



# Climate, Drought, and Change

Delta Science Program

August 25, 2014

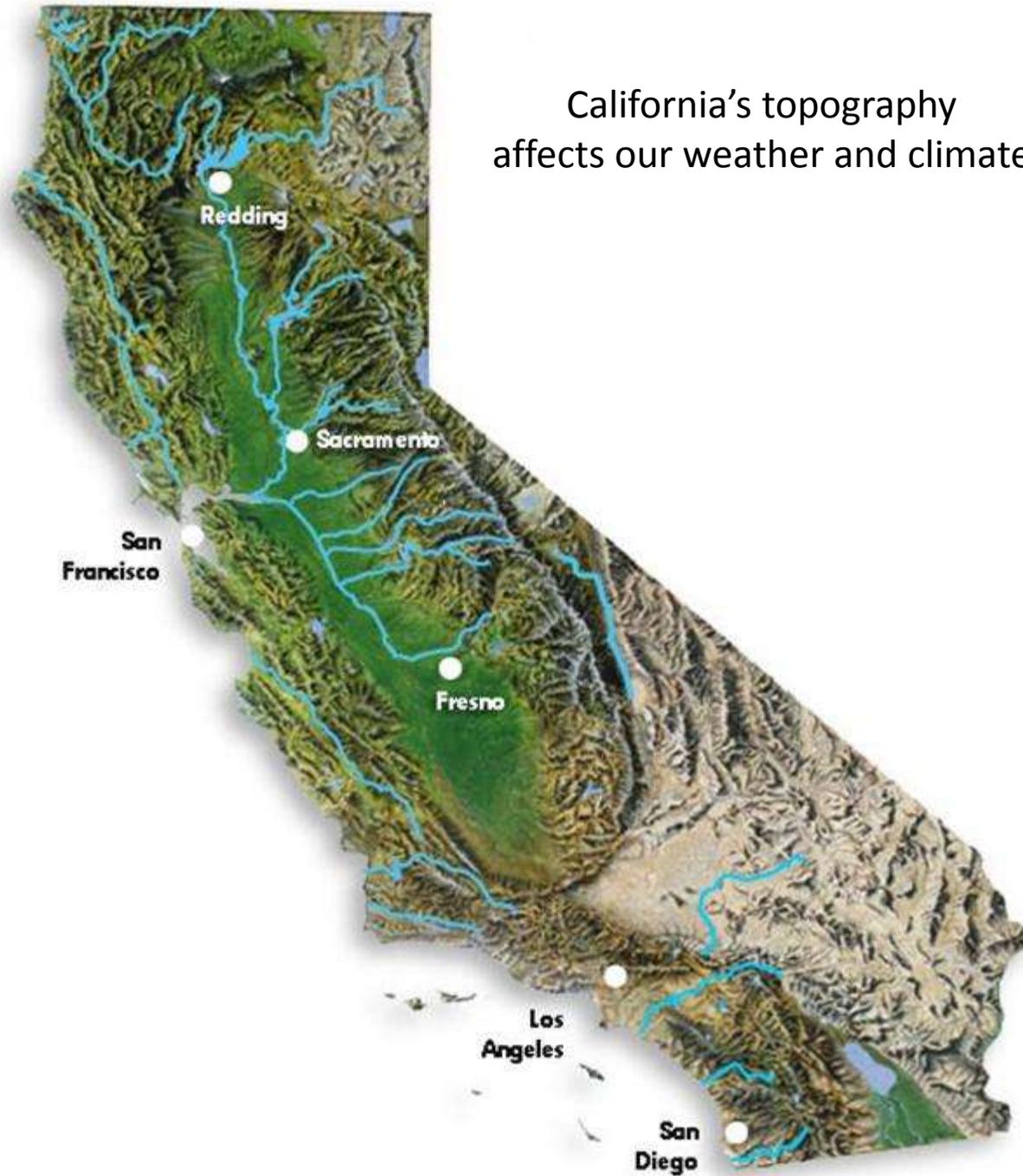
Oroville Reservoir January 2009

# Presentation Overview

- Current Drought Conditions
- Relation to 20<sup>th</sup> Century Droughts
- Decadal Scale Variability
- Signs of Change

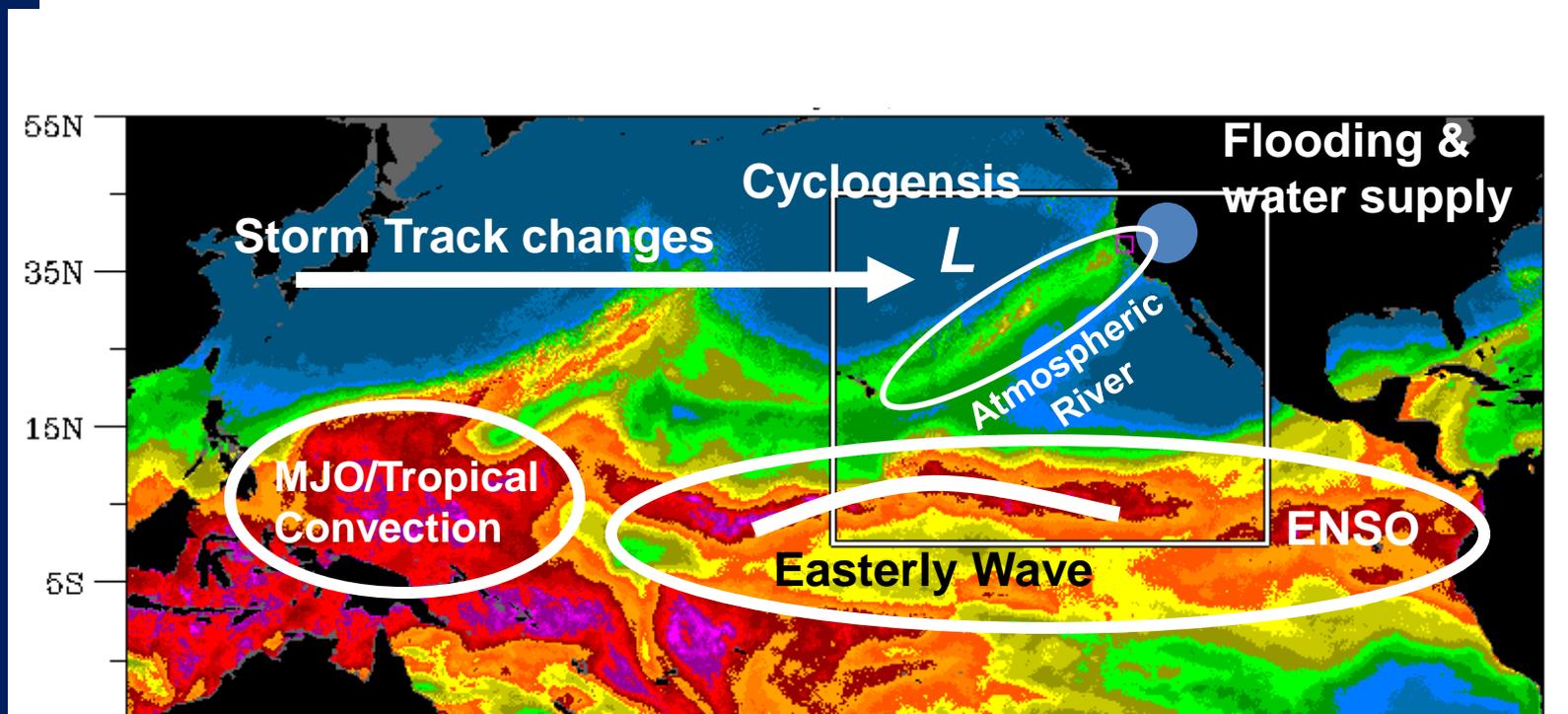
Folsom Reservoir January 2014

California's topography affects our weather and climate



# Key Phenomena Affecting California

## Water Supply/Flooding:



**The size of the AR results from the alignment of key processes**

The absence of AR activity important to drought

# PSD Near Realtime Observations - Map



Map Satellite

## SurfaceMet Data

- Temperature (F)
- Integrated Water Vapor (cm)
- Snow Depth (in)
- Wind Speed & Direction (mph)
- Accumulated Precipitation (in)

## Wind and Precipitation Radar Data

- Snow Level (kft msl)
- Integrated Water Vapor Flux (cm)(m/s)

## Radar NEXRAD Data

- Radar Relectivity Mosaic
- Radar 1 Hour Precip Mosaic

12/27/2013

# PSD Near Realtime Observations - Map

## SurfaceMet Data

- Temperature (F)
- Integrated Water Vapor (cm)
- Snow Depth (in)
- Wind Speed & Direction (mph)

Accumulated Precipitation (in)

- [v]

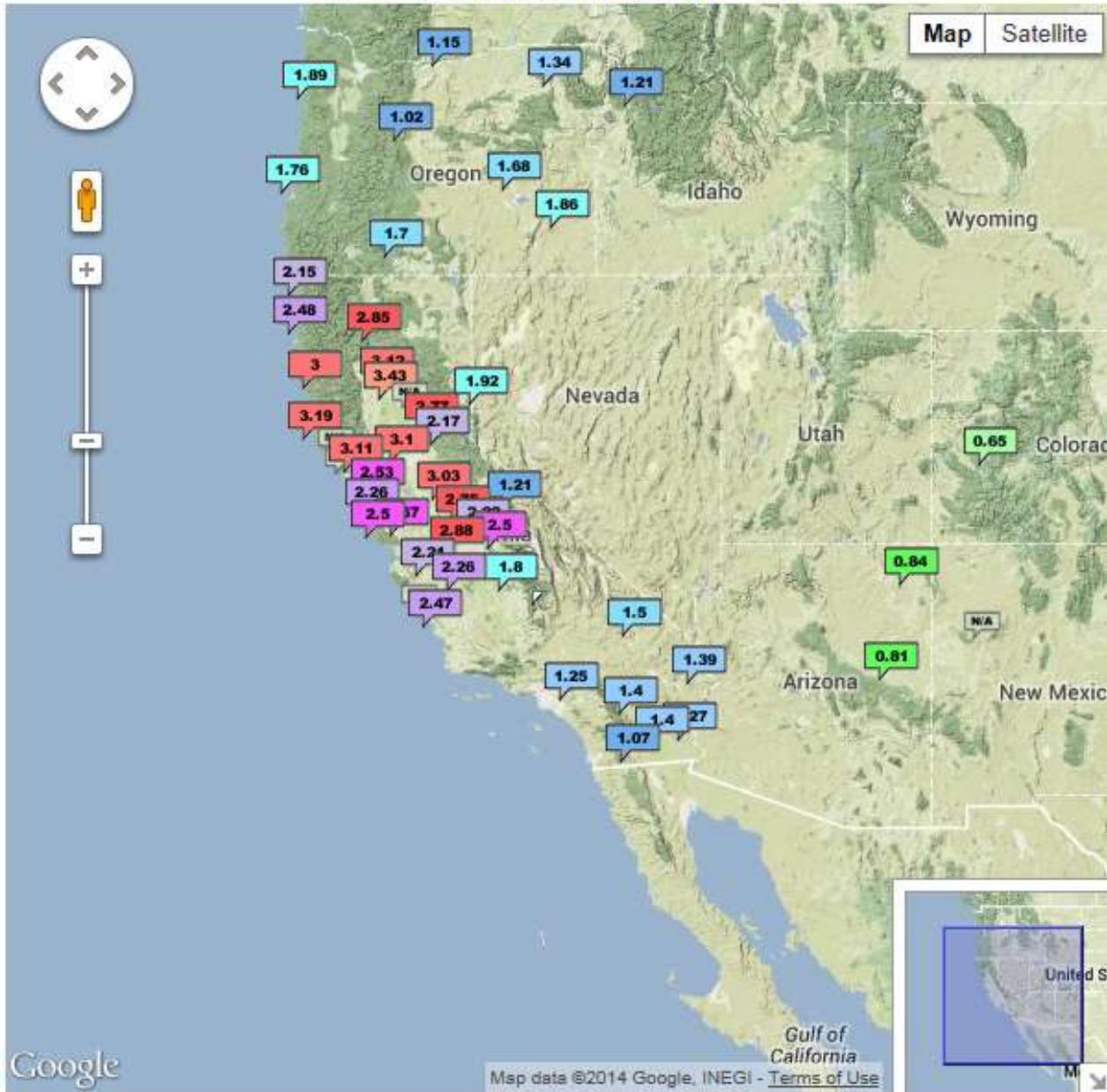
## Wind and Precipitation Radar Data

- Snow Level (kft msl)
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- [v]

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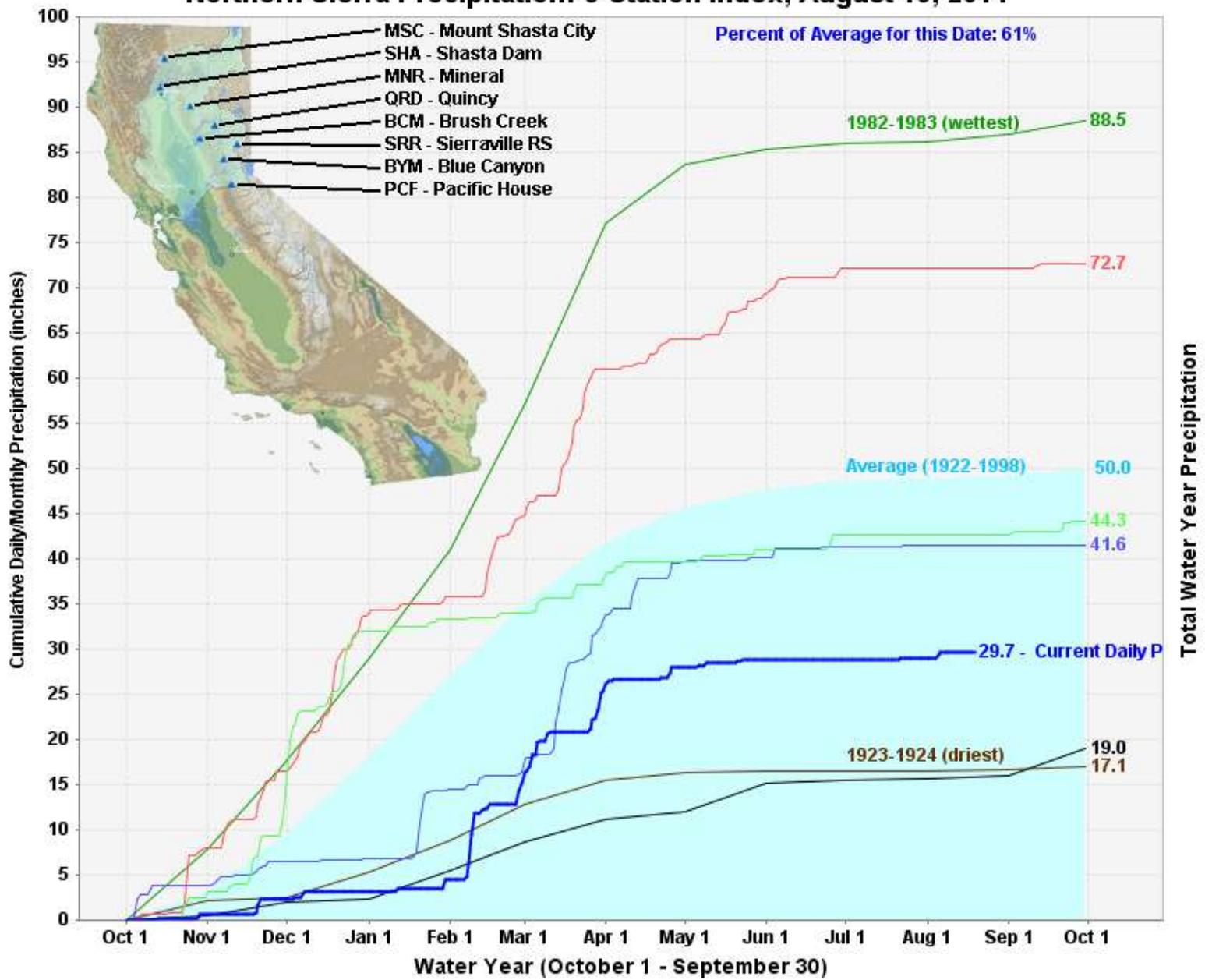


1/29/2014

☐ = Data Missing    ☐ = No Valid Data

# Northern Sierra Precipitation: 8-Station Index, August 19, 2014

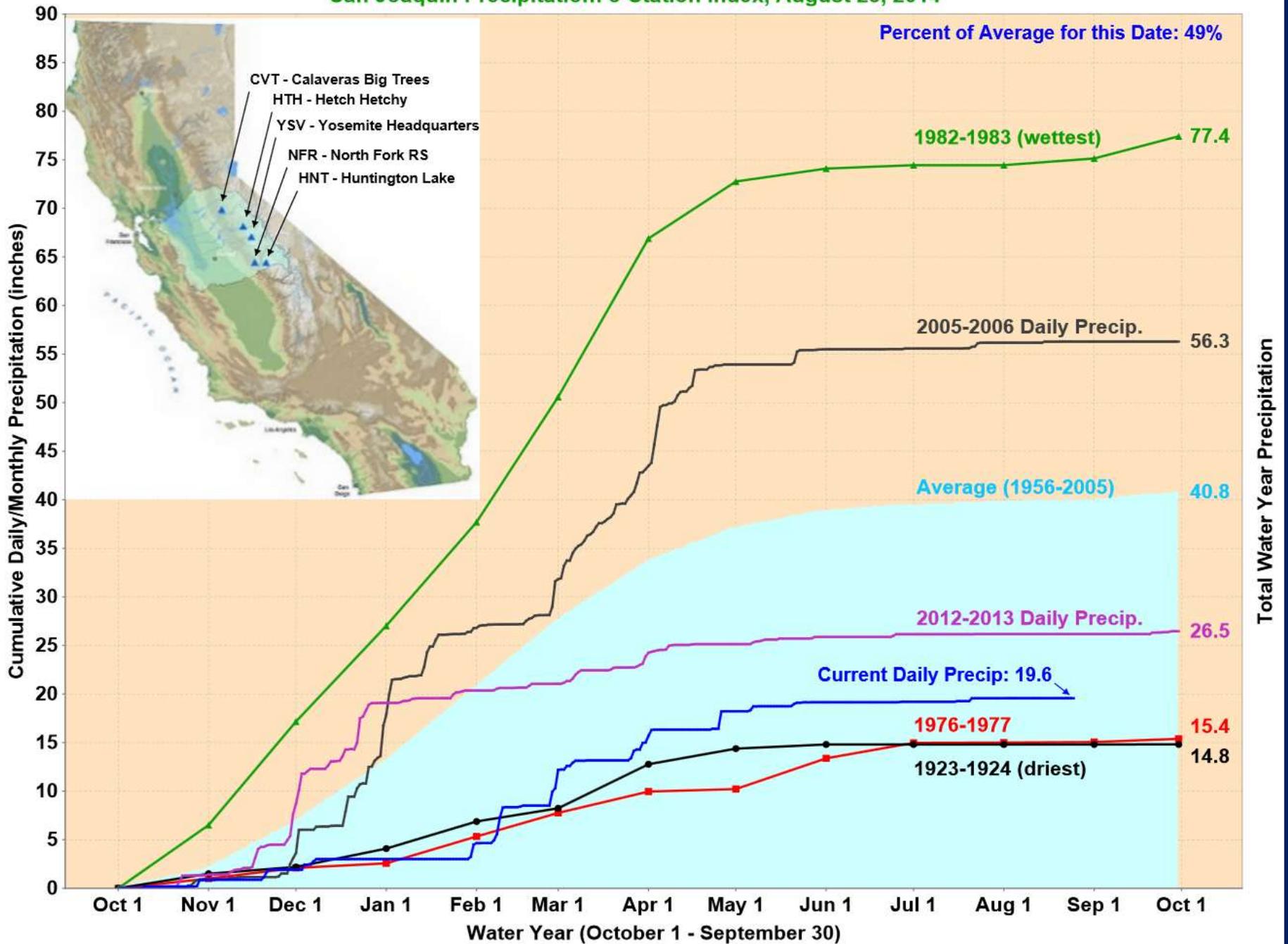
Percent of Average for this Date: 61%



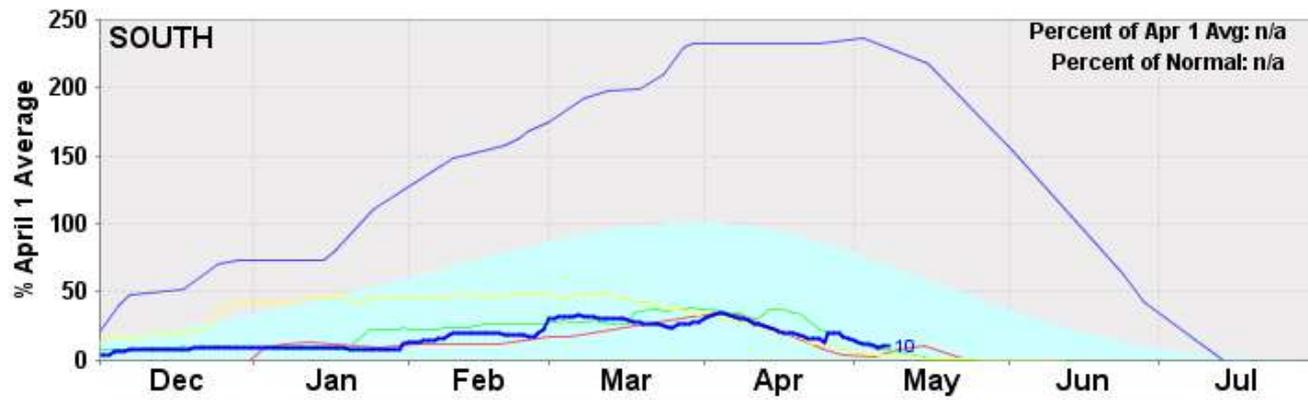
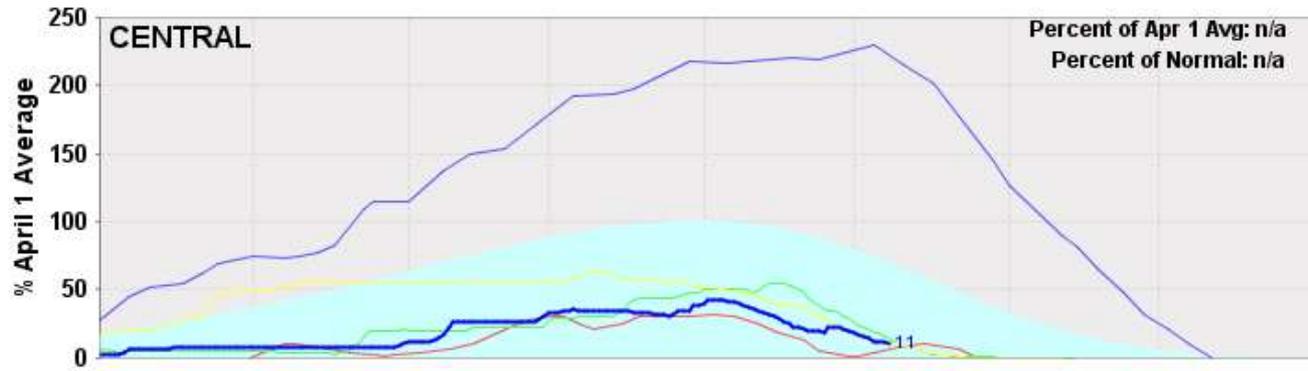
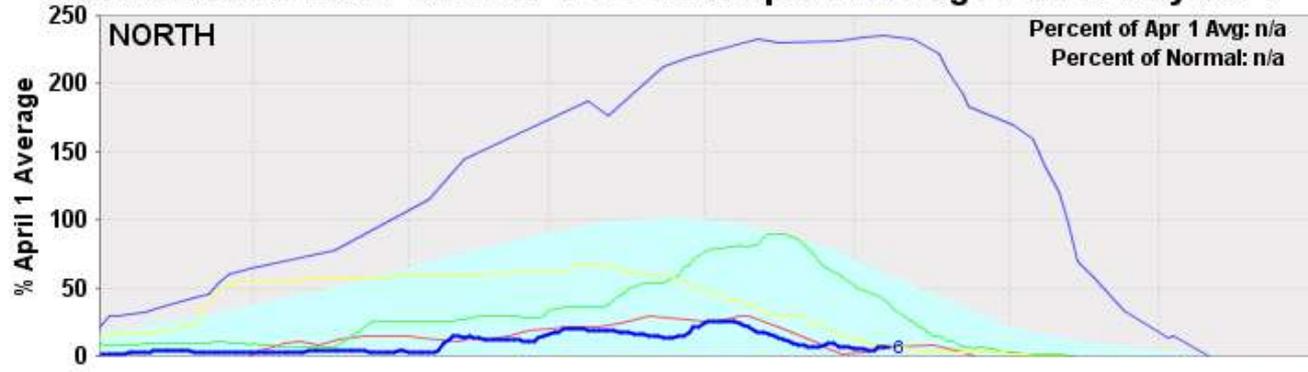
— Average (1922-1998) 
 — 1923-1924 (driest) 
 — 1976-1977 (2nd Driest) 
 — 1982-1983 (wettest) 
 — 2010-2011 
 — 2011-2012 
 — 2012-2013 
 — 2013-2014 (current)

# San Joaquin Precipitation: 5-Station Index, August 25, 2014

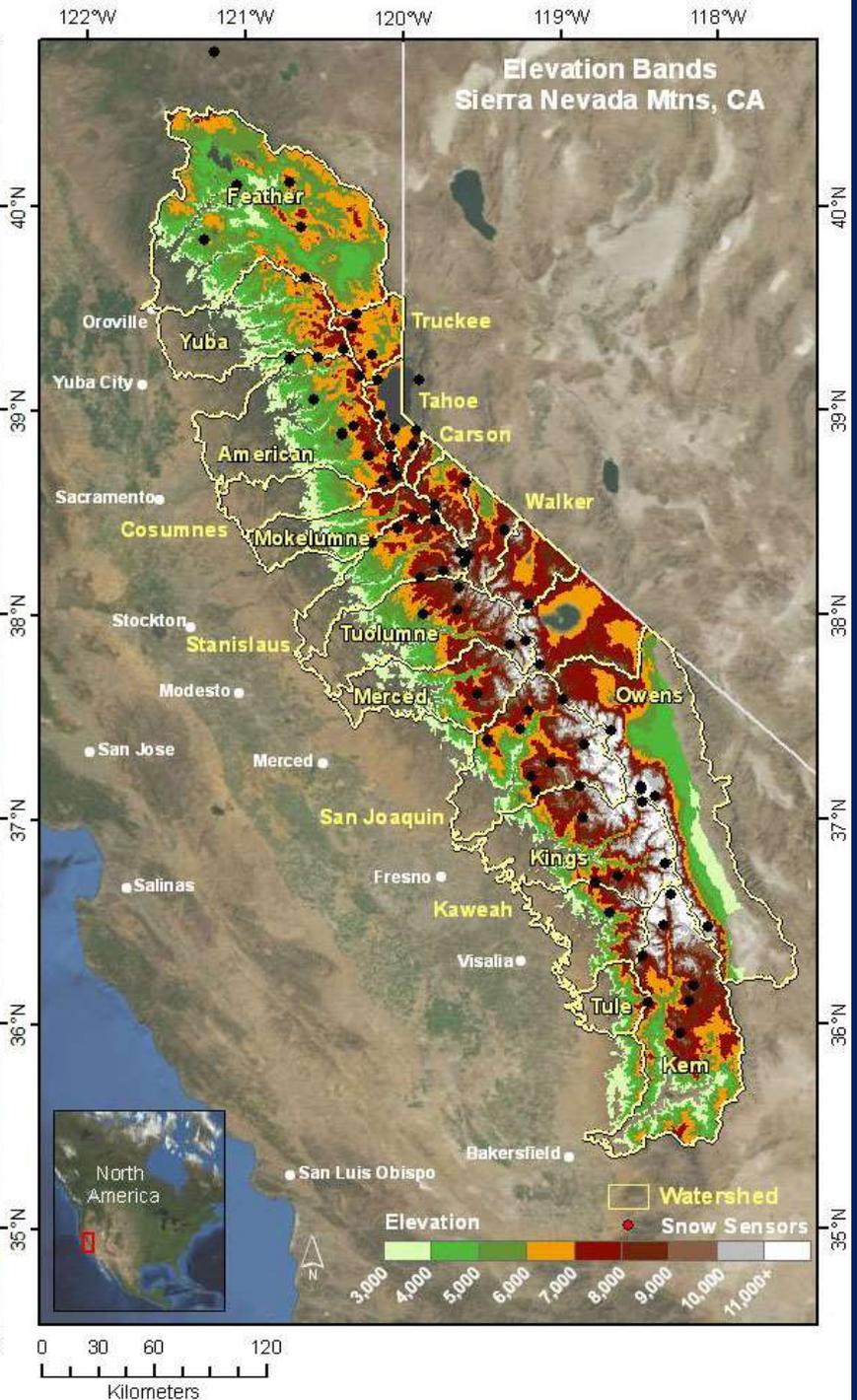
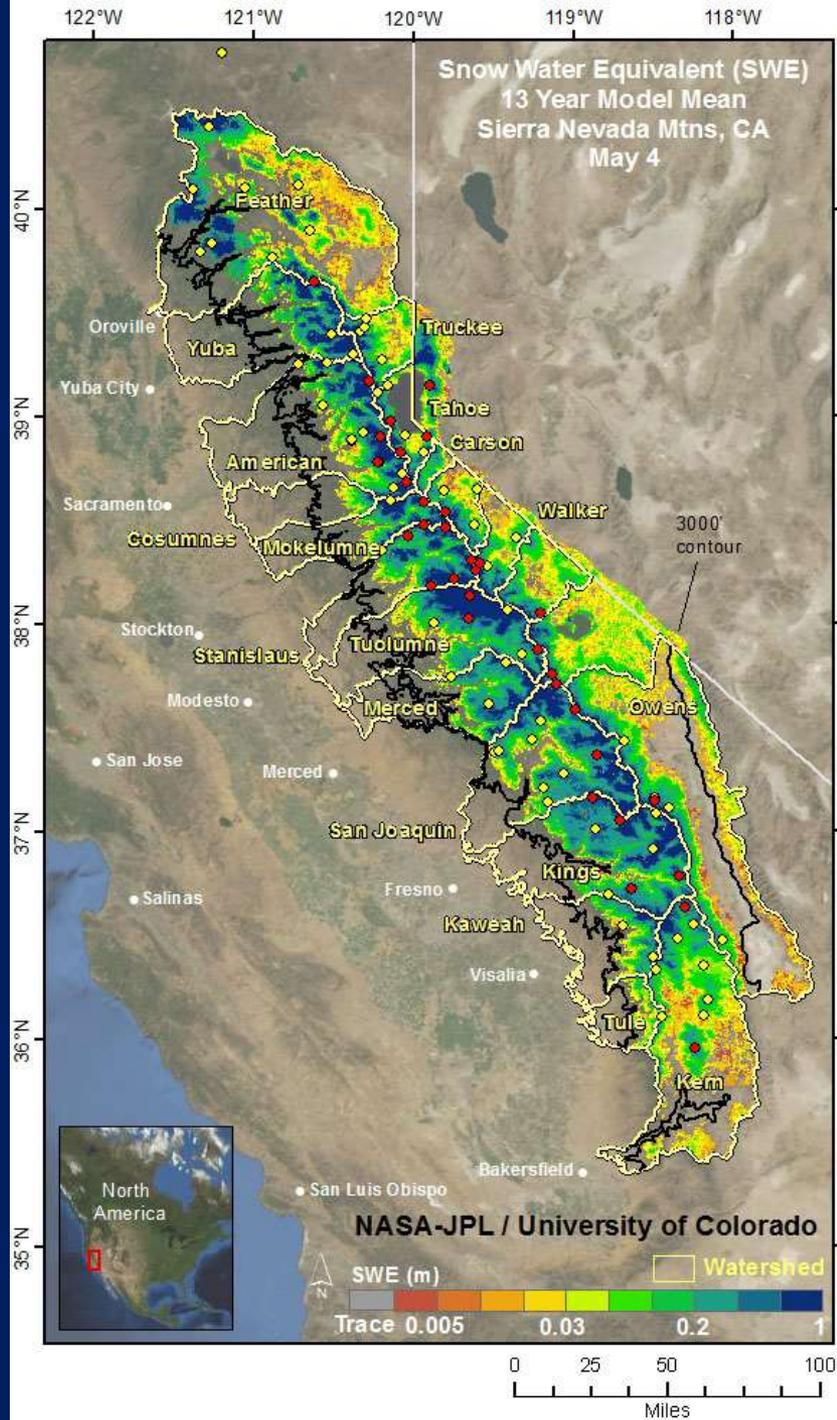
Percent of Average for this Date: 49%

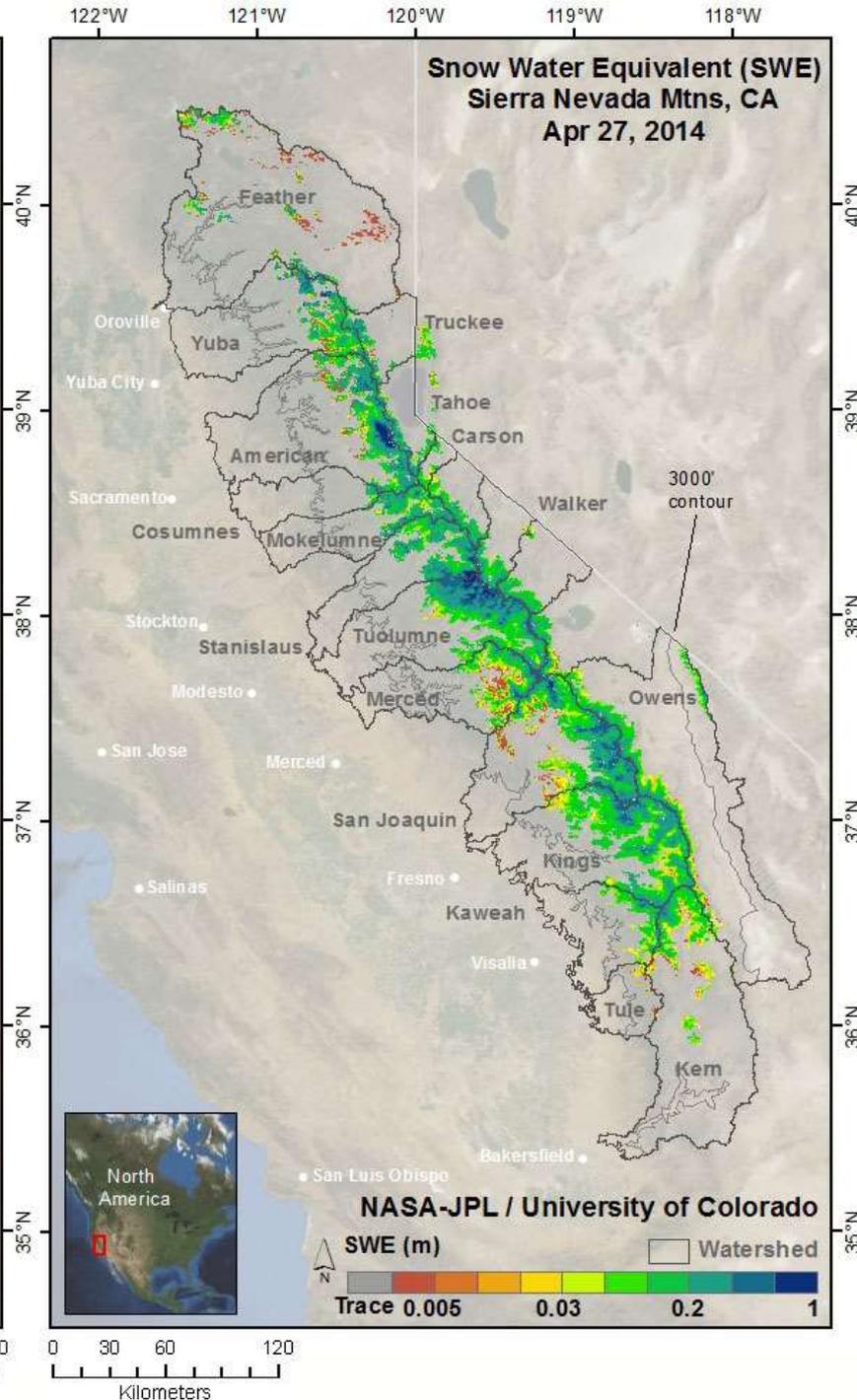
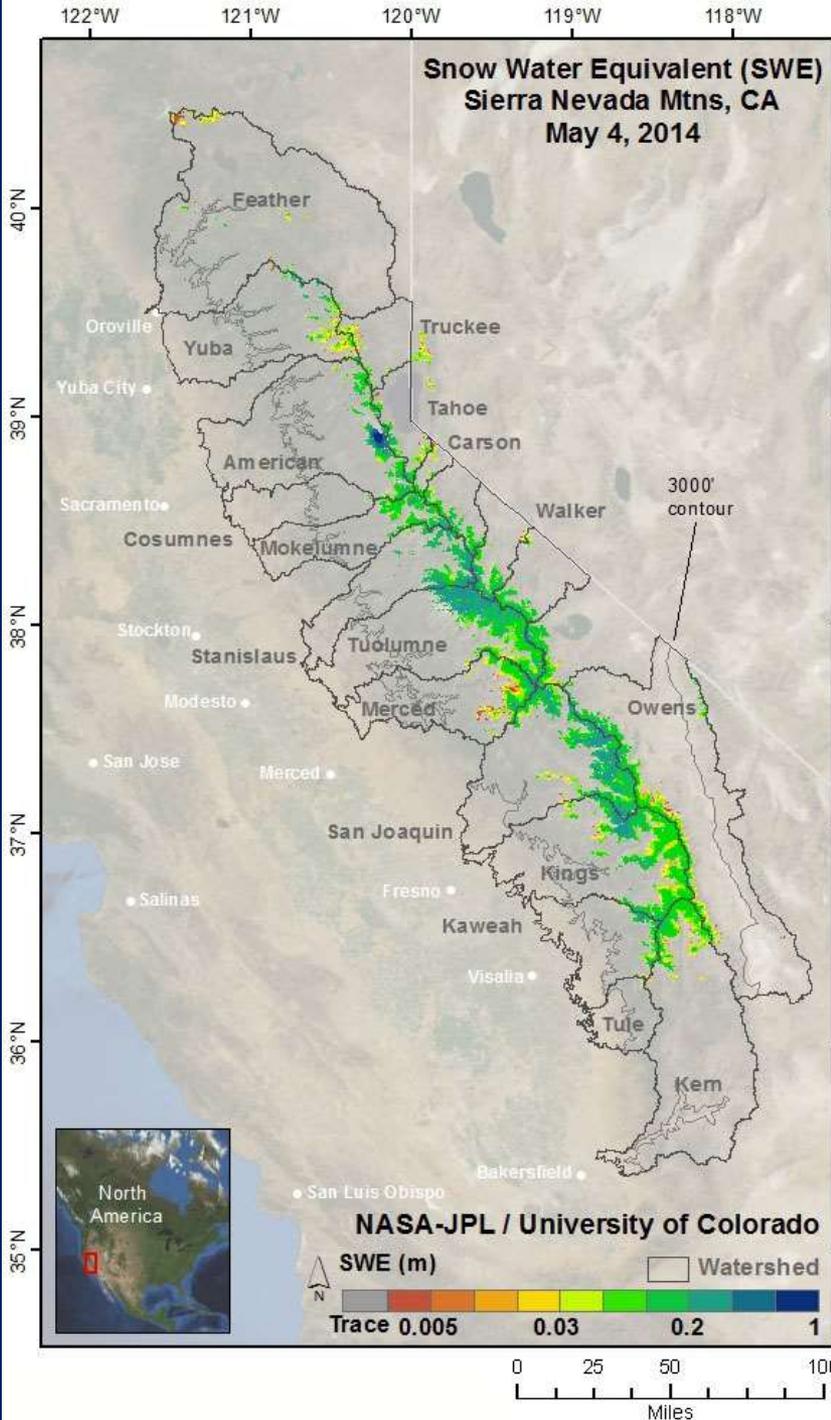


# California Snow Water Content - Percent of April 1 Average For: 08-May-2014

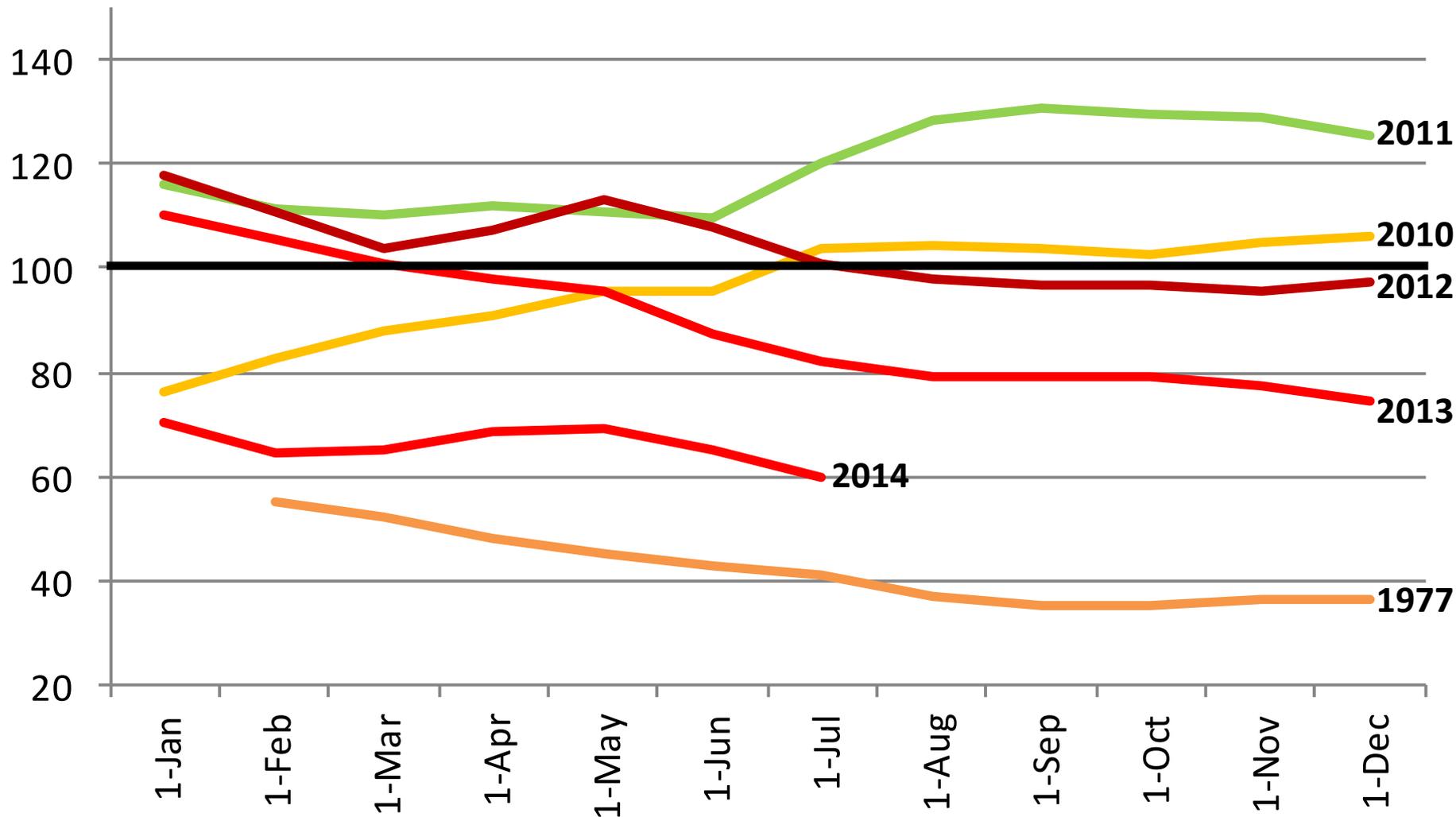


Average — 1976-1977 (min) — 1982-1983 (max) — 2011-2012 — 2012-2013 — 2013-2014 (current)





# California Reservoir Storage, Percent of Normal, 1977 and 2010-14



Source: California Department of Water Resources

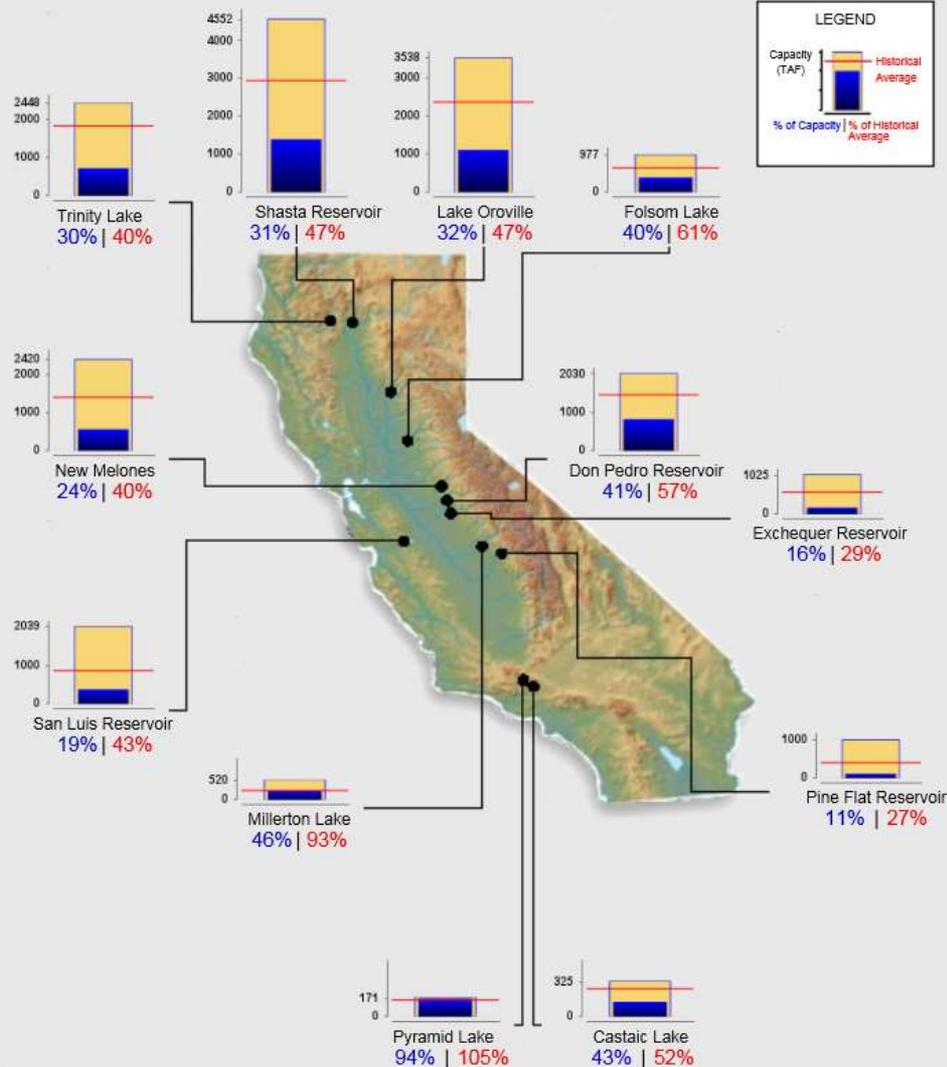
Credit: Brad Rippey, USDA



# Reservoir Conditions

Ending At Midnight - August 24, 2014

## CURRENT RESERVOIR CONDITIONS



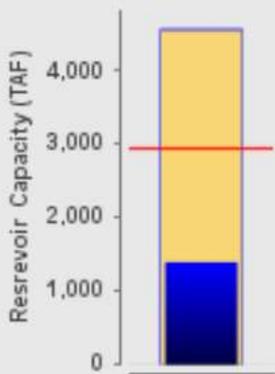


# Reservoir Conditions - Shasta Reservoir



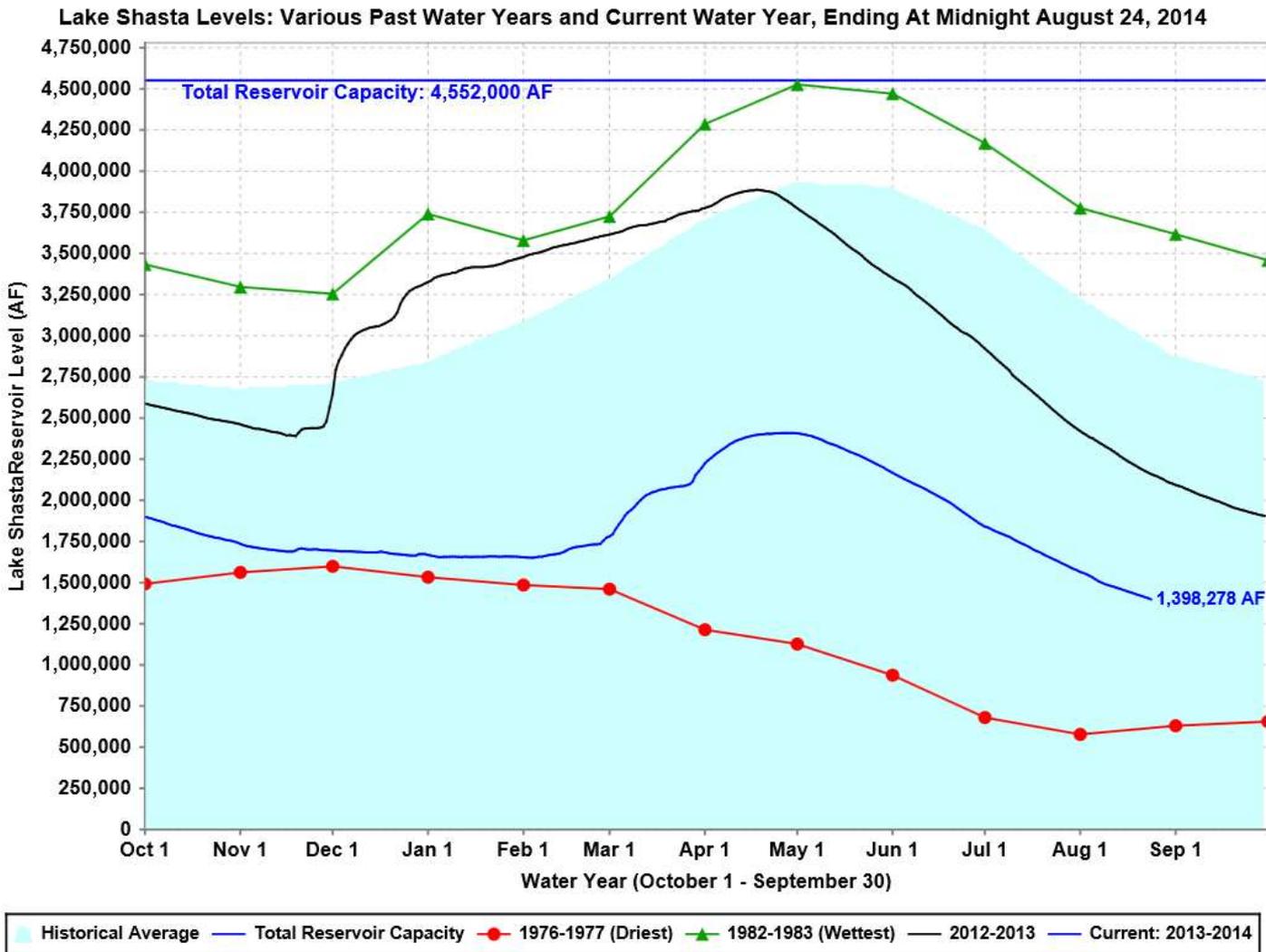
## Lake Shasta Conditions

(as of Midnight - August 24, 2014)



Current Level: 1,398,278 AF

31% | 47%  
(Total Capacity) | (Historical Avg.)





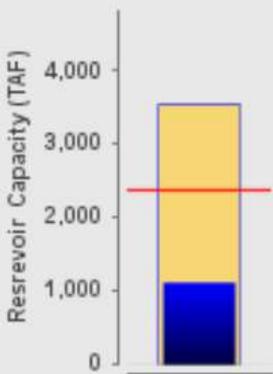
# Reservoir Conditions - Lake Oroville



Lake Oroville

## Lake Oroville Conditions

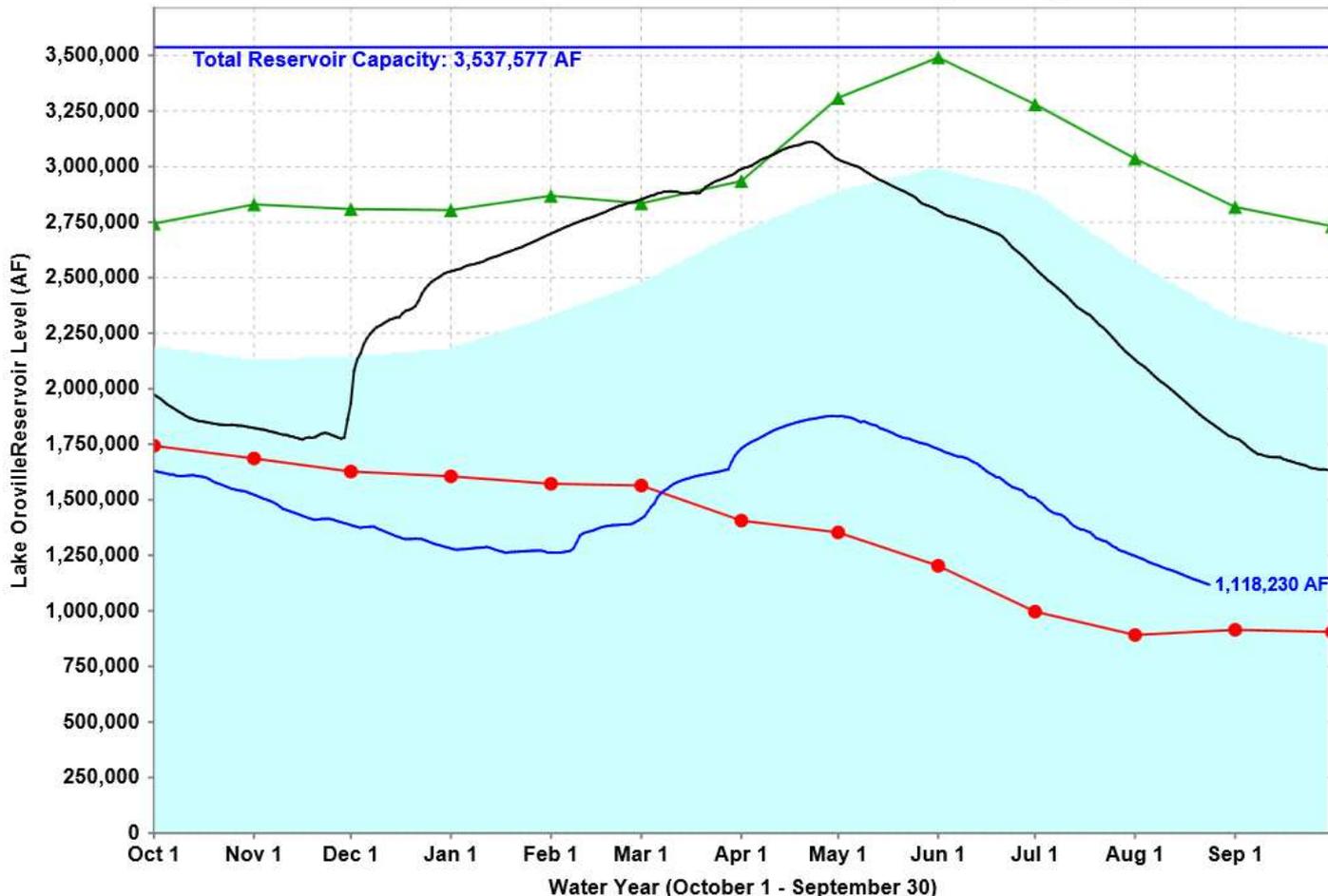
(as of Midnight - August 24, 2014)



Current Level: 1,118,230 AF

32% | 47%  
(Total Capacity) | (Historical Avg.)

Lake Oroville Levels: Various Past Water Years and Current Water Year, Ending At Midnight August 24, 2014



Historical Average | Total Reservoir Capacity | 1976-1977 (Driest) | 1982-1983 (Wettest) | 2012-2013 | Current: 2013-2014

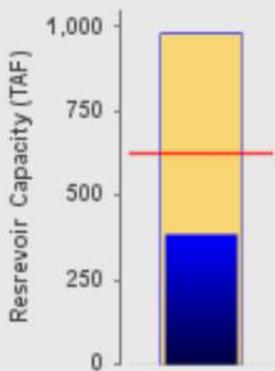


# Reservoir Conditions - Folsom Lake



## Folsom Lake Conditions

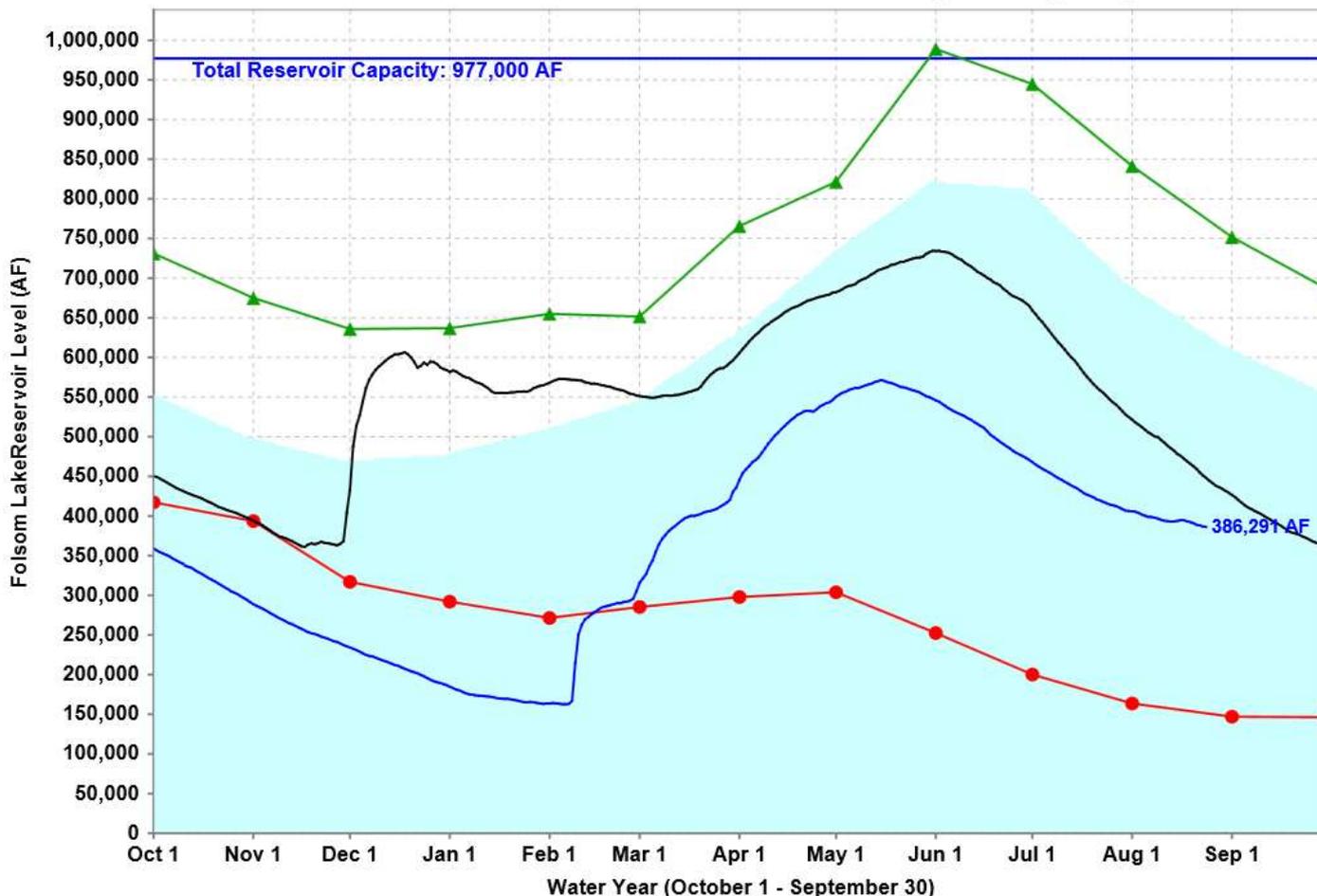
(as of Midnight - August 24, 2014)



Current Level: 386,291 AF

40% (Total Capacity) | 61% (Historical Avg.)

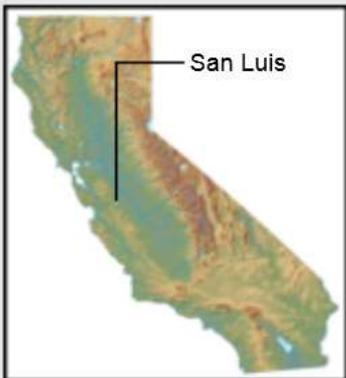
Folsom Lake Levels: Various Past Water Years and Current Water Year, Ending At Midnight August 24, 2014



Historical Average | Total Reservoir Capacity | 1976-1977 (Driest) | 1982-1983 (Wettest) | 2012-2013 | Current: 2013-2014

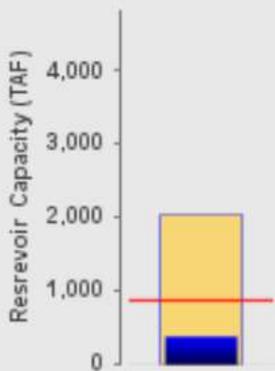


# Reservoir Conditions - San Luis



## San Luis Conditions

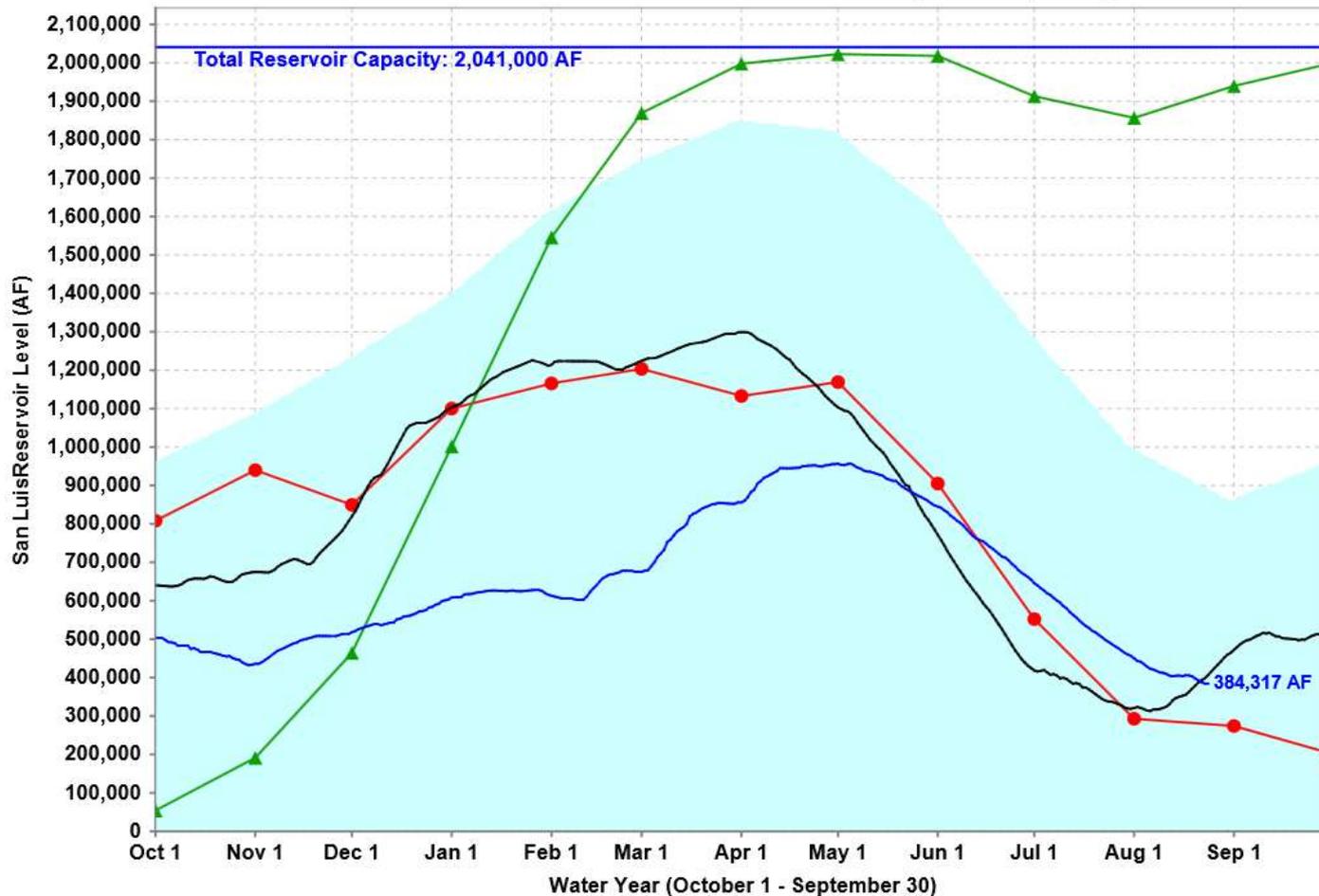
(as of Midnight - August 24, 2014)



Current Level: 384,317 AF

19% (Total Capacity) | 43% (Historical Avg.)

San Luis Levels: Various Past Water Years and Current Water Year, Ending At Midnight August 24, 2014



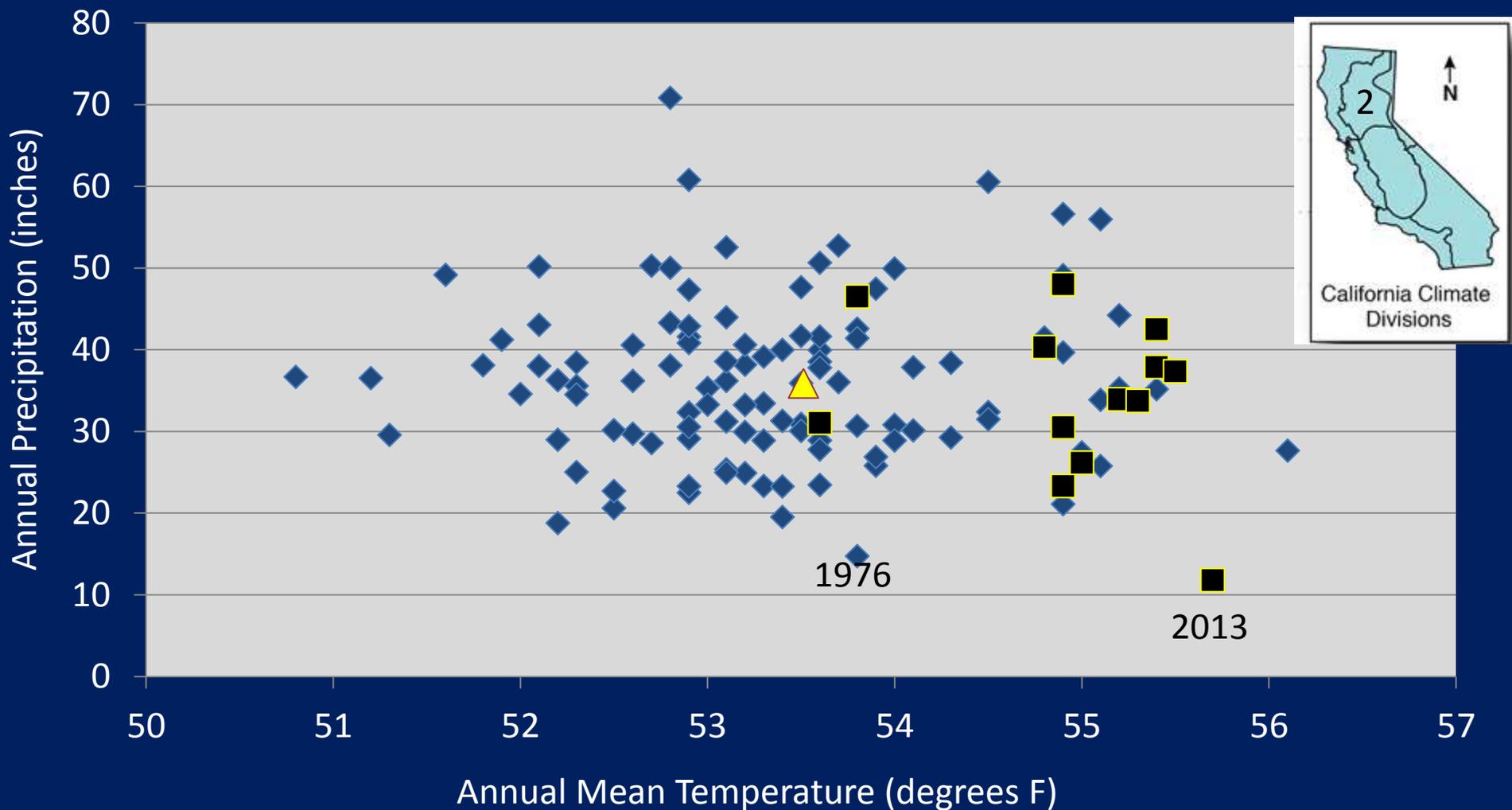
Historical Average | Total Reservoir Capacity | 1976-1977 (Driest) | 1982-1983 (Wettest) | 2012-2013 | Current: 2013-2014

An aerial photograph of Lake Oroville in 2014, showing a significant drop in water levels. The water is a deep blue, and the surrounding banks are exposed, revealing a light brown, sandy soil. Numerous white boats are scattered across the water, and a large marina area is visible in the distance. The background features rolling hills and a clear blue sky. The word "Context" is overlaid in yellow text in the center of the image.

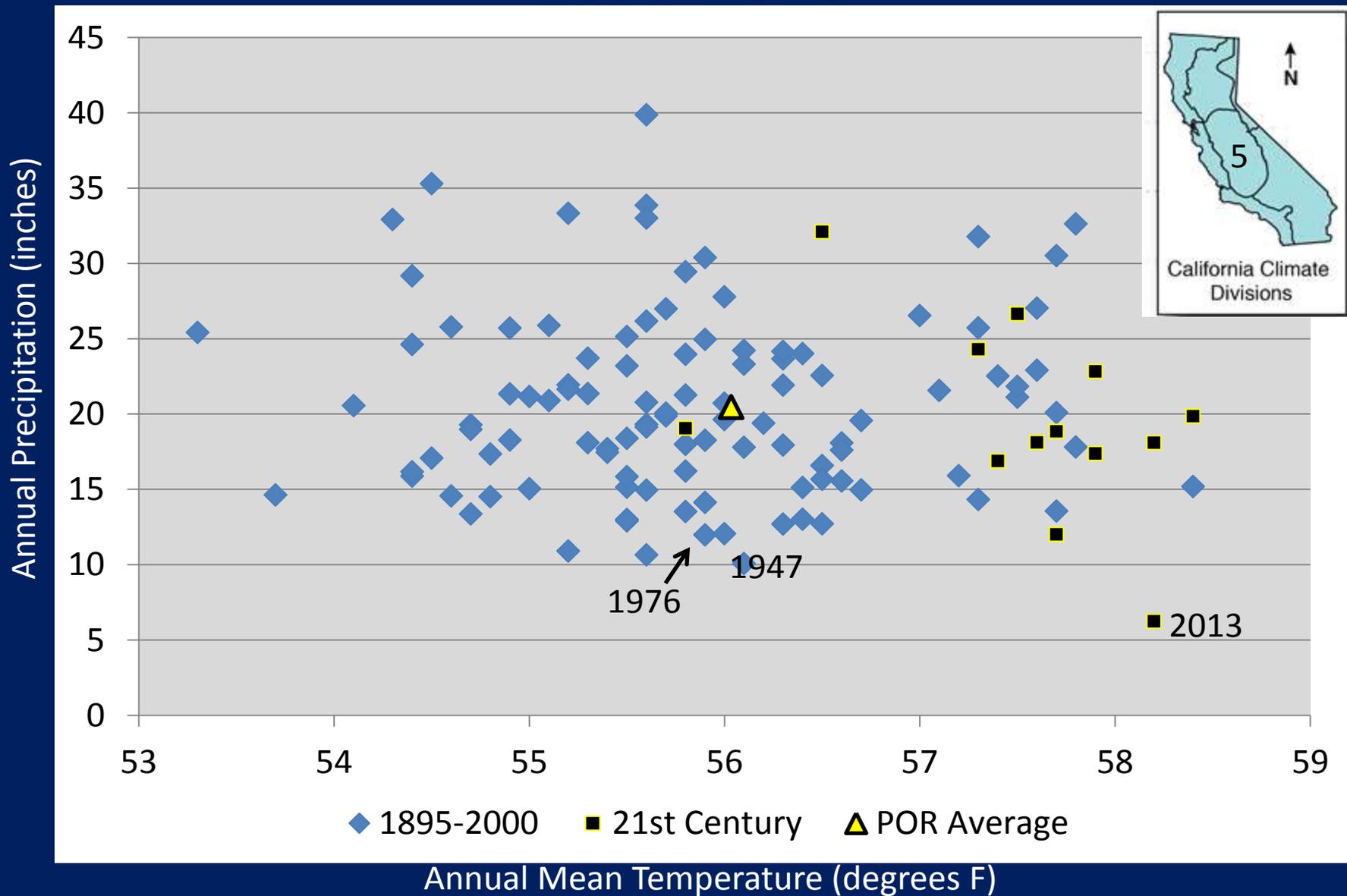
# Context

Lake Oroville 2014, DWR Photo

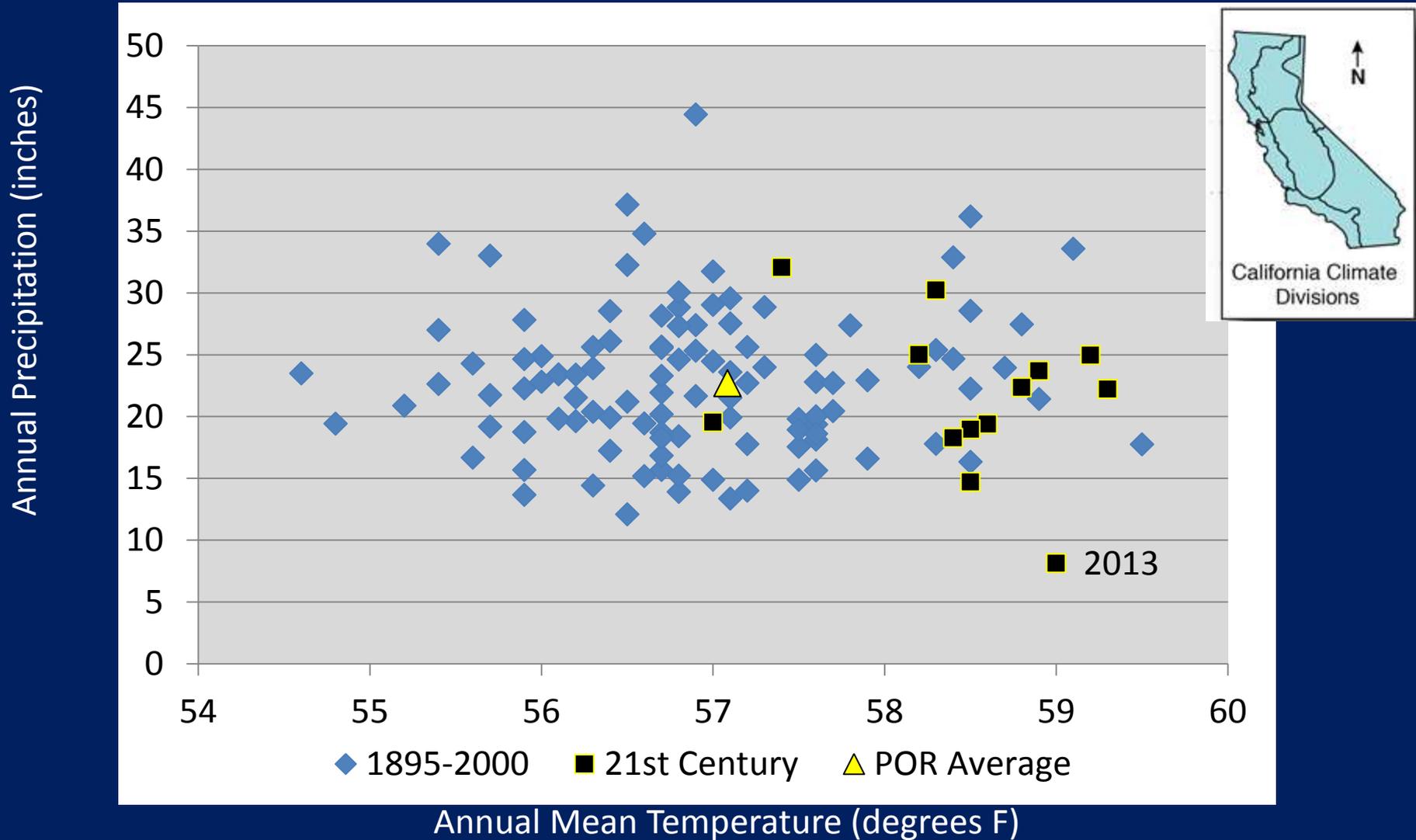
# NOAA Climate Division 2 Calendar Year Data 1895-2013



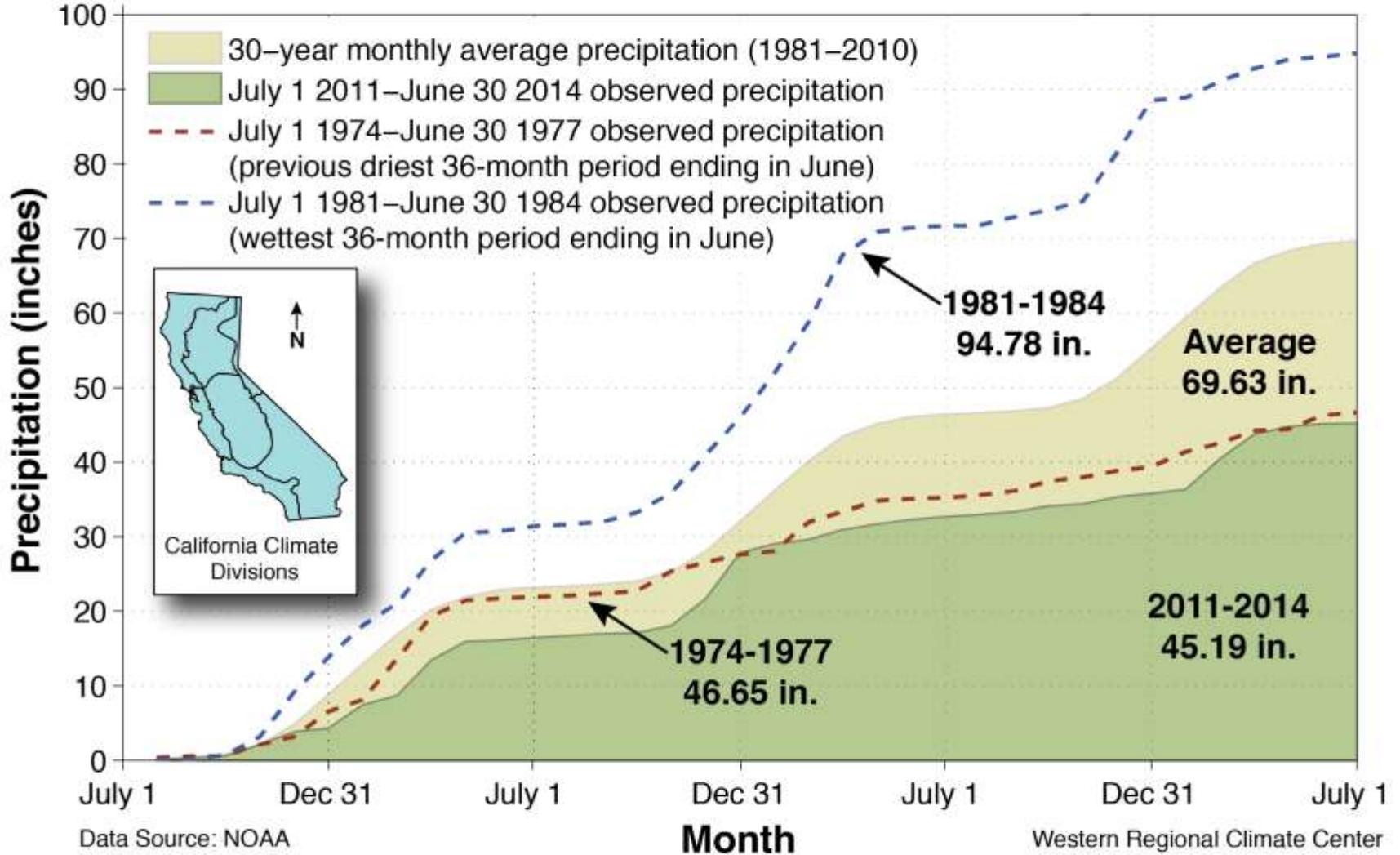
# NOAA Climate Division 5 Calendar Year Data 1895-2013



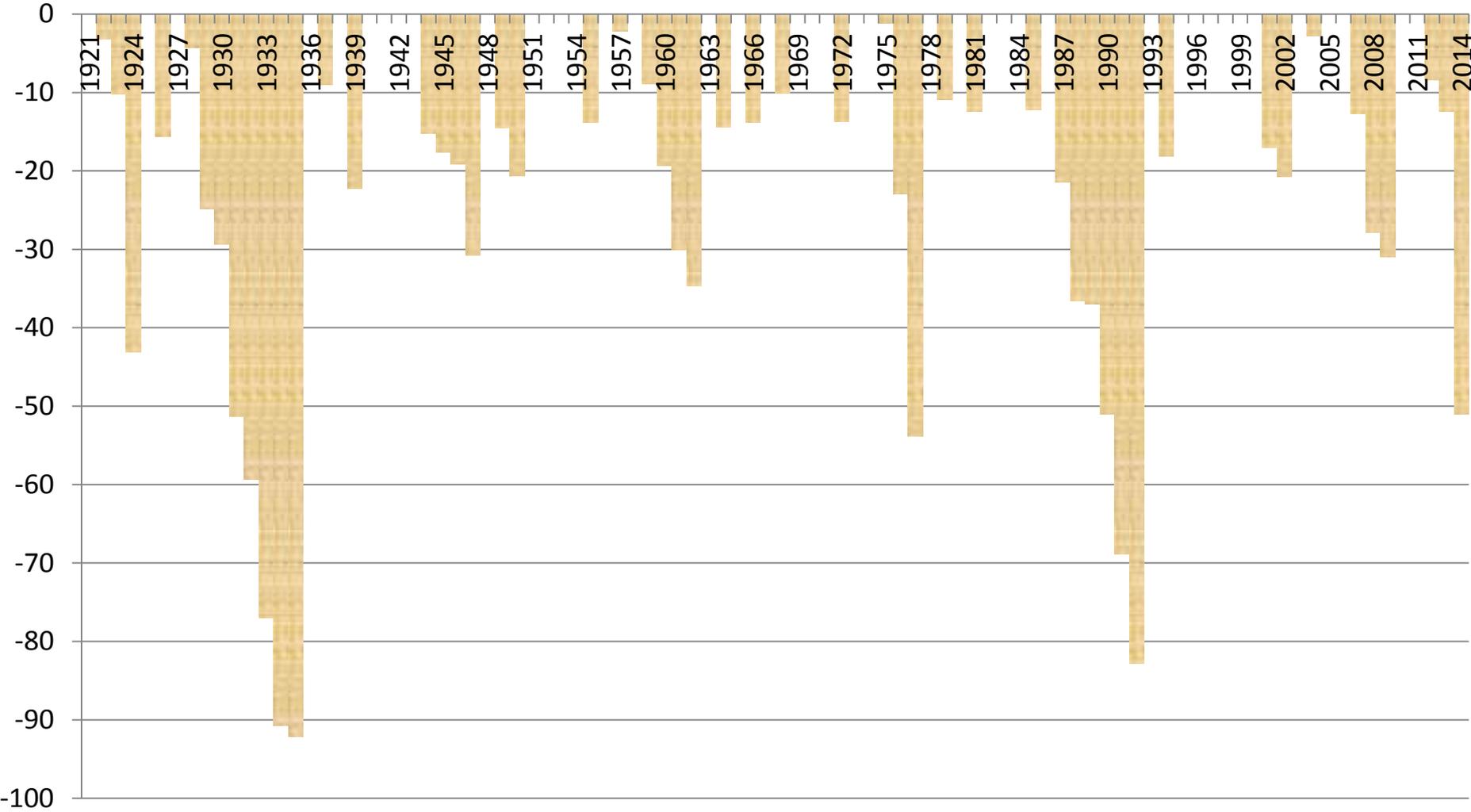
# Westmap Statewide Calendar Year Data 1895-2013



# 36 Month CA Statewide Precipitation Accumulation



# 8-Station Index Cumulative Deviations WY1921 – WY2014\*



\*WY2014 assumes no further precipitation this year

# Other Rankings

- 8 Station Precipitation Index 8<sup>th</sup> driest water year
- 5 Station Precipitation Index 3<sup>rd</sup> driest water year
- 8 River Index 4<sup>th</sup> driest single year and 3<sup>rd</sup> driest 3-year
- California Climate Tracker warmest winter, second warmest water year to date for Sierra region

# Multi-Year Sequencing

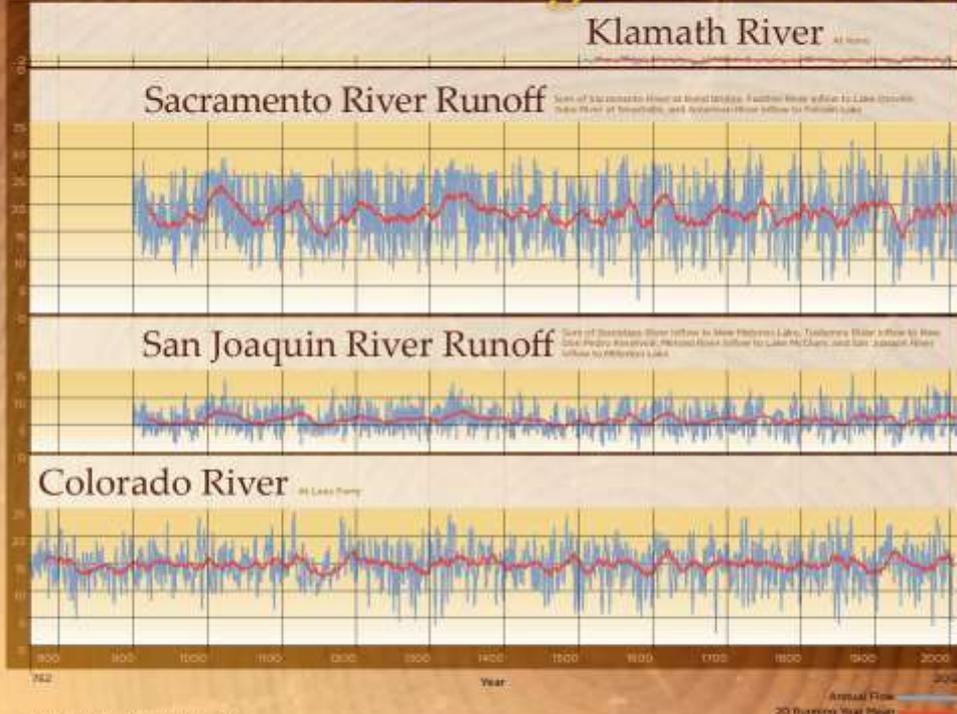
- 20<sup>th</sup> Century shows 2, 3, 4, and 6 year droughts
- Multi-decadal dry period 1910-1940 in observed record for 8 Station Index & Sacramento Basin Runoff
- Paleorecord shows multiple 10+ year droughts as well as 2 century-long dry periods (climate shifts)

# DWR Paleohydrology Study

- Extend existing record for Sacramento, San Joaquin and Klamath Basins
- Conducted by University of Arizona Laboratory for Tree Ring Research (Dave Meko, Connie Woodhouse, and Ramzi Touchan)
- Data and report available at:  
<http://water.ca.gov/waterconditions/waterconditions.cfm>



# Reconstructed Streamflows & Drought Periods



**USING TREE-RINGS TO RECONSTRUCT STREAMFLOW**

A tree-ring reconstruction is a set of tree-ring widths that has been calibrated with an instrumented or gauged reach of a hydrologic or fluvial system such as annual streamflow or precipitation. The reconstruction, based on a statistical model that describes the relationship between tree growth and the gauged reach, extends that reach back hundreds of years into the past.

Tree growth is dry (shrinks) or wet (swells) by water availability. Droughts are the best information about hydroclimate variability we have particularly relevant to water resources. These include extreme events such as the 1952-53 California drought and western drought causing a forest mortality in western Idaho on dry periods when water and nutrient storage is minimal.

Tree-ring reconstruction of hydroclimate variability is developed from tree-ring characteristics. A tree-ring chronology is a time series of annual widths derived from the ring widths measurements of 10 or more trees of the same species at a single site. To create a tree-ring chronology, parts from the pithed ends of each site are cross-dated (the number of summer and winter rings are matched) and then to extend the record or later rings, so that every annual ring is identified dated to the correct year. Tree-ring rings are measured to the nearest thousandth of a millimeter using a microscope equipped measuring device. After growth response models are used to relate an annually measured tree-ring width value to a specific flow for each year, we averaged to create a time series of annual flow width values. The complete series of tree-ring values from a site is called a tree-ring chronology.

Over a gauged reach of stream is obtained for reconstruction. As an example, streamflow from the upper part of the gauged reach with the gauged reach of being reconstructed model. A statistical technique called multiple flow regression is a common tool. The reconstruction is produced by comparing the measured gauged reach with the reconstructed which is gauged the amount of variance in the gauged reach that is explained by the reconstruction.

**EXCISES PRIOR TO THE HISTORICAL RECORD**

The period of widely measured streamflow is used throughout the third volume reaches beyond 20 years, which represents only a fraction of climatologically variable flow. An 800-year tree-ring reconstruction shows streamflow from roughly 800 to the historical period that were more variable, particularly in California. This flow is the reconstructed record. The reconstructed record captures considerable range of hydrologic variability that occur the historical record, making hydrologic more useful for drought preparedness planning. US particular interest from a scientific perspective is the historical climate journals to see things which contained annual stream gauged reach of the western United States as described elsewhere in the Sacramento, San Joaquin, and Colorado River reconstructions.

Reconstructed Streamflows and Drought Periods. The University of Arizona, Center for Global Change Research. ©2015. Reconstructed Streamflows and Drought Periods. Center for Global Change Research, Tucson, Arizona, USA.



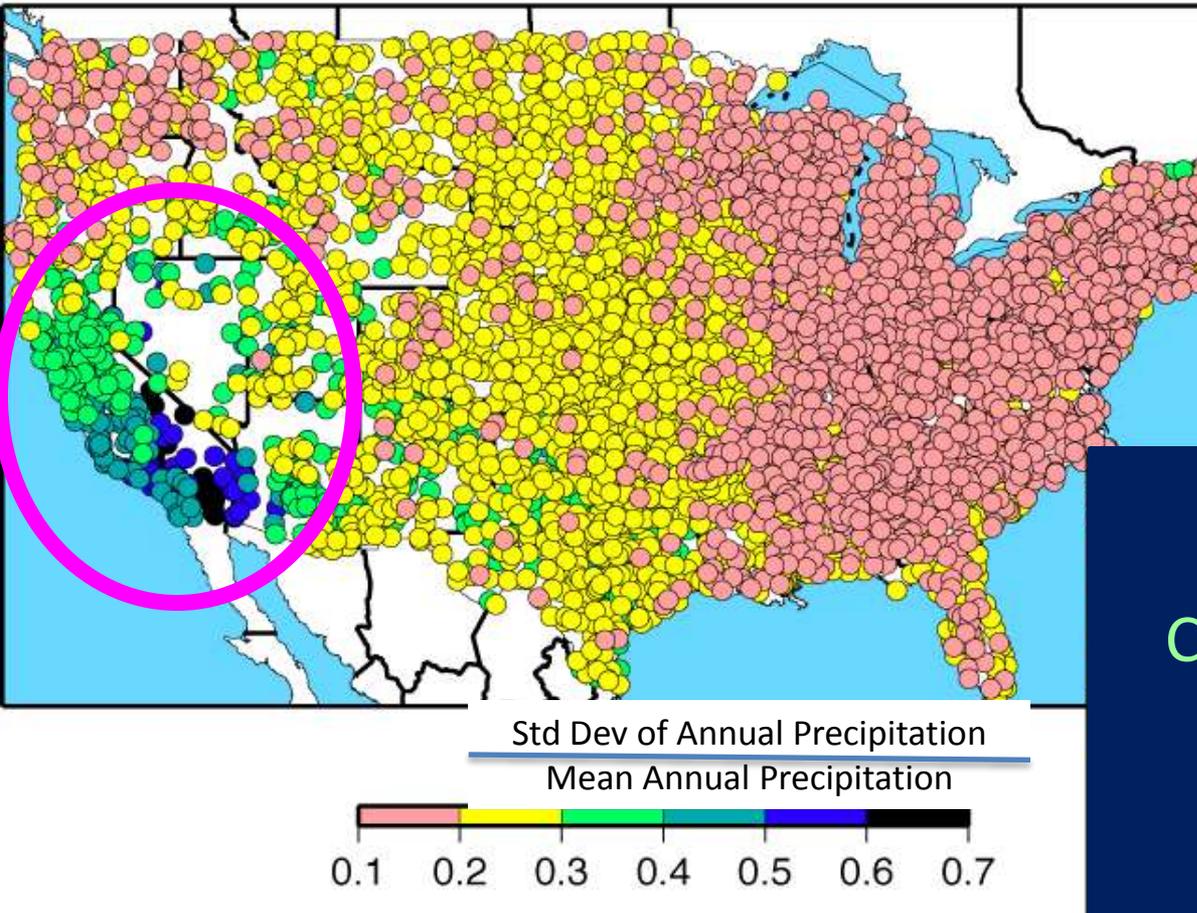
An aerial photograph of the San Luis Reservoir in California. The water is a deep blue-green color, and the surrounding landscape is arid and hilly. The water level is significantly lower than normal, exposing large areas of brown, silty sediment banks with distinct horizontal layering. A small, isolated island of water is visible in the center of the reservoir. The sky is clear and blue.

# Temporal Variability

San Luis Reservoir 2014, DWR Photo

# Year to Year Precipitation Variability

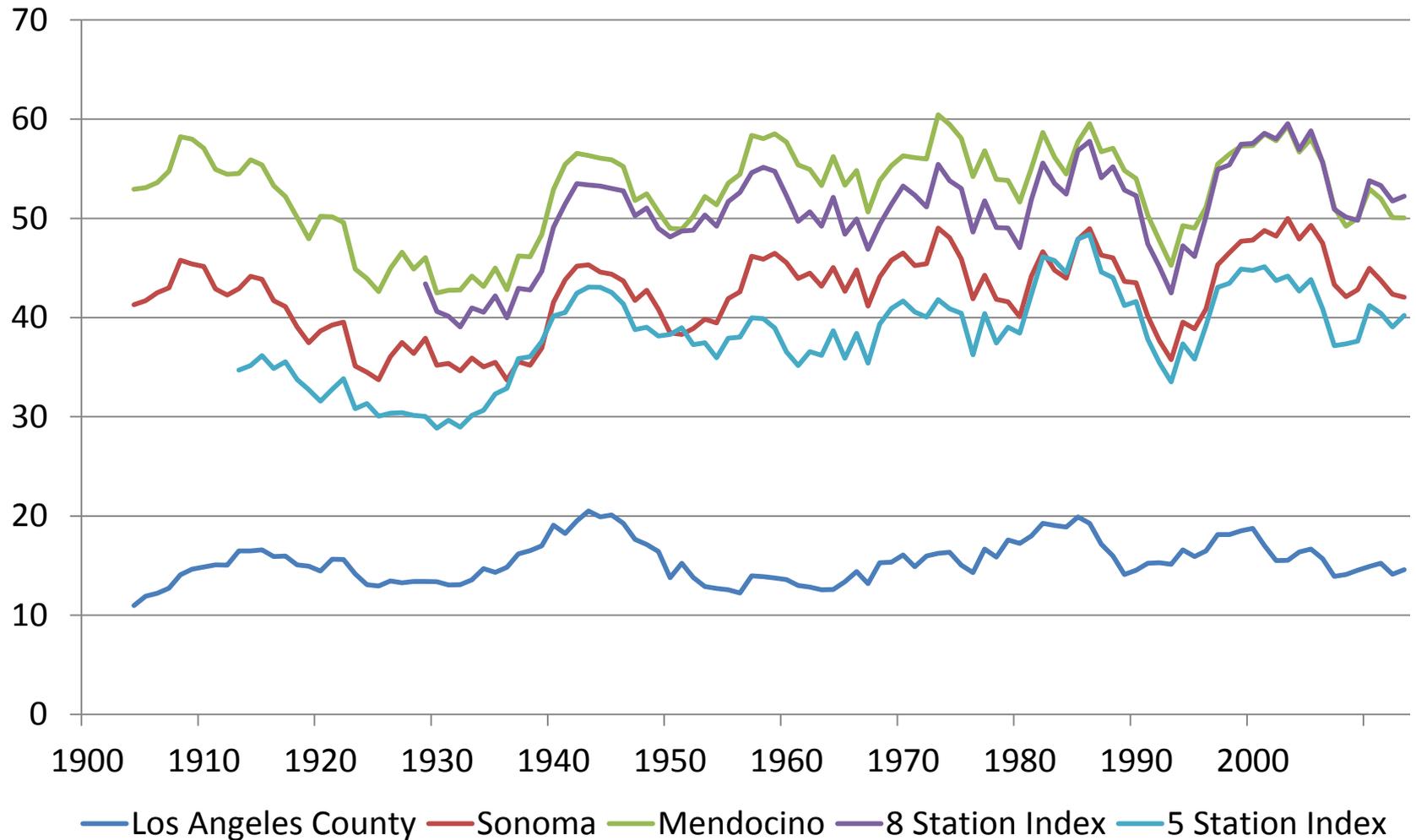
a) COEFFICIENTS OF VARIATION OF TOTAL PRECIPITATION, WY 1951-2008



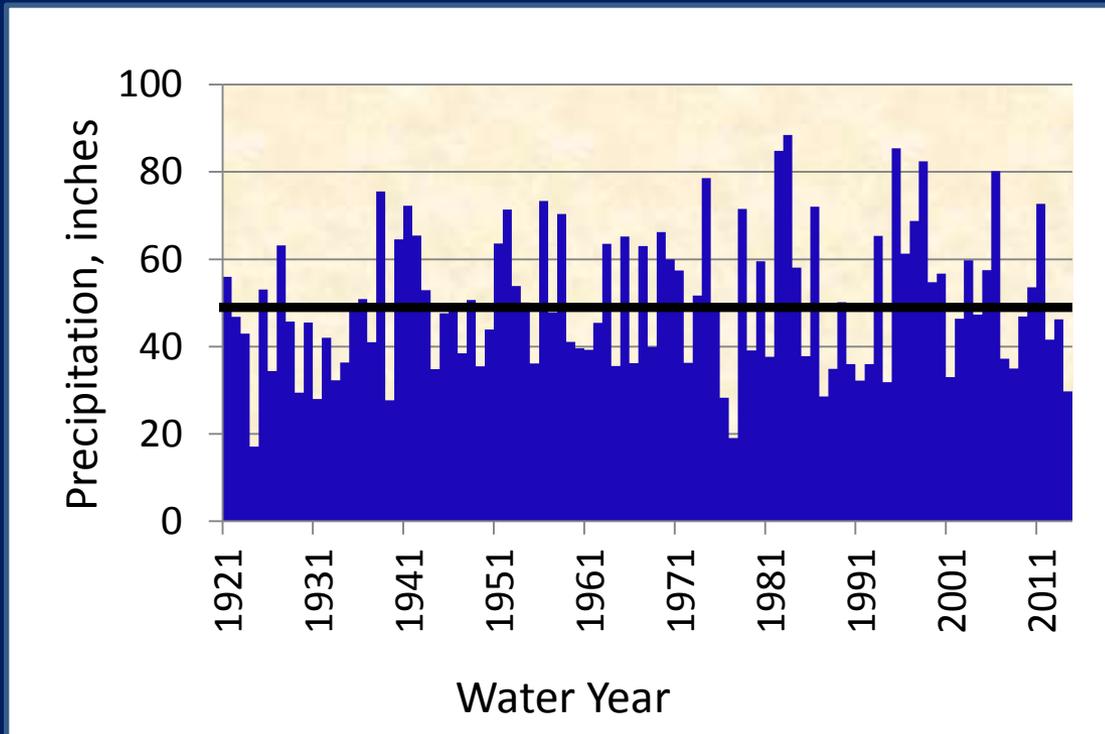
Higher values are higher variability

California precipitation  
is uniquely variable

# Decadal Scale Variability



# Northern Sierra 8 Station Index

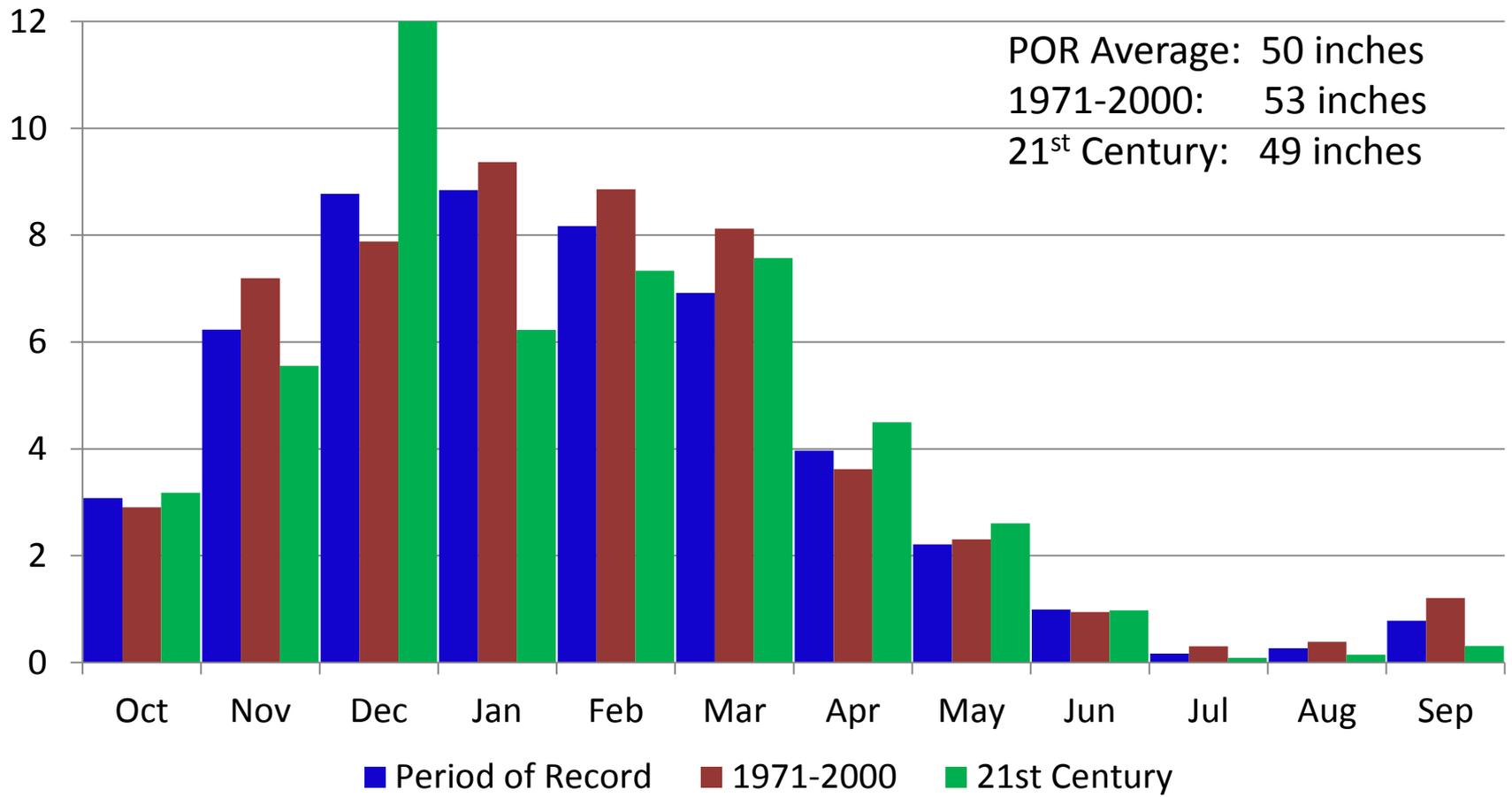


Annual Average: 50 inches  
Maximum Year (1983): 88.5 inches  
Minimum Year (1924): 17.1 inches  
Period of Record 1921- Present

9 of 14 years of 21<sup>st</sup> Century below average

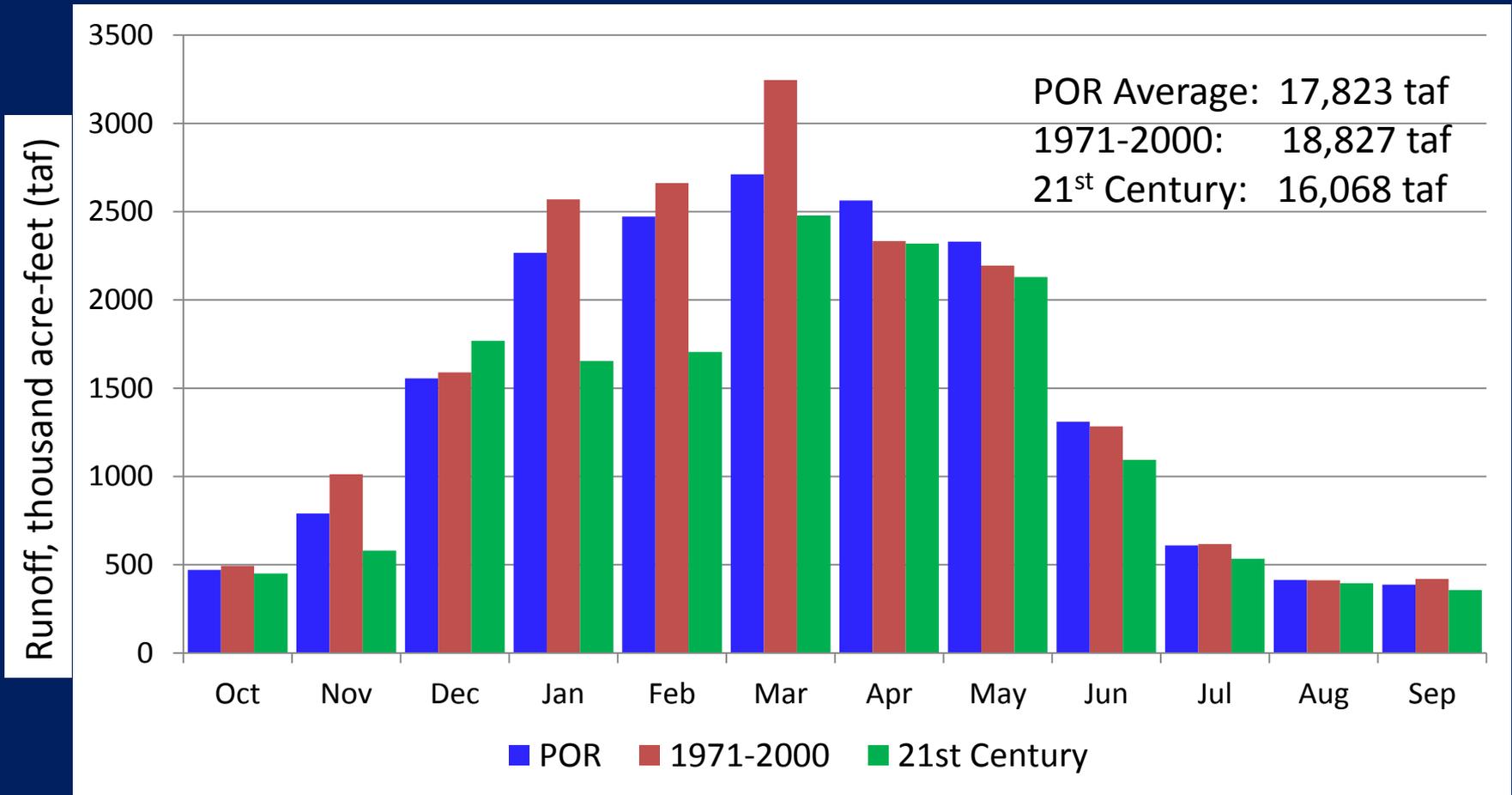
Average of:  
Mt. Shasta City Quincy  
Shasta Dam Sierraville RS  
Mineral Pacific House  
Brush Creek RS Blue Canyon

# 21<sup>st</sup> Century Breakdown So Far – 8 Station Index

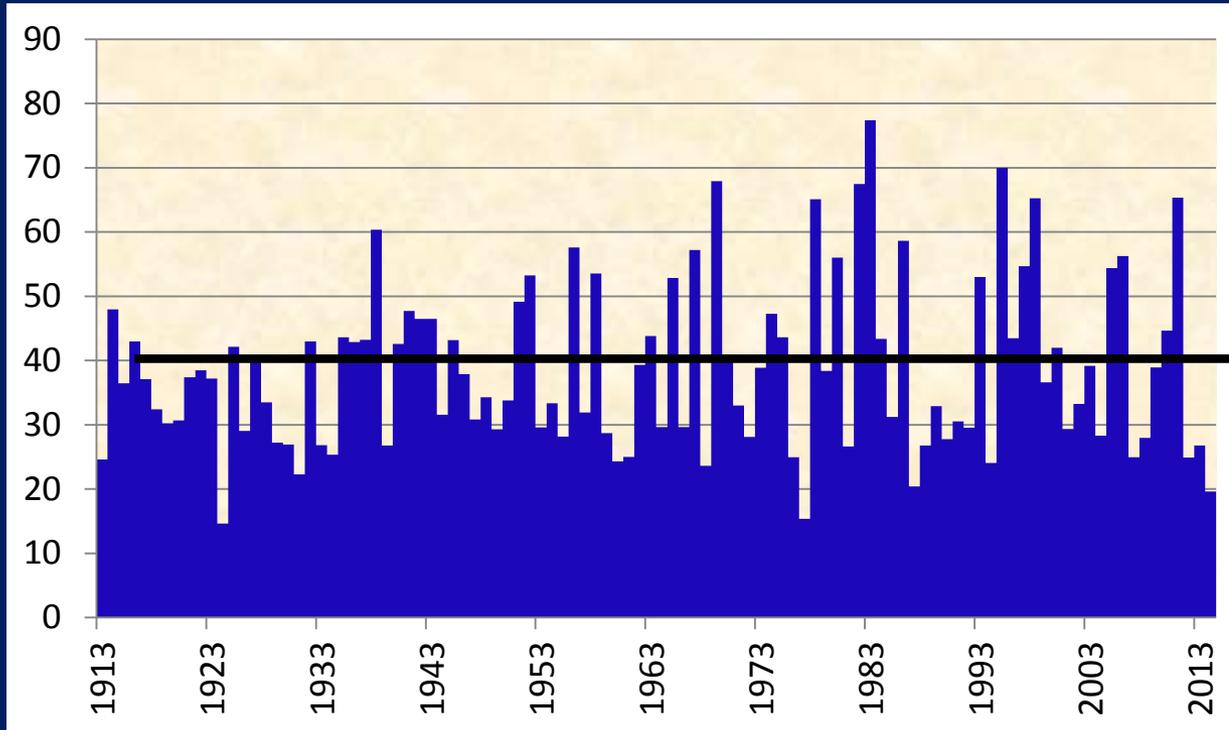


Note WY2012 was 3<sup>rd</sup> driest December (0.34") and WY2014 was 4<sup>th</sup> driest (0.80")

# Sacramento River Runoff Distributions (Thousand Acre-Feet)



# San Joaquin 5-Station Index



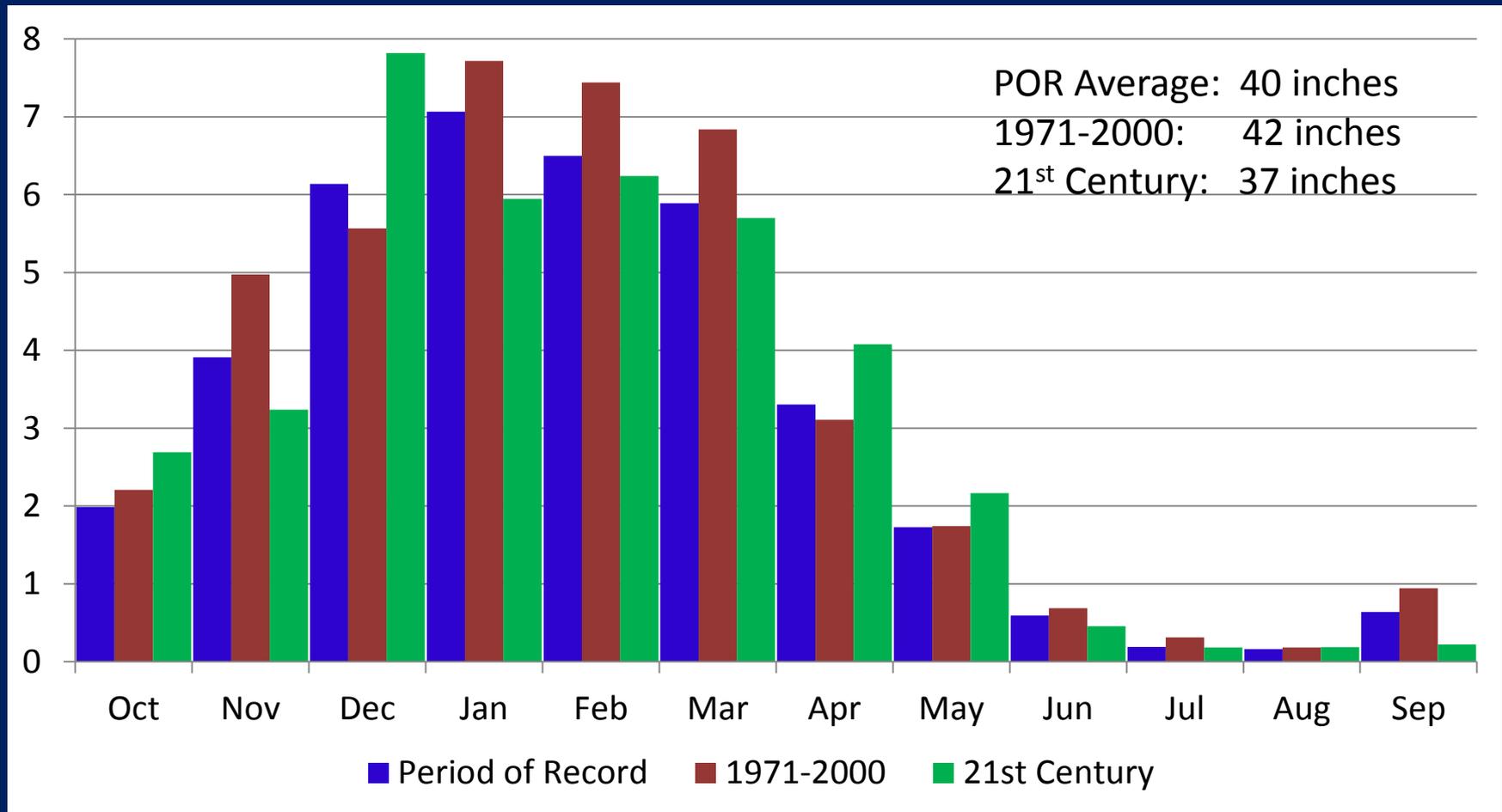
Annual Average: 40 inches  
Maximum Year (1983) 77.4 inches  
Minimum Year (1924) 14.8 inches  
Period of Record 1913 - Present

10 of 14 years of 21<sup>st</sup> Century below average



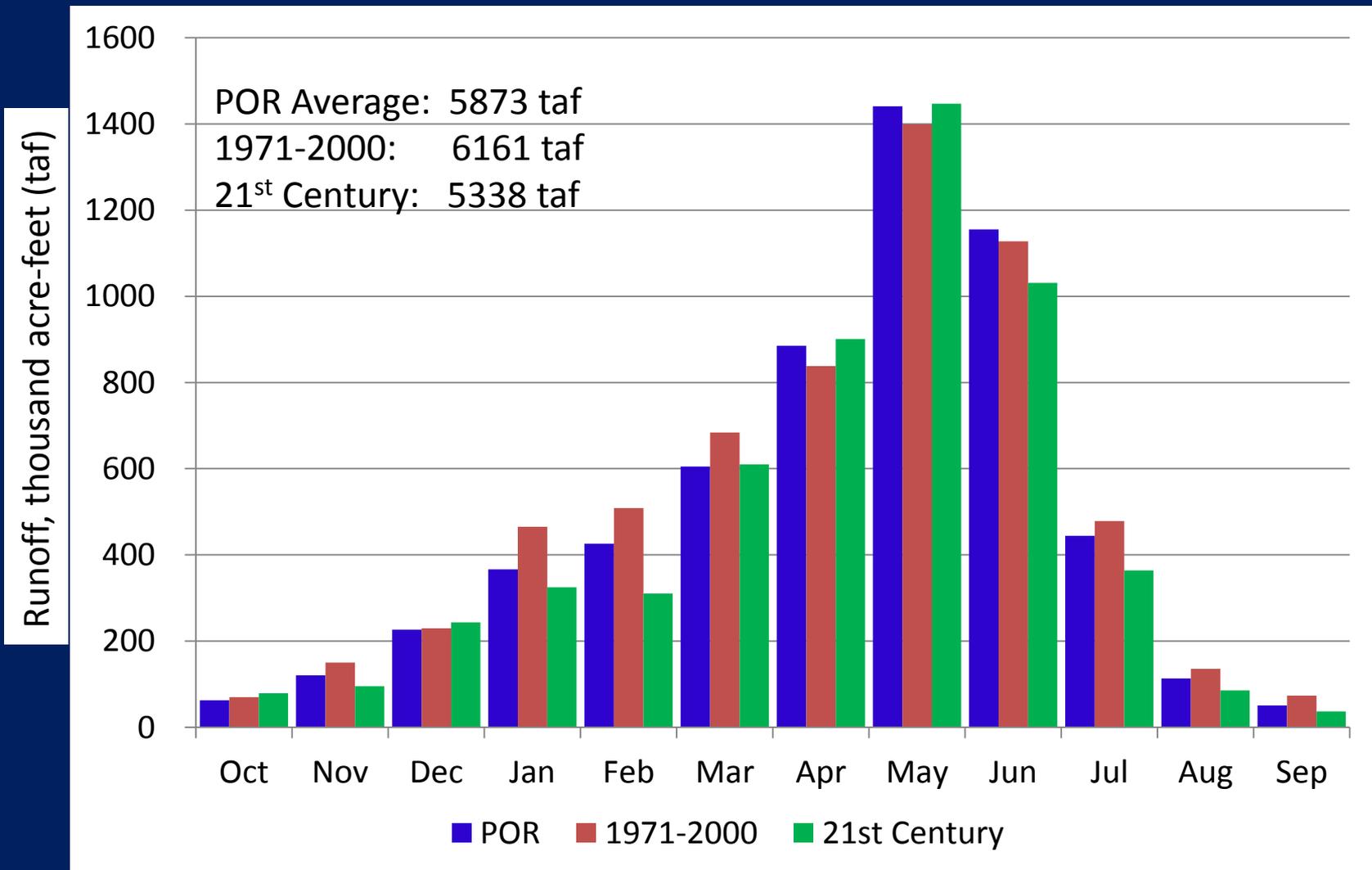
Average of:  
Calaveras Big Trees  
Hetch Hetchy  
Yosemite HQ  
North Fork Ranger Station  
Huntington Lake

# 21<sup>st</sup> Century Breakdown So Far – 5 Station Index



Note WY2012 driest Dec (0") and WY2014 10<sup>th</sup> driest (1.10")

# San Joaquin River Runoff Distributions (Thousand Acre-Feet (taf))





# Climate Change

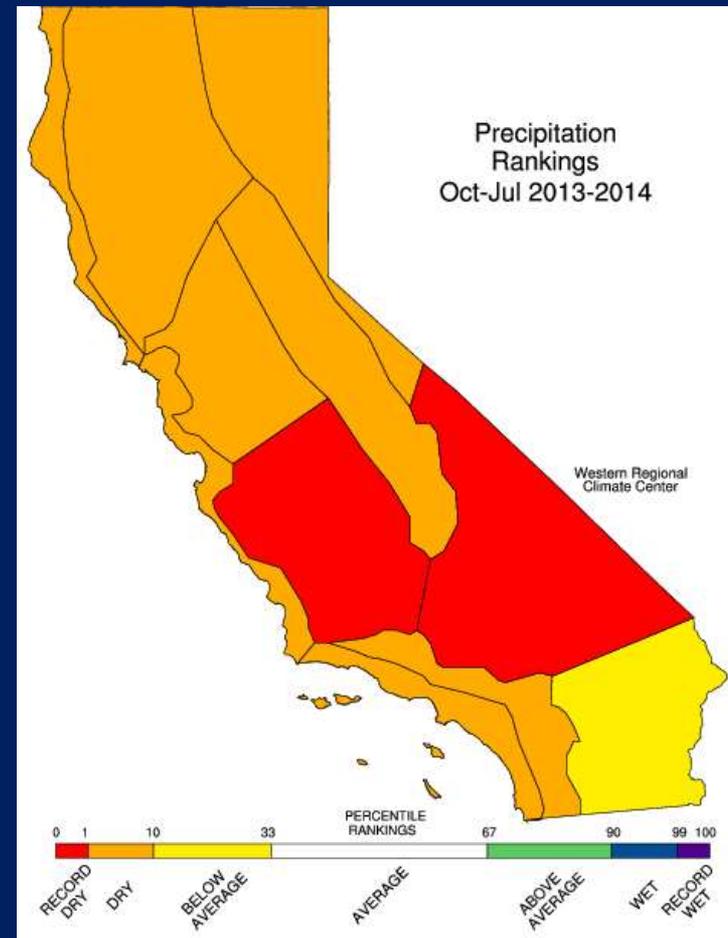
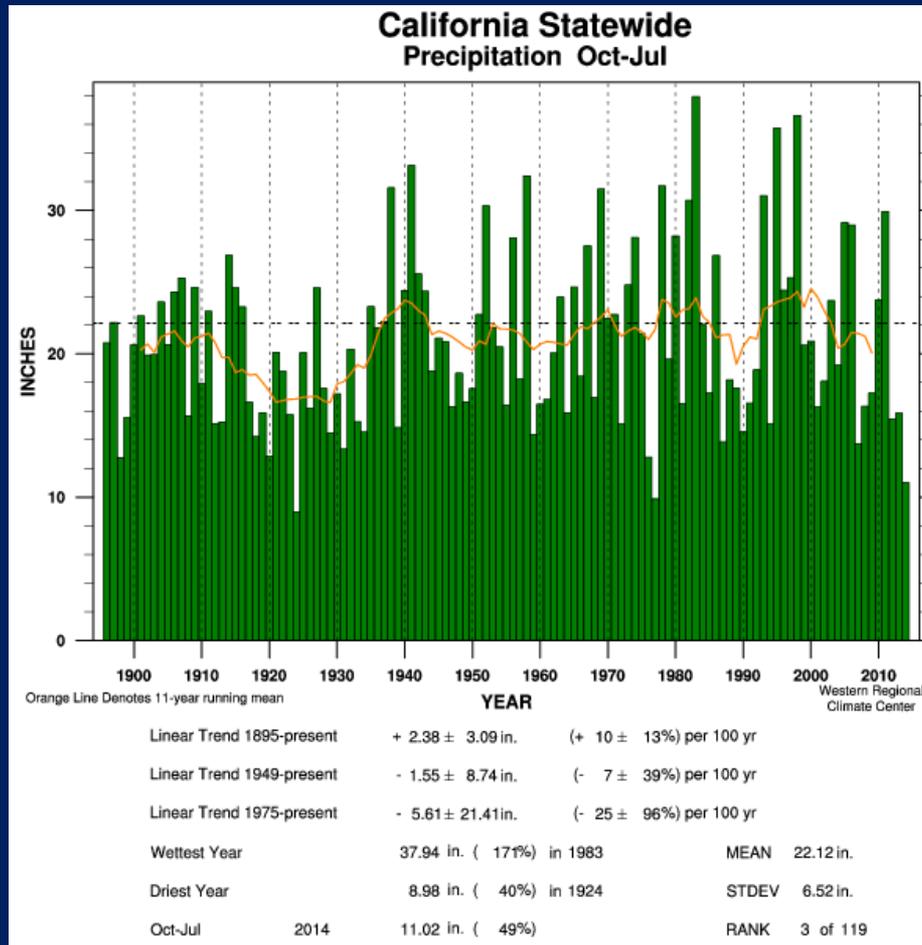
Tenaya Lake

# Climate Change Expectations

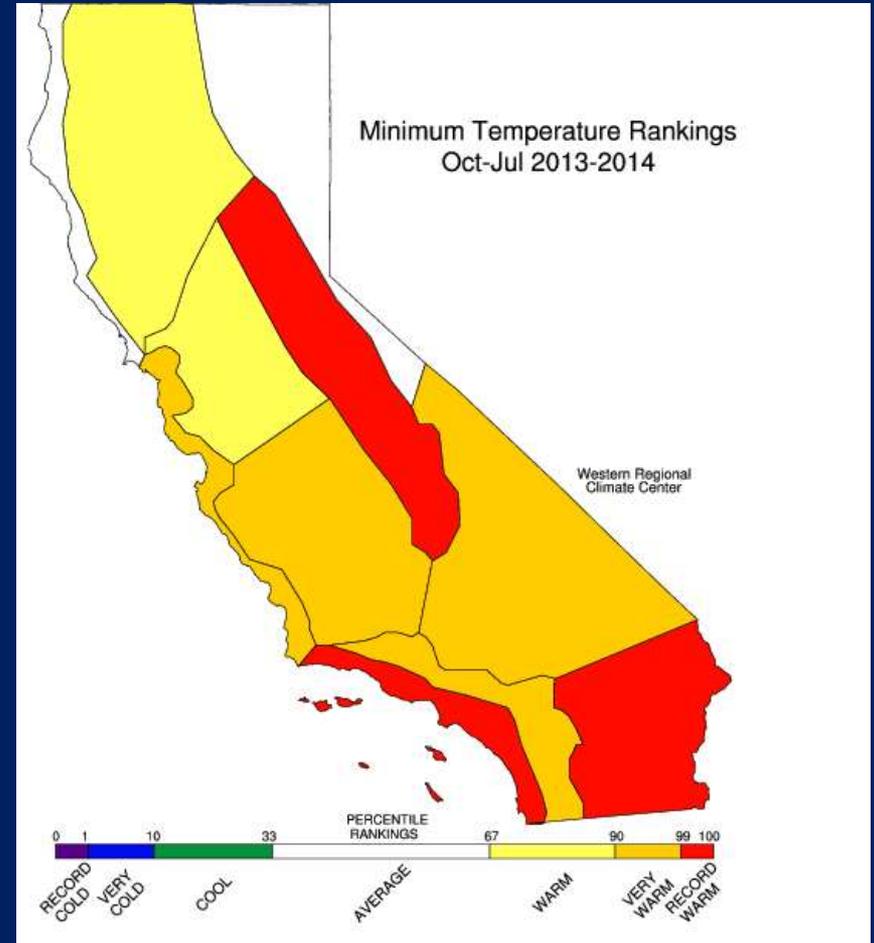
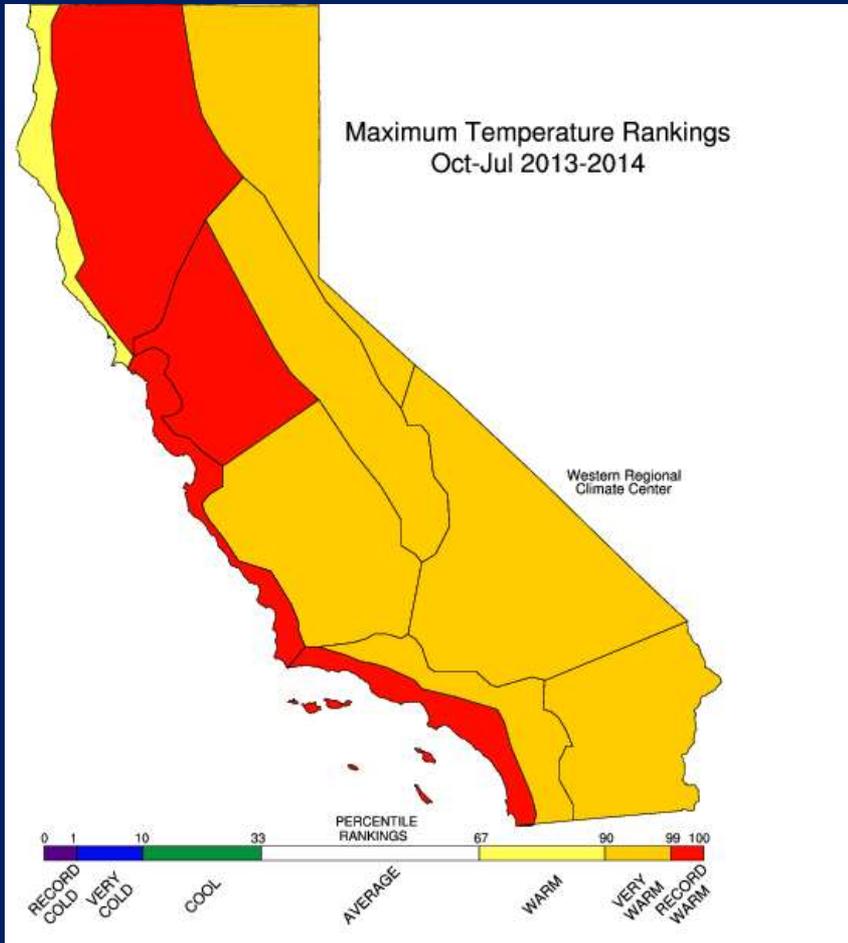
- Smaller Snowpack/More Rain Less Snow
- Earlier Snowmelt Onset
- More Variability
- More Extremes

Are we seeing these already?

# California Climate Tracker - WRCC

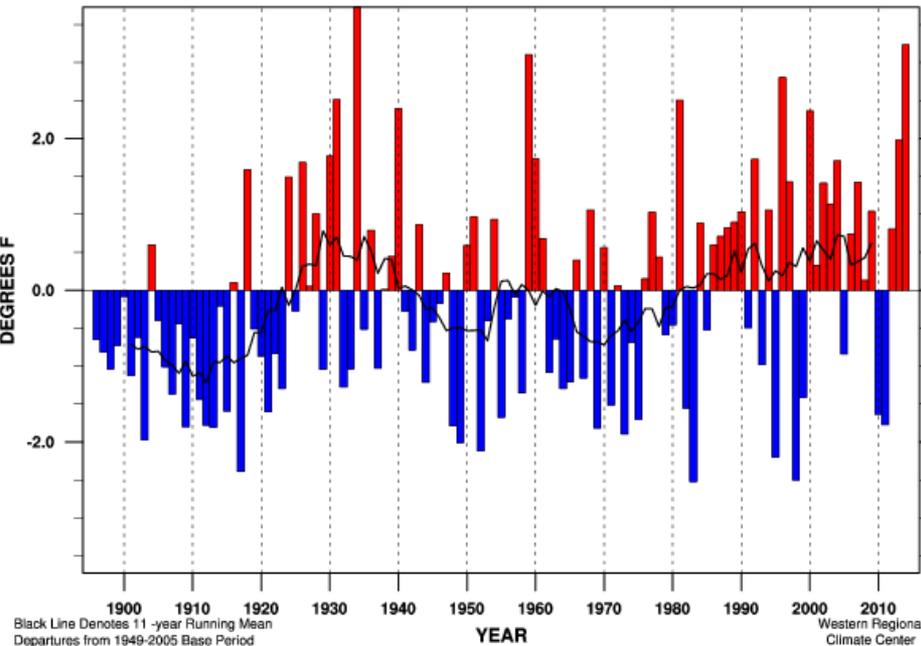


# California Climate Tracker - WRCC



# California Climate Tracker - WRCC

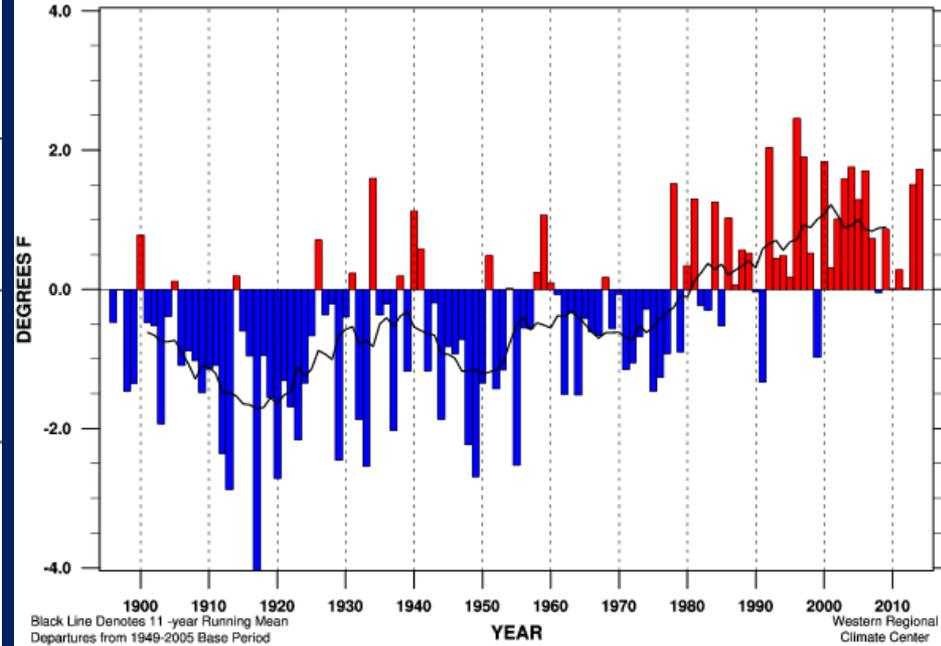
**California Statewide  
Maximum Temperature Departure Oct-Jul**



Black Line Denotes 11 -year Running Mean  
Departures from 1949-2005 Base Period  
Western Regional Climate Center

Linear Trend 1895-present	+ 1.04 ± 0.70 °F/100yr	
Linear Trend 1949-present	+ 1.75 ± 1.85 °F/100yr	
Linear Trend 1975-present	+ 2.02 ± 4.20 °F/100yr	
Warmest Year	69.6 °F (+ 3.7 °F) in 1934	MEAN 65.9 °F
Coldest Year	63.3 °F (- 2.5 °F) in 1983	STDEV 1.39 °F
Oct-Jul	2014 69.1 °F (+ 3.2 °F)	RANK 118 of 119

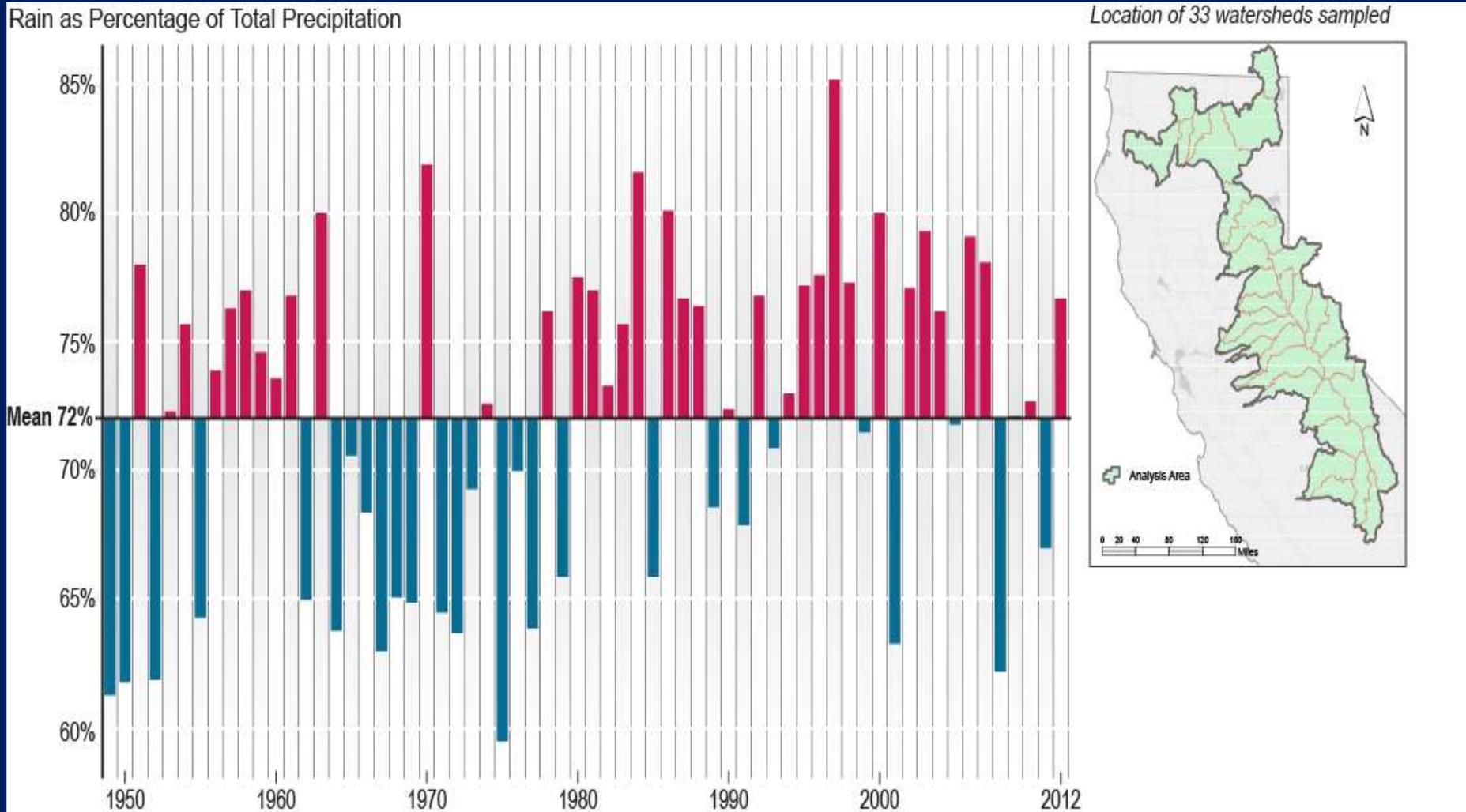
**California Statewide  
Minimum Temperature Departure Oct-Jul**



Black Line Denotes 11 -year Running Mean  
Departures from 1949-2005 Base Period  
Western Regional Climate Center

Linear Trend 1895-present	+ 1.90 ± 0.53 °F/100yr	
Linear Trend 1949-present	+ 3.30 ± 1.15 °F/100yr	
Linear Trend 1975-present	+ 3.08 ± 2.65 °F/100yr	
Warmest Year	43.4 °F (+ 2.5 °F) in 1996	MEAN 40.9 °F
Coldest Year	36.9 °F (- 4.0 °F) in 1917	STDEV 1.09 °F
Oct-Jul	2014 42.6 °F (+ 1.7 °F)	RANK 114 of 119

# New Rain/Snow Metric for DWR



Credit: Aaron Cuthbertson, Elissa Lynn DWR  
Kelly Redmond WRCC

# Summarizing Thoughts

- Current drought along with 21<sup>st</sup> century droughts have shown record setting characteristics and are warmer than 20<sup>th</sup> century counterparts
- Atmospheric river events provide significant inputs into annual precipitation totals – fewer such events in drought years

# Conclusions

- The expectation of increased variability means new extremes and extreme transitions with WY 2013 serving as an example.
- Planning for future droughts can take advantage of information in the historical record including paleo reconstructions. The trick will be to increase our understanding of causal mechanisms and watershed condition/response.

An aerial photograph of a mountainous region. The foreground shows a grid of agricultural fields in various shades of green and brown. The middle ground and background consist of rugged, brownish mountains with some snow patches on the peaks. The text "Questions?" is centered in the middle of the image.

Questions?

[Michael.L.Anderson@water.ca.gov](mailto:Michael.L.Anderson@water.ca.gov)