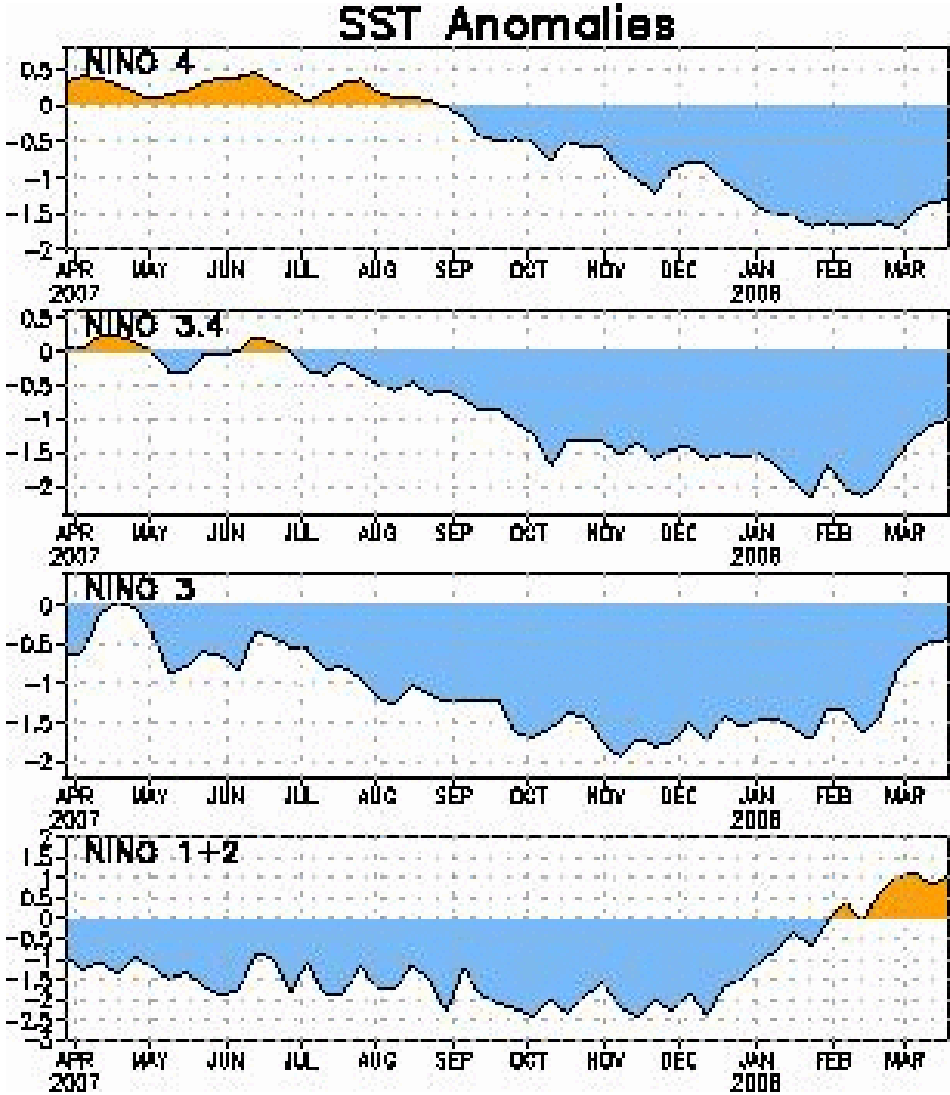
NOAA ESRL (“CDC”)

Recent Evolution of Equatorial Pacific SST Departures

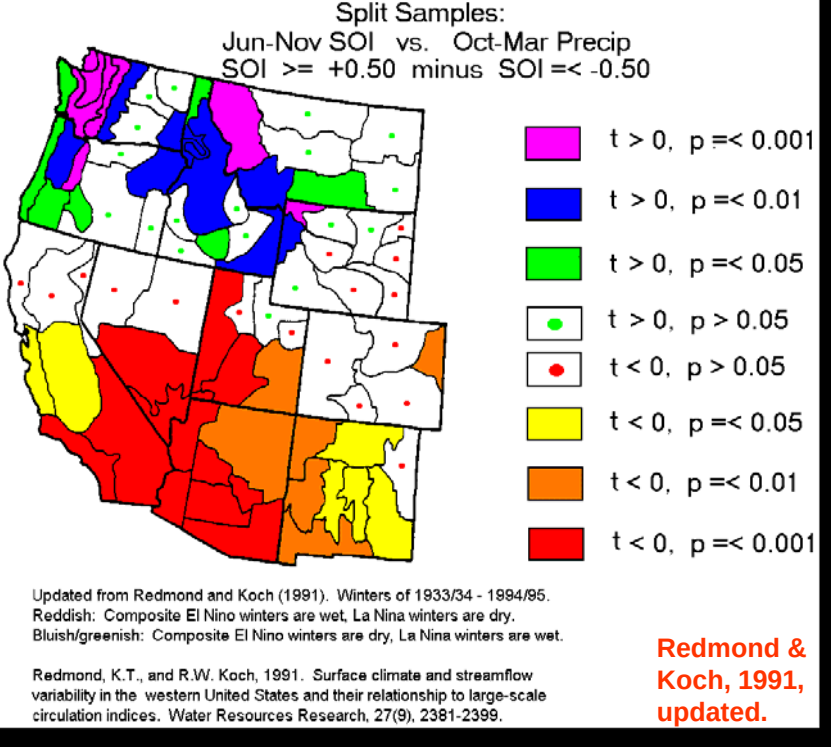


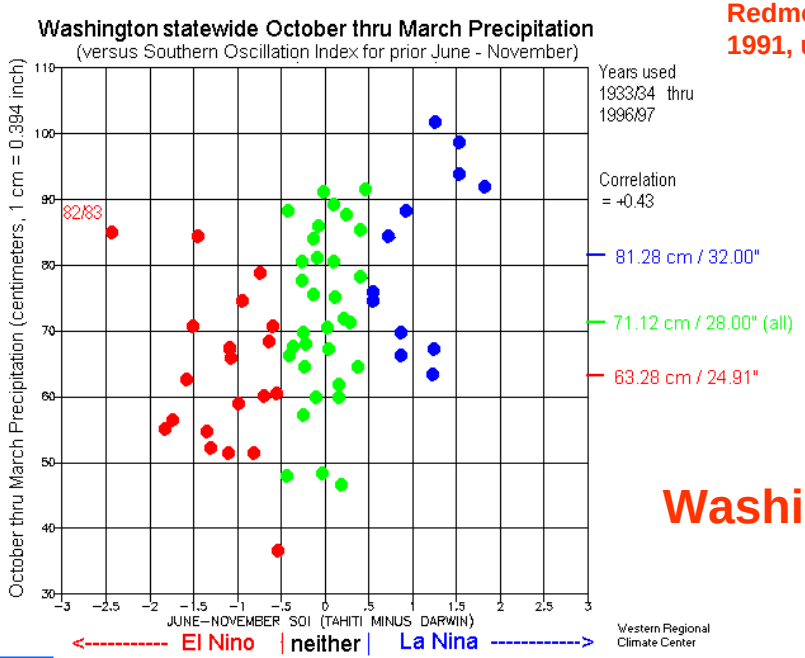




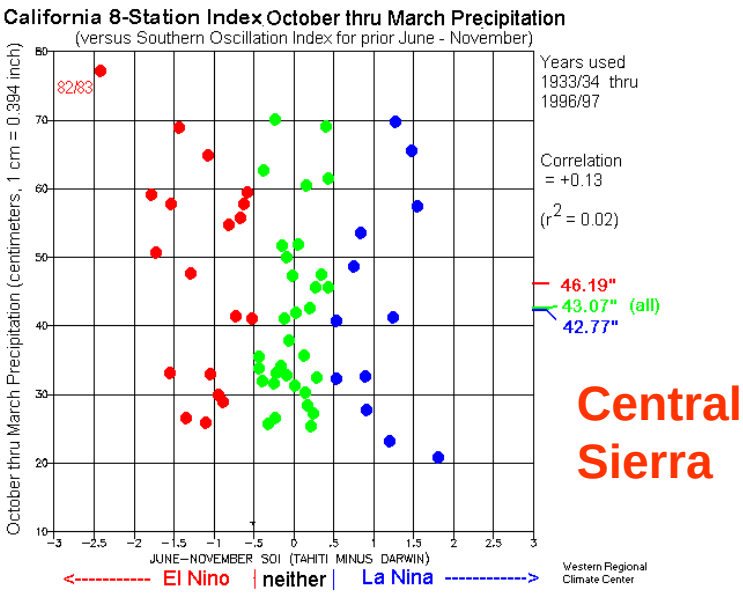


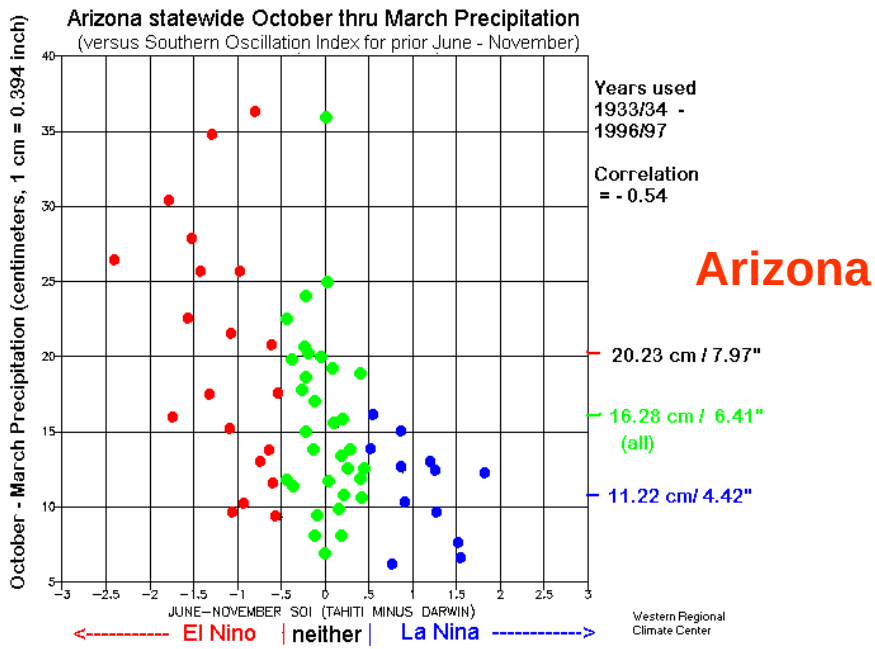
Updated through 2008 March 16-22


Split Samples:
Jun-Nov SOI vs. Oct-Mar Precip
SOI >= +0.50 minus SOI =< -0.50
t > 0, p =< 0.001
t > 0, p =< 0.01
t > 0, p =< 0.05
t > 0, p > 0.05
t < 0, p > 0.05
t < 0, p =< 0.05
t < 0, p =< 0.01
t < 0, p =< 0.001
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.

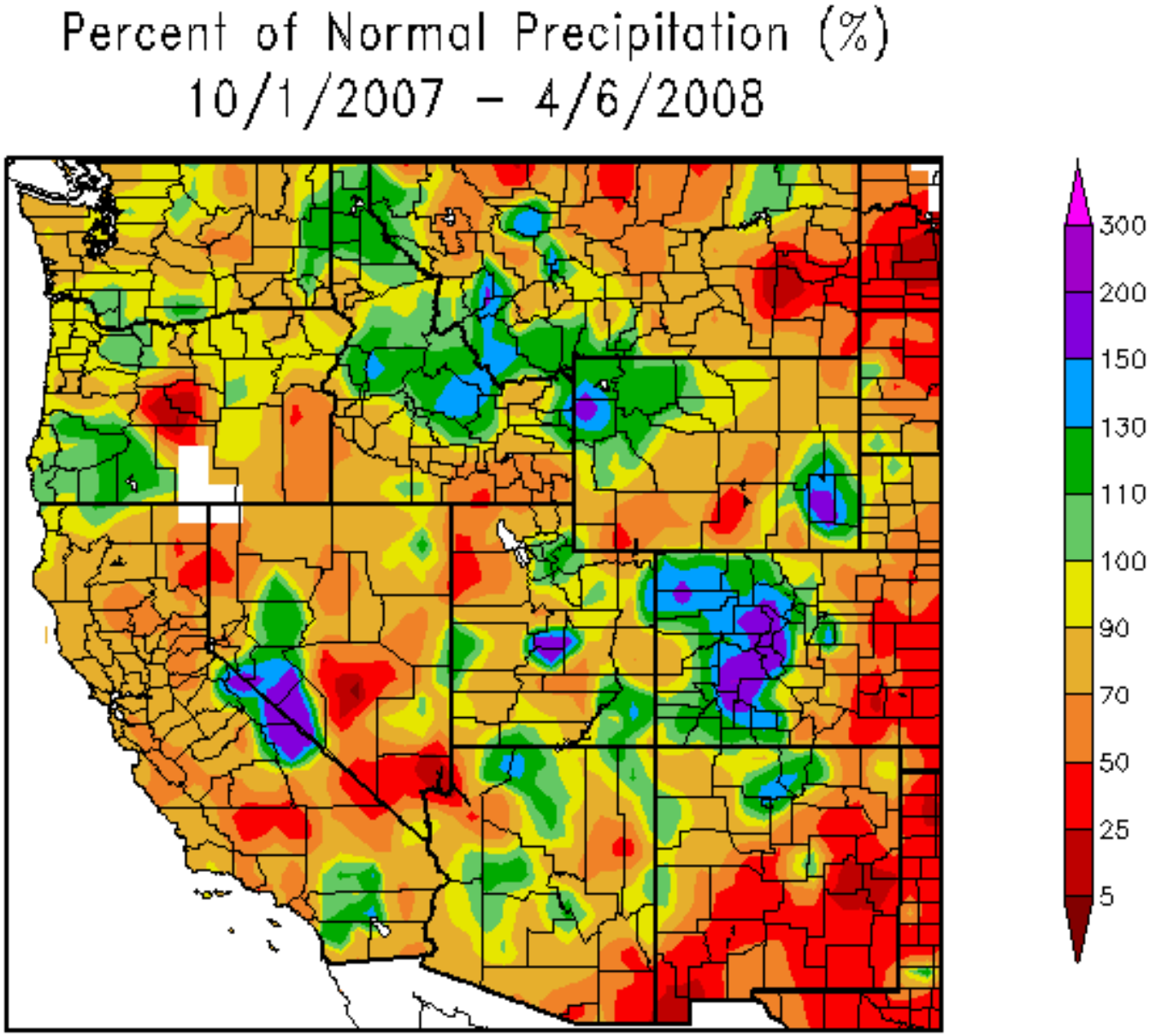

Washington statewide October thru March Precipitation
(versus Southern Oscillation Index for prior June - November)
Redmond & Koch, 1991, updated.
Years used 1933/34 thru 1996/97
Correlation = +0.43
82/83
81.28 cm / 32.00"
71.12 cm / 28.00" (all)
63.28 cm / 24.91"
October thru March Precipitation (centimeters, 1 cm = 0.394 inch)
JUNE–NOVEMBER SOI (TAHITI MINUS DARWIN)
<---------- El Nino | neither | La Nina ---------->
Western Regional Climate Center
Washington

ENSO


California 8-Station Index October thru March Precipitation
(versus Southern Oscillation Index for prior June - November)
Years used 1933/34 thru 1996/97
Correlation = +0.13
(r^2 = 0.02)
82/83
46.19"
43.07" (all)
42.77"
October thru March Precipitation (centimeters, 1 cm = 0.394 inch)
JUNE–NOVEMBER SOI (TAHITI MINUS DARWIN)
<---------- El Nino | neither | La Nina ---------->
Western Regional Climate Center
Central Sierra


Arizona statewide October thru March Precipitation
(versus Southern Oscillation Index for prior June - November)
Years used 1933/34 - 1996/97
Correlation = - 0.54
20.23 cm / 7.97"
16.28 cm / 6.41" (all)
11.22 cm/ 4.42"
October - March Precipitation (centimeters, 1 cm = 0.394 inch)
JUNE–NOVEMBER SOI (TAHITI MINUS DARWIN)
<---------- El Nino | neither | La Nina ---------->
Western Regional Climate Center
Arizona

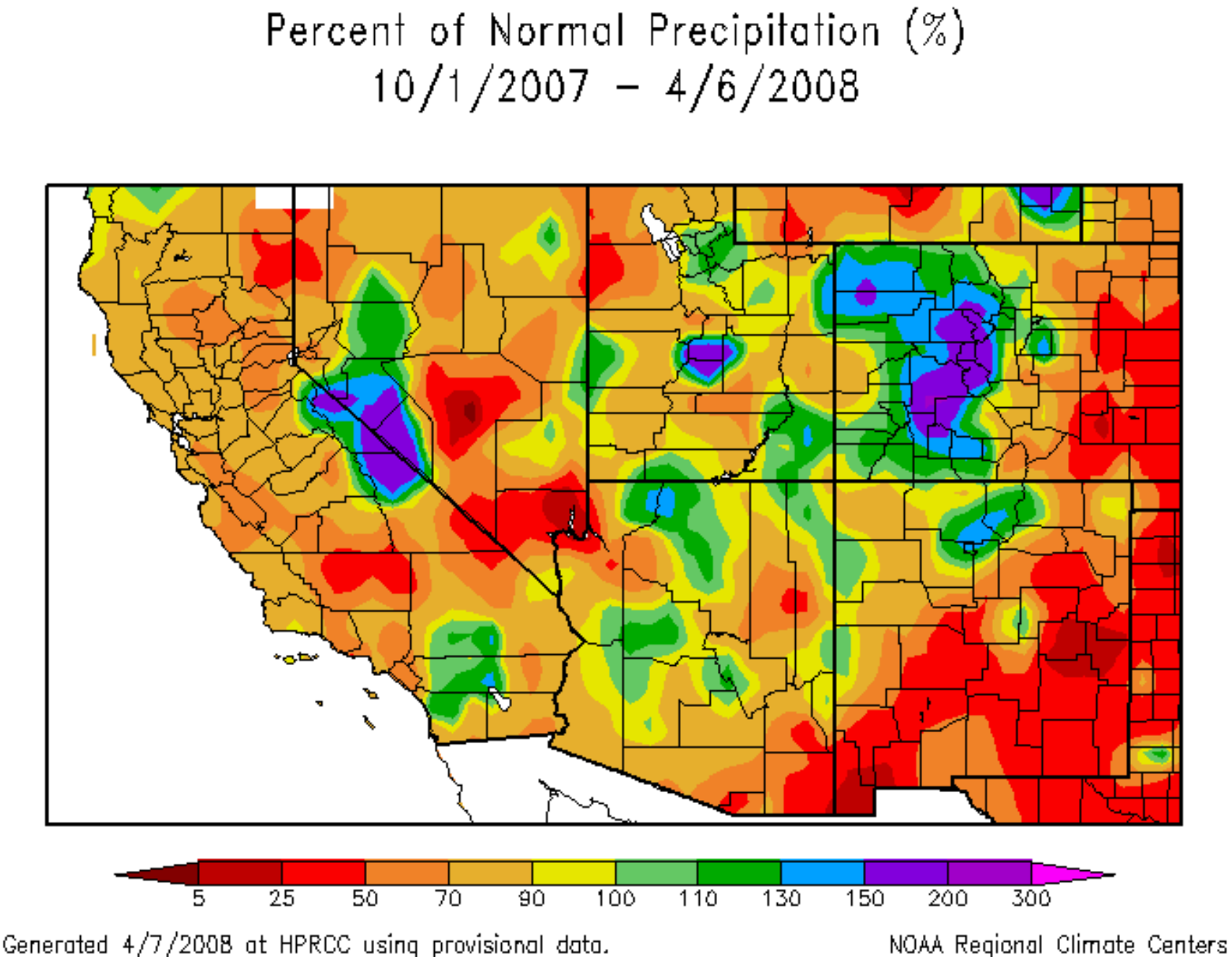
Water Year Precipitation Percentage 2007 October 1 thru 2008 April 6



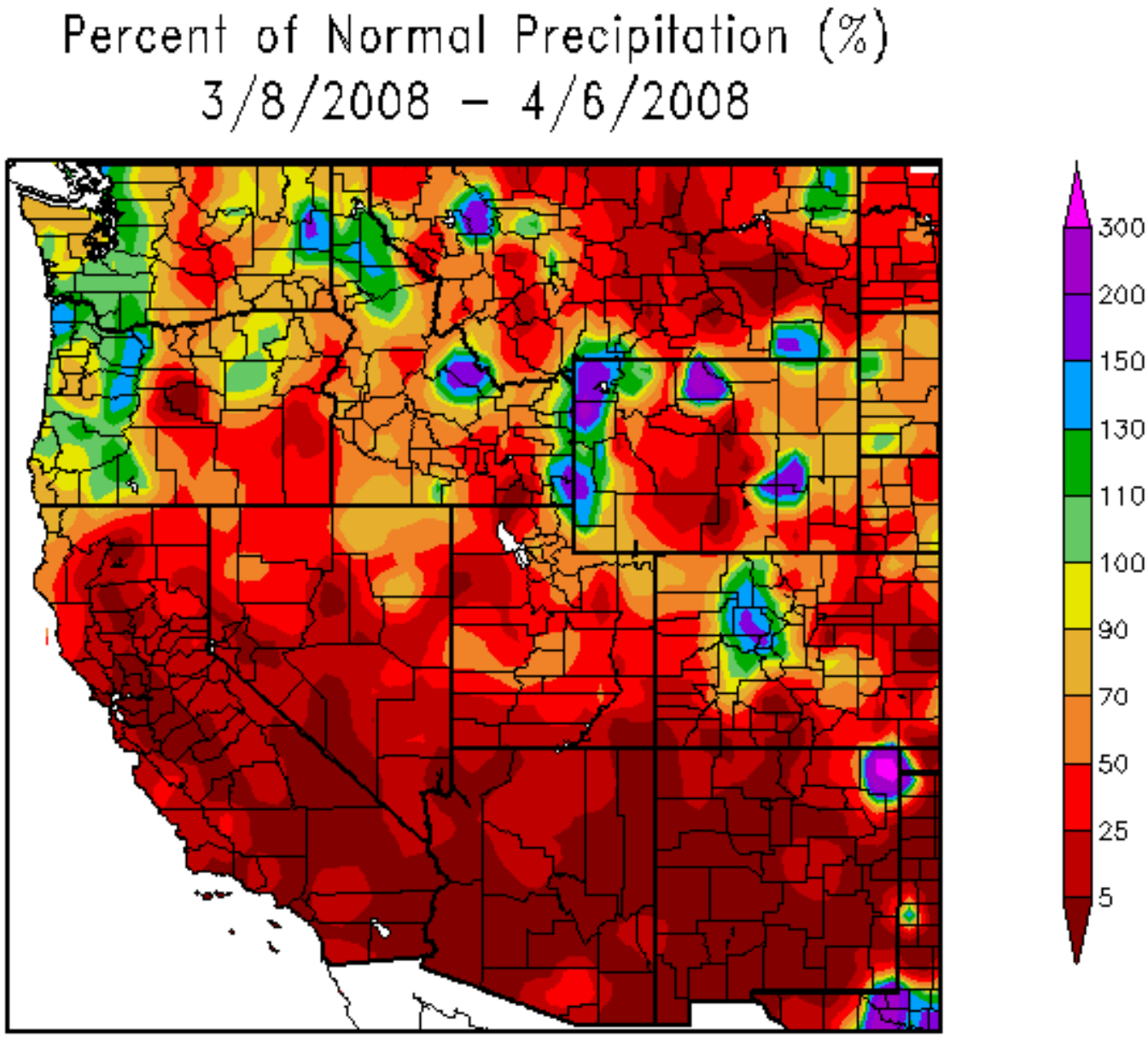
Generated 4/7/2008 at HPRCC using provisional data.

NOAA Regional Climate Centers

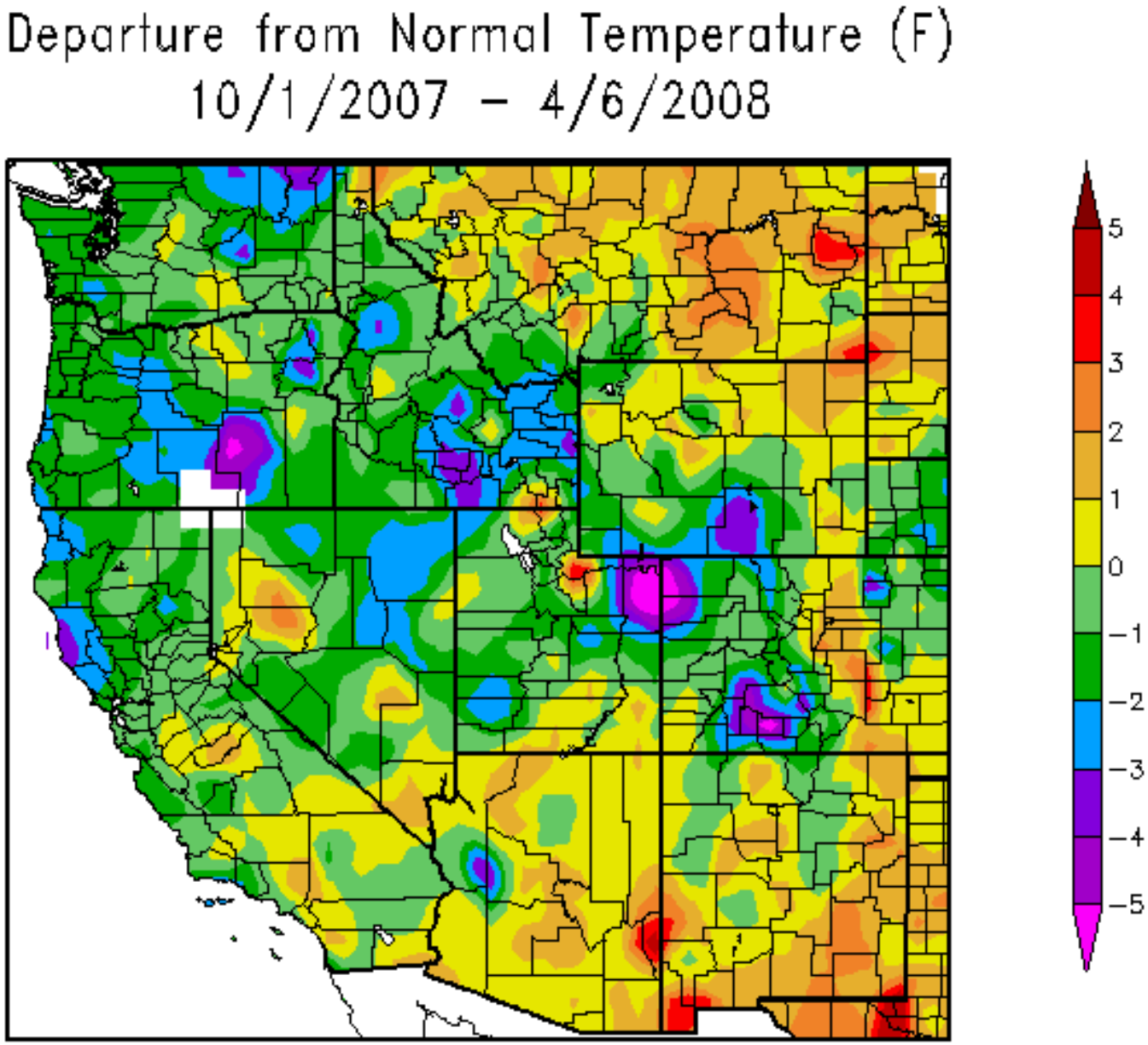
Water Year Precipitation Percentage 2007 October 1 thru 2008 April 6



Water Year Precipitation Percentage 30 Days thru 2008 April 6

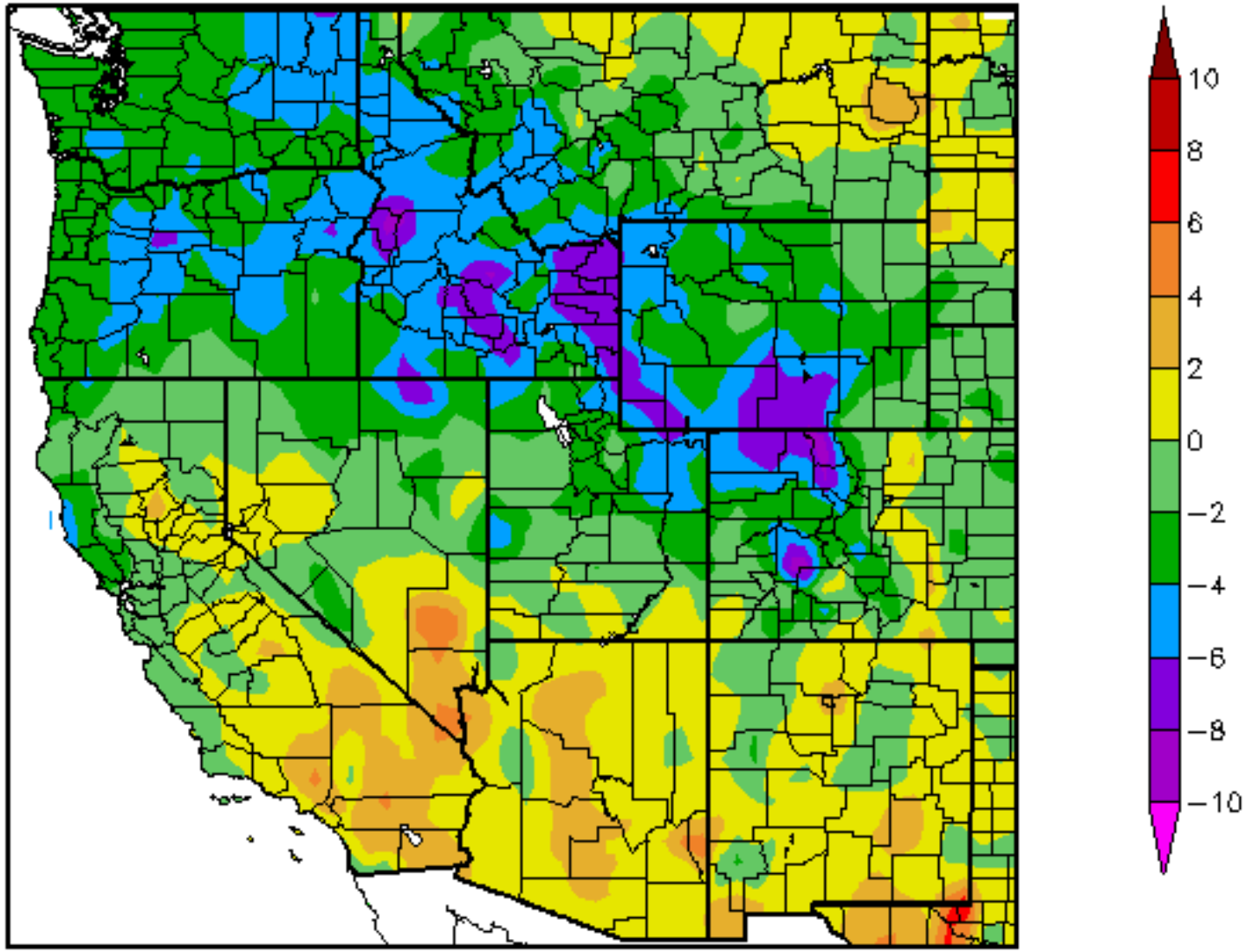


Water Year Temperature Departure 2007 October 1 thru 2008 April 6



Last 30 days
Thru
2008 Apr 05

Departure from Normal Temperature (F)
3/7/2008 – 4/5/2008



Generated 4/6/2008 at HPRCC using provisional data.

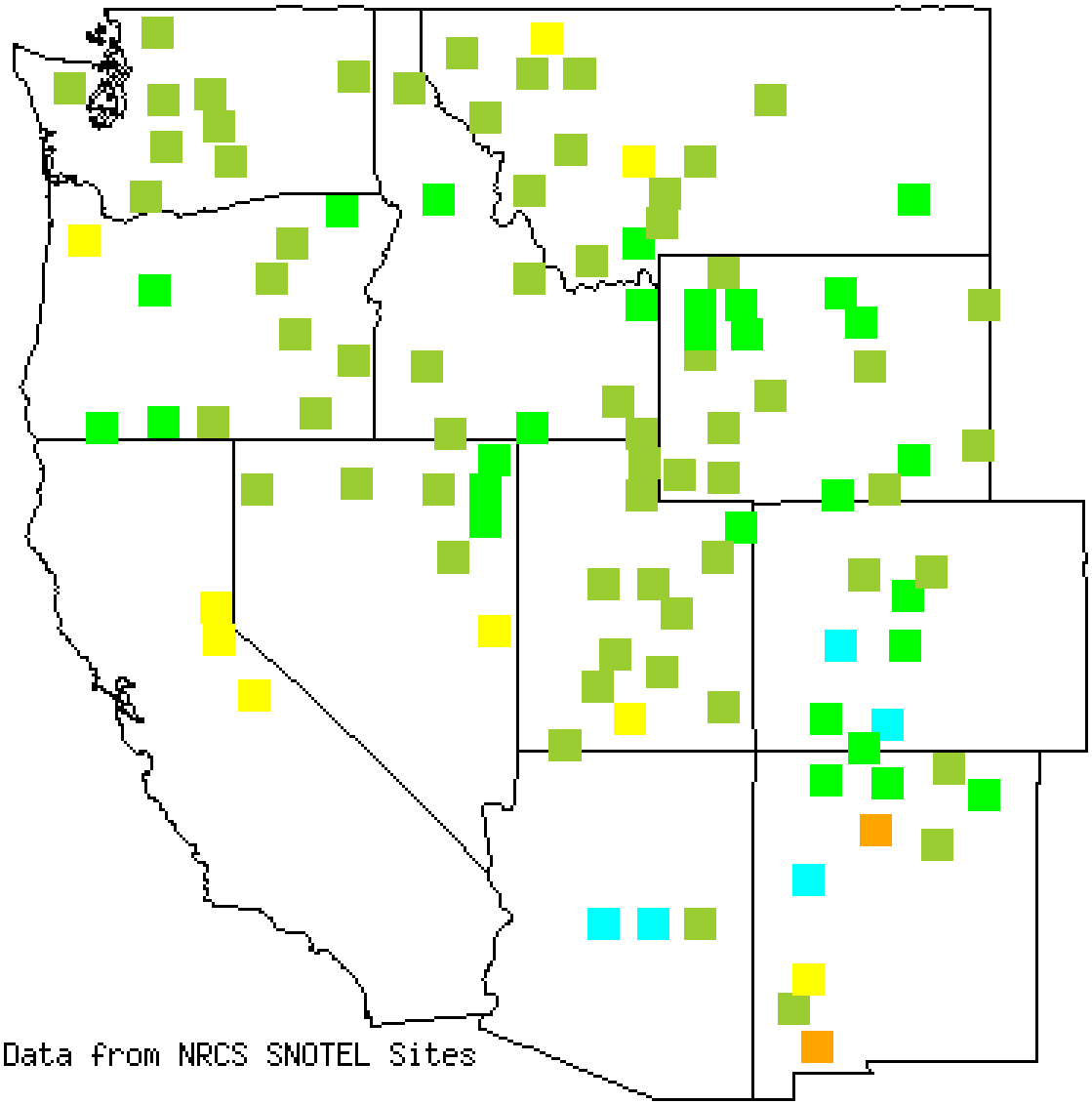
NOAA Regional Climate Centers

River Basin Precipitation

Water Year 2007 Oct 01 thru 2008 Apr 07

Basin Average Precipitation. (% of Average.)

OCTOBER 1 , 2007 thru APRIL 7 , 2008



Percent of Average

- > 200
- 175 to 200
- 150 to 175
- 125 to 150
- 110 to 125
- 90 to 110
- 75 to 90
- 50 to 75
- 25 to 50
- < 25

Report Date:

APRIL 7 , 2008

Provisional Data
Based on Mountain Data from NRCS SNOTEL Sites

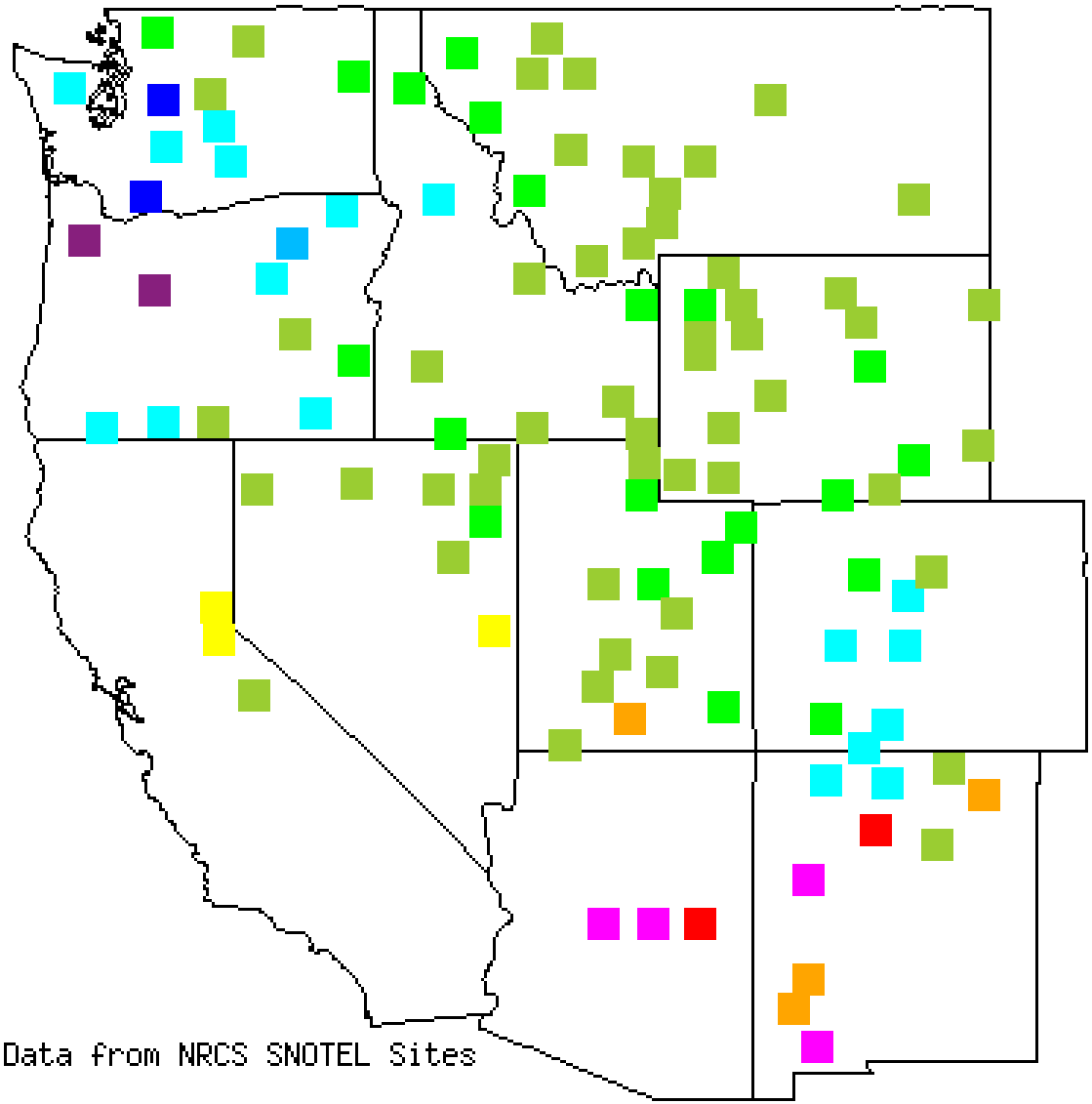
Data provided by
Water and Climate Center
Natural Resources Conservation Service
Portland, Oregon

Western Regional Climate Center
Desert Research Institute
Reno, Nevada

River Basin Snowpack

2008 Apr 07

Basin Average Snow Water Content. (% of Average.)



Percent of Average

- > 200
- 175 to 200
- 150 to 175
- 125 to 150
- 110 to 125
- 90 to 110
- 75 to 90
- 50 to 75
- 25 to 50
- < 25

Report Date:

APRIL 7 , 2008

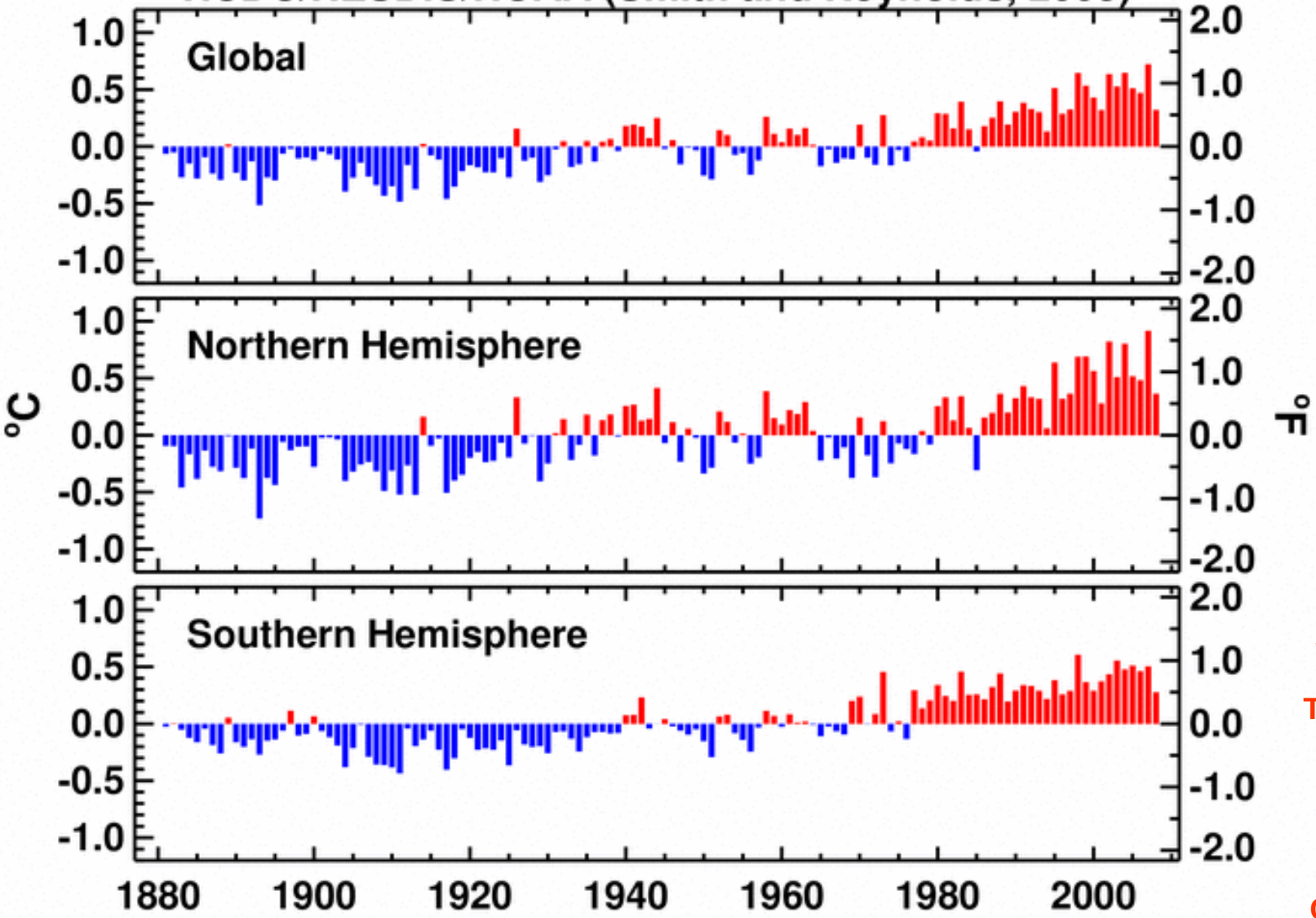
Provisional Data
Based on Mountain Data from NRCS SNOTEL Sites

Data provided by
Water and Climate Center
Natural Resources Conservation Service
Portland, Oregon

Western Regional Climate Center
Desert Research Institute
Reno, Nevada

Dec-Feb Land & Ocean Surface Mean Temp Anomalies

NCDC/NESDIS/NOAA (Smith and Reynolds, 2005)



Winter (DJF)

Thru Feb 2008

NOAA

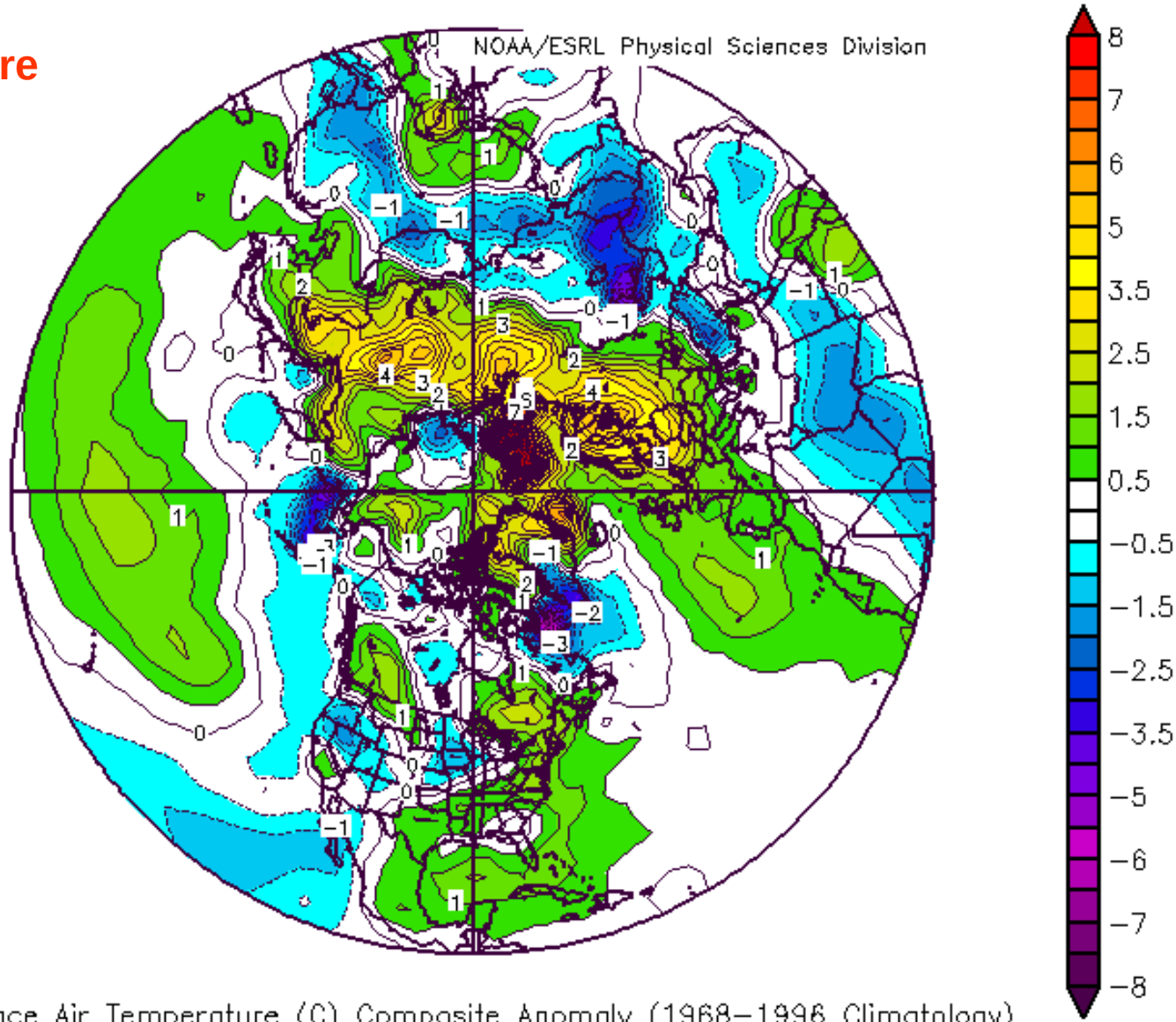
National Climatic Data Center

Winter 2007-2008
Dec 01 – Mar 14

Surface Temperature

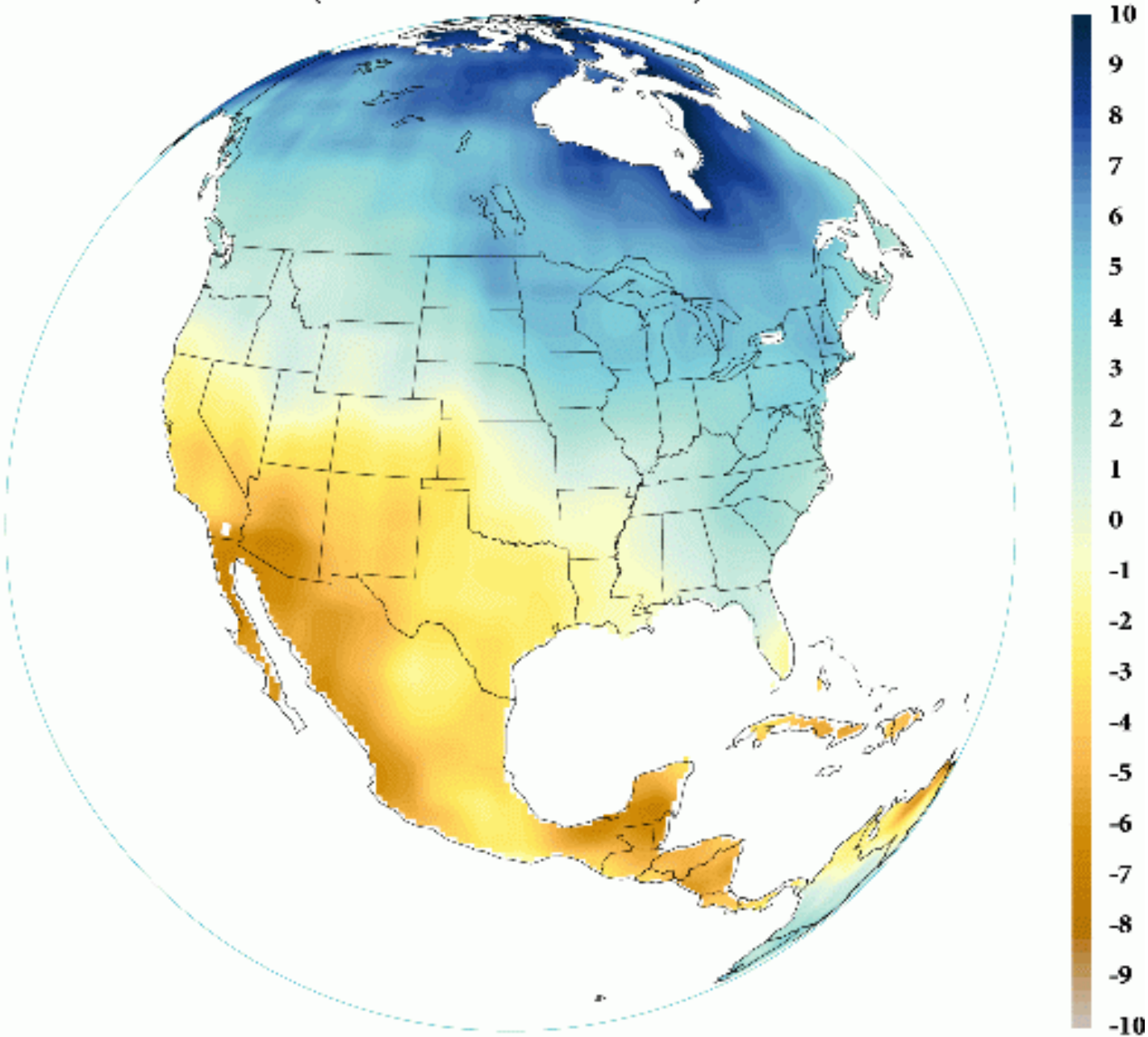
Departure from Climatology (1968-1996)

Reanalysis Data



Surface Air Temperature (C) Composite Anomaly (1968–1996 Climatology)
12/1/07 to 3/14/08
NCEP/NCAR Reanalysis

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

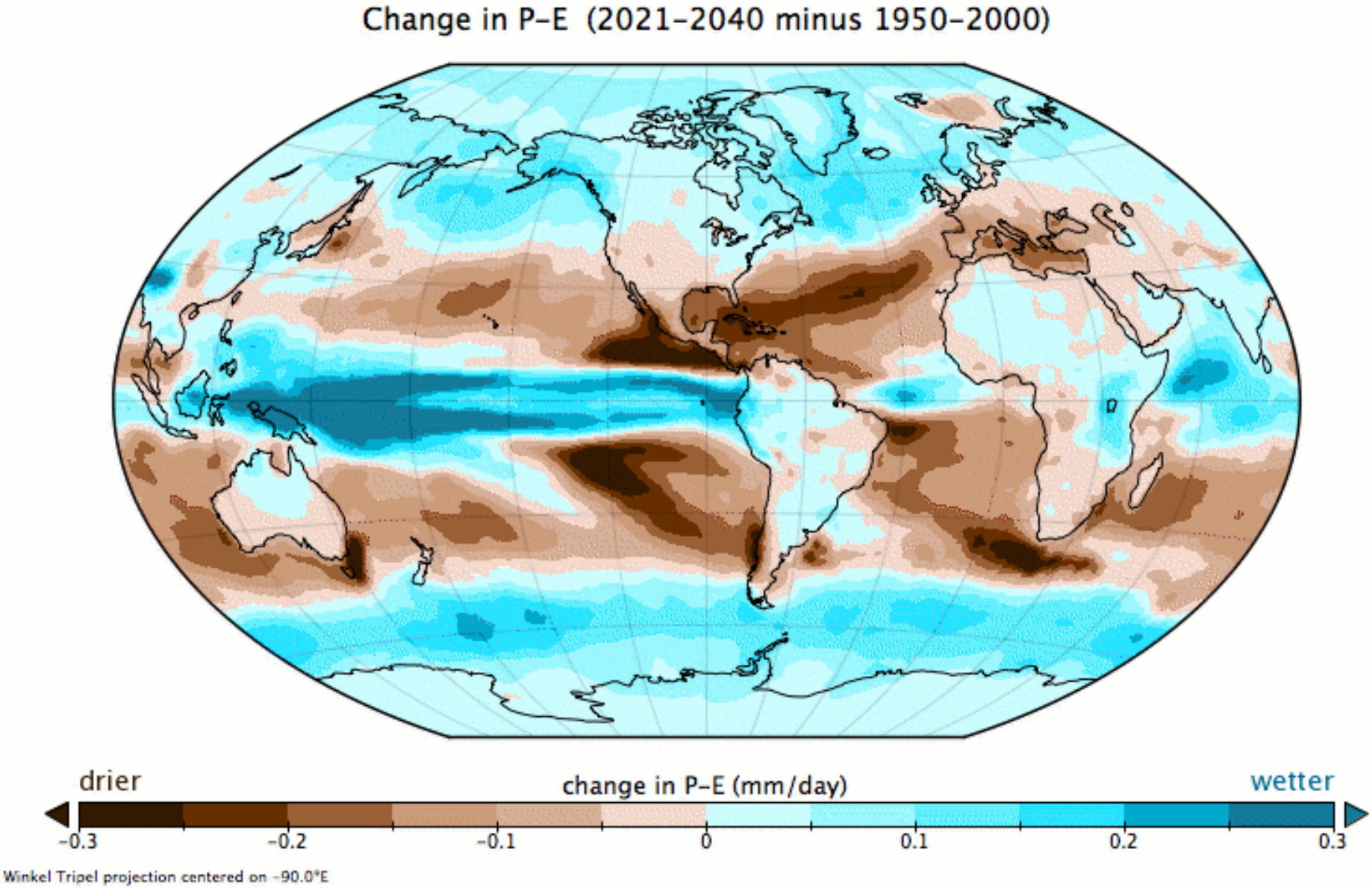


Average of 19 climate models. 2007.

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

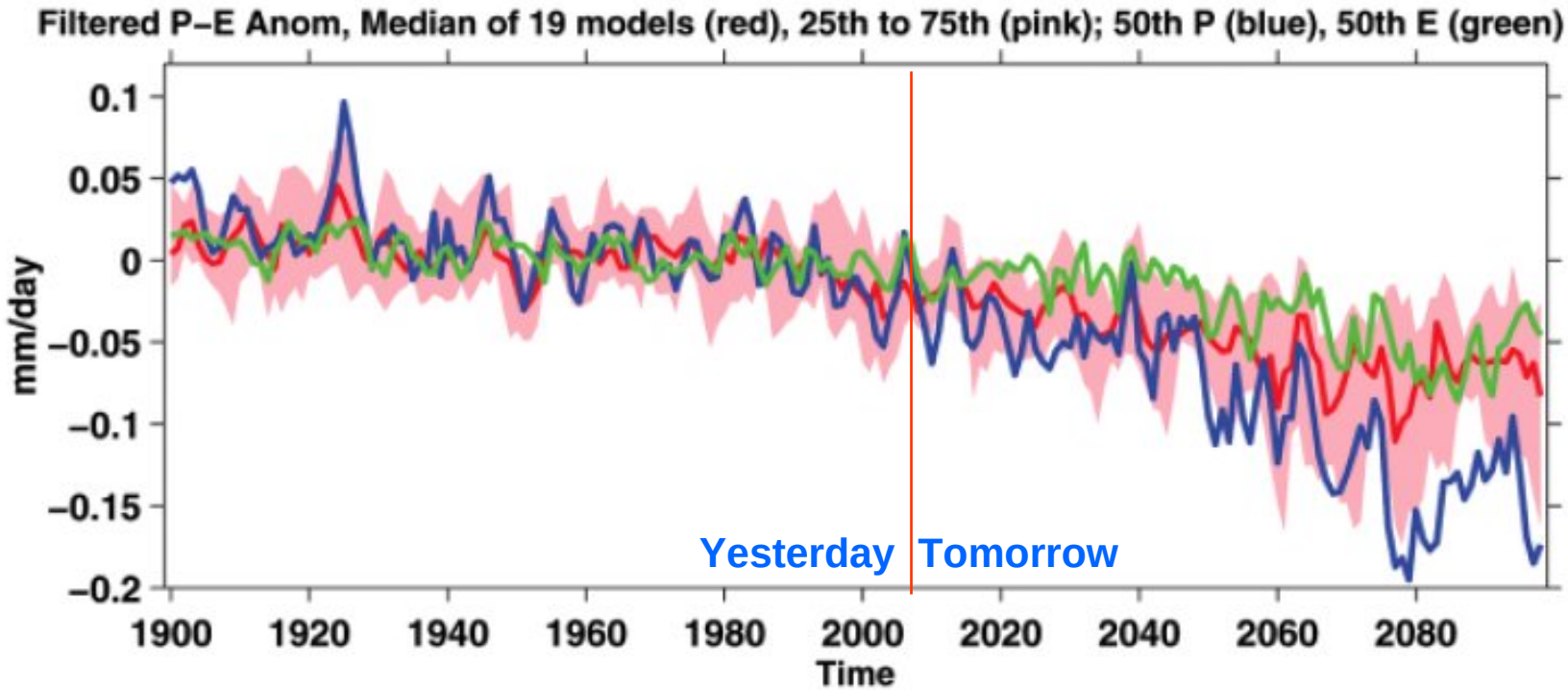
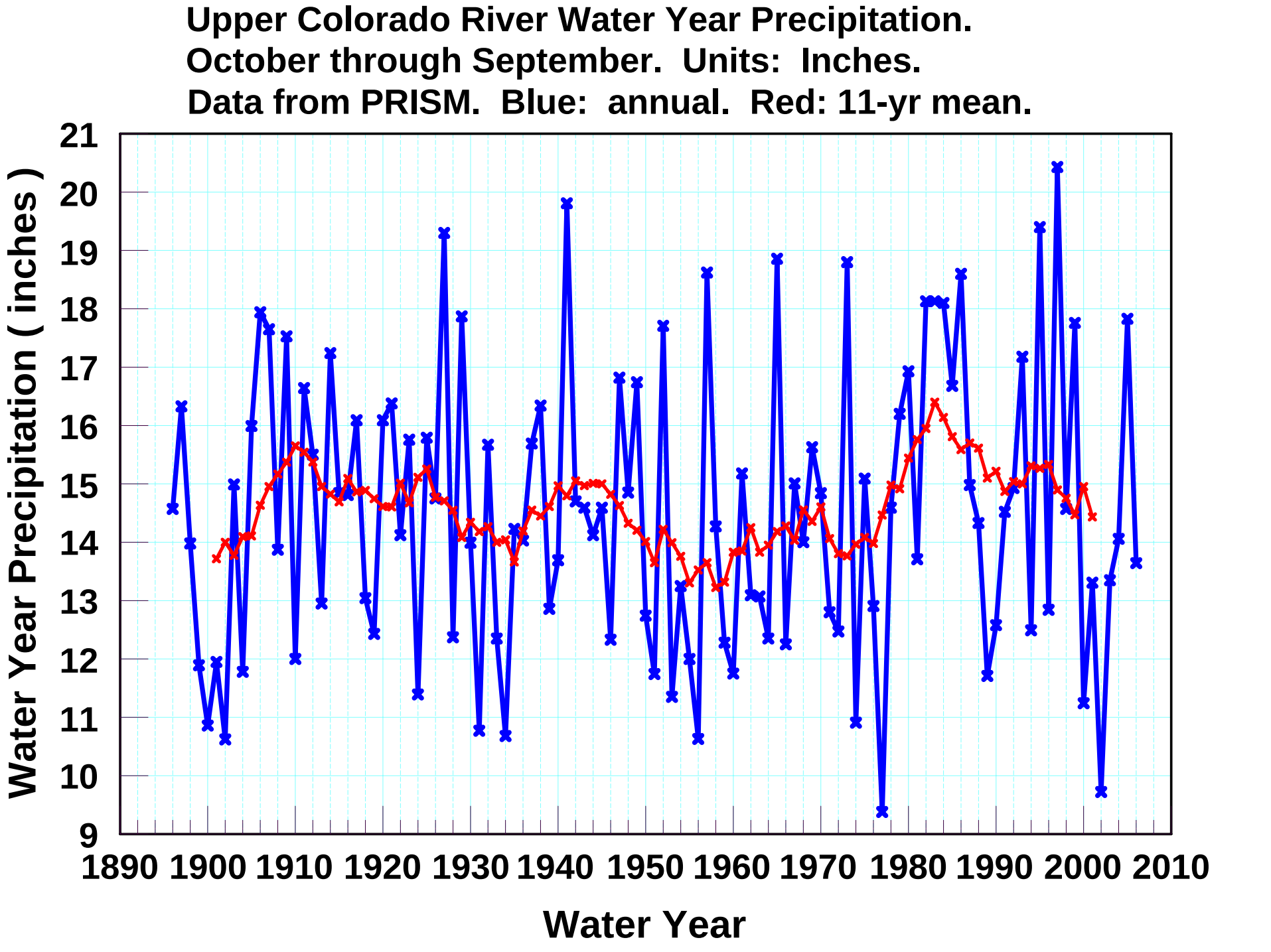
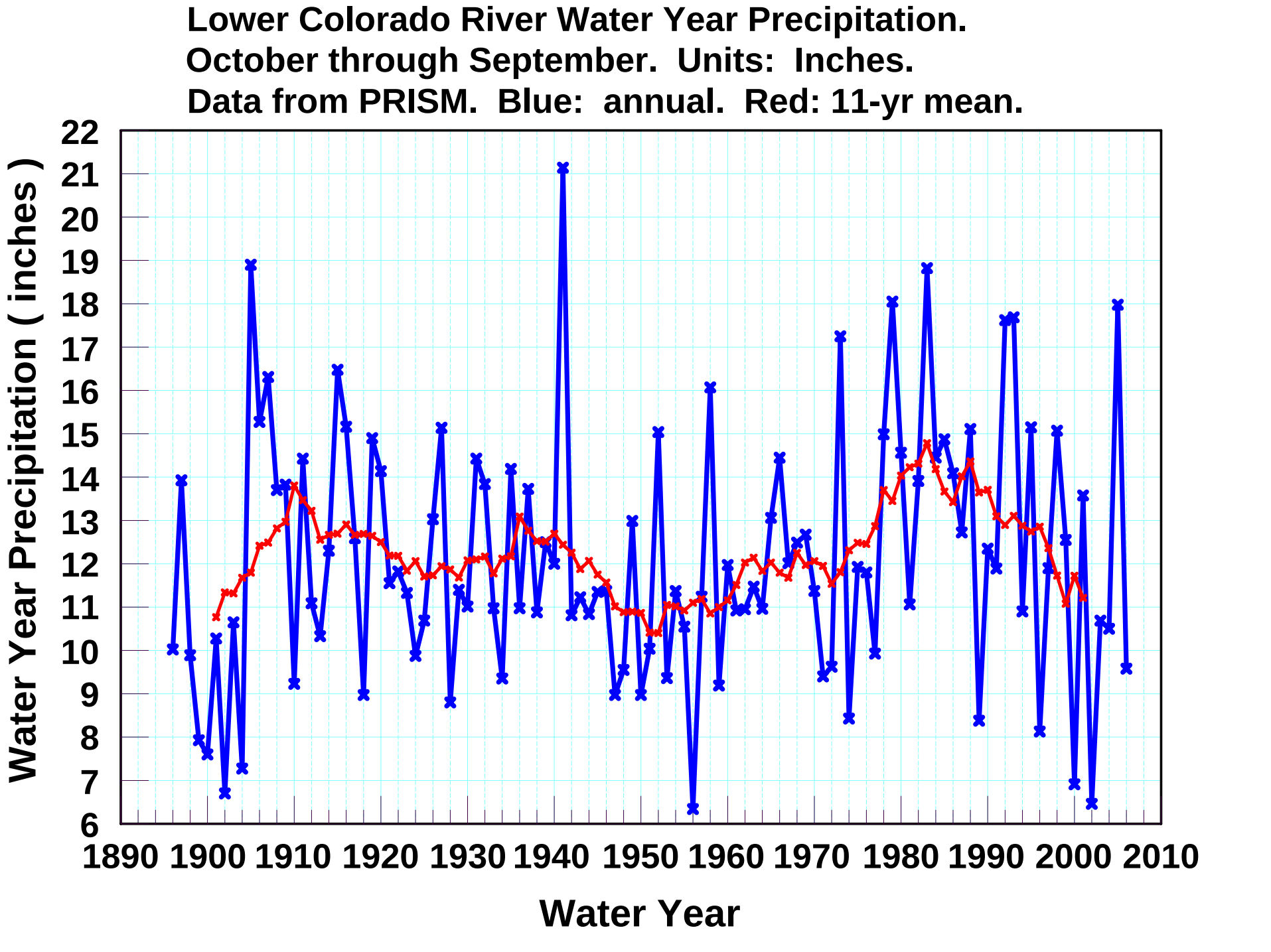


Fig. 1. Modeled changes in annual mean precipitation minus evaporation over the American Southwest (125°W to 95°W and 25°N to 40°N, land areas only), averaged over ensemble members for each of the 19 models. The historical period used known and estimated climate forcings, and the projections used the SResA1B emissions scenario. The median (red line) and 25th and 75th percentiles (pink shading) of the $P - E$ distribution among the 19 models are shown, as are the ensemble medians of P (blue line) and E (green line) for the period common to all models (1900–2098). Anomalies (Anom) for each model are relative to that model's climatology from 1950–2000. Results have been 6-year low-pass Butterworth-filtered to emphasize low-frequency variability that is of most consequence for water resources. The model ensemble mean $P - E$ in this region is around 0.3 mm/day.

Seager et al, 2007.


Upper Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Water Year Precipitation (inches)
21
20
19
18
17
16
15
14
13
12
11
10
9
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Water Year


Lower Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Water Year Precipitation (inches)
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Water Year

?

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 ?

?

Karl and Knight, 1998.

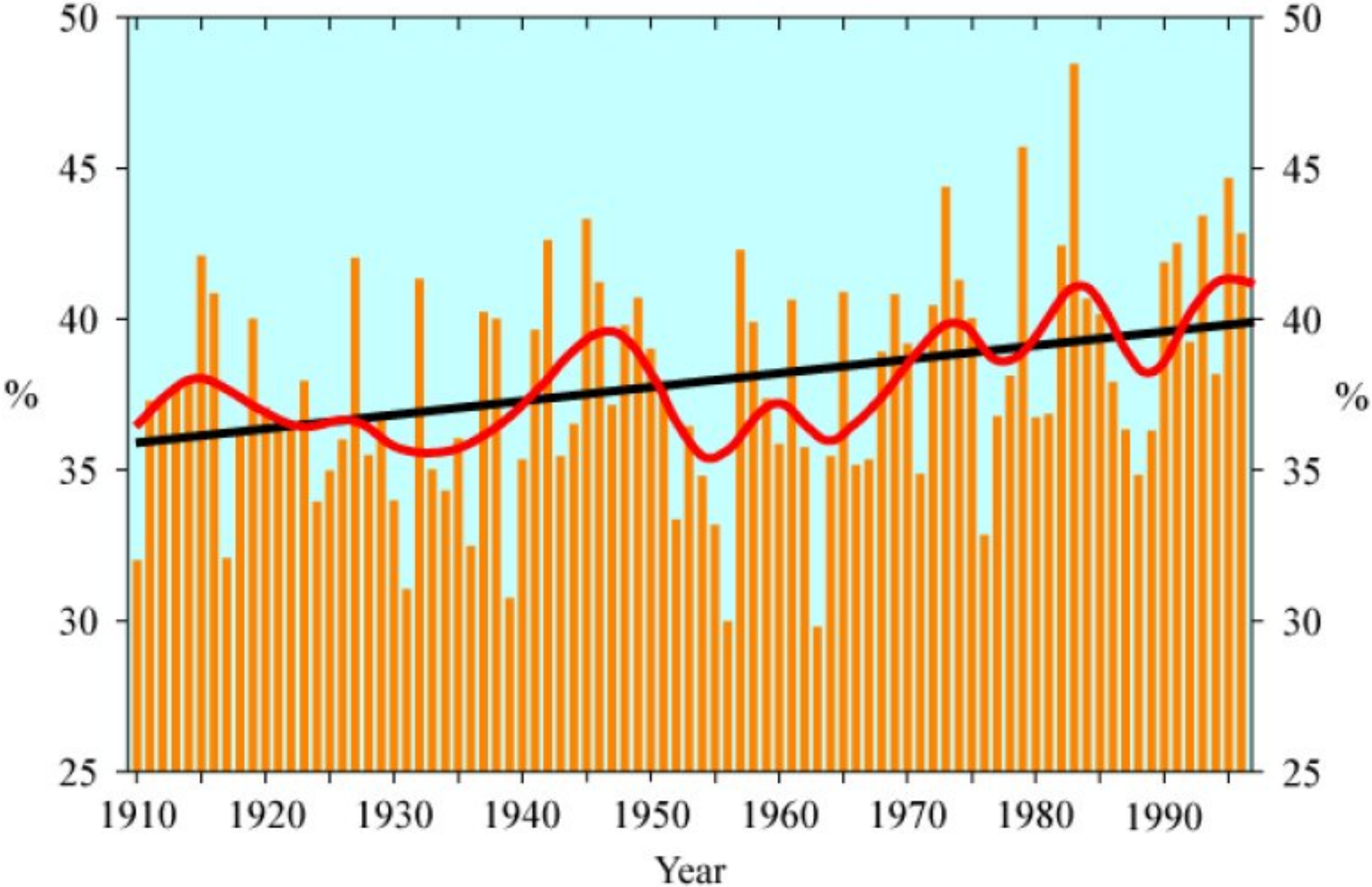
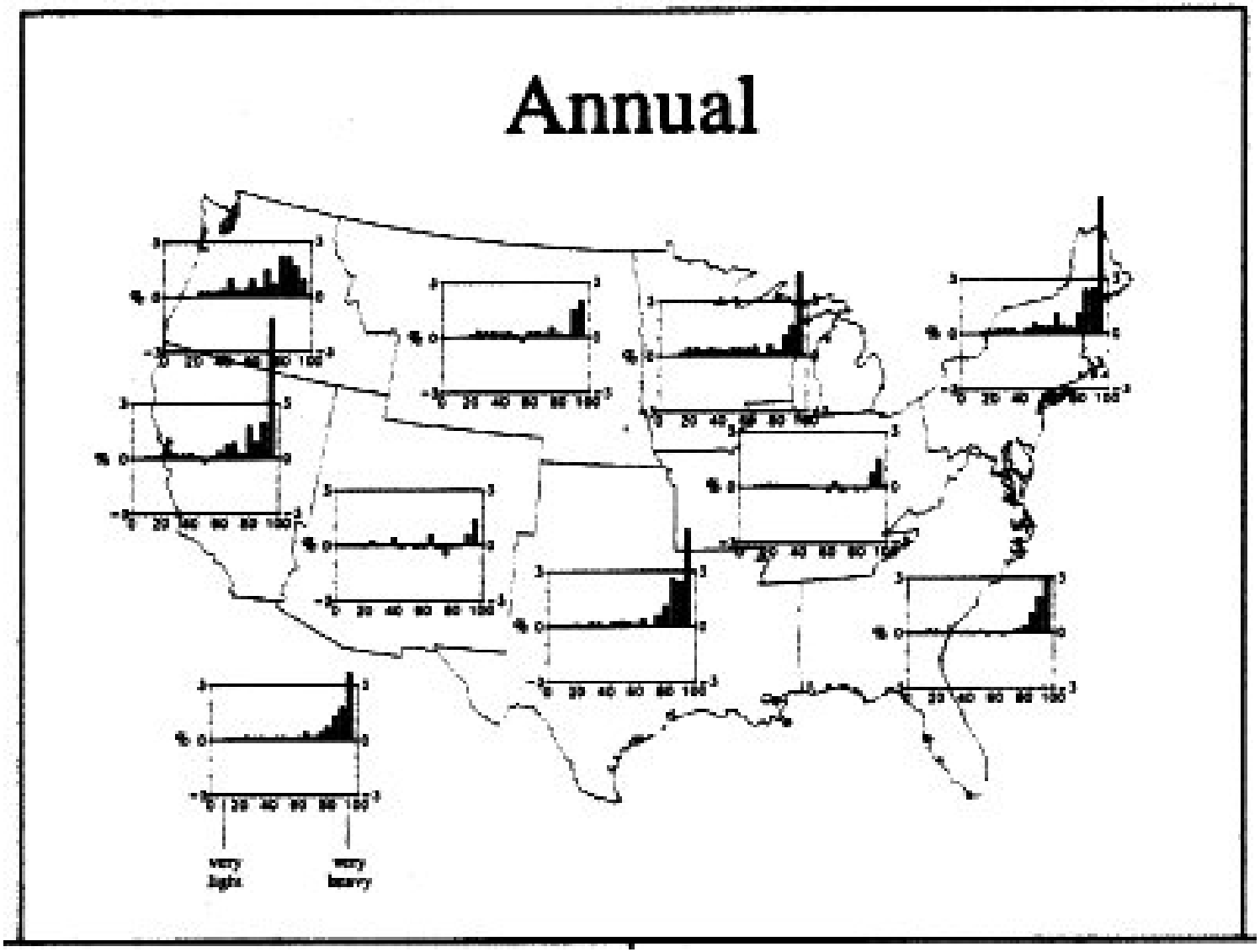


FIG. 2. Time series of the percent contribution of the upper 10 percentile of daily precipitation events to the total annual precipitation area-averaged across the United States. Smooth curve is a nine-point binomial filter, and the trend is also depicted.



Trends in Extreme Daily Precipitation, 1910-1996, by category.

Thomas R. Karl and Richard W. Knight, 1998. Secular Trends of Precipitation Amount, Frequency, and Intensity in the United States. *Bulletin of the American Meteorological Society* , 79 (2), 231–241.

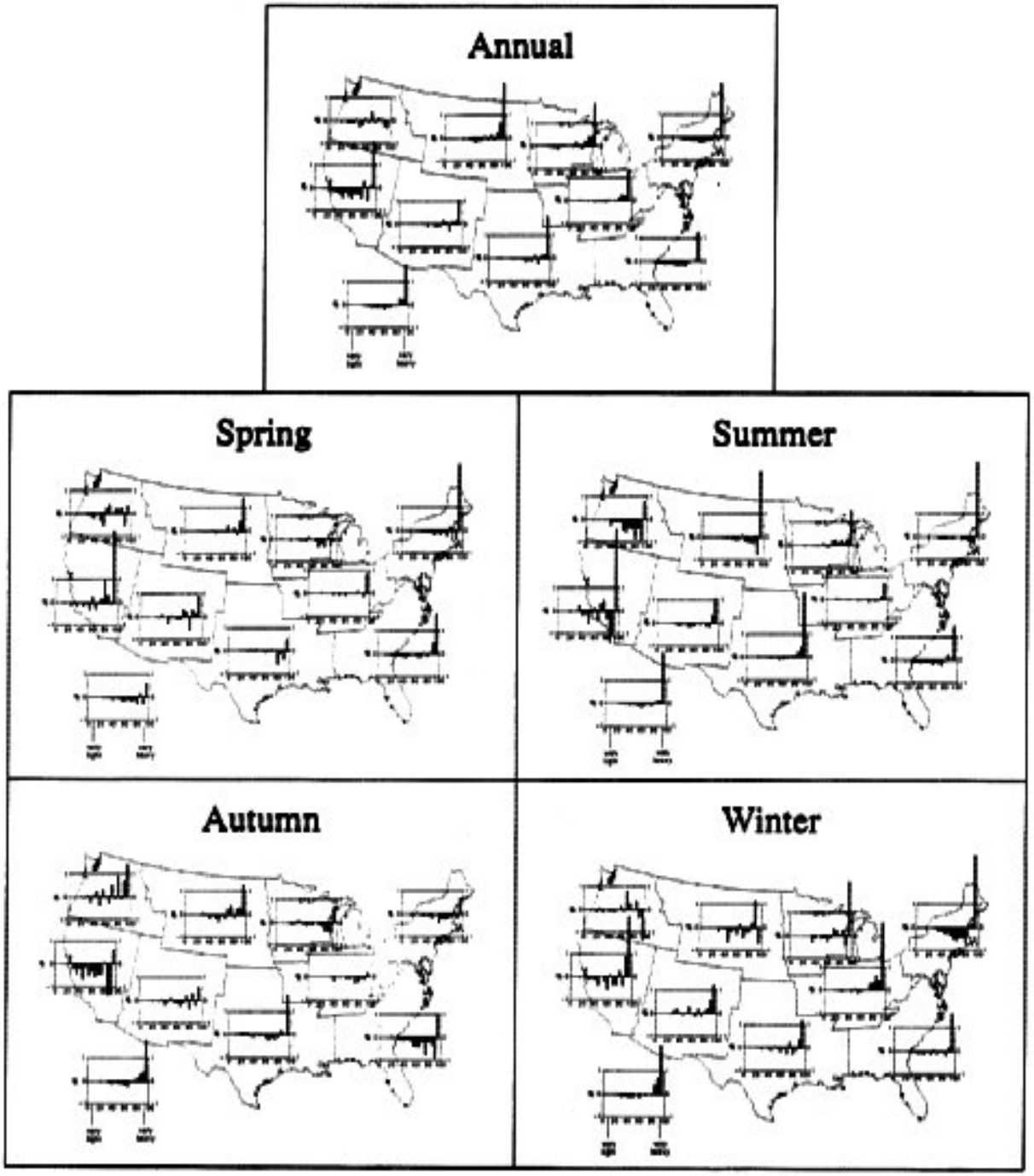


FIG. 5. The contribution to the trends in Fig. 1 attributed to trends in precipitation intensity. Trends are expressed as in Fig. 1.

Karl and Knight, 1998.

Contribution to change in total precipitation from different intensity classes.

1910-1996.

-- The intensity of precipitation has increased for very heavy and extreme precipitation days only.

-- The proportion of total annual precipitation derived from heavy and extreme precipitation events has increased relative to more moderate precipitation.

Summary Points 1 of 3

Climate Change and Deserts - Comments

Something is happening. Began without our noticing.
Southwest seems to have some trends all year long.

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

Temp – Reasonable consensus on increase.
Temp – Already near life limits. Small changes can push beyond.

Temperature as a hydrologic element – significant water implications.

Some suggestion that high elevations are warming more than low.

Precipitation. Several characteristics matter, and can change:
- Amount (annual totals) – modest decrease toward US-Mex border
- Seasonality (fraction of annual) – more winter, less spring, monsoon ??
- Frequency (how often) – probably somewhat less
- Type (rain, or snow?) – more rain, less snow

Summary Points 2 of 3

Climate Change and Deserts

Soil Moisture Recharge

- Cool precipitation "better" (more effective) than warm precipitation
- Big need to understand the whole recharge process much better
- Warmer temperatures may reduce soil moisture recharge

Changes in climate probably facilitate disturbance regimes

Changes in disturbance regimes and in climate favor opportunism …

- … invasive species

Fire conditions likely more favorable, more disturbances

- More arid deserts do not burn well, semi-arid can support fire better

System still has "unrealized warming;" earth radiation not in balance

- We're committed, like it or not.

Managers still have a continuing need for:

- High quality gridded data sets (atmosphere, surface, subsurface)
- Better tools to make information available to public and researchers

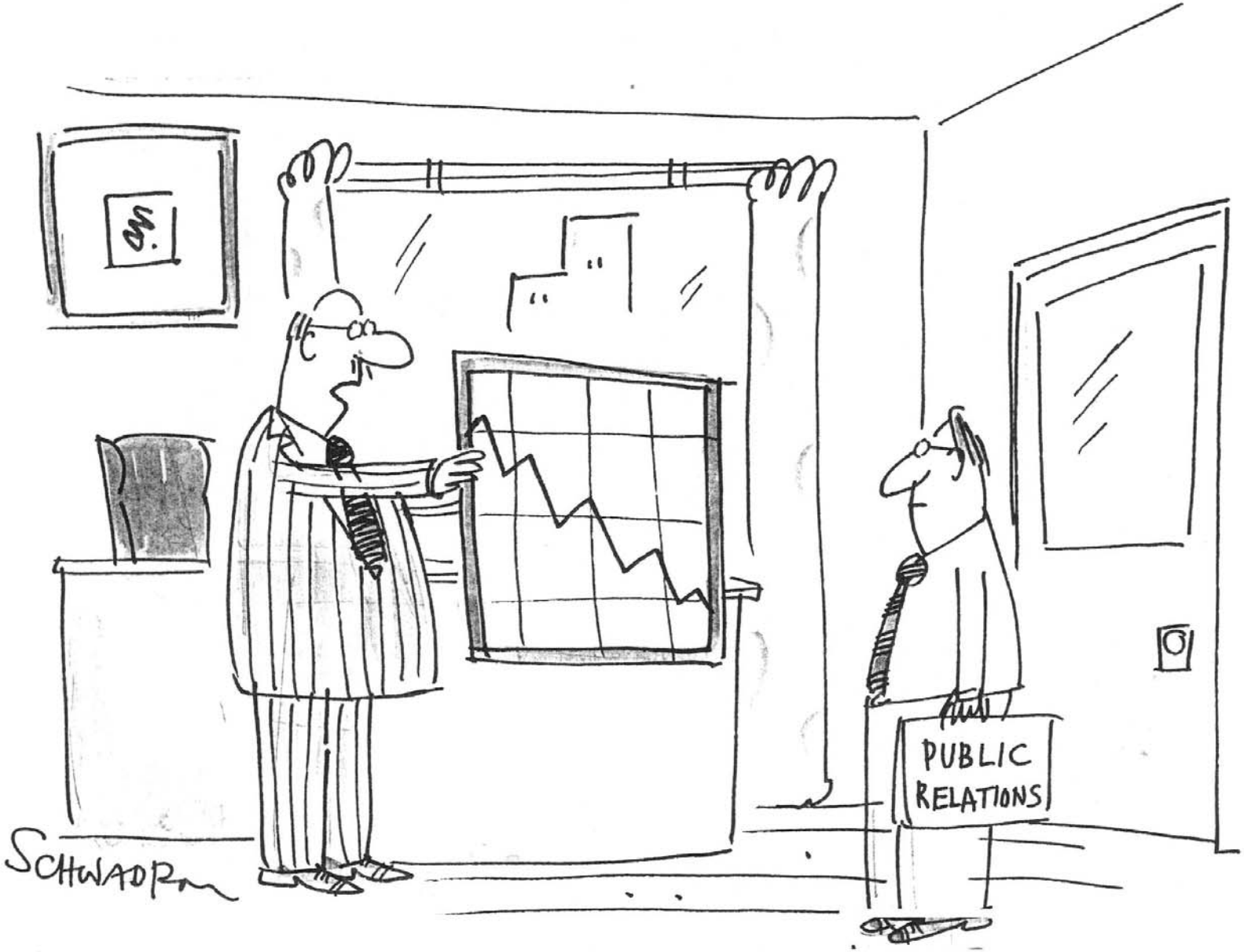
Summary Points 3 of 3

Climate Change and Deserts

In desert regions Climate Change is not the only big problem

- Multiple stressors
- Climate reduces “wiggle room” for testing and experimentation

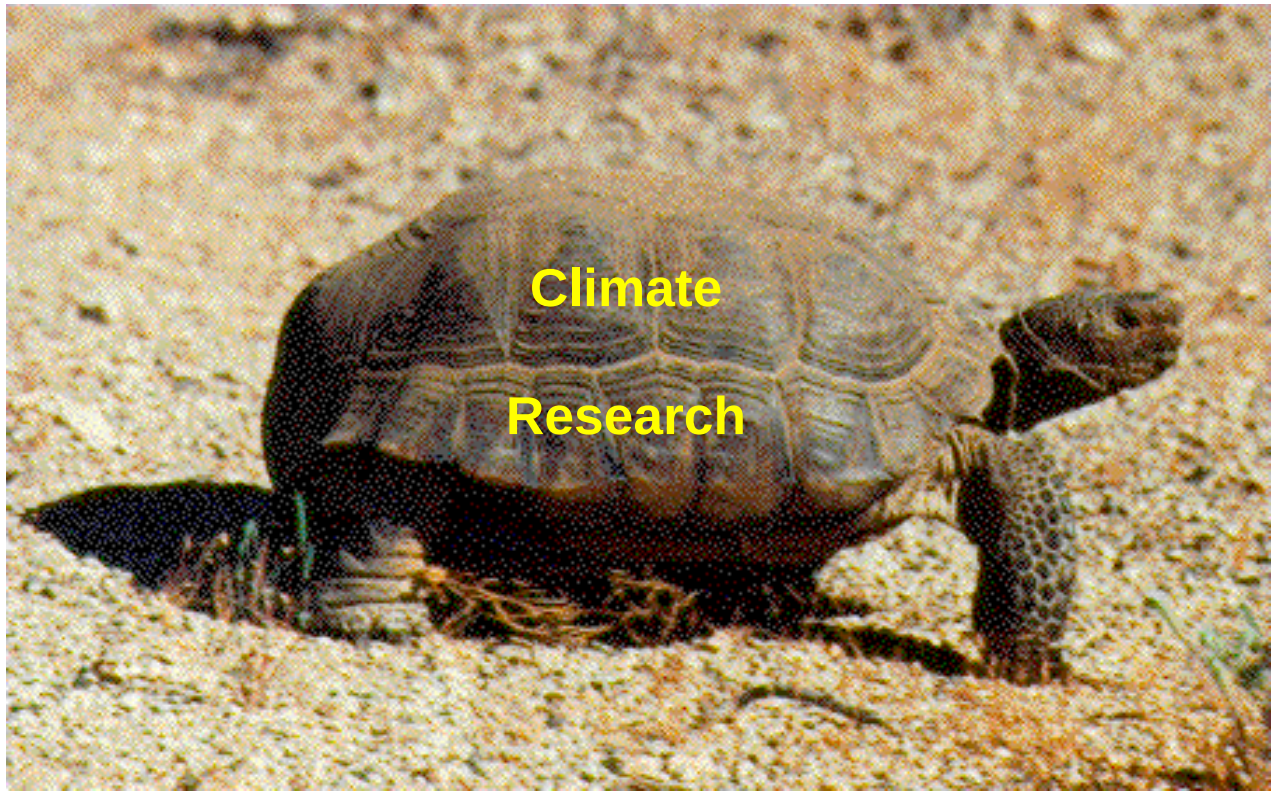
Not hopeless. Not easy.



"CURTIS, I WANT YOU TO FIND A WAY TO BLAME ALL THIS ON ~~EL NINO.~~" **Climate Change**

Ctsy CDC

We’re still plugging along!



Thank You !

Discards

20 February 2007

Complex attitudes rain on climate change

GLOBAL WARMING

▪ **In-depth:** Latest news and graphics | Resources | Overview | Kyoto | IPCC

▪ **Poll:** Climate seen as world's leading threat

▪ **Vote:** Biggest fear of global warming?

▪ **Reports:** Key findings left out | Earth nearing 'tipping points' | Scientists: Act now

▪ **Endangered?:** Birds move northward | High acidity endangers ocean reefs

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More

By Heather Terwilliger, USA TODAY

Mixx it
Other ways to share:
Yahoo! Buzz
Digg
Newsvine
Reddit
Facebook
What's this?

An American public that is more informed about global warming isn't necessarily one that is more concerned about it.

Researchers at Texas A&M University came to that conclusion after a telephone survey of 1,093 Americans.

Noting the great public debate despite increasing scientific certainty of global warming, the researchers set out to test the assumption that people will care more about climate change if they know more. The assumption fuels many efforts to raise awareness, researchers say, citing as an example the Oscar-winning 2006 documentary *An Inconvenient Truth*.

Participants were asked to rate their familiarity with climate change and then were led through a series of questions to determine their level of concern. Surprisingly, the study found that more informed respondents felt less responsibility for a warming planet than the less informed.

People who expressed confidence in the ability of scientists to deal with the problem also showed much less concern than those who had less faith in researchers.

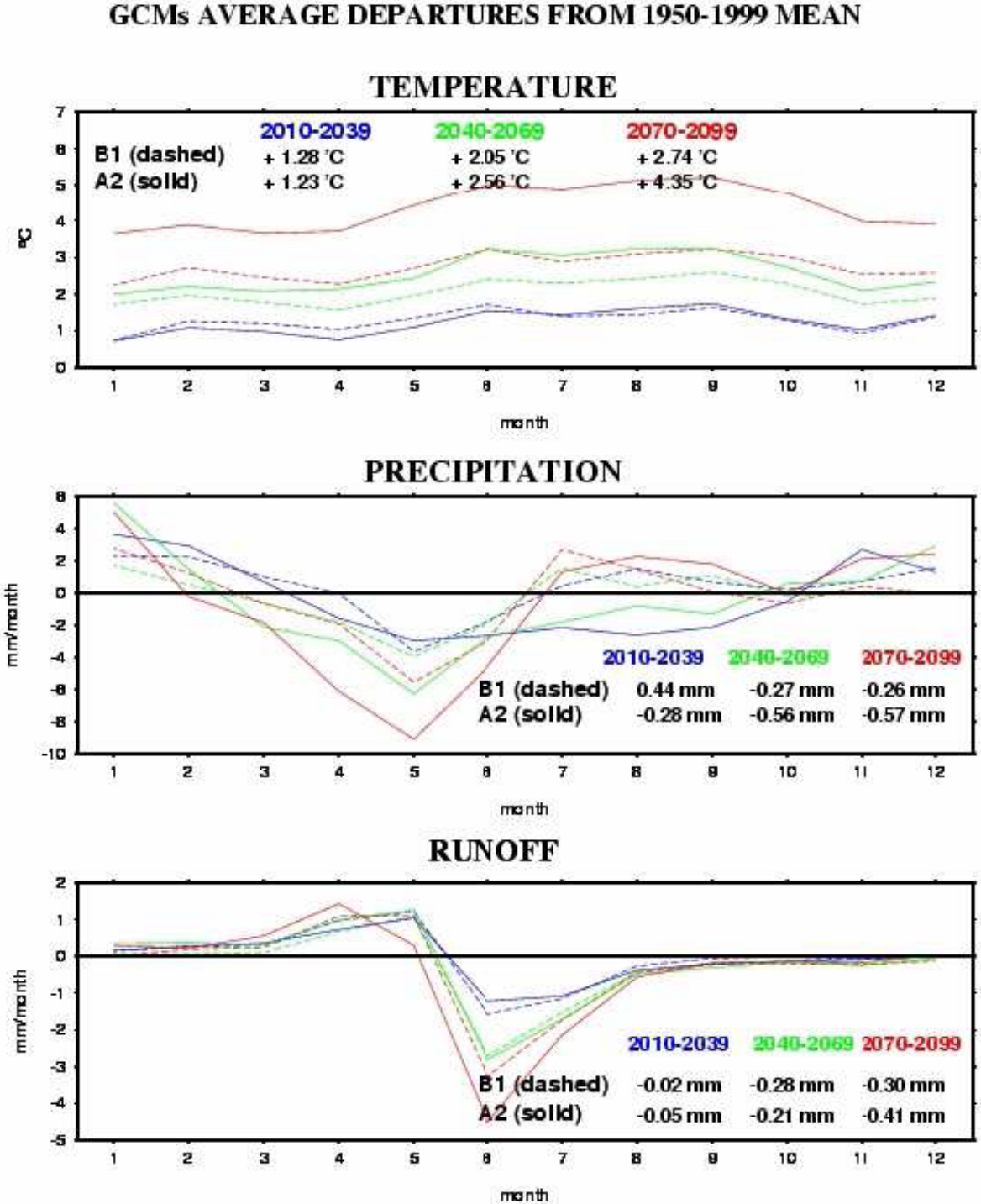
FIND MORE STORIES IN: Oscar-winning | Yeah | Texas A&M University | An Inconvenient Truth | Alliance for Climate

2008 April 7

Complex attitudes rain on climate change

By Heather Terwilliger, USA TODAY

Mixx it



11-Model Consensus
2 Scenarios

Colorado River Basin

By Month

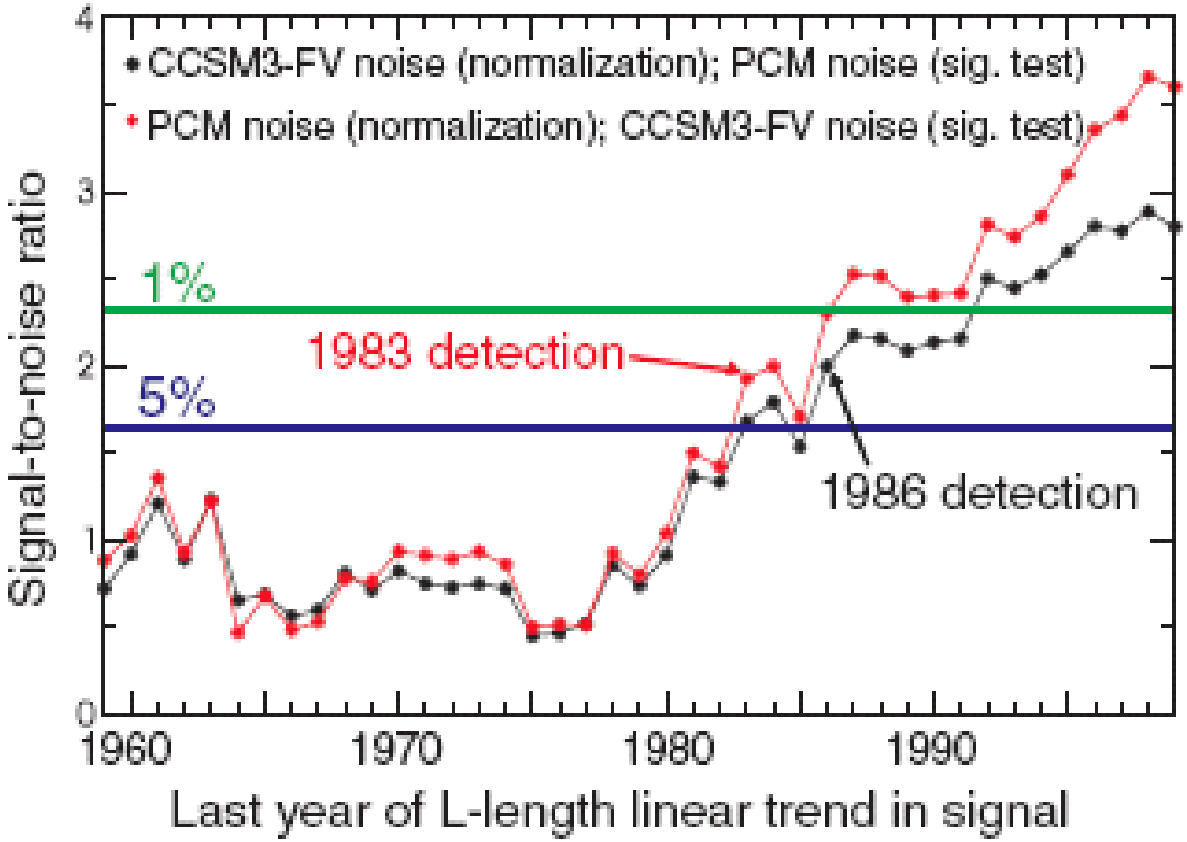
3 Future Periods

From Christensen and Lettenmaier, 2007

20 February 2007

White Mtn Summit, 14246 ft
Reconfigured July 2004

Fig. 5. Time-dependent S/N estimates for two different estimates of natural variability. The *x* axis is the last year of *L*-length linear trend in the signal estimate.



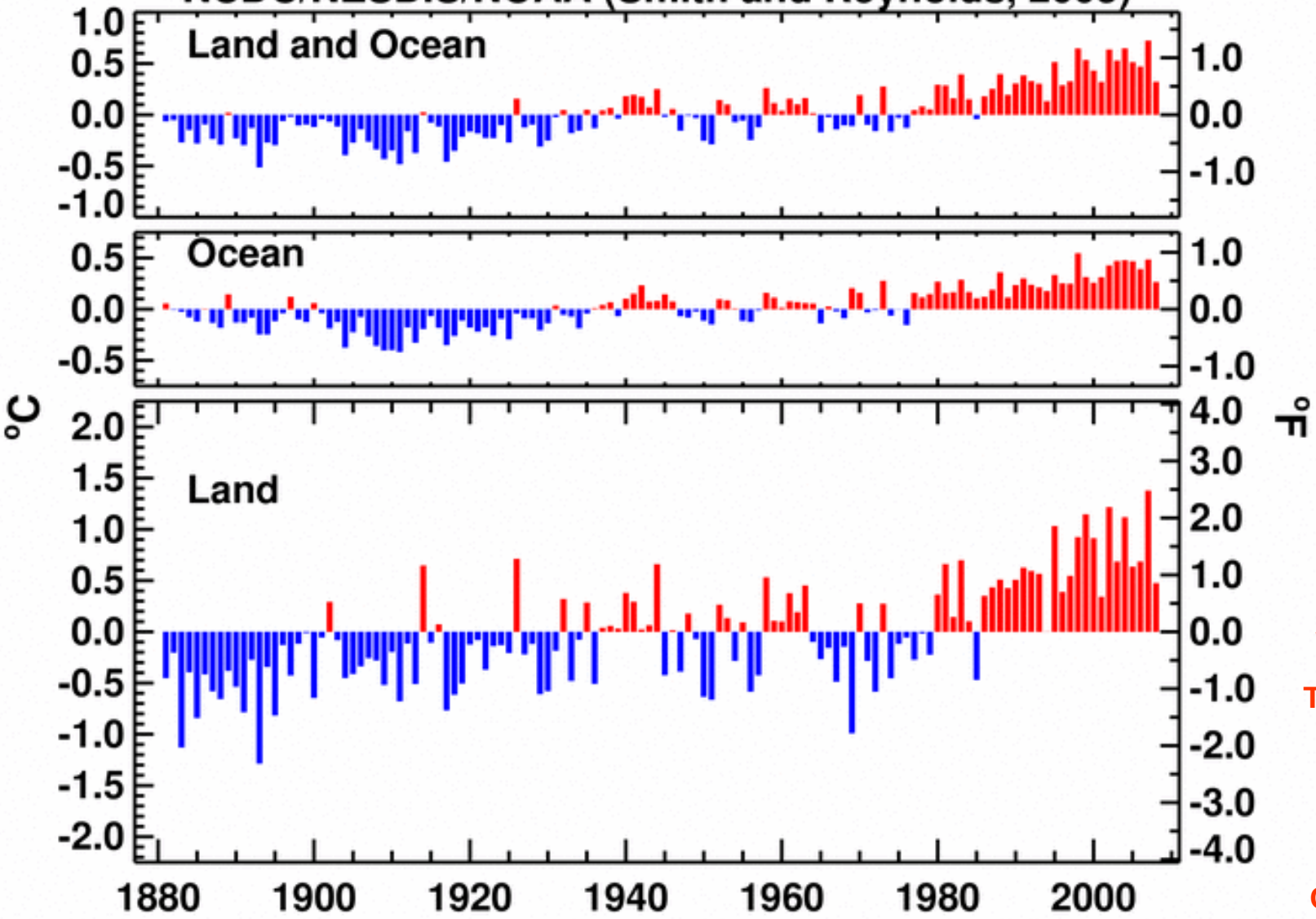
Human-Induced Changes in the Hydrology of the Western United States

2008, Science,, 319, 1080-1082, February 22

Tim P. Barnett,[1*] David W. Pierce,[1] Hugo G. Hidalgo,[1] Celine Bonfils,[2] Benjamin D. Santer,[2] Tapash Das,[1] Govindasamy Bala,[2] Andrew W. Wood,[3] Toru Nozawa,[4] Arthur A. Mirin,[2] Daniel R. Cayan,[1,5] Michael D. Dettinger[1,5]

Dec-Feb Global Surface Mean Temp Anomalies

NCDC/NESDIS/NOAA (Smith and Reynolds, 2005)



Winter (DJF)

Thru Feb 2008

NOAA

National Climatic Data Center

Estimated effects of climate change on Colorado River streamflow (Lees Ferry):

By mid-Century, water managers can expect:

Small decrease (0-8 percent (-6)) Christensen and Lettenmaier, 2007

Large decrease (up to 40 percent) Hoerling and Eischeid 2007

Moderate decrease (in between) Seager et al 2007

More moderate decrease (10 to 25 pct, -13 pct) from Milly et al 2005

A. None of these show streamflow going up !

B. Any decrease is a source of concern !

C. We have to resolve these differences !