# Climate Variability and Change and California Water

Lahontan Water Board   Barstow, CA   November 13, 2014

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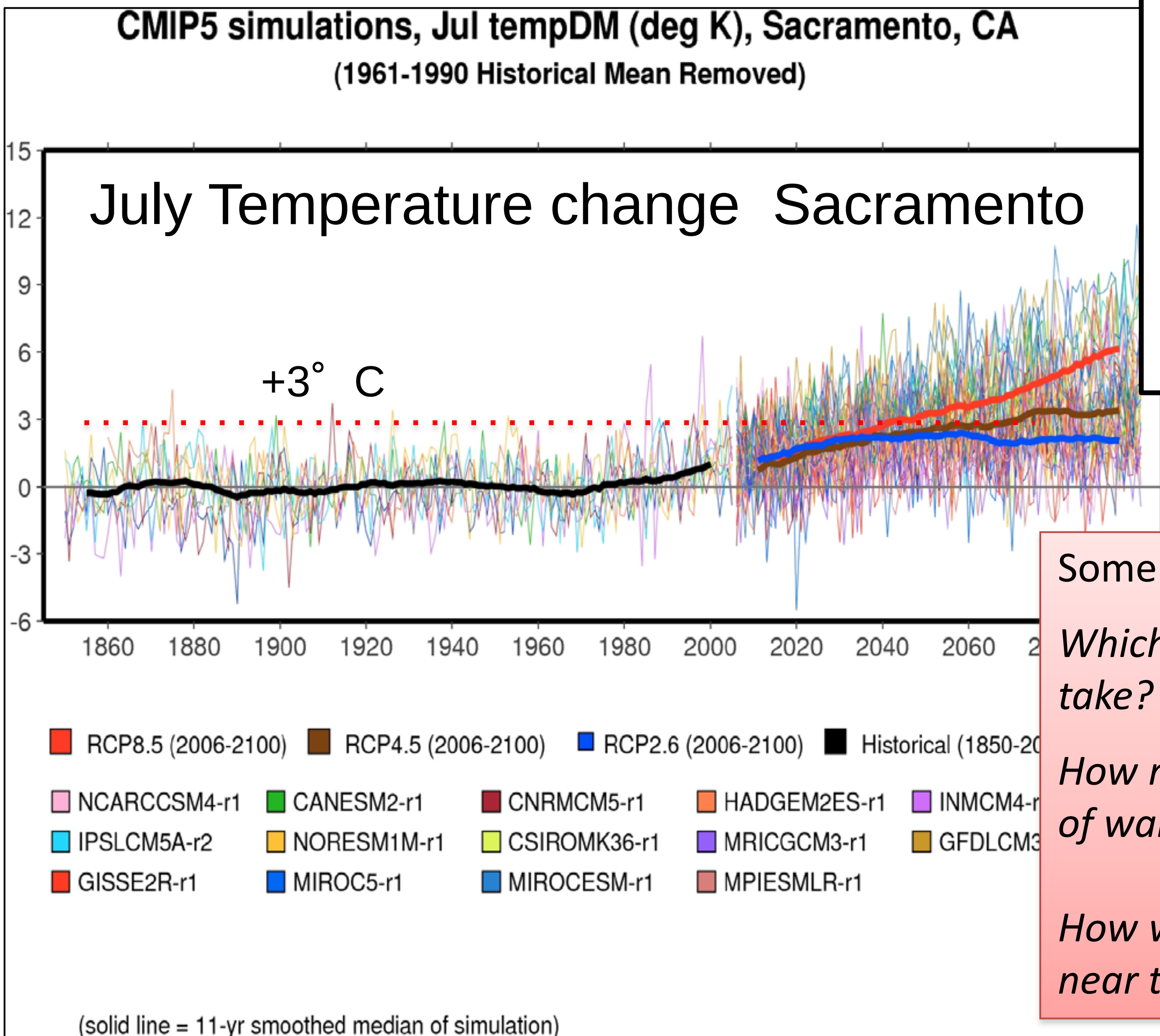
(with Mike Dettinger, David Pierce,  Suraj Polade, Mary Tyree, Alexander Gershunov)

## *key points*

- Broad impacts of climate change will increase in future decades
- Average precipitation may not change much, but volatile precipitation climate in present and future produces periodic dry (and wet) spells.
- Importance of the presence or absence of few very large storms

# 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:

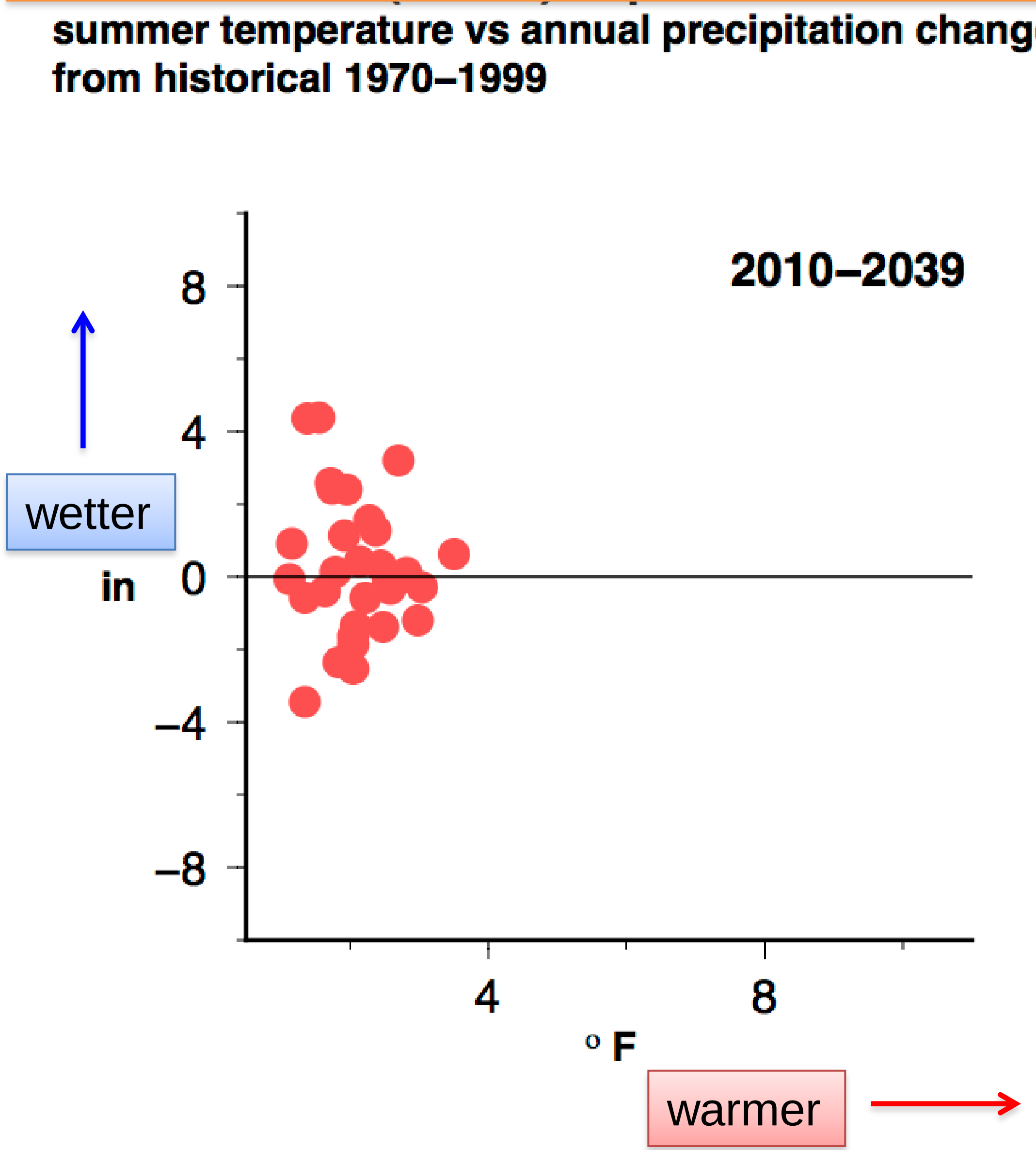
*Which emissions pathway will we take?*

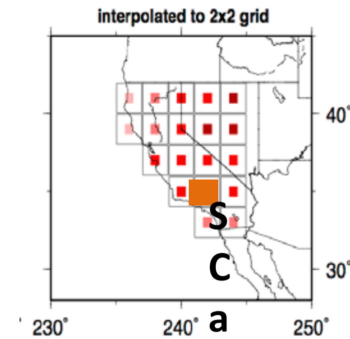
*How much summer amplification of warming?*

*How will temperature change in near term?*

# Projected change temperature and precipitation

31 Global Climate Models RCP 8.5 Los Angeles region

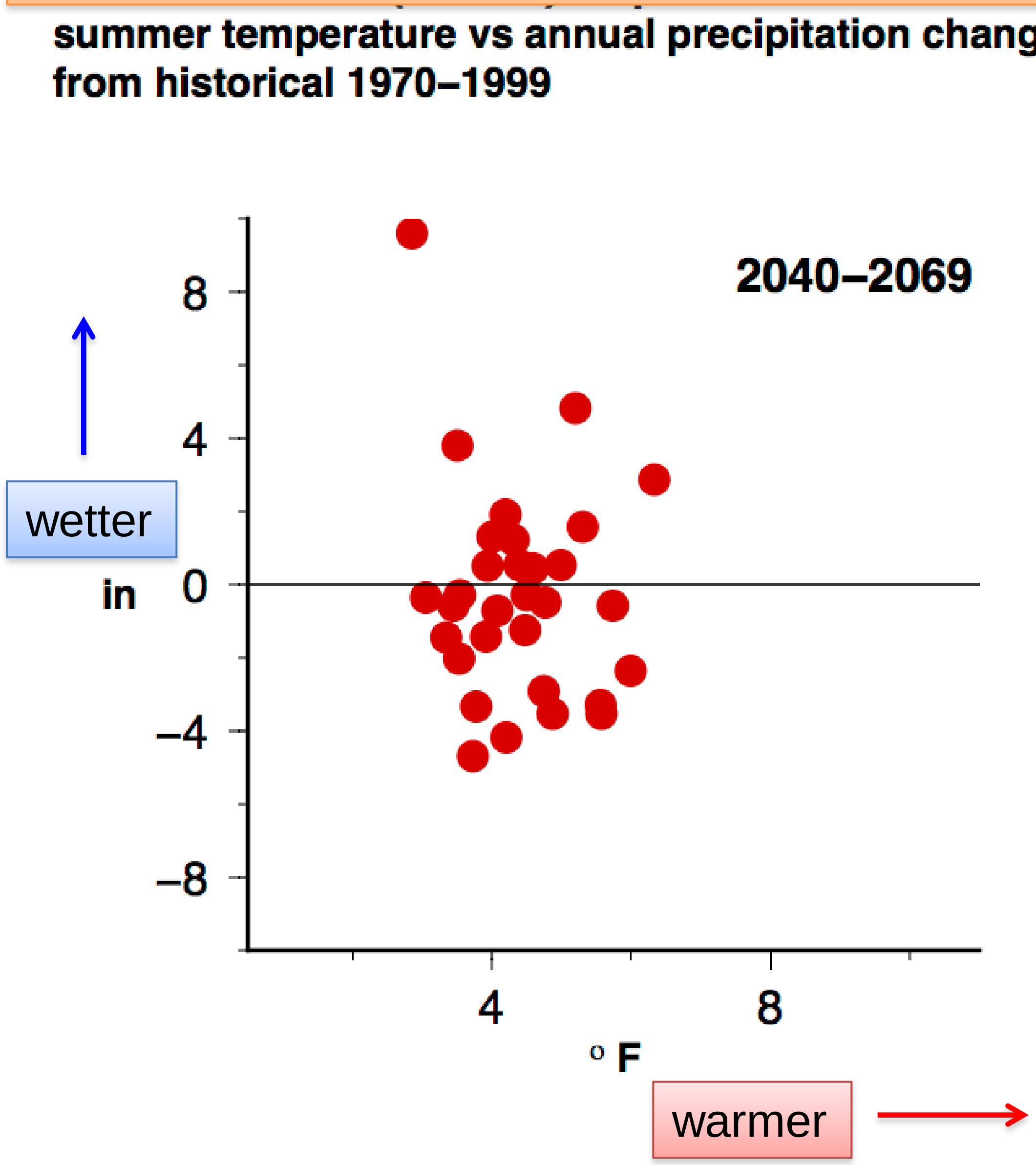



a warmer future
but uncertain
changes in precipitation

# Projected change temperature and precipitation

31 Global Climate Models RCP 8.5 Los Angeles region

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# Projected change temperature and precipitation

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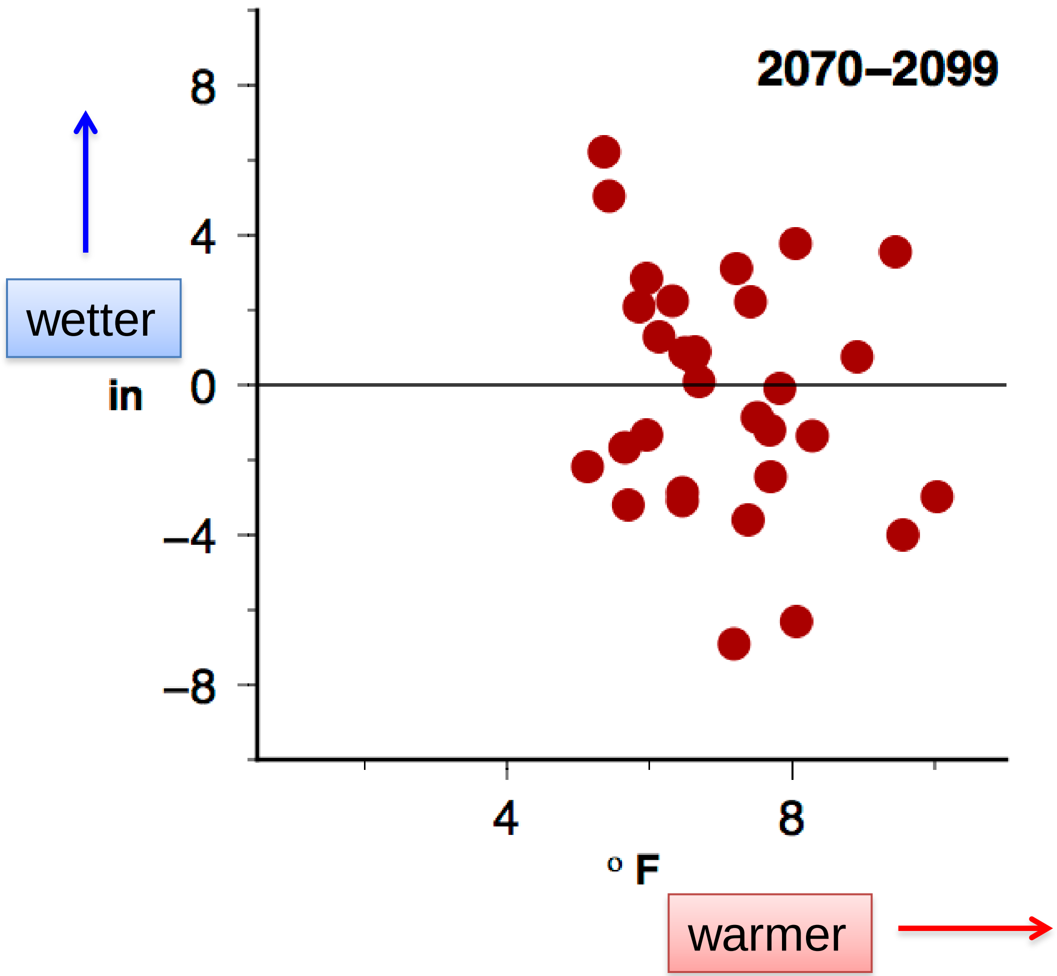
**summer temperature vs annual precipitation change from historical 1970–1999**

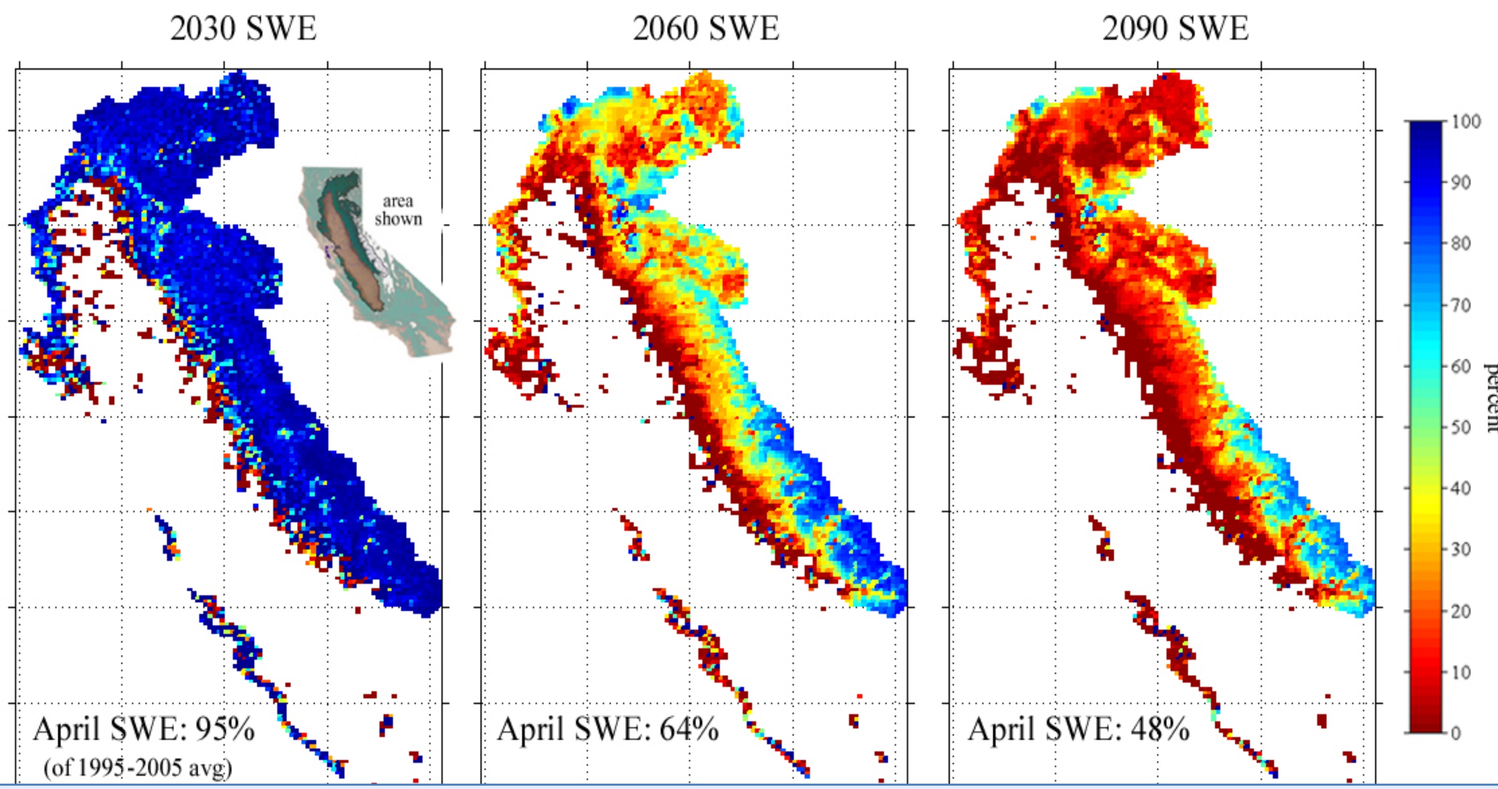



a warmer future
but uncertain
changes in precipitation

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

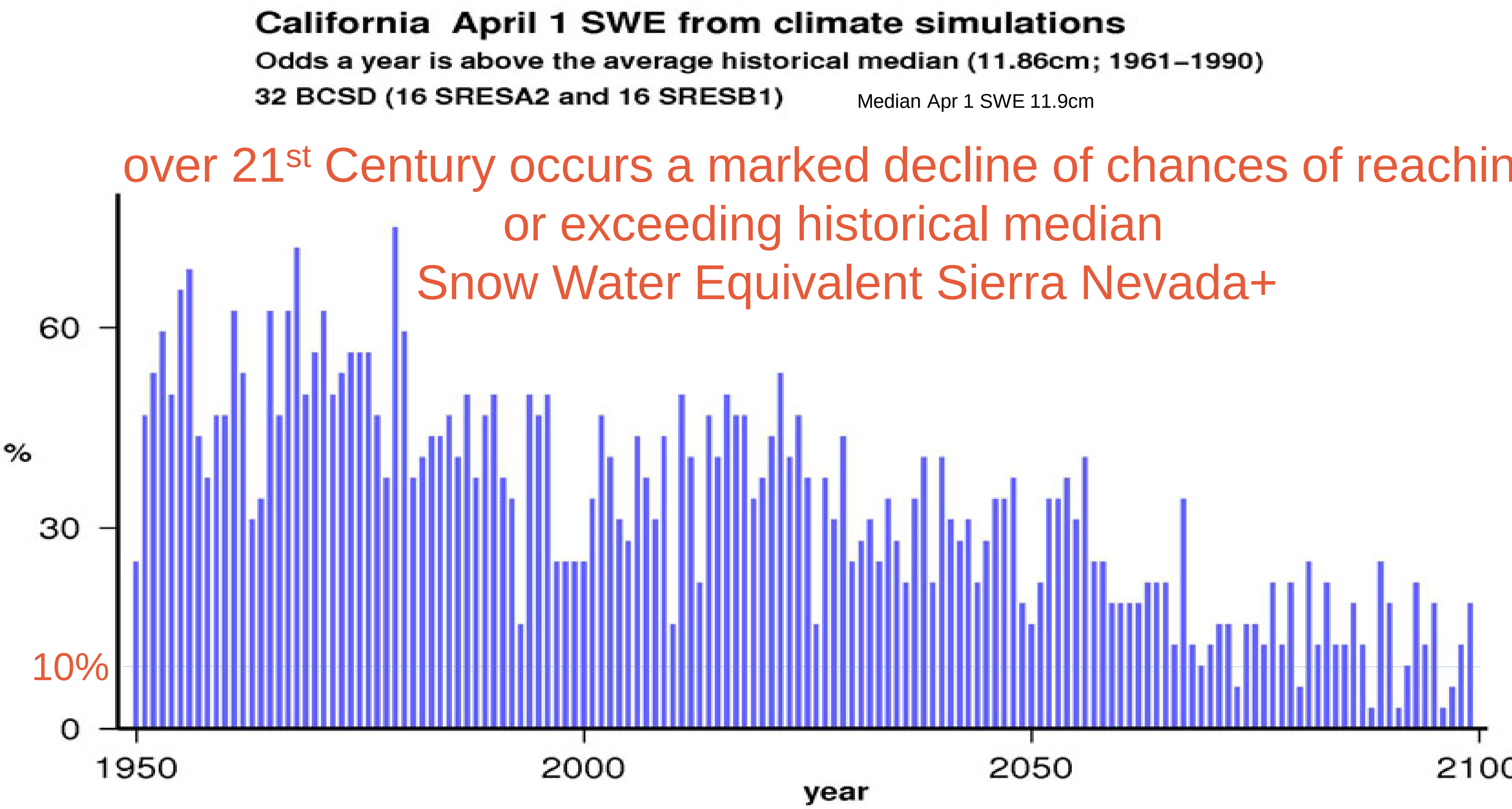
Douglas Alden
Scripps Institution
of Oceanography
Installing met station
Lee Vining, CA

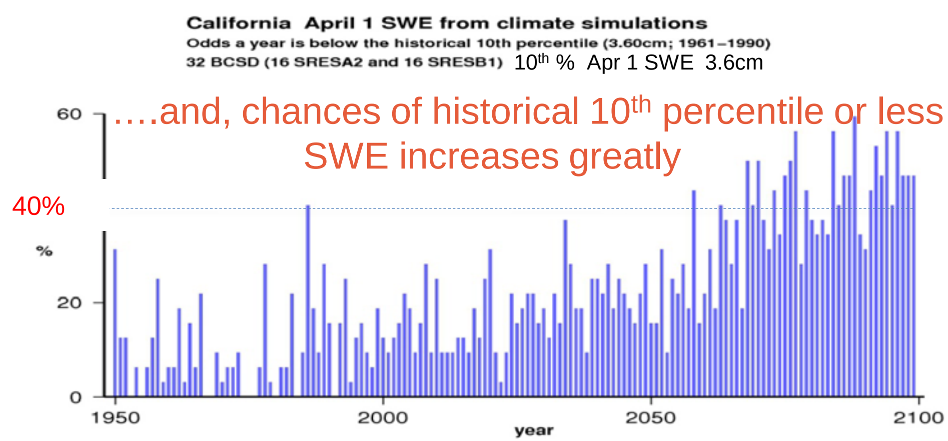
# Loss of California Spring Snowpack from 21st Century warming

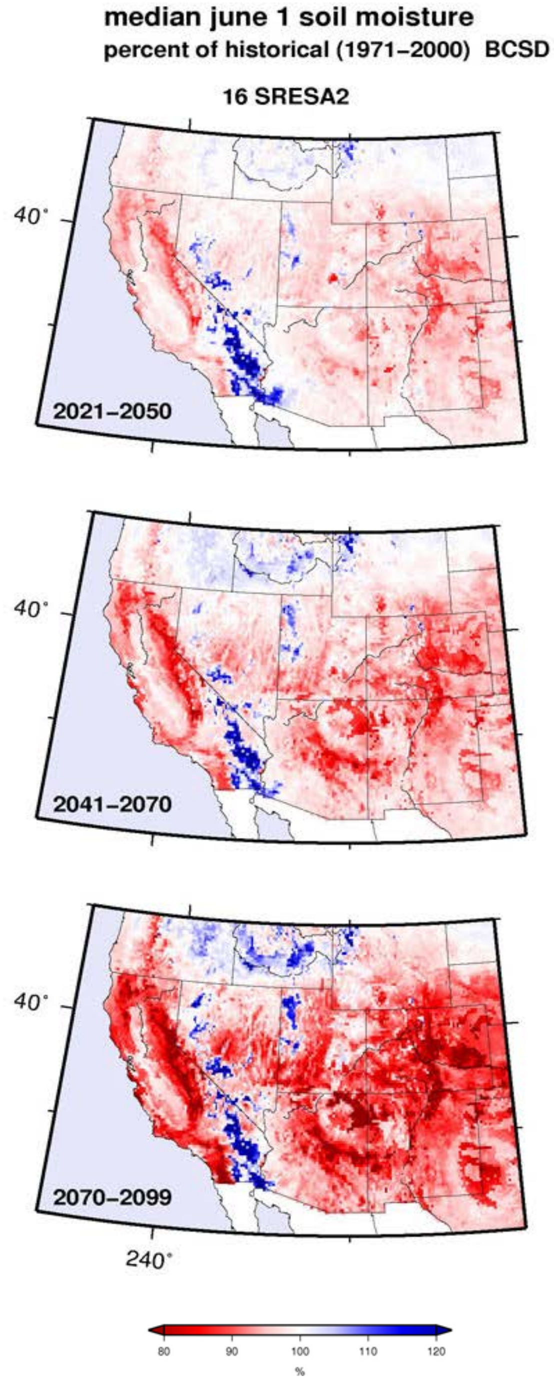



•Under this scenario, California loses half of its spring (April 1) snow pack due to climate warming. Less snow, more rain, particularly at lower elevations. The result is earlier run-off, more floods, Less stored water. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual 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
over 21st Century occurs a marked decline of chances of reaching or exceeding historical median
Snow Water Equivalent Sierra Nevada+
60
%
30
10%
0
1950
2000
2050
2100
year


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
60
40%
%
20
0
1950
2000
2050
2100
year




early 21st

middle 21st

late 21st

# Drier Summer Landscapes

increased warming and diminished snow causes successively greater soil drying throughout 21$^{st}$ Century

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

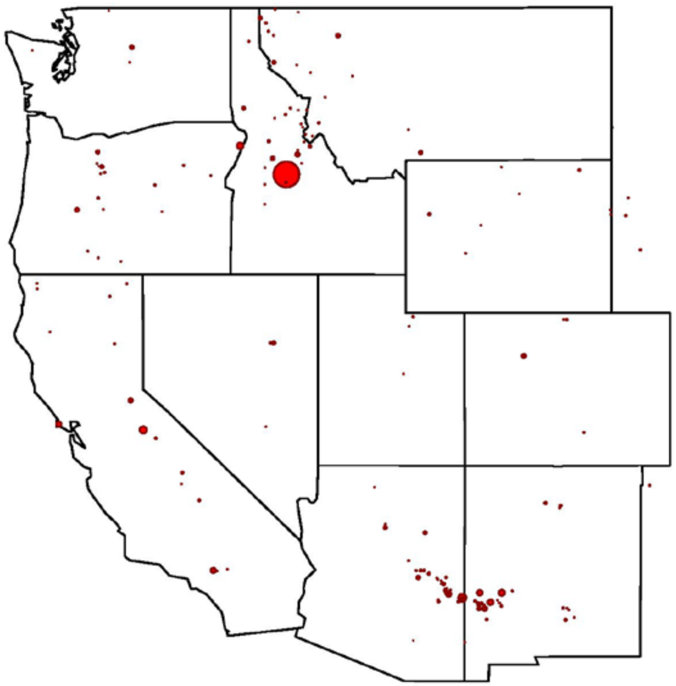
Cayan et al. Ch 6 Southwest Climate Assessment

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

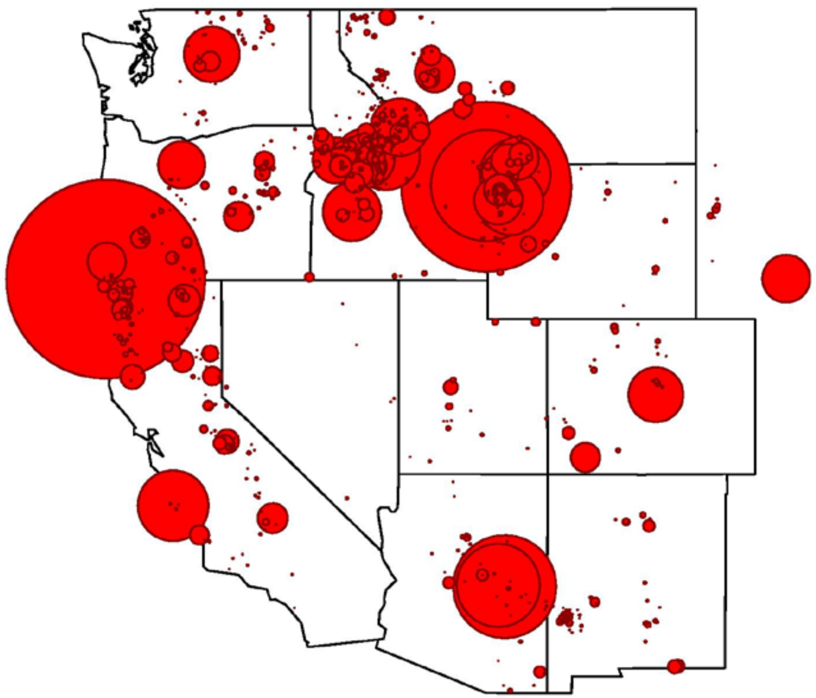
Anthony Westerling et al. *Science* August 2006

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

Late Snowmelt Years



Early Snowmelt Years



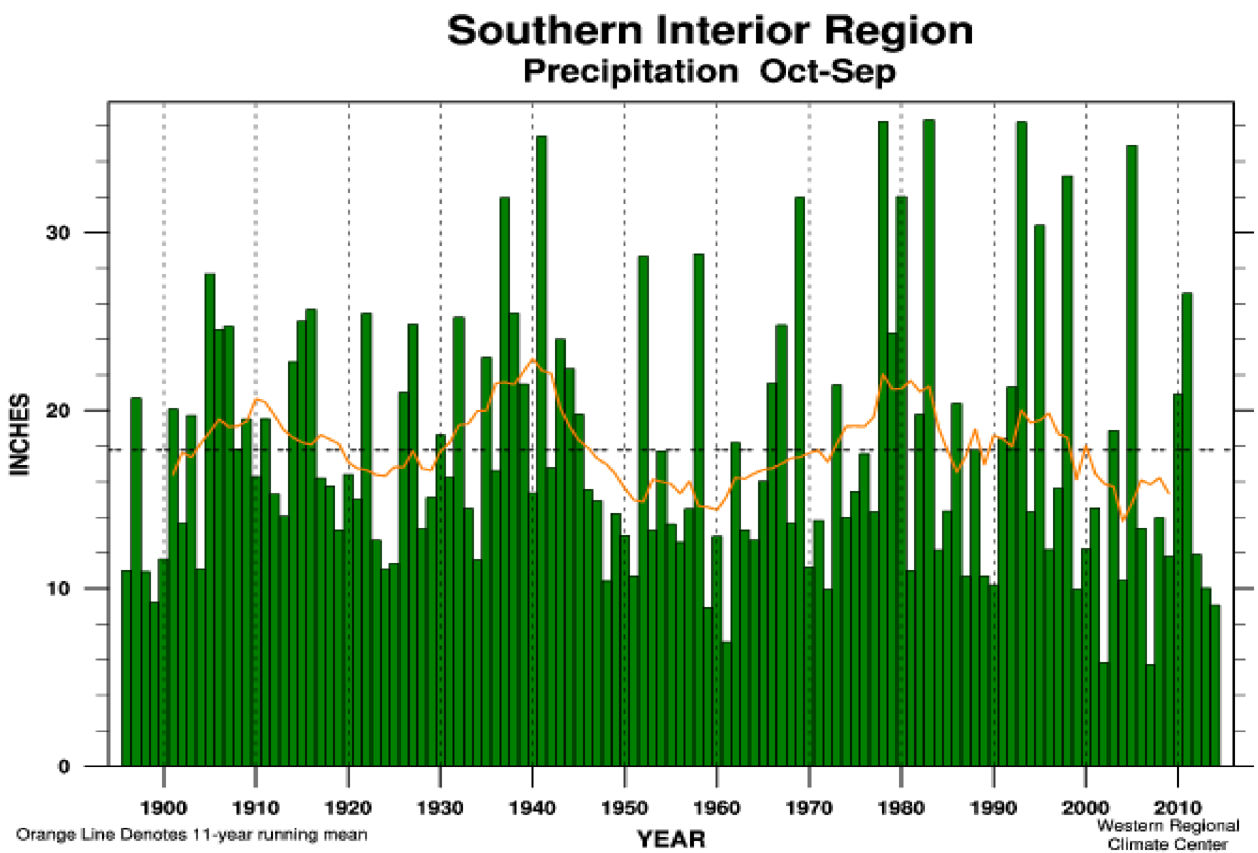
1972 - 2003, NPS, USFS & BIA Fires over 1000 acres

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

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




| | | | | |
|---|---|---|---|---|
| Linear Trend 1895-present | | - 0.85 ± 3.76 in. | (- 4 ± 21%) per 100 yr | |
| Linear Trend 1949-present | | - 0.57 ± 10.69 in. | (- 3 ± 60%) per 100 yr | |
| Linear Trend 1975-present | | -22.50 ± 25.10 in. | (-126 ± 141%) per 100 yr | |
| Wettest Year | | 36.33 in. ( 204%) | in 1983 | MEAN 17.78 in. |
| Driest Year | | 5.70 in. ( 32%) | in 2007 | STDEV 8.13 in. |
| Oct-Sep | 2014 | 9.05 in. ( 50%) | | RANK 5 of 119 |

Southern California Interior Annual Precipitation

coef of Variation 46%
mean 17.8 inches
std dev 8.1 inches

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

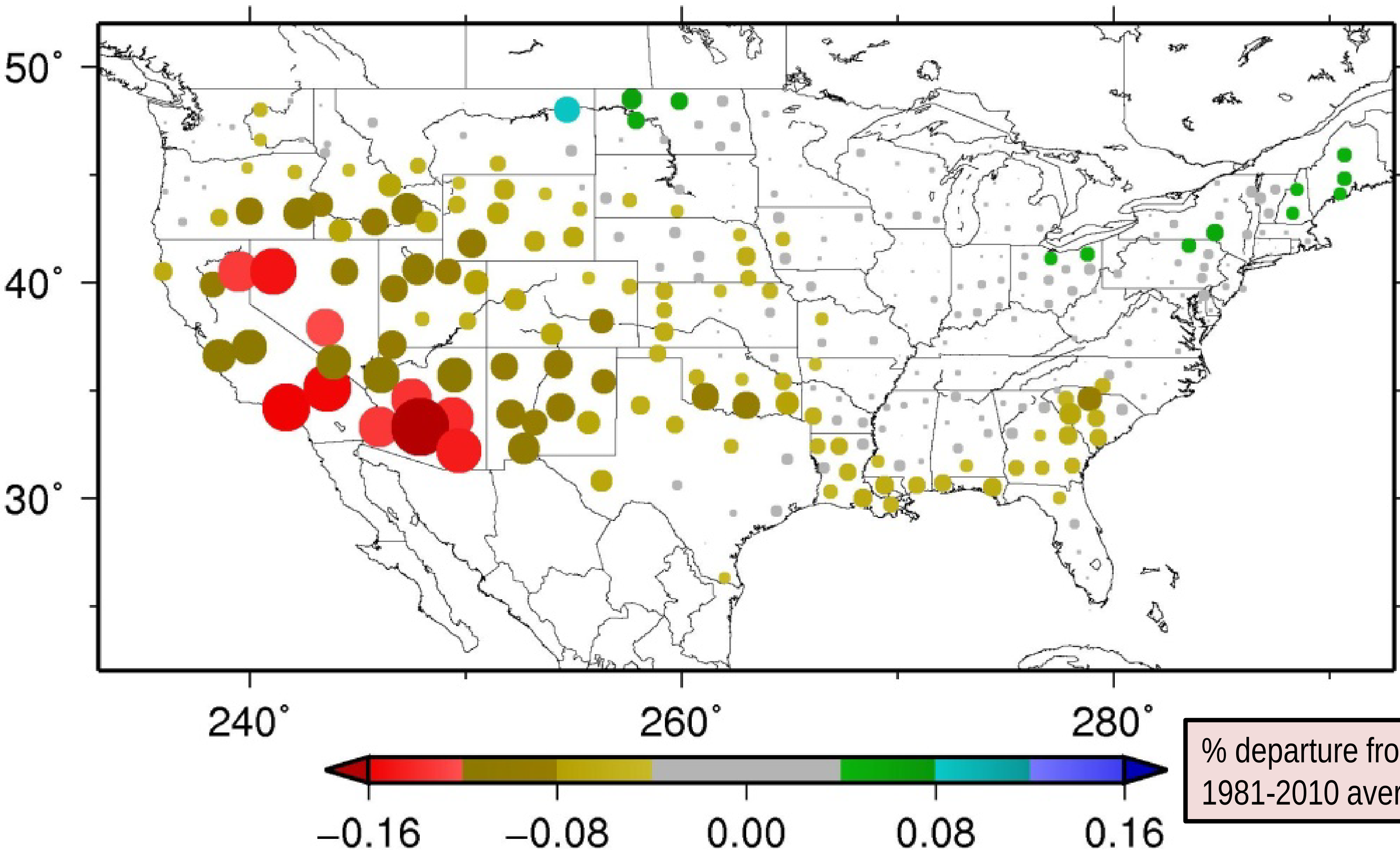
If atmospheric conditions are unfavorable during that period, a dry year results

2014 ~50% of long term average

California Climate Tracker
Western Regional Climate Center

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

observed precipitation departure (% of average), 1998-99 thru 1912-13 Inot including  the present water year)




% departure from 1981-2010 average

# Loss of water during the recent drought has caused the earth's crust to rise

GPS displacements relative to 2003-2012 average—4mm upward displacement (10cm water) average over western US maximum loss of 50cm has occurred in Sierra Nevada

**Ongoing drought-induced uplift in the western United States**
by A. A. Borsa (1), D. C. Agnew(1) and D. R. Cayan(1,2)
published in the online version of *Science* on August 20, 2014.
1 Scripps Institution of Oceanography, UC San Diego
2 US Geological Survey La Jolla, CA

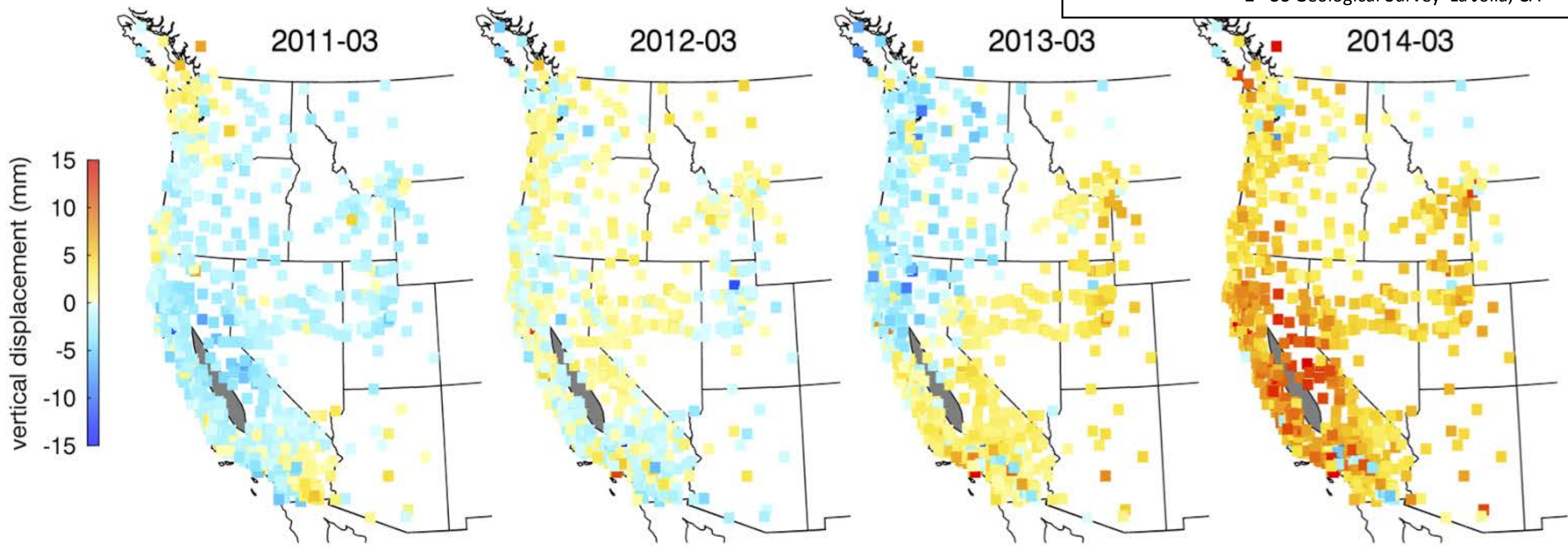
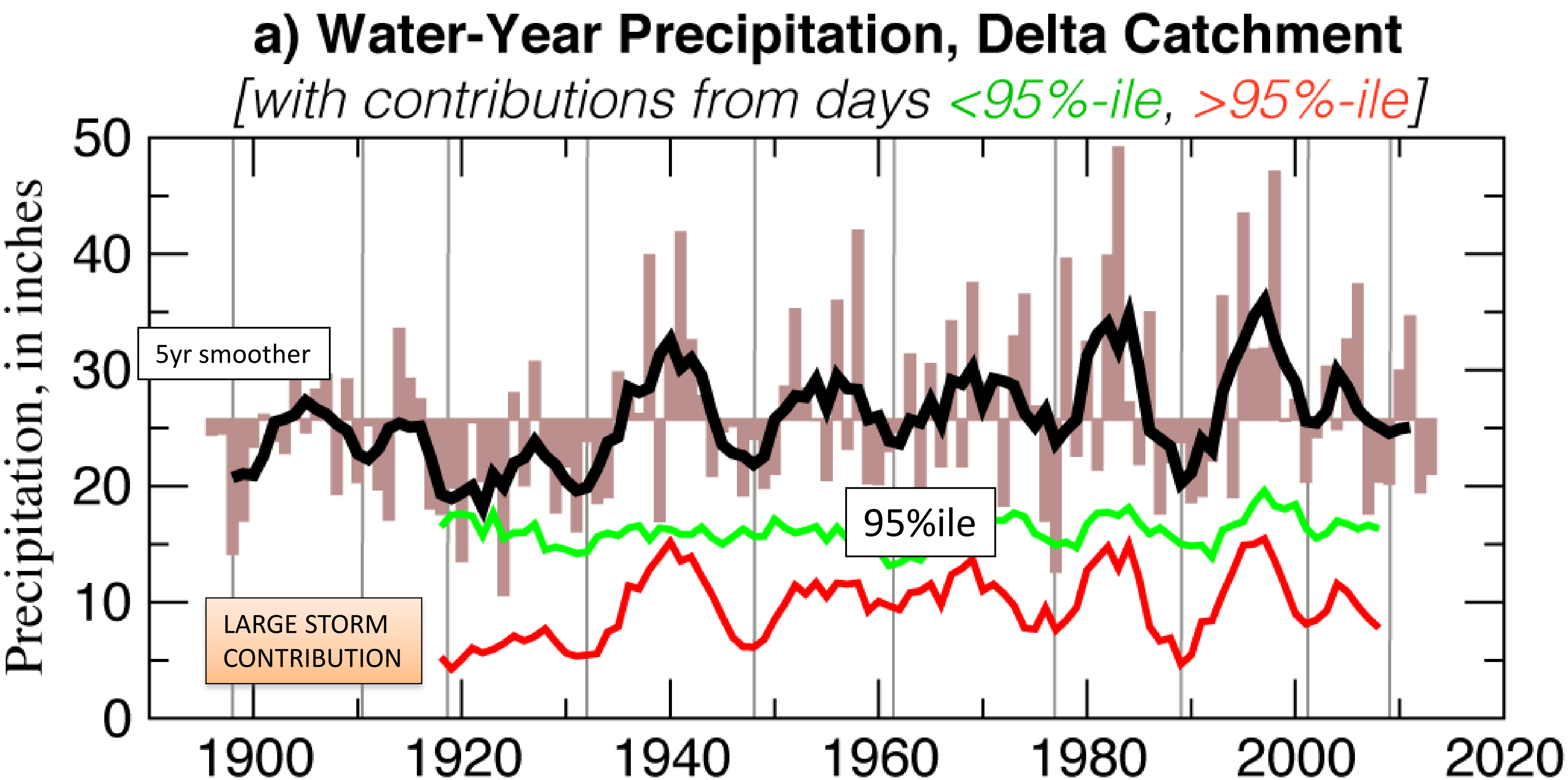



*Figure 2.* Maps of vertical GPS displacements on March 1 of 2011 through 2014. Uplift is indicated by yellow-red colors and subsidence by shades of blue. Gray region is where stations were excluded in the Central Valley of California due to strong agricultural pumping signal.

GPS estimate by Borsa et al. in present study showing deficit of ~240km**3 water in March 2014 relative to 2003-2014 baseline over western U.S., west of 109° W. This is in general agreement with GRACE satellite observations, S. Castle et al 2014 GRL found ~65km**3 water water loss in Colorado Basin during 2004-2013.

# a few large storms (or their absence)

account for a disproportionate amount of California's precipitation variability




Mike Dettinger

Dettinger and Cayan **Drought and the Delta—A Matter of Extremes**

*accepted, San Francisco Estuary and Watershed Science, April 2014*

# 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—present and future.
- California dry spells often build 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.
- 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 change will broadly affect California hydroclimate and impact sectors and systems across-the-board. Expected impacts of climate change: longer "warm" season, loss of spring snow pack, increased wildfire threat, more winter floods.
- 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. Climate change projections—warmer, fewer overall wet days but more intense heavy events.
- Implications:
    - Less snow, more rain
    - Earlier run-off from traditionally snow-fed mountain watersheds
    - Higher floods
    - Potentially, less stored water
    - Water quality implications: warmer surface water, warmer dry spells, occasional higher runoff, greater sediment influx from high runoff events and burned landscape