Implications of Climate Change and California Water

Drought Forum Sacramento May 15 2014

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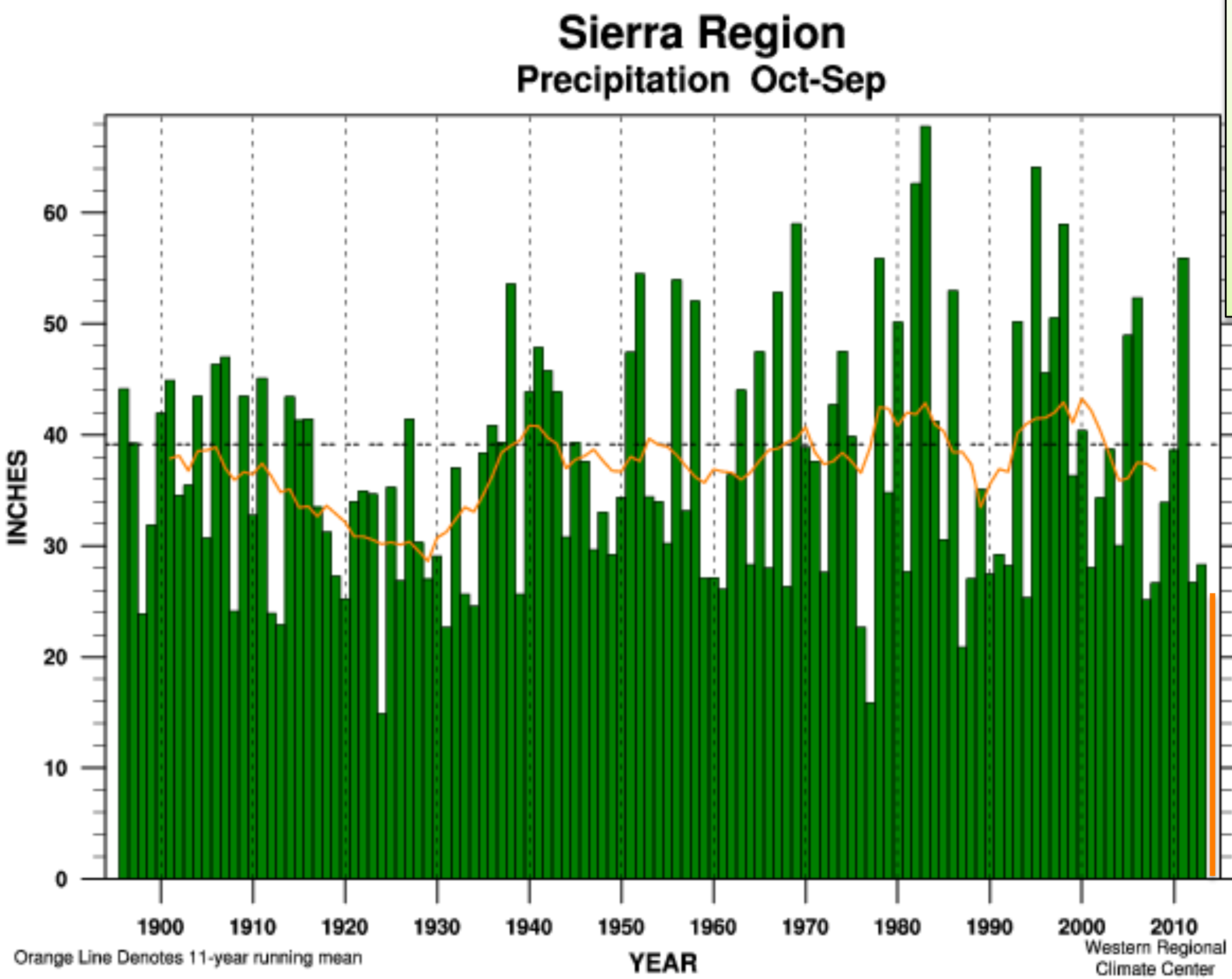
key points

- Climate change will broadly affect California hydroclimate and impact sectors and systems across-the-board.
- California's precipitation climate is volatile and prone to drought—climate change may accentuate this volatility
- Dry spells (including 2014-15) often build up over multiple years.
- The absence of a few very large storms drives California dry spells.
- Climate change projections—warmer, fewer overall wet days but more intense heavy events.

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



Sierra Nevada
Annual Precipitation
Coef of Variation ~31.5%

mean 39.1 inches
std dev 12.3 inches

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

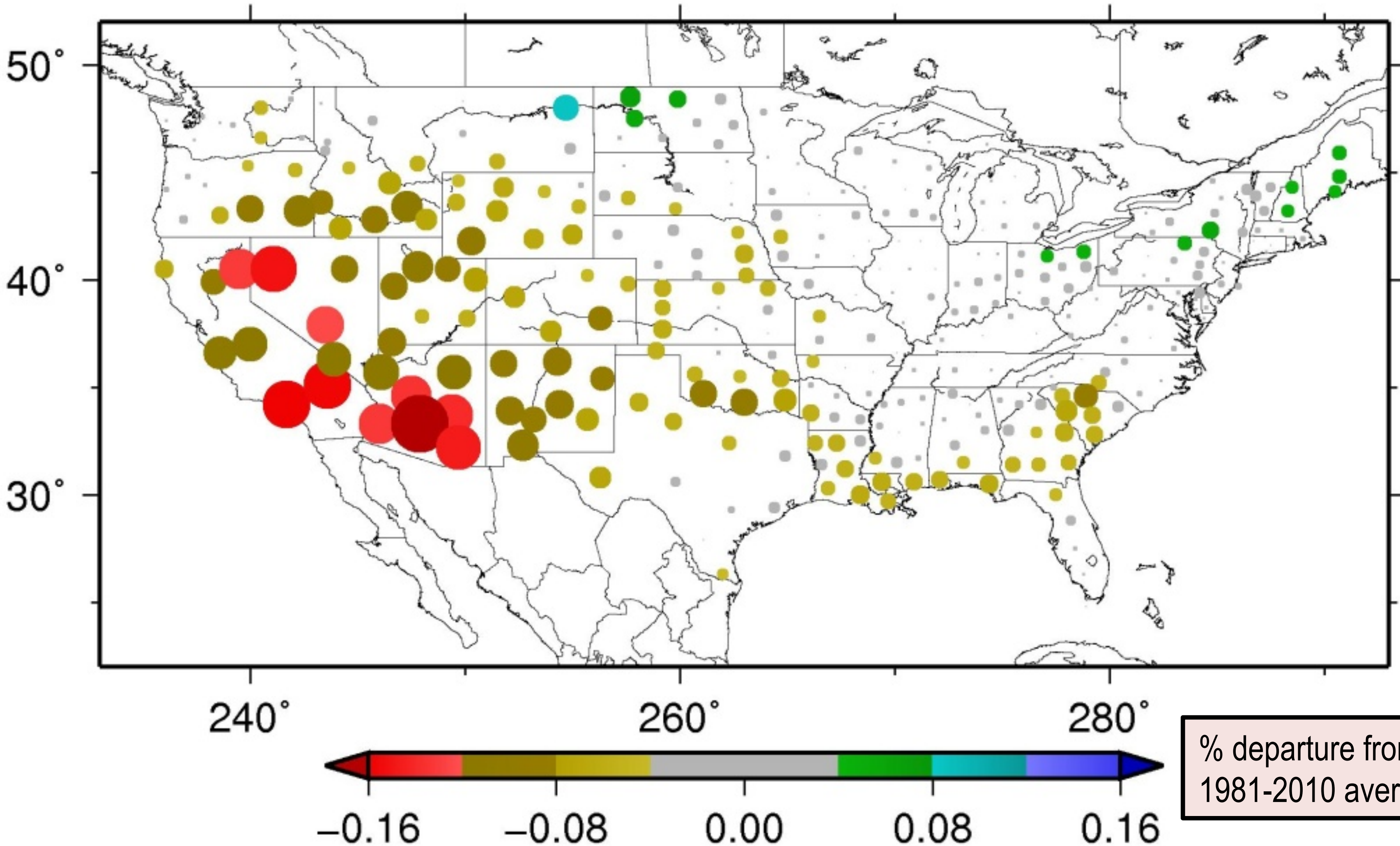
If atmospheric conditions are unfavorable during that period, a dry year results

WY 2014 precip estimated at 65% of LT mean

From California Climate Tracker
Western Regional Climate Center

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

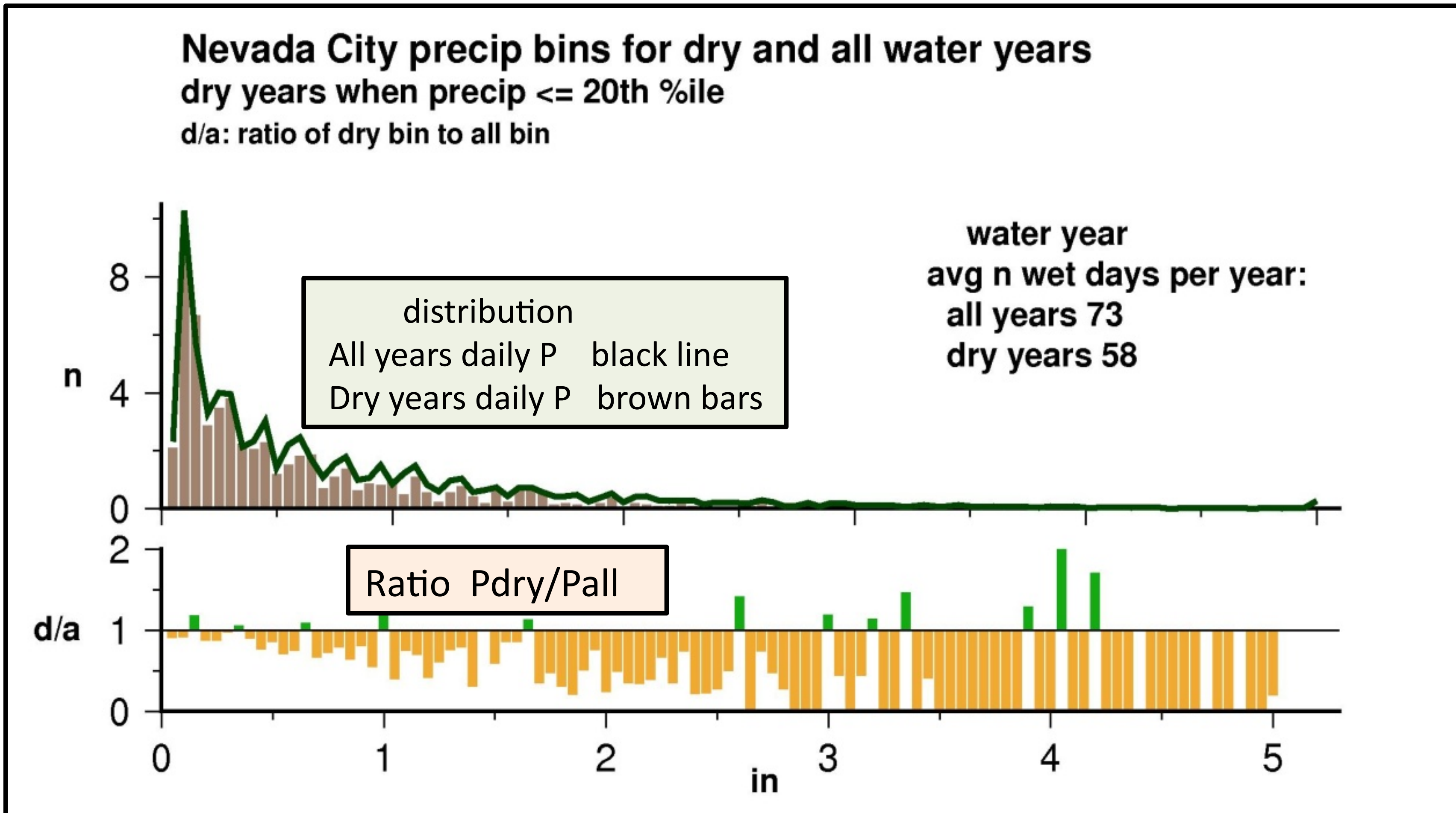
observed precipitation departure (% of average), 1998-99 thru 1912-13 Inot including the present water year)



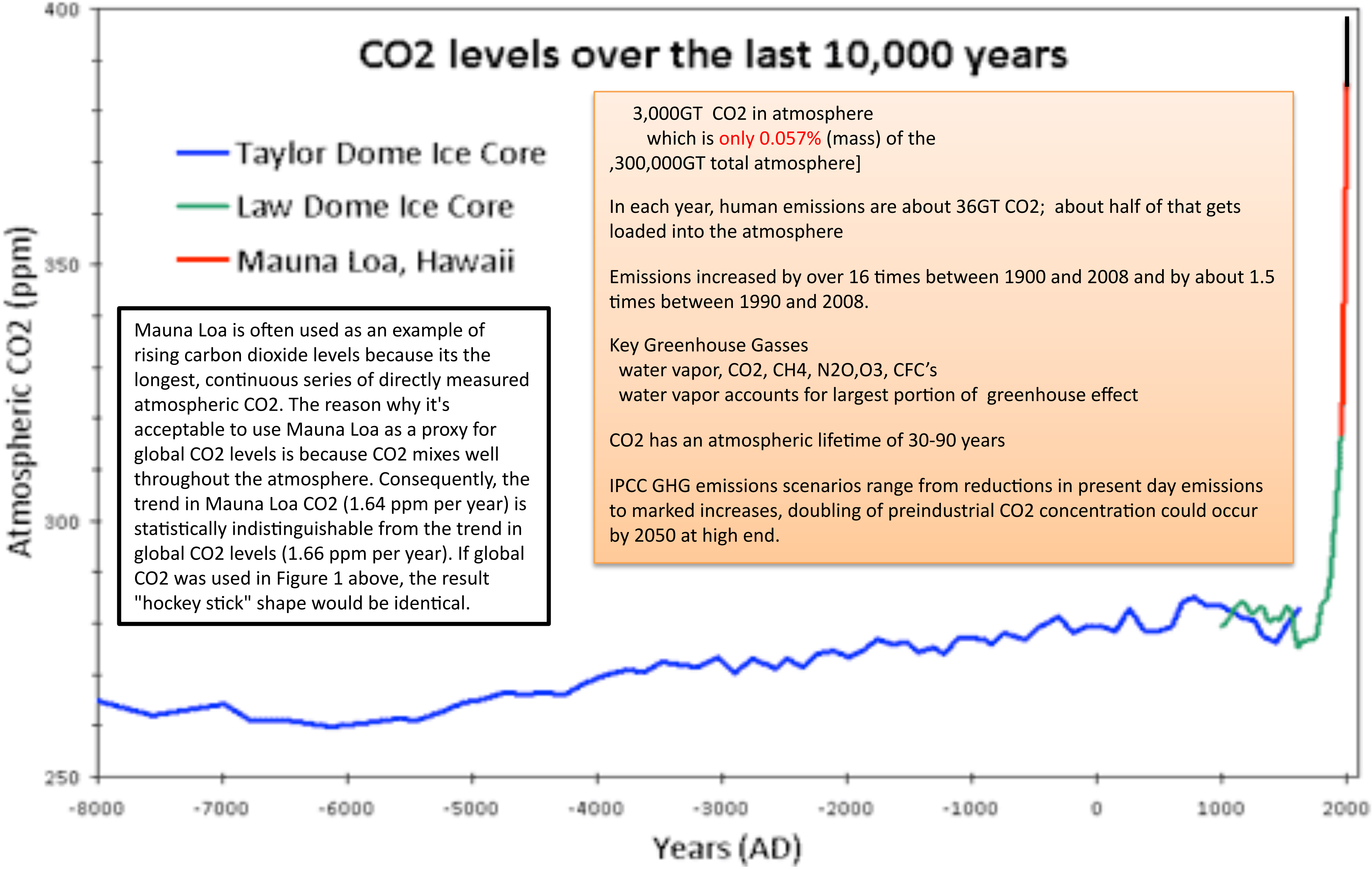
% departure from 1981-2010 average

A fingerprint of drought in California -- the missing very-wet days

distribution wet days (P at least .01”) all calendar days 108 years (1895-2013 w a few missing years)



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

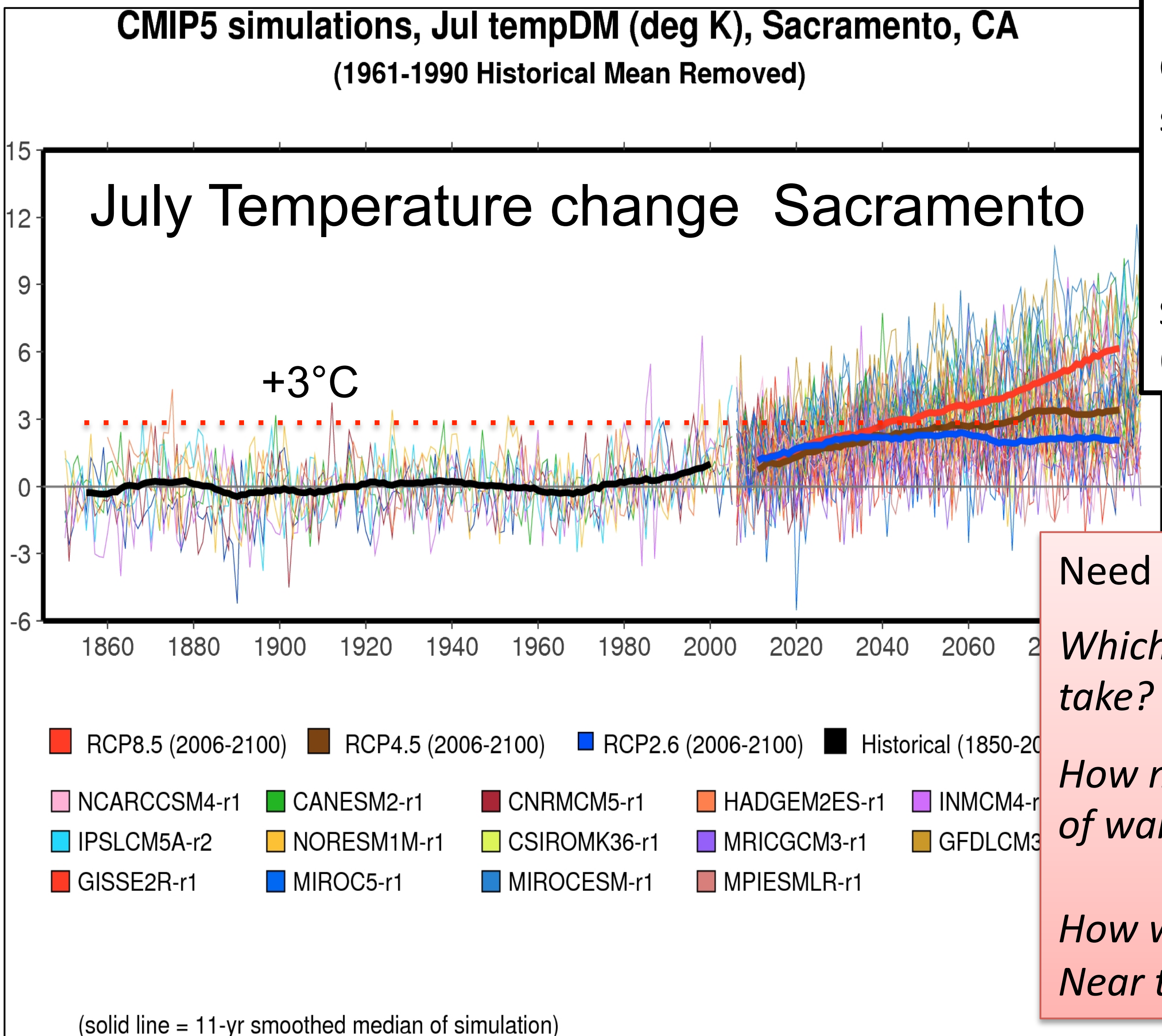
CO2 has an atmospheric lifetime of 30-90 years

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).

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



CMIP5 GCMs project +3°C summer warming by 2060, under mid and high RCPs

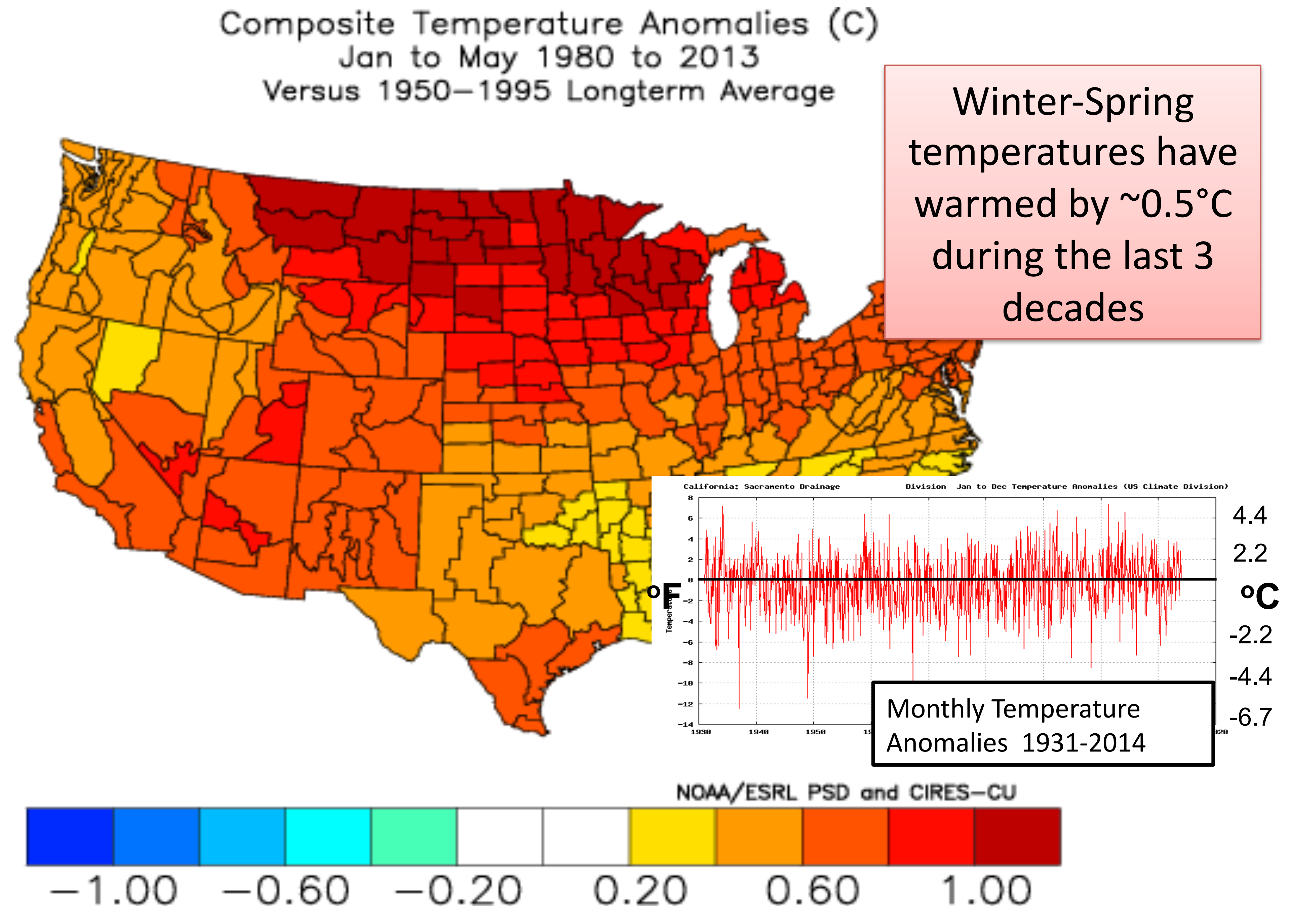
14 GCMs X 3 RCP Emissions Scenarios IPCC 5th Assessment (CMIP5) models

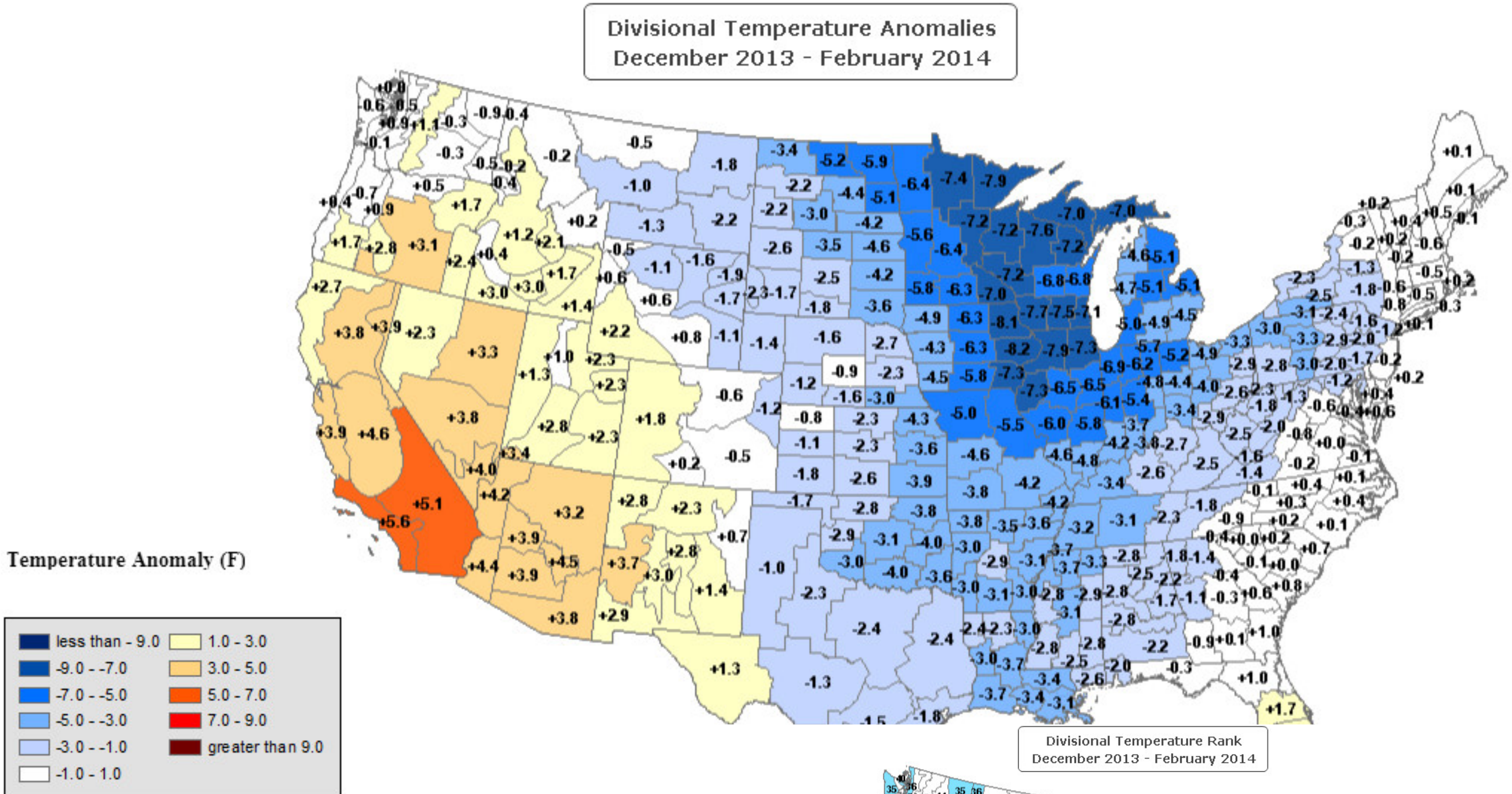
Need to kmow

Which emissions pathway will we take?

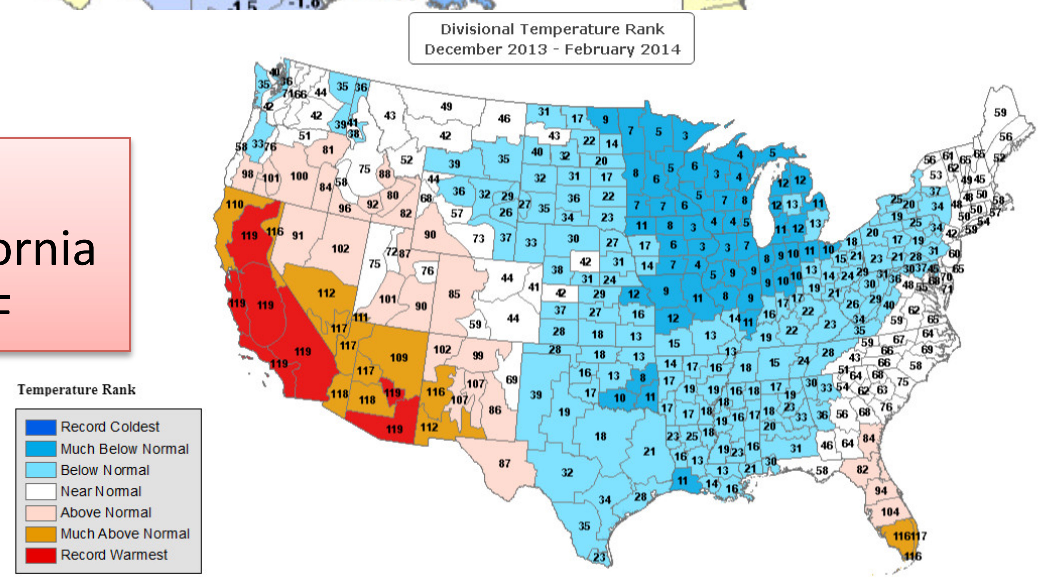
How much summer amplification of warming?

How will temperature change in Near term?


Composite Temperature Anomalies (C)
Jan to May 1980 to 2013
Versus 1950–1995 Longterm Average
Winter-Spring temperatures have warmed by ~0.5°C during the last 3 decades
California: Sacramento Drainage
Division Jan to Dec Temperature Anomalies (US Climate Division)
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
1930
1940
1950
°F
4.4
2.2
°C
-2.2
-4.4
-6.7
Monthly Temperature Anomalies 1931-2014
NOAA/ESRL PSD and CIRES–CU
–1.00
–0.60
–0.20
0.20
0.60
1.00



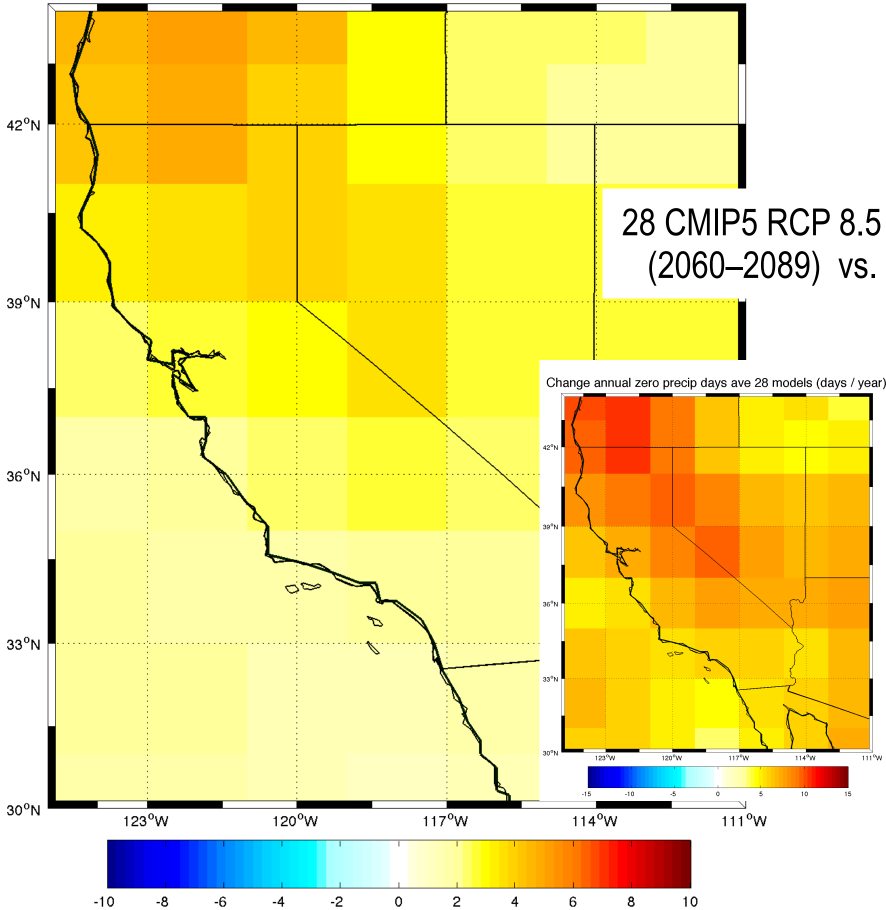
December-February 2013-14
a record warmest winter in California
temperature anomalies 4- 5°F



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

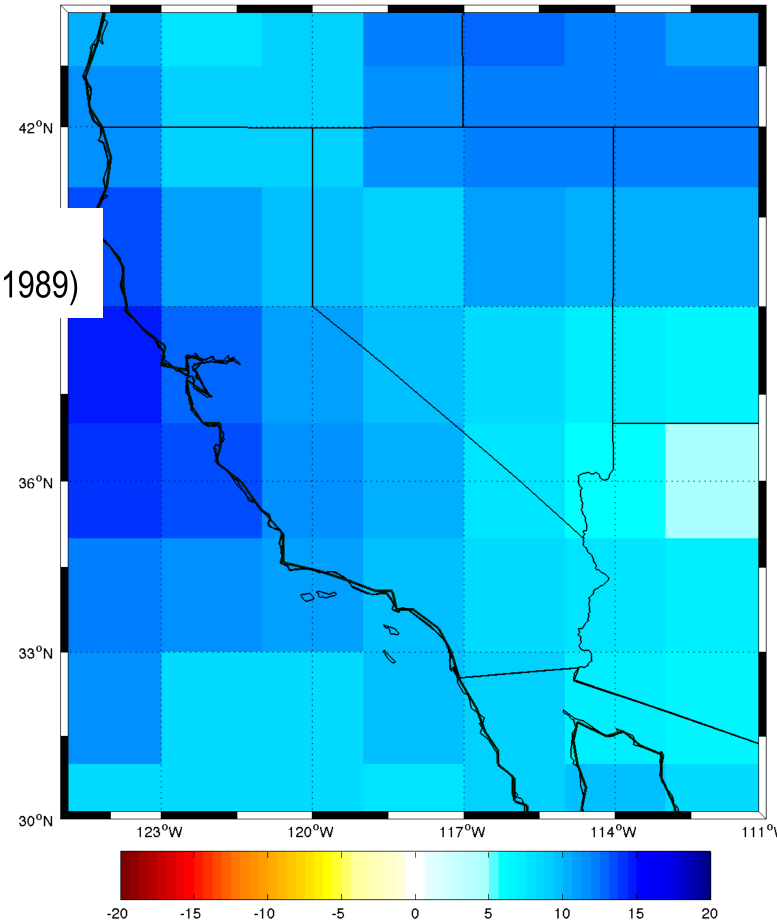
the *intensity* of the largest wet days is projected to *increase* !

Change annual zero precip days ave 28 models (%)

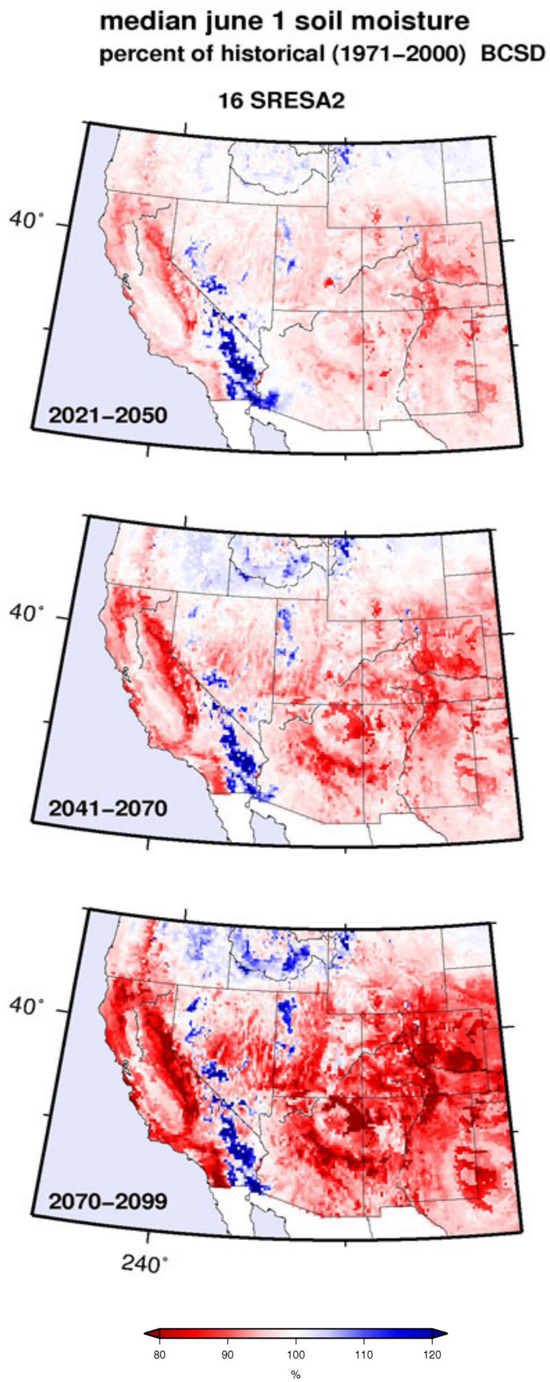


28 CMIP5 RCP 8.5 GCMs
(2060–2089) vs. (1960-1989)

Change in annual precip Intensity (%) (average; 28 models) (for Rain Days)



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.



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*)

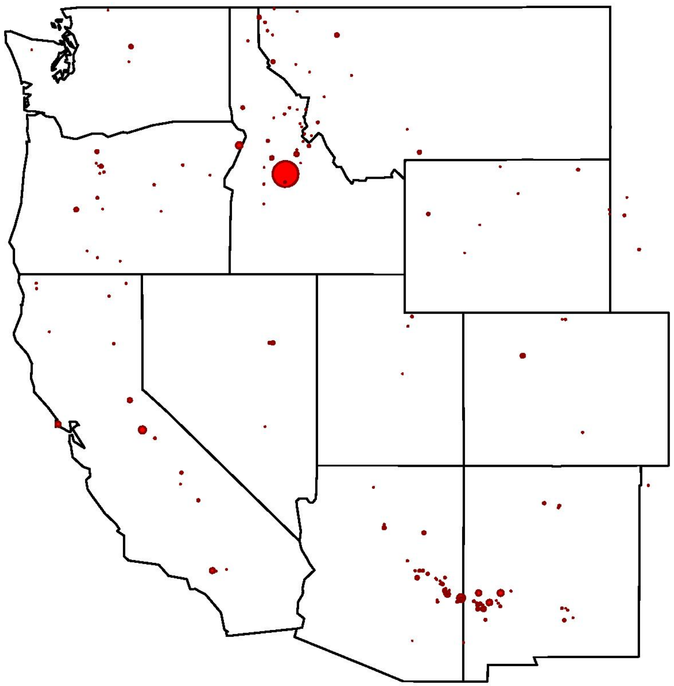
Cayan et al. Ch 6 Southwest Climate Assessment

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

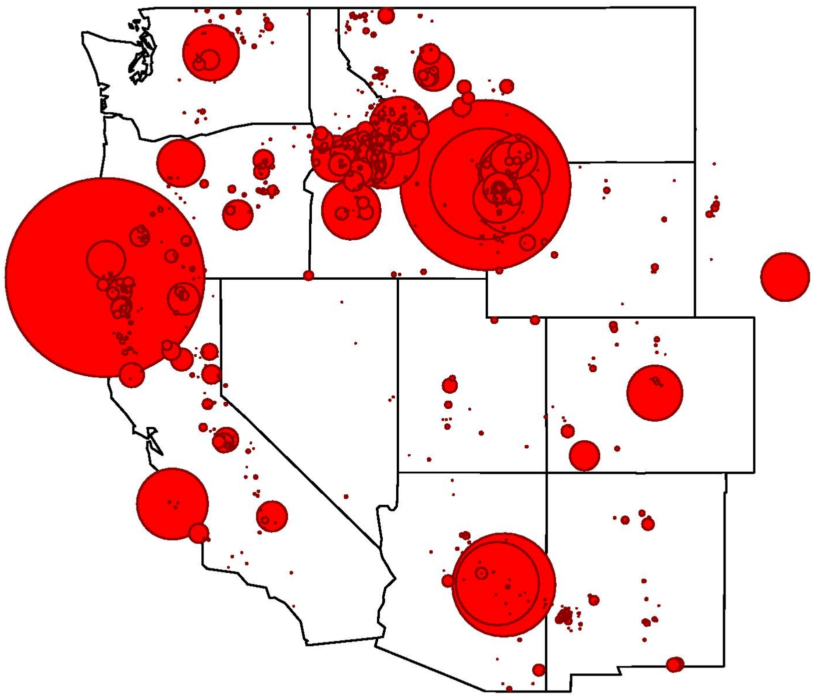
Anthony Westerling et al. *Science* August 2006

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

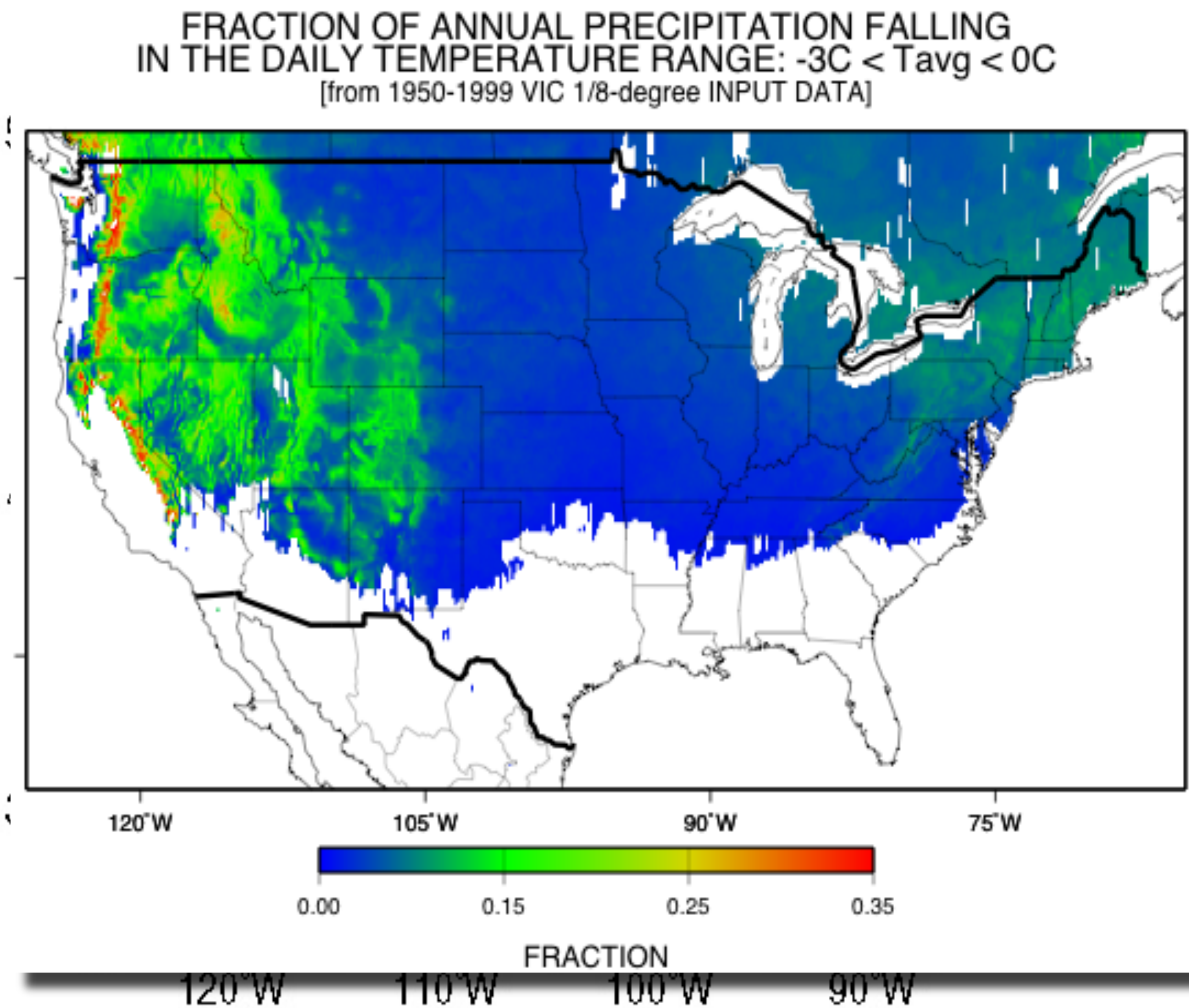
The warming and earlier springs during last few decades have extended and intensified the fire season in mid-elevation forests

Tony Westerling et al *Science* 2006

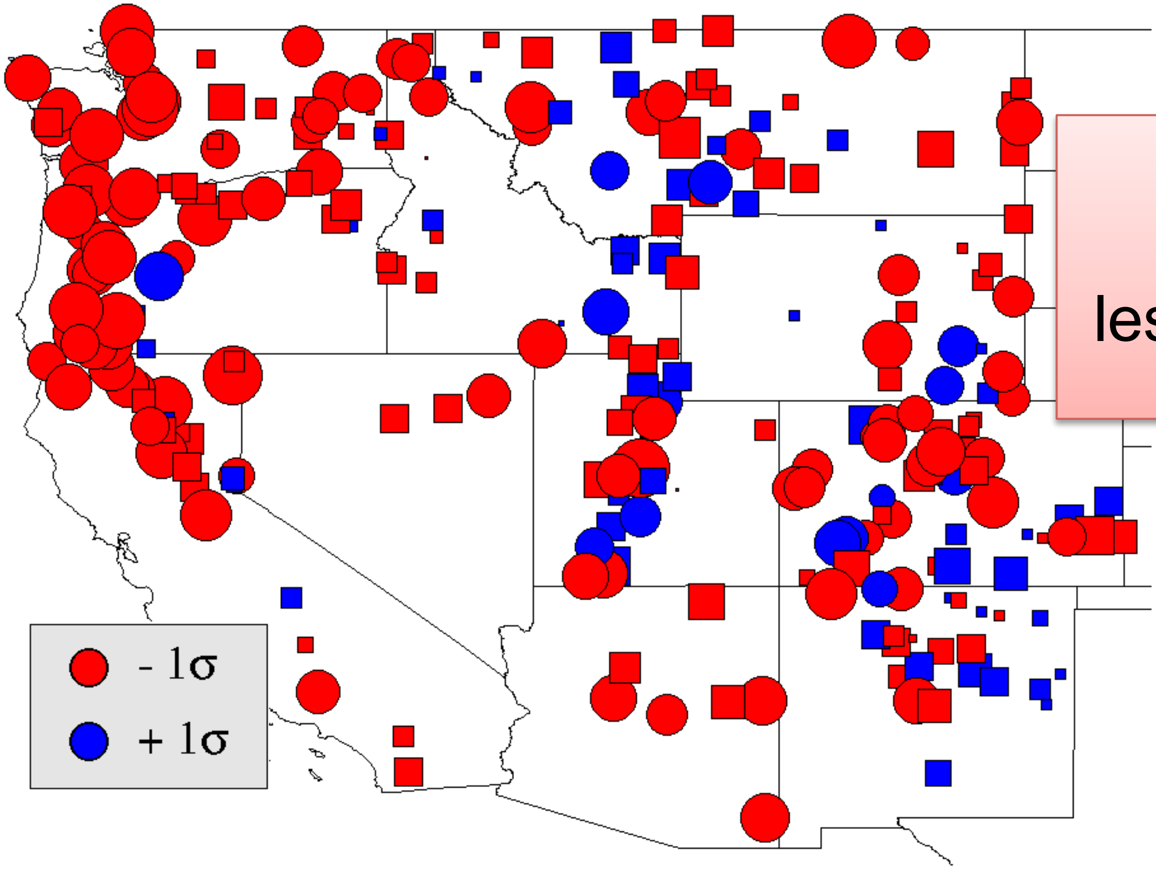
regional snow and hydrology—
a sensitive index of climate variation and change

A major part of California's annual precipitation occurs as snow, at temperatures within 3°C of melting

The western U.S., including California, has developed water resource management around the seasonal snow pack that accumulates in mountain catchments. Climate warming is a challenge to this paradigm.



Mike Dettinger

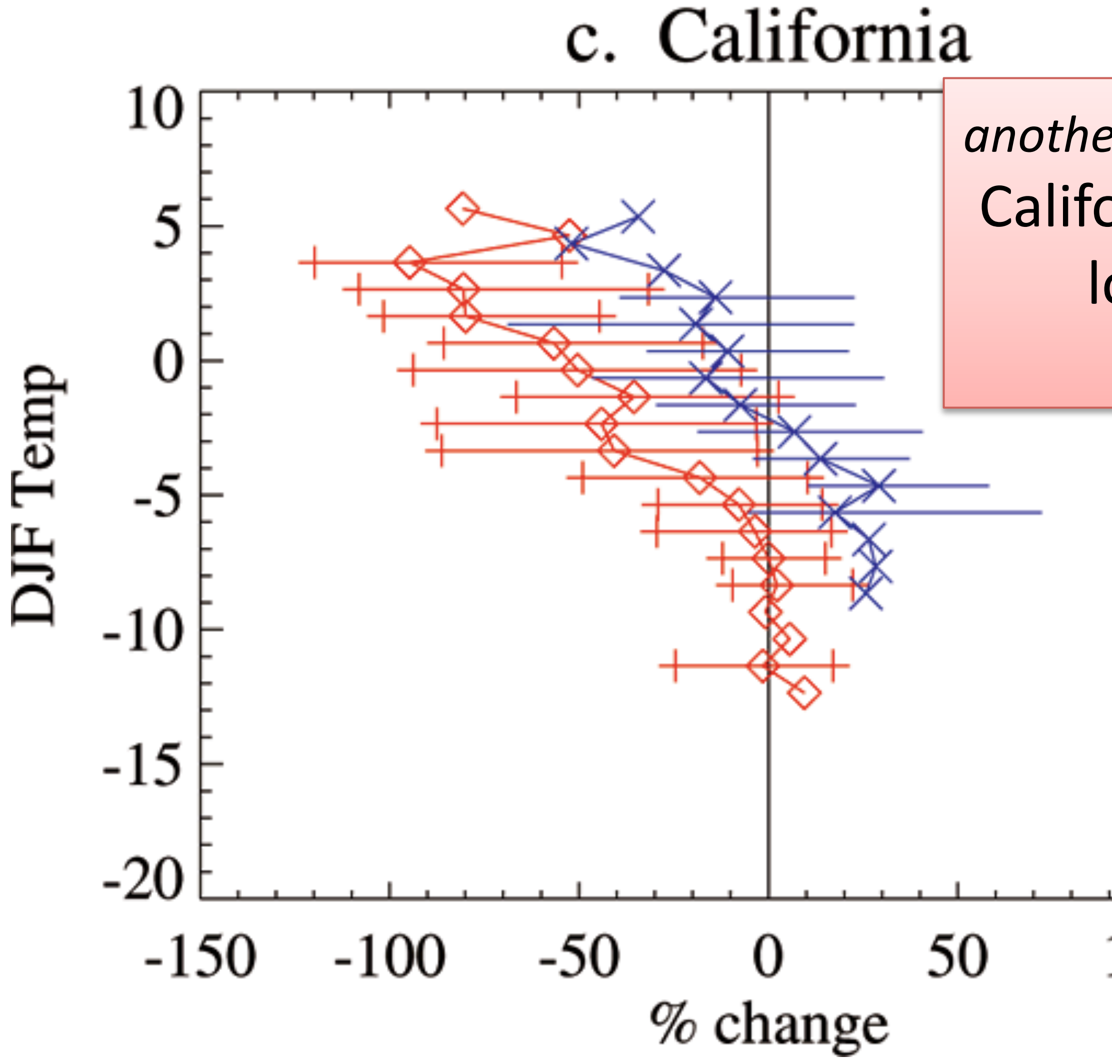


observed changes lean strongly toward less snow and more rain
WY 1949-2004

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

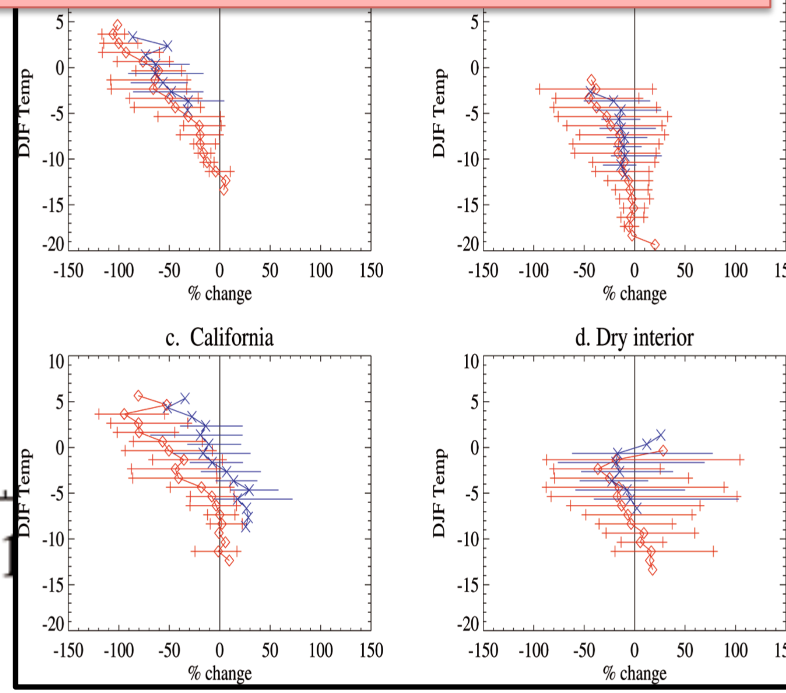
symbol area is proportional to study-period changes, measured in standard deviations as indicated; circles indicate high trend significance ($p<0.05$), squares indicate lower trend significance ($p>0.05$).

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.



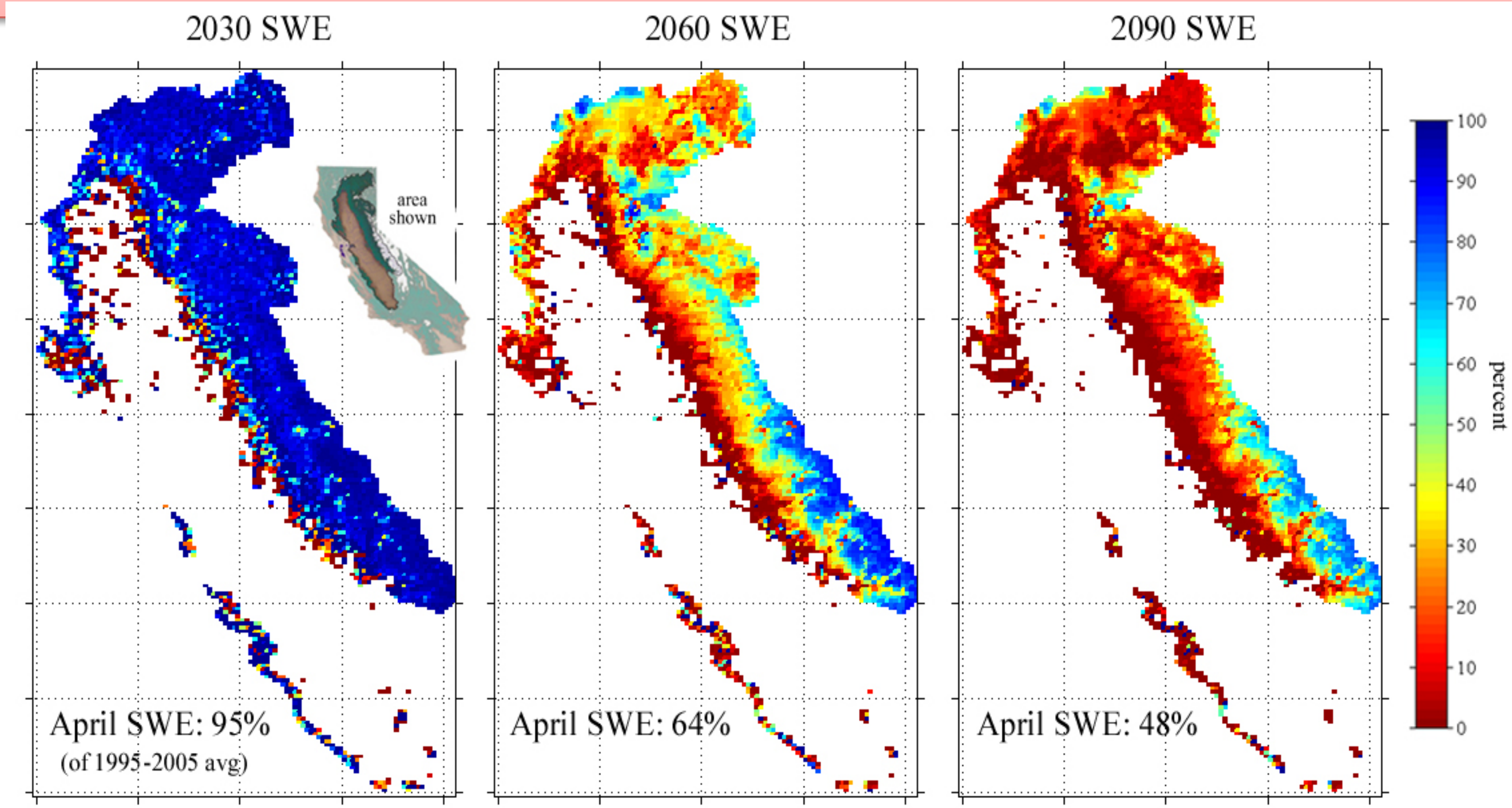
another warming symptom:

California (along with the West) is losing Its lower elevation spring snowpack



Across the western U.S., April 1 snow losses have occurred in lower (warmer) elevations as shown directly from snow course observations (blue) and VIC hydrological model reanalysis (red) from Phil Mote and colleagues (2005)

Warming drives loss of spring snowpack



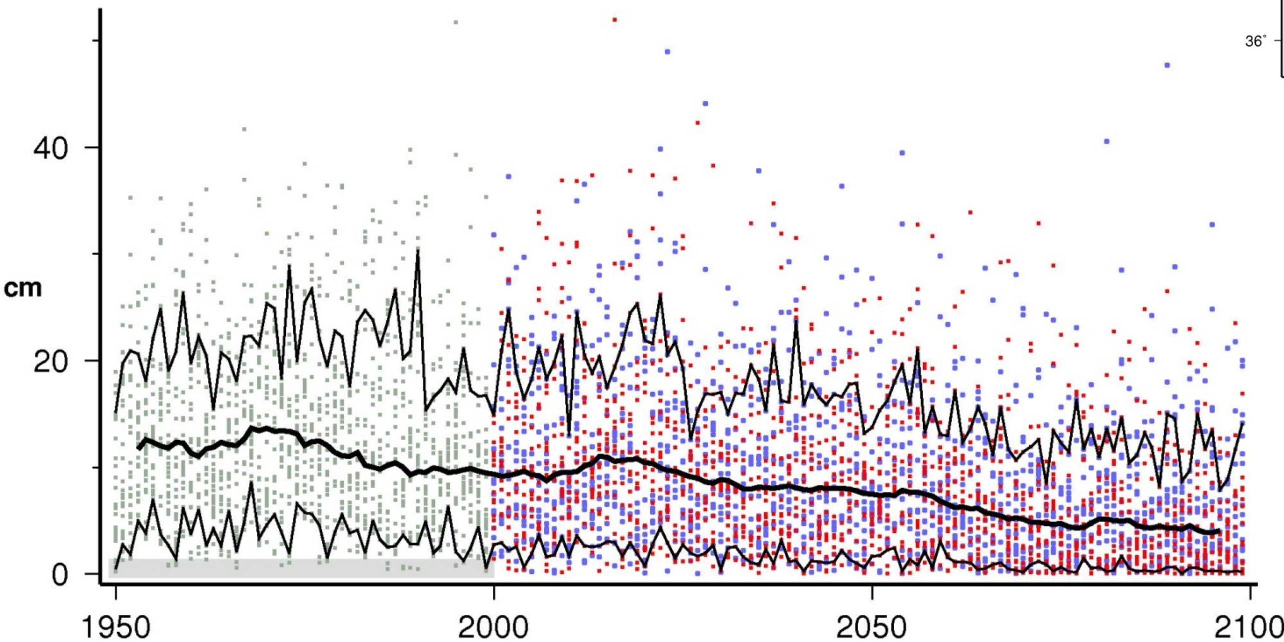
•Under this scenario, California loses half of its spring (April 1) snow pack due to climate warming. Less snow, more rain, particularly at lower elevations. The result is earlier run-off, more floods, Less stored water. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual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

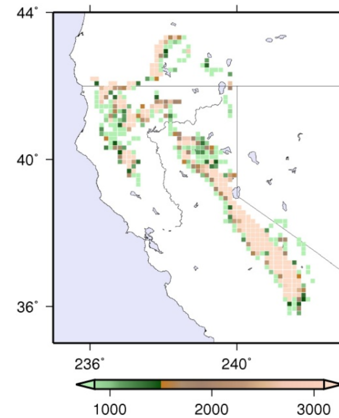
Knowles, N., and D.R. Cayan, 2002: Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. *Geophysical Research Letters*, **29**(18), 1891.

projected reduction in California's spring snow pack under a warmer climate
VIC model estimates indicate ~25% loss per C°

Sierra Nevada Spring Snow Water Equivalent

32 BCSD (16 SRESA2 and 16 SRESB1)
7–year smoothed median: heavy black line
90th and 10th percentiles: light black lines





declining Apr 1 SWE:
2050 median SWE ~ 2/3 historical median
2100 median SWE ~ 1/3 historical median

- SRESA2
- SRESB1
- historical

warming-reduction of snow pack will add to water management challenges.

…besides effect on snow, warming will likely increase warm season water demands by humans and ecosystems.

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.