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California climate change, on top of already high climate variability

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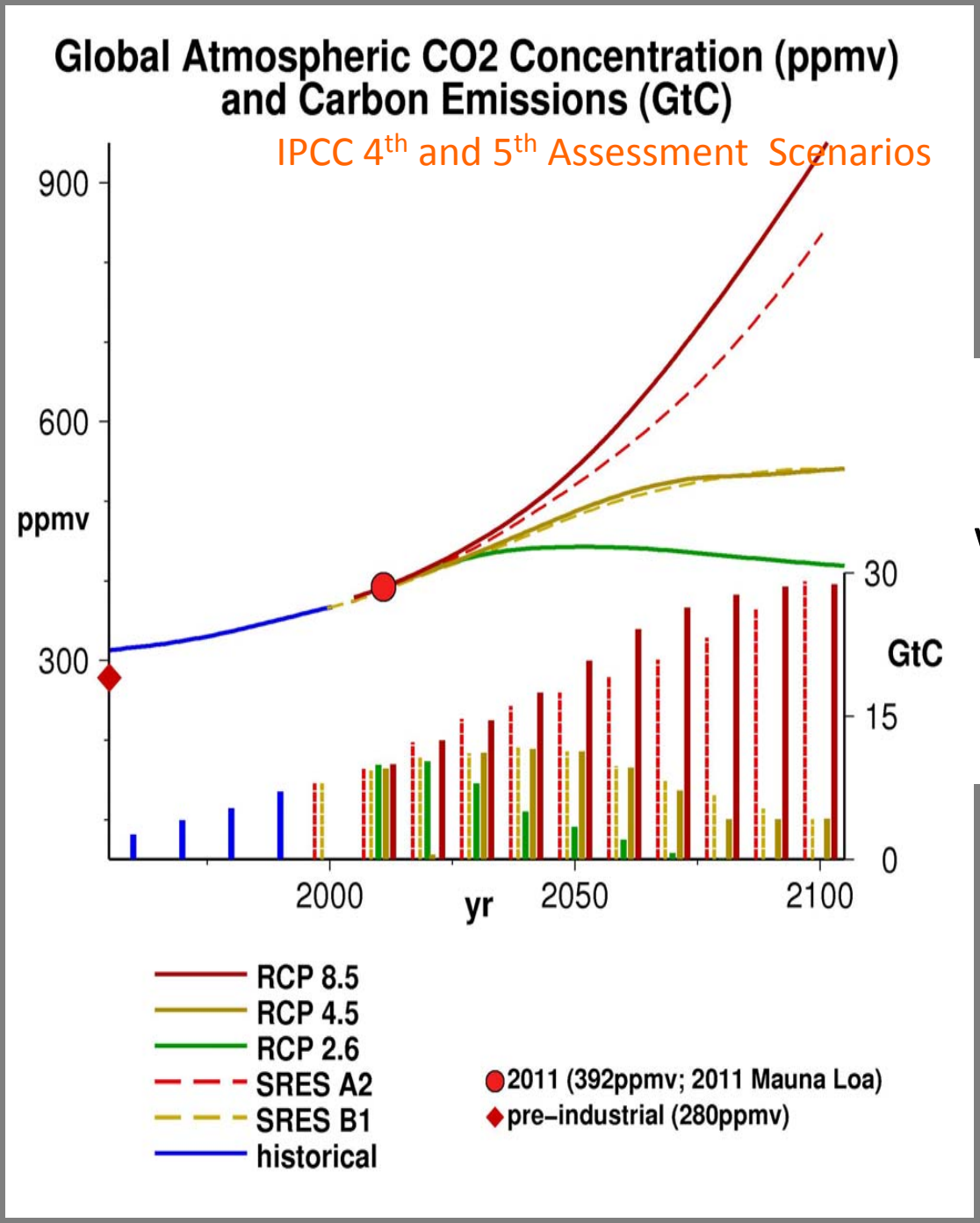
much support from Mary Tyree, Mike Dettinger and other colleagues

Sponsors:

California Energy Commission

NOAA RISA program

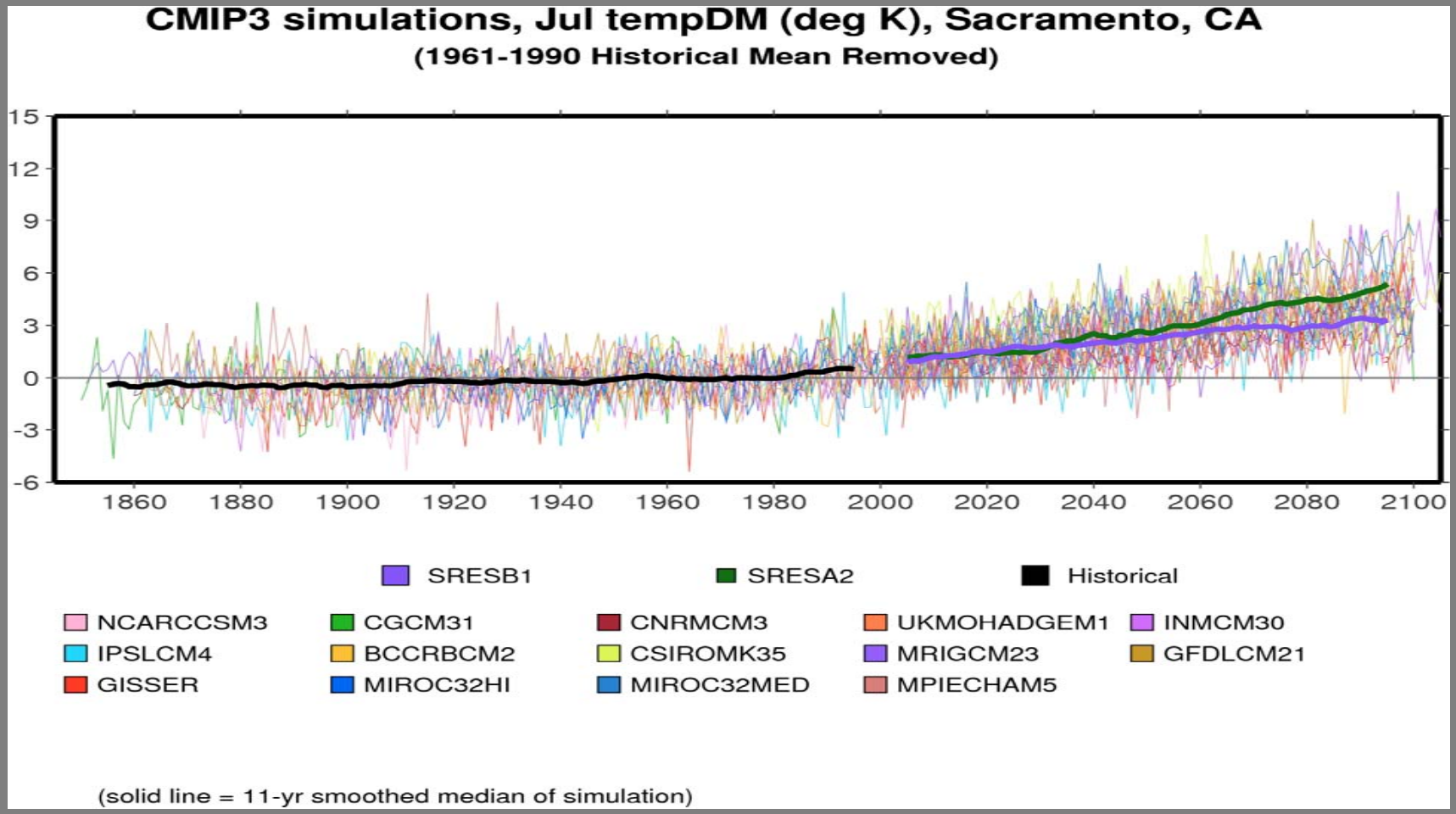
California DWR, DOE, NSF



different greenhouse gas emissions trajectories would have enormous impacts on climate in future decades

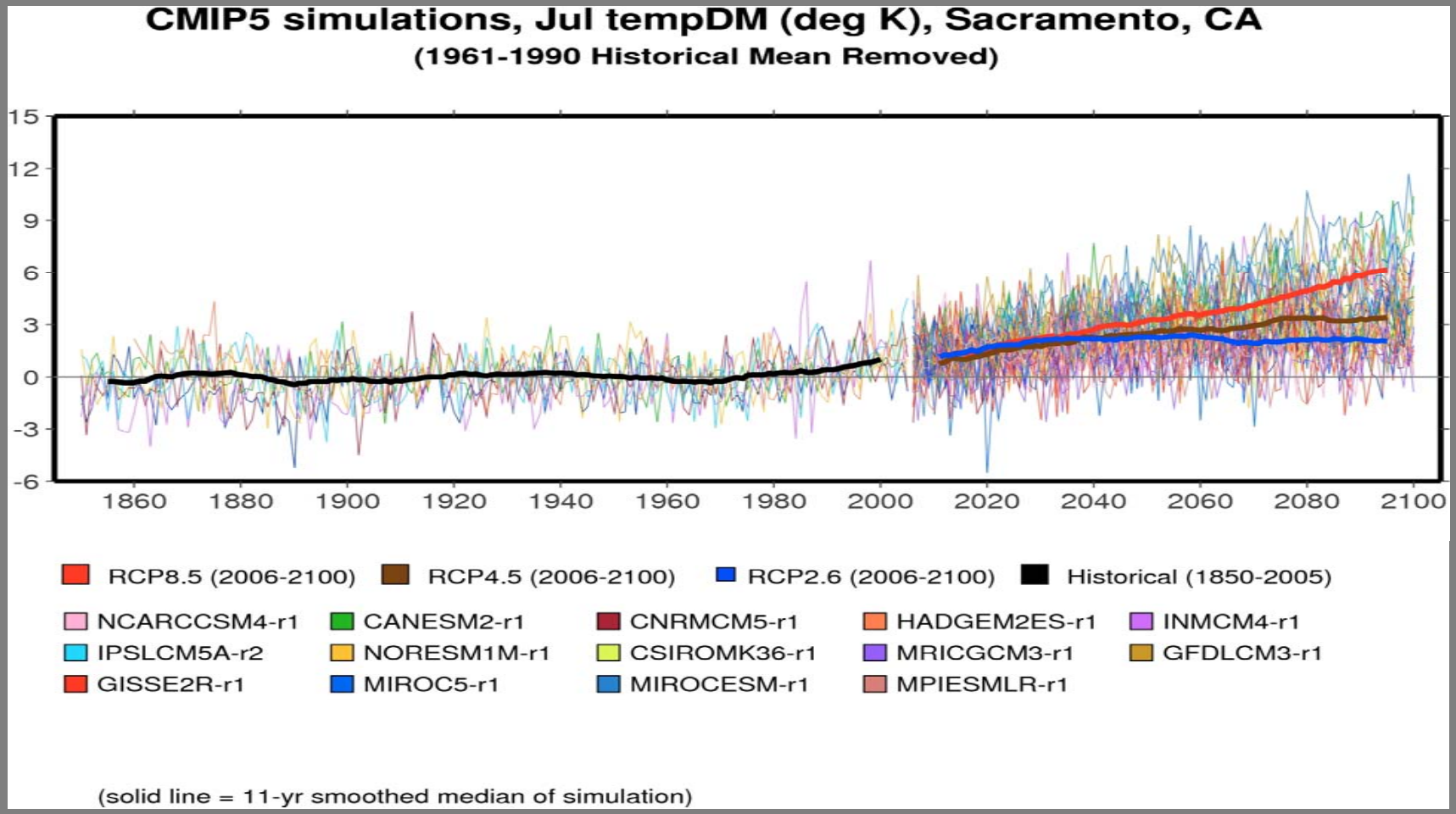
Temperature Change 14 GCMs X 2 Emissions Scenarios

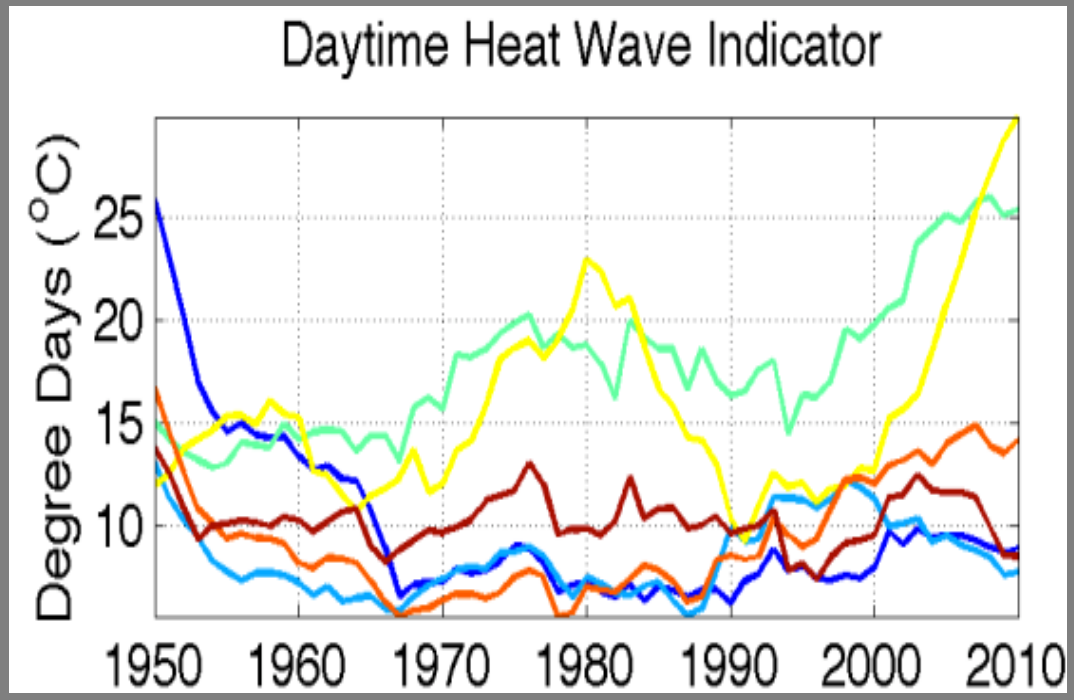
IPCC 4th Assessment models

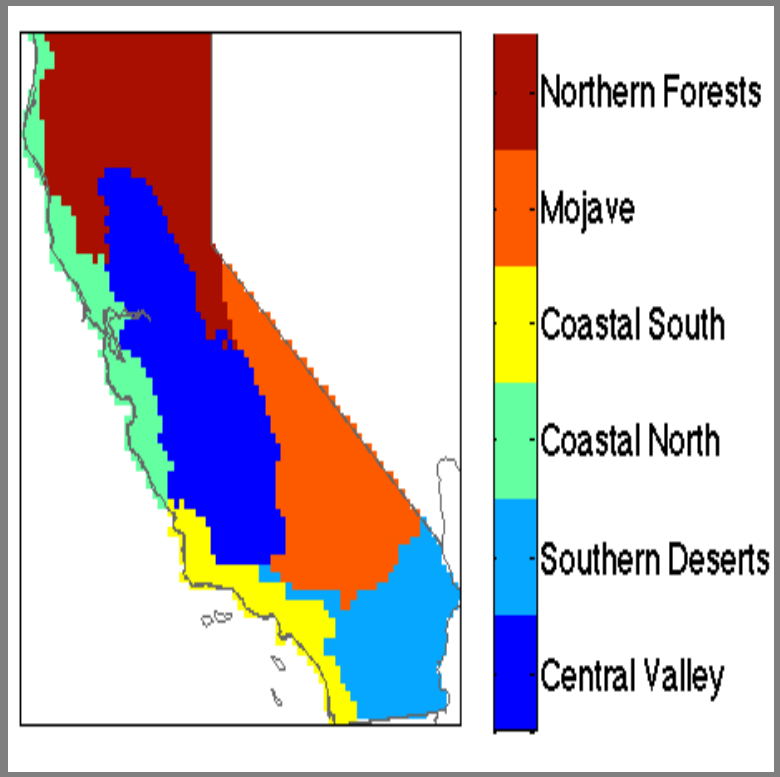


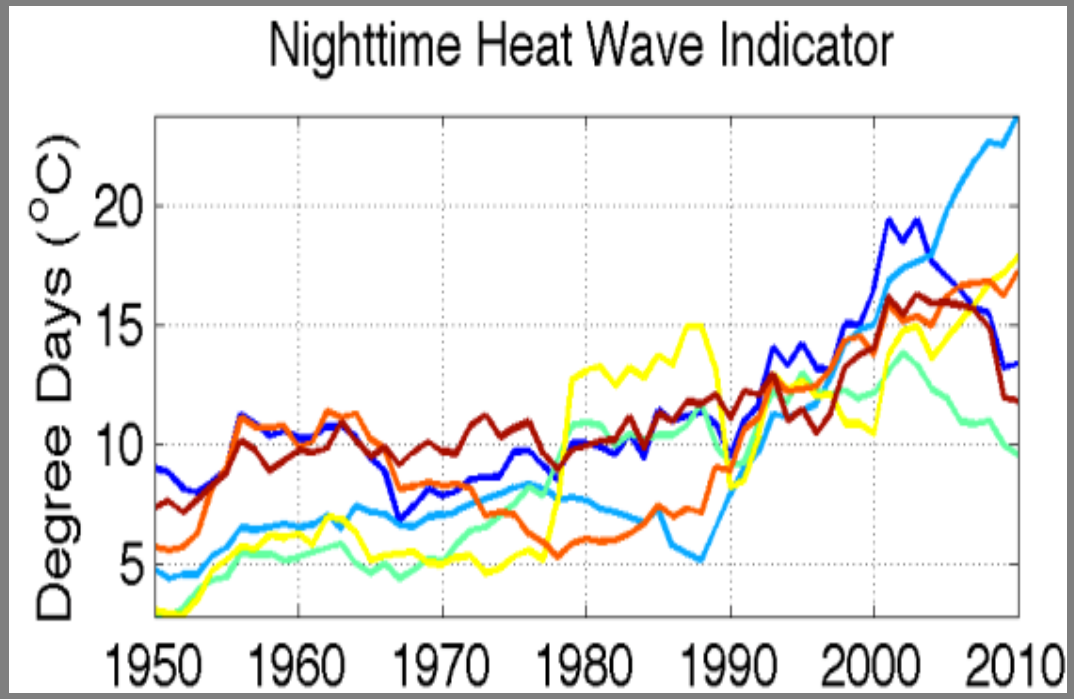
Temperature Change 14 GCMs X 3 new Emissions Scenarios

IPCC 5th Assessment models









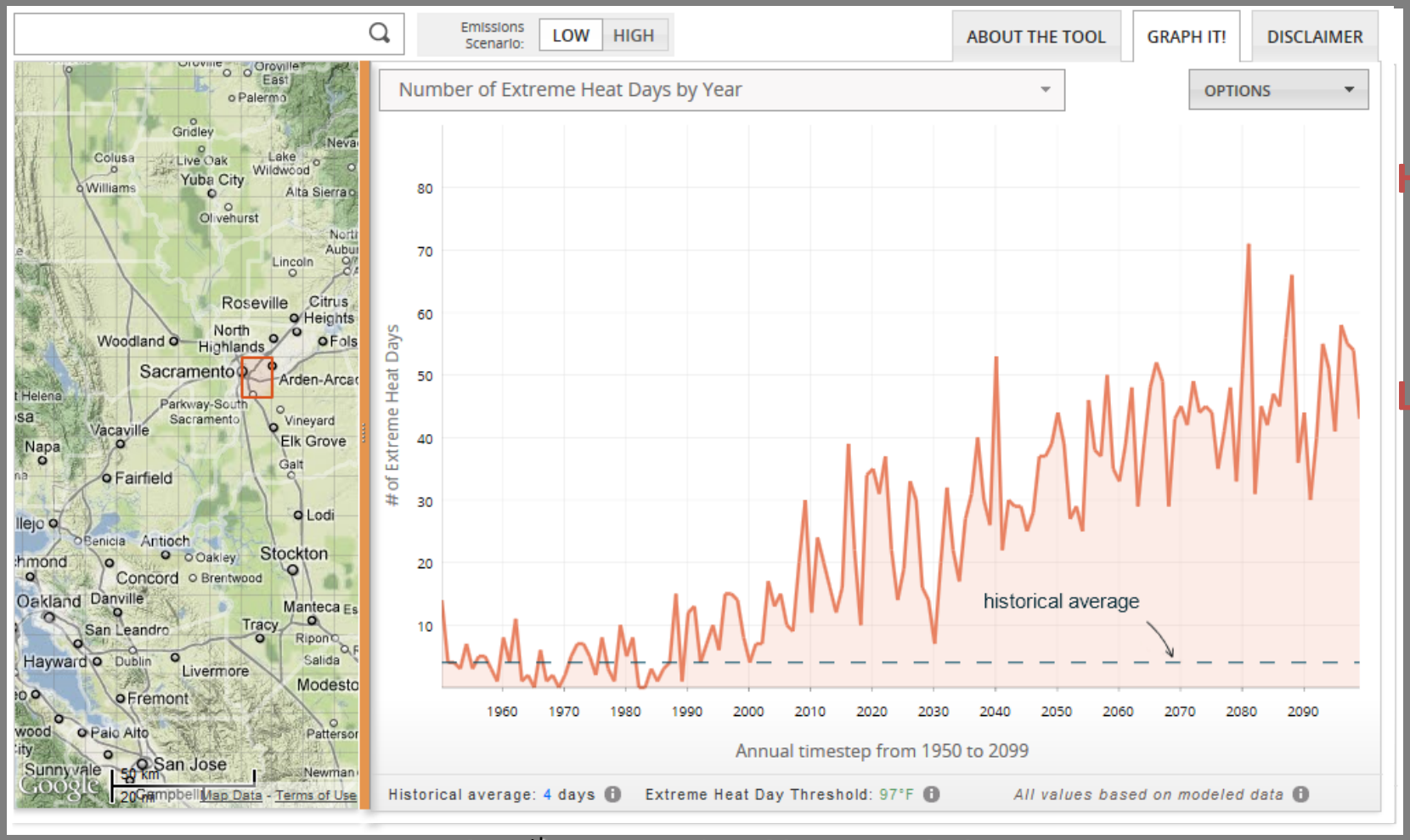
California Heat Waves

with extreme *night-time* temps observed to have increased over last 2 decades

A. Gershunov and K. Guirguis, GRL in review

Number of Extreme Heat Days*

Projections Depend Strongly on Emissions Scenarios



Higher

Lower

Cal-adapt

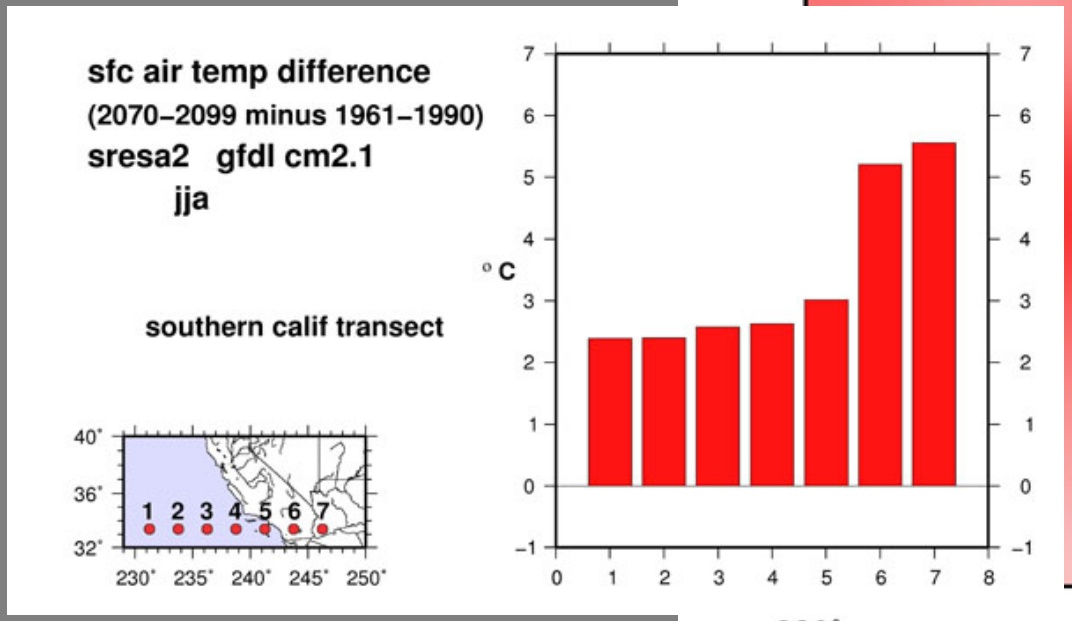
Source: http://cal-adapt.org

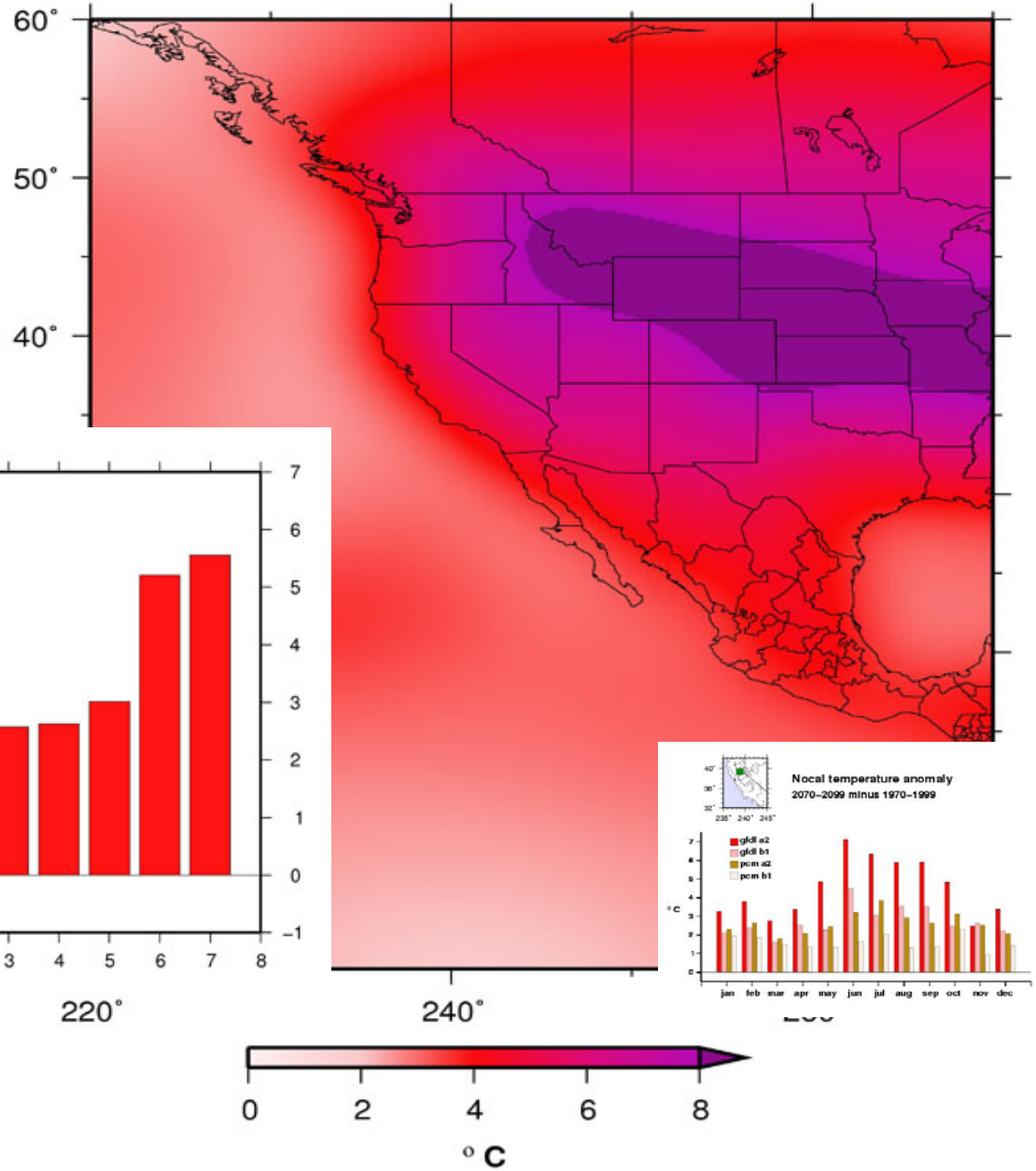
* 98th Percentile of historic daily maximum temperature between 1960-1991 for the given location (Sacramento)

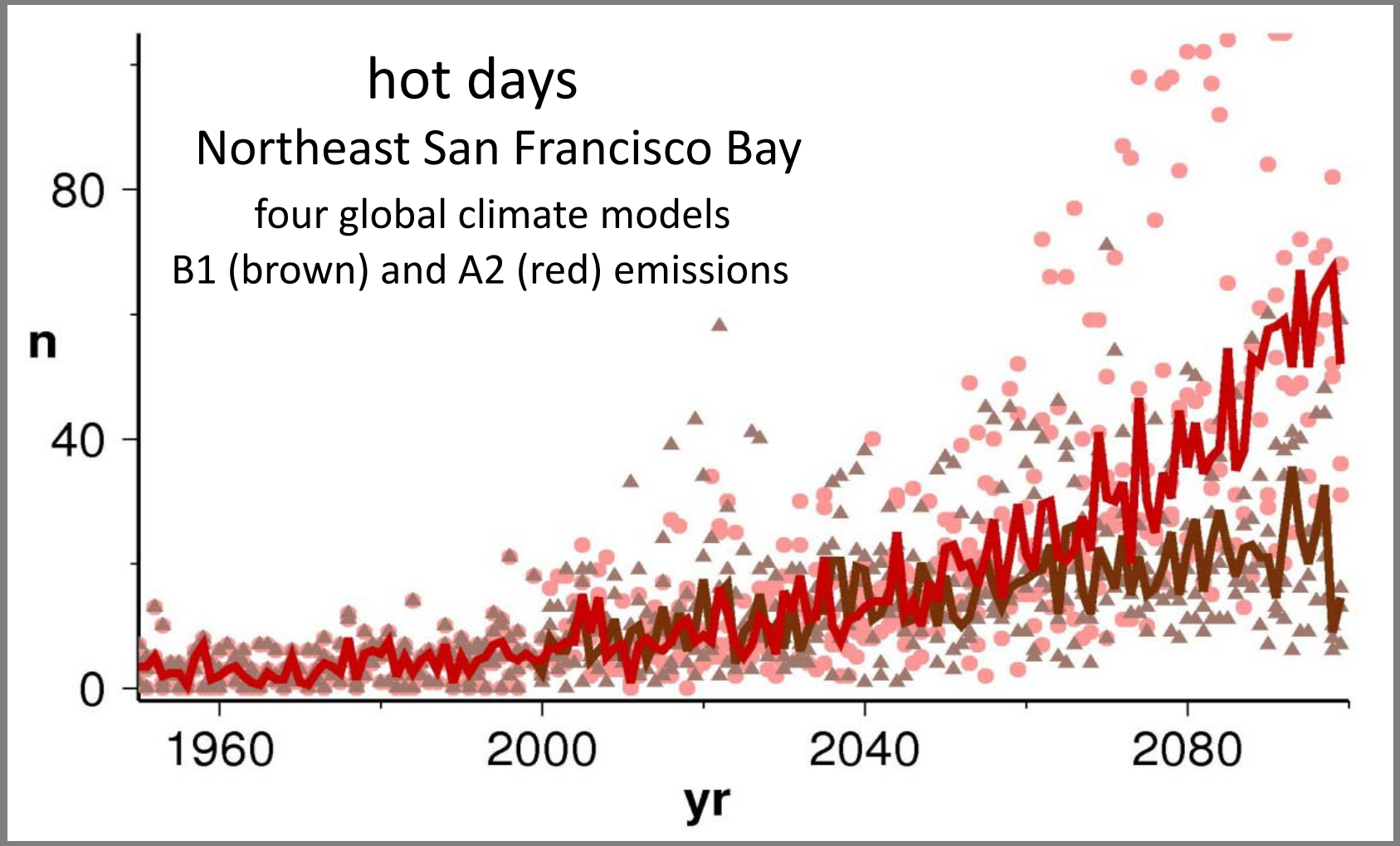
Climate models project ocean warming by end of century of 1.5-2.C greater warming on land than oceans would amplify thermal gradient across California coast-interior

Summer land warming is accentuated

GFDL CM2.1 Jun-Aug air temp change
2070-2099 minus 1961-1990



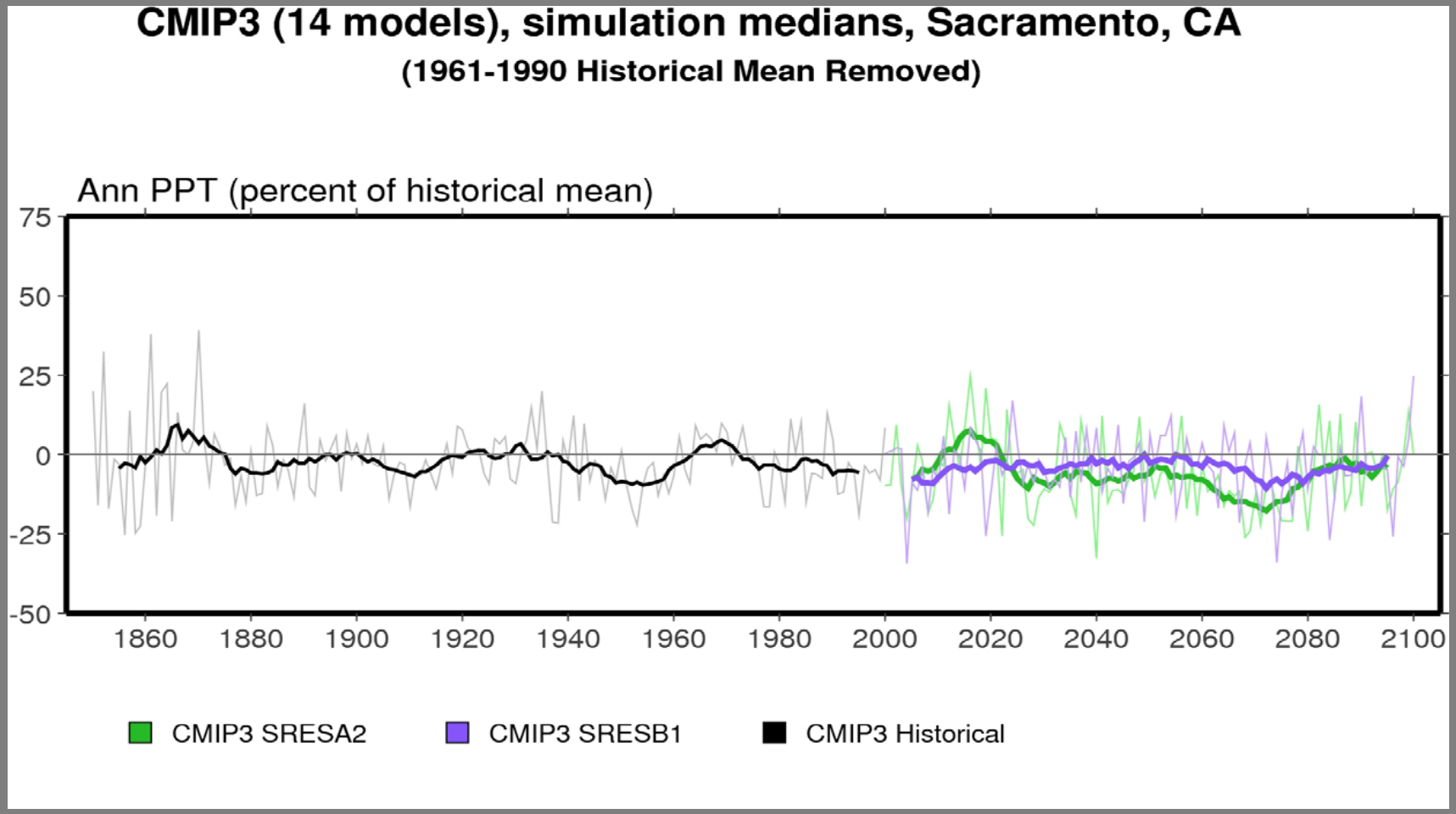




Number of days (n), April–October, when maximum temperature (Tmax) exceeds the 98th percentile historical (1961–1990) level of 28°C (82.4°F) for the northeast bay from four BCCA downscaled GCMs. Brown carrots and red dots show n for B1 and A2 emission scenarios, respectively. Thick brown (B1) and red (A2) lines show median value from the four simulations.

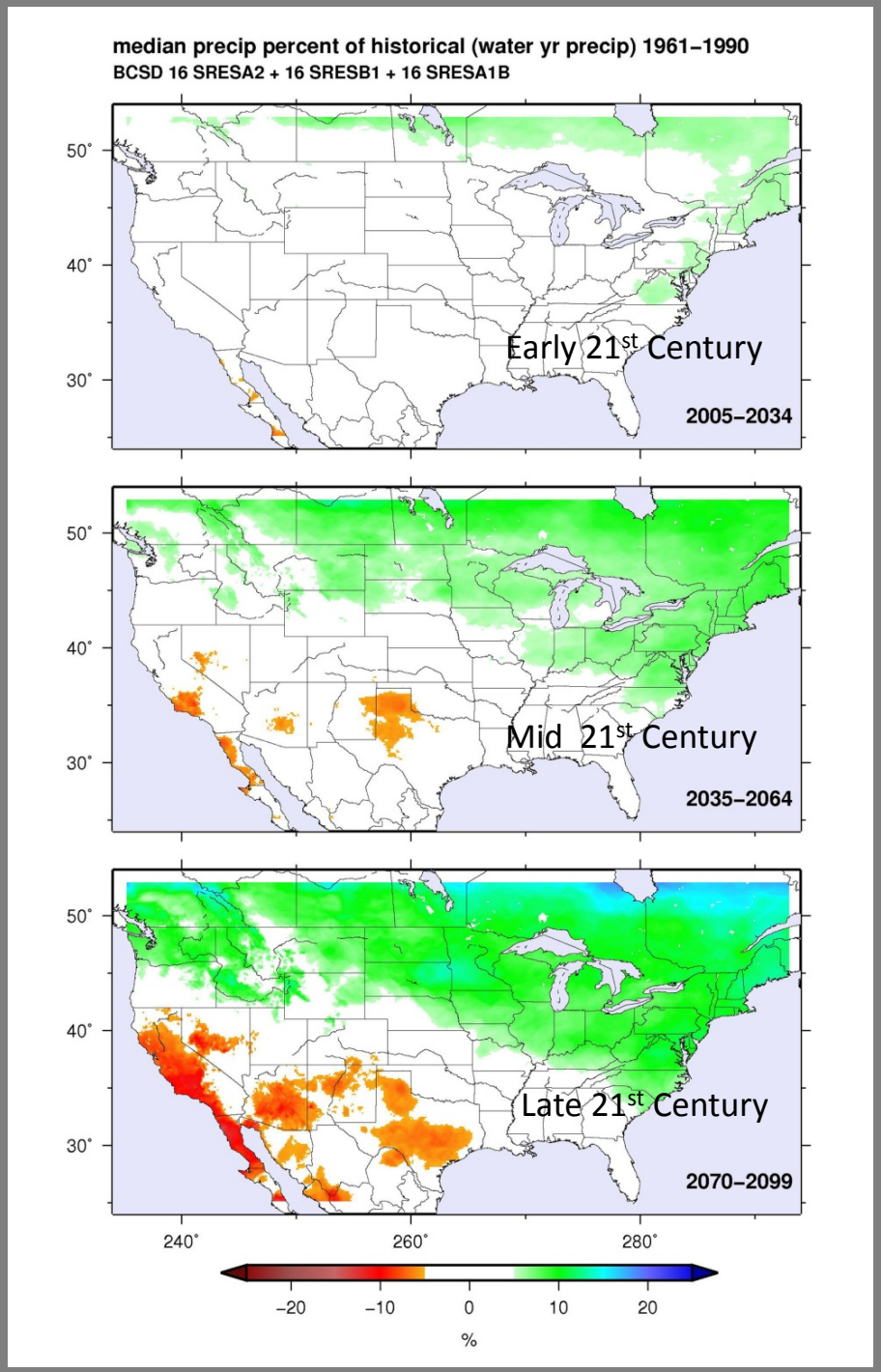
Precipitation Change 14 GCMs X 2 Emissions Scenarios

IPCC 4th Assessment models



A tendency toward
drying in the Southwest,
especially Southern California
develops over the 21st Century.

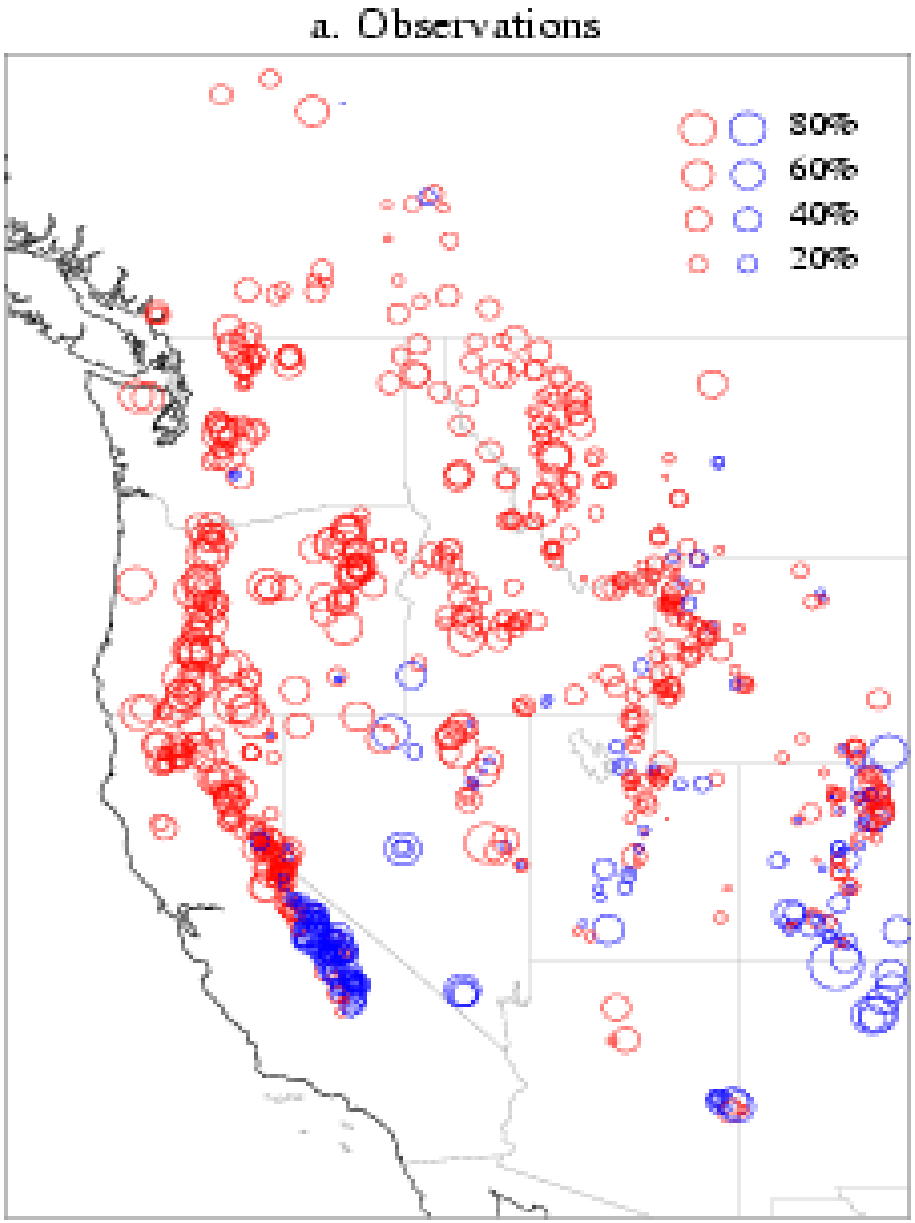
Drying becomes greater
as climate becomes warmer



from 48 climate model projections
downscaled to 12km using BCSD

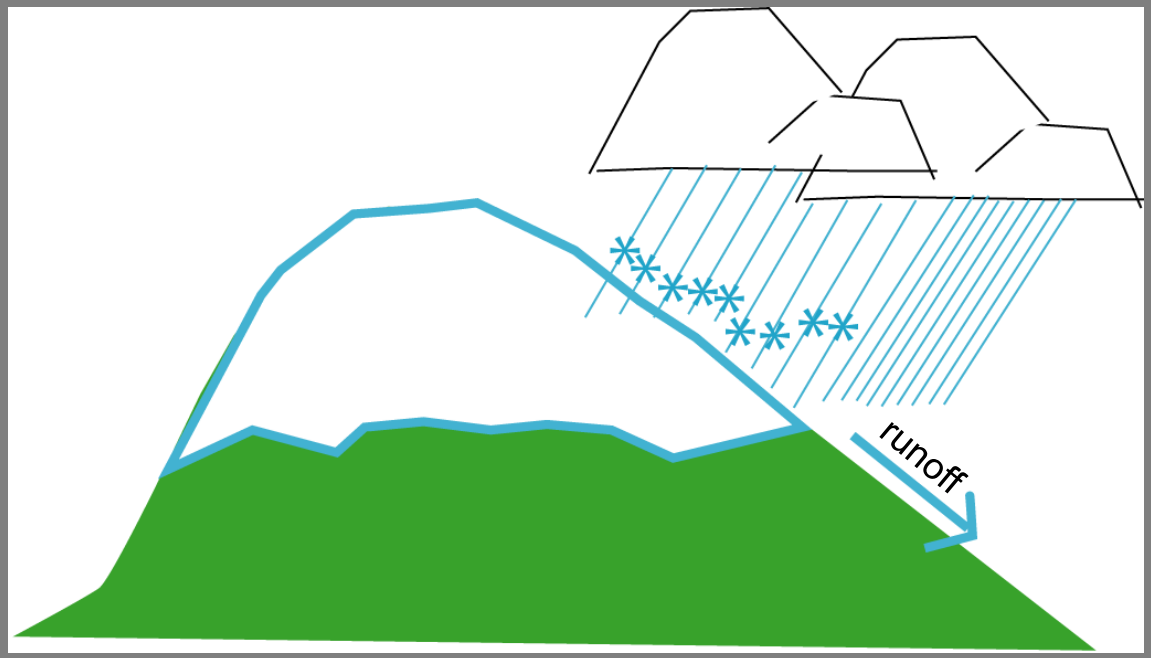
Trends
April 1 Snow Water Equivalent
1950-1997

Spring Snowpack has declined since 1950, mostly because of warmer winters and springs

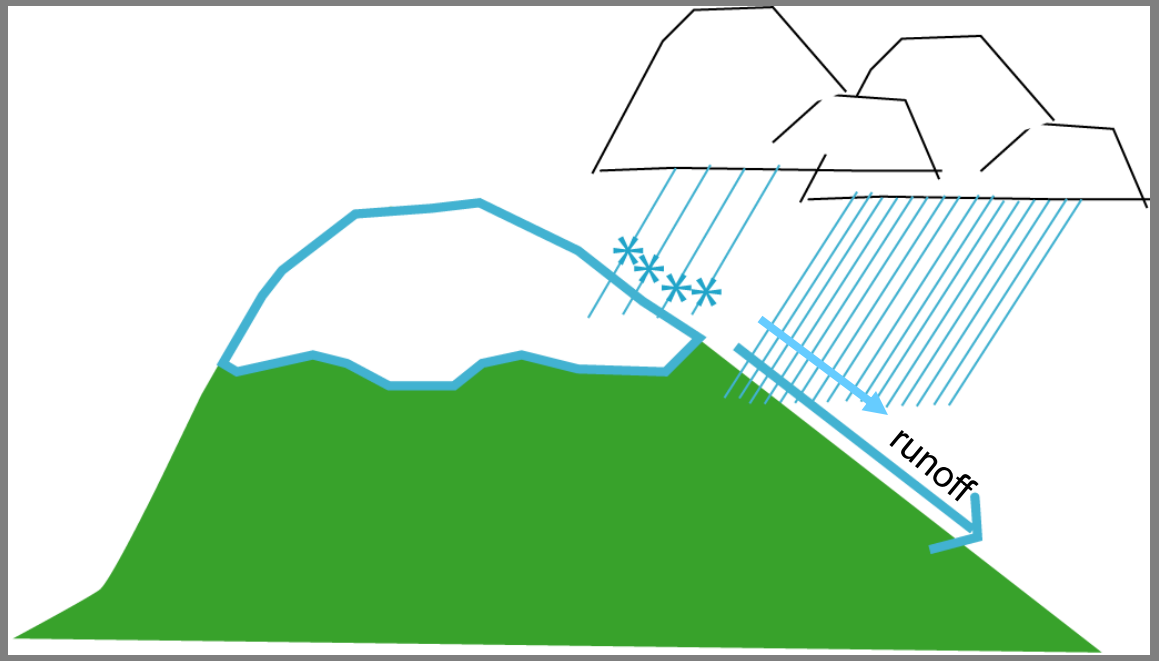


Source: Phil Mote et al. (2004) (university of Washington

historically:
"Cool" storms contribute immediate runoff from smaller areas of the river basin (the rest goes into snowpack for later)

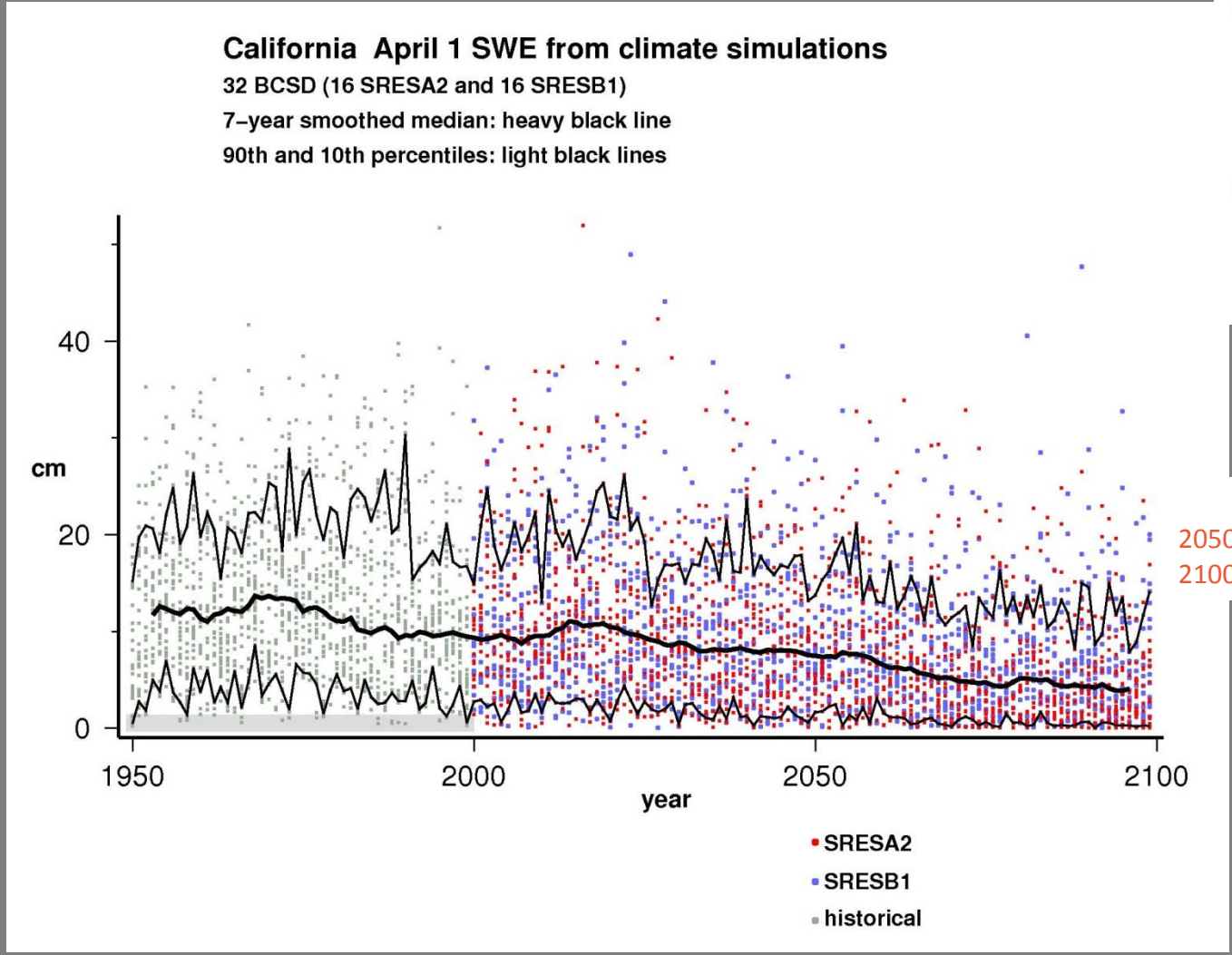


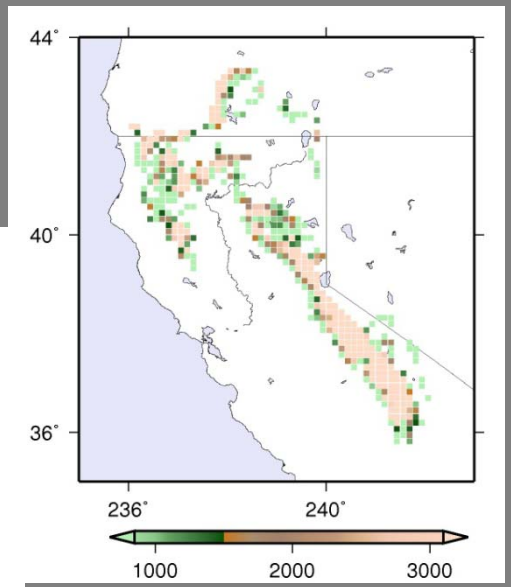
In a warmer climate:
Warm storms contribute immediate runoff from larger areas of the river basin



but change in snow water projected for Sierra Nevada+ is substantial

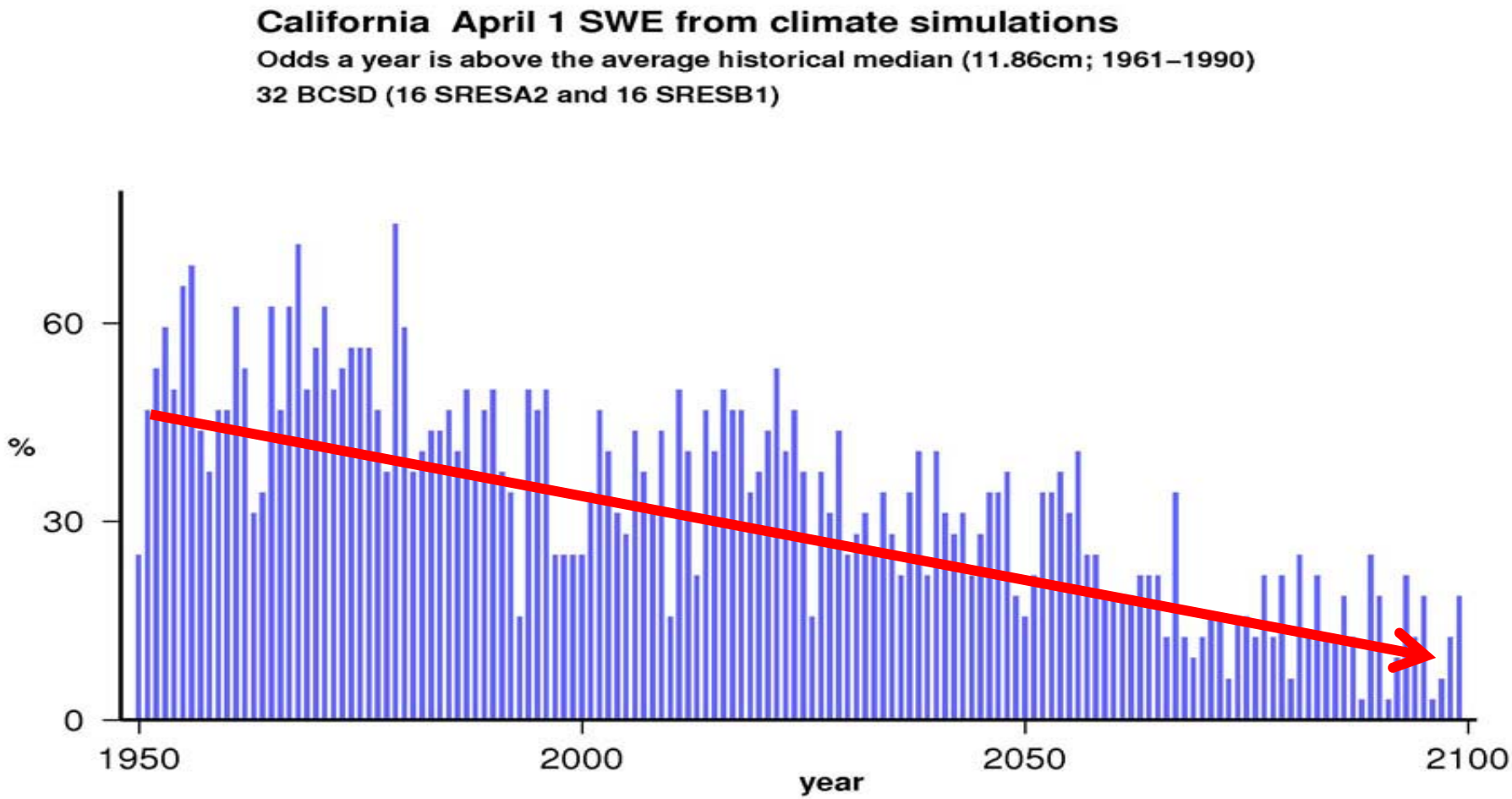
16 GCMs, A2 and B1 emissions scenarios





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

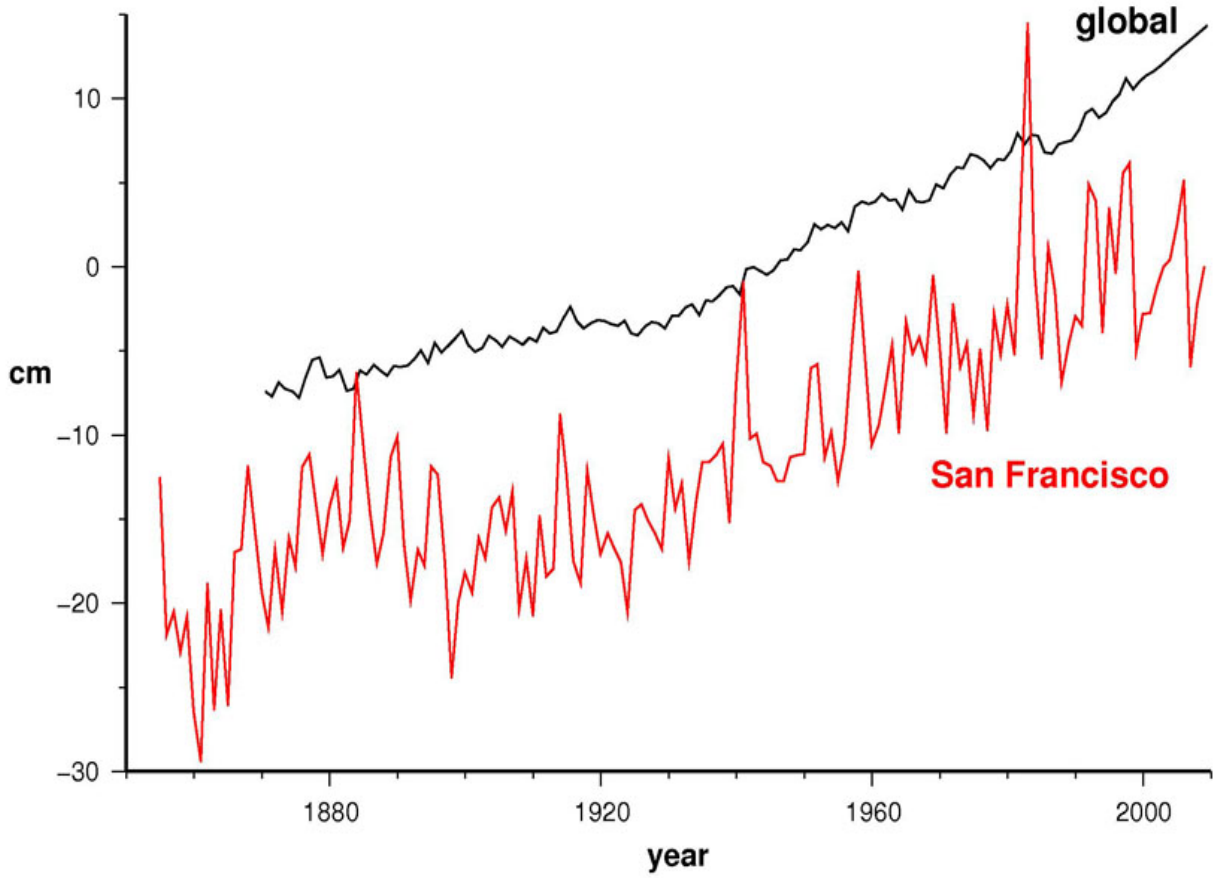
Declining odds of median or higher snowpack



Source: Cayan et al. (2011)

during high sea levels, the sea is often *not* quiescent

San Francisco sea level and global estimated sea level rise



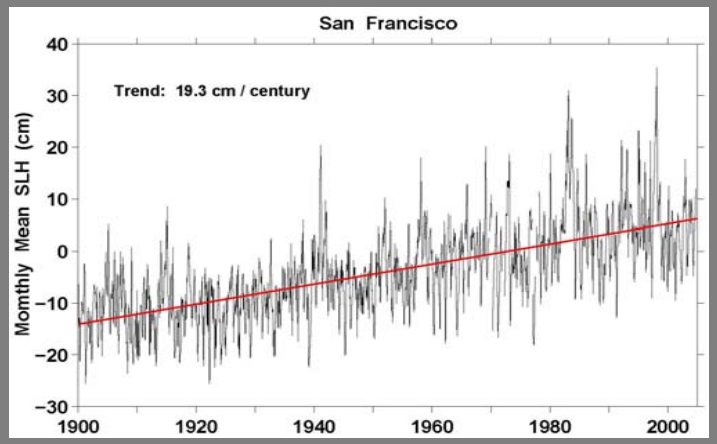
global: 1871–2002 from Church and White (2006); 2003–2009 3.4mm/yr (WMO, 2009)
San Francisco: NOAA tides MSL datum 1983–2001 2.773m
MSL datum 1960–1978 2.713m

rise of sea level along California coast has followed closely the Estimated global SLR rate

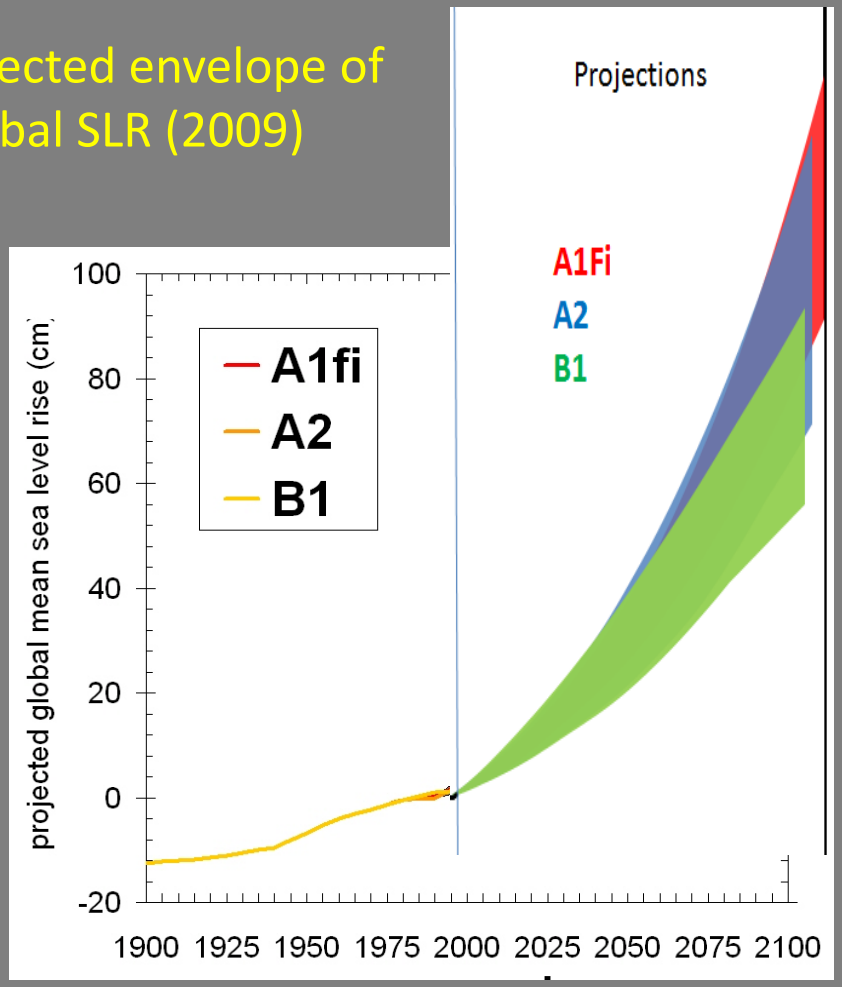
recent two decades have not seen much rise along California coast however

Observed SFO (left) and modeled Global (right). Sea level rise estimates based upon an envelope of output from several GHG emission scenarios

observed



Projected envelope of global SLR (2009)



Climate models only provide loose guidance on the amount of sea level rise—full physics models are still under development.

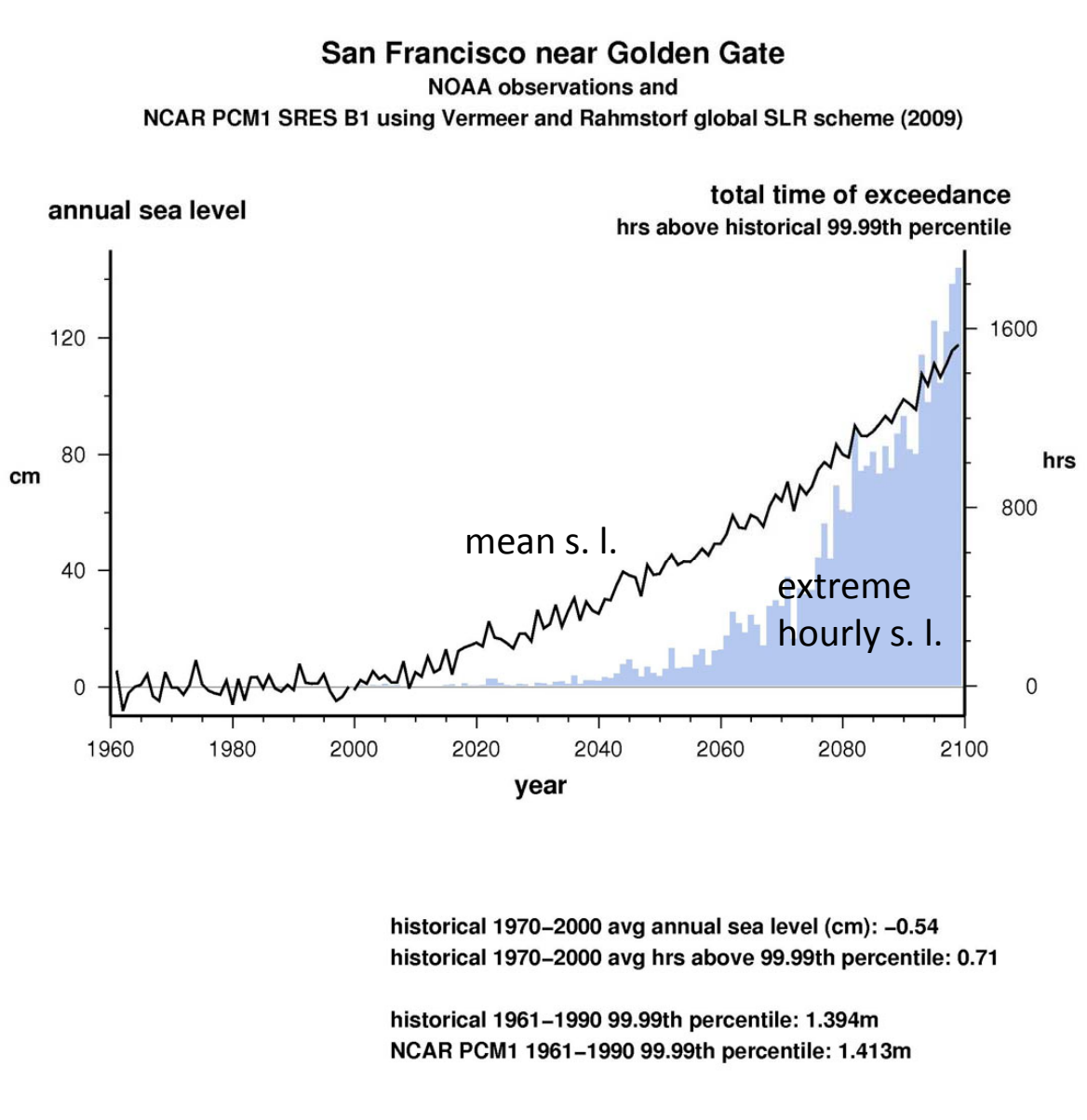
But it is quite likely that rates will increase greatly in future decades

INCREASING SEA LEVEL EXCEEDENCES

As mean sea level rises the frequency and magnitude of extremes would increase markedly. Under plausible rates of sea level rise, an event which in present day occurs less than once per year occurs scores of times per year by mid 21st Century and becomes commonplace by end of 21st Century.

Importantly the duration of extremes becomes longer, so exposure to waves is considerably greater.

ncar pcm1 sresb1 v&r



Cloern et al. 2011 PLOS ONE

Summary

Warming is already underway and considerably more is projected.

Recent IPCC model projections for California precipitation are scattered, but *several* simulations show moderate drying in Southern California as tends to be characteristic of Mediterranean regions globally.

Wildfire could become a larger threat.

Climate warming projections, combined with recent global sea level rise estimates suggest increases in California open coast sea levels of 0.5m to more than 1.5m by 2100. Tides, weather, short period climate will exacerbate SLR impacts.

Although some model simulations yield drier conditions in California over the next century, large storms likely to occur at about historical recurrence intervals.

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