Hydropower Workshop Washington, DC 1/28/2010

Climate Change Implications upon water resources In the western United States

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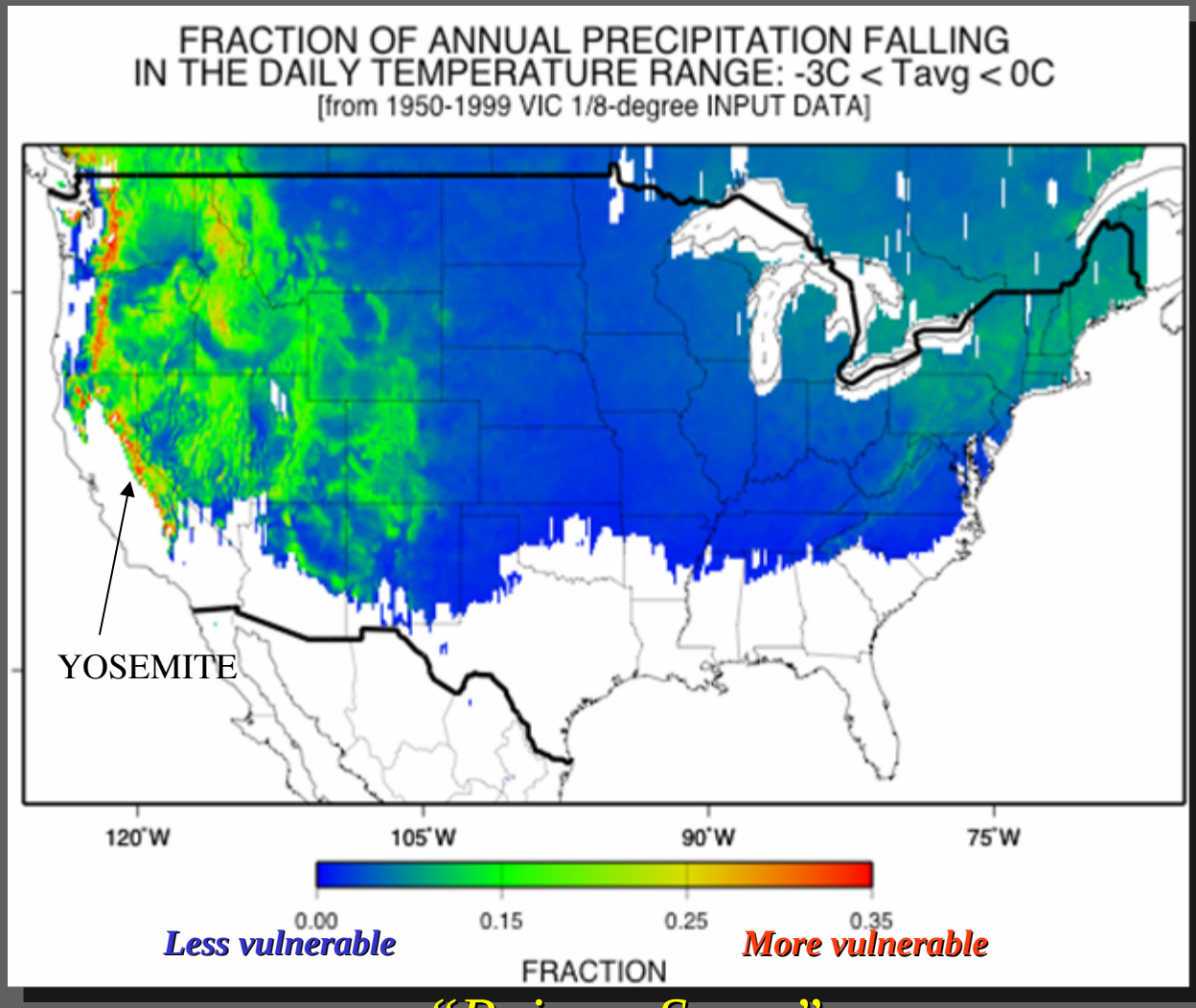
sponsors:

California Energy Commission PIER program
NOAA OGP RISA element

http://meteora.ucsd.edu/cap

SENSITIVITY TO A +3ºC WARMING…

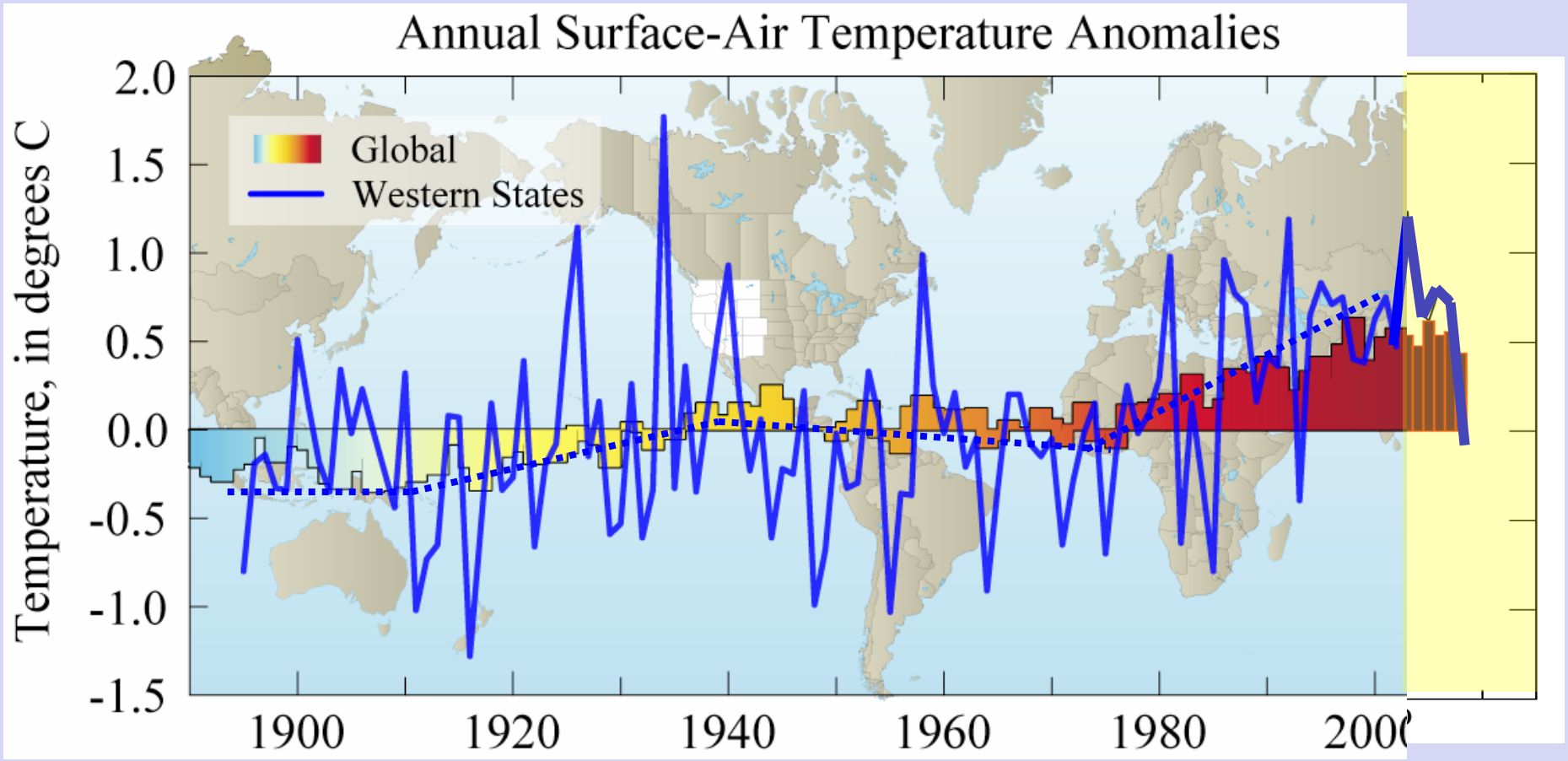
What fraction of each year's precipitation historically fell on days with average temperatures just below freezing?



"Rain vs Snow"

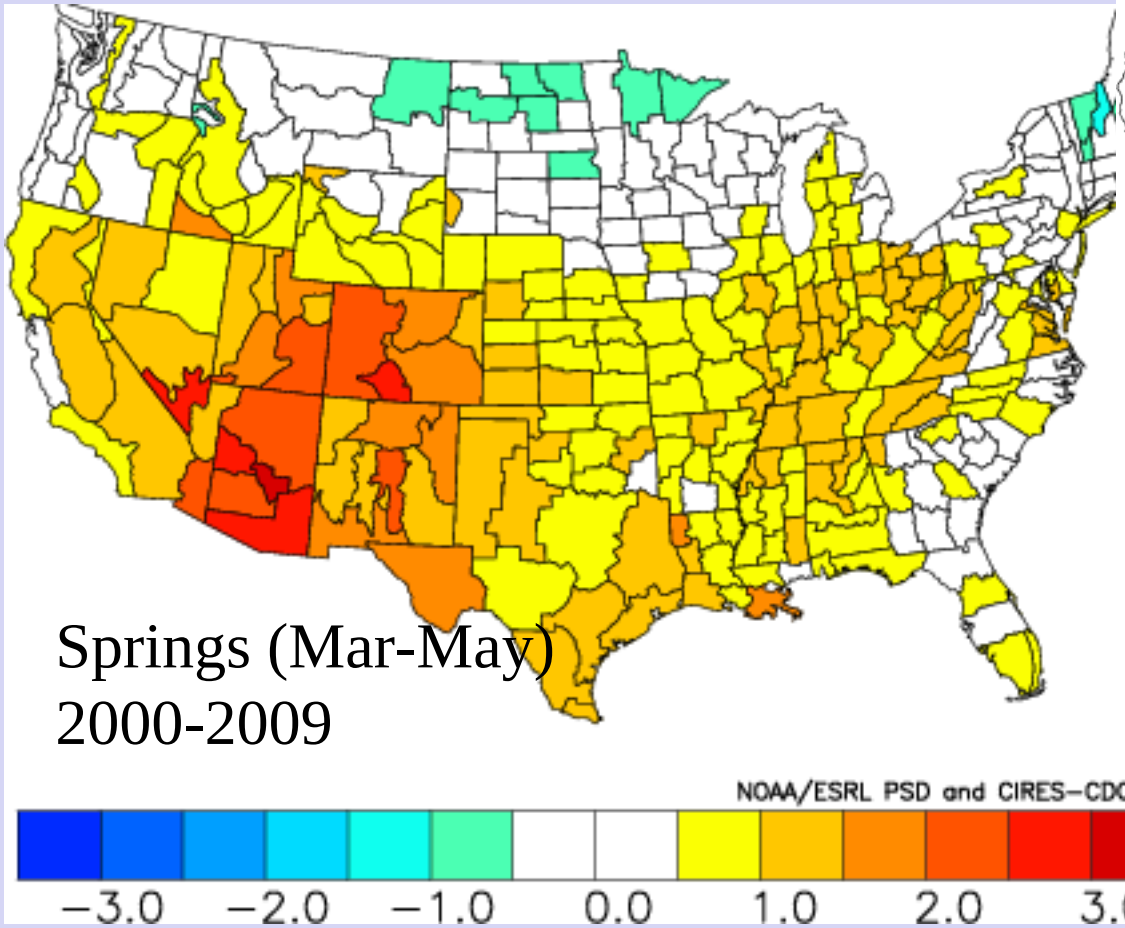
Computed by Mike Dettinger from gridded historical US weather data (from Bates et al, in rev)

During recent history, temperature changes in the western U.S. have tracked those in global temperature

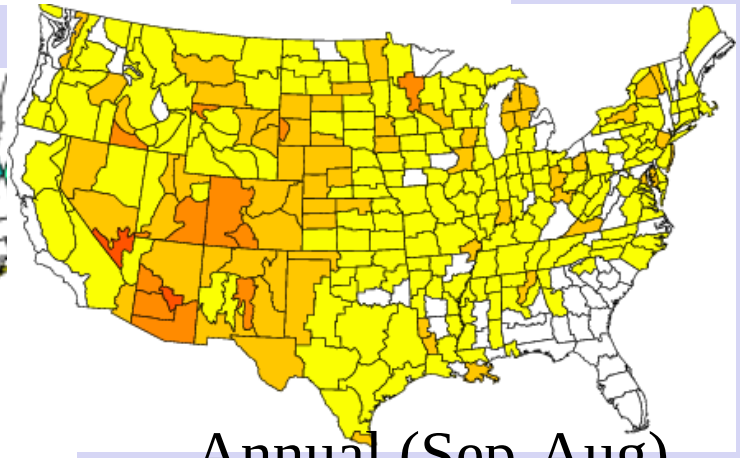


Here is the pattern of warming since 2000.

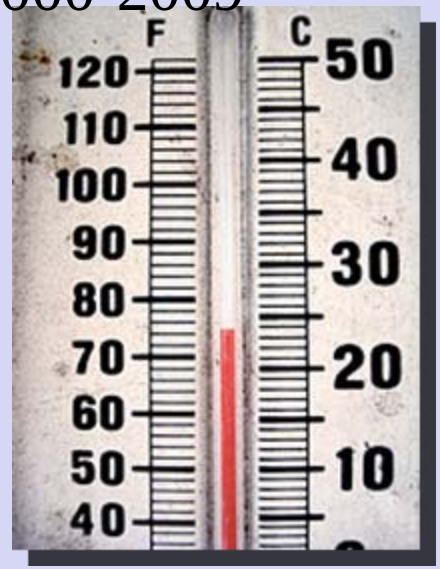
Deviation from 1971-2000 average temperatures:



Springs (Mar-May)
2000-2009

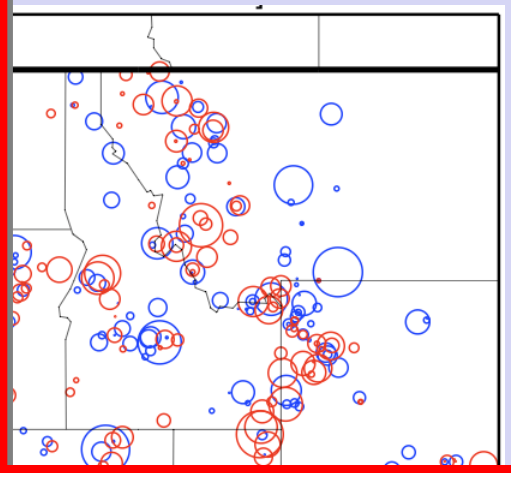


Annual (Sep-Aug)
2000-2009



TRENDS IN CENTER OF FLOW DATES

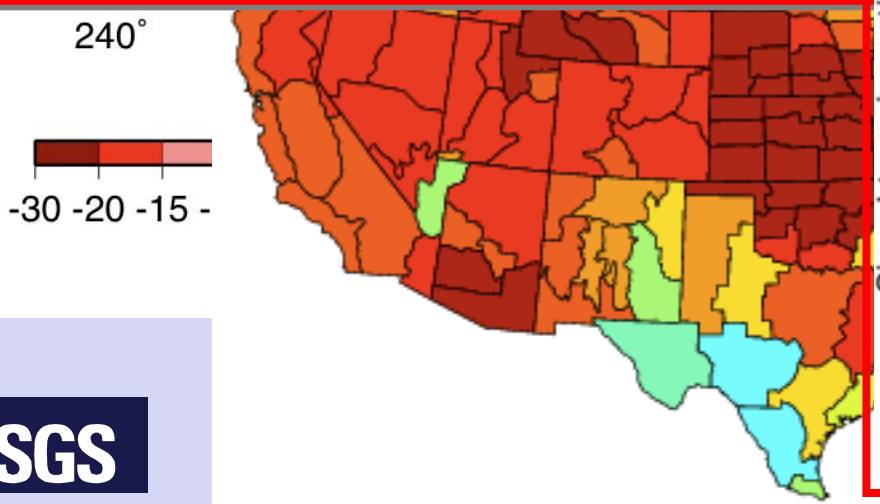
TRENDS in April 1 snow-water
nt at snow courses



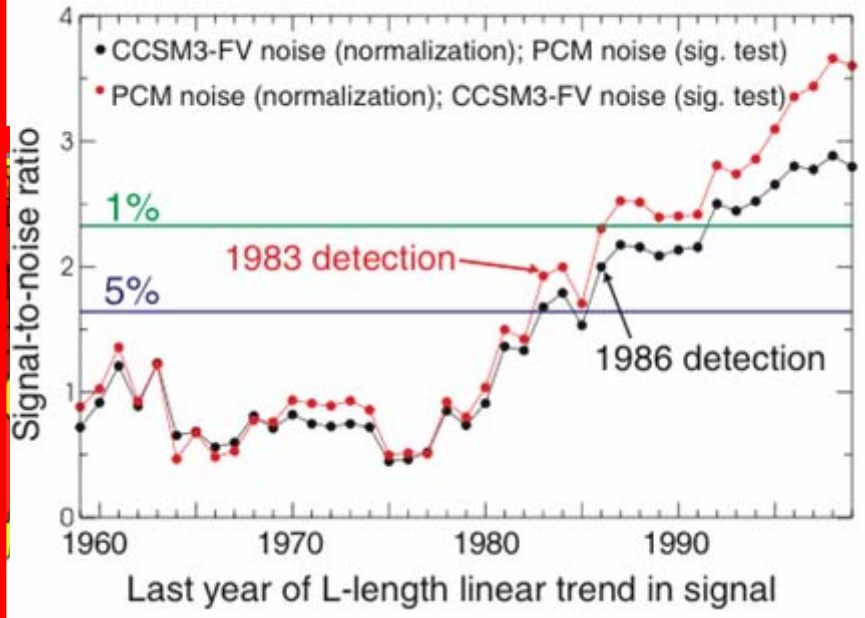
Barnett et al., Science, 2008 →
Formal detection & attribution of the combination of changes in

- **winter temperature**
- **SWE/P**
- **streamflow timing**

to greenhouse origins!



When did detection become possible?



USGS

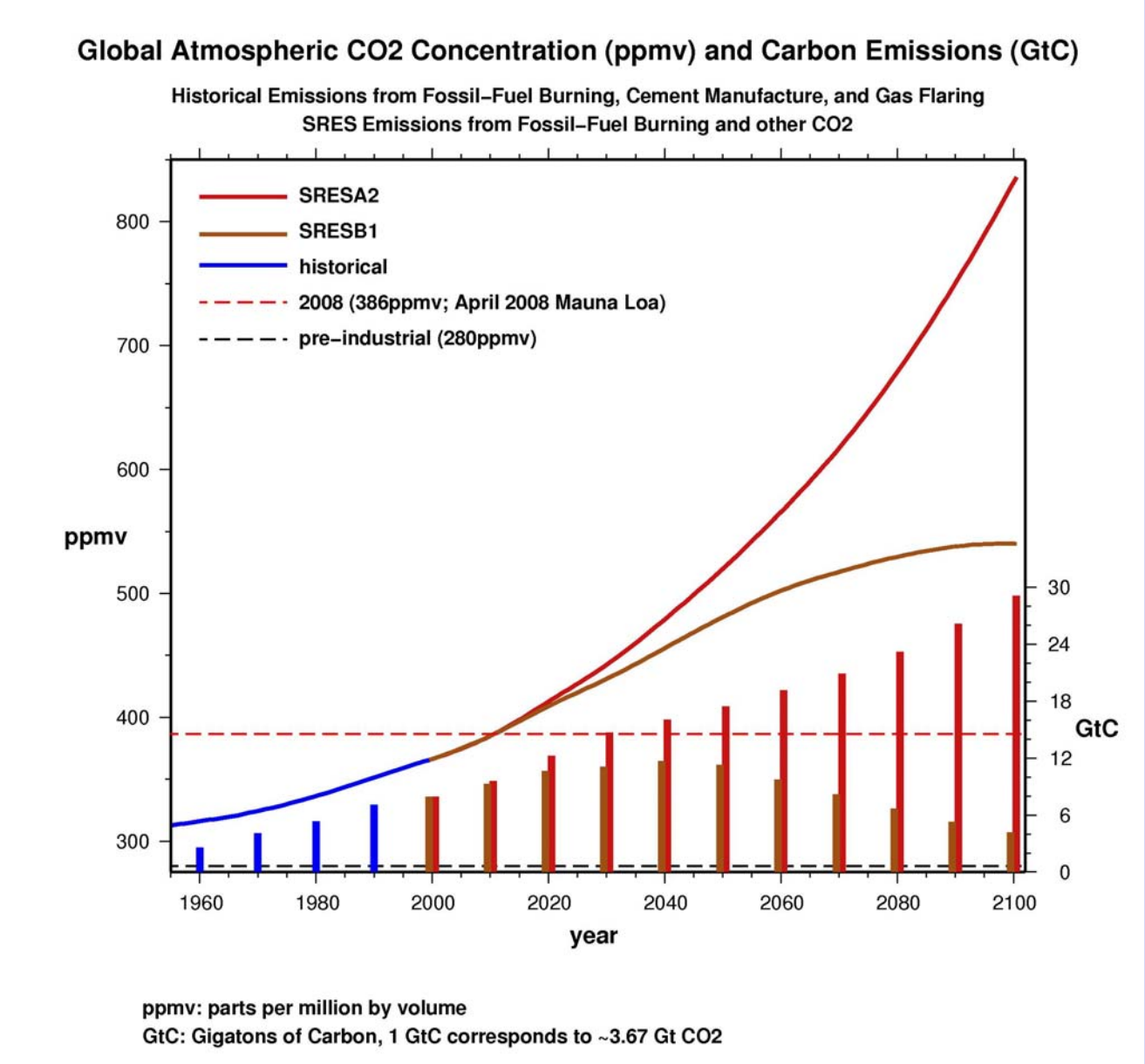
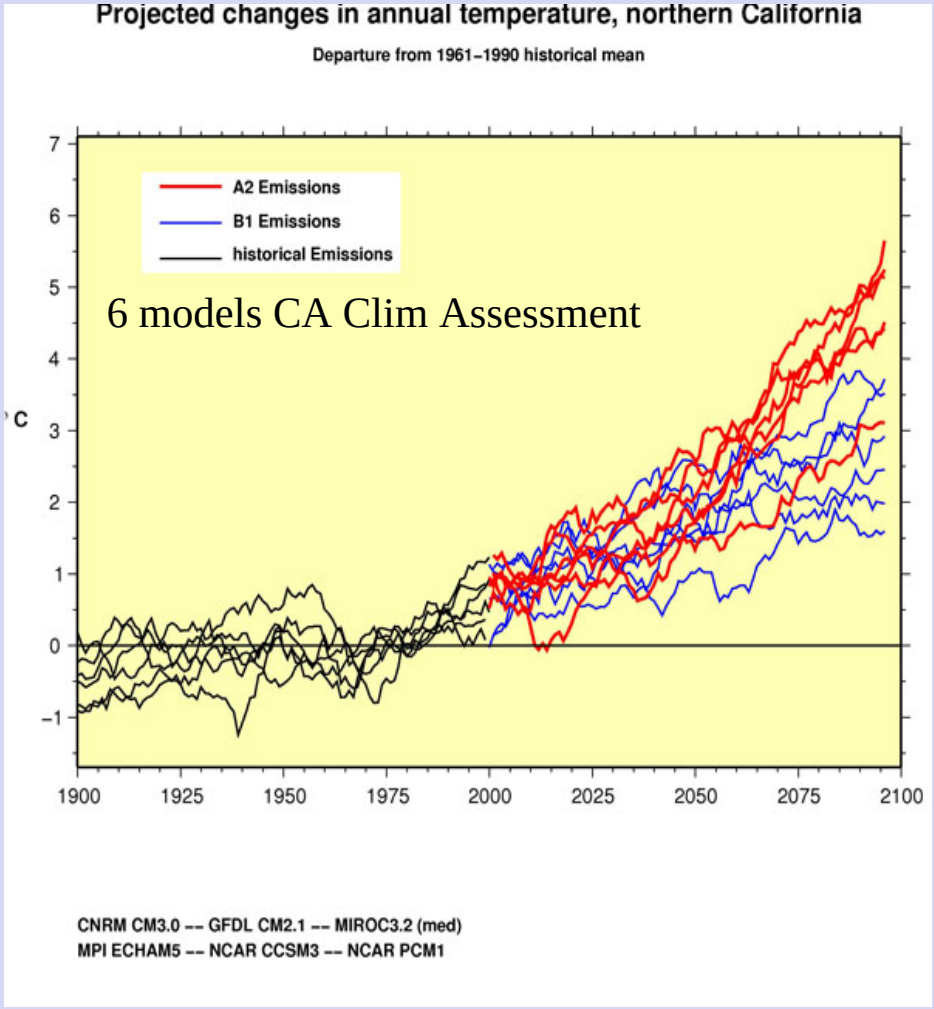


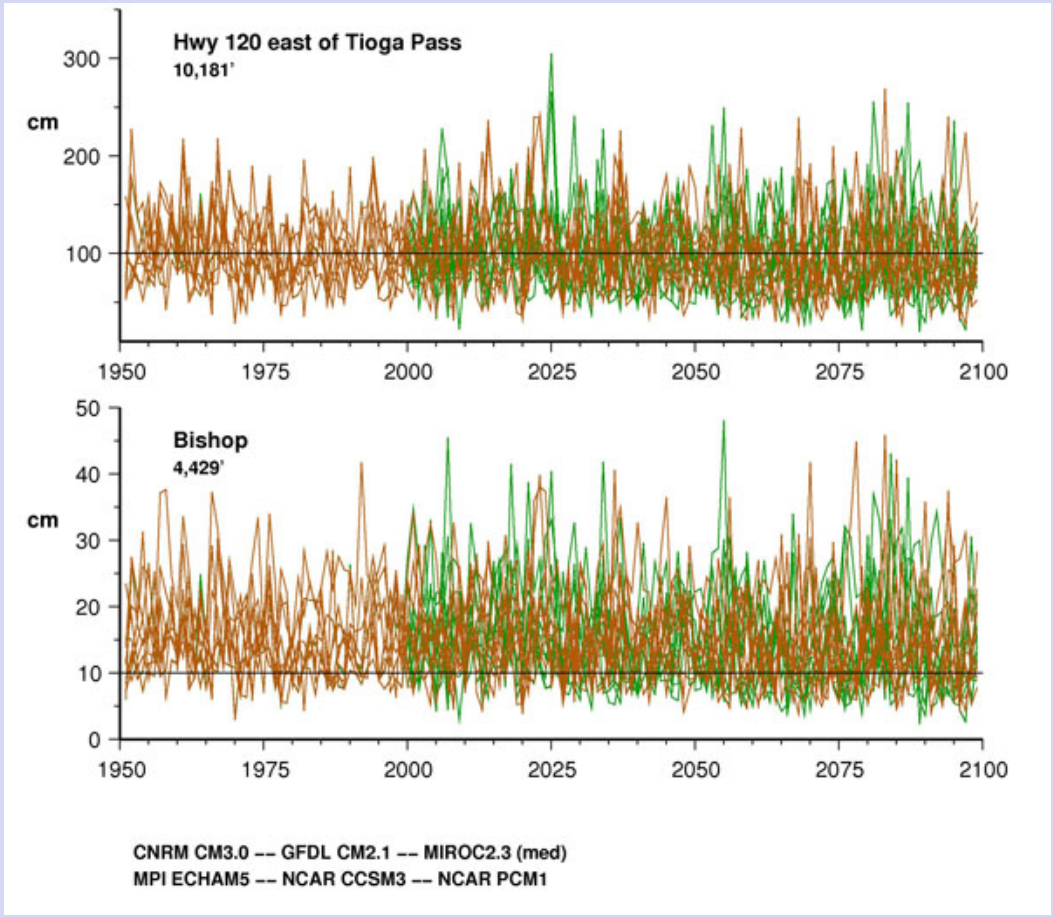
Figure 2. Global carbon emissions (GtC), shown by bars, and CO2 concentrations (ppmv), shown by lines, for historical period (blue) and for SRES B1 (brown) and SRES A2 (red) emissions scenarios. Pre-industrial and present day CO2 concentrations indicated by gray and mauve dashed lines.



All simulations warm over the 21st Century, at very substantial rates

A2 simulations (red) warm more than B1 simulations (blue)

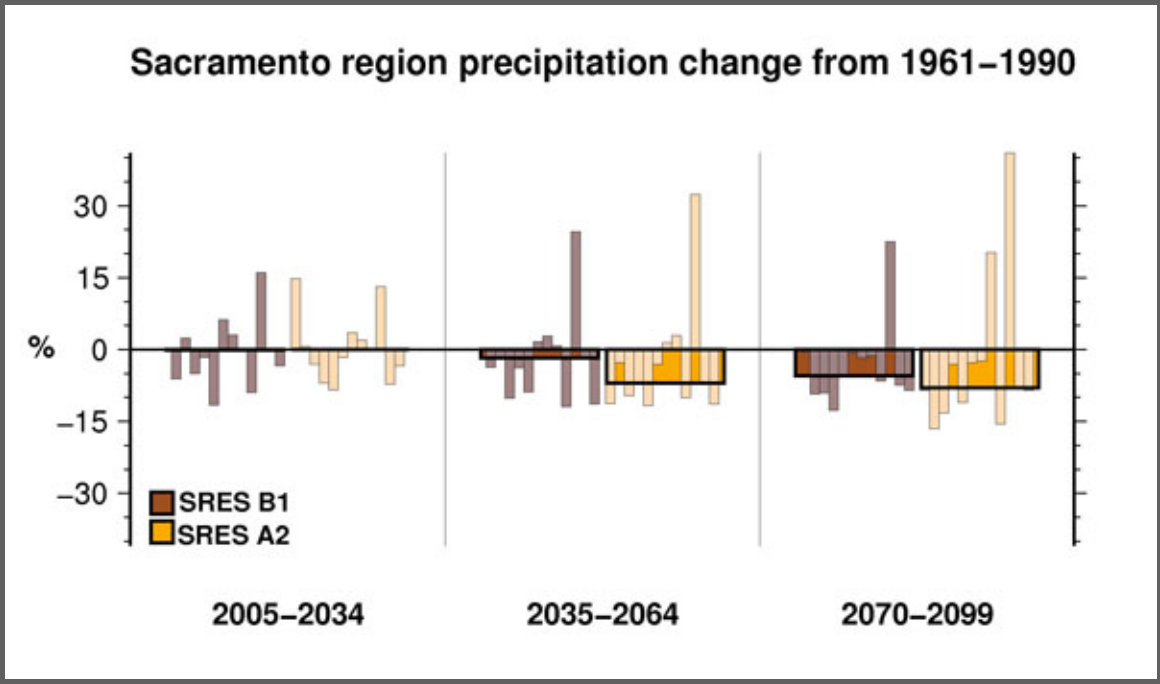
6 models selected for California Assessment are representative of larger population of IPCC AR4 models

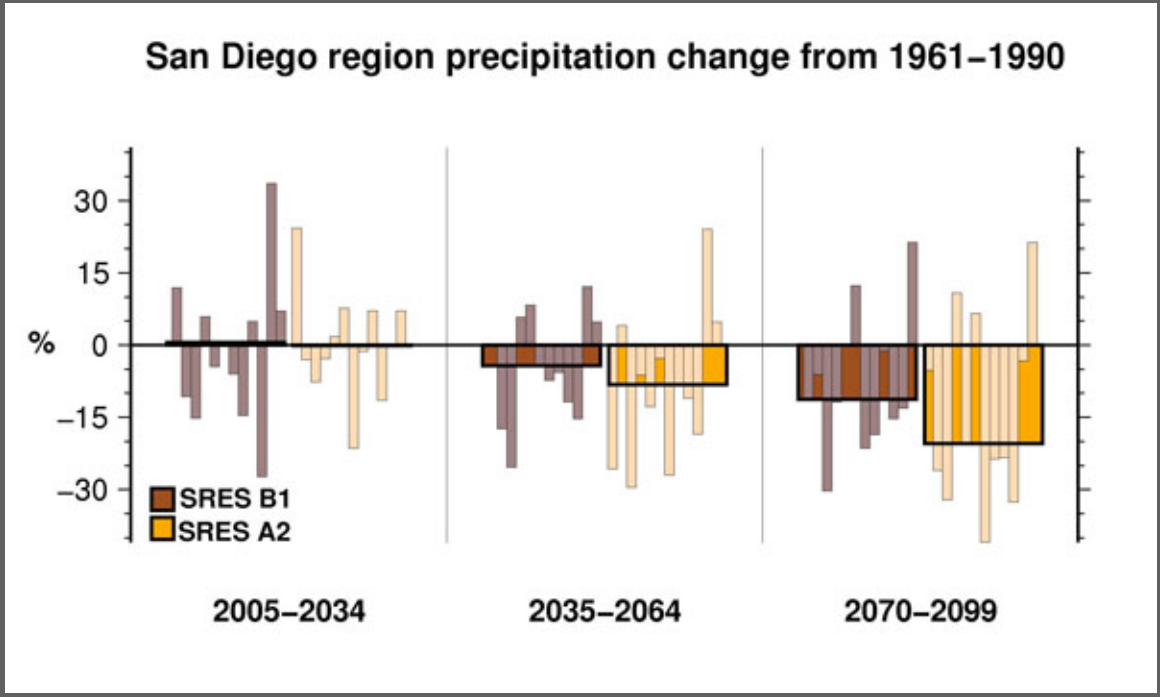


precipitation
projected by
6 different GCMs
downscaled to
Western Sierra
Eastern Sierra
Owens Valley

All contain strong
interannual-interdedal
Variability

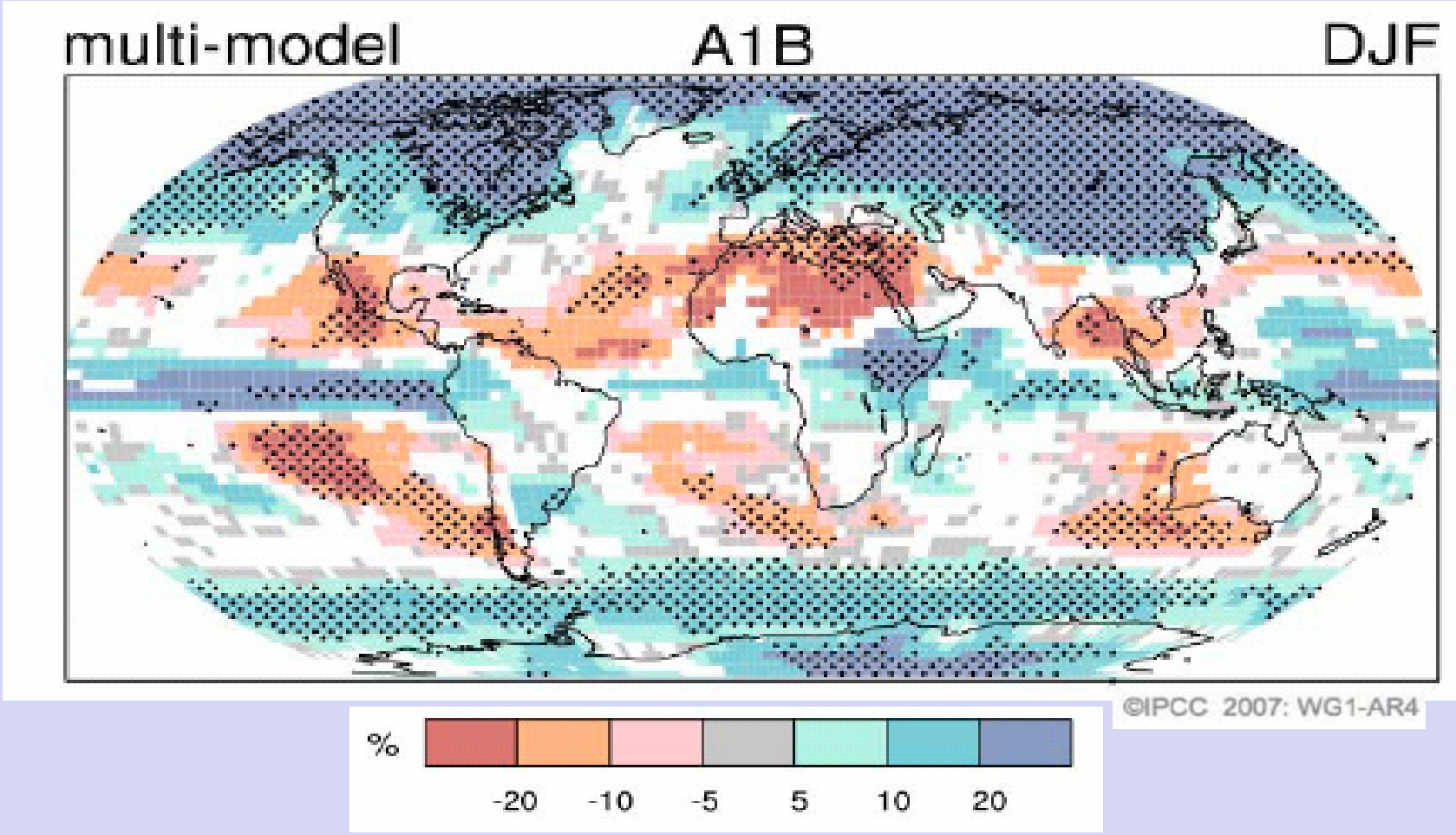
The ensemble
creeps drier
over 21st Century





12 AR4 GCMs,
2 emissions s
scenarios---
an uneven consensus
toward lower
California
precipitation

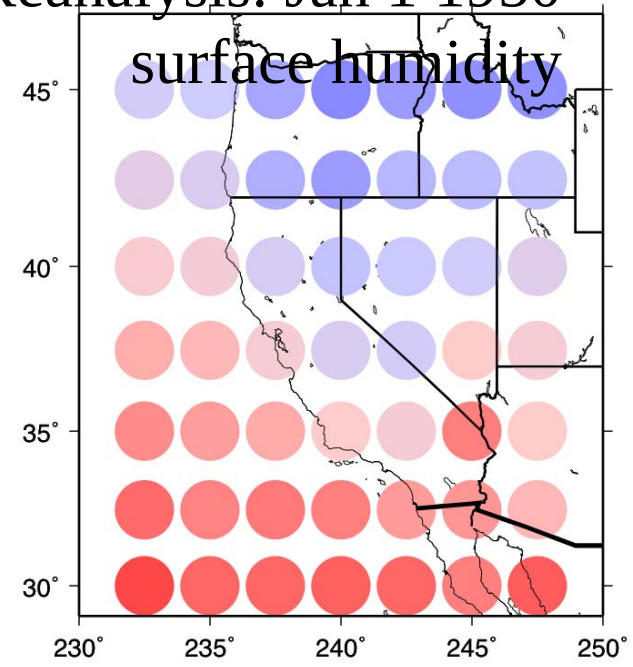
Projected patterns of precipitation changes 2090-2099 versus 1980-1999



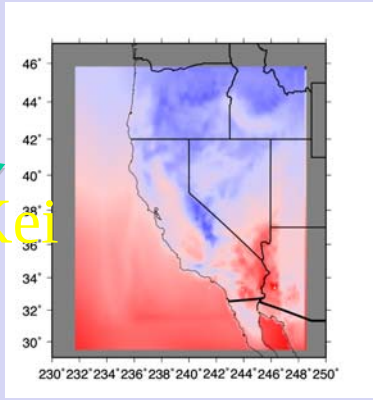
Globally, dry regions become drier?

Downscaling & probabilities at CCCC

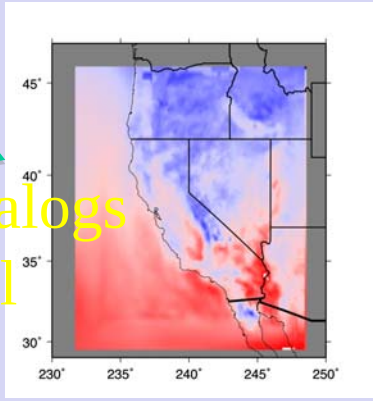
Reanalysis: Jan 1 1950 surface humidity

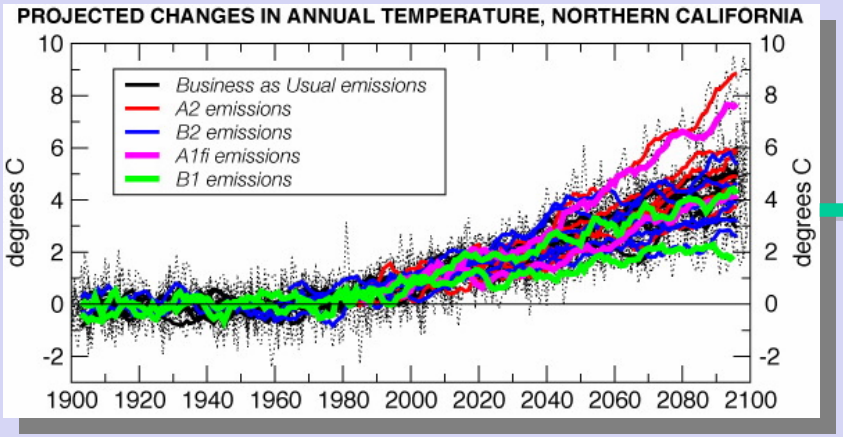


Dynamical: CARD10 by Kanamitsu & Kei

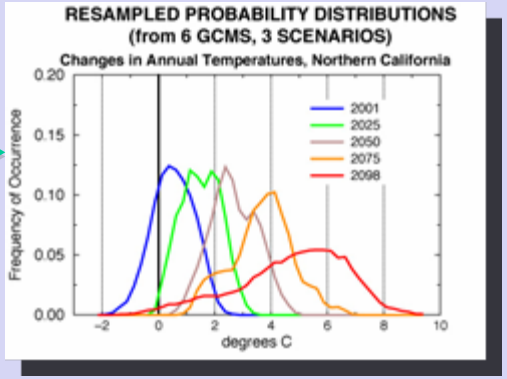


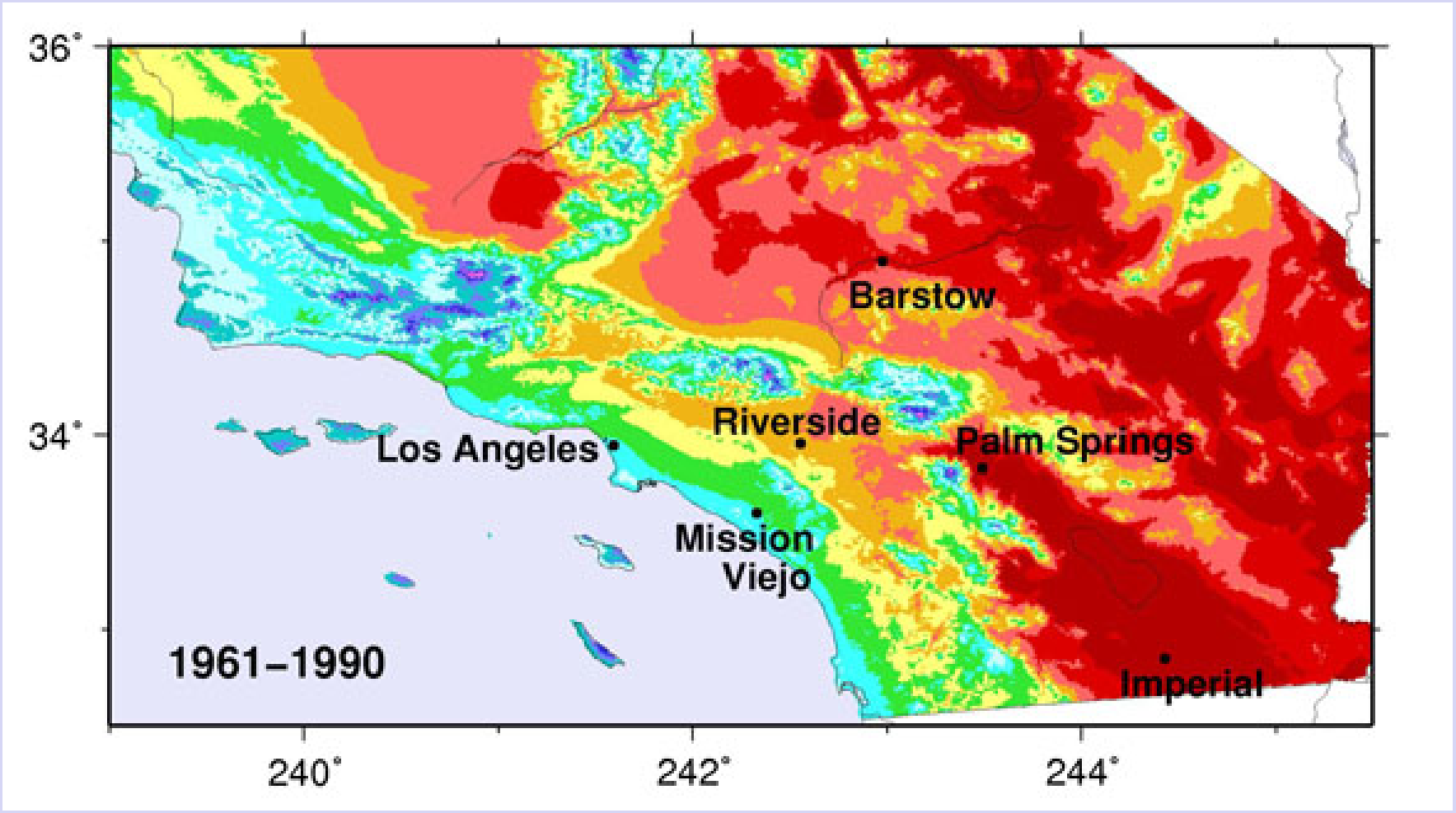
Statistical: Constructed analogs by Hidalgo et al

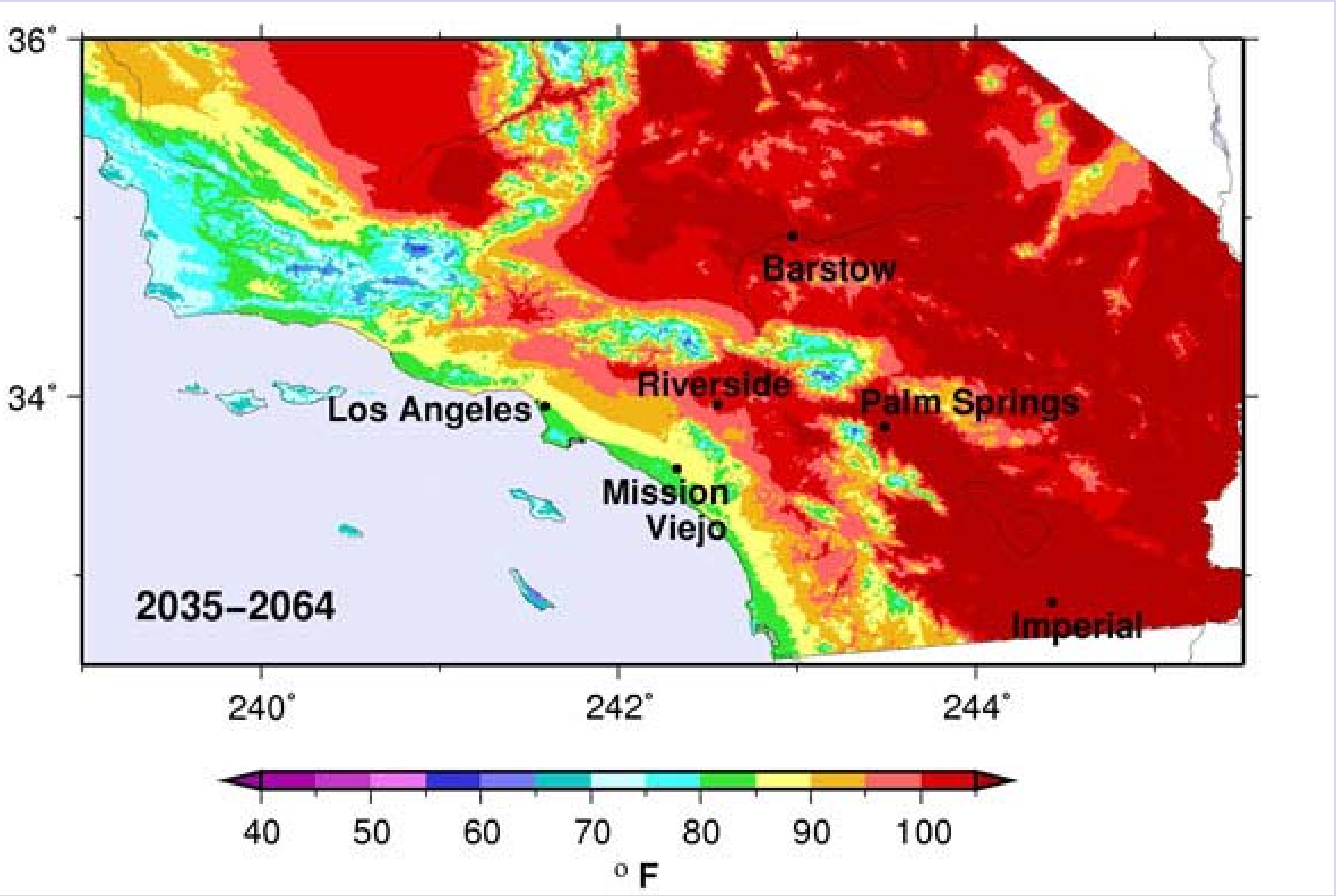




Resampling by Dettinger




36°
34°
240°
242°
244°
Barstow
Riverside
Palm Springs
Los Angeles
Mission
Viejo
Imperial
1961–1990



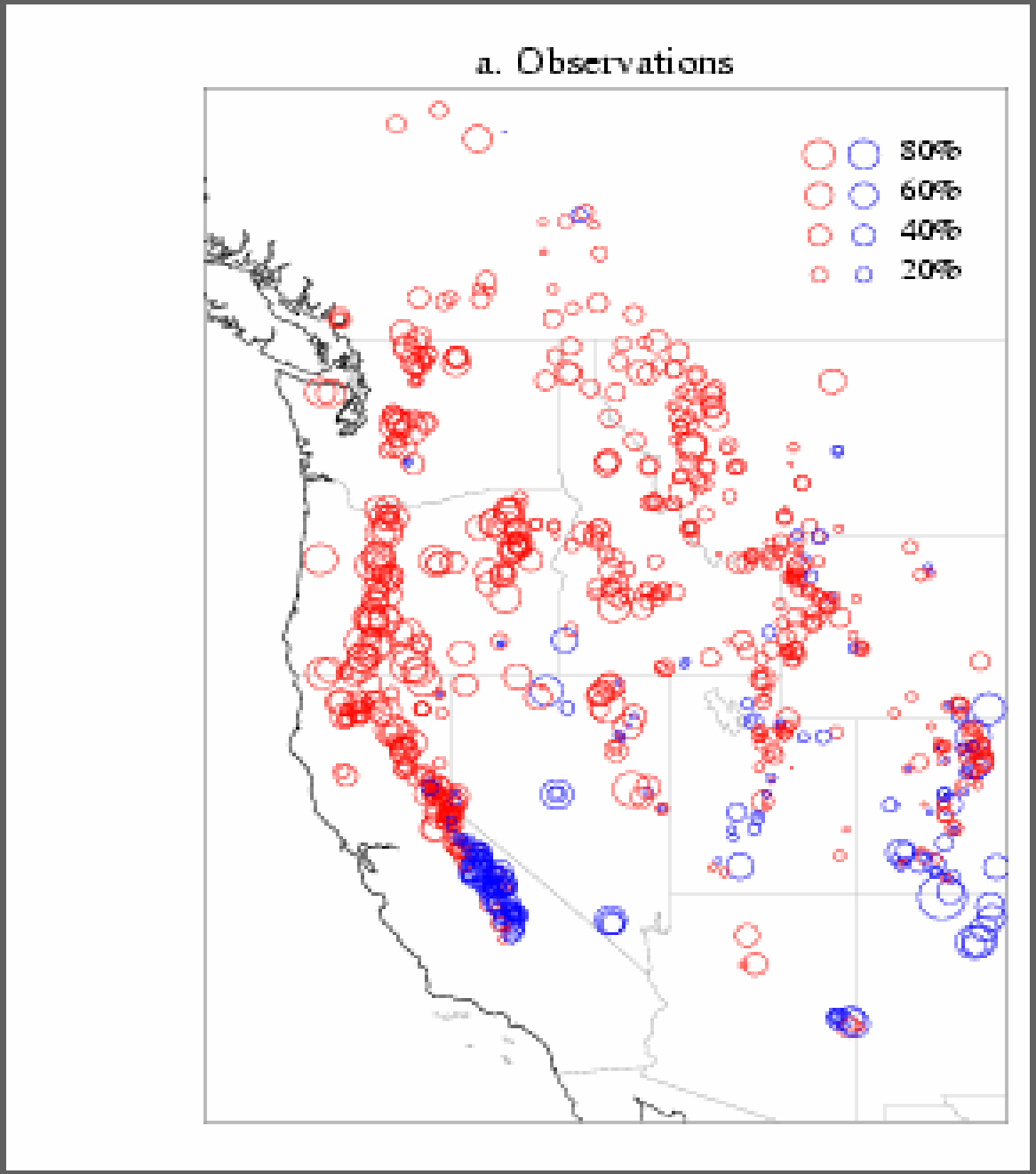
GFDL A2 1km downscaled to 1km
Hugo Hidalgo Tapash Das Mike Dettinger

How much snowpack will be lost?

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

Western Spring Snowpack has declined since 1950

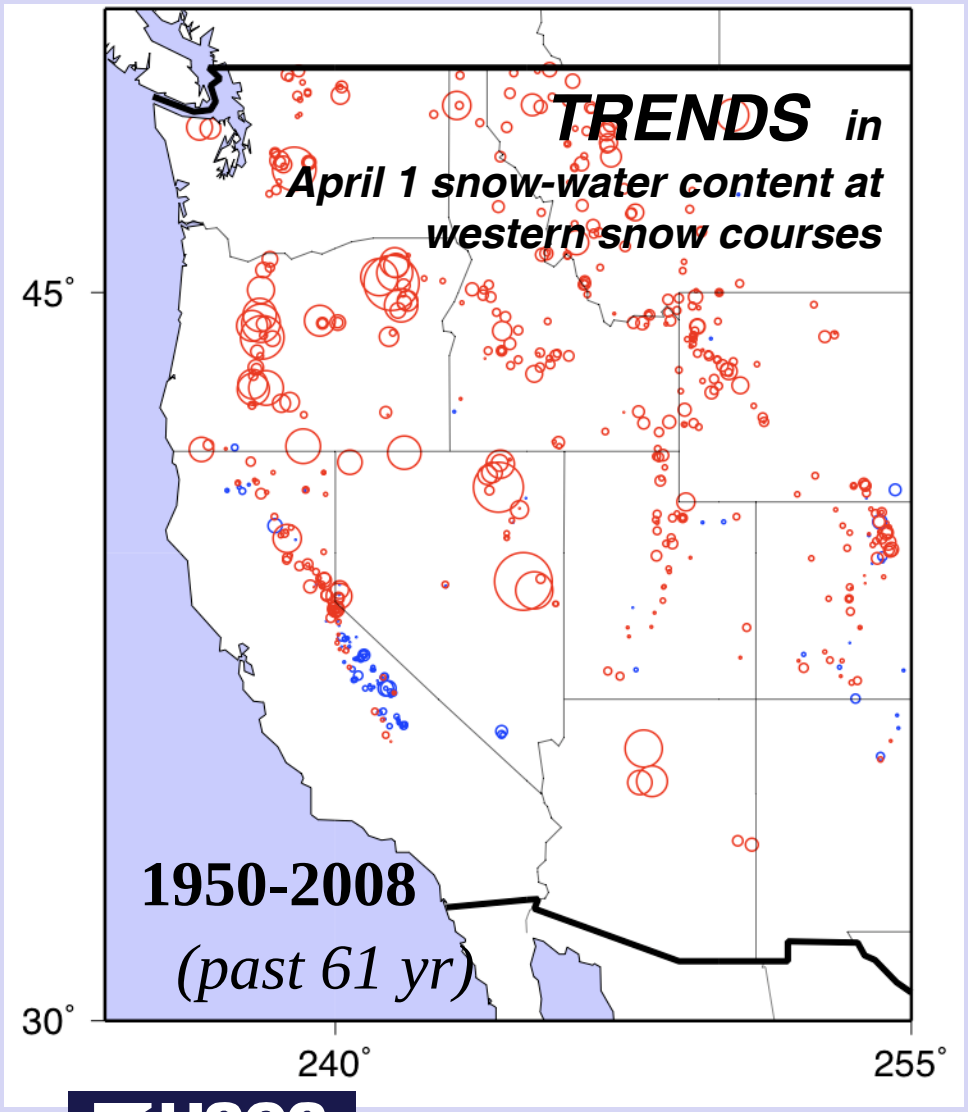
Trends in April 1 Snow Water Equivalent 1950-1997

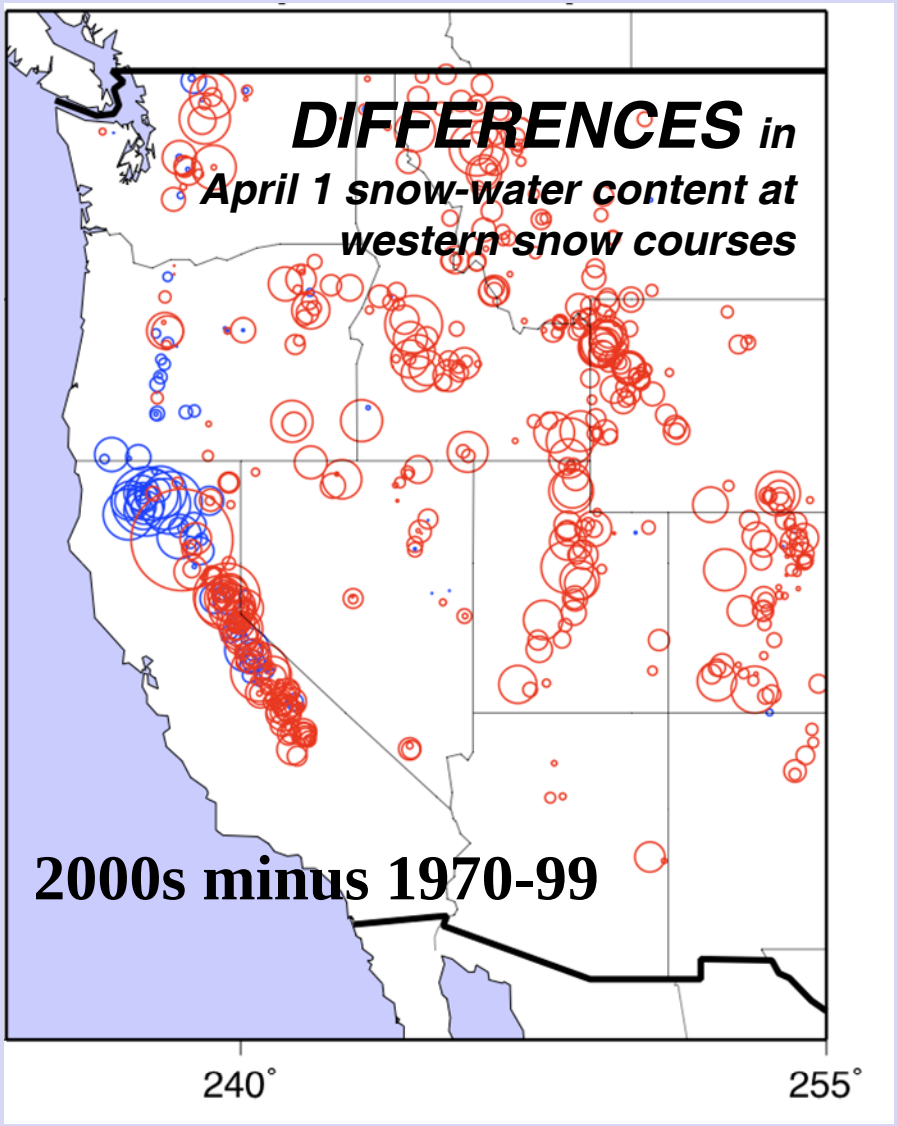


Source: Phil Mote et al. (2004) (university of Washington

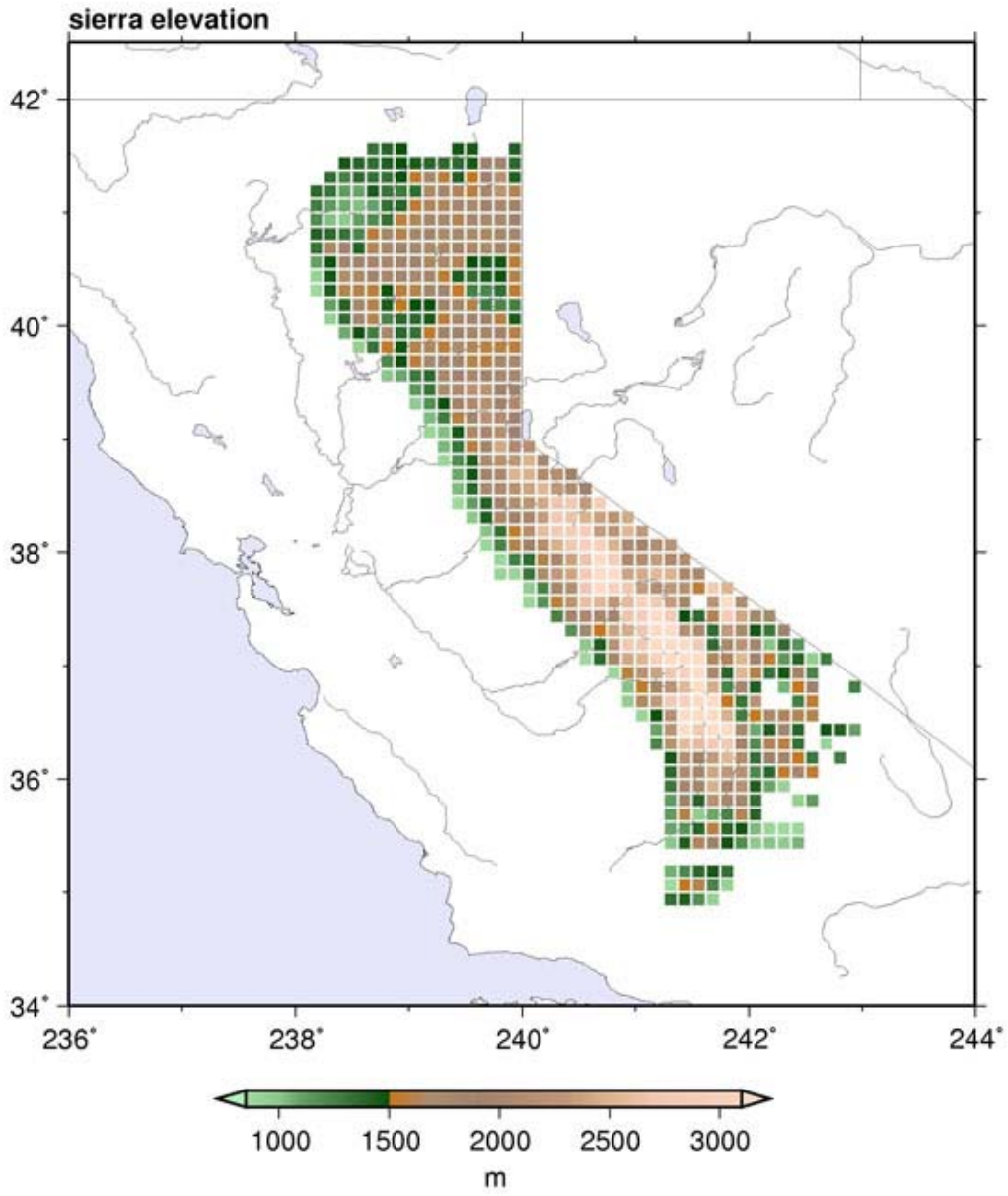
More recent trends:

--> Snowpack declines continue



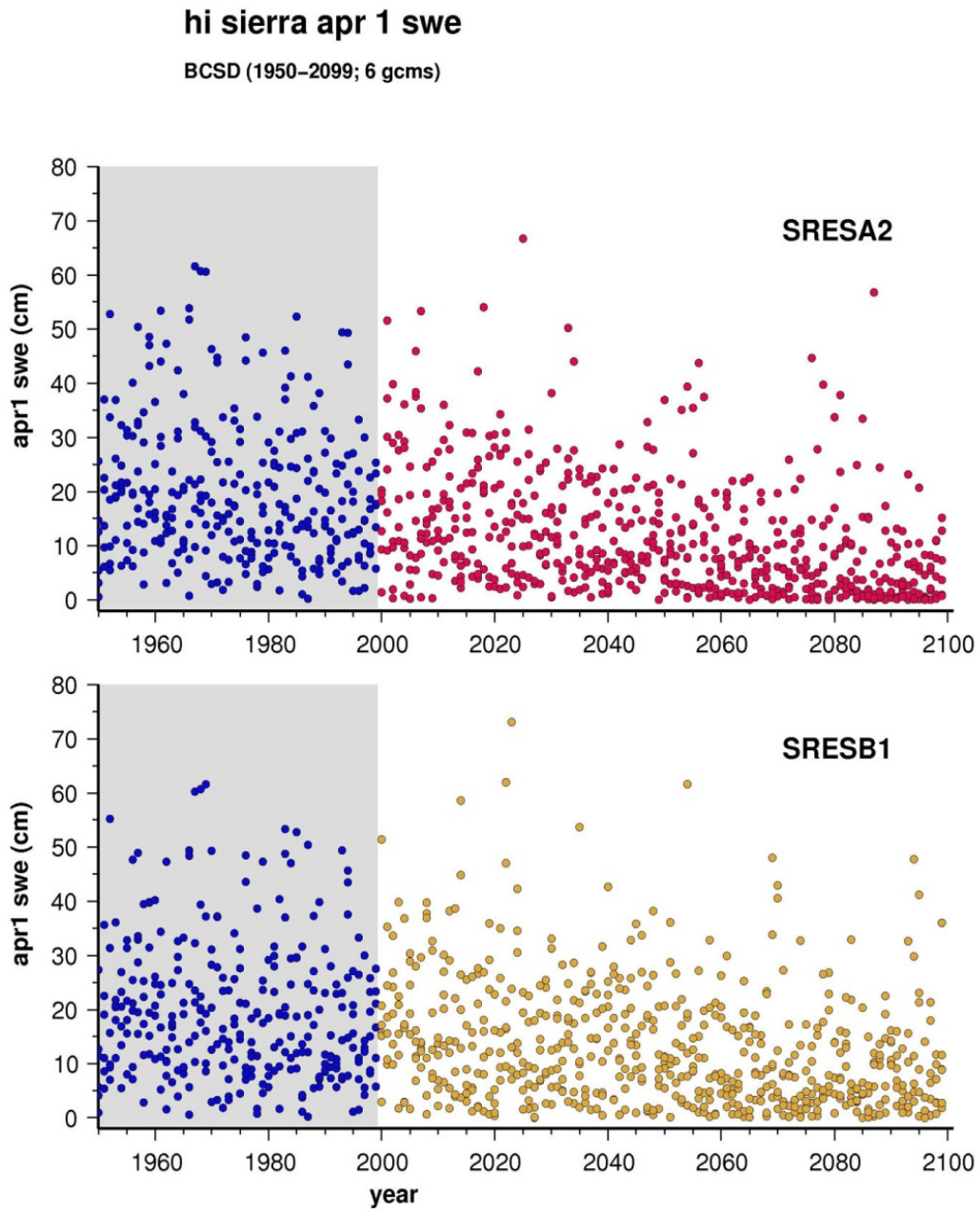


USGS

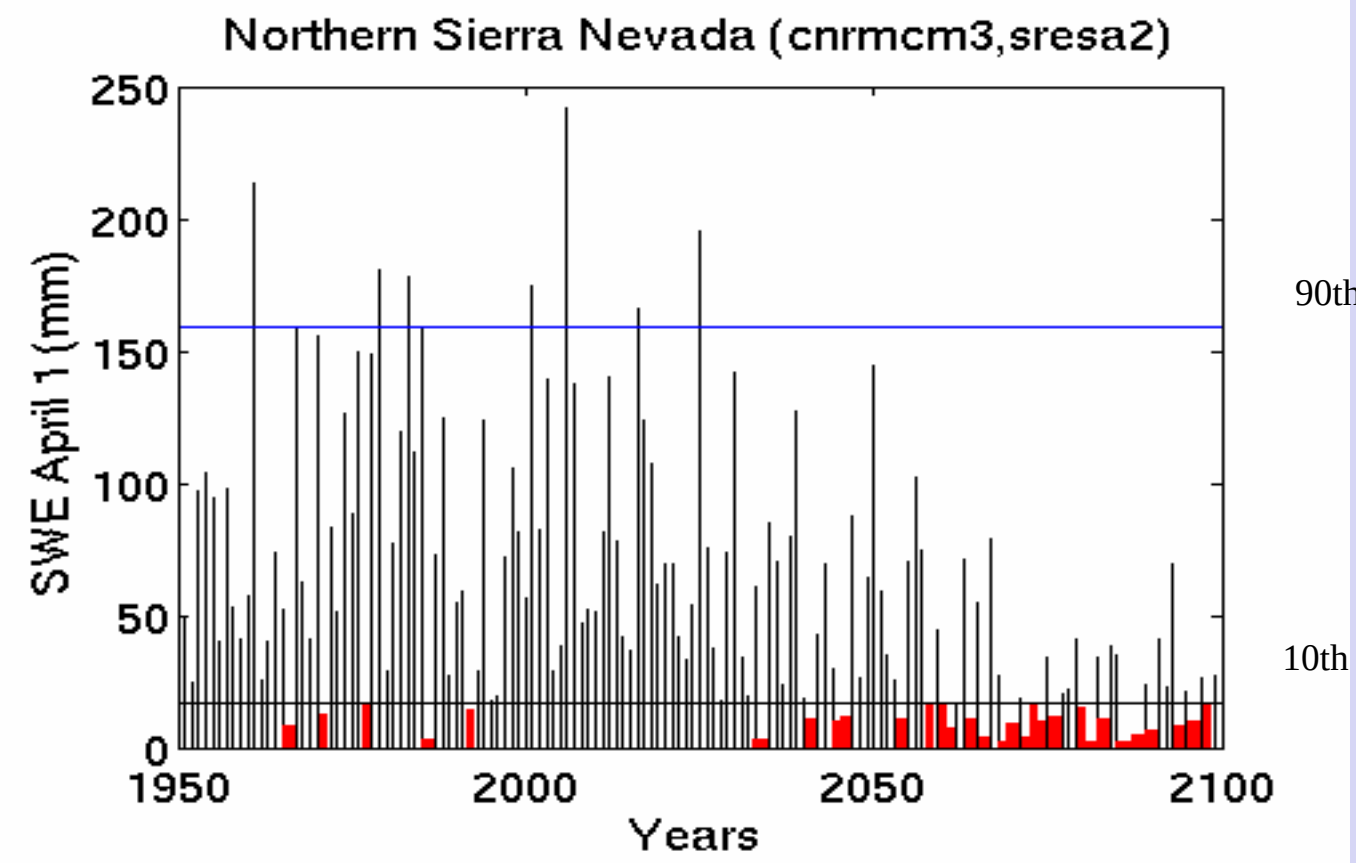


consider
aggregate Sierra Nevada
Snow Water Equiv (SWE)
elevations 800-3500m

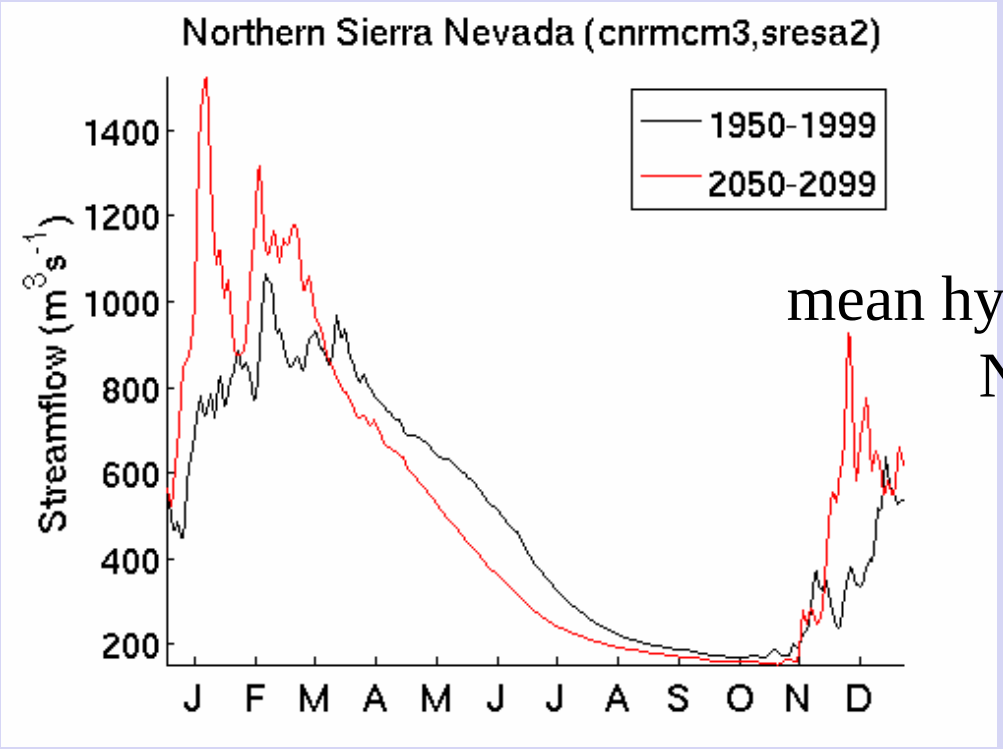
from 9 GCM's
downscaled via BCSD
calculated using VIC
hydrological model



by 2050, occurrences of cases with minimal Sierra Nevada spring SWE is much more frequent, especially in A2 scenario simulations

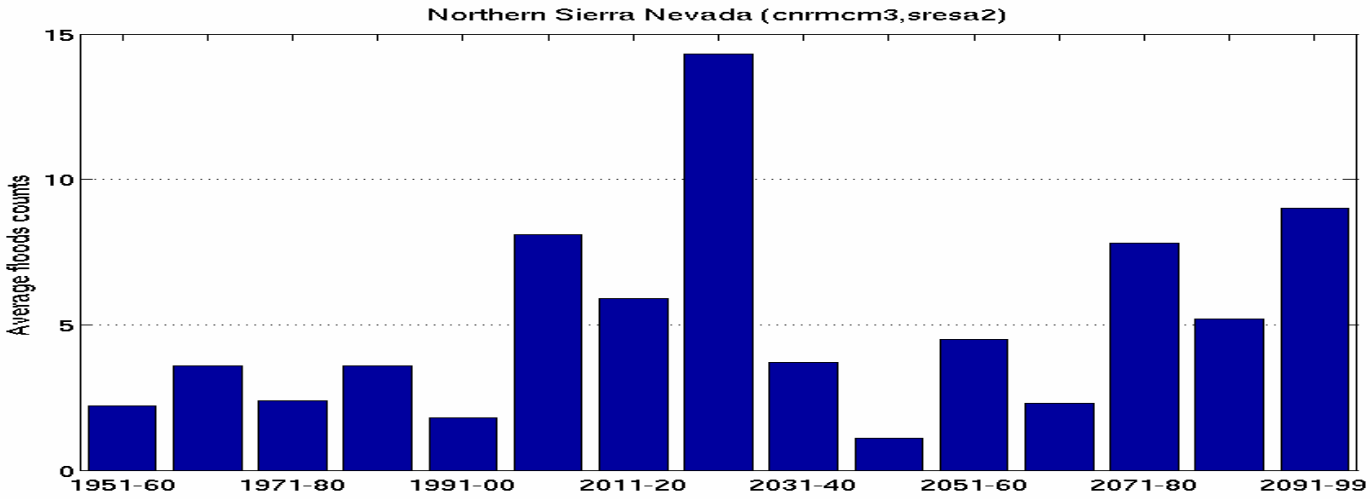


Snow Accumulation (April 1) CNRM A2
10th percentile years (1961-1990) shown in red



mean hydrographs CNRM A2
Northern Sierra becomes more flood-prone

99th percentile streamflow events come twice as often



OBSERVATIONS AND MODELS INDICATE:

The West's water supply is vulnerable to climate changes and weather extremes.

Humans have altered atmospheric composition and thus are altering the earth's climate; GH gases have long lifetimes, so choices made now and in future will greatly impact future climate.

The West has already seen signs of warmer winter storms, more rain, less snow, and earlier spring snowmelt. A substantial portion of these changes appear to be attributable to anthropogenic warming. More warming is very likely in future decades.

Recent IPCC model projections for western precipitation are scattered, but *several* show moderate drying as tends to be characteristic of Mediterranean regions globally. A reduction in precipitation is amplified into even greater reduction in soil moisture and runoff in the more arid basins of the West.

Research on downscaling is yielding climate projections of regional, local measures suitable for hydrologic model simulations. Ensembles are available from which uncertainties can be explored.

California Climate Assessment Report:

Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment Publication CEC-500-2009-014-D. *62 pp. 2.2 megabytes*

www.climatechange.ca.gov/publications/cat/

THANK YOU