Delta Challenges

expected climate changes on top of already high climate variability

Dan Cayan

Scripps Institution of Oceanography, UC San Diego

USGS

much support from Mike Dettinger, Mary Tyree, David Pierce and other colleagues

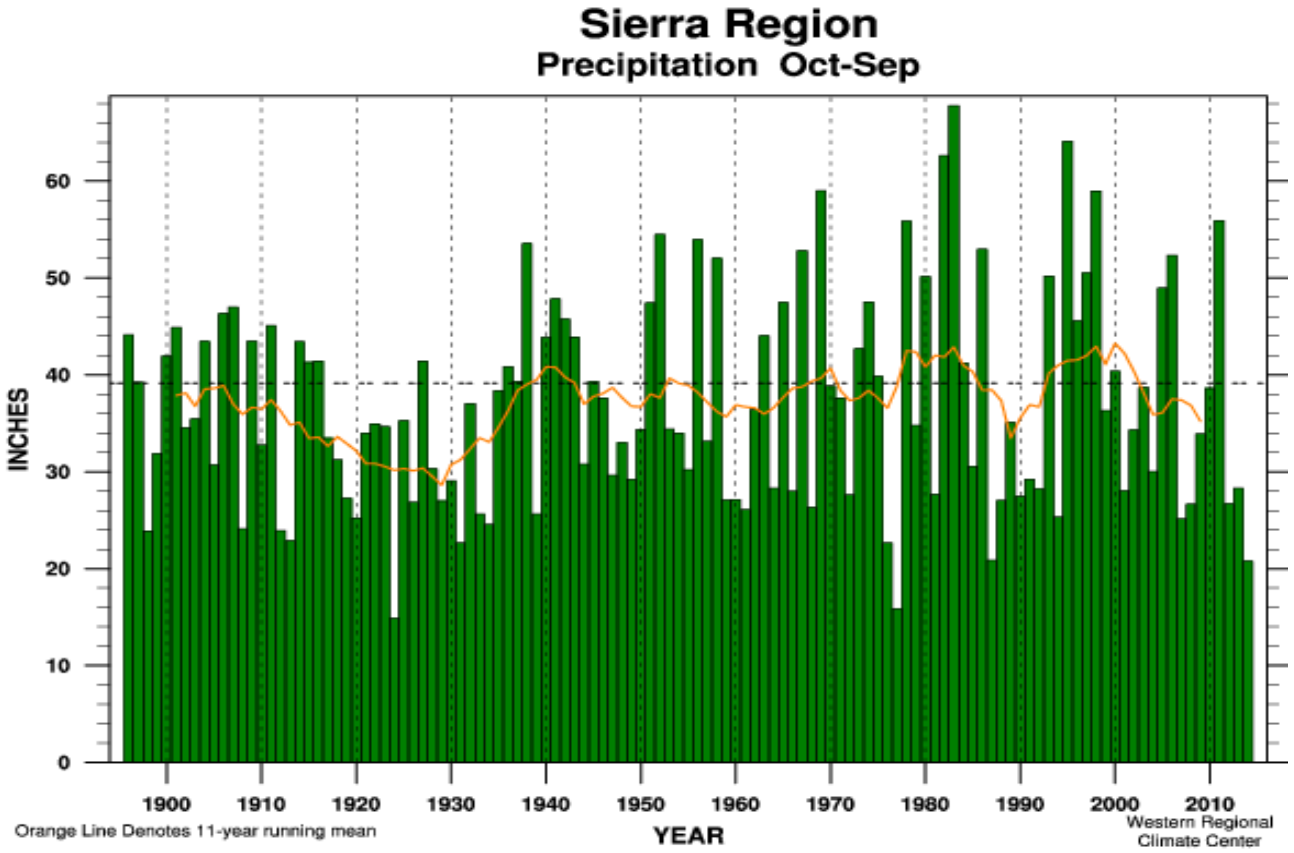
Sponsors:

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

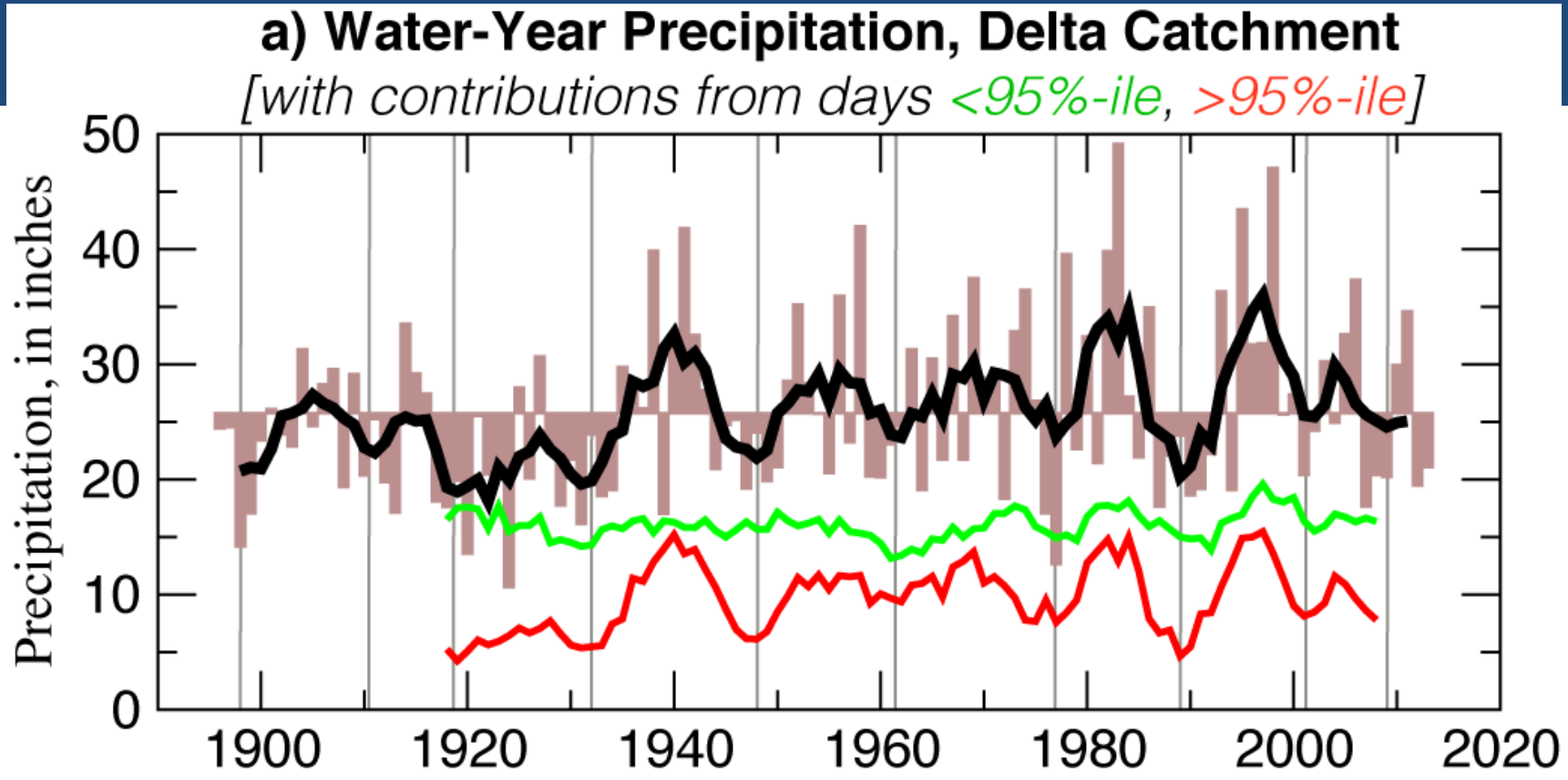
California has a narrow seasonal window to generate its annual water supply.

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

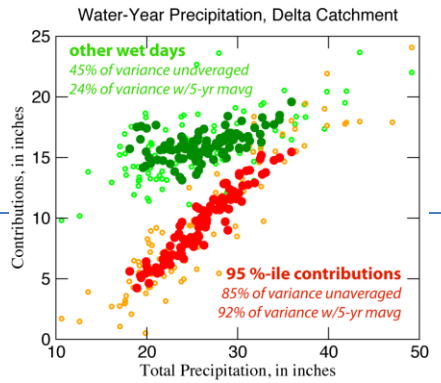
2014 ~55% of long term average

California Climate Tracker
Western Regional Climate Center

Highest Precipitation events dictate California Dry and Wet spells



R**2 = 92% (5-yr mavg)
= 85% (unfiltered)
R**2 = 24% (5-yr mavg)
= 45% (unfiltered)



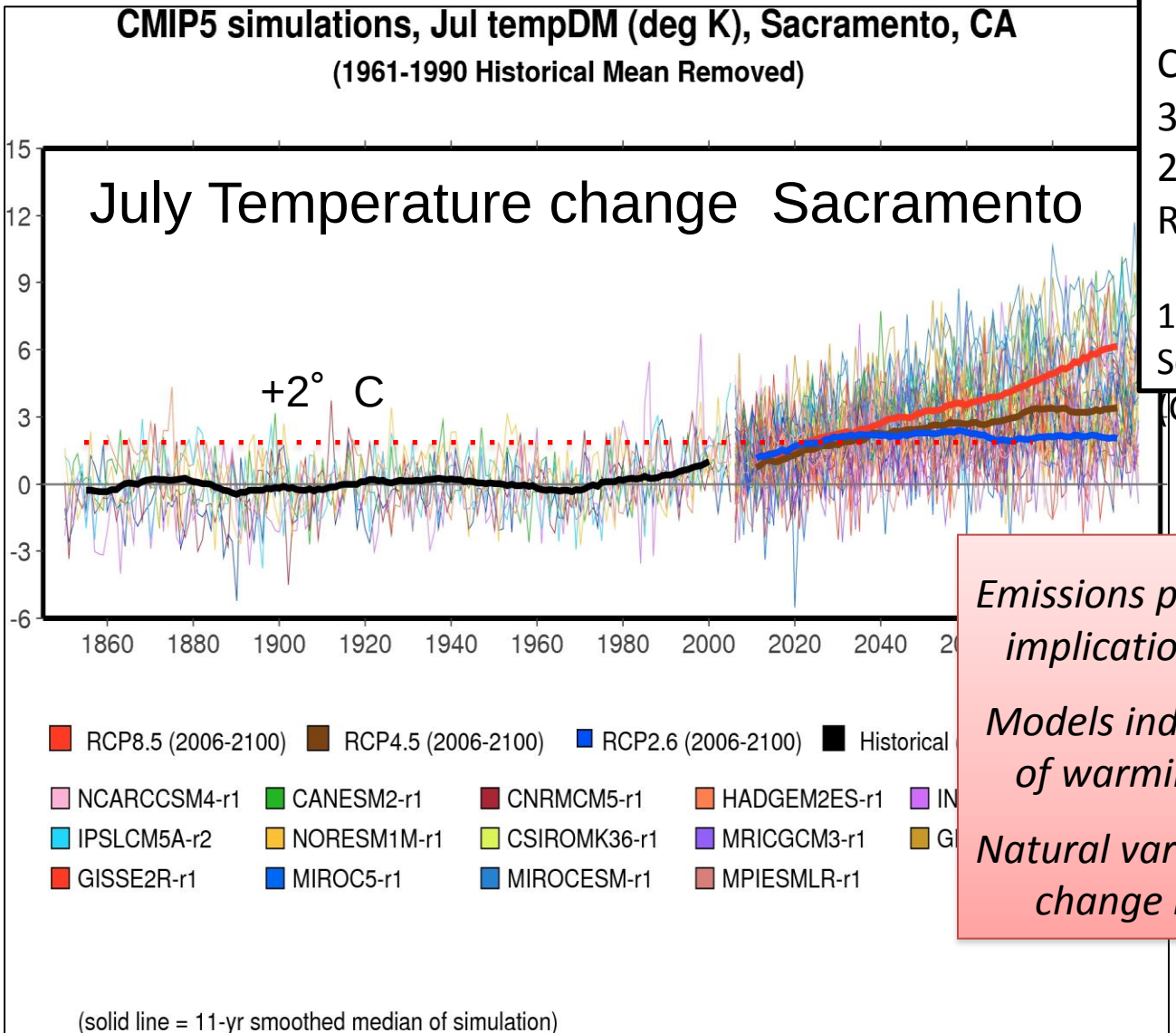
USGS science for a changing world

CNAP California-Nevada Climate Applications Program

Dettinger & Cayan, SFEWS, 2014

virtually all climate simulations project warming

a wide envelope, but substantial warming is projected



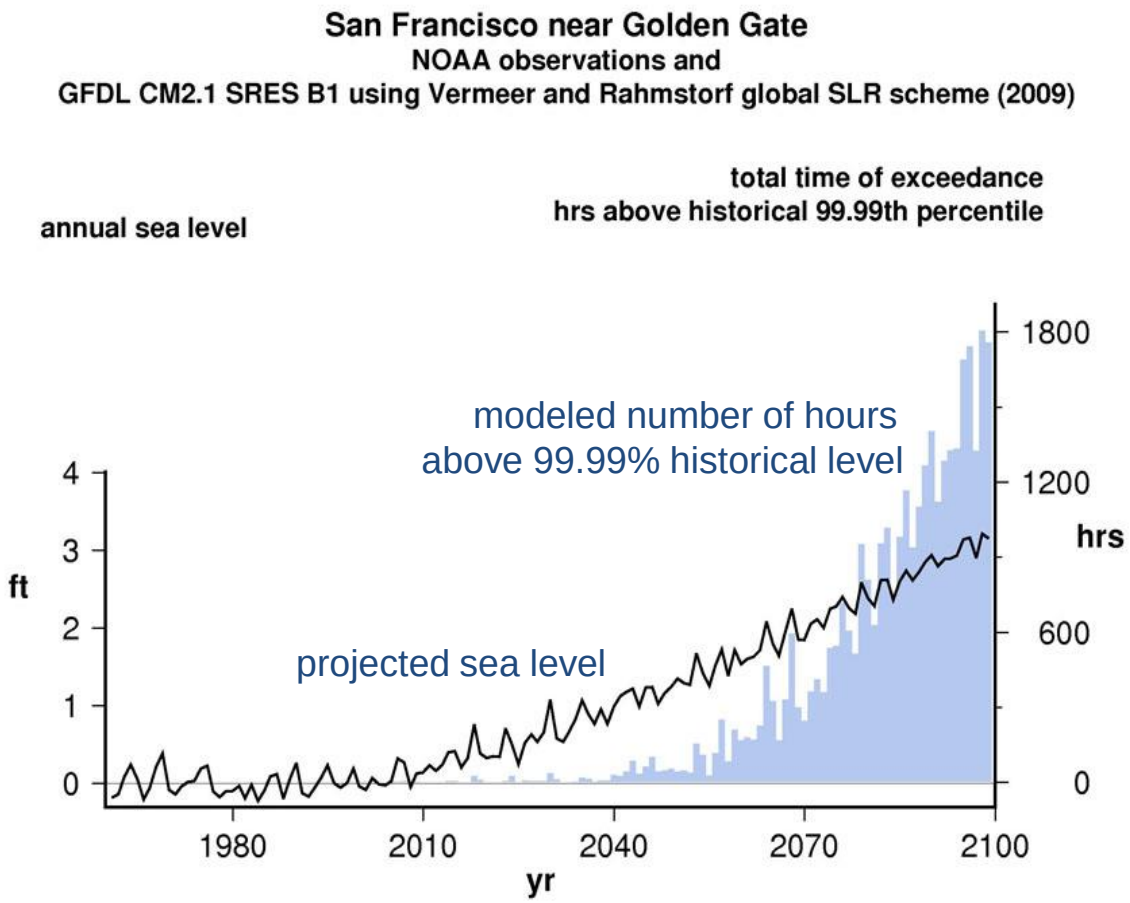
CMIP5 GCMs project +2-3.5° C summer warming by 2060, under mid and high RCPs

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

Emissions pathways matter, but greatest implications after mid-Century.

Models indicate summer amplification of warming.

Natural variation on top of climate change is substantial.



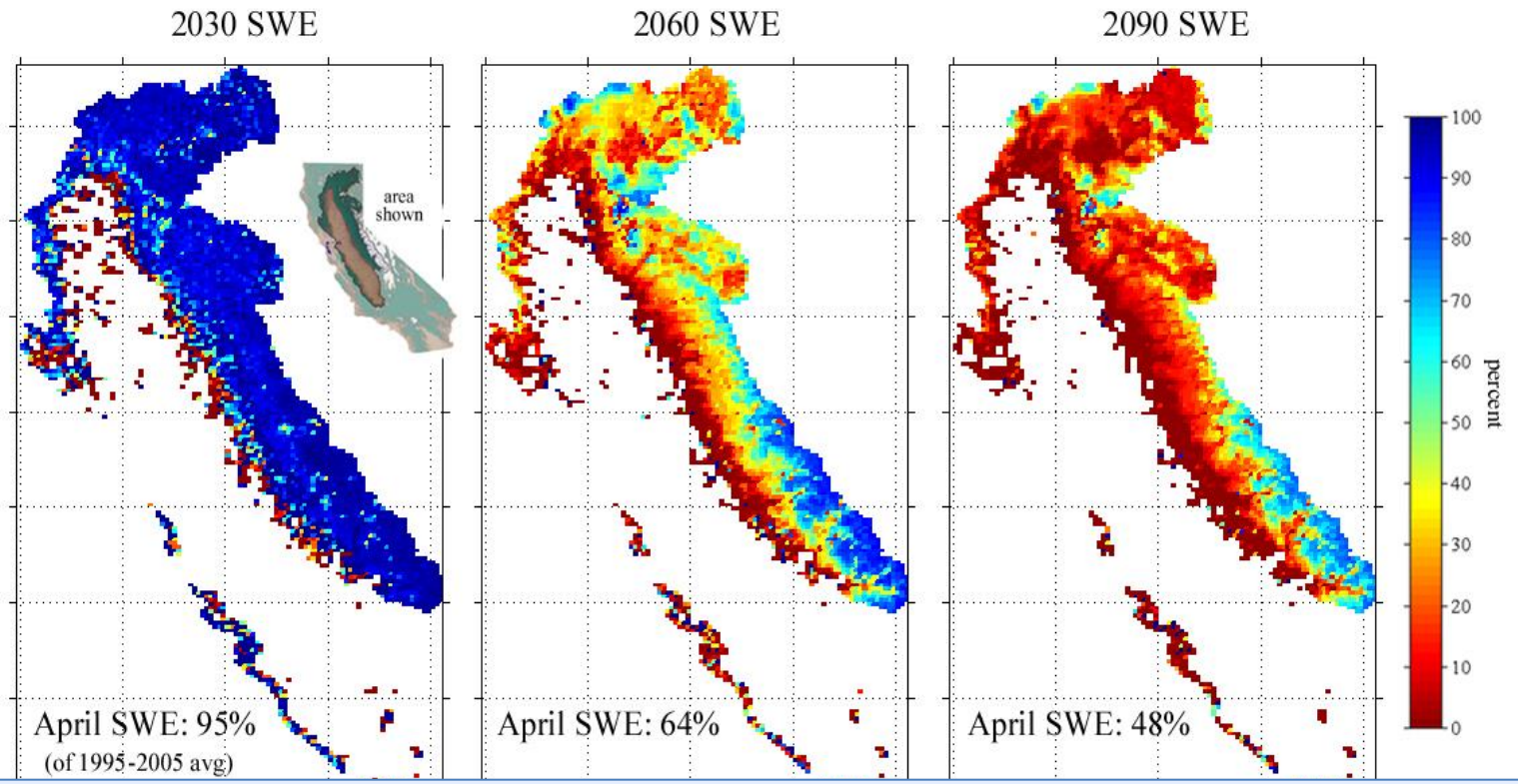
as mean sea level rises, projections indicate a marked increase in the likelihood of exceeding historical extreme levels

NRC West Coast SLR Study 2012

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.

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

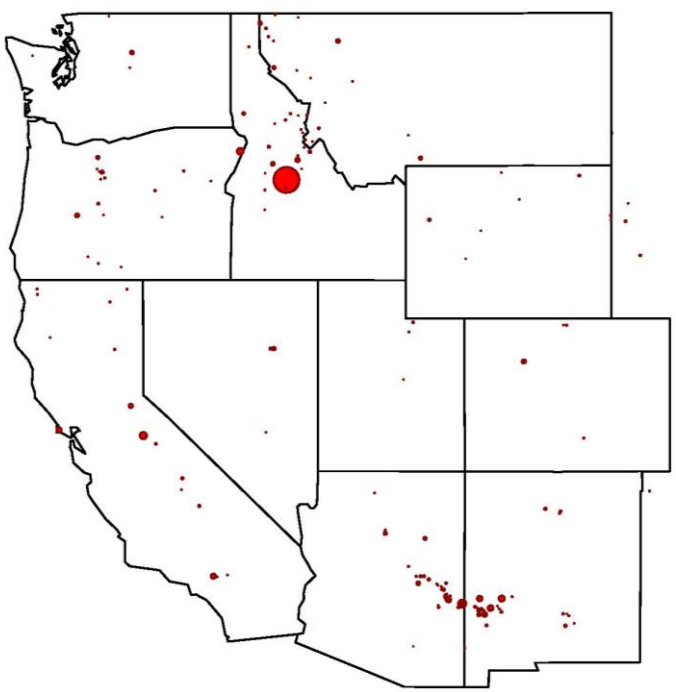
relative to previous 15 years, mostly forest fires, not shrubland fires

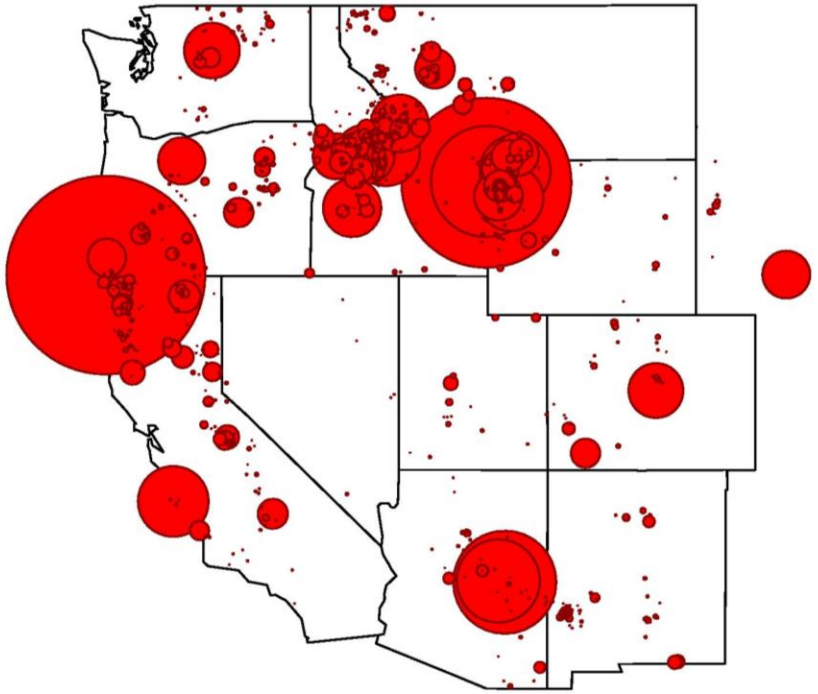
Anthony Westerling et al. *Science* August 2006

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

Delta Challenges

- **WARMER** air and water
- **LARGE FLOODS** Less snow, more rain => Higher floods and earlier run-off from traditionally snow-fed watersheds
- **DROUGHT** in an increasingly warmer climate
- **SEA LEVEL RISE** Increasing Salinity, heightened water levels
- **LESS STORED WATER** lower snow pack, potentially lower reservoir levels
- **CHANGES ARE NOT GRADUAL** because natural variation adds (or subtracts) secular climate change

Climate change, if projections are realistic, 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, ,overall wet days but more intense heavy precipitation events, loss of spring snow pack, increased wildfire threat, more winter floods, Sea Level Rise.