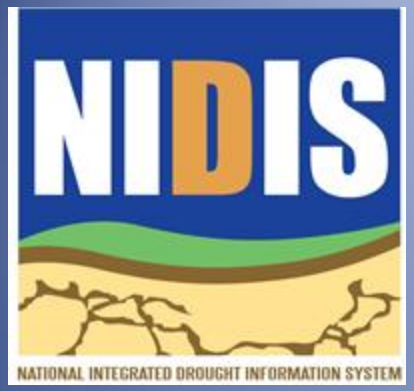


California Drought - a Big Picture Perspective with NIDIS Insights

Carl Nettleton
President, Nettleton Strategies
Founder, Open Oceans Global
October 2, 2014
San Diego Regional Chamber of Commerce
Energy and Water Committee

National Integrated Drought Information System (NIDIS)

- Established in 2006
- Reauthorized by Congress in March 2014
- Purpose
  - Promote drought early warning and preparedness;
  - Coordinate, develop, and communicate drought monitoring and forecast data and information;
  - Work with federal, tribal, state, and local partners on assessing impacts; and
  - Assist in managing those impacts and reducing potential losses.

NIDIS Participating Agencies
Western Regional Climate Center

- U.S. Geological Survey
- National Weather Service
- U.S. Department of Agriculture
- NOAA
- U.S. Department of Interior
- California Department of Water Resources
- Scripps Institution of Oceanography
- Arizona State University
- Colorado State University
- University of Washington
- University of Wyoming
- Utah State University
- University of Alaska
- University of Hawaii
- University of Montana
- University of Nevada
- New Mexico State University
- Oregon State University

California Drought Forum

Making Decisions in Dry Times: Science and Strategies for Dealing with Drought

Sacramento, May 2014

- Drought Conditions and Forecasts
- Current Drought Related Science
- Sectorial Drought Impacts, Information Uses, Needs and Decisions
- Integrated Information Systems and Resources
- NOAA California Drought Services Assessment



CURRENT DROUGHT

U.S. Drought Sept 2013 – Sept 2014

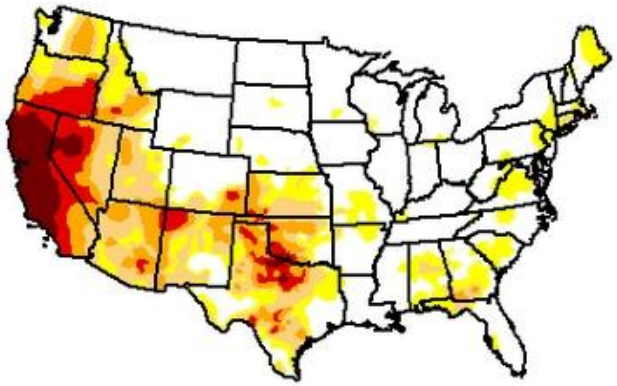
Maps And Data 〉 Weekly Comparison

U.S. Drought Monitor Weekly Comparison

Contiguous U.S.

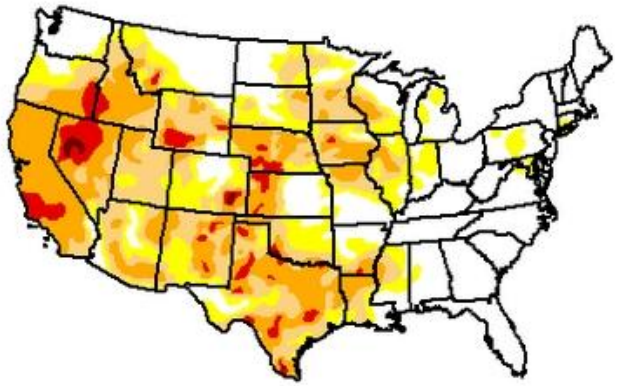
Drought Severity

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



PNG PDF JPG

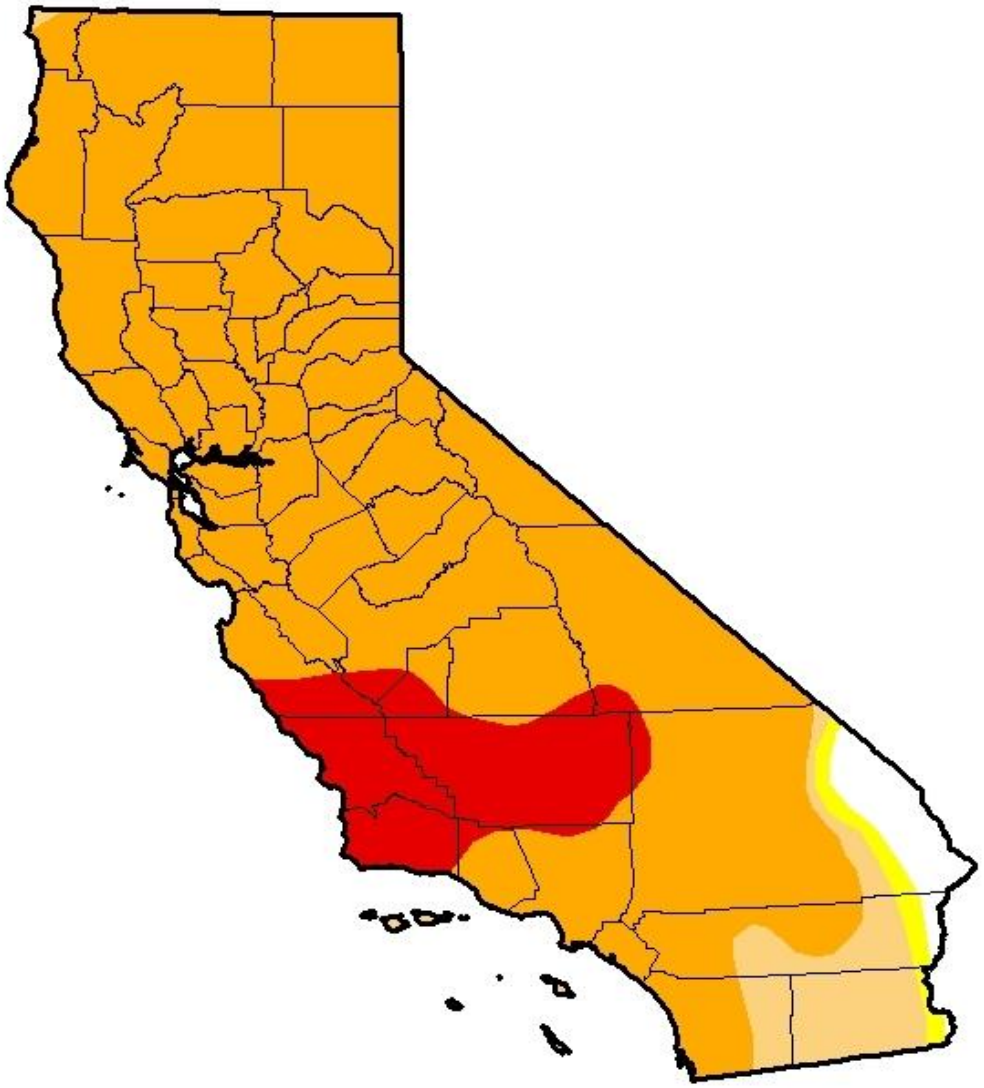
September 23, 2014



PNG PDF JPG

September 24, 2013

U.S. Drought Monitor
California



September 24, 2013
(Released Thursday, Sep. 26, 2013)
Valid 7 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	2.63	97.37	96.04	89.84	11.36	0.00
Last Week *9/17/2013*	2.63	97.37	96.04	89.84	11.36	0.00
3 Months Ago *6/25/2013*	0.00	100.00	98.21	92.61	0.00	0.00
Start of Calendar Year *1/1/2013*	31.75	68.25	55.32	22.50	0.00	0.00
Start of Water Year *9/25/2012*	11.95	88.05	69.41	22.27	1.14	0.00
One Year Ago *9/25/2012*	11.95	88.05	69.41	22.27	1.14	0.00

Intensity:

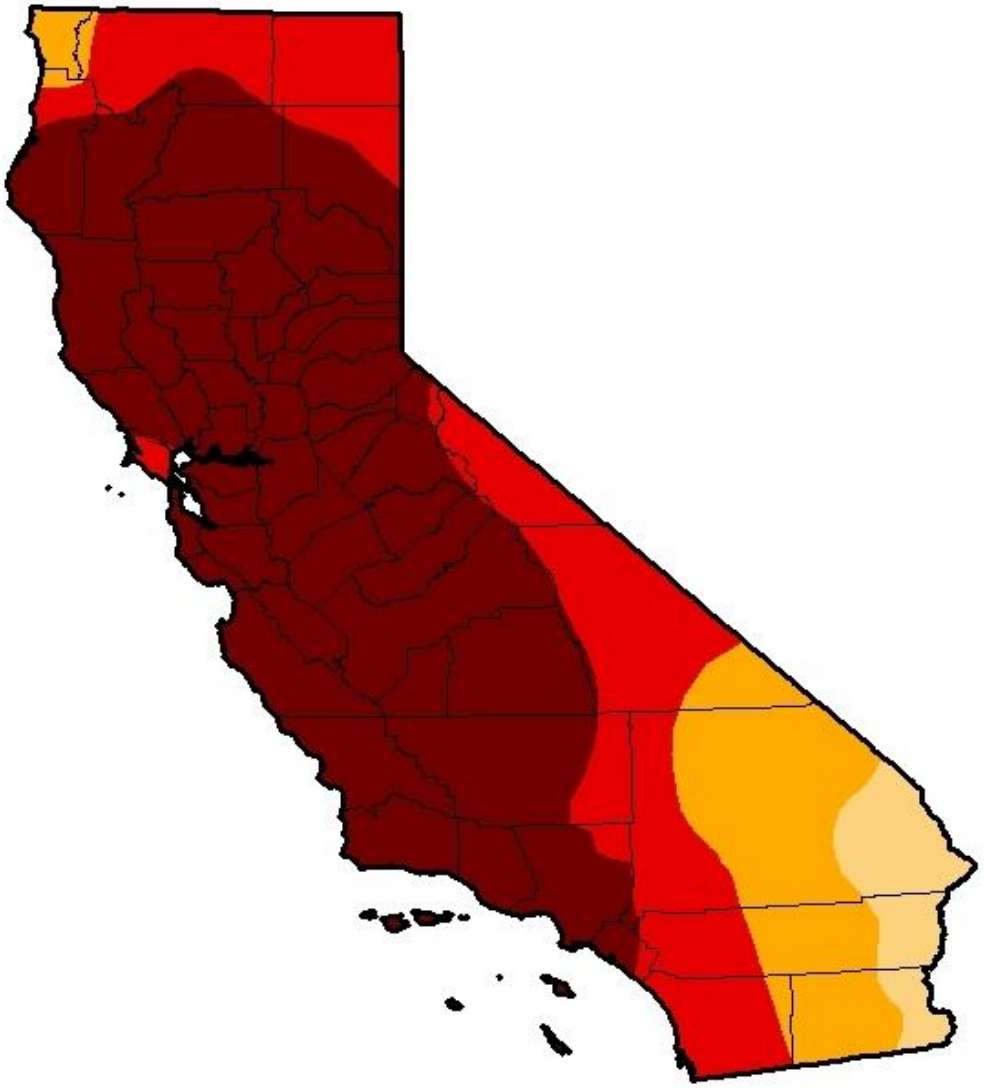
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brad Rippey
U.S. Department of Agriculture

http://droughtmonitor.unl.edu/

U.S. Drought Monitor
California



September 23, 2014
(Released Thursday, Sep. 25, 2014)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	95.34	81.92	58.41
Last Week 9/16/2014	0.00	100.00	100.00	95.42	81.92	58.41
3 Months Ago 6/24/2014	0.00	100.00	100.00	100.00	76.69	32.98
Start of Calendar Year 12/31/2013	2.61	97.39	94.25	87.53	27.59	0.00
Start of Water Year 10/1/2013	2.63	97.37	95.95	84.12	11.36	0.00
One Year Ago 9/24/2013	2.63	97.37	96.04	89.84	11.36	0.00

Intensity:

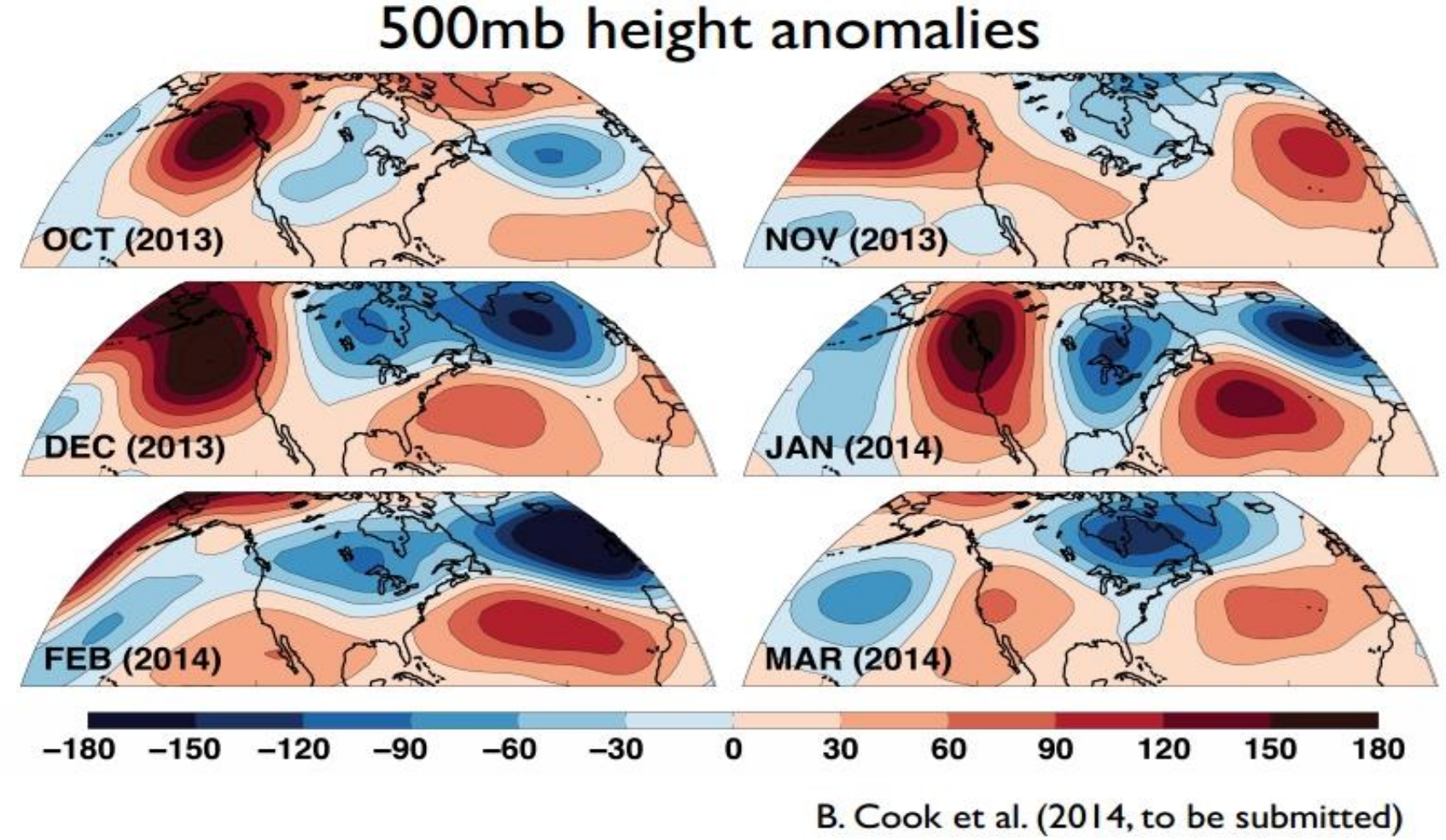
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Richard Heim
NCDC/NOAA

http://droughtmonitor.unl.edu/

2013/14 winter drought caused by a persistent (but varying) ridge over west coast of North America

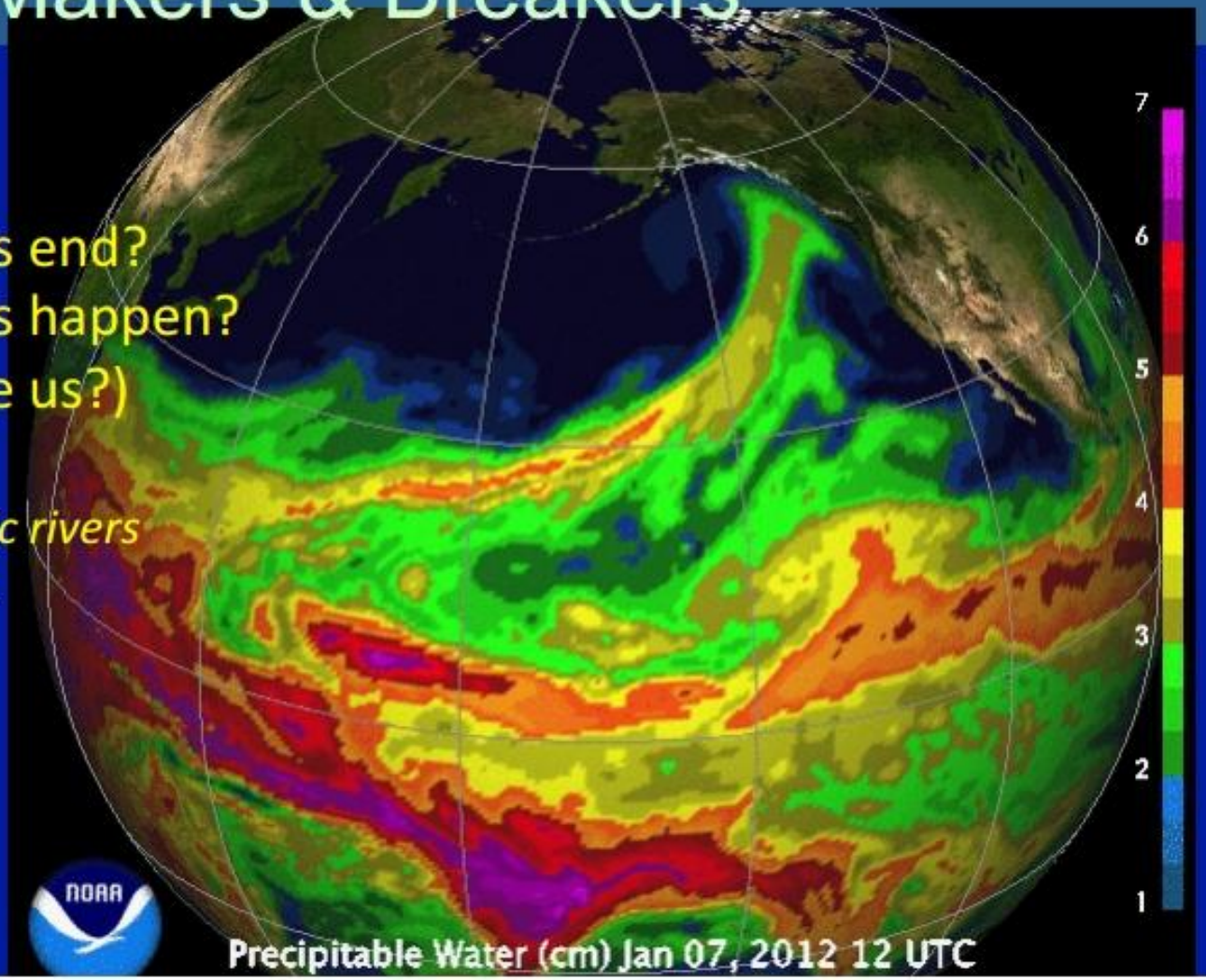


Credit: Richard Seager, Lamont Doherty Earth Observatory, and Brad Lyon, International Research Institute for Climate and Society, both at Columbia University

Atmospheric rivers as Drought Makers & Breakers

- How do droughts end?
- How do droughts happen?
- (Will El Nino save us?)

…and what atmospheric rivers have to do with all this.

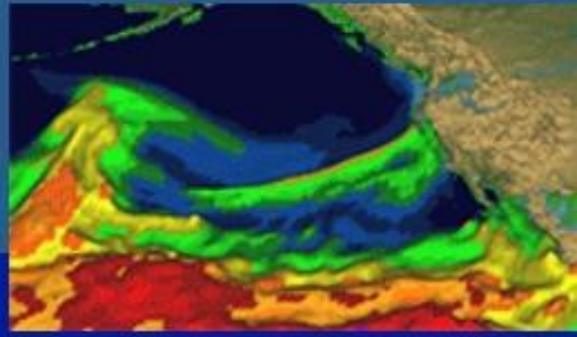


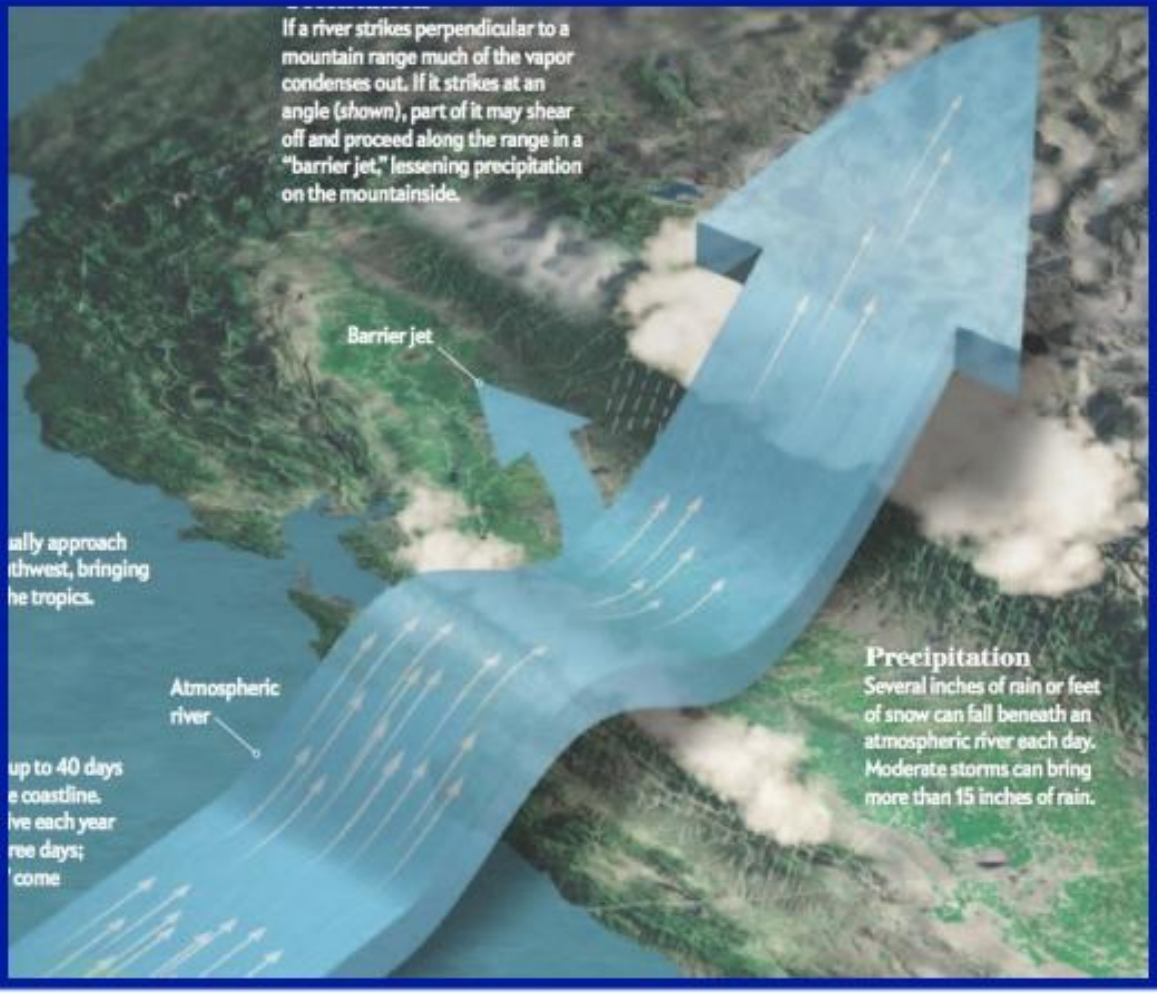
USGS science for a changing world

CNAP California-Nevada Climate Applications Program

Mike Dettinger, USGS/SIO

Atmospheric Rivers





-Map-view structure *(~400 km width & 2000 km long)--from satellite data*

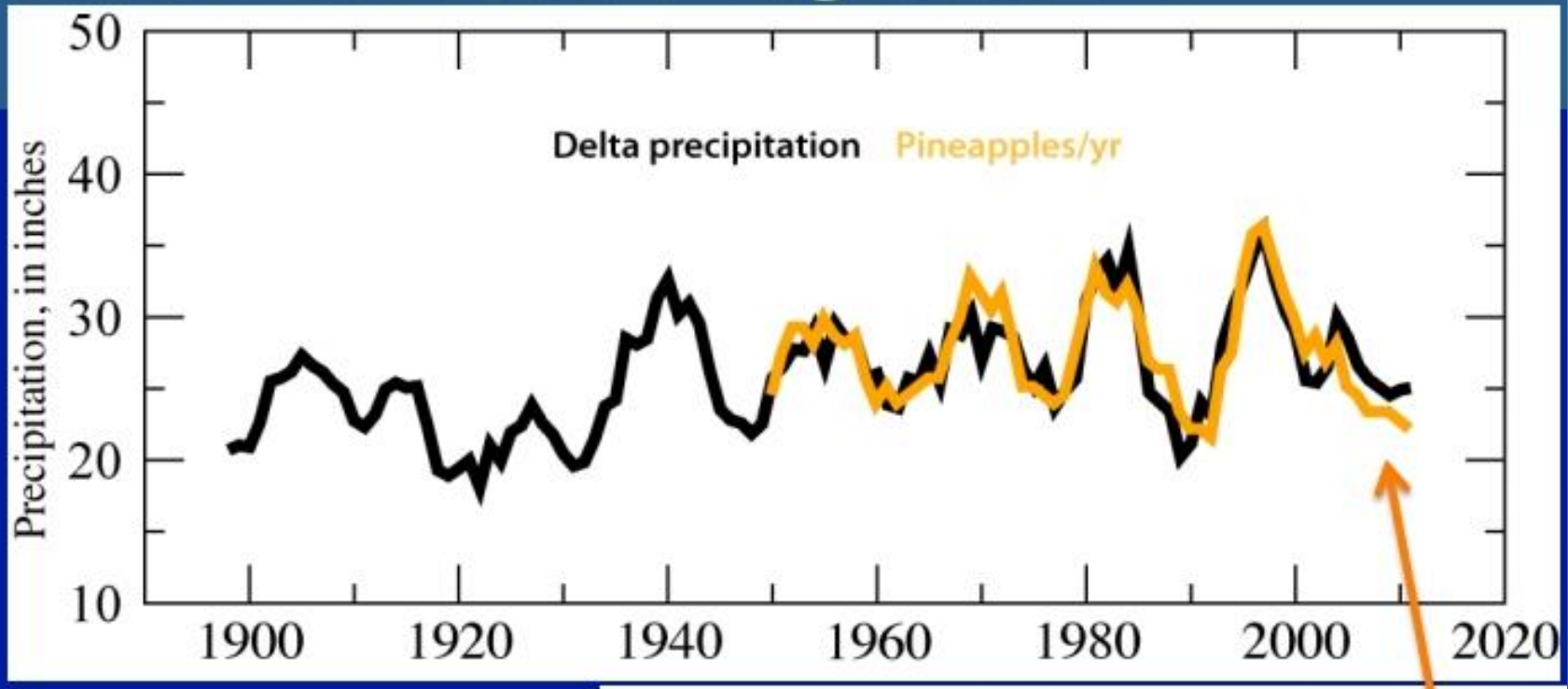
-Vertical structure *(intense jet of vapor between 1 – 2 km above sea level; 10-20 Mississippis; easily uplifted)--from airplanes & AROs*

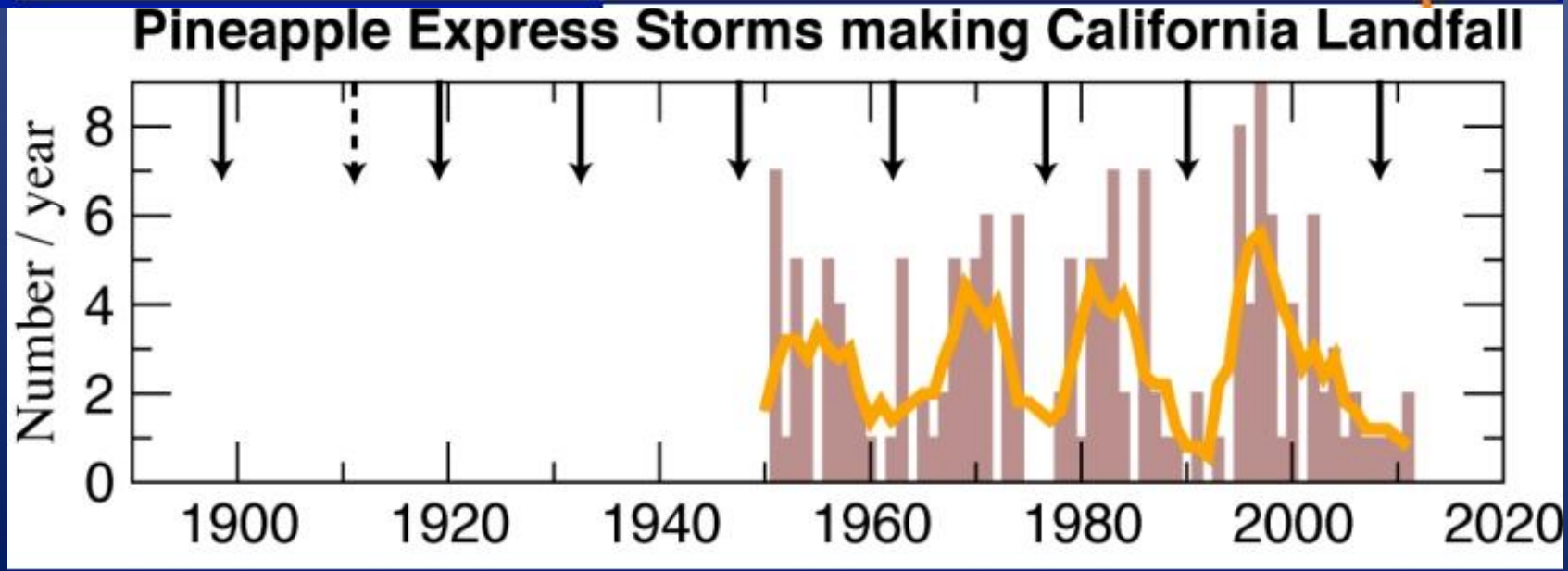
USGS science for a changing world

CNAP California-Nevada Climate Applications Program

Dettinger & Ingram, Sci Am, 2013

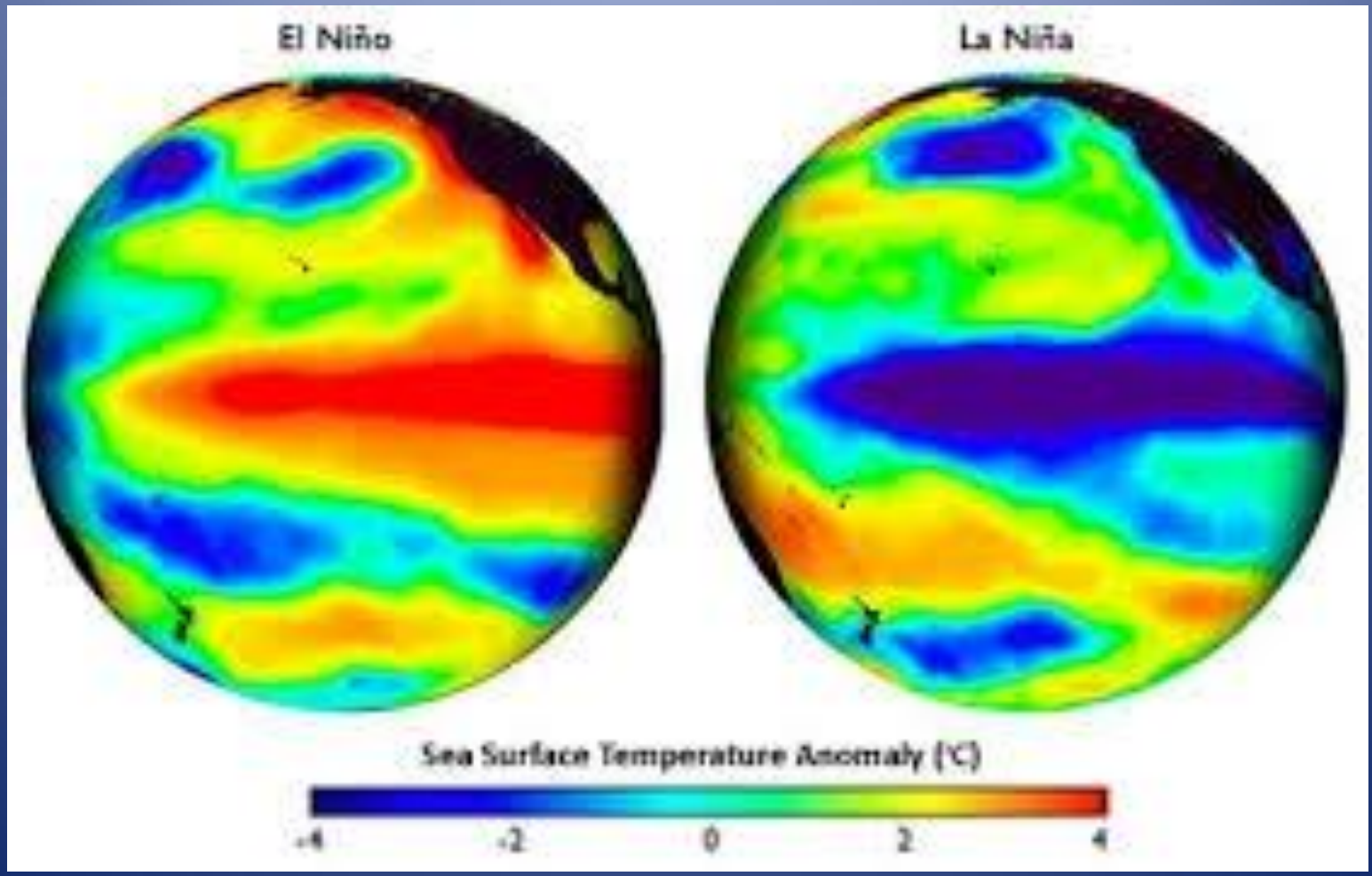
ARs as West Coast drought makers





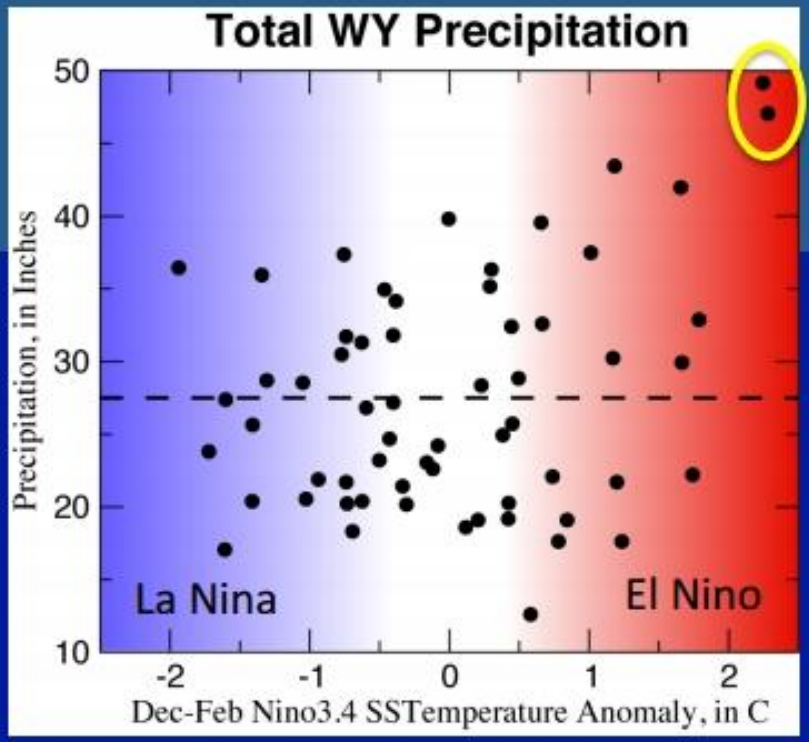
Credit: Mike Dettinger
Scripps Institution of Oceanography
U.S. Geological Survey

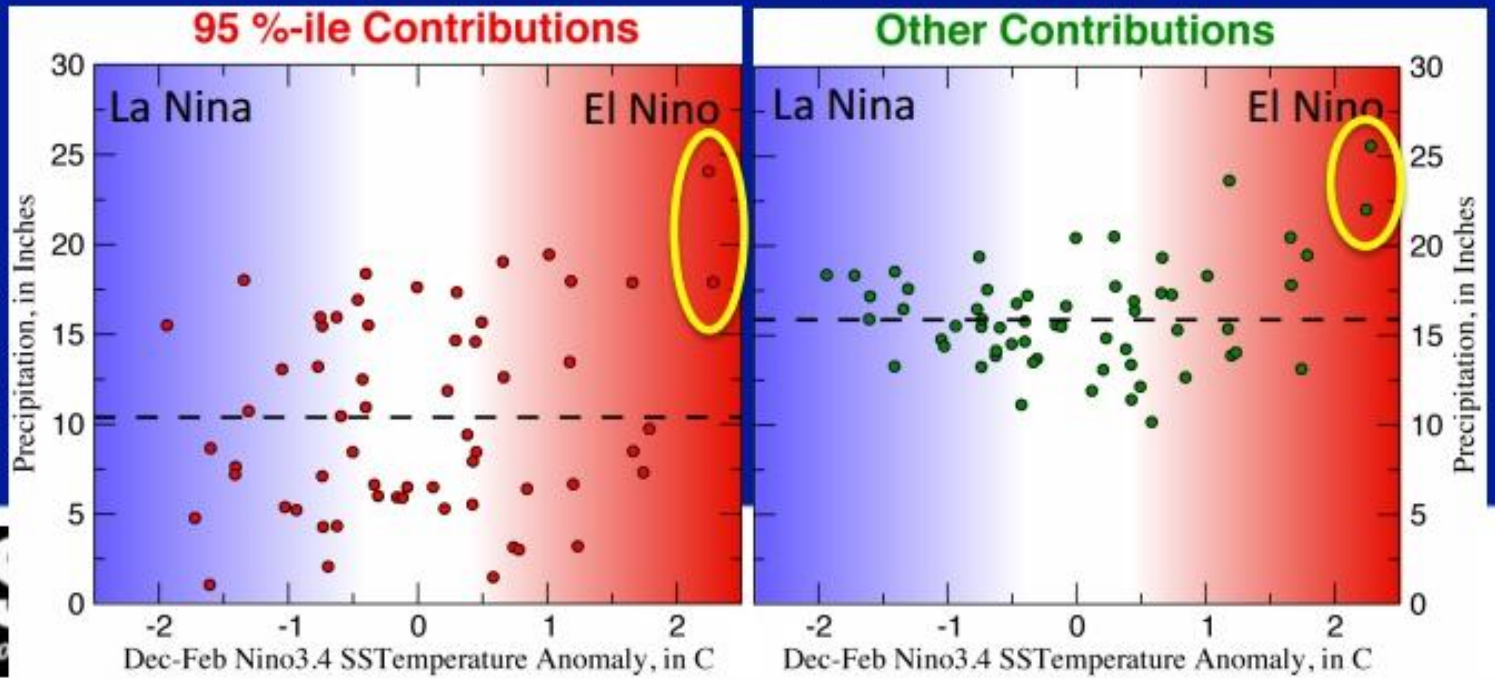
El Niño vs. La Niña
The difference in average temperature in the Equatorial Pacific



El Nino as savior?

Nothing is guaranteed…
except maybe in a really
BIG El Nino

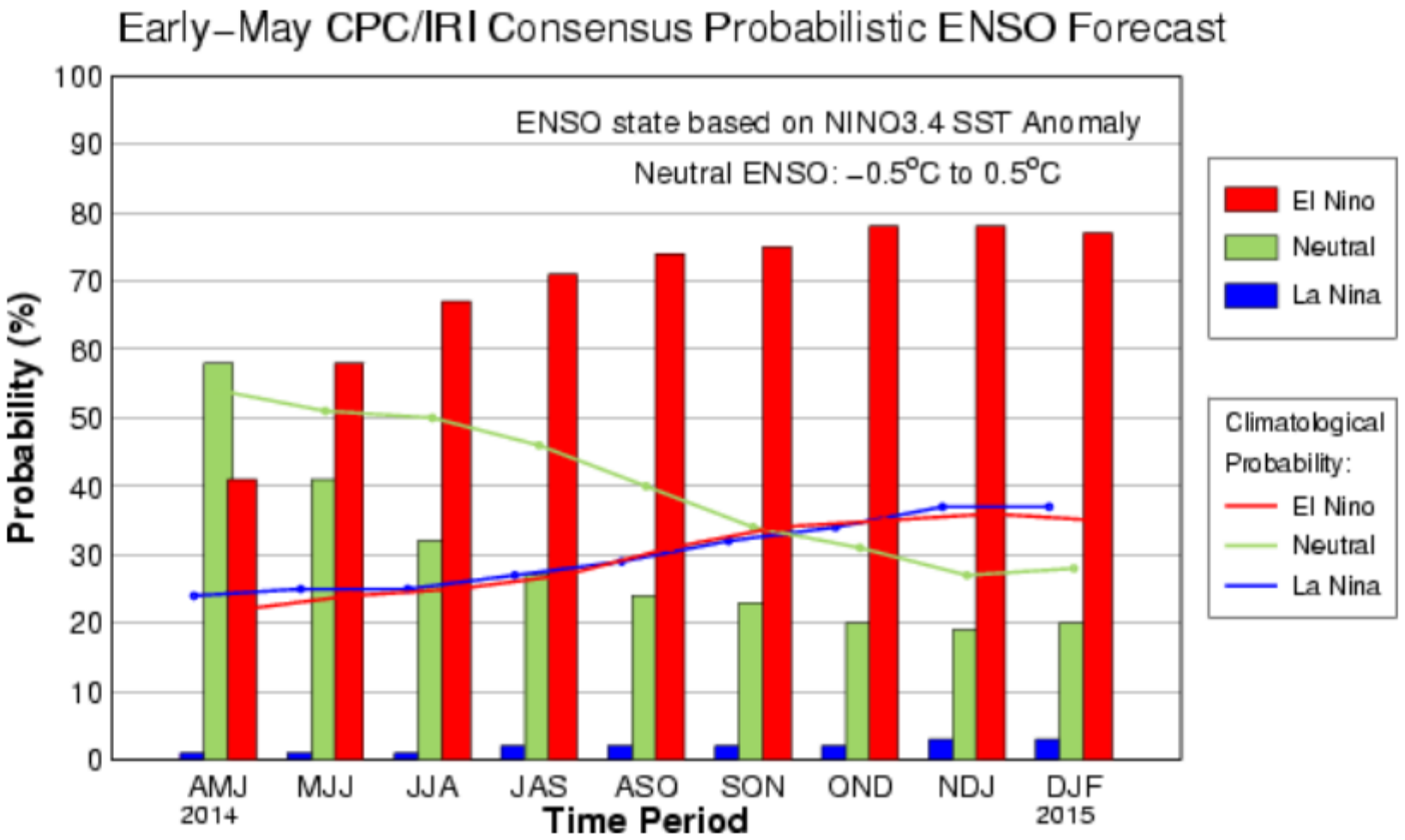




Credit: Mike Dettinger
Scripps Institution of Oceanography
U.S. Geological Survey

USGS
science for a changing wo

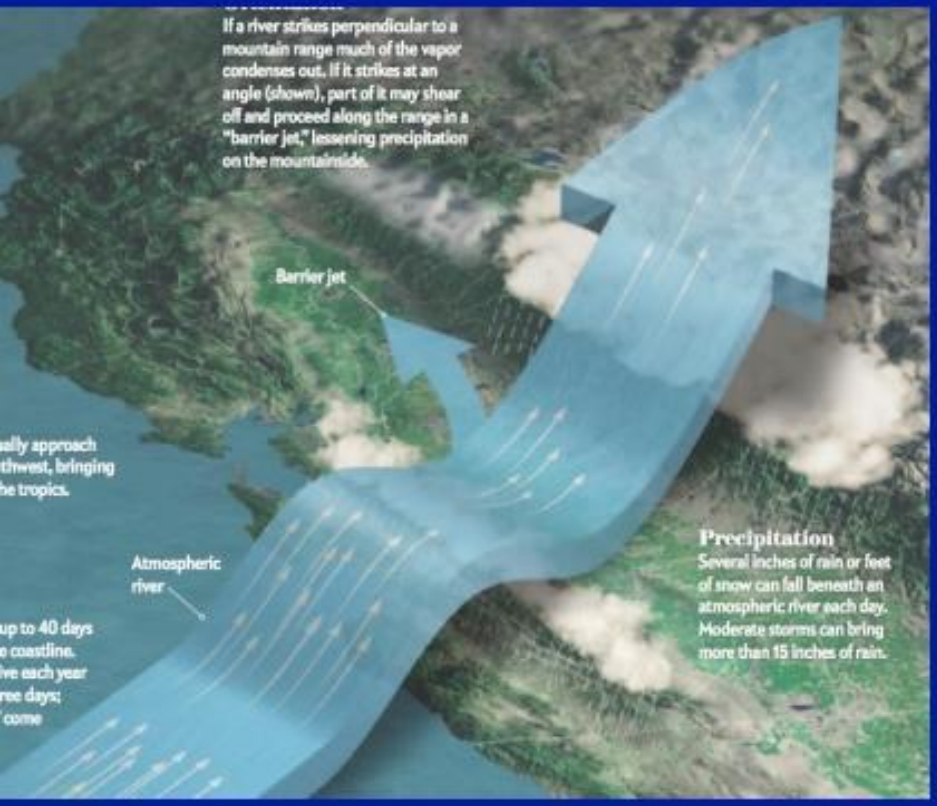
The next 8 months … ENSO



Credit: Jon Gottschalck, Operational Prediction Branch, Climate Prediction Center
NOAA, Department of Commerce

Conclusions

Nor/Cen California droughts:



- **End abruptly in big storms,** *with ARs contributing disproportionately to drought busting*
- **Are mostly due to missing "big" storms (95 %-ile wet days),** *with ARs contributing disproportionately to drought formation*
- **An El Nino does not guarantee a very wet year nor an end to drought,** *except for unusually warm El Ninos?*

USGS science for a changing world

CNAP California-Nevada Climate Applications Program

Credit: Mike Dettinger
Scripps Institution of Oceanography
U.S. Geological Survey

But Drought Is Relative with an Artificial Water System in Place

June 26, 2014



Sept 28, 2014



From MWD website

COLORADO RIVER

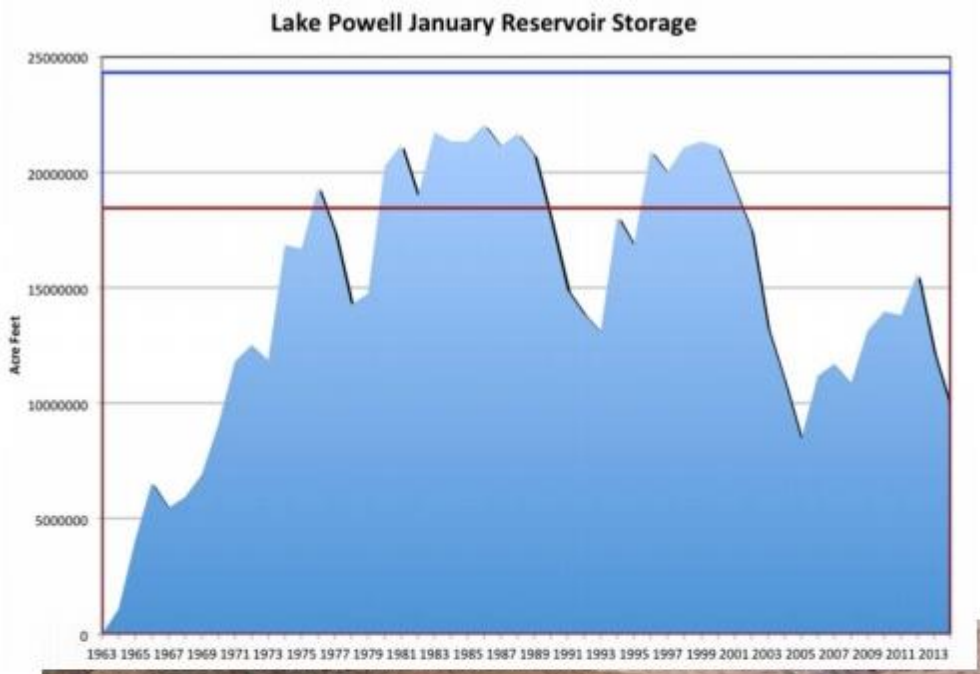


Credit:
Colorado Climate Center
Department of Atmospheric Science
Colorado State University

- “ . . . a division of the Department of Interior that provides water and power in the West—announced today it would cut water released from Lake Powell's Glen Canyon Dam by 750,000 acre-feet next year. That's about enough water to serve 1.5 million homes.”

- “It's the first time in the history of the nearly 50-year-old Glen Canyon Dam that water going downstream would be cut. "This is the worst 14-year drought period in the last hundred years," said Upper Colorado regional director Larry Walkoviak in a press release.”

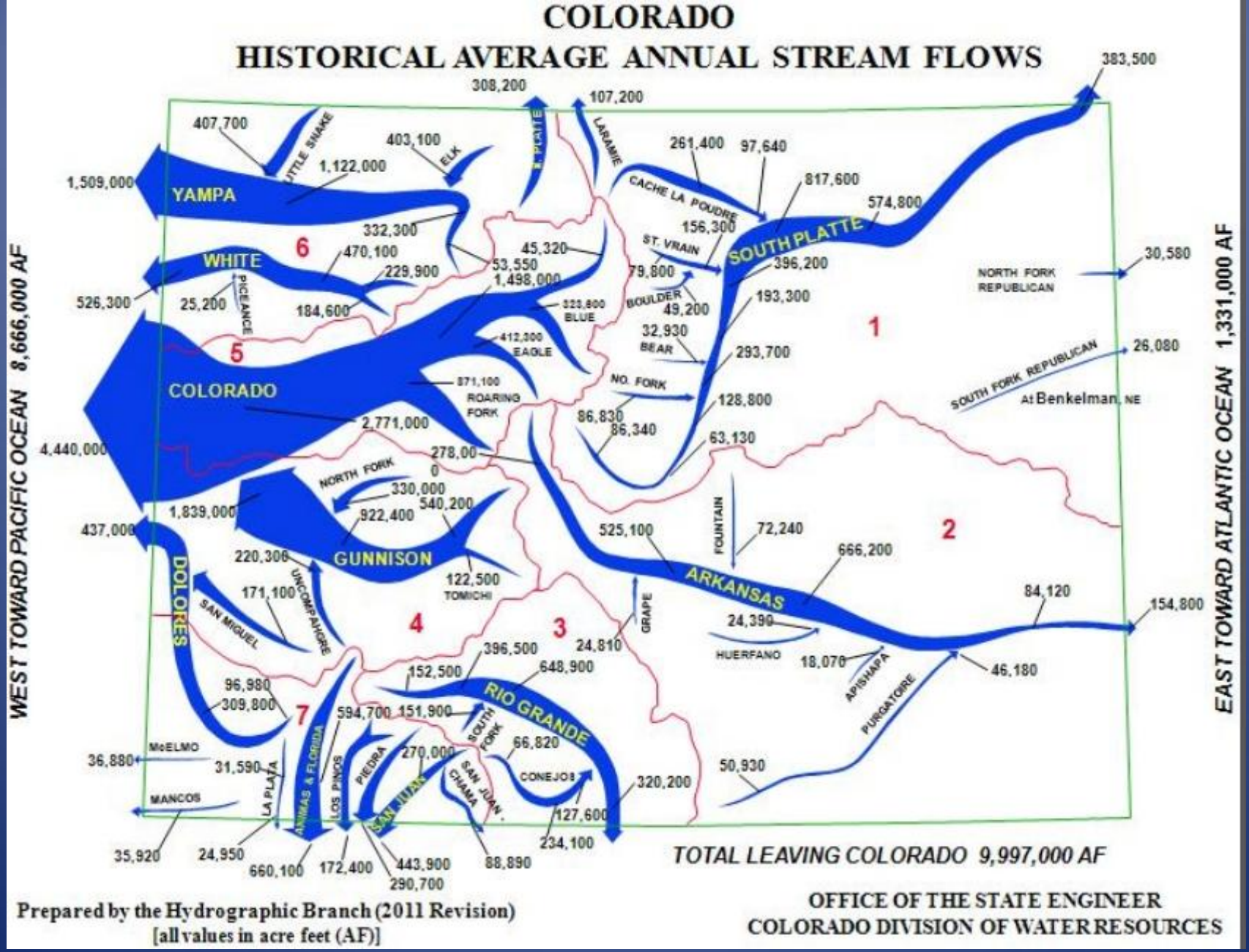
National Geographic Daily News, August 16,2013



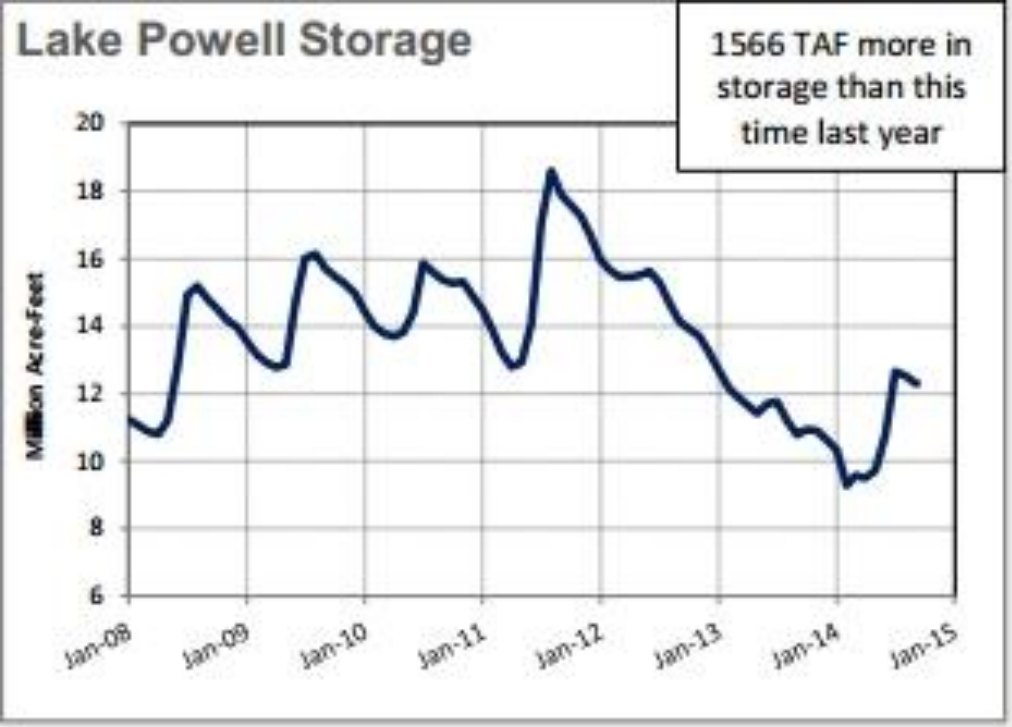


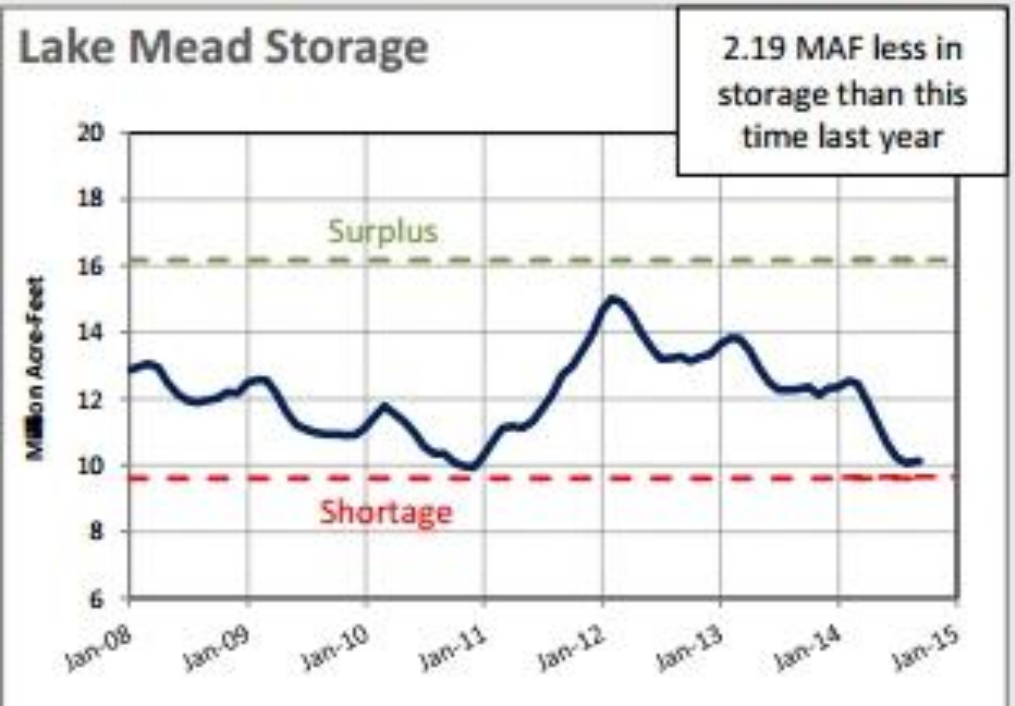


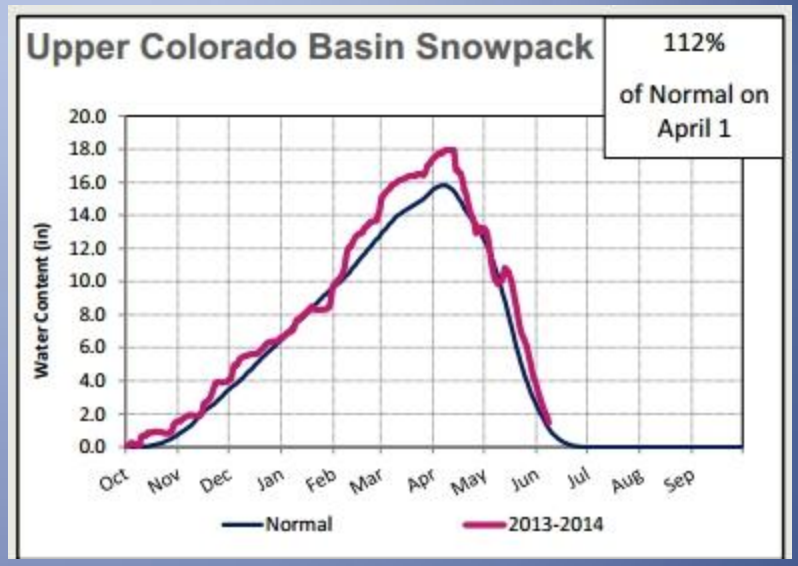
Credit: Colorado Climate Center, Department of Atmospheric Science, Colorado State University



Credit: Colorado Climate Center, Department of Atmospheric Science, Colorado State University







April 2014 Lake Mead Outlook

Lake Mead Outlook
Likelihood of Shortage/Surplus

	2015	2016	2017	2018	2019
Shortage	0%	23%	51%	62%	58%
Surplus	0%	0%	6%	9%	17%

Based on results from the April 2014 Colorado River Simulation System model run

August 2014 Lake Mead Outlook

Lake Mead Outlook
Likelihood of Shortage/Surplus

	2015	2016	2017	2018	2019
Shortage	0	36%	58%	68%	61%
Surplus	0%	0%	5%	7%	14%

Based on results from the August 2014 Colorado River Simulation System model run

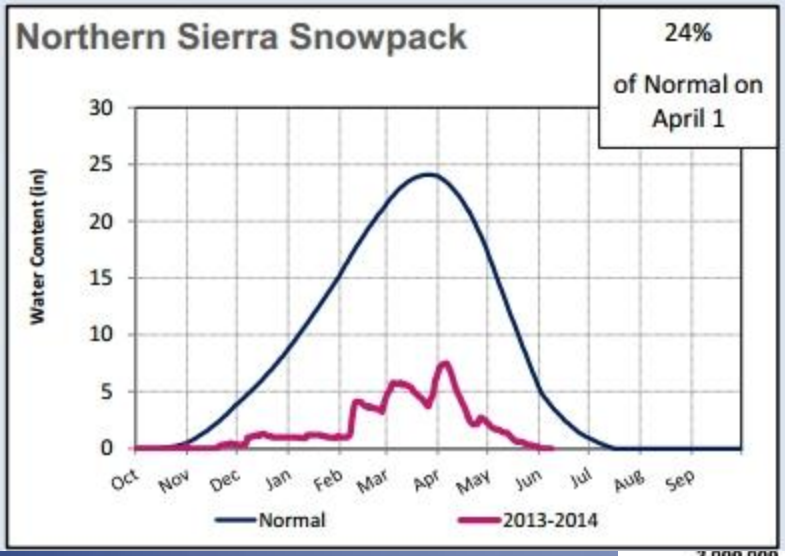
STATE WATER PROJECT

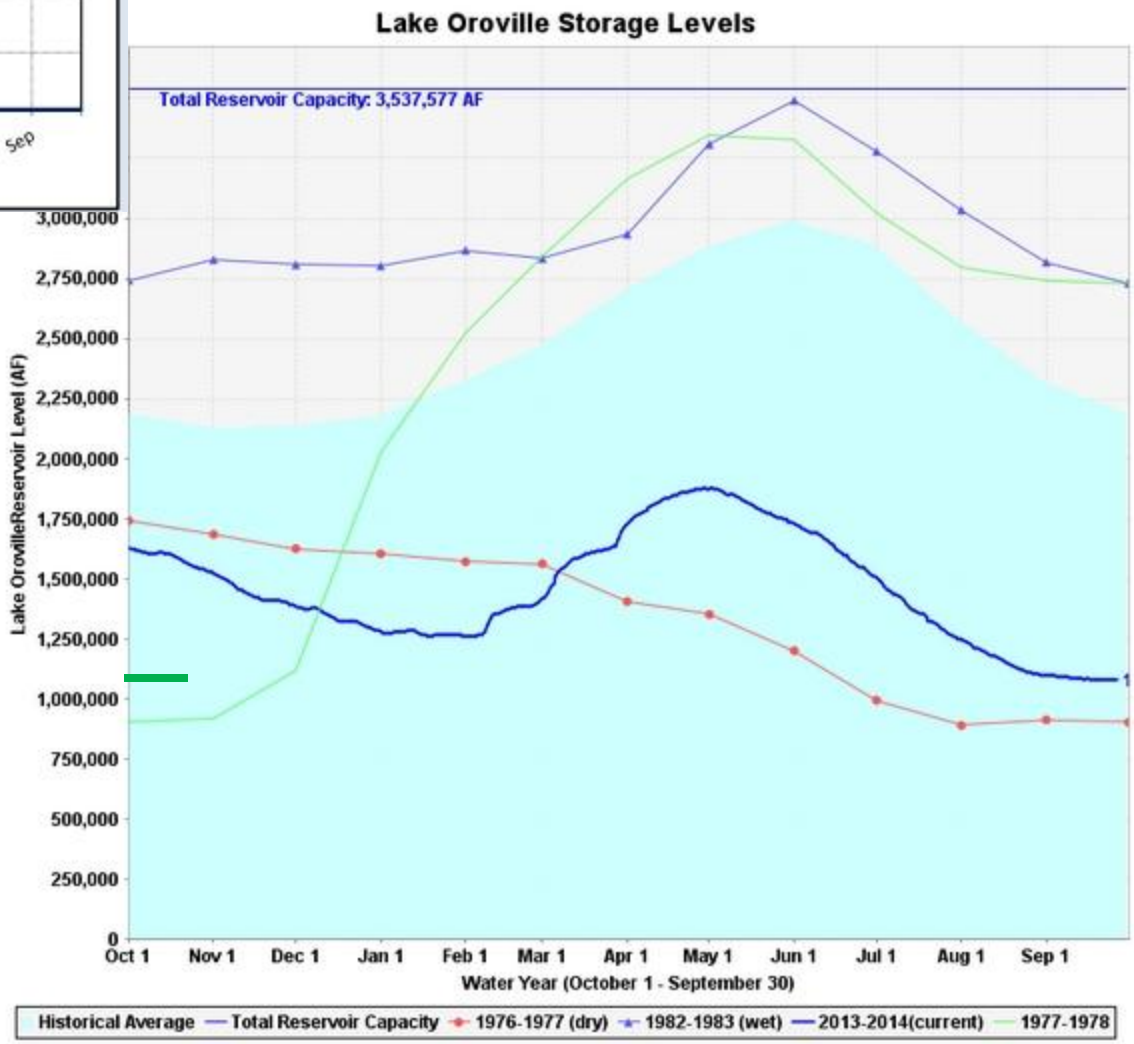


State Water Project Operations

"Challenging operations in 2014; likely 3-4th driest year in Sacramento and San Joaquin basins, no operational precedent in recent years"

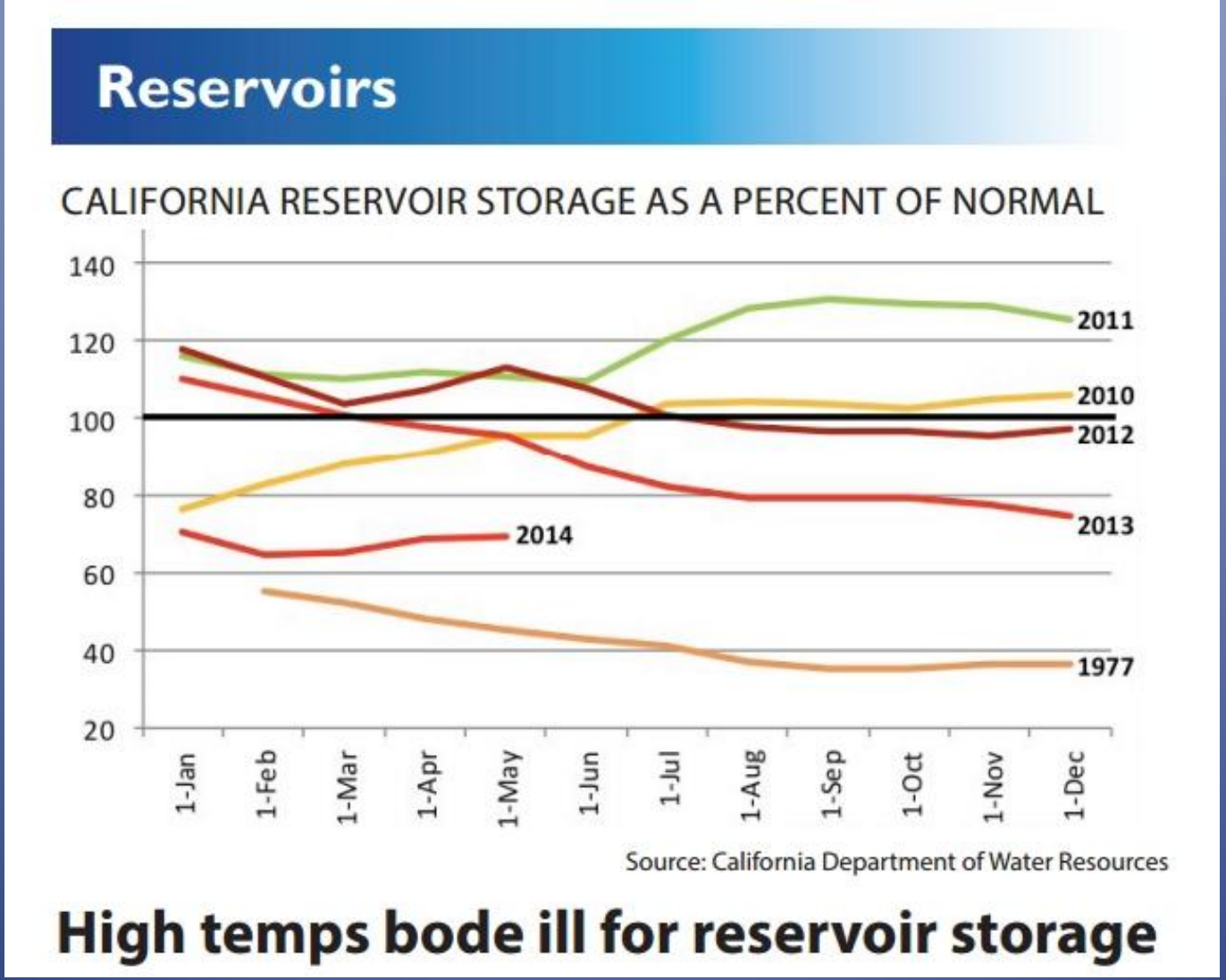
Credit: Jeanine Jones California Department of Water Resources


Northern Sierra Snowpack
24%
of Normal on April 1
Water Content (in)
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Normal
2013-2014


Lake Oroville Storage Levels
Total Reservoir Capacity: 3,537,577 AF
Lake OrovilleReservoir Level (AF)
3,000,000
2,750,000
2,500,000
2,250,000
2,000,000
1,750,000
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Water Year (October 1 - September 30)
Historical Average
Total Reservoir Capacity
1976-1977 (dry)
1982-1983 (wet)
2013-2014(current)
1977-1978

Lake Oroville, August 2014





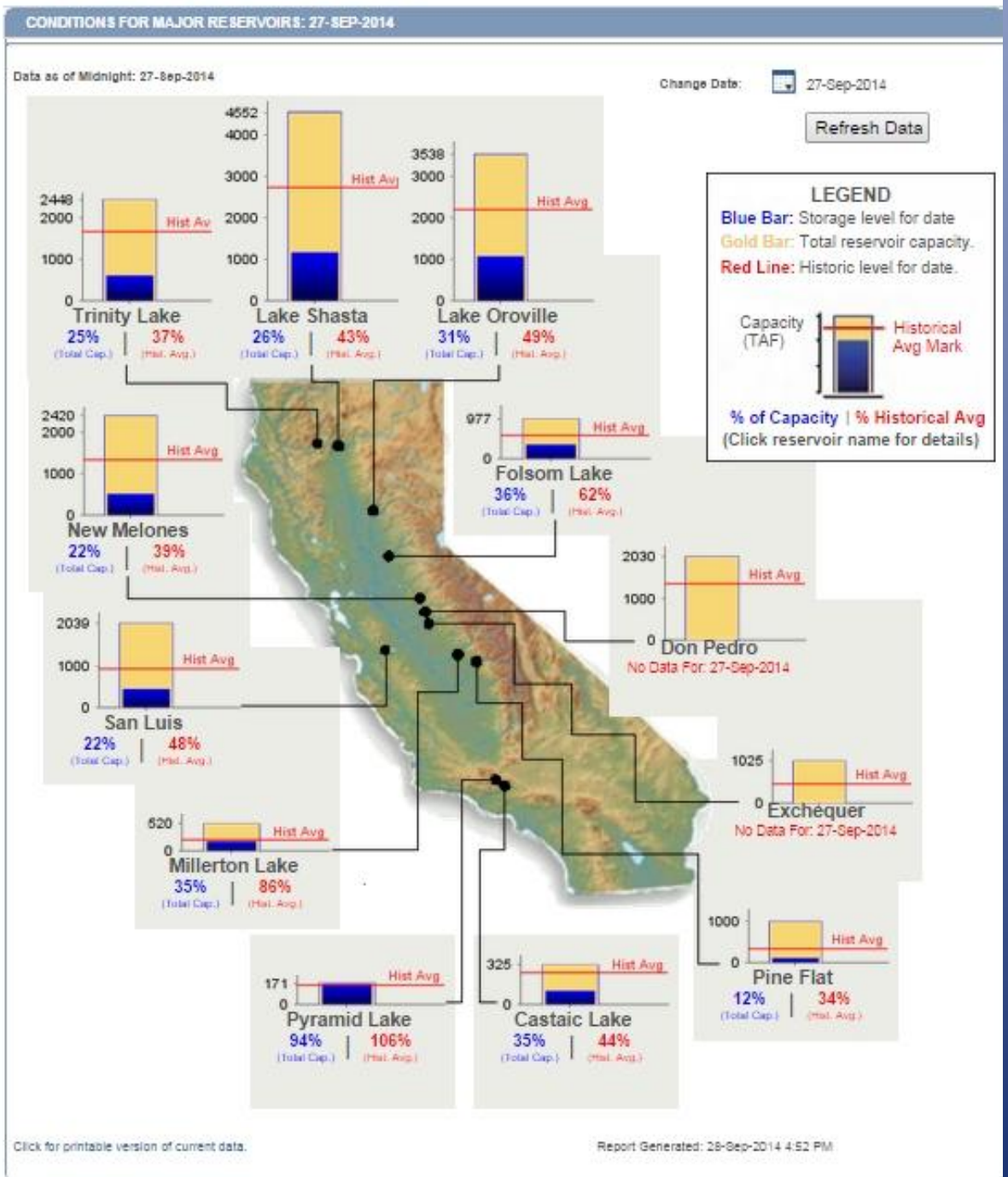
California Drought
Outlook, May 15, 2014

Average spring storage under usage patterns the last two years:

- Would support 3½ years of water usage.
- Has less than two years of water remaining in storage.

With temperatures reaching triple digits in parts of the state already this year and the heat expected to continue, there is a risk of rapid depletion of reservoir storage.

California Data Exchange Center - Reservoirs

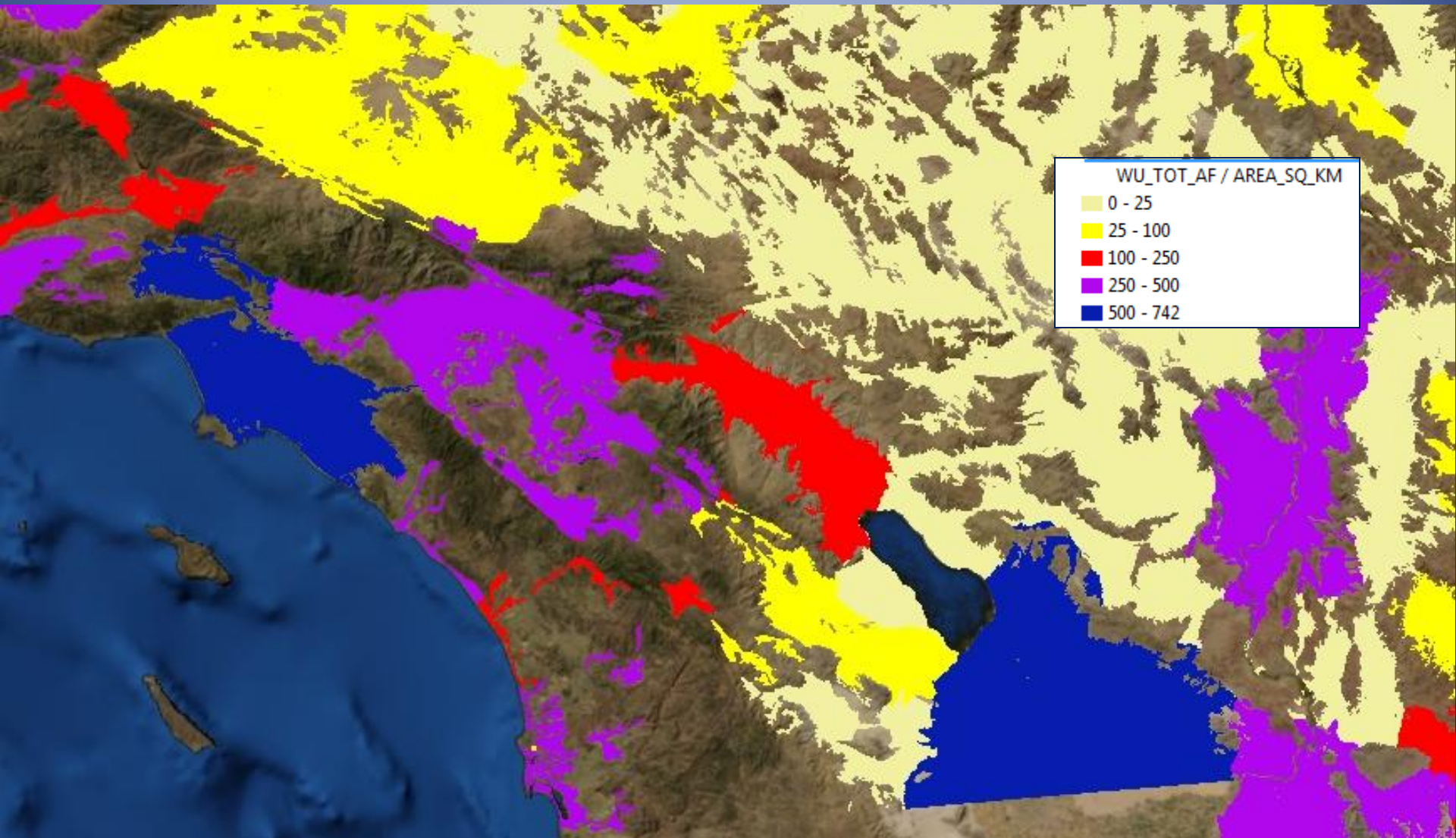


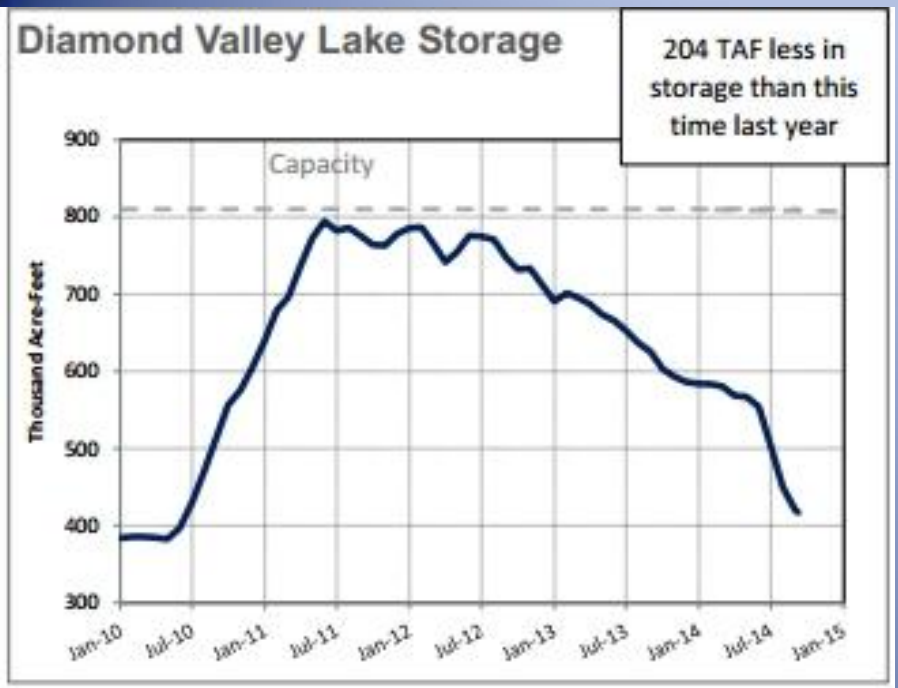
Change in Reservoir Storage
May 7 – Sept 27, Five Large Reservoirs

Reservoir	% Capacity May 7	% Capacity Sept 27	% Change Capacity	% Average May 7	% Average Sept 27	% Change Average
Oroville	52	31	**-21**	64	49	**-15**
Shasta	52	28	**-24**	67	43	**-24**
New Melones	37	22	**-15**	58	39	**-18**
Don Pedro	54	42 (data 8/17)	**-10**	72	57(data 8/17)	**-15**
San Luis	46	22	**-24**	53	48	**-5**

LOCAL/REGIONAL

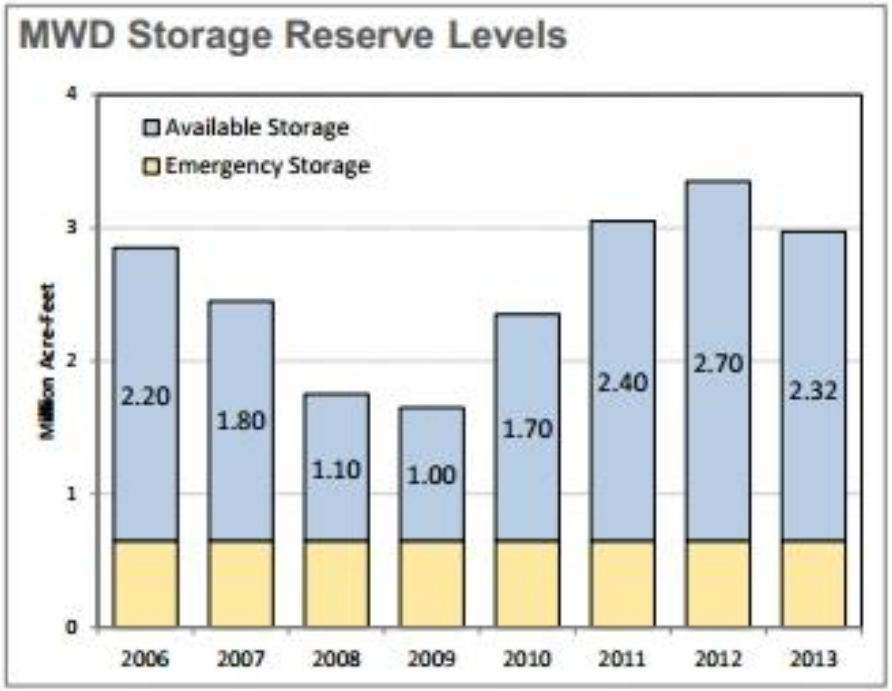
Southern California Aquifers





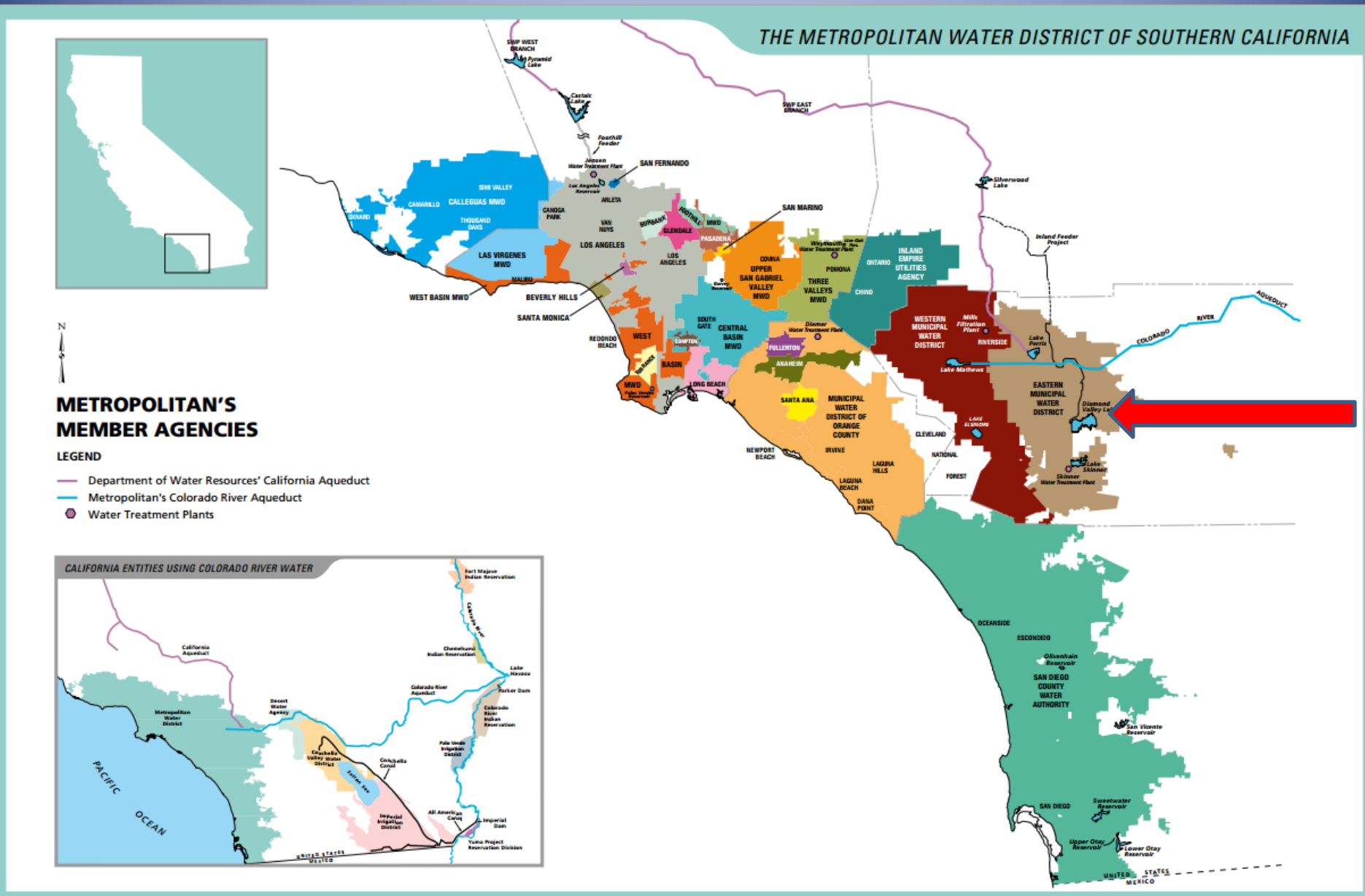


To view the full animation showing the region's progress in water supply diversification, go to sdcwa.org/annualreport/2013/water-supply-reliability.



SDCWA Sources of Water 2013	Acre Feet
Metropolitan Water District	296,623
Imperial Irrigation District	103,173
All American Canal	83,828
Local Surface Water	45,138
Recycled Water	25,793
Groundwater	19,345
Total	573,901
Imported Supplies	84%
Local Supplies	16%

Diamond Valley Lake



Quantification Settlement Agreement

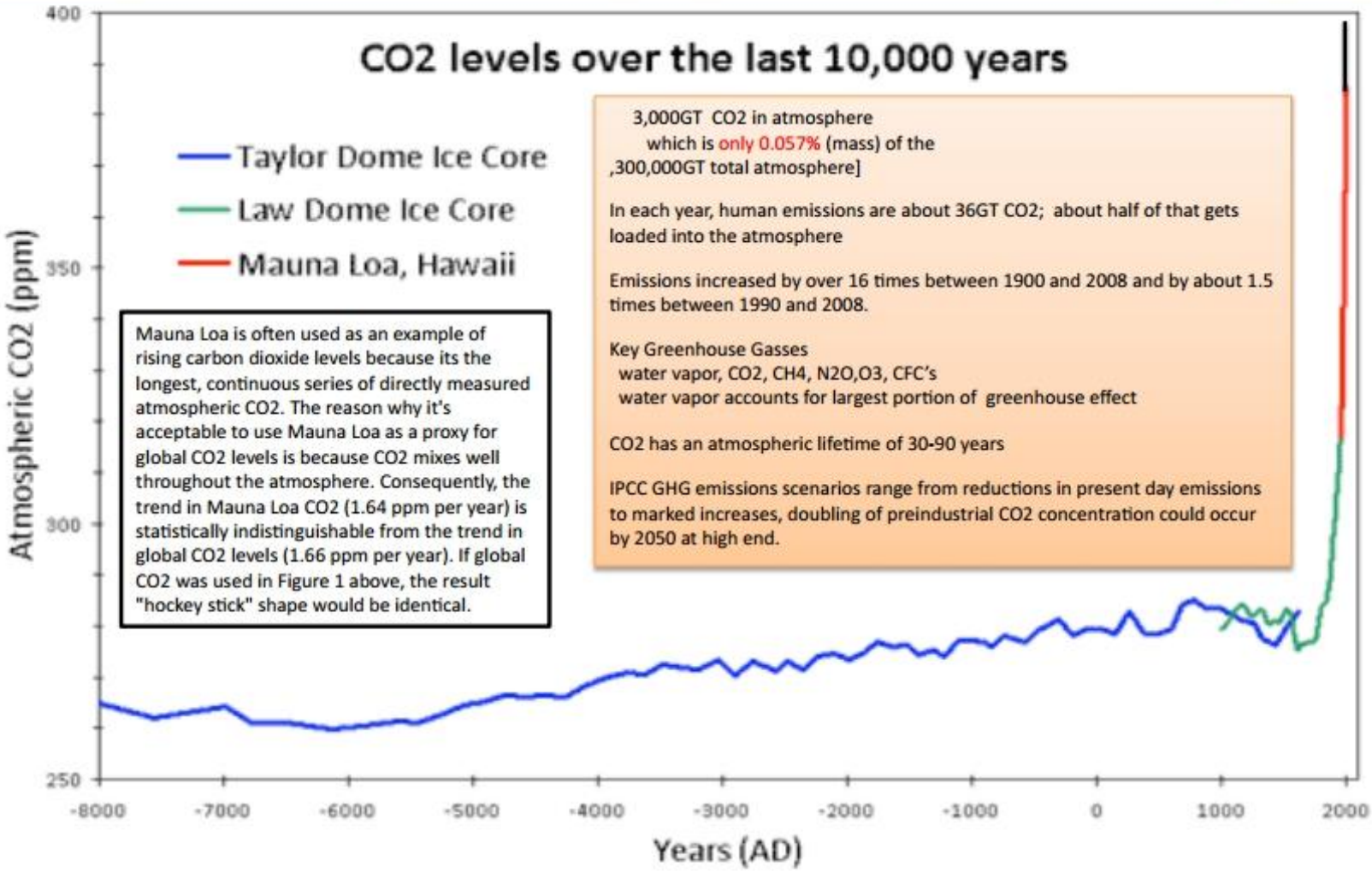


What was different about this year?

- First time there was a zero allocation from the State Water Project (last minute 5% to ag)
- First time the Upper Colorado River had its allocation cut
- The turbines in the Hoover Dam at Lake Mead were replaced to operate at lower water levels – even though they will produce less electricity

CLIMATE CHANGE

Atmospheric Greenhouse Gas (GHG) concentrations are rising rapidly



3,000GT CO2 in atmosphere
which is only 0.057% (mass) of the
,300,000GT total atmosphere]

In each year, human emissions are about 36GT CO2; about half of that gets loaded into the atmosphere

Emissions increased by over 16 times between 1900 and 2008 and by about 1.5 times between 1990 and 2008.

Key Greenhouse Gasses
water vapor, CO2, CH4, N2O,O3, CFC's
water vapor accounts for largest portion of greenhouse effect

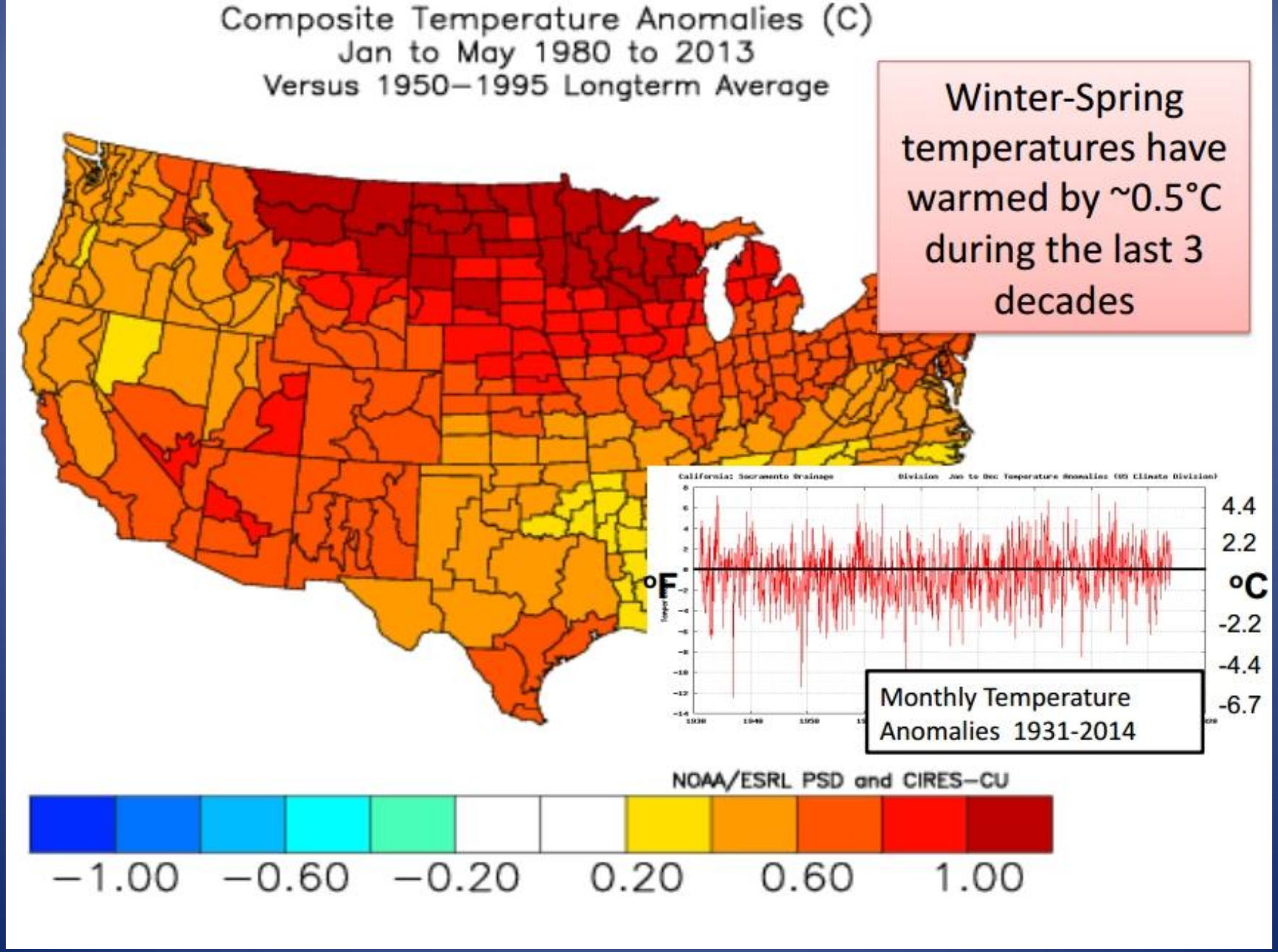
CO2 has an atmospheric lifetime of 30-90 years

IPCC GHG emissions scenarios range from reductions in present day emissions to marked increases, doubling of preindustrial CO2 concentration could occur by 2050 at high end.

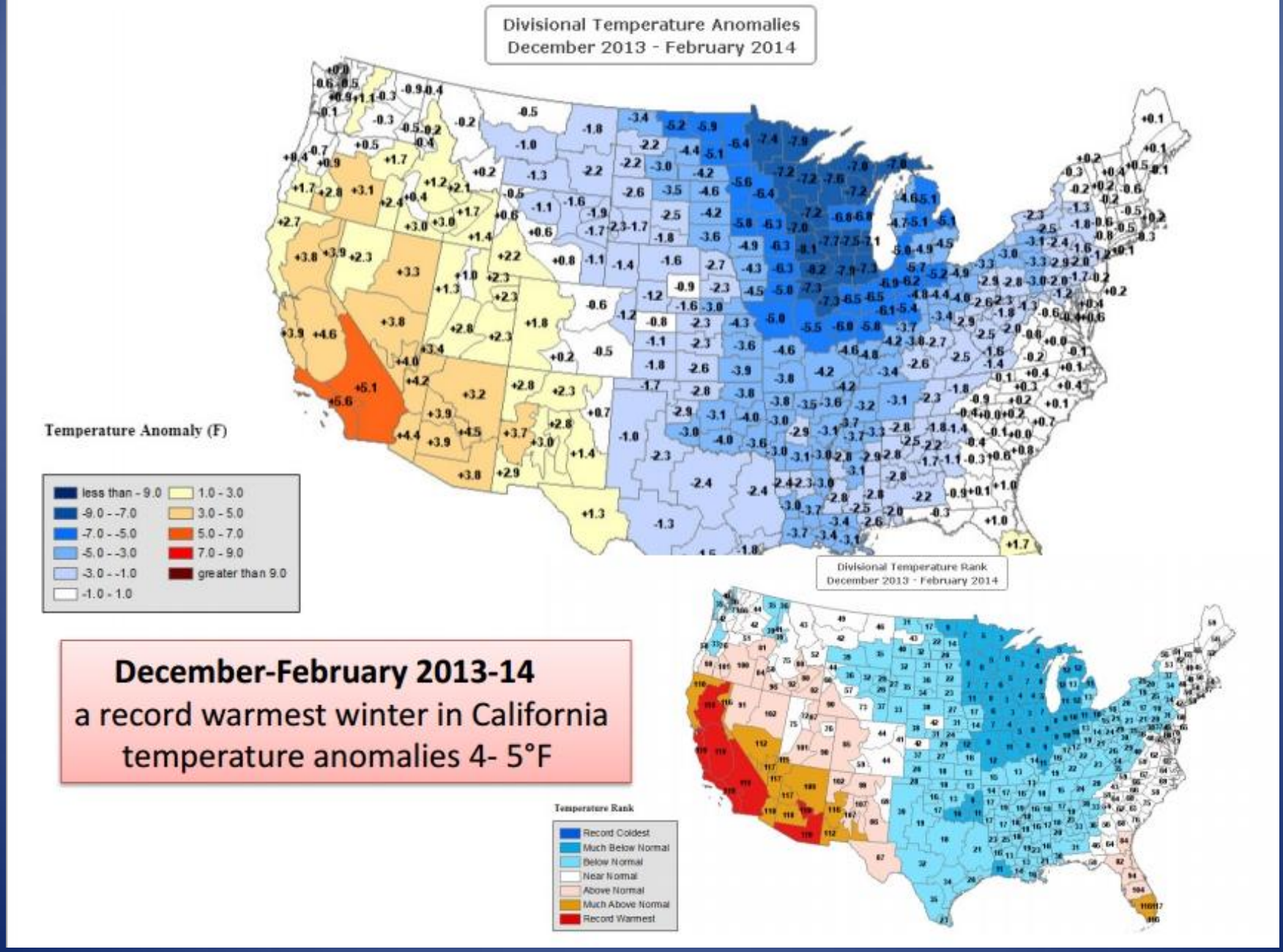
Mauna Loa is often used as an example of rising carbon dioxide levels because its the longest, continuous series of directly measured atmospheric CO2. The reason why it's acceptable to use Mauna Loa as a proxy for global CO2 levels is because CO2 mixes well throughout the atmosphere. Consequently, the trend in Mauna Loa CO2 (1.64 ppm per year) is statistically indistinguishable from the trend in global CO2 levels (1.66 ppm per year). If global CO2 was used in Figure 1 above, the result "hockey stick" shape would be identical.

CO2 levels (parts per million) over the past 10,000 years. Blue line from Taylor Dome ice cores (NOAA) Green line from Law Dome ice core (CDIAC). Red line from direct measurements at Mauna Loa, Hawaii (NOAA).

Credit: Dan Cayan, Scripps Institution of Oceanography



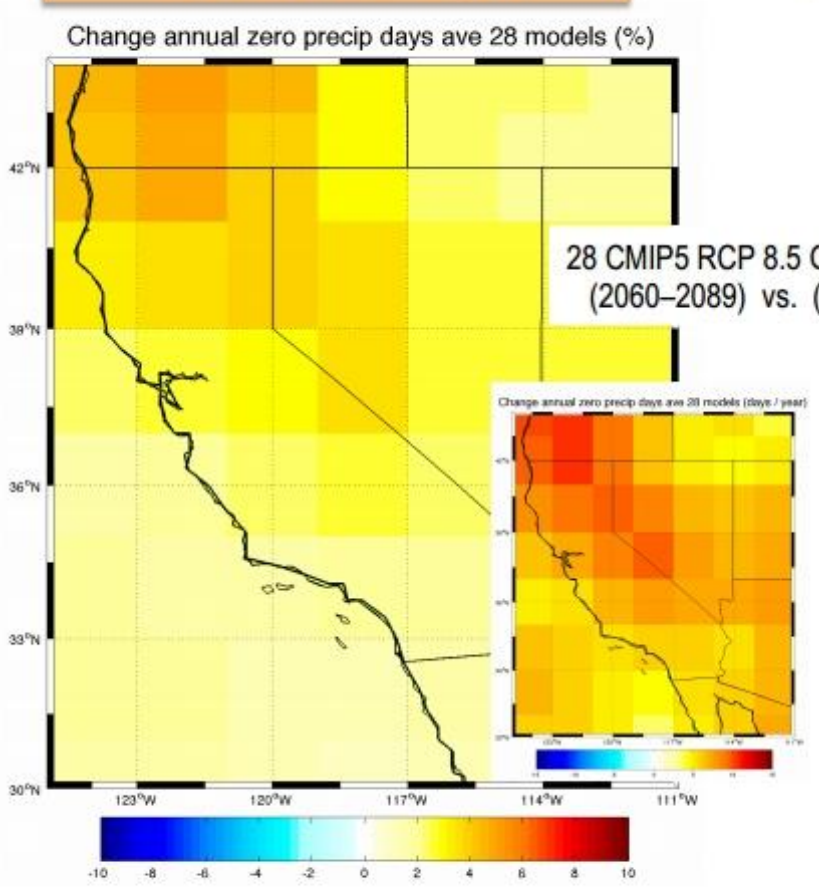
Credit: Dan Cayan, Scripps Institution of Oceanography



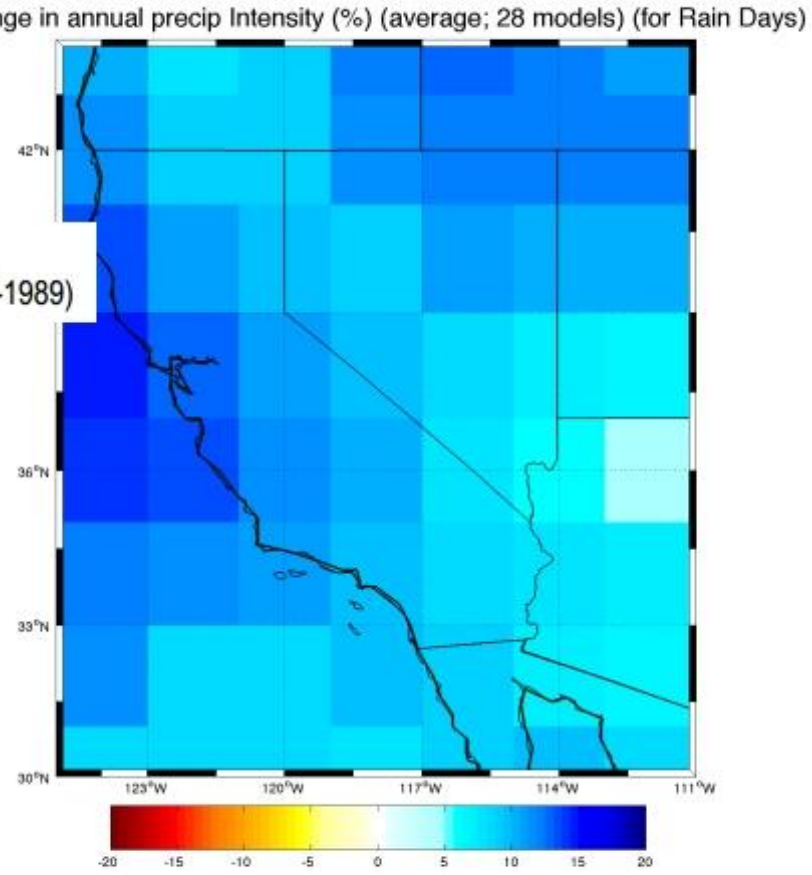
Credit: Dan Cayan, Scripps Institution of Oceanography

Although the *number* of wet days is projected to *decrease* with climate change,

the *intensity* of the largest wet days is projected to *increase* !



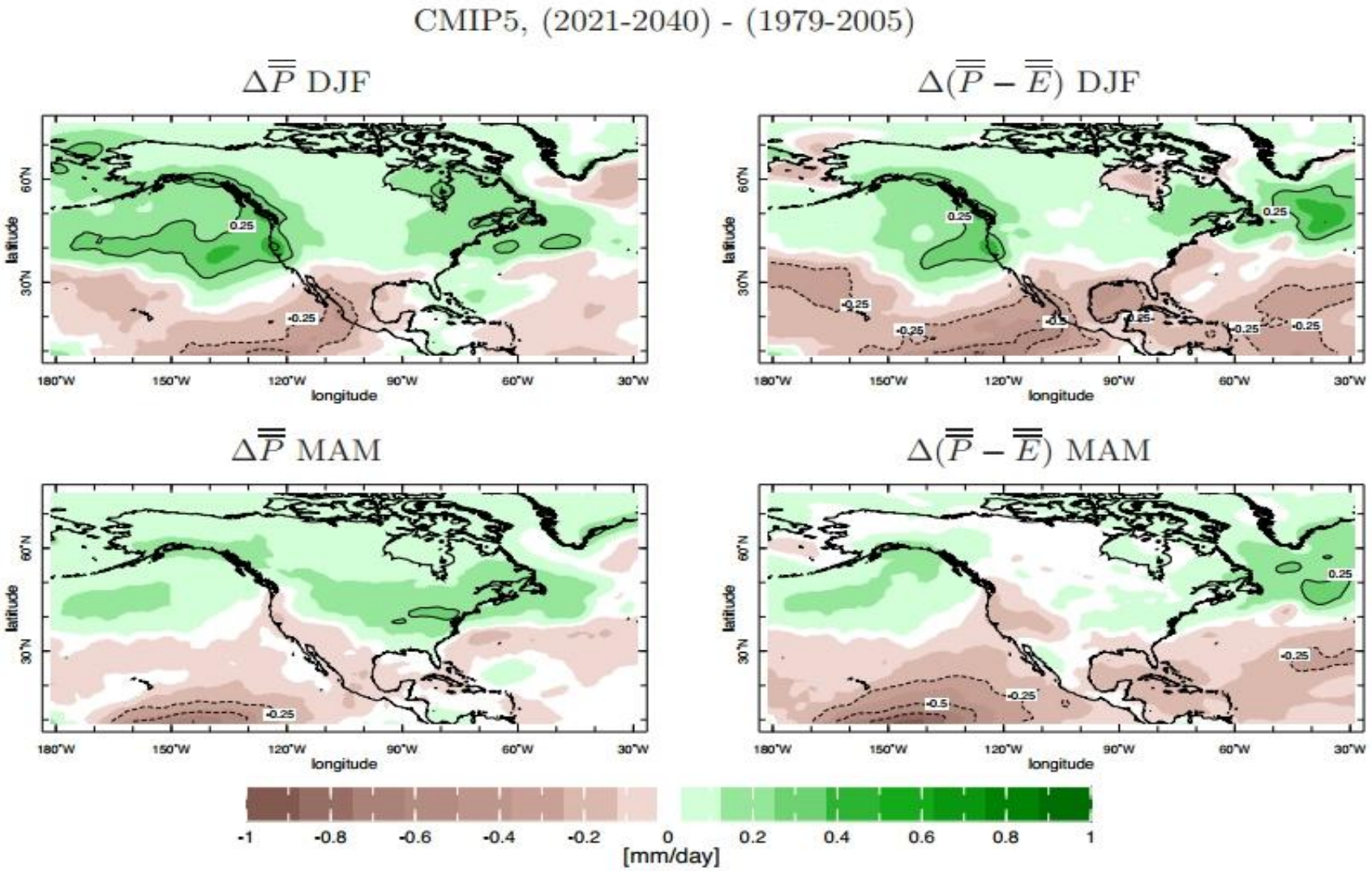
28 CMIP5 RCP 8.5 GCMs
(2060–2089) vs. (1960-1989)



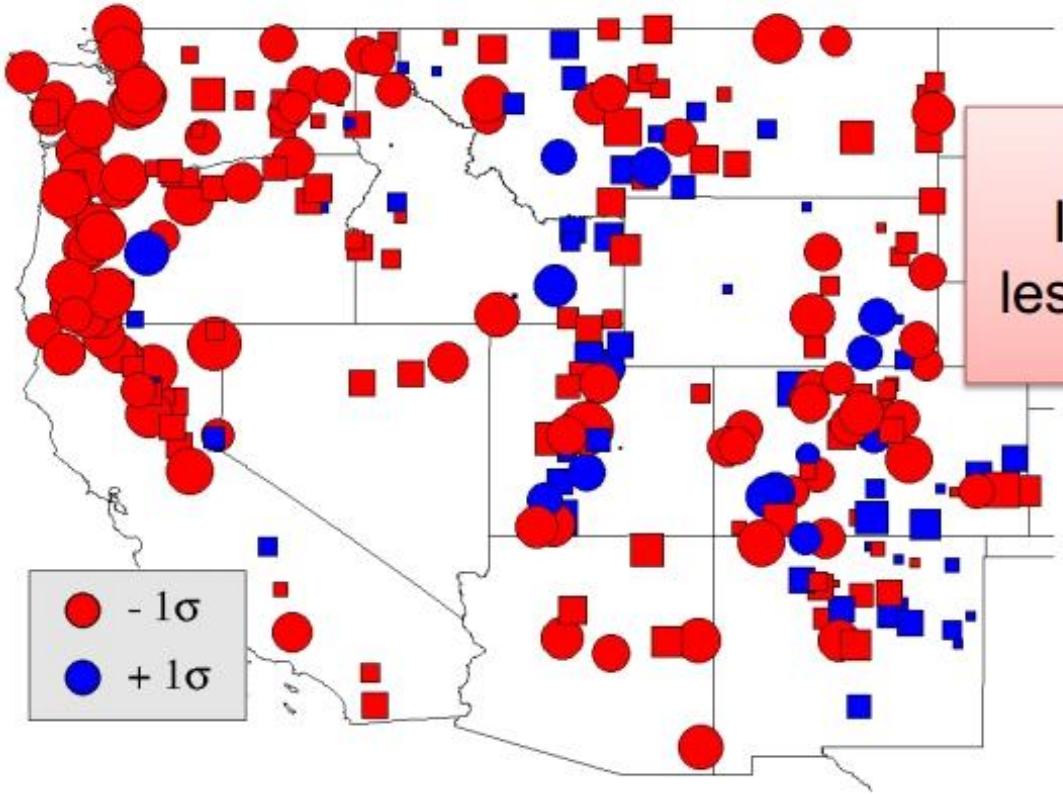
Suraj Polade Polade, S.D., Pierce, D.W., Cayan, D.R., Gershunov, A., and Dettinger, M.D., 2014, The key role of dry days in changing regional climate and precipitation regimes: Nature Scientific Reports, 4:4364, 8 p., doi:10.1038/srep04364.

Credit: Dan Cayan, Scripps Institution of Oceanography

Climate models project for California wetter winters/ drier springs due to rising greenhouse gases



Credit: Richard Seager, Lamont Doherty Earth Observatory, and Brad Lyon, International Research Institute for Climate and Society, both at Columbia University



observed changes lean strongly toward less snow and more rain

WY 1949-2004

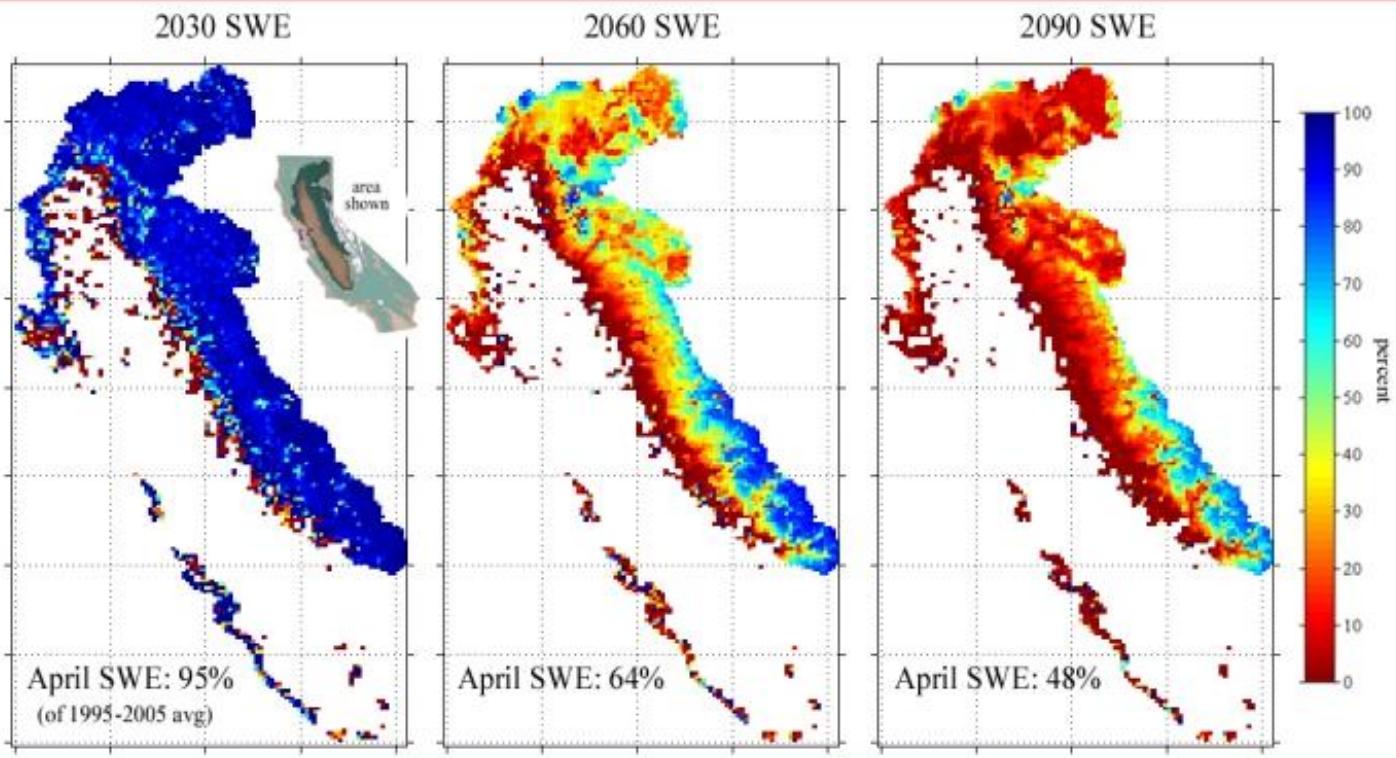
Winter (Nov-Mar) snowfall equivalent/precip trends at western US weather stations 1949-2004

symbol area is proportional to study-period changes, measured in standard deviations as indicated; circles indicate high trend significance ($p<0.05$), squares indicate lower trend significance ($p>0.05$).

Knowles, N., M.D. Dettinger and D.R. Cayan, 2006: Trends in Snowfall versus Rainfall in the Western United States. *J. Climate*, **19**(18), 4545-4559.

Credit: Dan Cayan, Scripps Institution of Oceanography

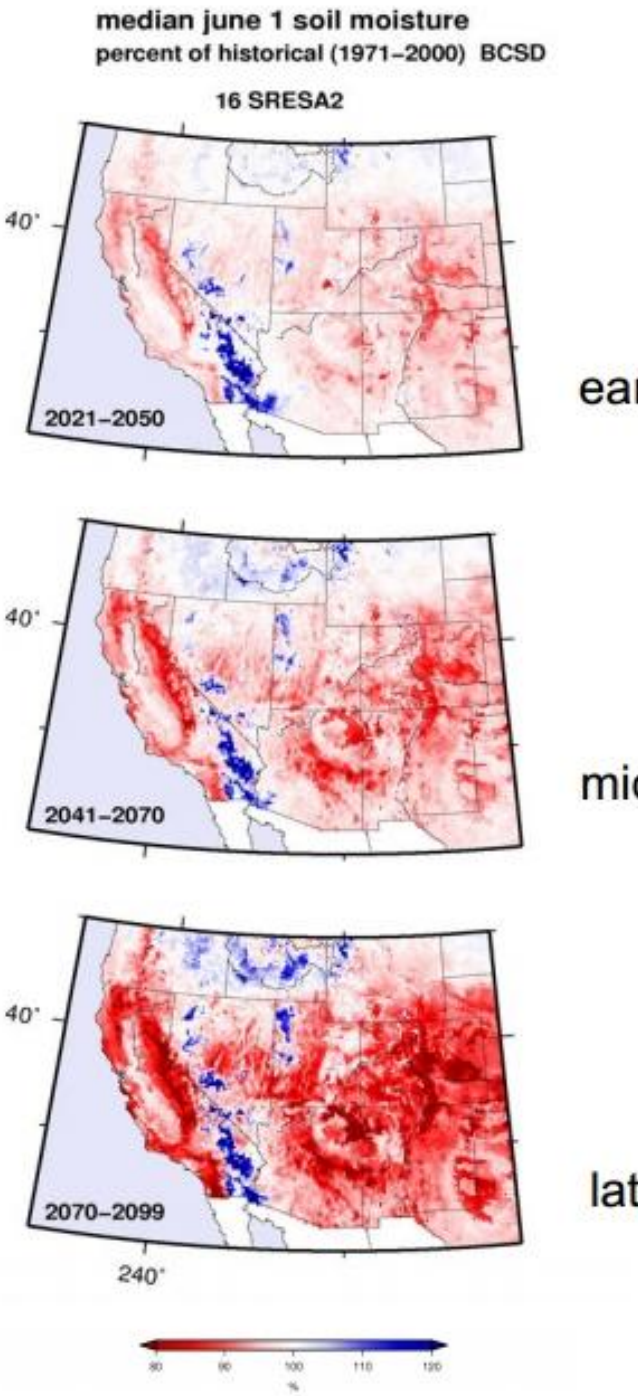
Warming drives loss of spring snowpack



•Under this scenario, California loses half of its spring (April 1) snow pack due to climate warming. Less snow, more rain, particularly at lower elevations. The result is earlier run-off, more floods, Less stored water. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual coupled climate simulation. (this is a low-middle of the road emissions and warming scenario)

Knowles, N., and D.R. Cayan, 2002: Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. *Geophysical Research Letters*, **29**(18), 1891.

Credit: Dan Cayan, Scripps Institution of Oceanography



early 21st

middle 21st

late 21st

Drier Summer Landscapes

increased warming and diminished snow causes successively greater soil drying throughout 21st Century

(*this picture could change somewhat under more recent CMIP5 simulations*)

Credit: Dan Cayan, Scripps Institution of Oceanography

Cayan et al. Ch 6 Southwest Climate Assessment

Impact: FIRE

Vegetation health



17 January – 01 February 2014
Compared to recent 10-year average



Credit: Timothy Brown , Desert Research Institute, Reno, Nevada
Program for Climate, Ecosystem and Fire Applications, Western Regional Climate Center

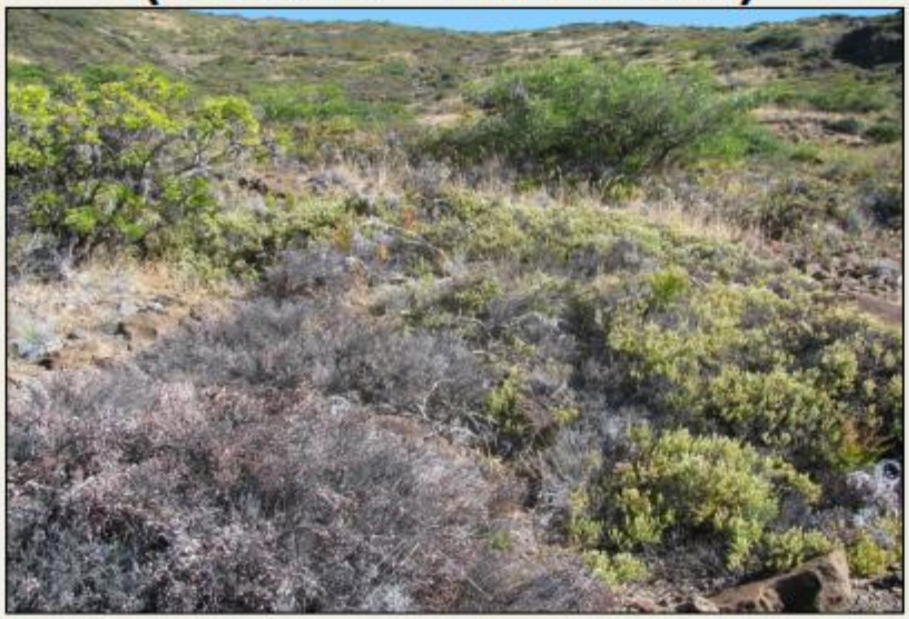
NASA MODIS

Fuel conditions





- Native brush is stressed due to long term drought conditions
- The amount of dead fuel is increasing throughout Region
- (Photos from SoCal)

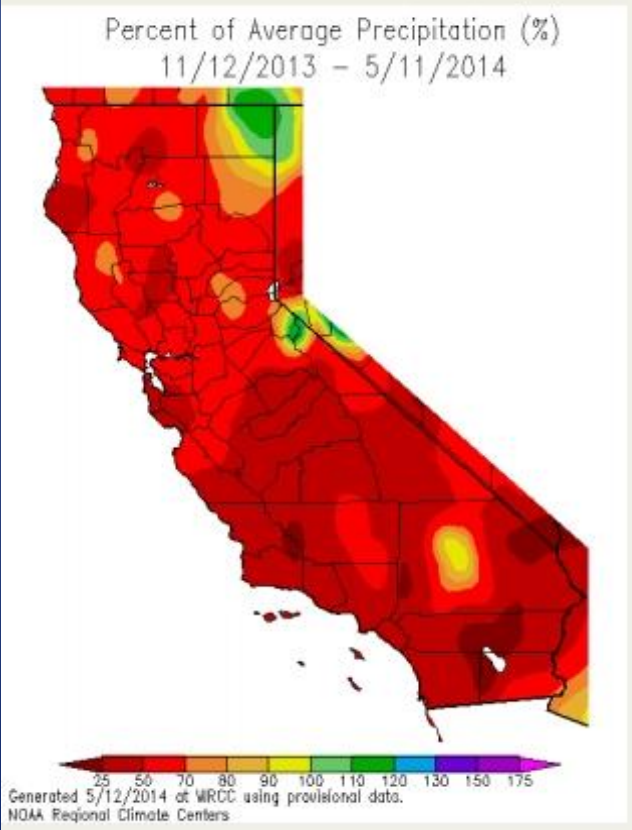


PREDICTIVE SERVICES

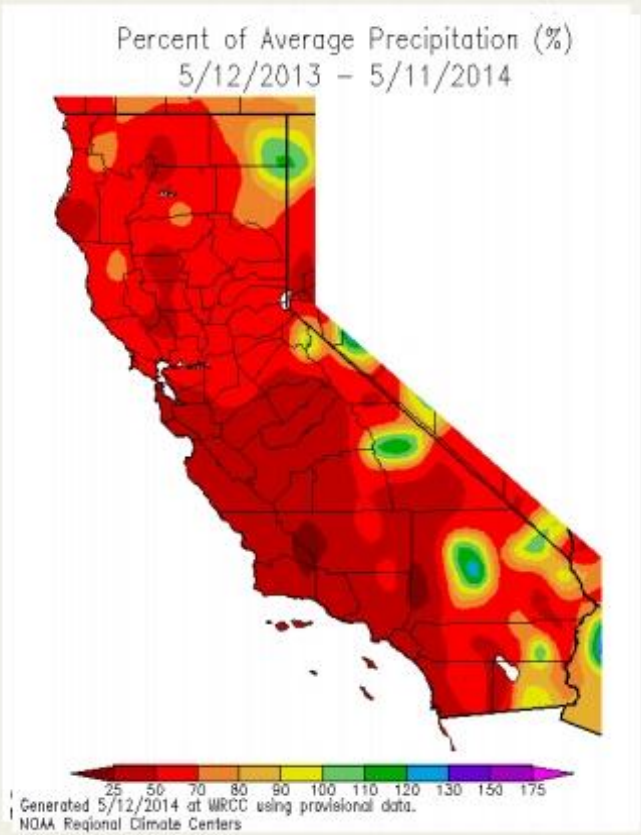
Credit: Timothy Brown , Desert Research Institute, Reno, Nevada
Program for Climate, Ecosystem and Fire Applications, Western Regional Climate Center

Precipitation (% of average)

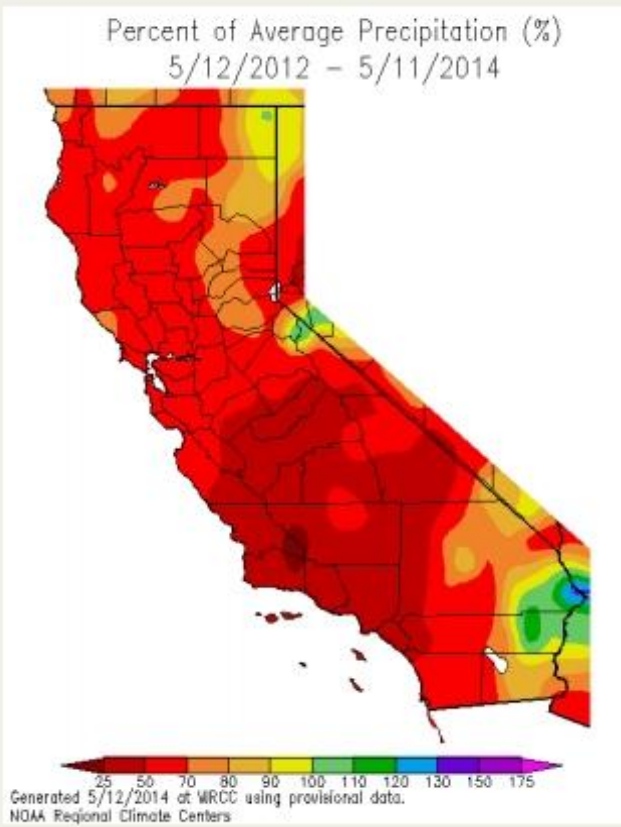
Past 6 months



Past Year



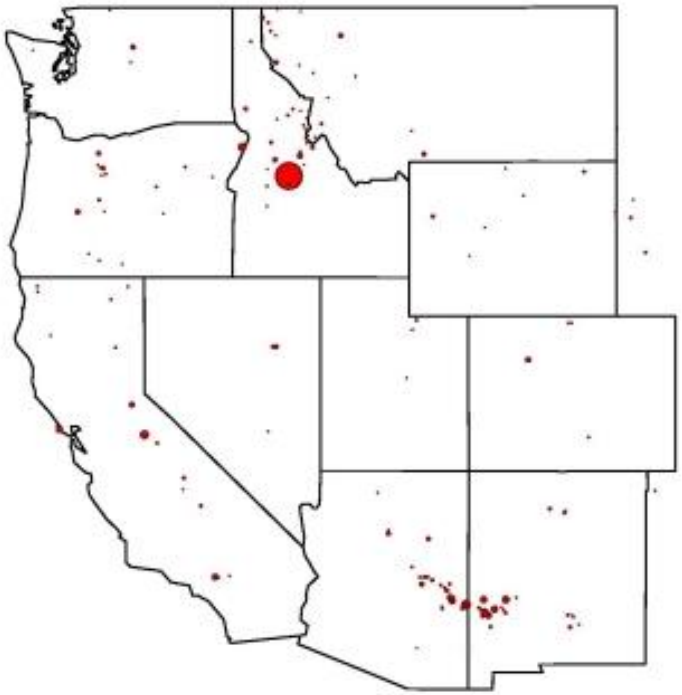
Past 2 years



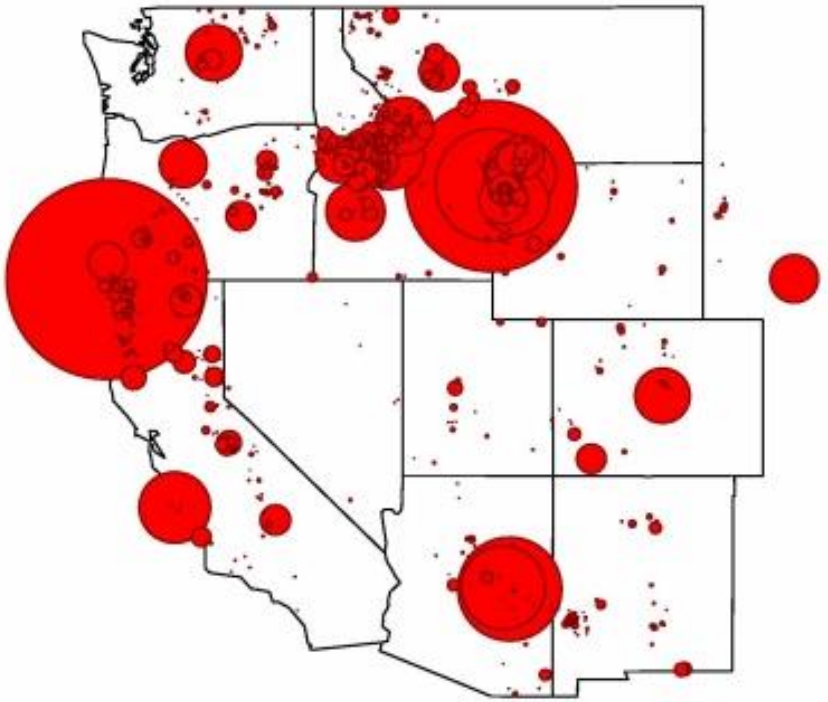
Credit: Timothy Brown , Desert Research Institute, Reno, Nevada
Program for Climate, Ecosystem and Fire Applications, Western Regional Climate Center

large summer wildfires occur more often in years with early/warm springs

Late Snowmelt Years



Early Snowmelt Years



1972 - 2003, NPS, USFS & BIA Fires over 1000 acres

Area burned is proportional to size of red dots

The warming and earlier springs during last few decades have extended and intensified the fire season in mid-elevation forests

Tony Westerling et al *Science* 2006

Credit: Dan Cayan, Scripps Institution of Oceanography



since 1985 the number of large wildfires in western U.S. increased four-fold

relative to previous 15 years, mostly forest fires, not shrubland fires

Credit: Dan Cayan, Scripps Institution of Oceanography

Anthony Westerling et al. *Science* August 2006

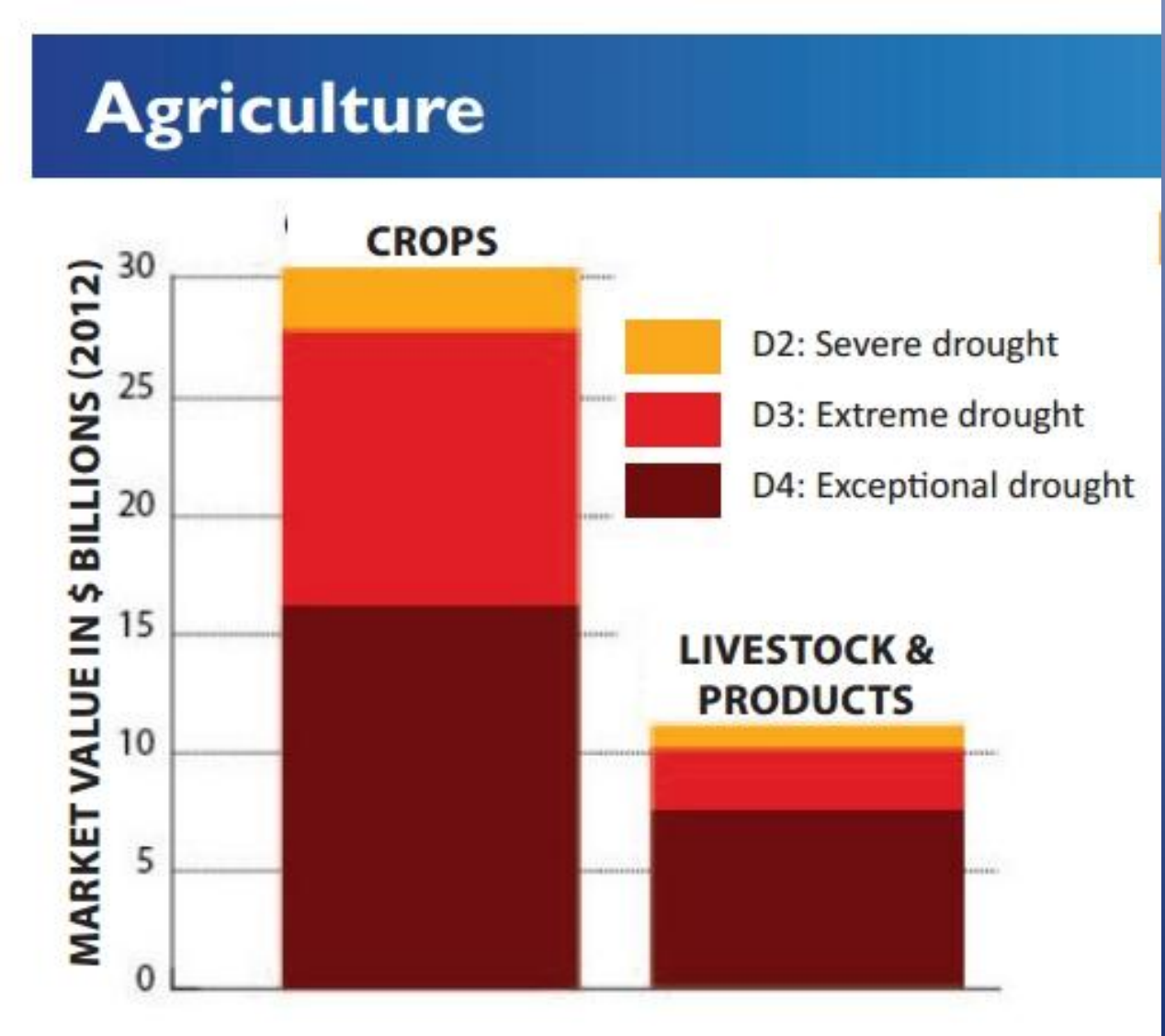
Fire danger

Fire potential expanding through August



Impact: AGRICULTURE

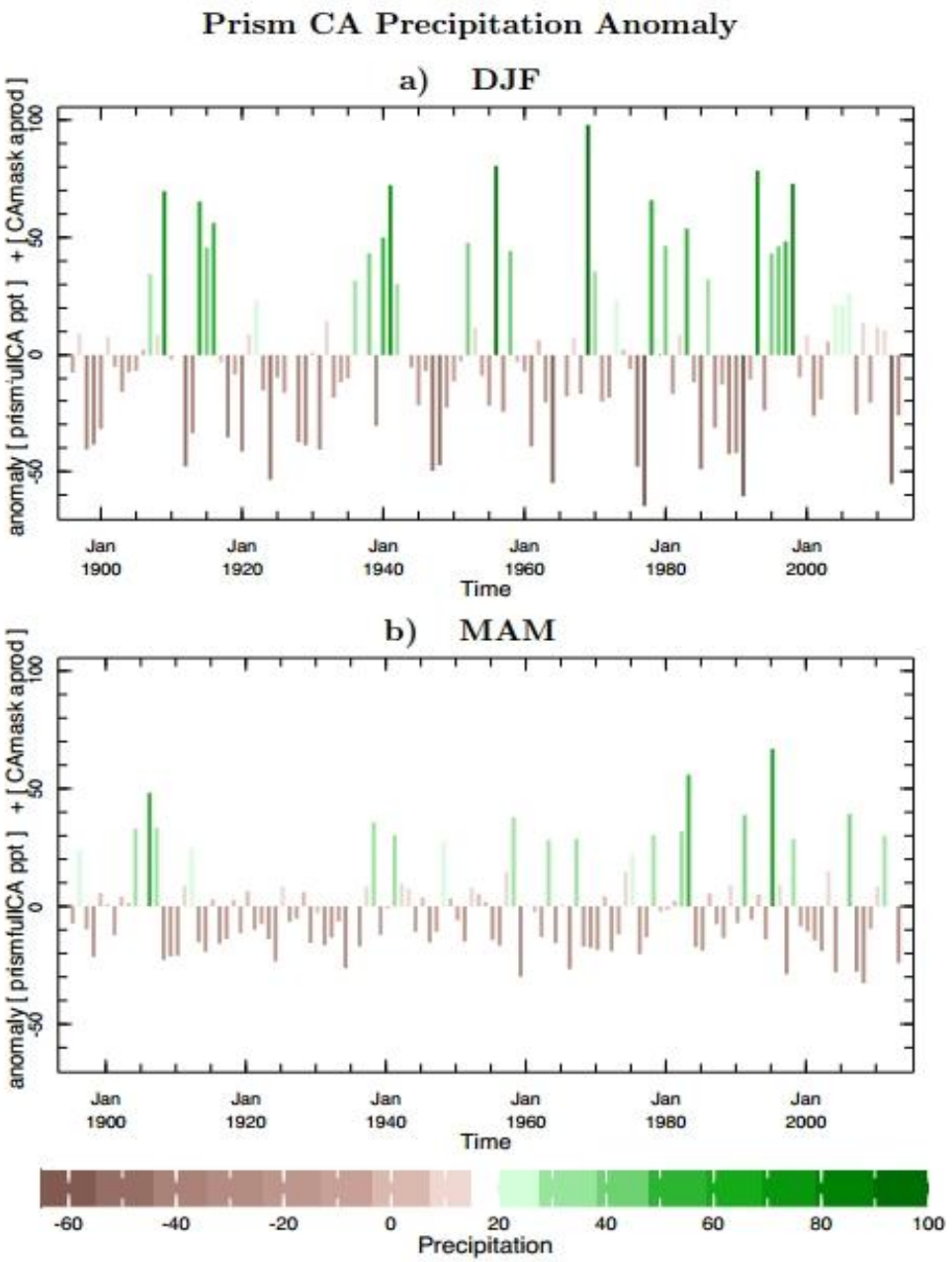
More than half of ag production is undergoing exceptional drought



California Drought Outlook, May 15, 2014

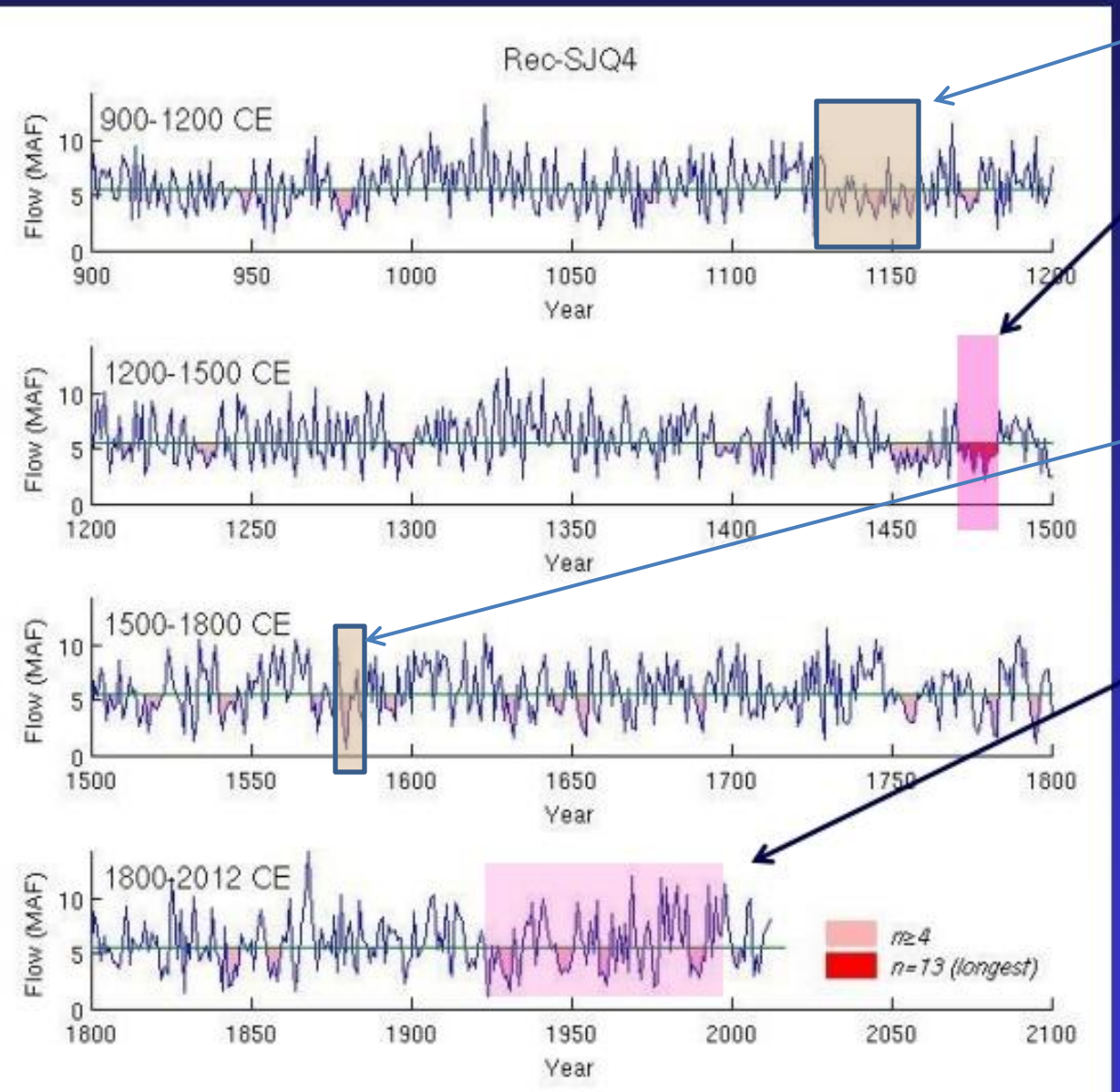
HISTORY

California has a rich history of droughts. Current drought appears as one of many such events both in terms of amplitude and duration.



Credit: Richard Seager, Lamont Doherty Earth Observatory, and Brad Lyon, International Research Institute for Climate and Society, both at Columbia University

Annual Runoff, San Joaquin River



Mid-1100s: unusual for rarity of wet years

Persistent drought in mid-1400s, with 13-year run below median

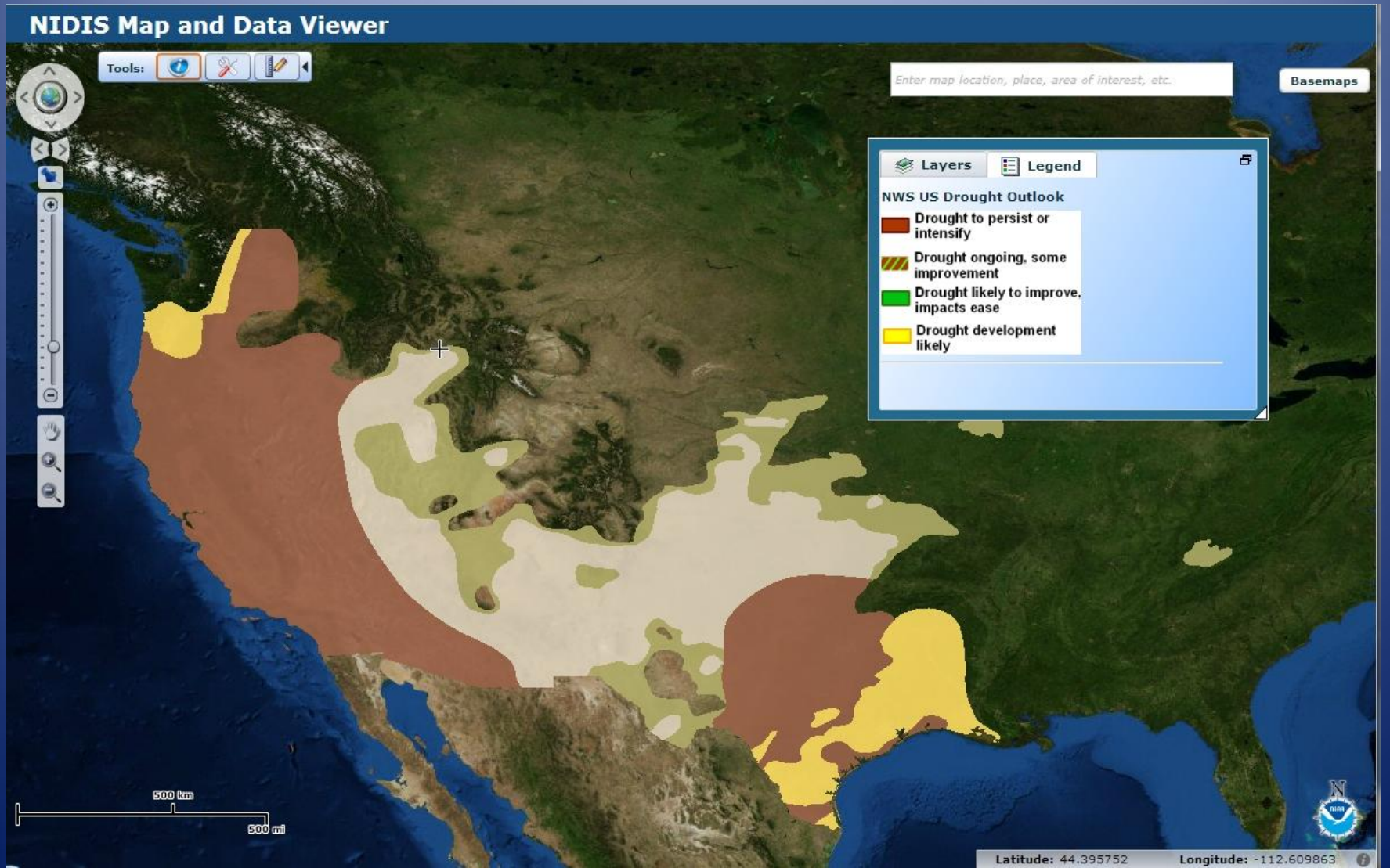
1580: driest single year, with estimated flow only about ½ the observed flow recorded in 1977

Droughts longer than 4 years well represented in 20th century

Credit: Dave Meko
Tree-Ring Lab
University of Arizona

OUTLOOK

National Weather Service Drought Outlook



Dan Cayan Summary Points

- California's climate is prone to year-to-year and longer term variation in precipitation—drought is an expected part of our climate.
- A variety of climate patterns may produce drought--there is not a unique atmospheric drought-circulation pattern.
- California's current dry spell has built up over multiple years, a more/less dry pattern has been in place since 1999.
- The absence of a few very large storms is often a key driver of dry years. And large storms are frequently involved in "busting" drought.
- Climate changes in annual precipitation is not so clear in California. However, climate change may shift precipitation characteristics—fewer overall wet days but more intense heavy events.
- The degree of recovery from the present dry spell is not certain next year, even though El Nino seems likely. Complete recovery is highly unlikely. Forecast skill is limited at seasonal and longer time scales.

Credit: Dan Cayan, Scripps Institution of Oceanography

California Drought - a Big Picture Perspective with NIDIS Insights

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