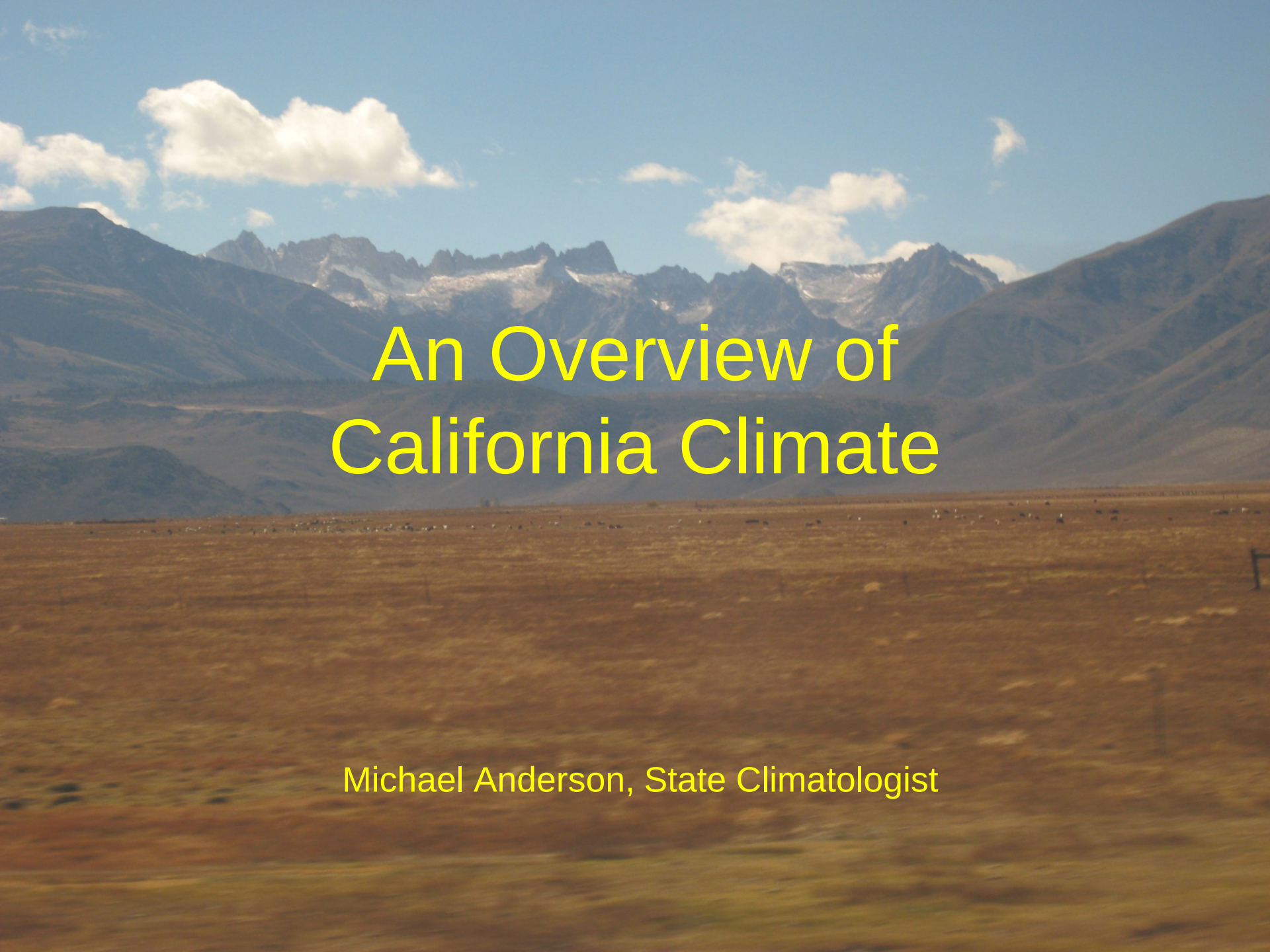


An Overview of California Climate

Michael Anderson, State Climatologist

Talk Overview

- California Climate
- Climate Signals
- Atmospheric Rivers

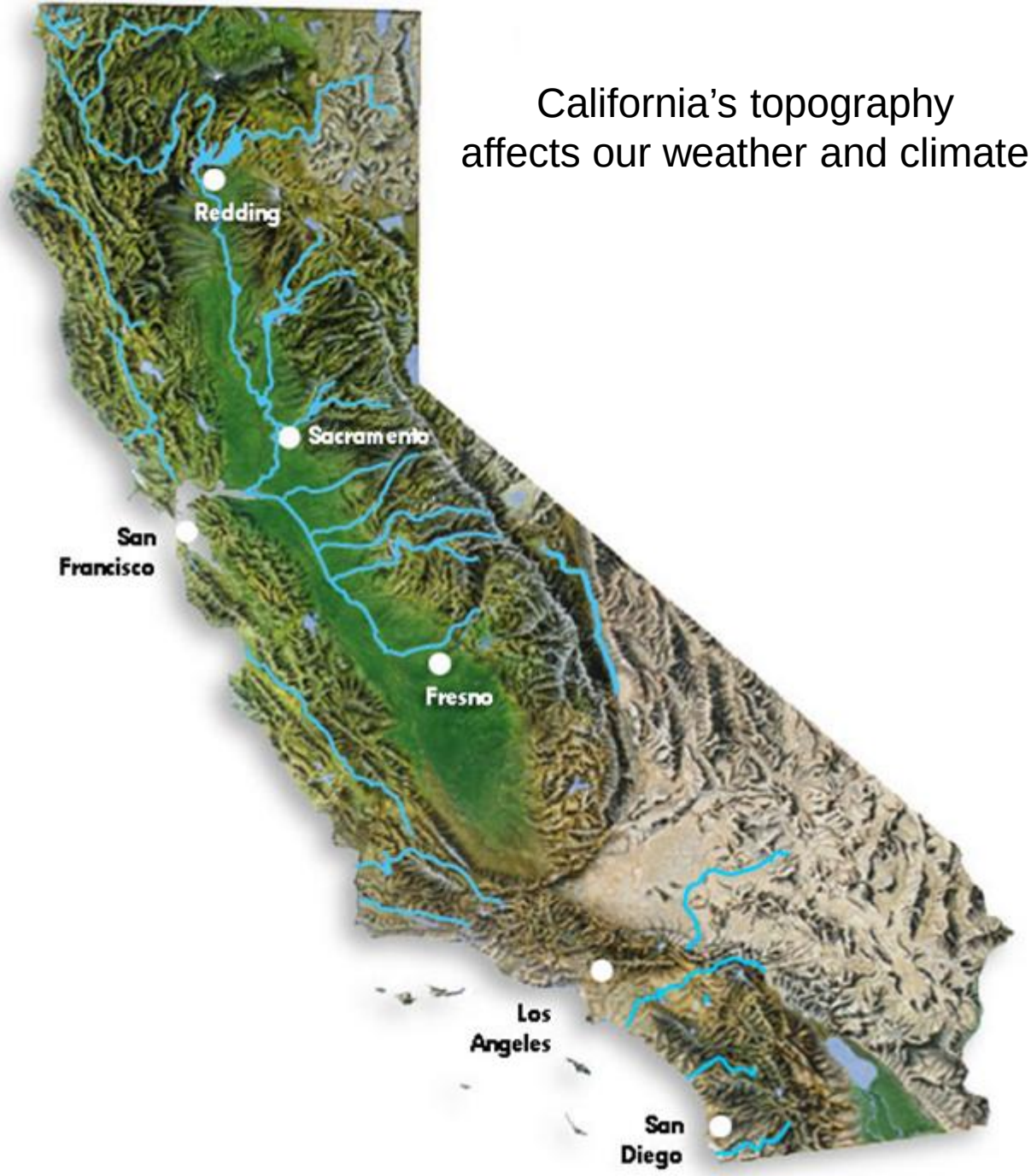
California

- 1340 miles of coastline
  (~75% of Pacific coast of conterminous US)
- 800 miles long
- Average width 250 miles but crosses
  550 miles of longitude (LA is east of Reno)
- Land area of 163,696 square miles
  - US Area is 3.79 million sq. miles
  - Rank 3rd behind Alaska and Texas

Elevation

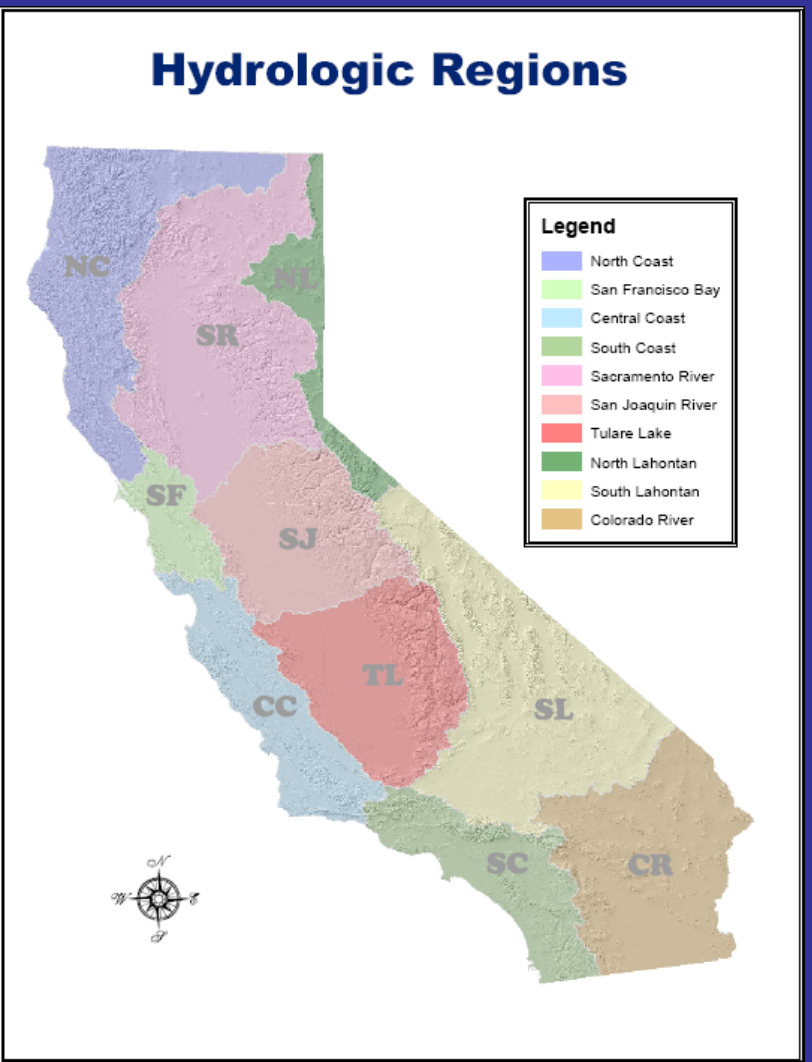
- Max Elevation – Mt Whitney 14,491ft (Mt Shasta 14,161 ft)
- Min Elevation – Death Valley -282 ft
- Mt Whitney and Death Valley are only ~150 miles apart!
- Many islands in Sacramento/San Joaquin Delta lie ~20 feet below sea level

California's topography affects our weather and climate

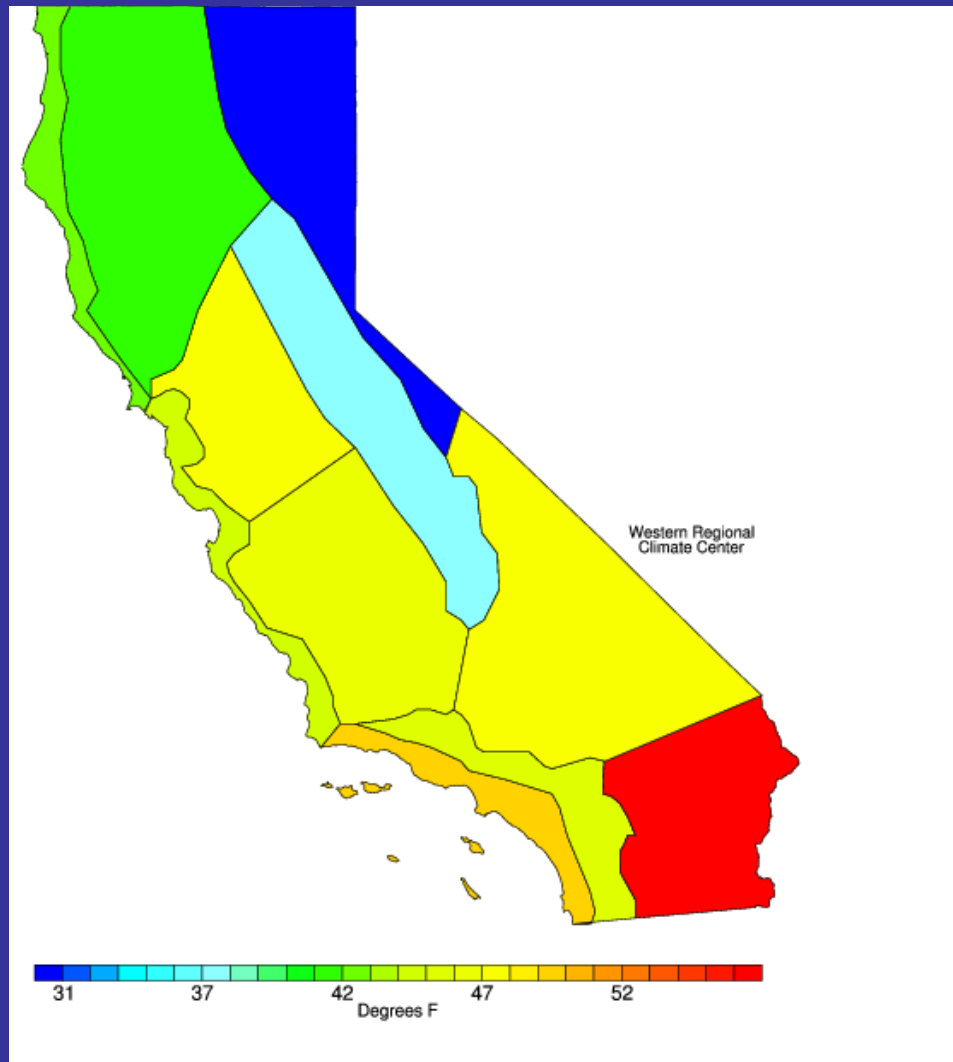


Comparing Regions

DWR Hydrologic Regions



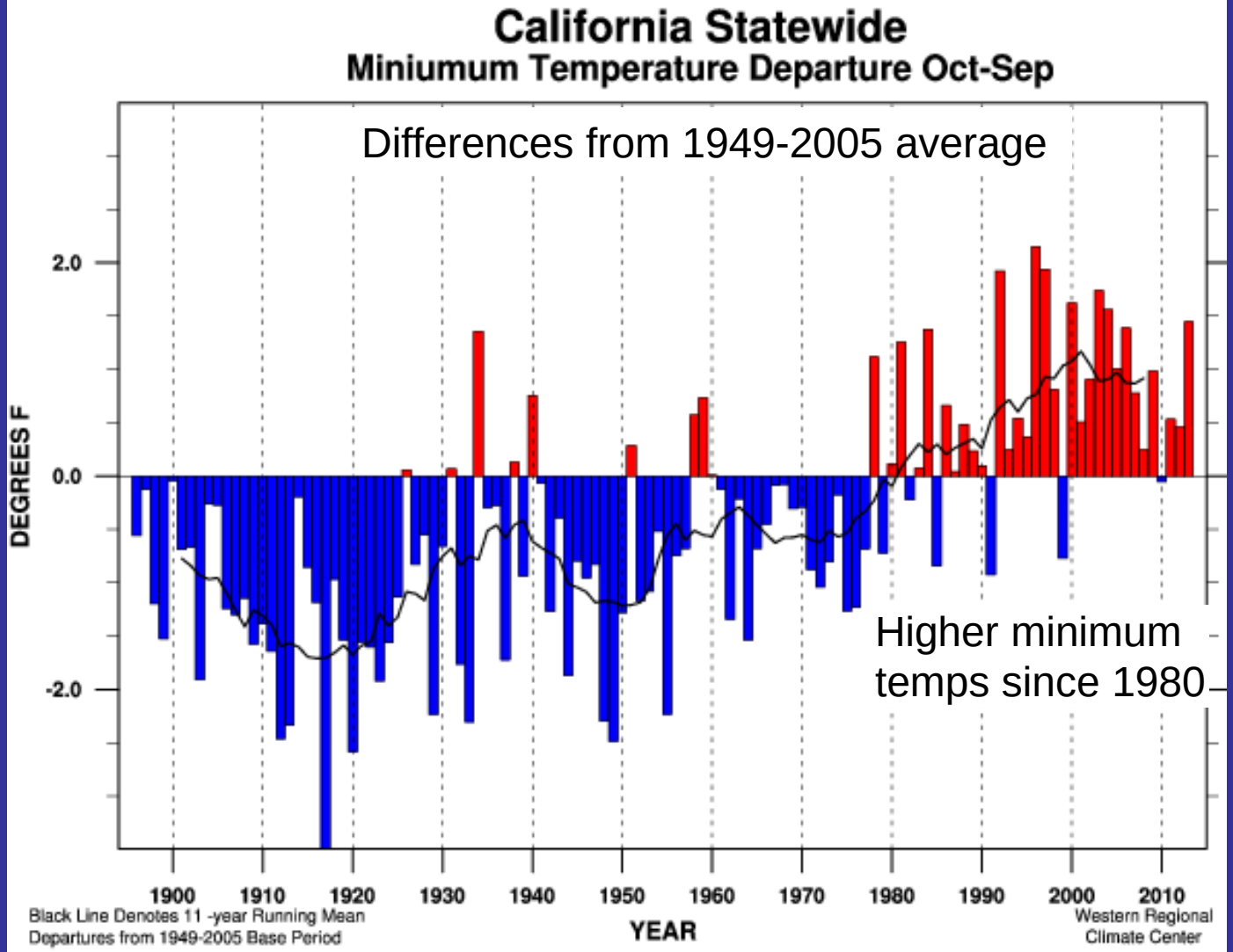
CA Climate Tracker



Climate Change Variables

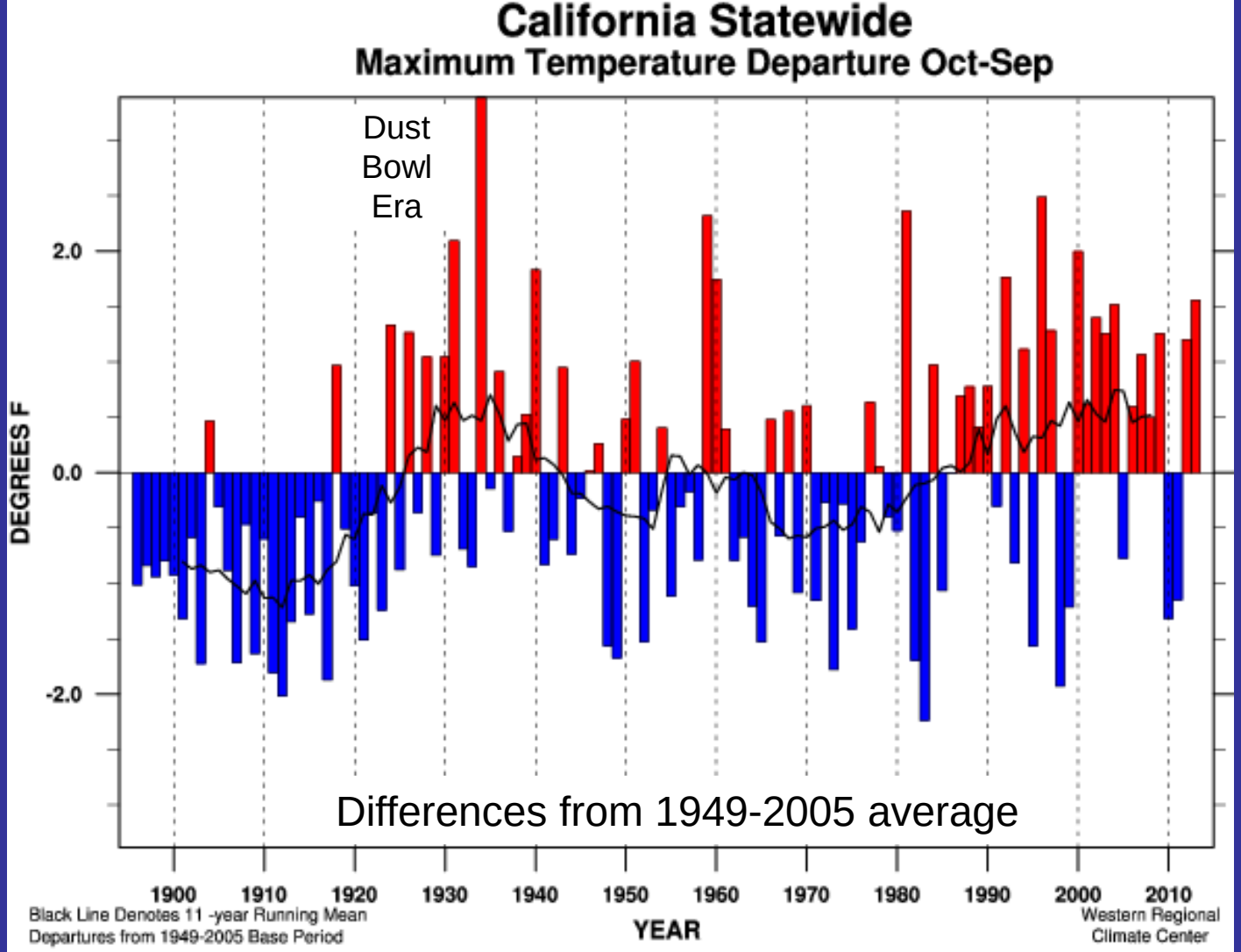
- Temperature
- Precipitation
- Snowpack
- Annual and Seasonal Runoff
- Peak River Flows
- Mean Sea Level

Statewide 20th Century Temperature and Precipitation



Linear Trend 1895-present		+ 2.03 ± 0.46 °F/100yr	
Linear Trend 1949-present		+ 3.28 ± 1.03 °F/100yr	
Linear Trend 1975-present		+ 3.15 ± 2.41 °F/100yr	
Warmest Year		45.3 °F (+ 2.2 °F) in 1996	MEAN 43.1 °F
Coldest Year		39.7 °F (- 3.5 °F) in 1917	STDEV 1.00 °F
Oct-Sep	2013	44.6 °F (+ 1.4 °F)	RANK 112 of 118

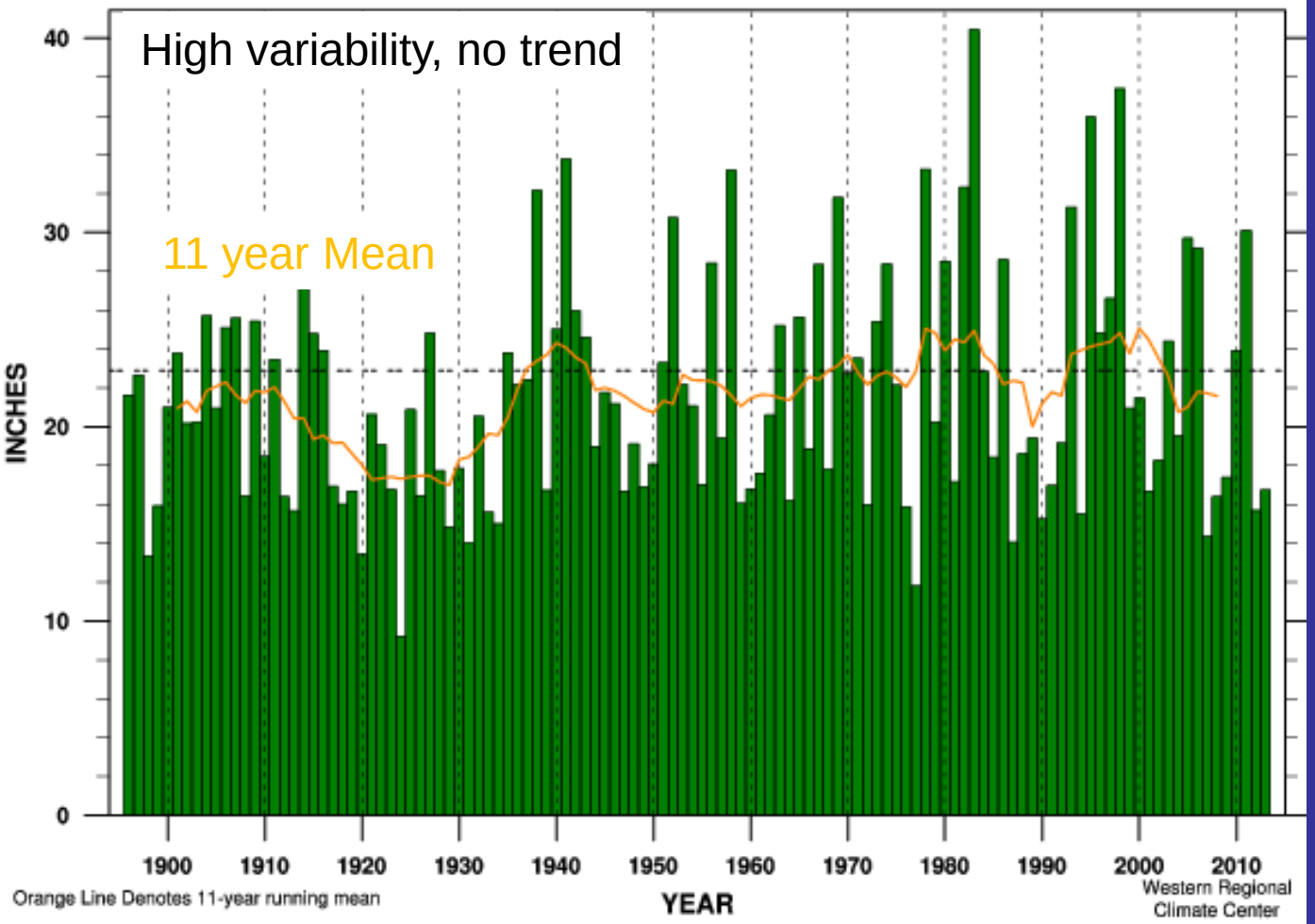
WRCC's California Climate Tracker



Linear Trend 1895-present	+ 1.03 ± 0.59 °F/100yr		
Linear Trend 1949-present	+ 1.43 ± 1.57 °F/100yr		
Linear Trend 1975-present	+ 2.22 ± 3.69 °F/100yr		
Warmest Year	72.4 °F (+ 3.4 °F) in 1934	MEAN	69.0 °F
Coldest Year	66.8 °F (- 2.2 °F) in 1983	STDEV	1.18 °F
Oct-Sep 2013	70.6 °F (+ 1.6 °F)	RANK	109 of 118

WRCC's California Climate Tracker

California Statewide
Precipitation Oct-Sep

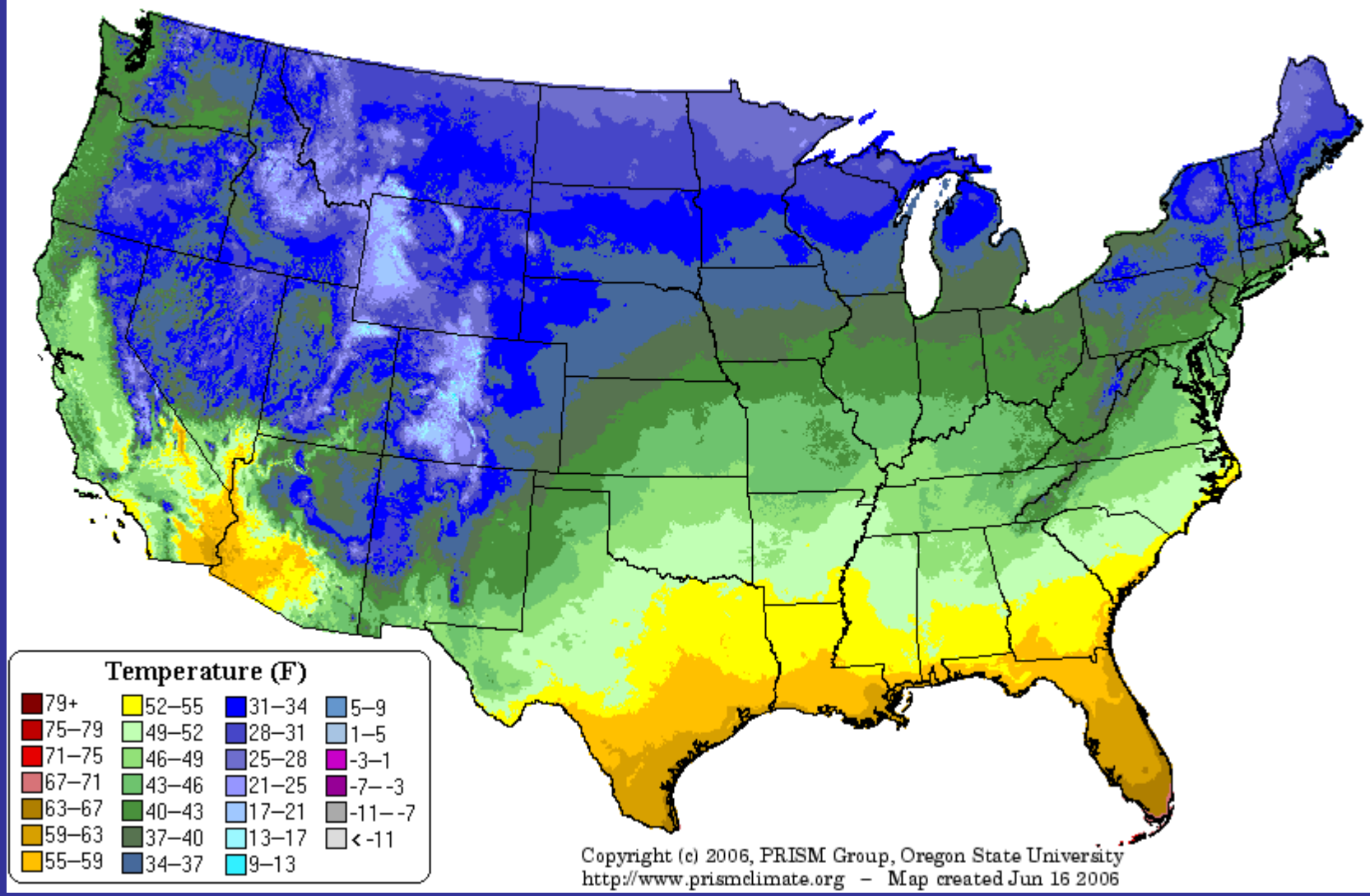


Linear Trend 1895-present	+ 2.92 ± 3.10 in.	(+ 12 ± 13%) per 100 yr	
Linear Trend 1949-present	- 0.62 ± 8.87 in.	(- 2 ± 38%) per 100 yr	
Linear Trend 1975-present	- 5.33 ± 22.19 in.	(- 23 ± 96%) per 100 yr	
Wettest Year	40.44 in. (176%)	in 1983	MEAN 22.90 in.
Driest Year	9.23 in. (40%)	in 1924	STDEV 6.53 in.
Oct-Sep 2013	16.75 in. (73%)		RANK 29 of 118

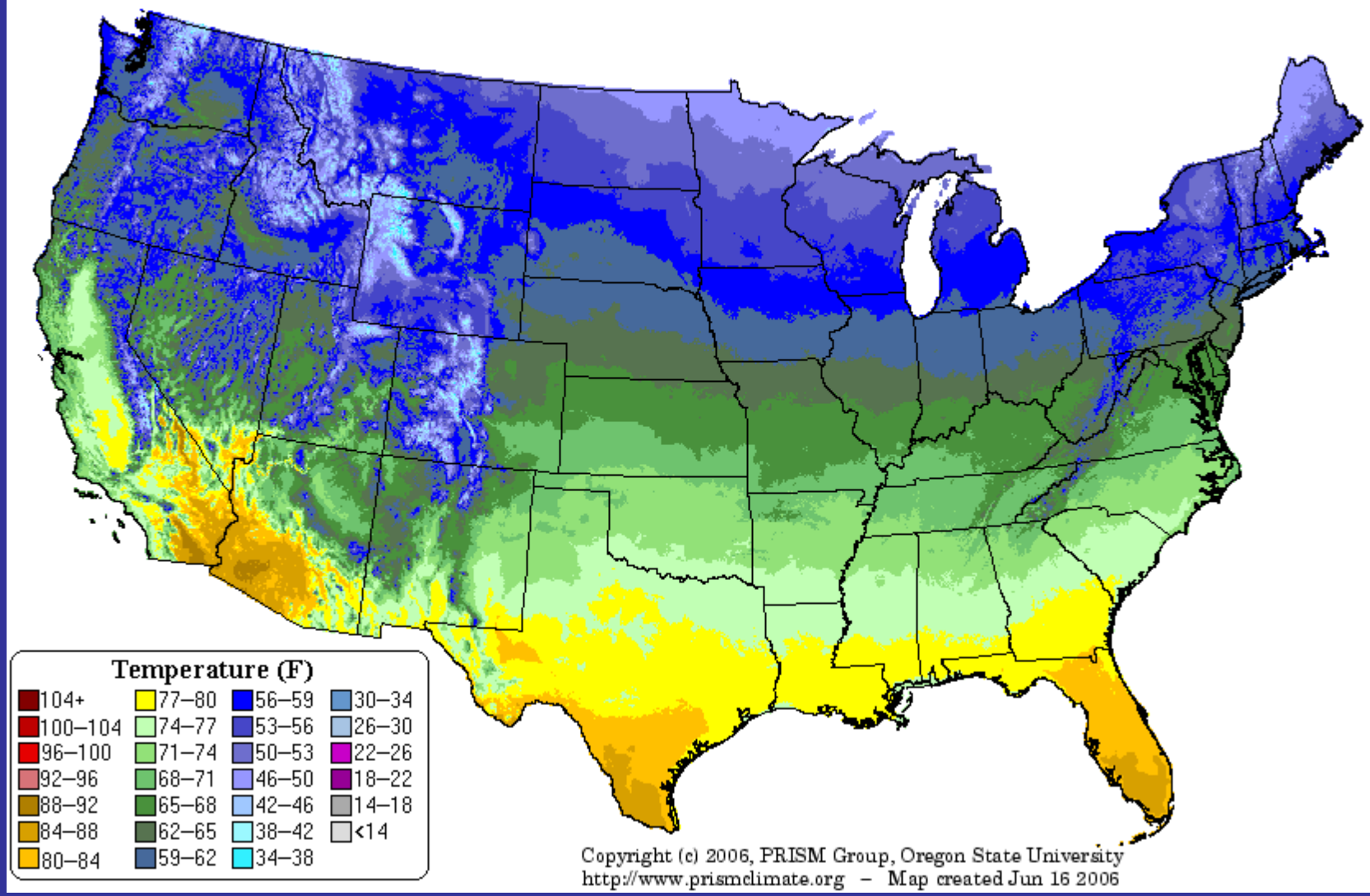
WRCC's California Climate Tracker

Spatial Variability

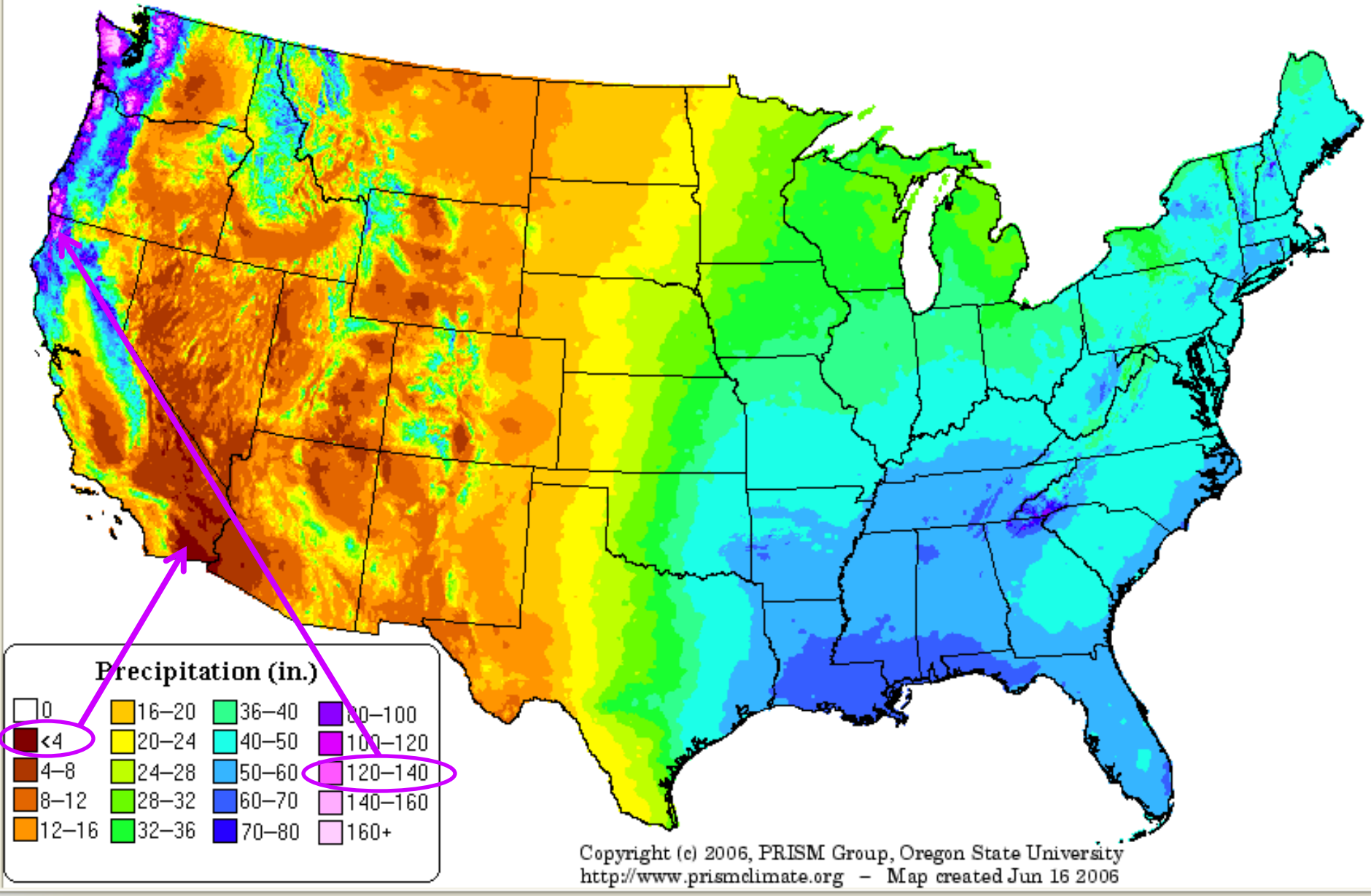
Minimum Temperature: Annual Climatology (1971–2000)



Maximum Temperature: Annual Climatology (1971–2000)

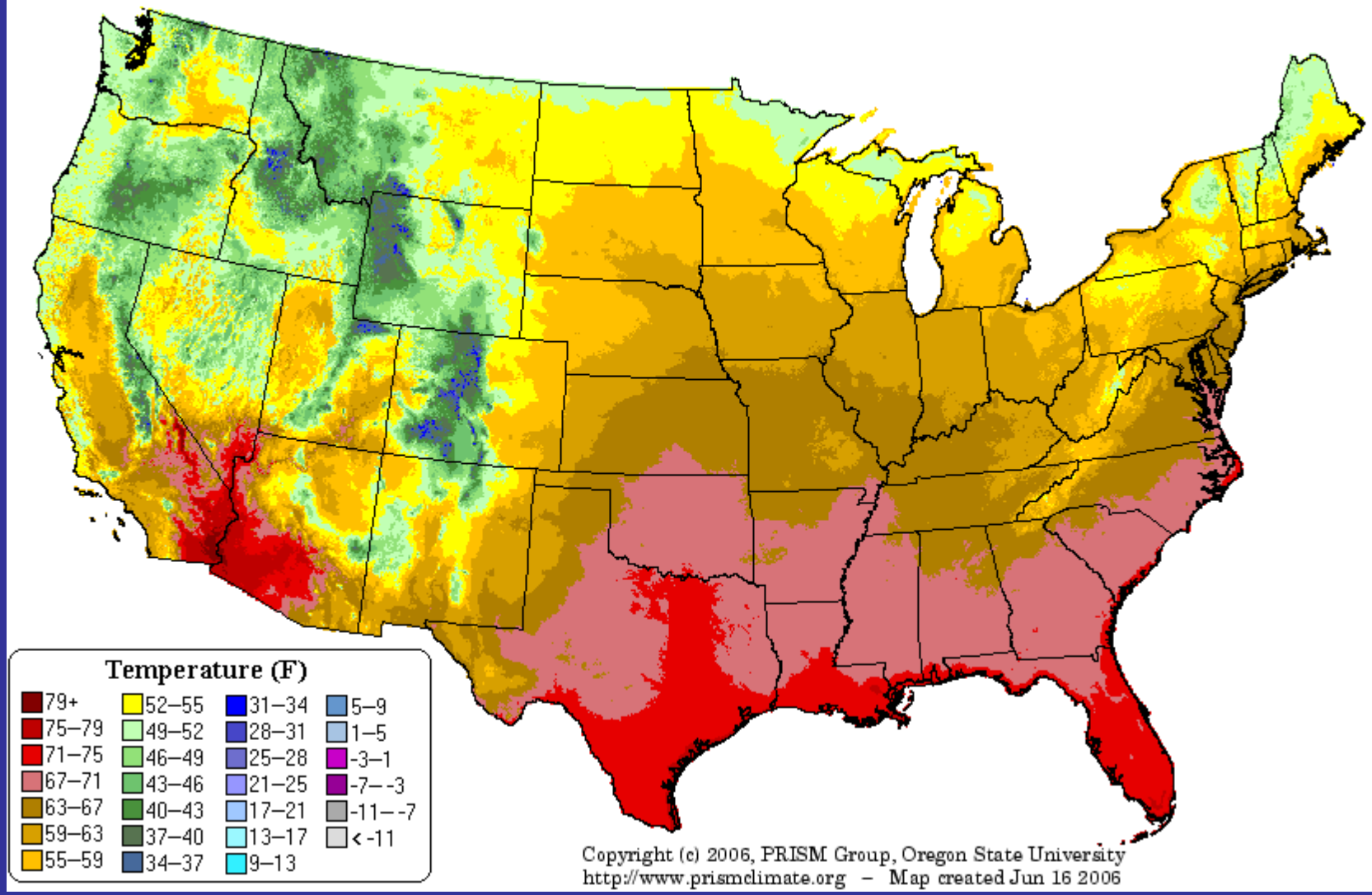


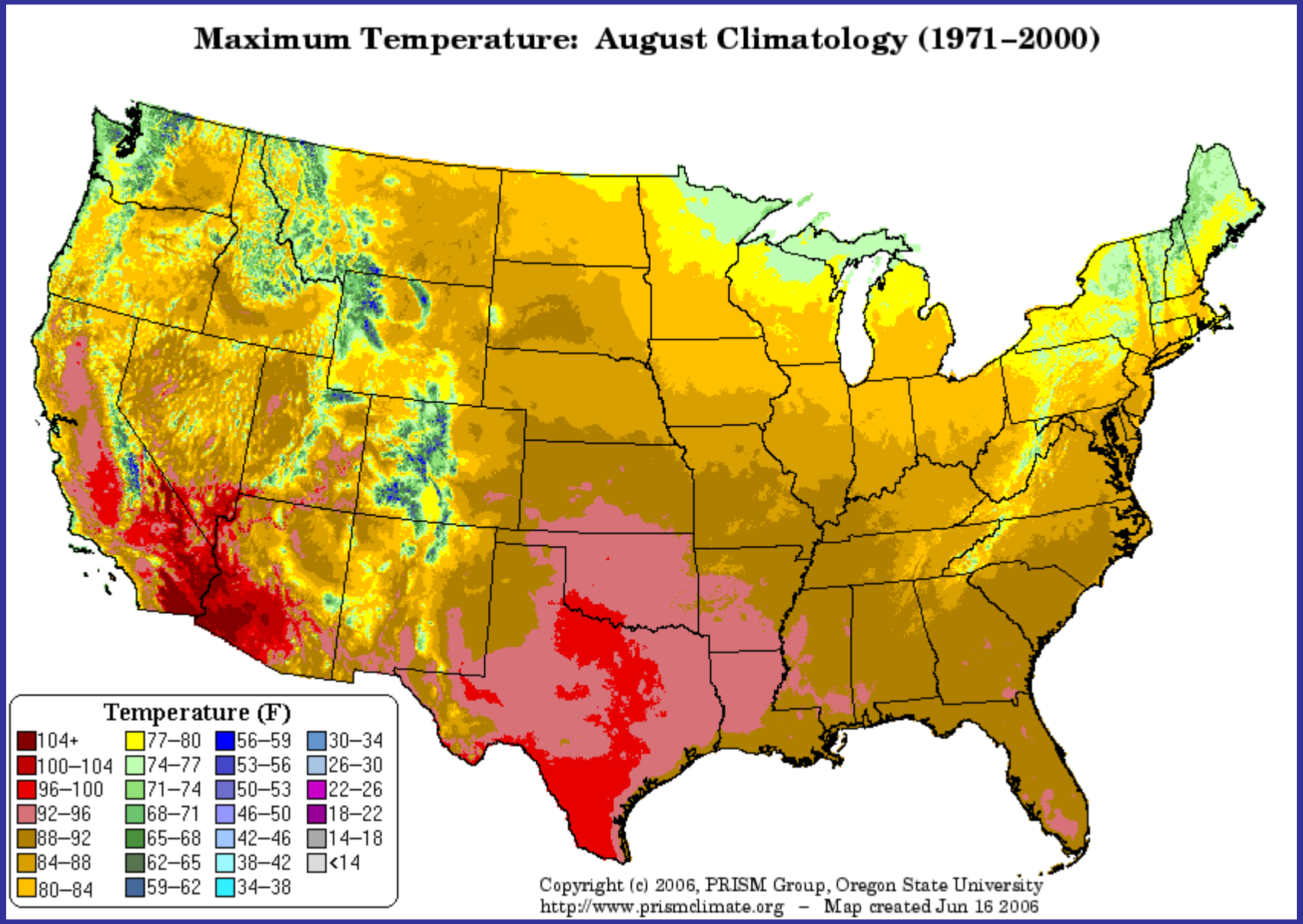
Annual Precipitation Map



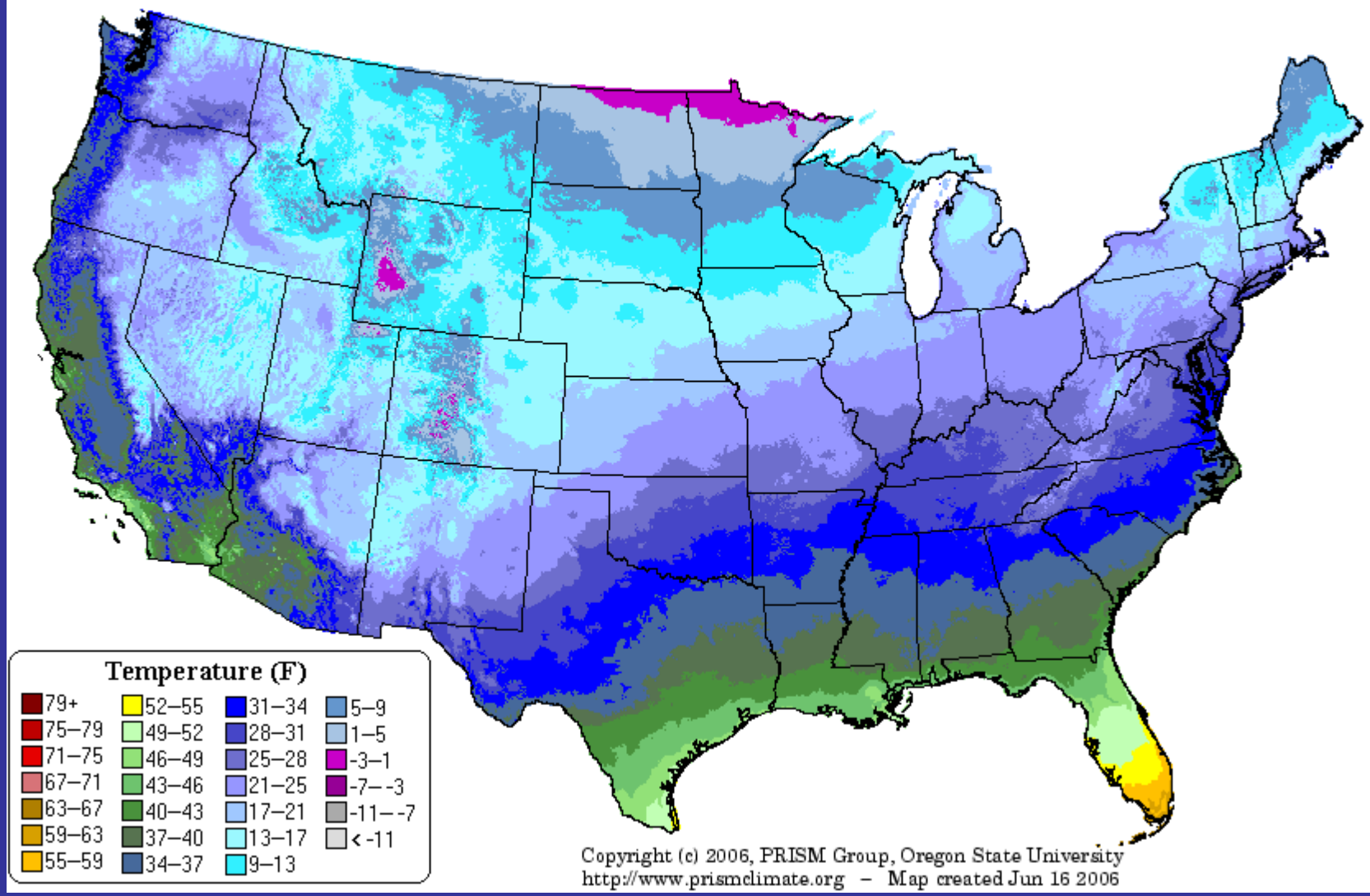
Seasonal Variability

Minimum Temperature: August Climatology (1971–2000)

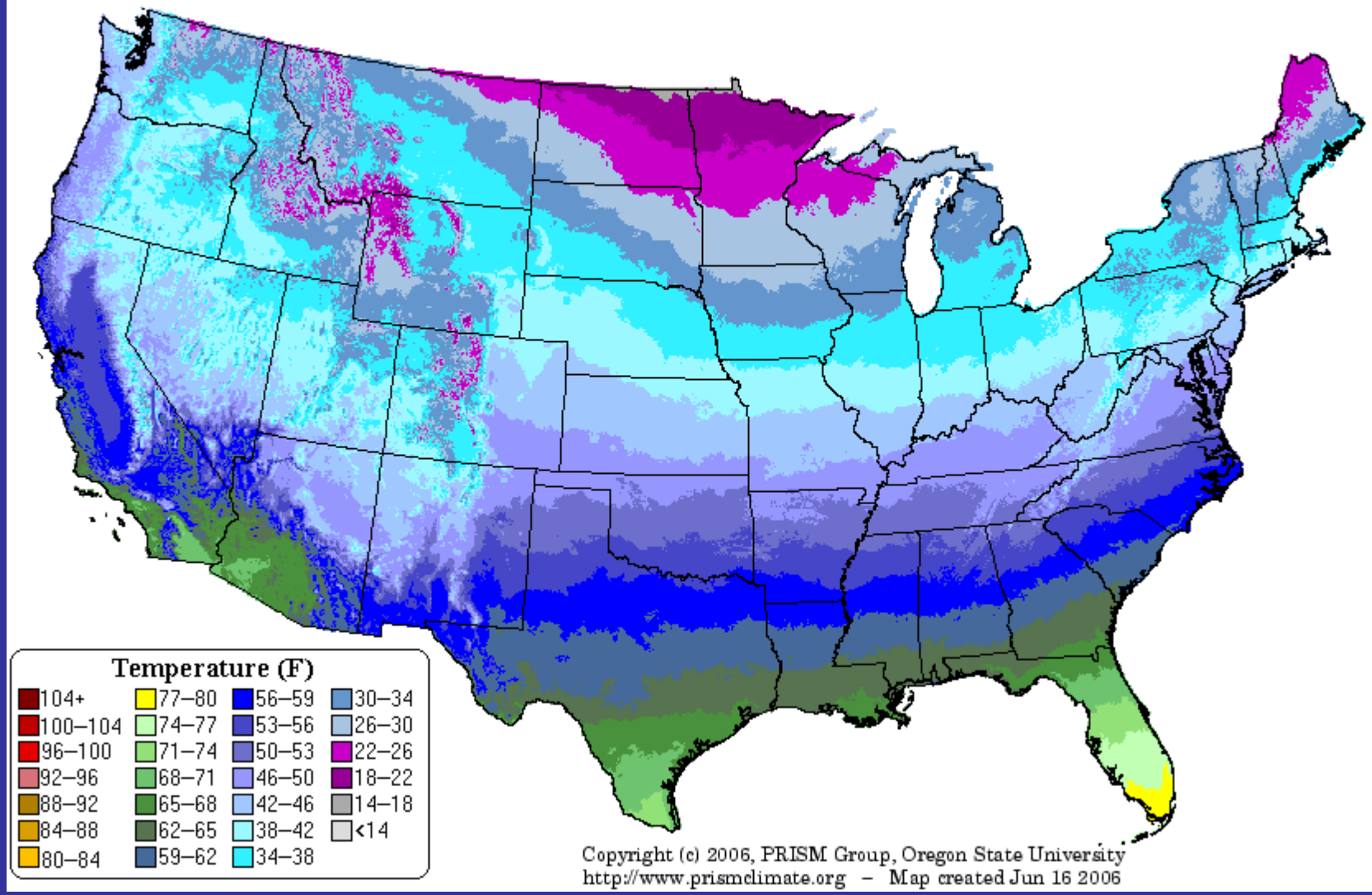



Maximum Temperature: August Climatology (1971–2000)
Temperature (F)
104+
100–104
96–100
92–96
88–92
84–88
80–84
77–80
74–77
71–74
68–71
65–68
62–65
59–62
56–59
53–56
50–53
46–50
42–46
38–42
34–38
30–34
26–30
22–26
18–22
14–18
<14
Copyright (c) 2006, PRISM Group, Oregon State University
http://www.prismclimate.org – Map created Jun 16 2006

Minimum Temperature: December Climatology (1971–2000)

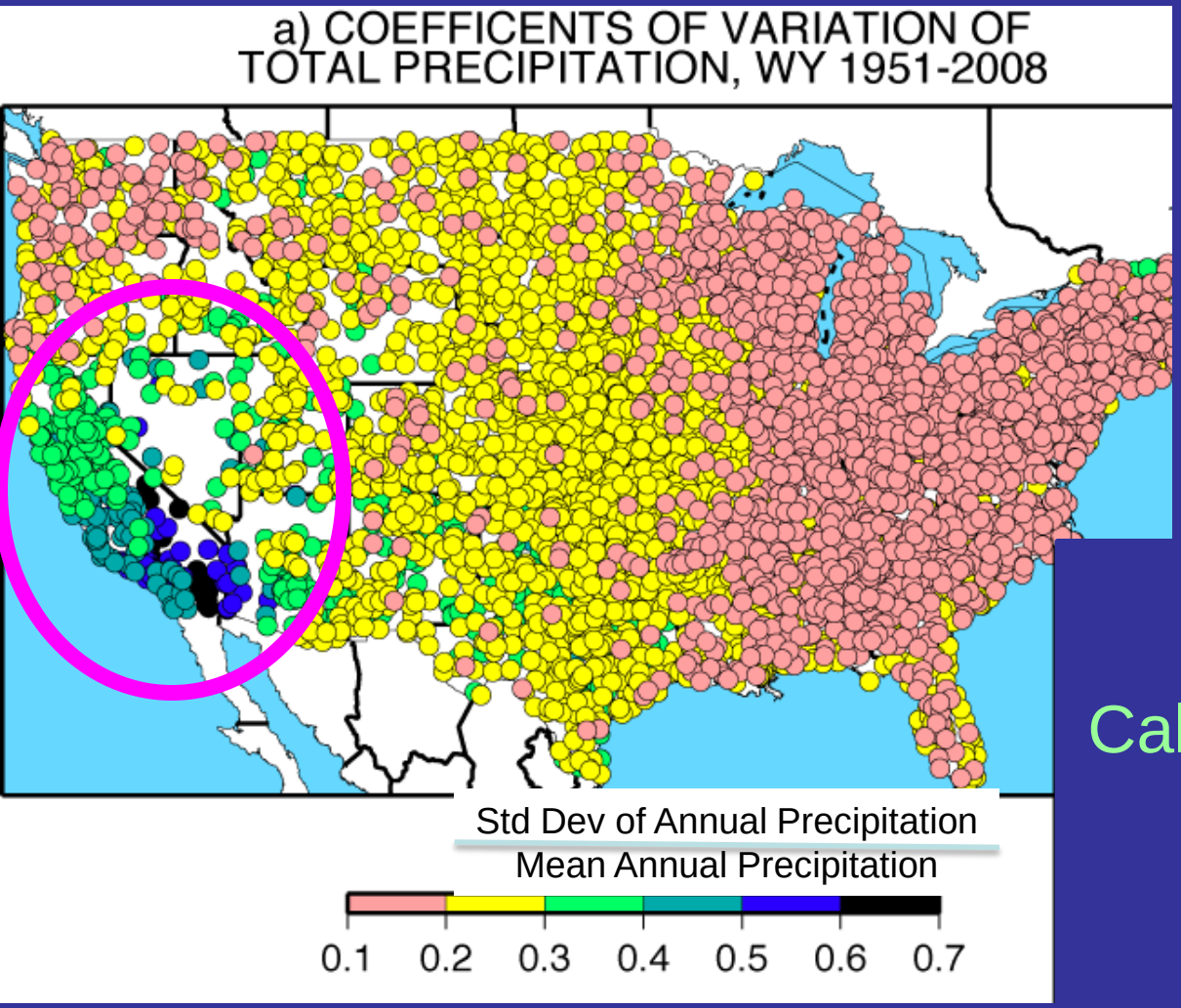


Maximum Temperature: December Climatology (1971–2000)



Inter-Annual Variability

Year to Year Precipitation Variability



California precipitation is uniquely variable

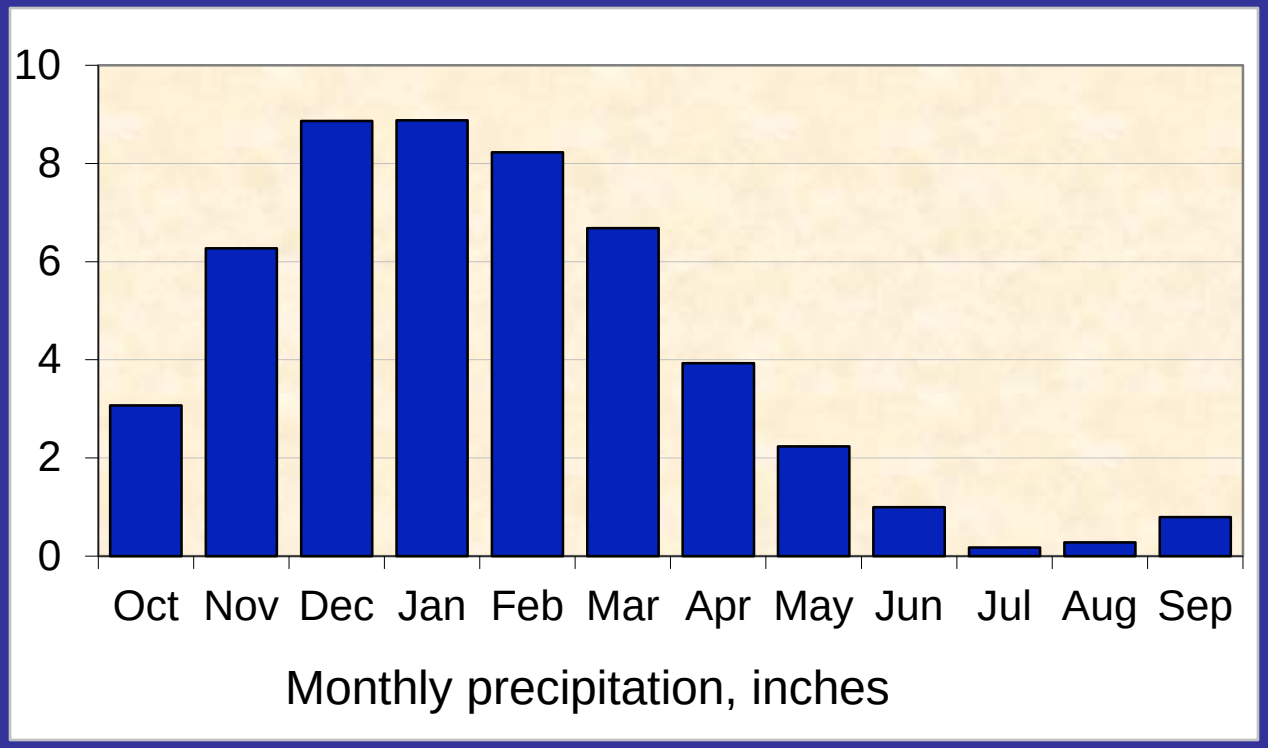
Higher values are higher variability

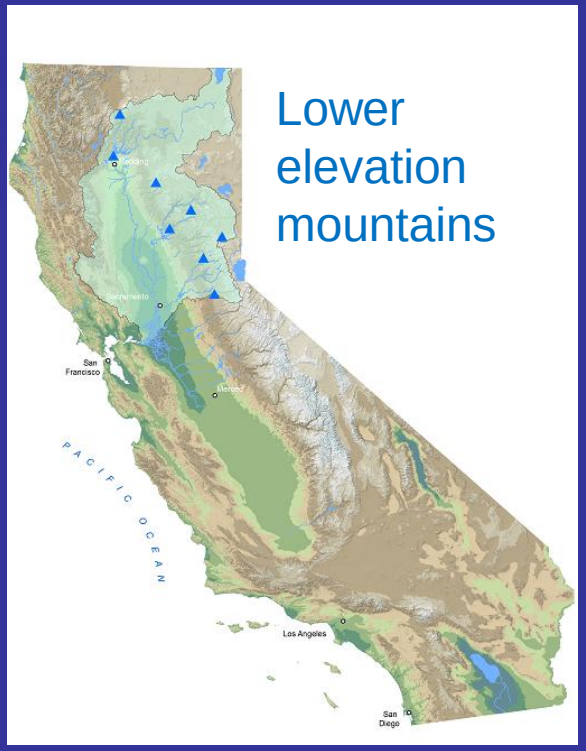
Dettinger et al, 2011

Precipitation and Runoff

Northern Sierra

Northern Sierra 8 Station Index



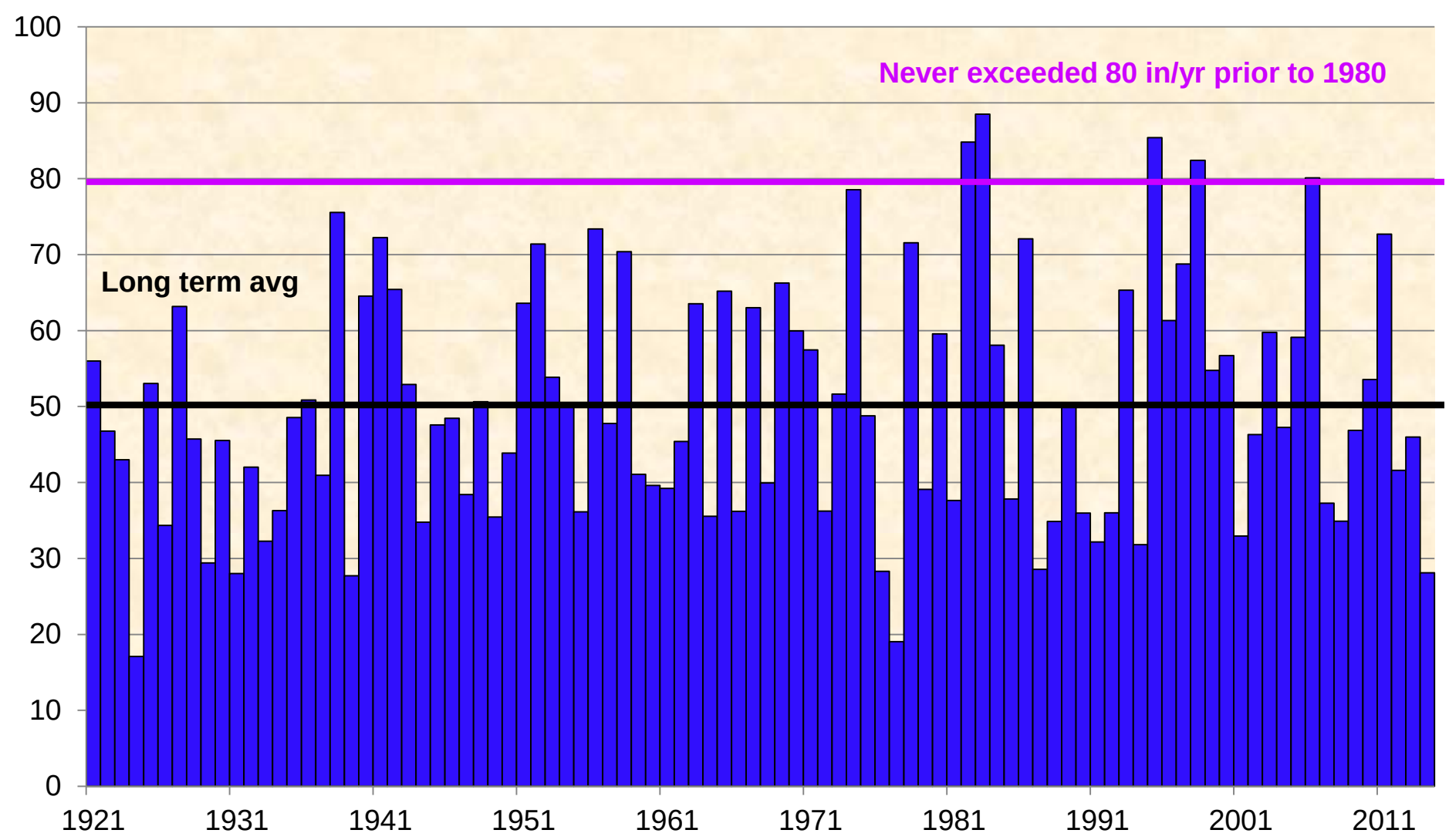


Annual Average: 50 inches
Maximum Year (1983): 88.5 inches
Minimum Year (1924): 17.1 inches
Period of Record 1921- Present

Average of:

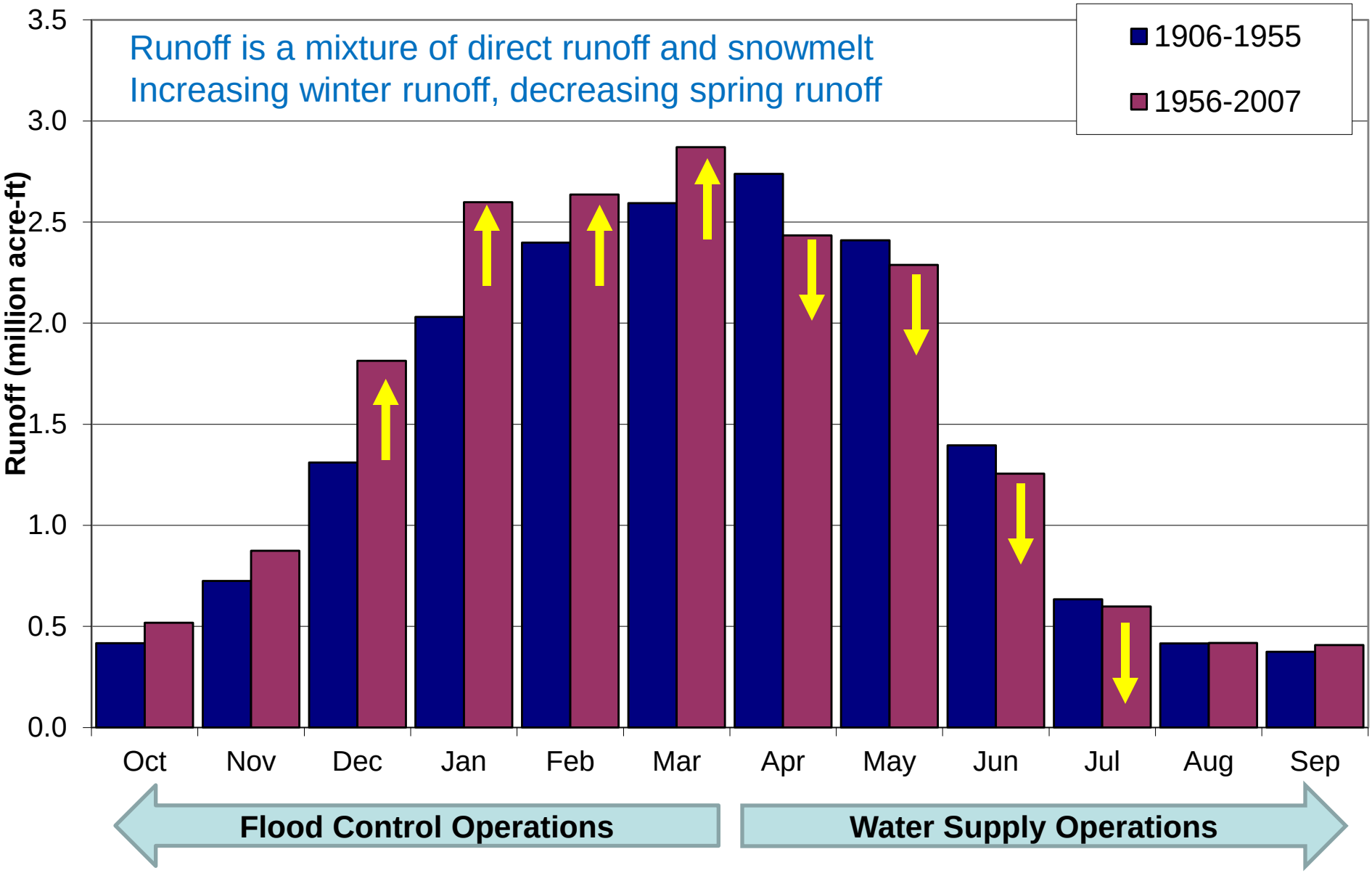
Mt. Shasta City	Quincy
Shasta Dam	Sierraville RS
Mineral	Pacific House
Brush Creek RS	Blue Canyon

Northern Sierra 8- Station Index Precipitation in Inches



Water Year

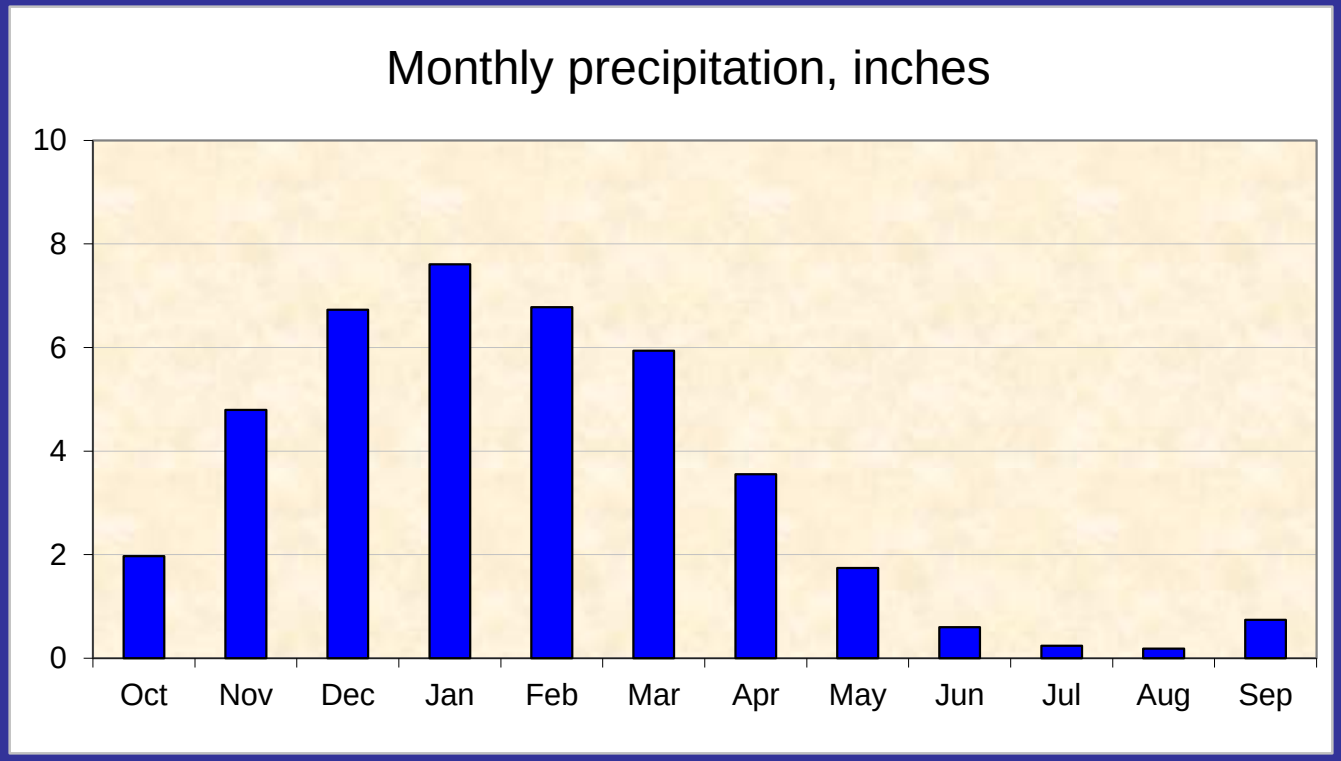
Monthly Average Runoff of Sacramento River System

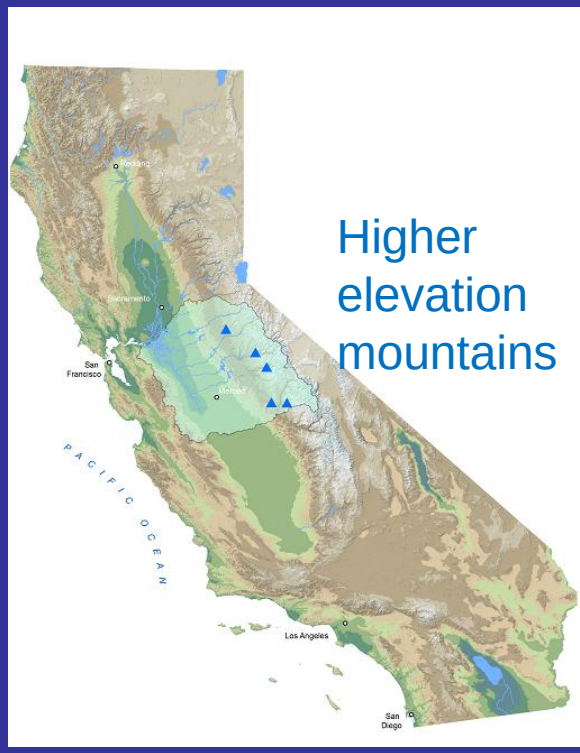


Precipitation and Runoff

Southern Sierra

San Joaquin 5-Station Index

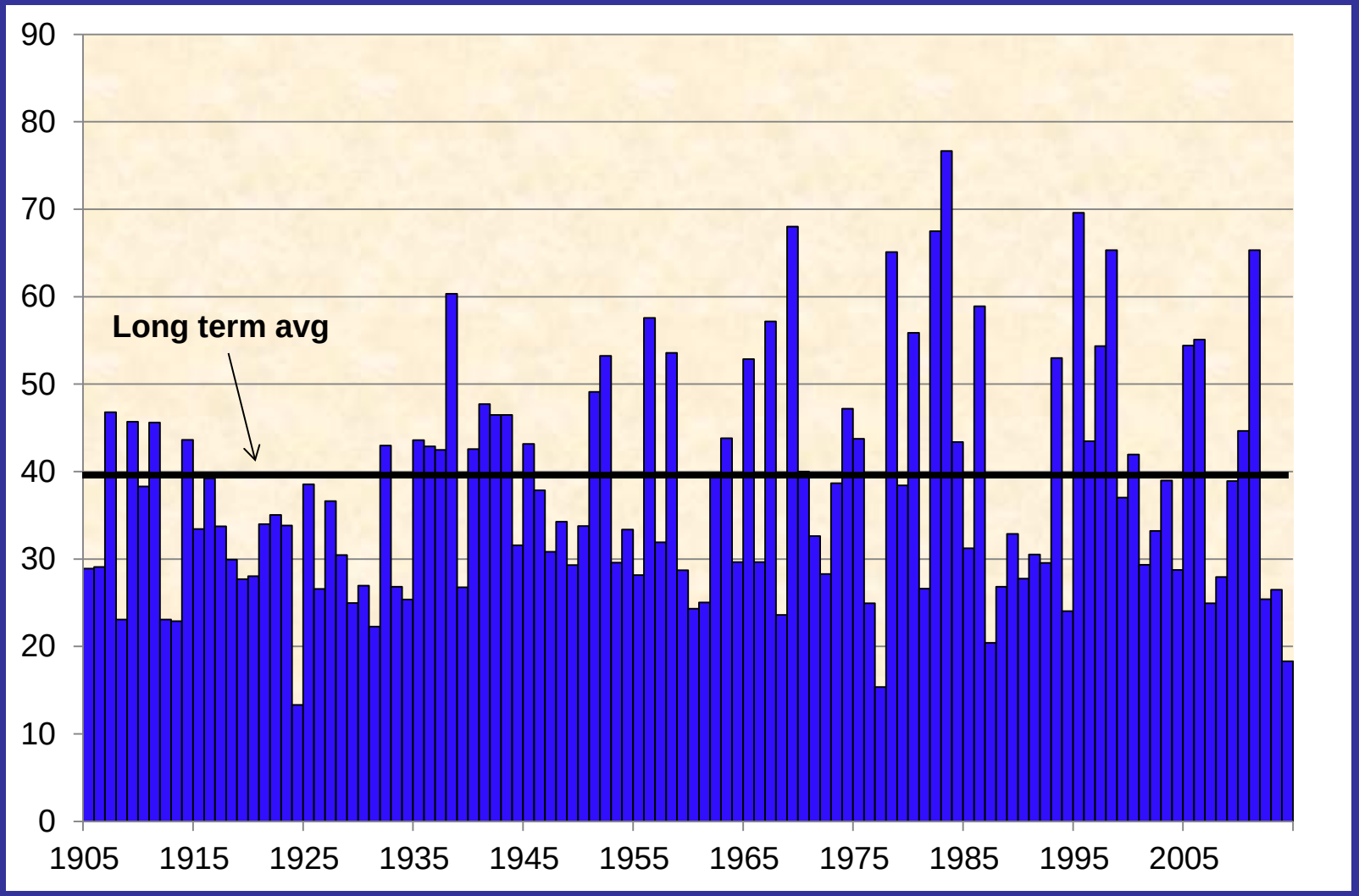




Annual Average: 40 inches
Maximum Year (1983) 77.4 inches
Minimum Year (1924) 14.8 inches
Period of Record 1949 - Present

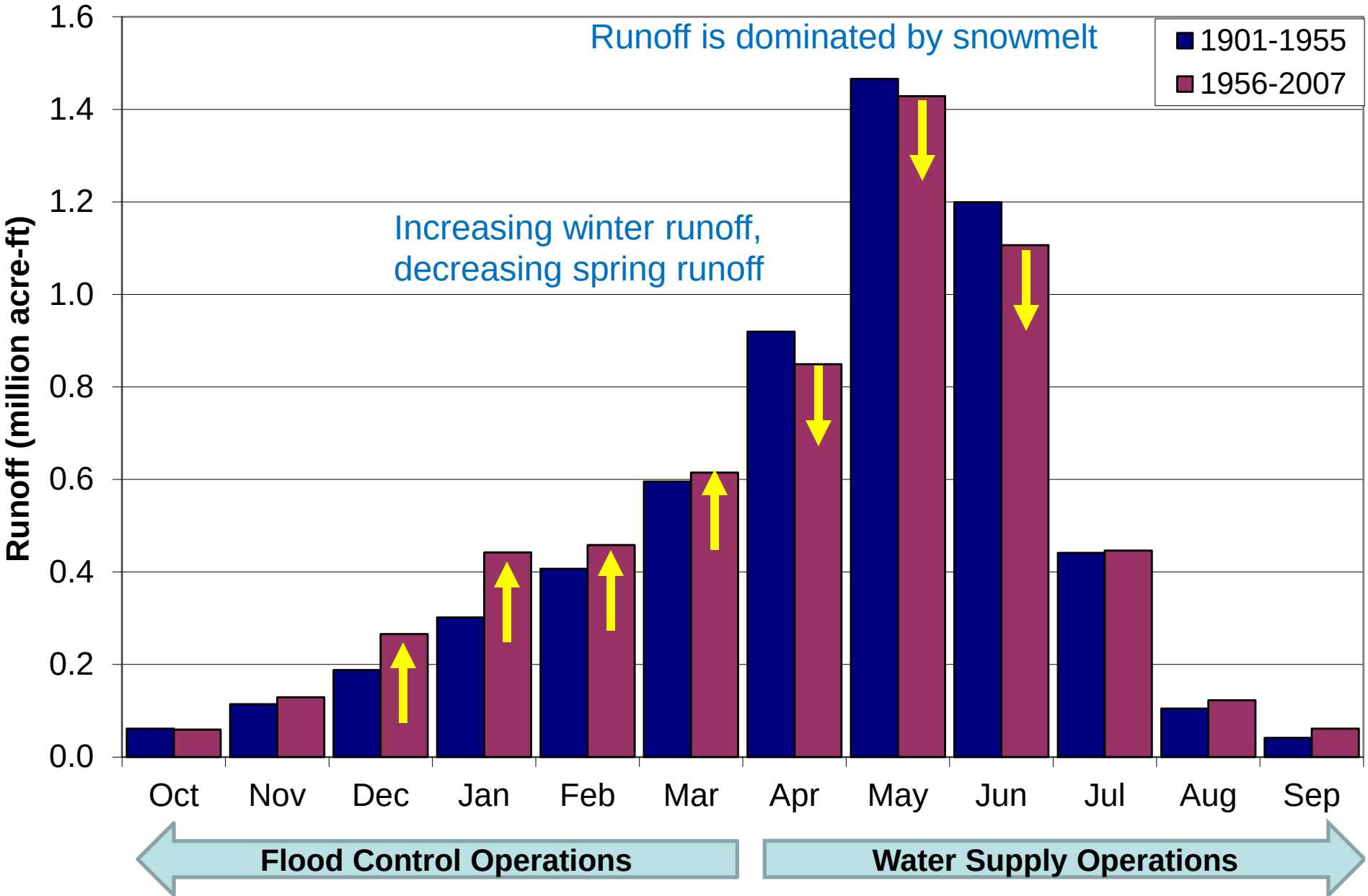
Average of:
Calaveras Big Trees
Hetch Hetchy
Yosemite HQ
North Fork Ranger Station
Huntington Lake

San Joaquin 5 Station Index Precipitation in inches

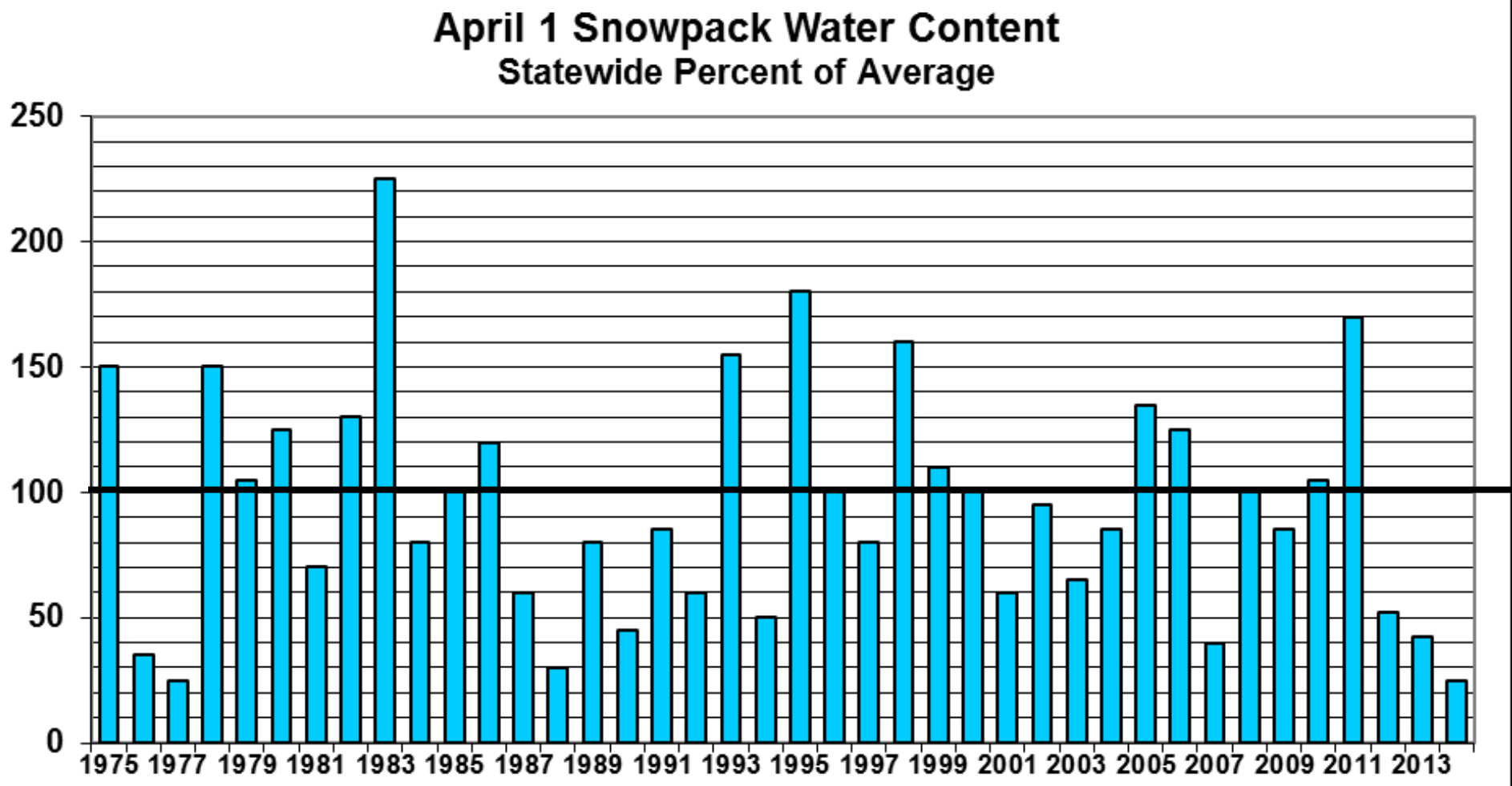


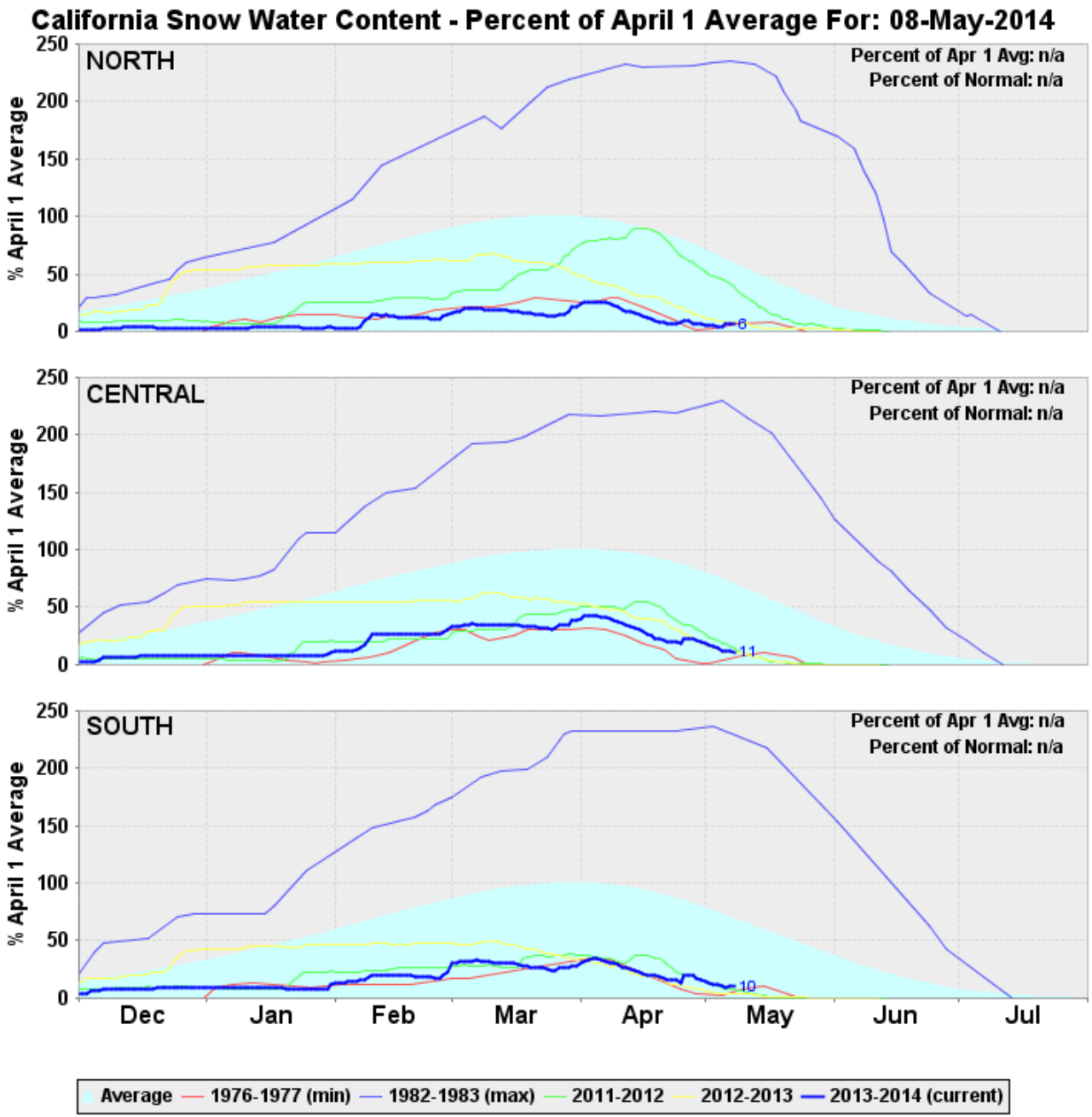
Water Year

Monthly Average Runoff in San Joaquin River System

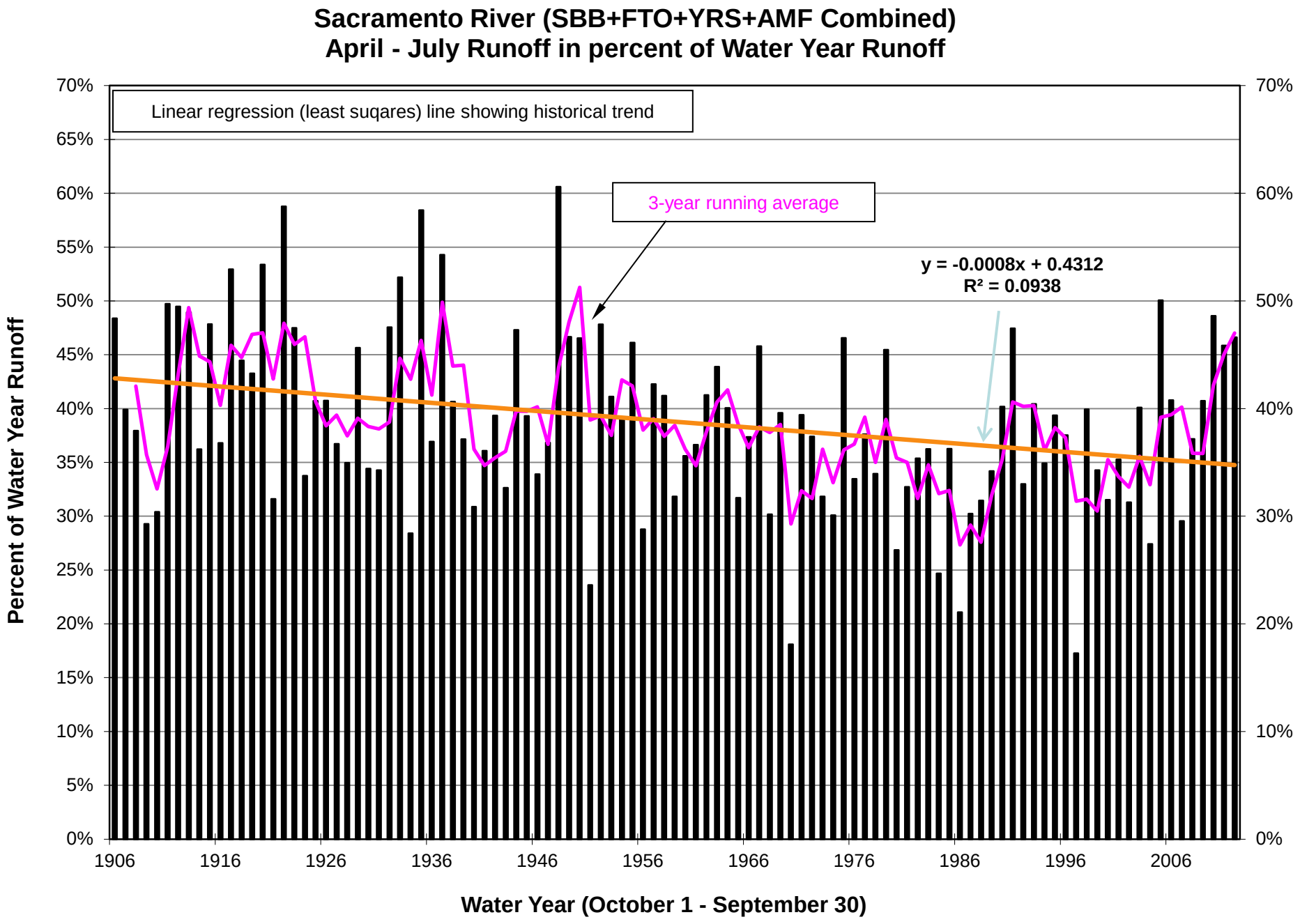


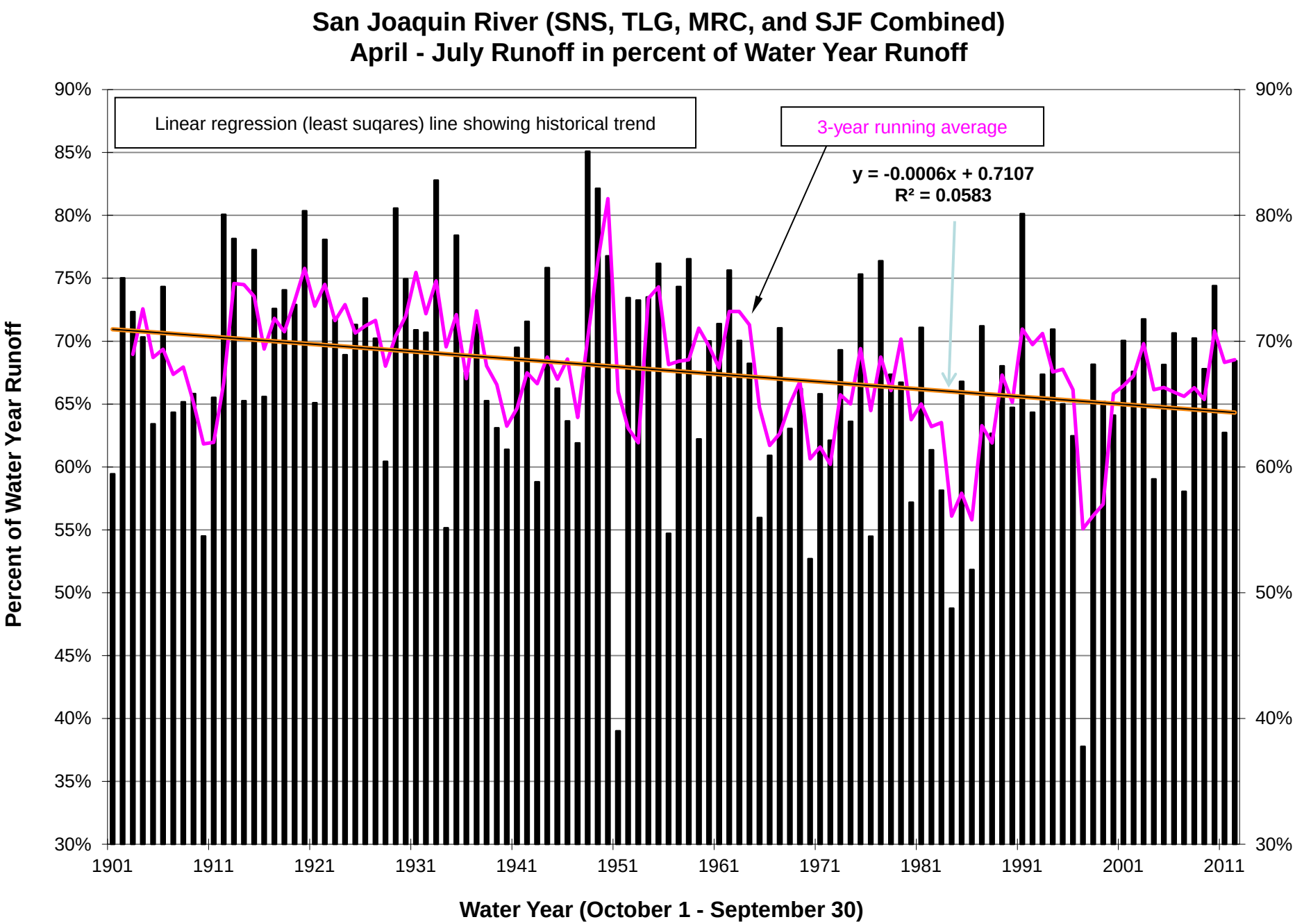
Snow Pack


April 1 Snowpack Water Content
Statewide Percent of Average
250
200
150
100
50
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013


California Snow Water Content - Percent of April 1 Average For: 08-May-2014
NORTH
Percent of Apr 1 Avg: n/a
Percent of Normal: n/a
CENTRAL
Percent of Apr 1 Avg: n/a
Percent of Normal: n/a
SOUTH
Percent of Apr 1 Avg: n/a
Percent of Normal: n/a
% April 1 Average
250
200
150
100
50
0
6
11
10
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Average
1976-1977 (min)
1982-1983 (max)
2011-2012
2012-2013
2013-2014 (current)

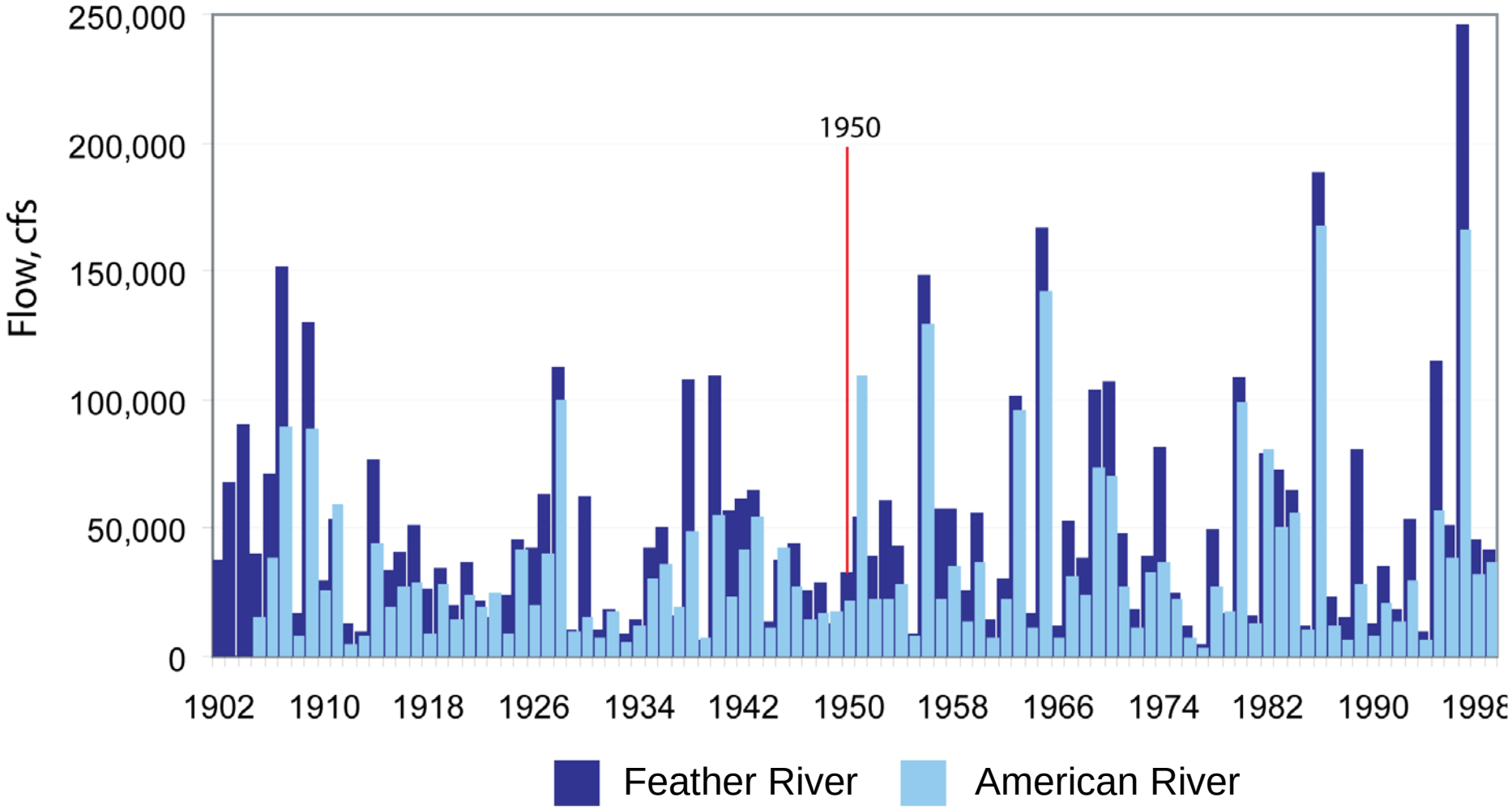
Snowmelt
April-July Runoff


Sacramento River (SBB+FTO+YRS+AMF Combined)
April - July Runoff in percent of Water Year Runoff
Linear regression (least suqares) line showing historical trend
3-year running average
y = -0.0008x + 0.4312
R² = 0.0938
Percent of Water Year Runoff
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
1906
1916
1926
1936
1946
1956
1966
1976
1986
1996
2006
Water Year (October 1 - September 30)

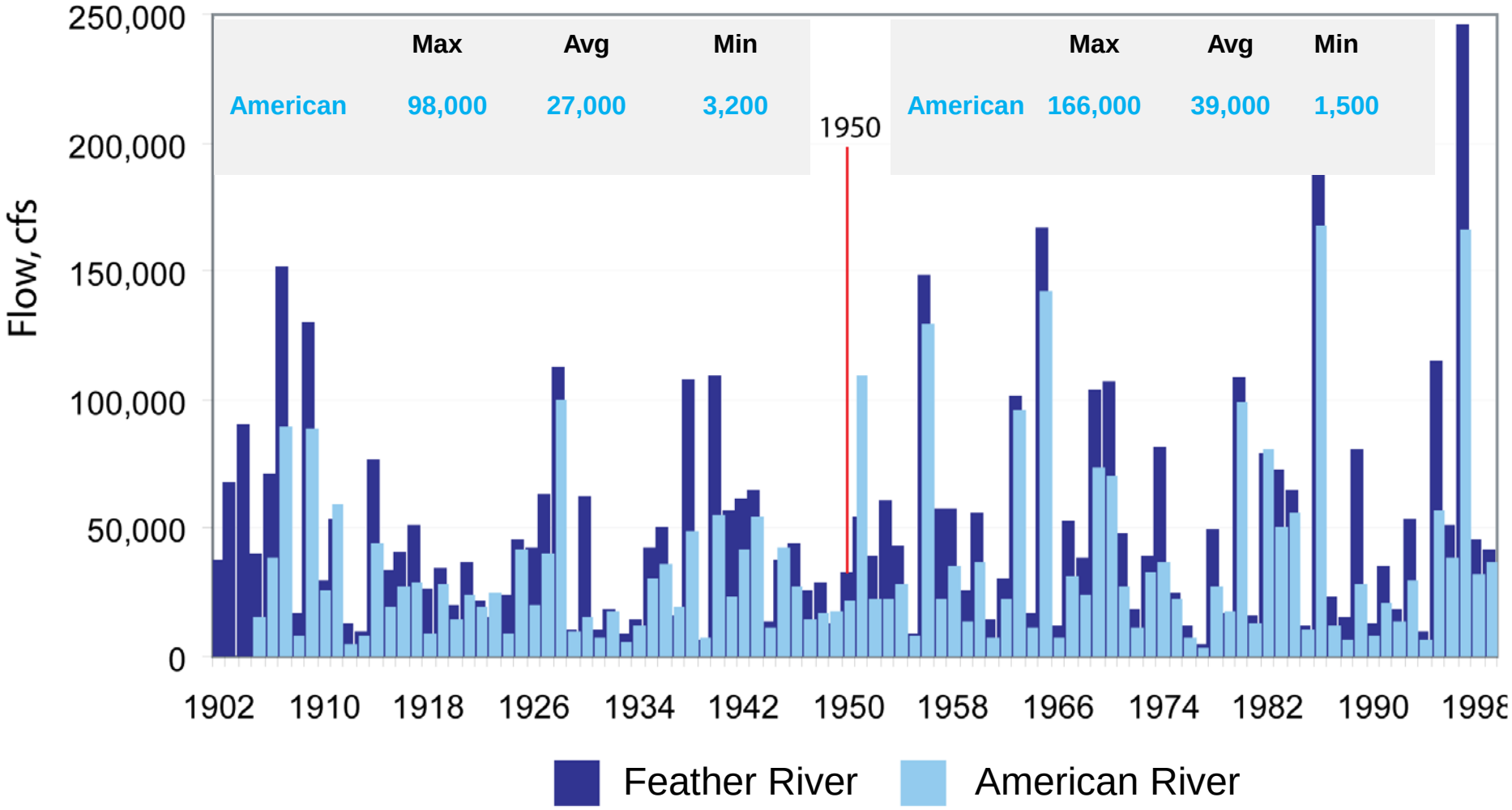

San Joaquin River (SNS, TLG, MRC, and SJF Combined)
April - July Runoff in percent of Water Year Runoff
Linear regression (least suqares) line showing historical trend
3-year running average
y = -0.0006x + 0.7107
R² = 0.0583
Percent of Water Year Runoff
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
2011
Water Year (October 1 - September 30)

Peak Runoff

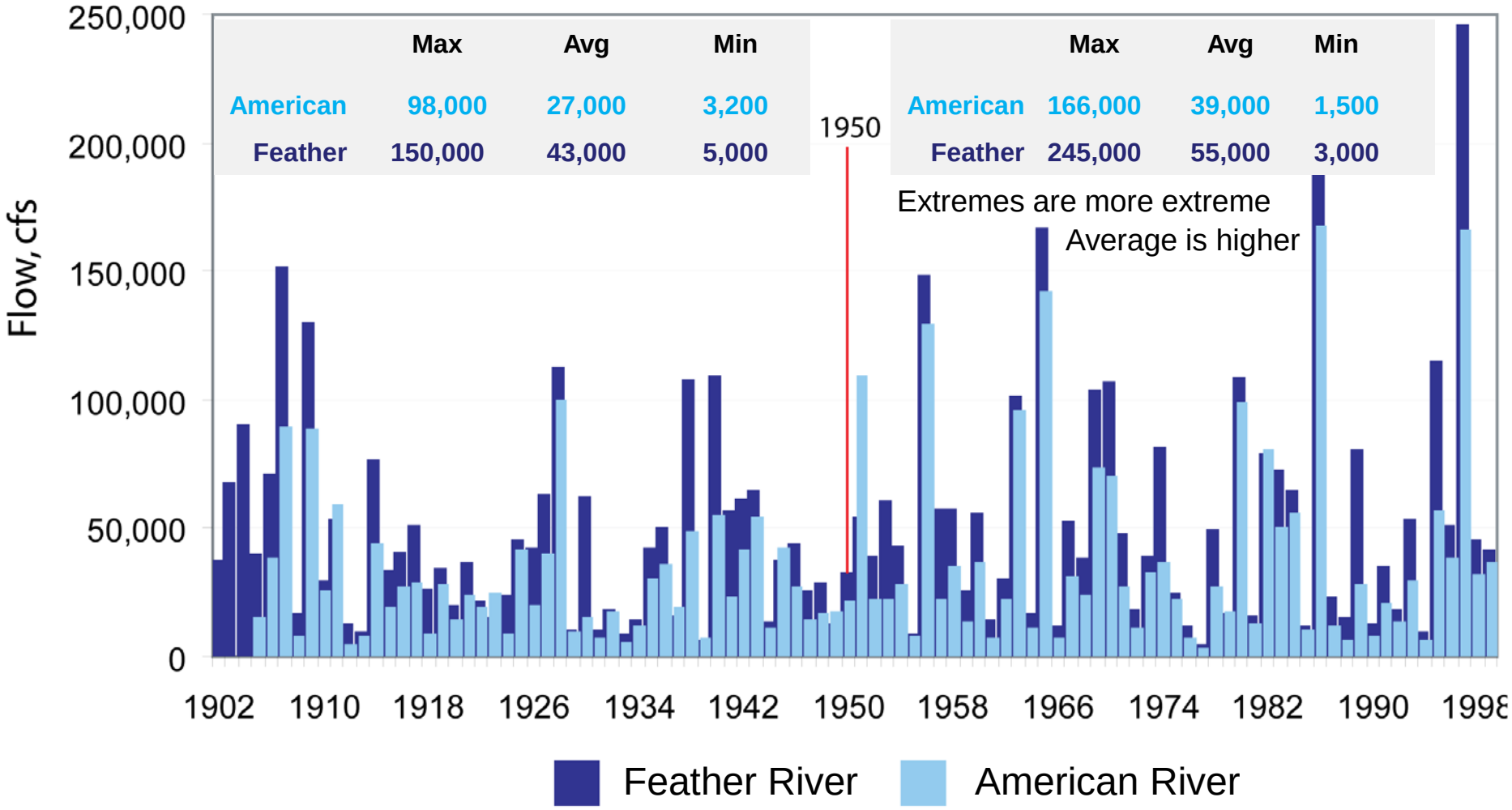
20th Century Annual Peak 3-Day Flows without the Influence of Reservoirs



20th Century Annual Peak 3-Day Flows without the Influence of Reservoirs



20th Century Annual Peak 3-Day Flows without the Influence of Reservoirs



Climate Signals

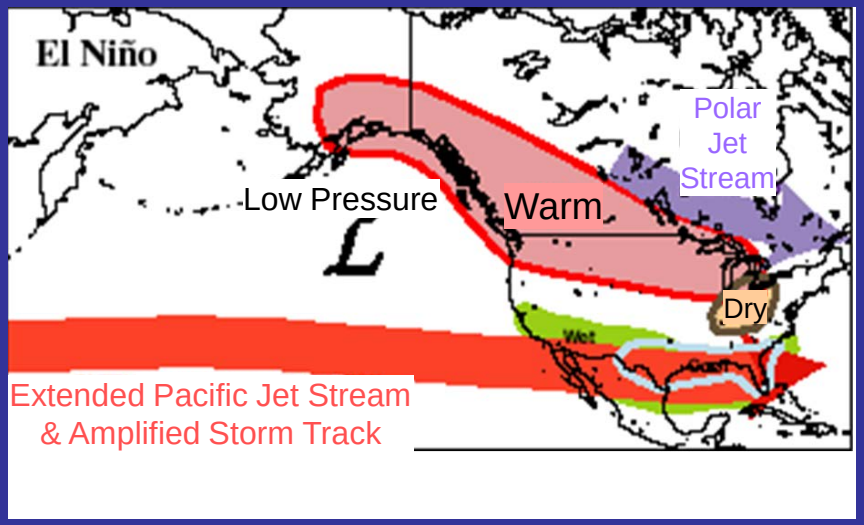
El Niño Southern Oscillation (ENSO)

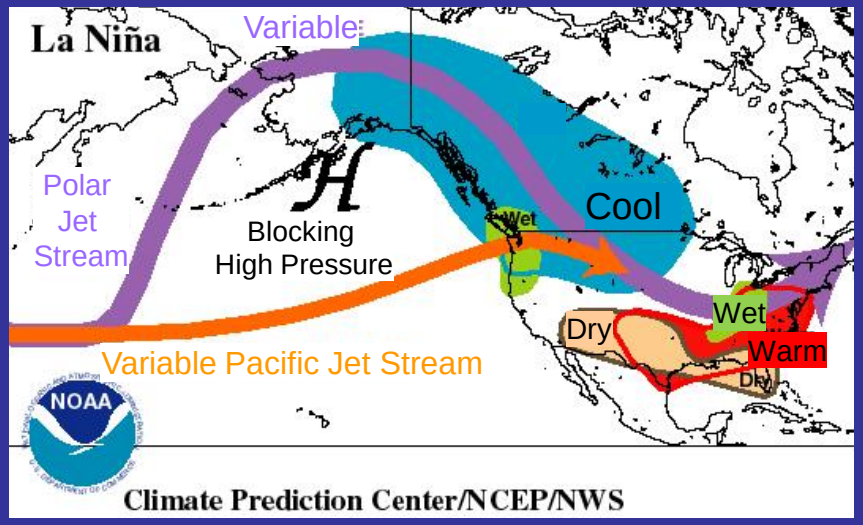
El Niño

- Warm equatorial Pacific ocean
- Flat Zonal Pacific Jet Stream
- Enhanced storm track, flooding
- **1983,**1986-87, 1991-92, 1993, 1994,**1997-98**, 2002-3, 2009-10

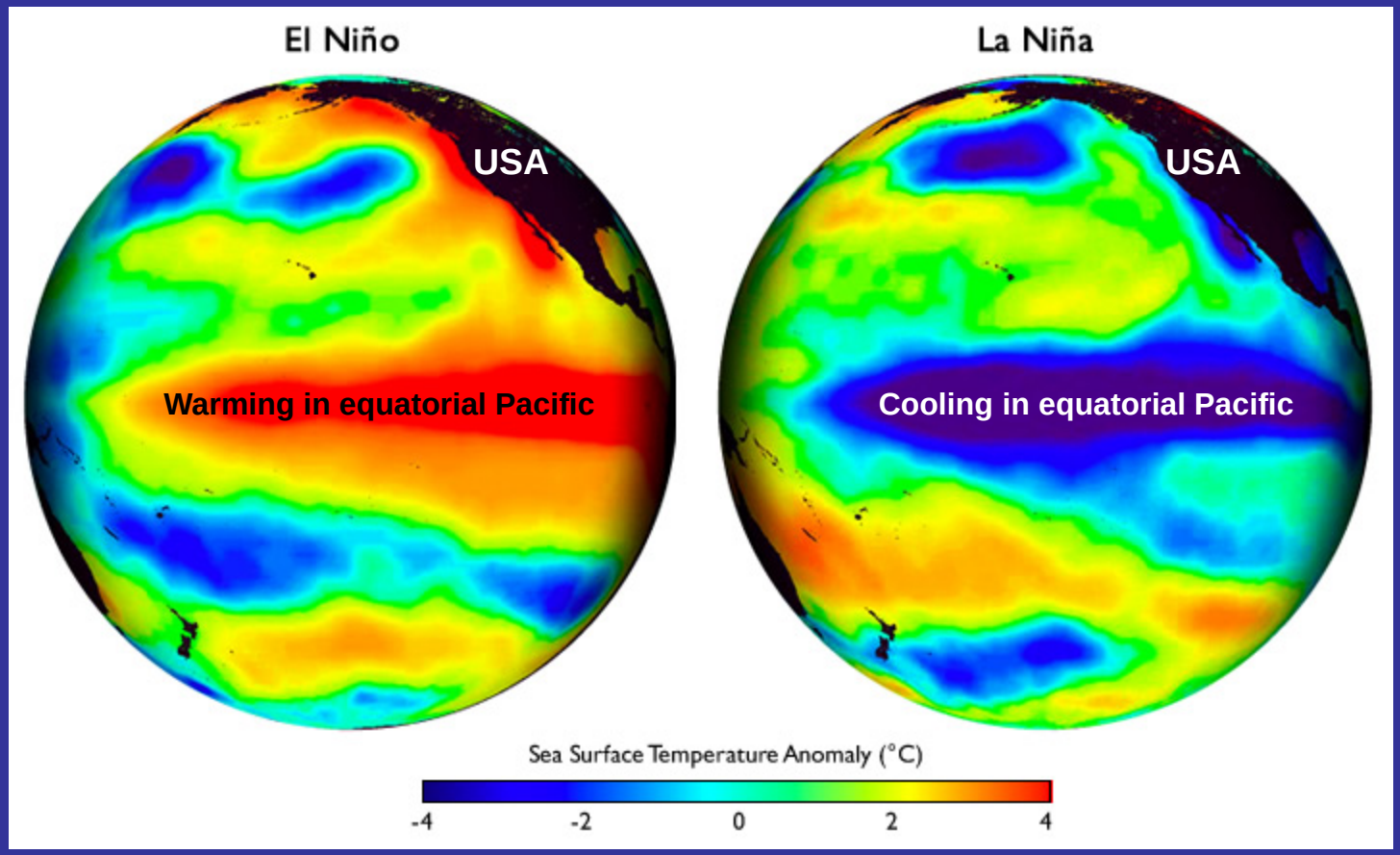
La Niña

- Cool equatorial Pacific ocean
- Variable Loopy Pacific Jet Stream
- 1985, 1995-96, 1999-2001, 2007-8, 2010-11, 2011-12



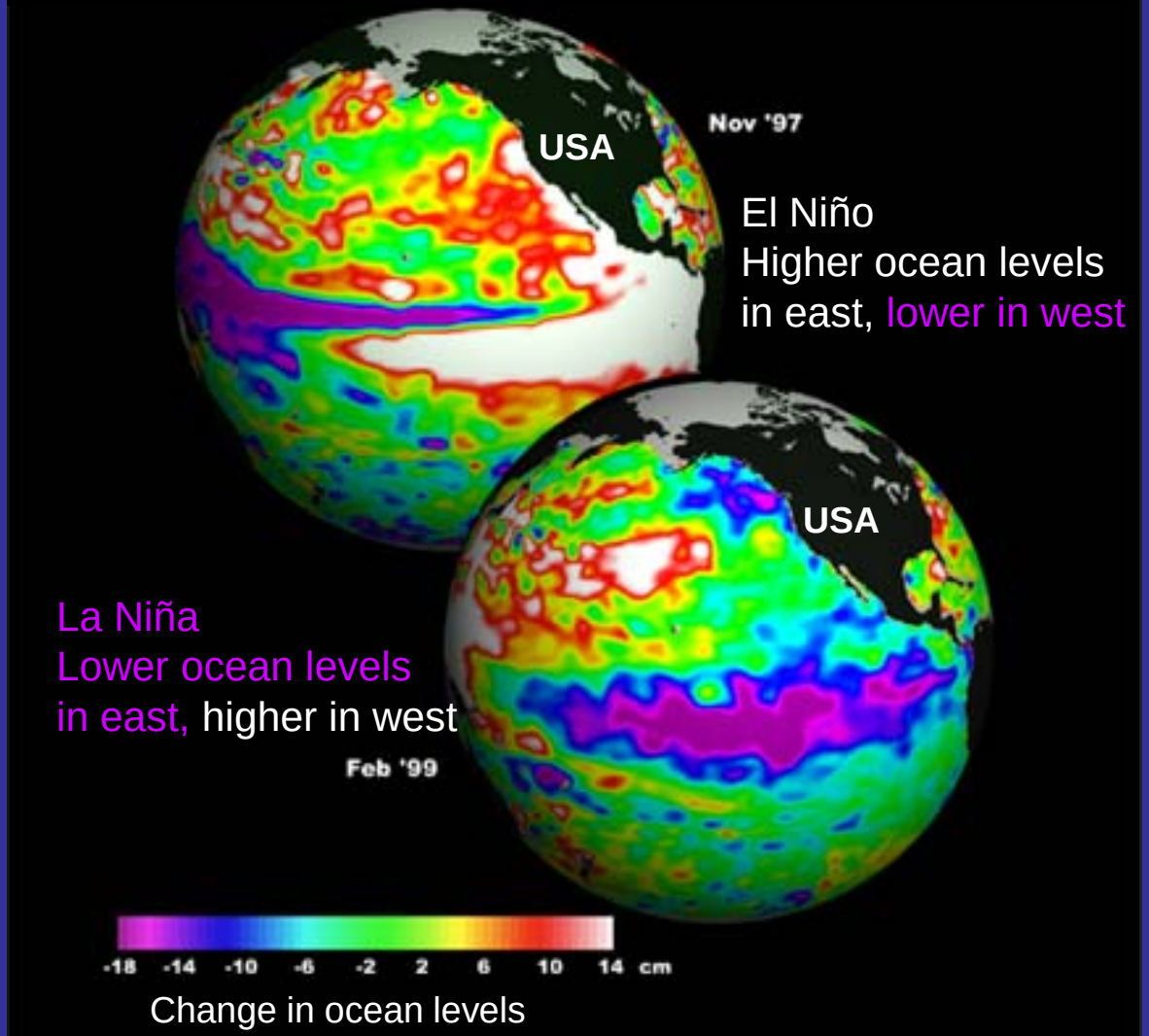


Ocean Temperature Differences during El Niño and La Niña



http://www.climatewatch.noaa.gov/wp-content/uploads/2009/10/ENSO-states-viz.jpg

Sea Surface Elevation Changes during El Niño and La Niña



El Niño
Higher ocean levels
in east, lower in west

La Niña
Lower ocean levels
in east, higher in west

Change in ocean levels

http://sealevel.jpl.nasa.gov/files/archive/science-elnino/el-nino-la-nina.jpg

When do we have El Niño/La Niña?

- Develops April-June, strongest in December-February
- Typically lasts 9-12 months, can last up to 2 years
- Typically occurs every 2-7 years

Oceanic Niño Index (ONI) Blue La Niña Red El Niño

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1997	-0.5	-0.4	-0.1	0.2	0.7	1.2	1.5	1.8	2.1	2.3	2.4	2.3
1998	2.2	1.8	1.4	0.9	0.4	-0.2	-0.7	-1.0	-1.2	-1.3	-1.4	-1.5
1999	-1.5	-1.3	-1.0	-0.9	-0.9	-1.0	-1.0	-1.1	-1.1	-1.3	-1.5	-1.7
2000	-1.7	-1.5	-1.2	-0.9	-0.8	-0.7	-0.6	-0.5	-0.6	-0.6	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.4	-0.2	-0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.3
2002	-0.2	0.0	0.1	0.3	0.5	0.7	0.8	0.8	0.9	1.2	1.3	1.3
2003	1.1	0.8	0.4	0.0	-0.2	-0.1	0.2	0.4	0.4	0.4	0.4	0.3
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.8	0.7	0.7	0.7
2005	0.6	0.4	0.3	0.3	0.3	0.3	0.2	0.1	0.0	-0.2	-0.5	-0.8
2006	-0.9	-0.7	-0.5	-0.3	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.0
2007	0.7	0.3	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.8	-1.1	-1.2	-1.4
2008	-1.5	-1.5	-1.2	-0.9	-0.7	-0.5	-0.3	-0.2	-0.1	-0.2	-0.5	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.2	0.4	0.5	0.6	0.8	1.1	1.4	1.6
2010	1.6	1.3	1.0	0.6	0.1	-0.4	-0.9	-1.2	-1.4	-1.5	-1.5	-1.5
2011	-1.4	-1.2	-0.9	-0.6	-0.3	-0.2	-0.2	-0.4	-0.6	-0.8	-1.0	-1.0
2012	-0.9	-0.6	-0.5	-0.3	-0.2	0.0	0.1	0.4	0.5	0.6	0.2	-0.3
2013	-0.6	-0.6	-0.4	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.2	-0.3	-0.4
2014	-0.6	-0.6	-0.5	-0.1	0.1	0.1	0.0	0.0	0.2			

Strong El Niño 97-98

2014 Warming Ocean (switch from negative to positive values)

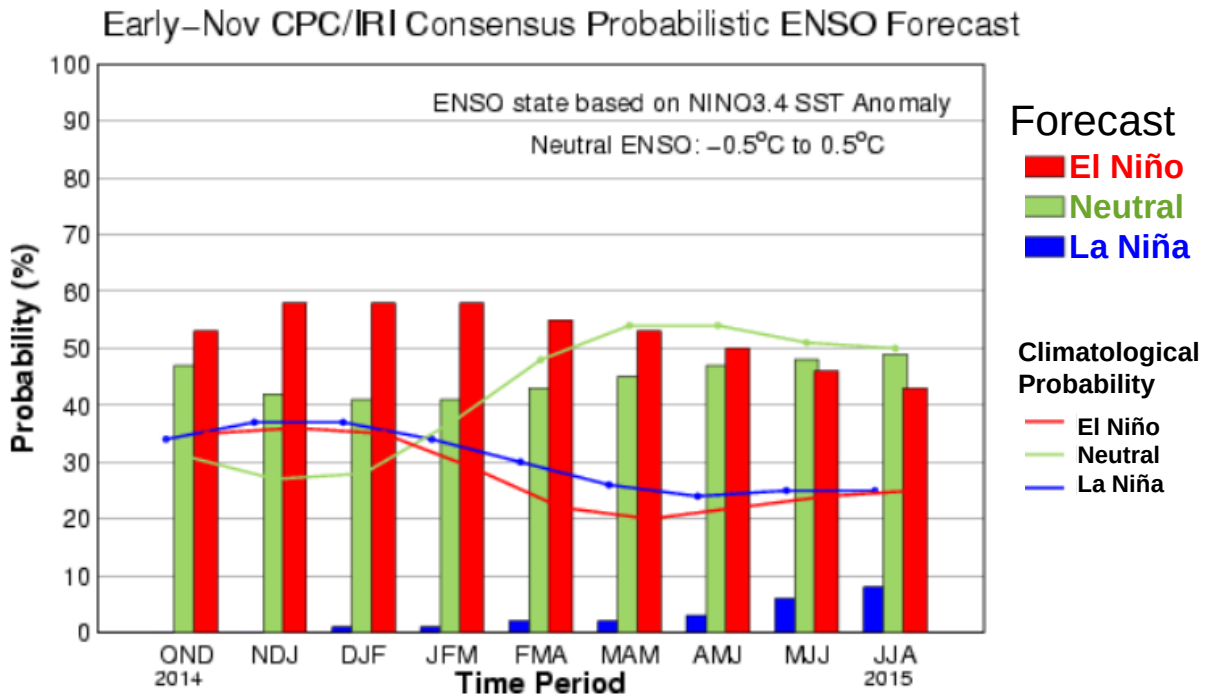
Updated 11-19-14 http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Is this year an El Niño year?

Most of the models predict weak El Niño conditions for winter and spring

Published: November 6, 2014

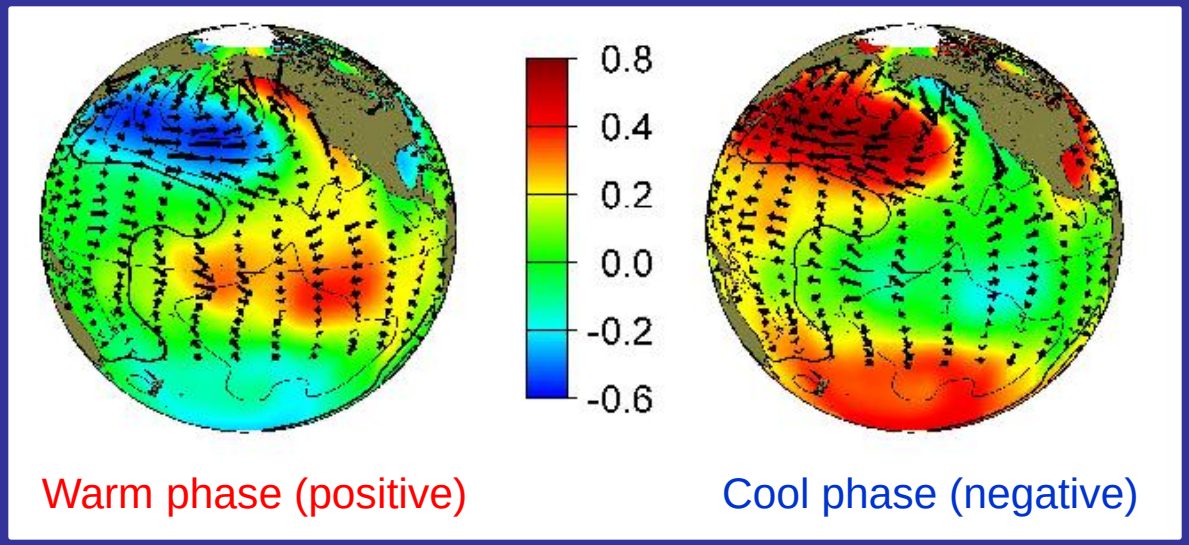
During September through October the observed ENSO conditions retreated from those of a borderline El Niño to a warmish ENSO-neutral state. However, most of the ENSO prediction models continue to indicate development of weak El Niño conditions during the October-December season in progress, peaking at weak strength during winter 2014-15 and lasting through most of northern spring 2015.



Red bars: El Niño conditions Green bars: neutral conditions Blue bars: La Niña conditions

Updated 11-19-14 http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/

Pacific Decadal Oscillation

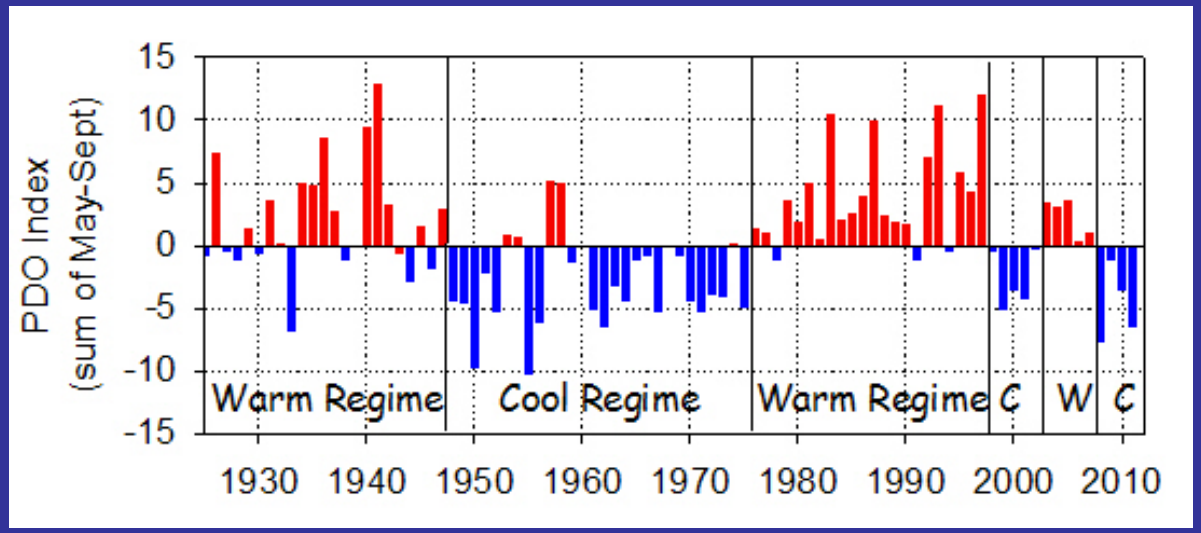


Long term pattern of climate variability similar to ocean component of El Niño

20-30 years vs 6-18 months

Anomaly patterns during warm and cool phases of PDO
Sea Surface Temp (colors),
Sea Level Pressure (contours) &
Surface Wind Stress (arrows)

http://jisao.washington.edu/pdo/



Historical Pattern of PDO

http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm

Atmospheric Rivers

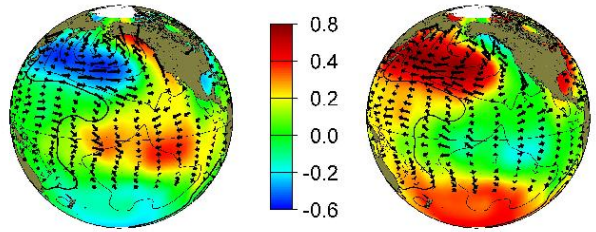
Group Activity

Count 20

Count 2

Group 1: Pacific Decadal Oscillation

Hands Up



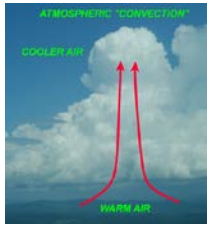
Warm Phase Cool Phase

Hands Down

Ocean

Group 3: Madden Julian Oscillation

Hands Up



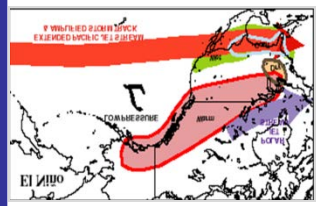
Wet phase Dry phase

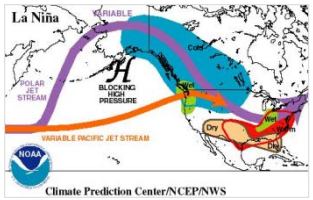
Hands Down

Atmosphere

Group 2: El Niño Southern Oscillation

Hands Up





El Niño La Niña

Hands Down

Ocean/Atmosphere

Group 4: Seasons

Hands Up

Wet Season Dry Season

Hands Down

Geophysical

Count 8

Count 3

Group 5: Scientists

Big Storm Conditions

Hands Up Hands Up Hands Up Hands Up

Likely Drier Conditions

Hands Down Hands Down Hands Down Hands Up

Take Home Points

- California has a Mediterranean Climate (warm dry summer, cool wet winter)
- Topography is important
- Lots of variability in space and time

Take Home Points

- Atmospheric Rivers important for floods and water supply
- Many processes in play to create a weather event recorded as obs of rain, snow, temperature
- Alignment of processes necessary for extreme events

Questions?

Email: manderso@water.ca.gov