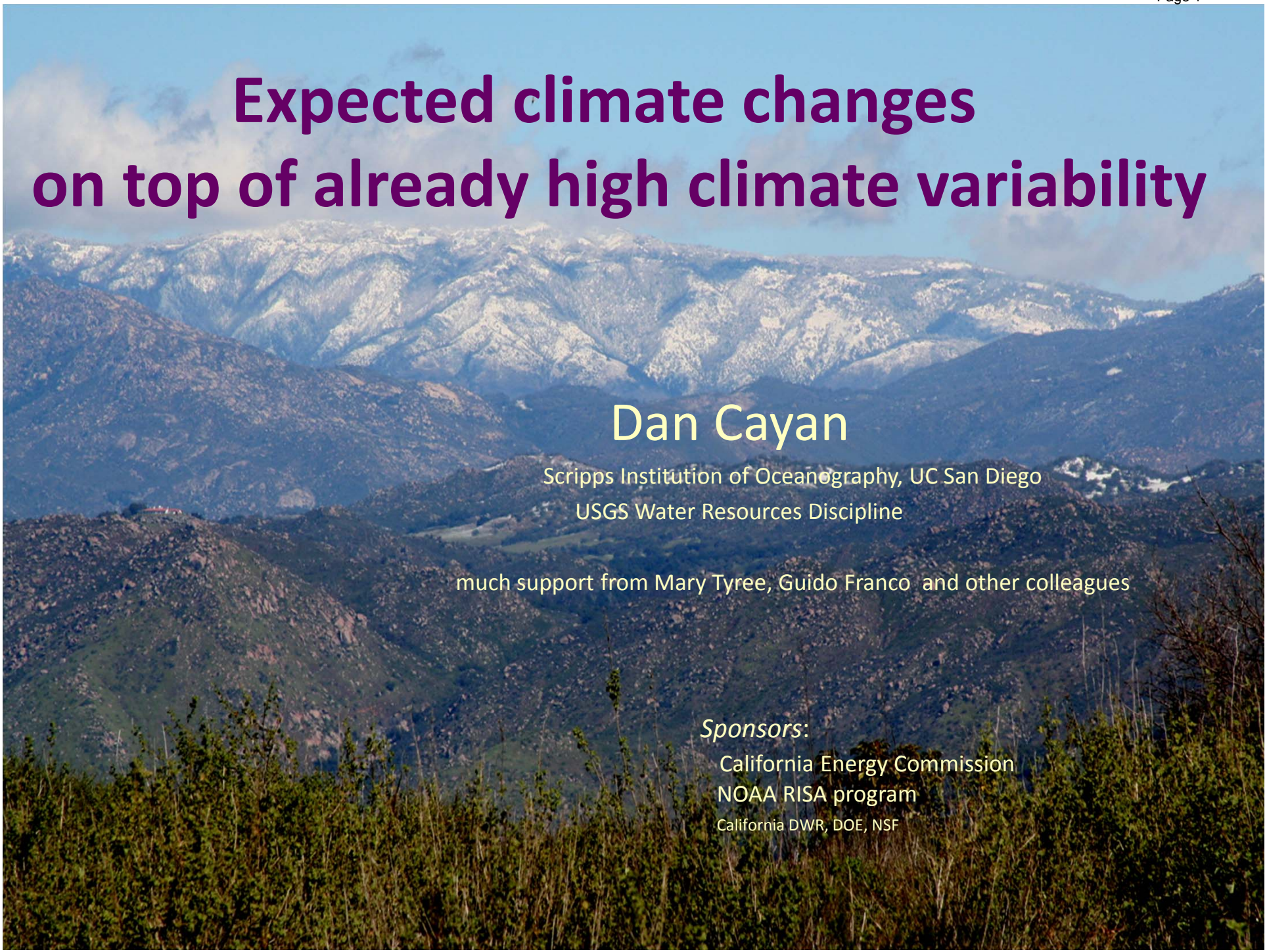


Expected climate changes on top of already high climate variability

Dan Cayan

Scripps Institution of Oceanography, UC San Diego

USGS Water Resources Discipline

much support from Mary Tyree, Guido Franco and other colleagues

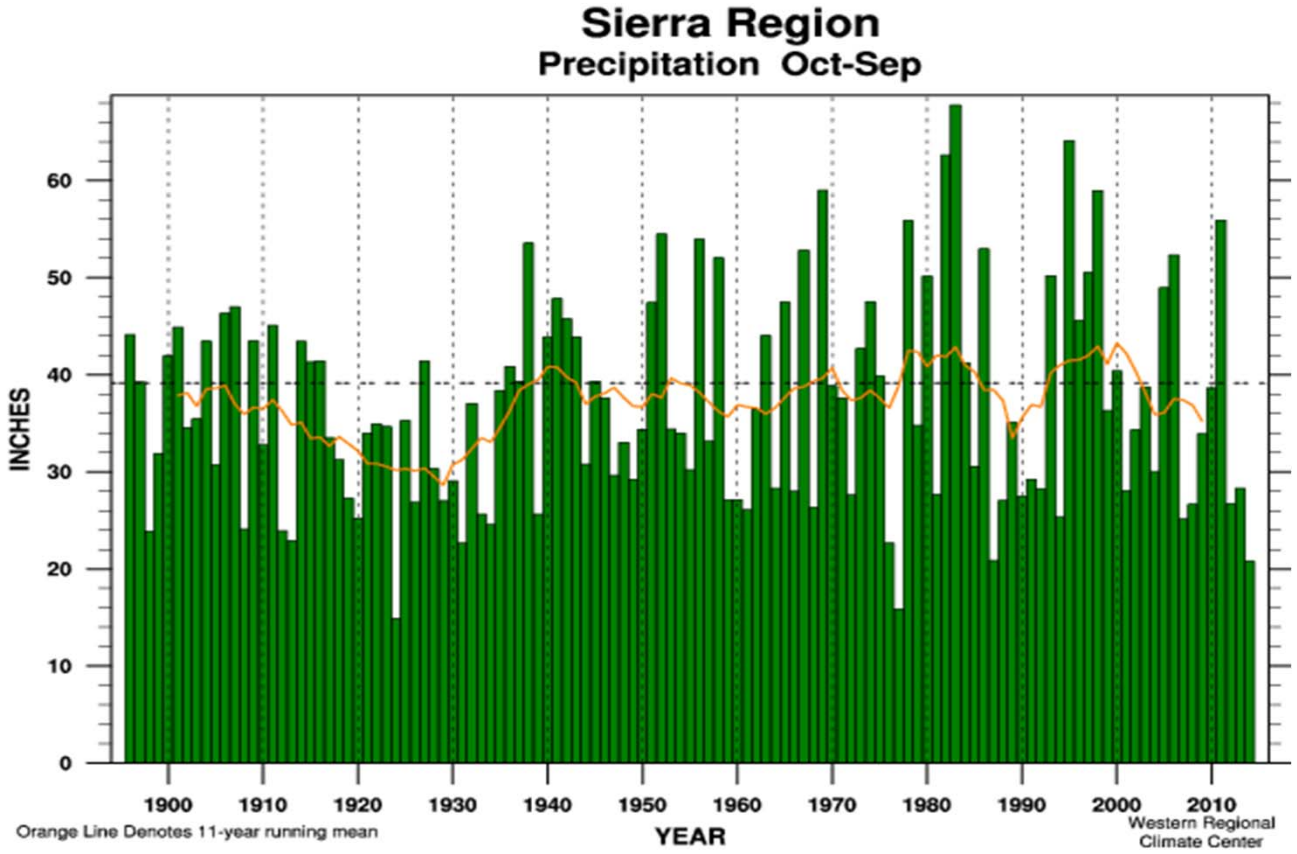
Sponsors:

California Energy Commission

NOAA RISA program

California DWR, DOE, NSF

2012-2014 dry spell is characteristic of California's volatile precipitation climate



Linear Trend 1895-present	+ 3.31 ± 5.69 in.	(+ 8 ± 14%) per 100 yr	
Linear Trend 1949-present	- 3.86 ± 16.40 in.	(- 9 ± 41%) per 100 yr	
Linear Trend 1975-present	-11.70 ± 39.69 in.	(- 29 ± 101%) per 100 yr	
Wettest Year	67.79 in. (173%)	in 1983	MEAN 39.15 in.
Driest Year	14.89 in. (38%)	in 1924	STDEV 12.33 in.
Oct-Sep 2014	20.75 in. (53%)		RANK 3 of 119

Sierra Nevada Precipitation water years 1896-2014

coef of Variation 31%
mean 39 inches
std dev 12 inches

California has a narrow seasonal window to generate its annual water supply.

If atmospheric conditions are unfavorable during that period, a dry year results

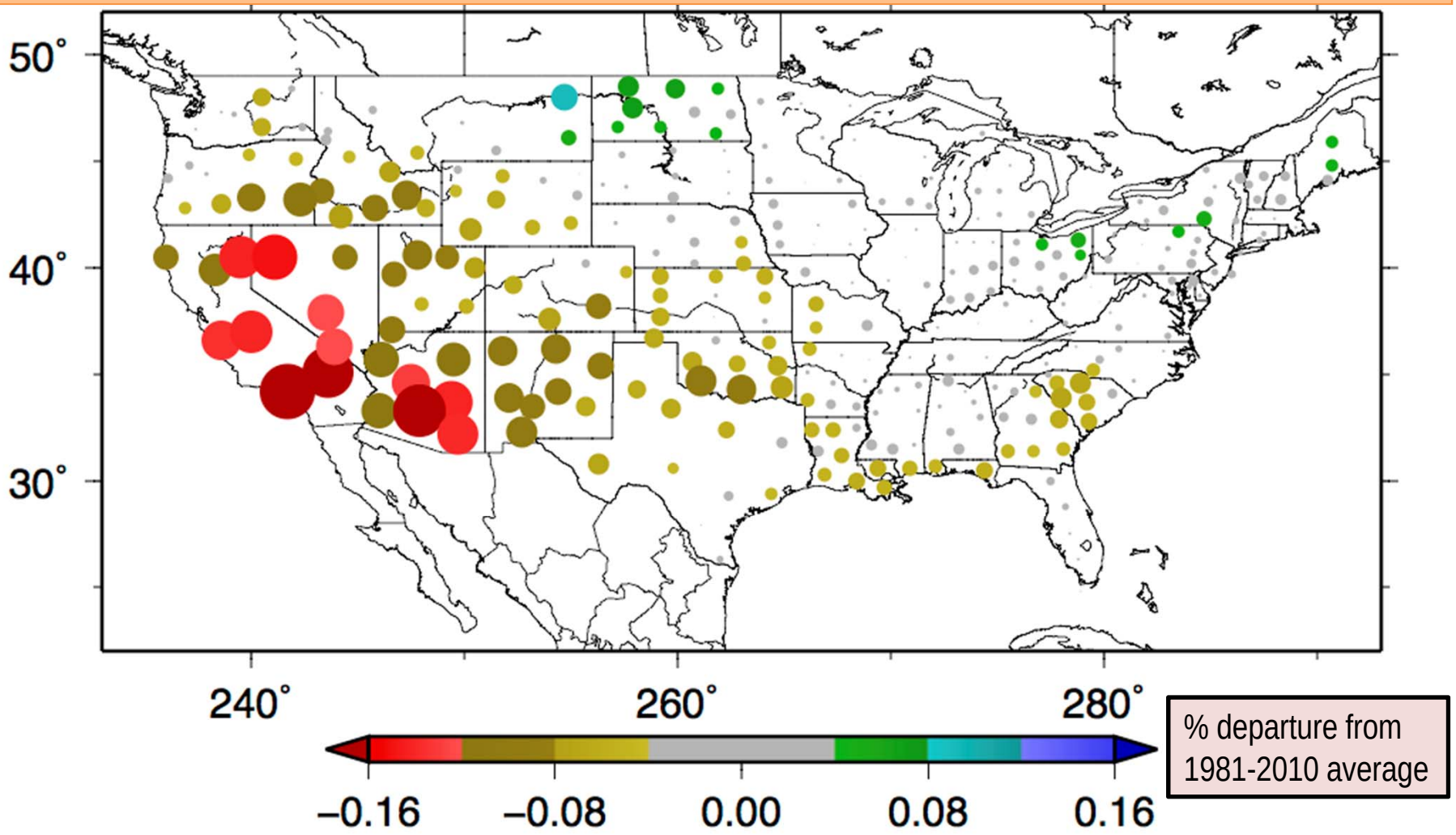
2014 ~55% of long term average

California Climate Tracker
Western Regional Climate Center

2013-2014 DROUGHT—BROAD FOOTPRINT, DECADAL LEGACY

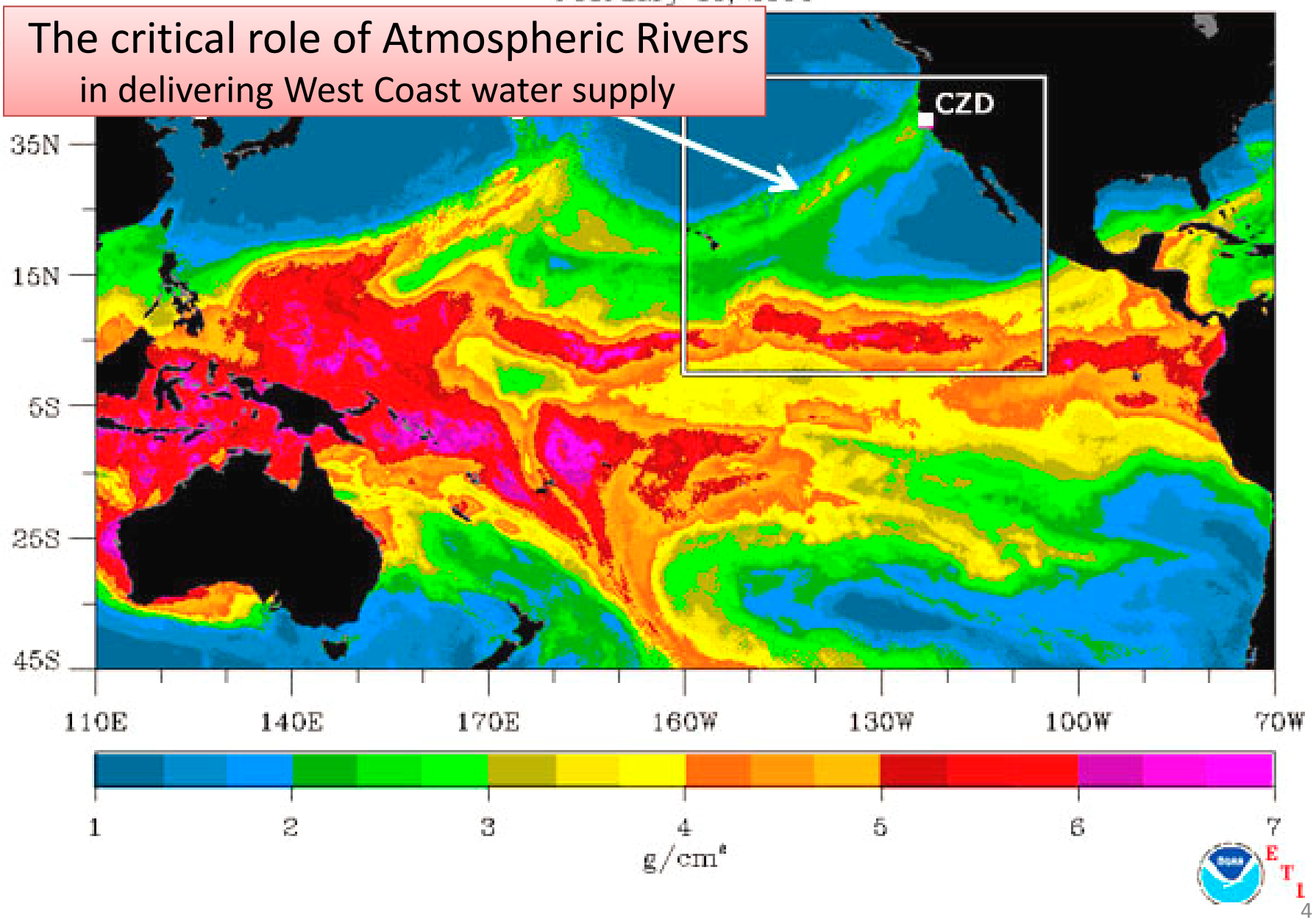
California and much of western region has been more-or-less dry since 1999

observed precipitation departure (% of average), 1998-99 thru 2013-14

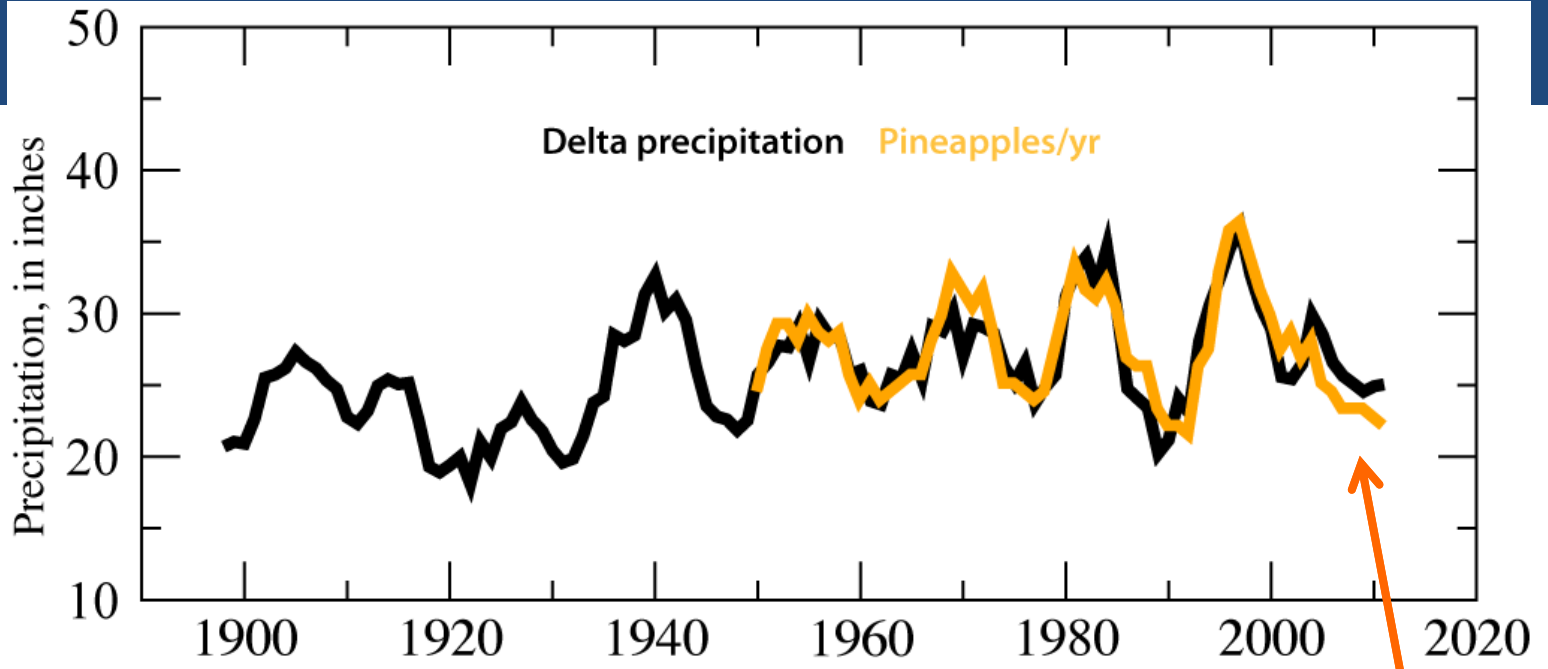


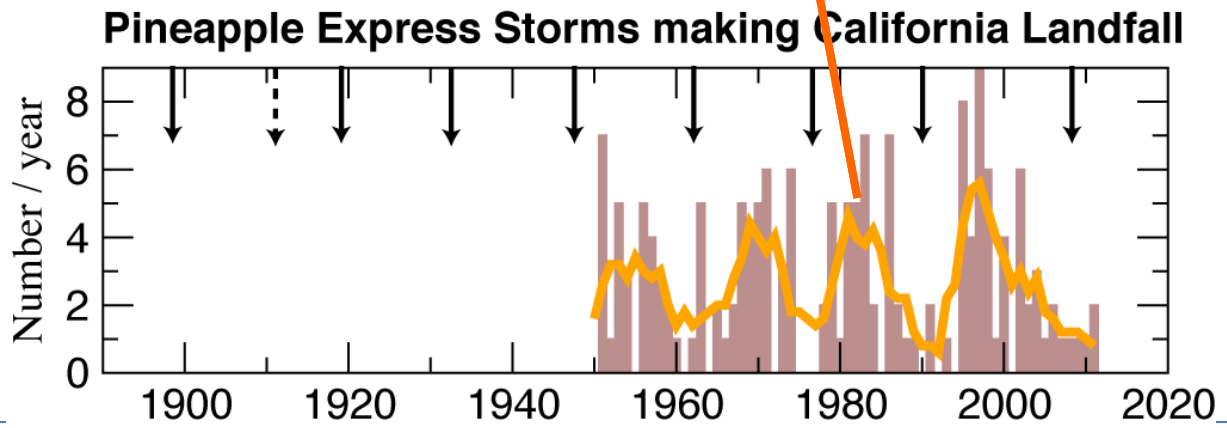
The critical role of Atmospheric Rivers

in delivering West Coast water supply



ARs as West Coast drought makers





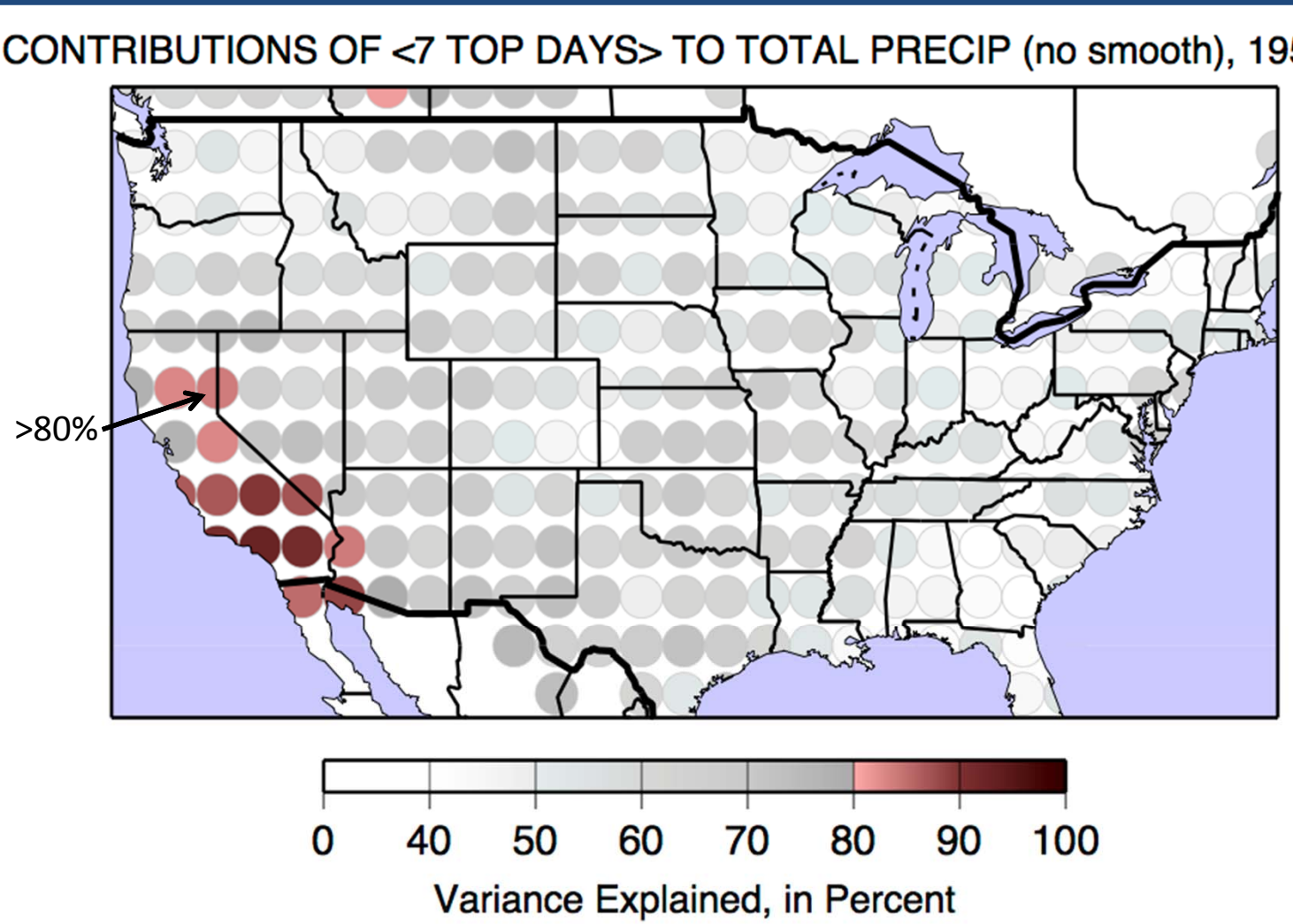
R**2 = 75% (5-yr mavg)
= 33% (unfiltered)

USGS science for a changing world

CNAP California-Nevada Climate Applications Program

Dettinger & Cayan, SFEWS, 2014

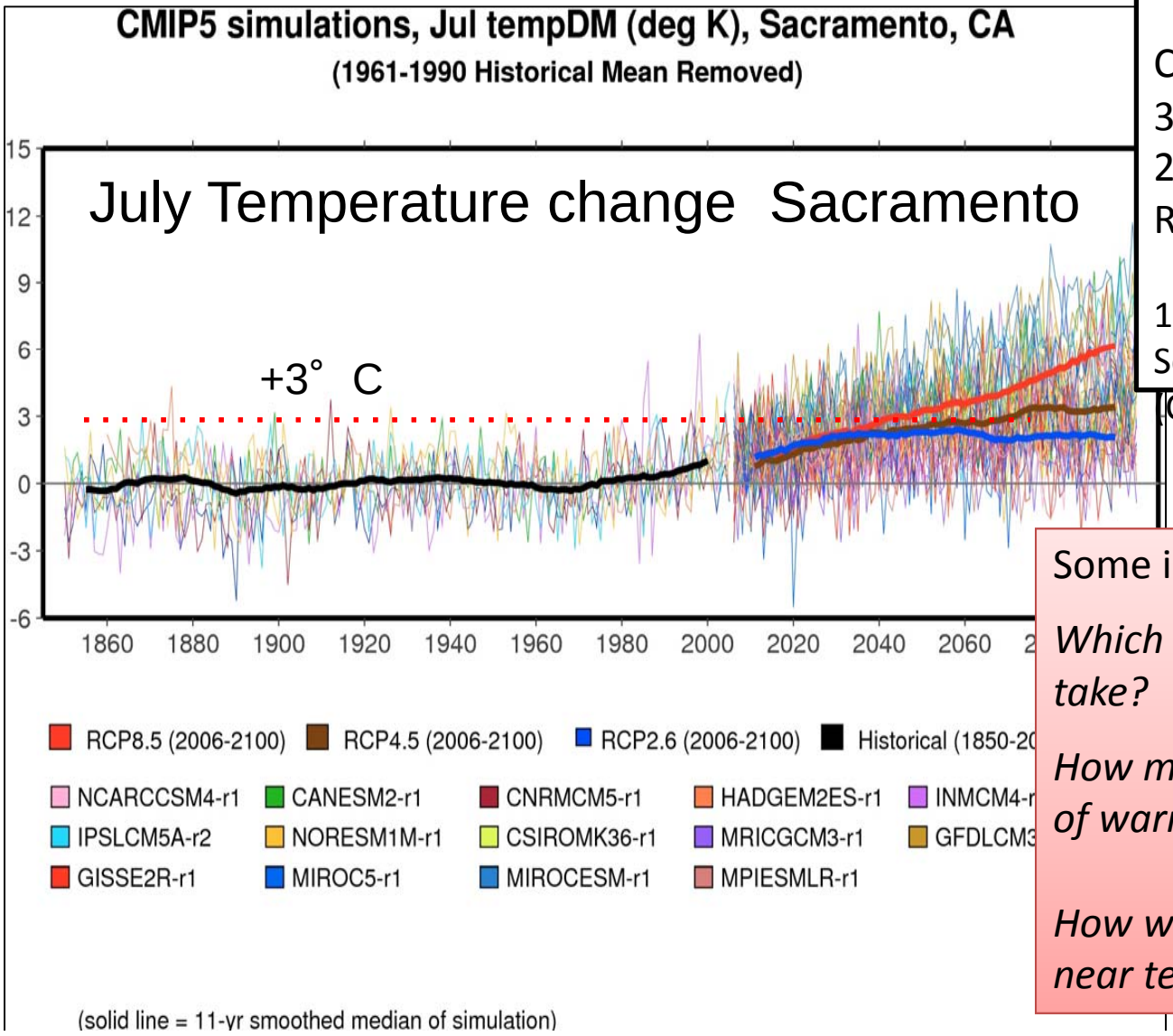
How are droughts made?



USGS science for a changing world

CNAP California-Nevada Climate Applications Program

virtually all climate simulations project warming, but with a wide envelope of temperature change



CMIP5 GCMs project +2-3.5° C summer warming by 2060, under mid and high RCPs

14 GCMs X 3 RCP Emissions Scenarios IPCC 5th Assessment (CMIP5) models

Some important questions:

Which emissions pathway will we take?

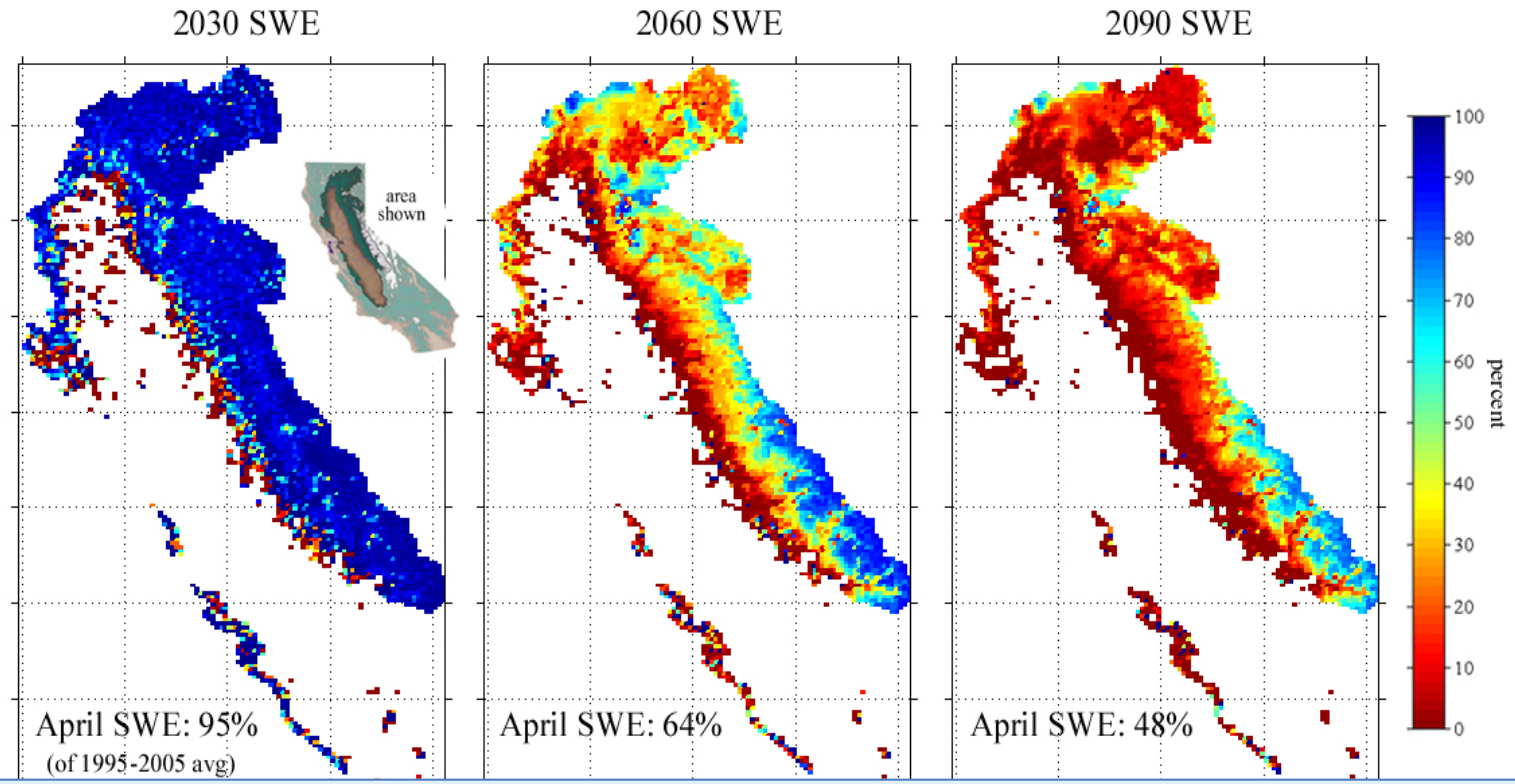
How much summer amplification of warming?

How will temperature change in near term?

regional snow and hydrology—
a sensitive index of climate variation and change

Douglas Alden
Scripps Institution
of Oceanography
Installing met station
Lee Vining, CA

Loss of California Spring Snowpack from 21st Century warming

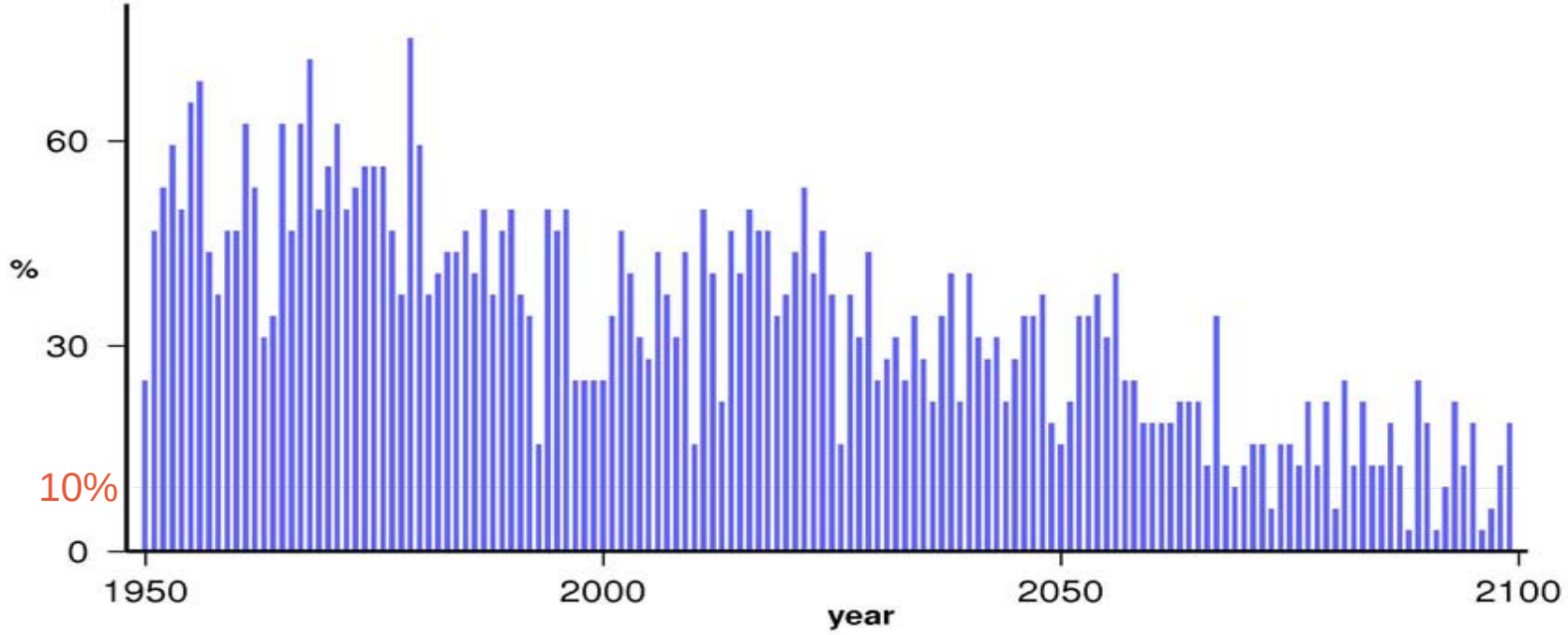


•Under this scenario, California loses half of its spring (April 1) snow pack due to climate warming. Less snow, more rain, particularly at lower elevations. The result is earlier run-off, more floods, Less stored water. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual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

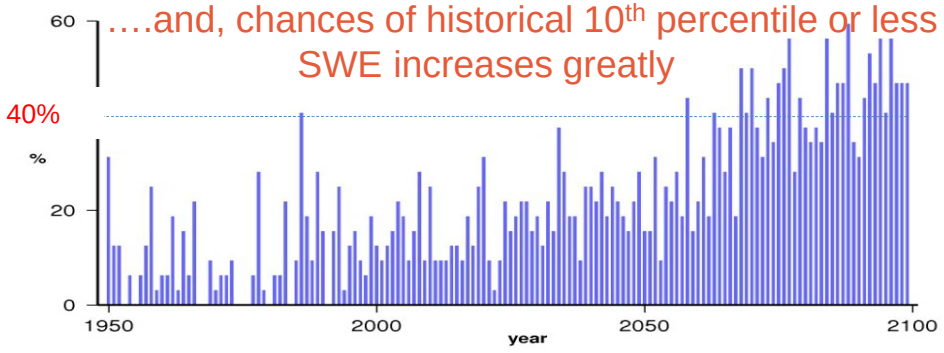
California April 1 SWE from climate simulations
Odds a year is above the average historical median (11.86cm; 1961–1990)
32 BCSD (16 SRESA2 and 16 SRESB1) Median Apr 1 SWE 11.9cm

DIMINISHING ODDS OF ACHIEVING MEDIAN SNOW PACK 21st Sierra Nevad



California April 1 SWE from climate simulations
Odds a year is below the historical 10th percentile (3.60cm; 1961–1990)
32 BCSD (16 SRESA2 and 16 SRESB1) 10th % Apr 1 SWE 3.6cm

….and, chances of historical 10th percentile or less SWE increases greatly



Summary

- California's climate is prone to year-to-year and longer term variation in precipitation—drought is an expected part of our climate—present and future.

- 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.

- The 2013-14 drought is most likely a symptom of natural variation. This drought has buiilt up over multiple years,. A more/less dry pattern has been in place since 1999. A variety of climate patterns may produce drought--there is not a unique atmospheric drought-circulation pattern.

- Over the 21st Centurey, climate change will progressively and broadly affect California hydroclimate and impact sectors and systems across-the-board. Climate changes in annual precipitation is not clear. But expected impacts of climate warming: longer "warm" season, , fewer overall wet days but more intense heavy events,
  loss of spring snow pack, increased wildfire threat, more winter floods.

  Implications:

  - **Less snow, more rain**
  - **Earlier run-off from traditionally snow-fed mountain watersheds**
  - **Higher floods**
  - **Potentially, less stored water**