



Climate in California and the Delta: observed trends, interpretation, and future projections

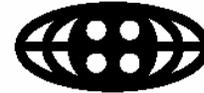
Philip B. Duffy

Lawrence Livermore National Laboratory
and
University of California, Merced

THIS TALK APPROVED FOR

G GENERAL AUDIENCES

All Ages Admitted

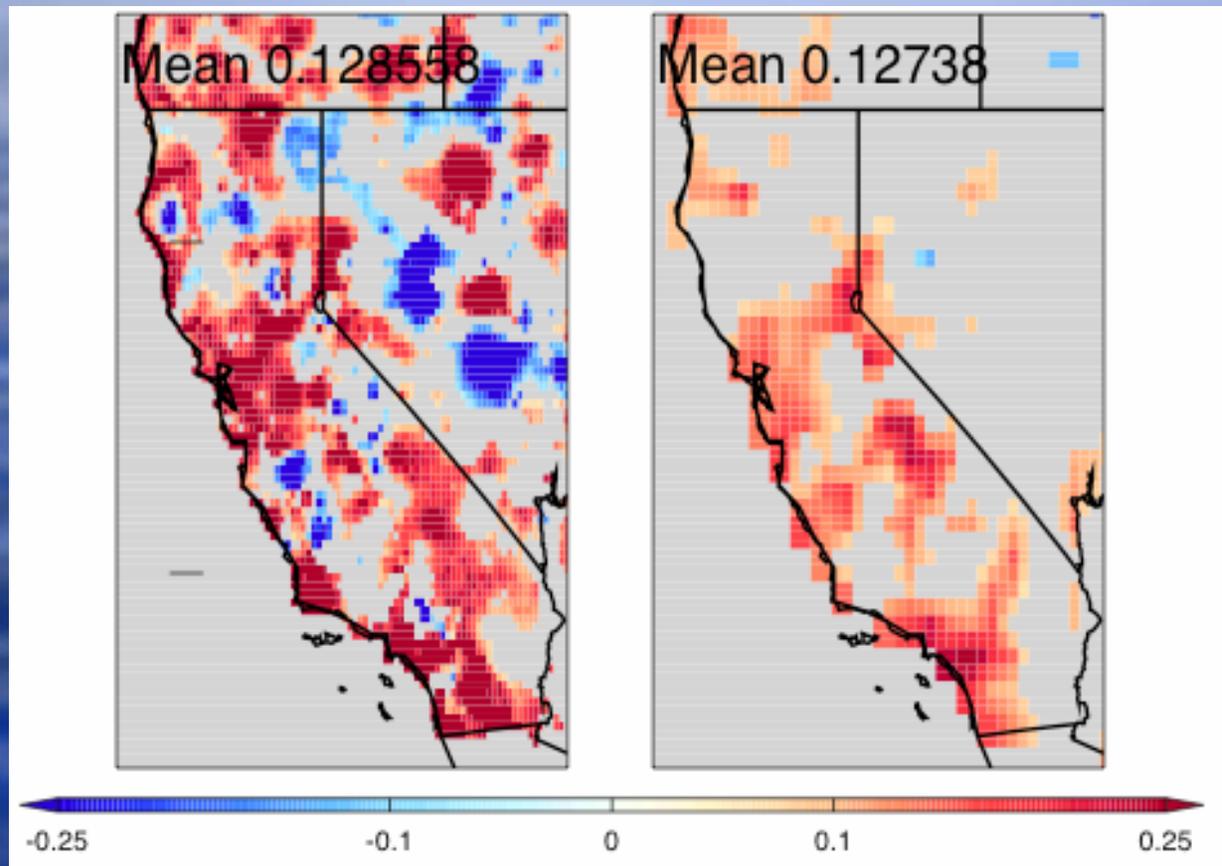


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The Past

California is warming

Two different observational data sets

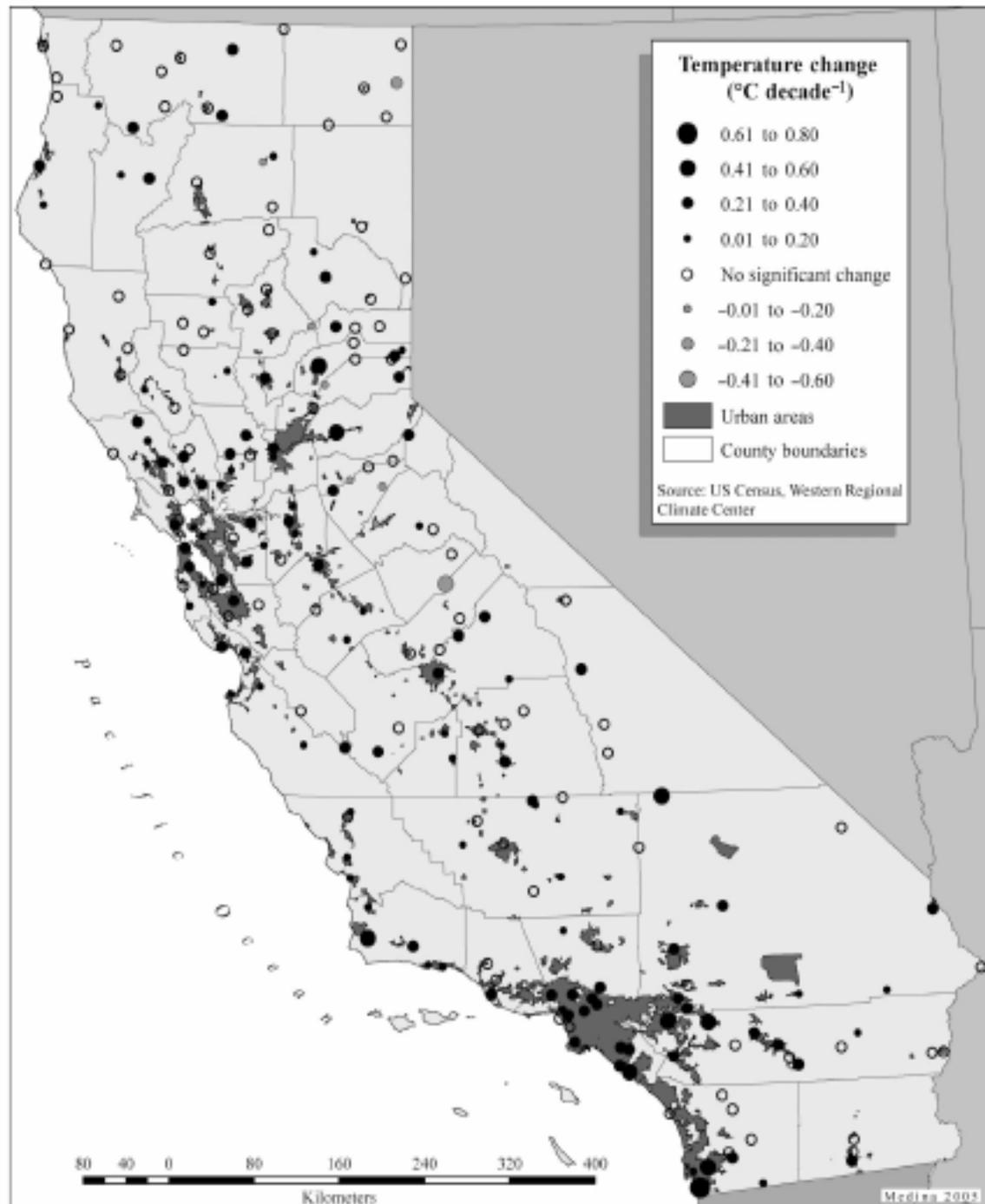


Observed trend in annual temperatures, 1949-1998 (deg. C per decade)

Observed trend in annual temperatures, 1950-2000 (deg. C per decade)

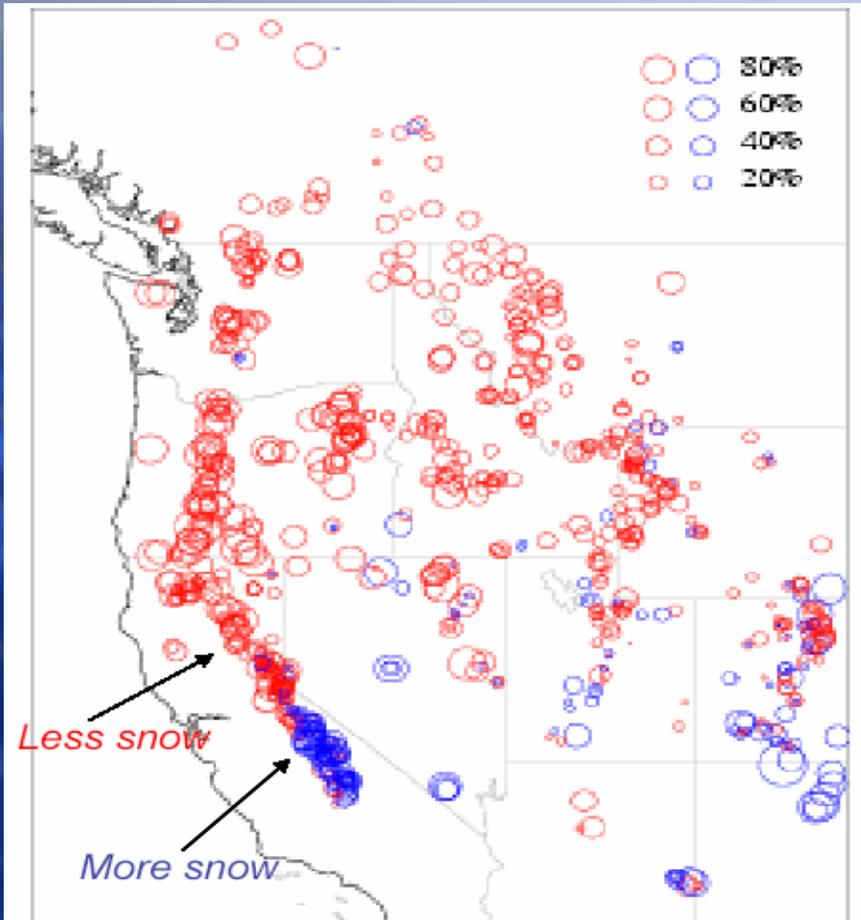
● = warming

○ = cooling

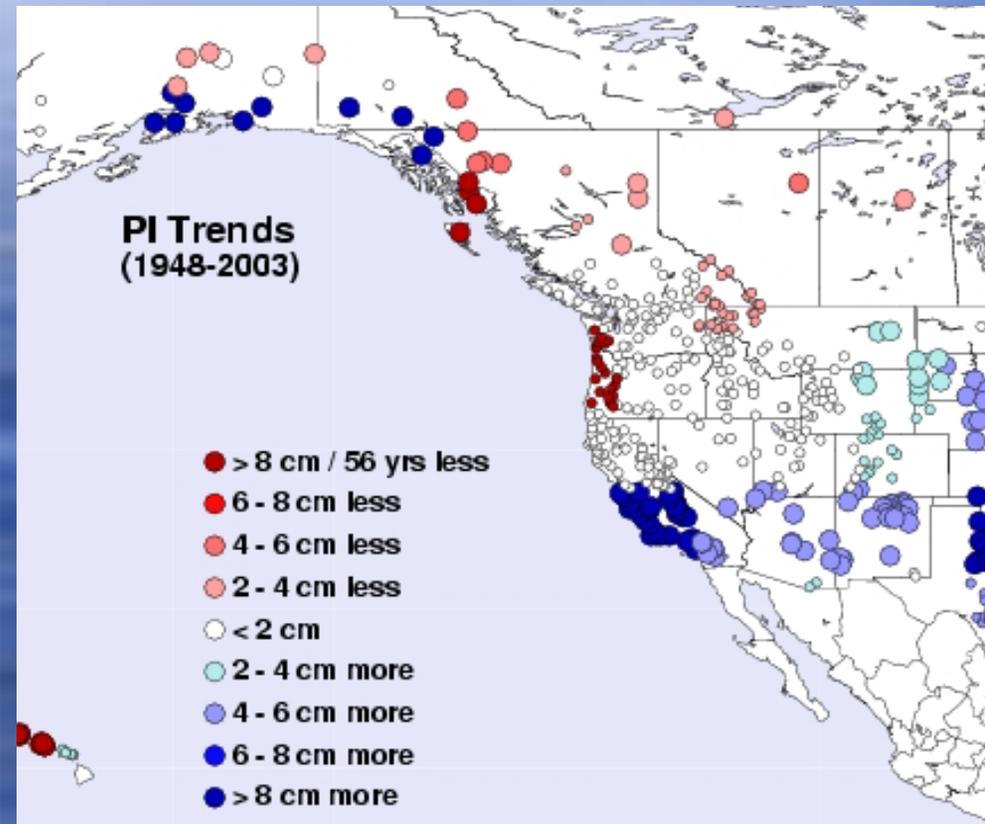


There is less snow in most of the west

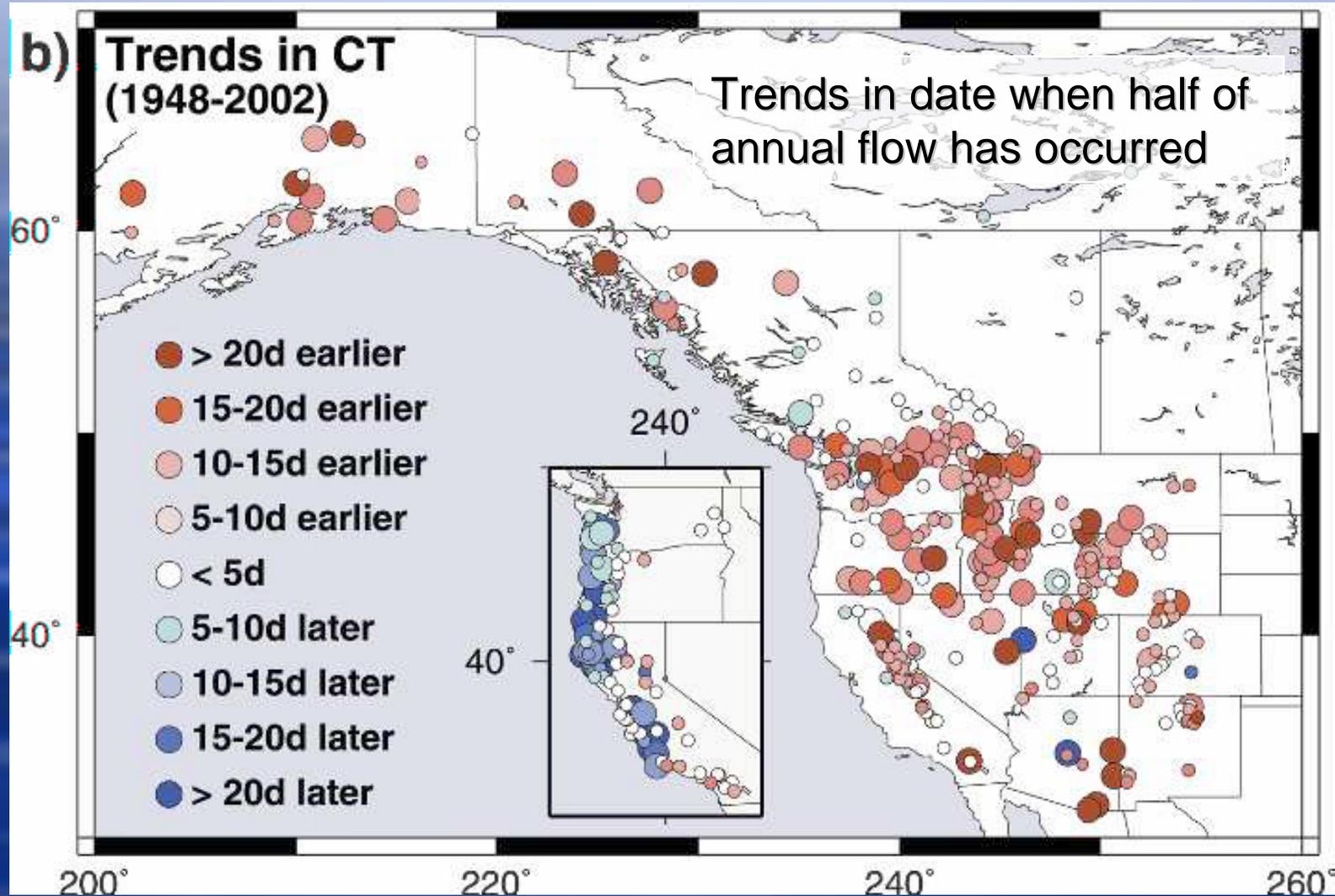
50-yr trends in snow water content



50-yr trends in precipitation



River flow is coming earlier in the year



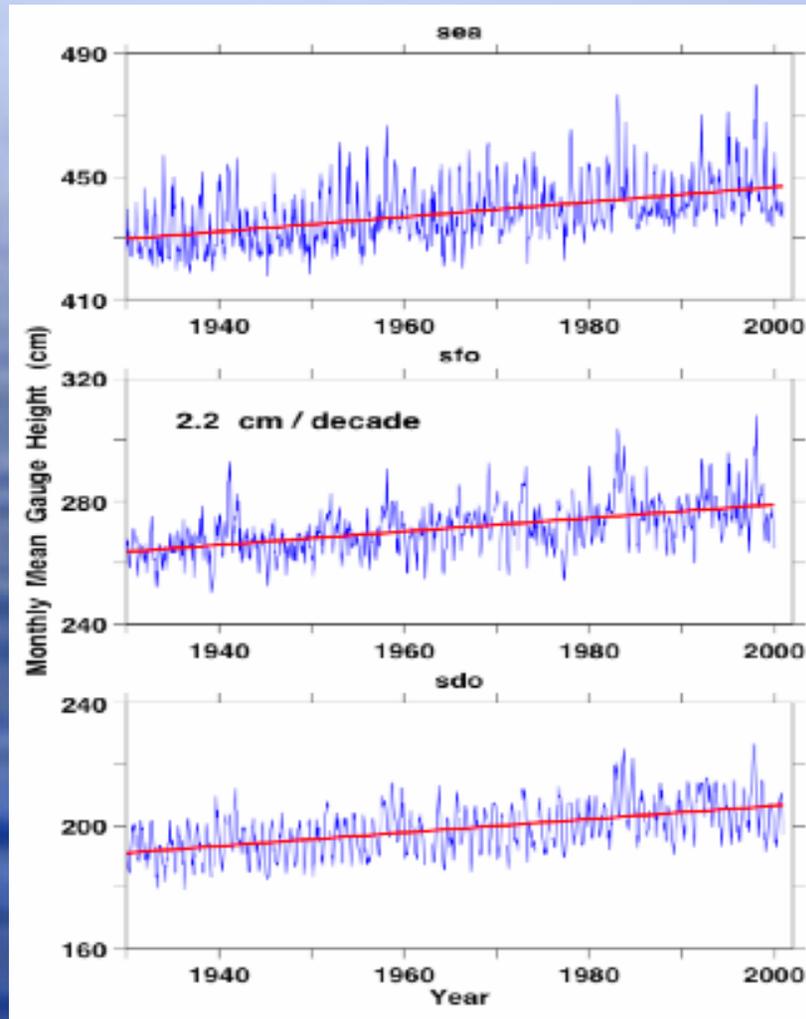
Source: Iris Stewart, UCSD

Sea level is rising (about 7" since 1930)

There are two components to sea level rise:

Increase in mean sea level (slow)

Shorter-timescale variations due to weather and tides



Seattle

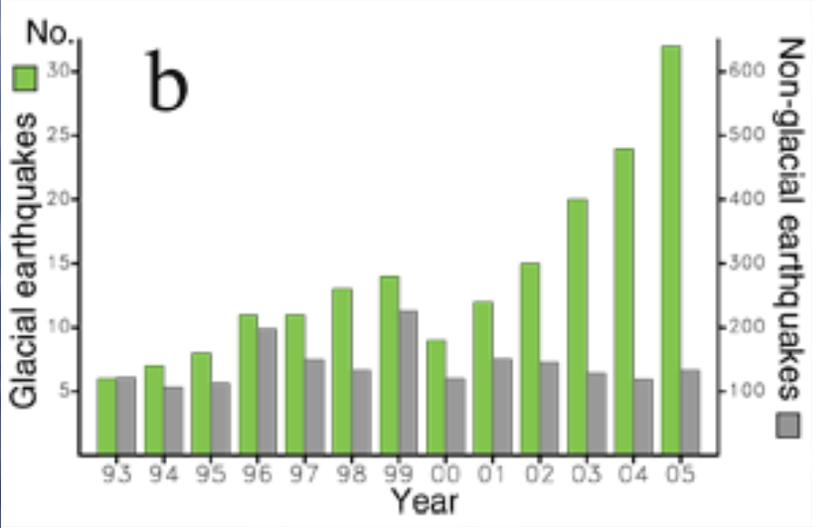
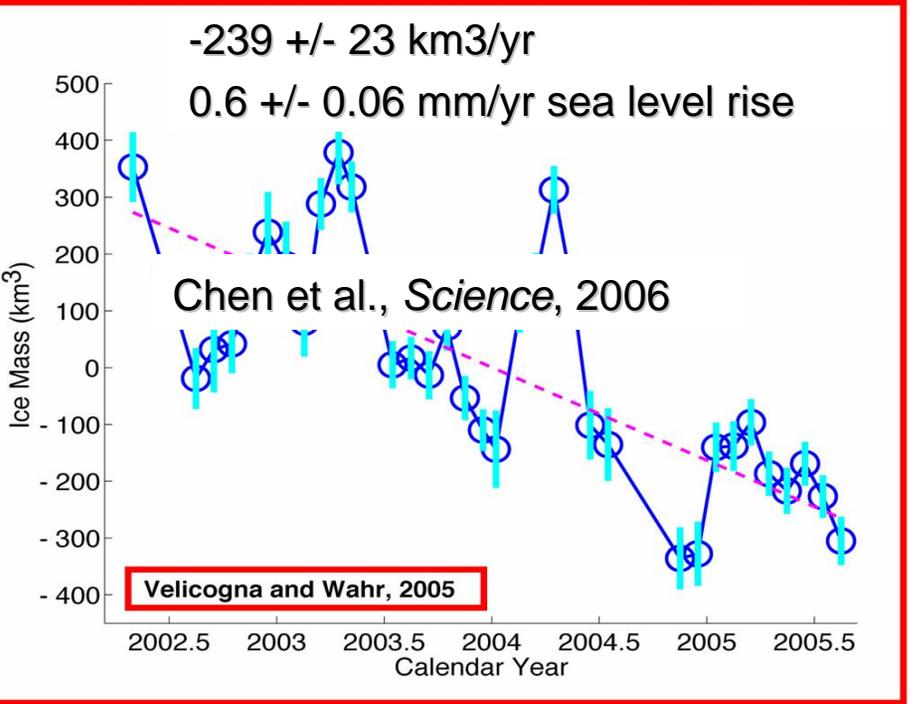
San Francisco

San Diego

Greenland is Melting...



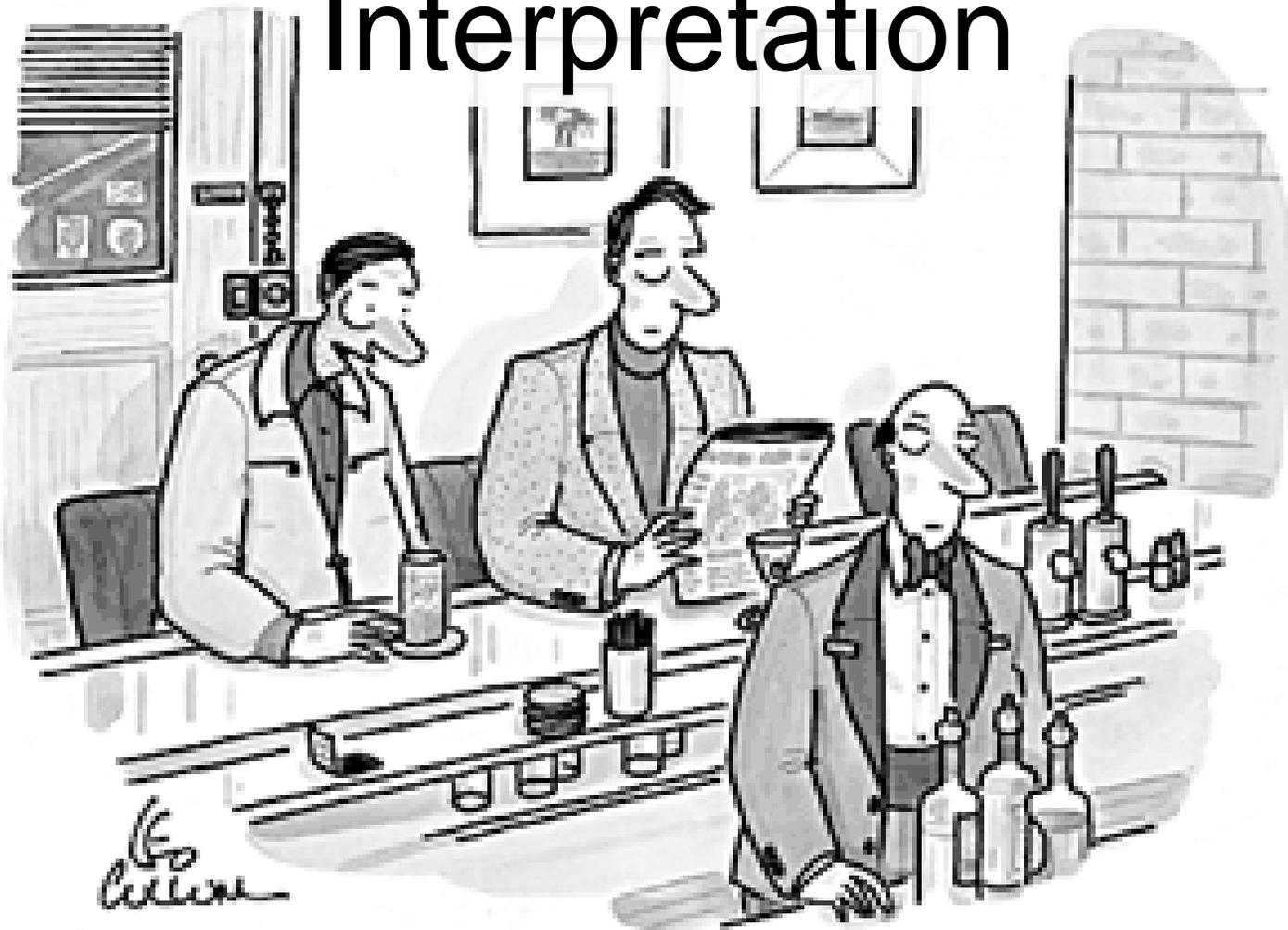
Rate of mass loss from satellite altimetry agrees with that from satellite gravity measurements.



"Ice-quakes" are more frequent

Satellite measurements show that Greenland is losing ice

Interpretation



“I don’t know anything about global warming, but these ice cubes are melting like crazy.”

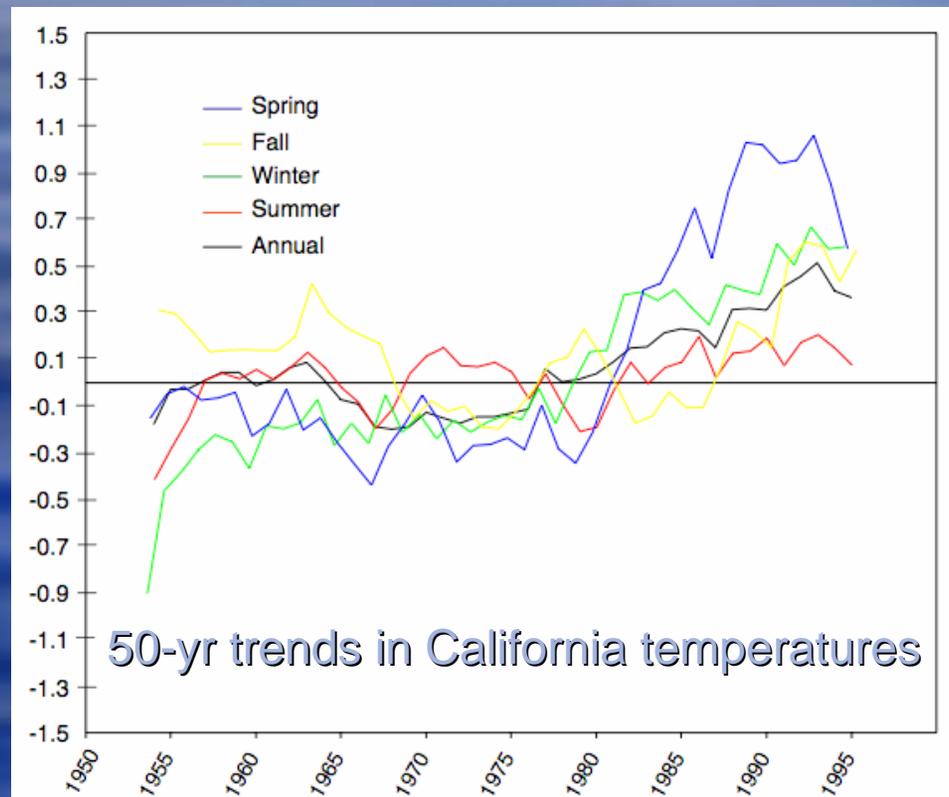
What is causing recent warming in California?

P. Duffy^{1,2}, C. Bonfils², B. Santer¹, T. Wigley³

¹University of California, LLNL

²University of California, Merced

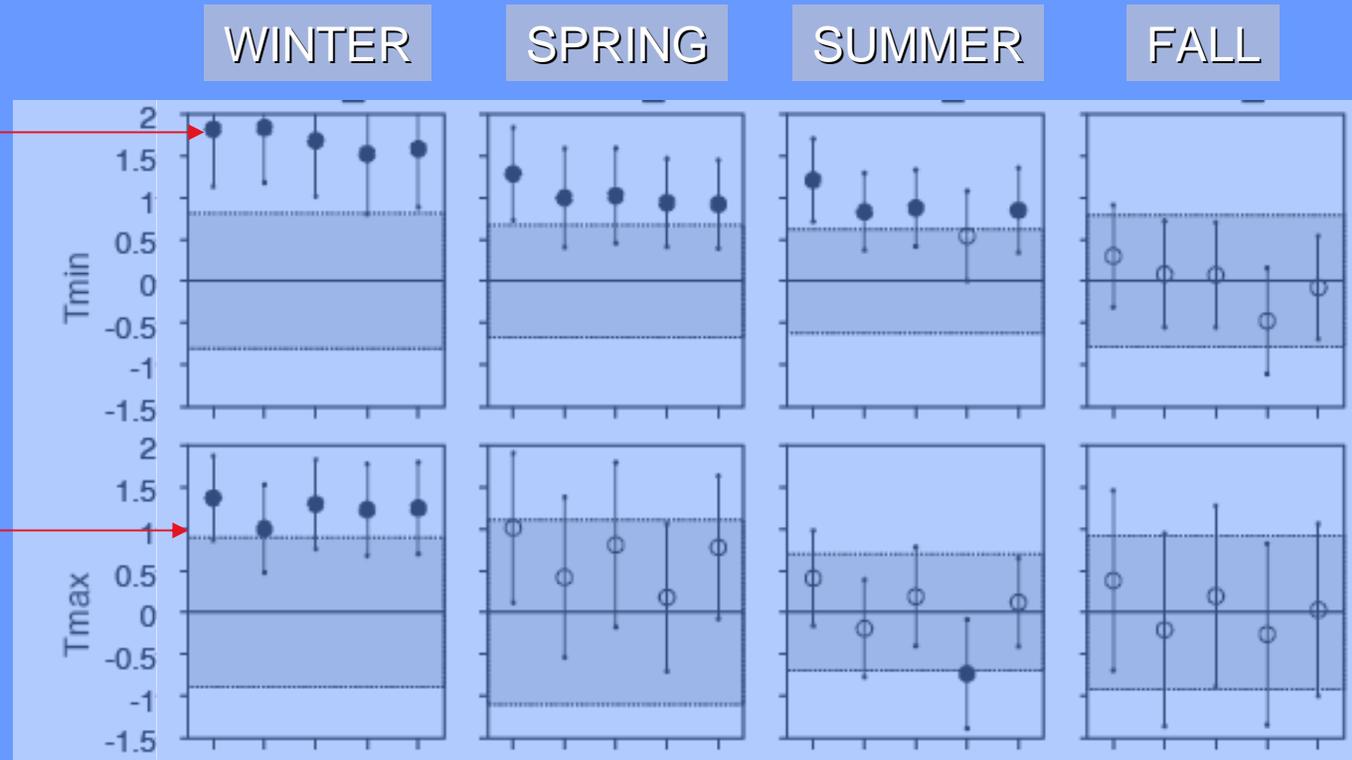
³National Center for Atmospheric Research



Temperature changes in some seasons are faster than expected from natural internal variability

Observed trends from 5 different data sets

Maximum trend expected from natural internal variability

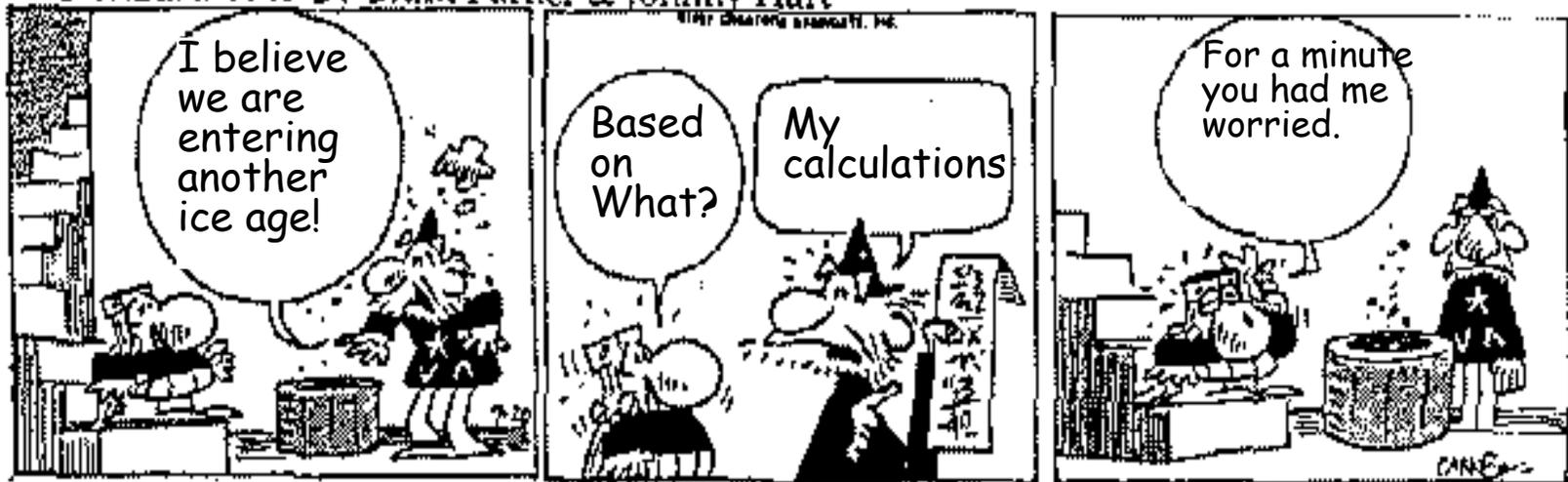


Conclusion: some external factor is contributing to seasonal warming in California.

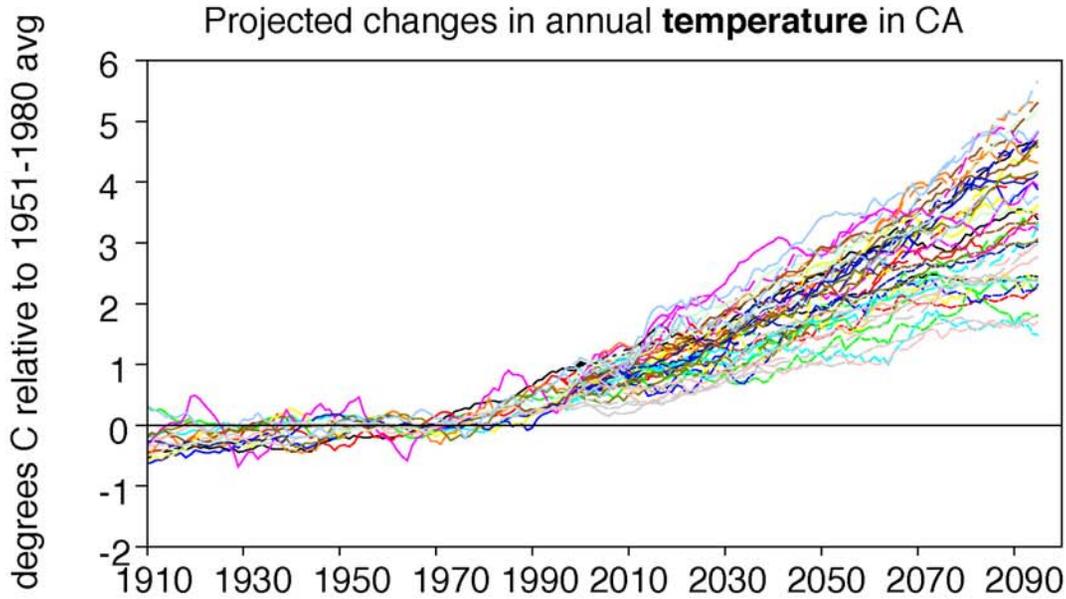
The Future

Climate projections are not perfect...

The Wizard of Id By Brant Parker & Johnny Hart

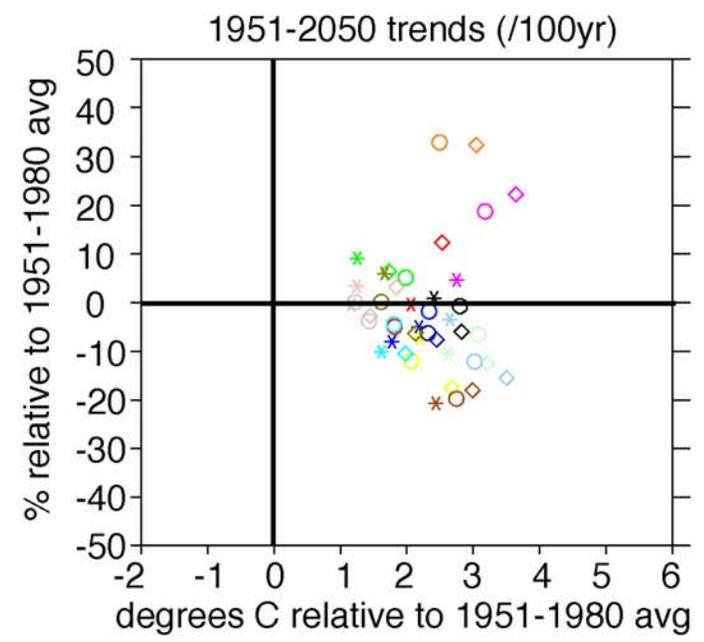
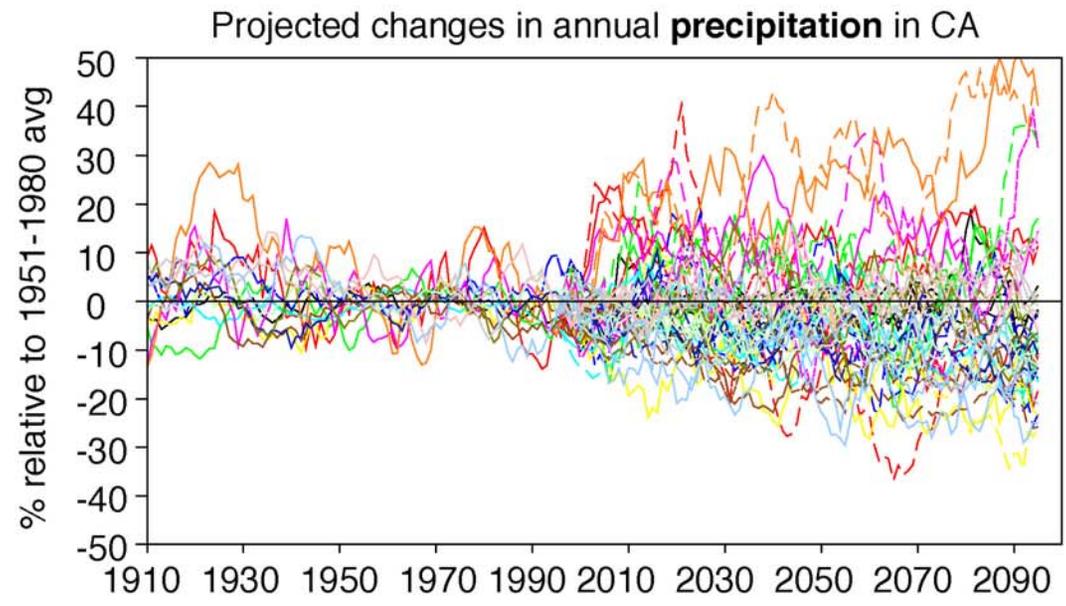


...So we make projections with quantified uncertainties



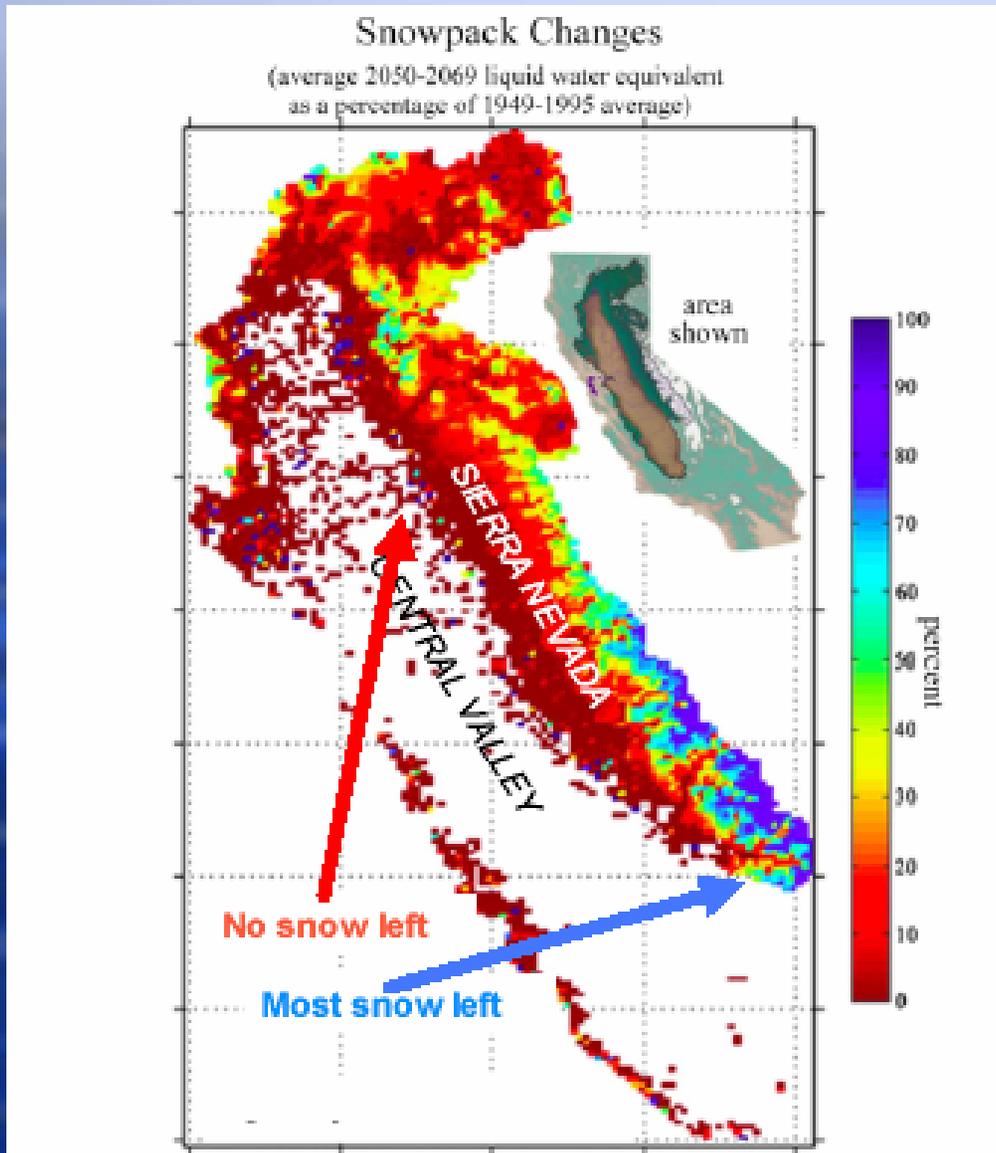
- cccma_cgcm3_1
- cnrm_cm3
- csiro_mk3_0
- gfdl_cm2_0
- gfdl_cm2_1
- giss_model_e_r
- inmcm3_0
- ipsl_cm4
- miroc3_2_medres
- miub_echo_g
- mpi_echam5
- mri_cgcm2_3_2a
- ncar_ccsm3_0
- ncar_pcm1
- ukmo_hadcm3

15 models
x 3 “scenarios”



dot & star: SRESB1, solid & diamond: SRESA1B, long-dash & circle: SRESA2

California's snowpack will decrease



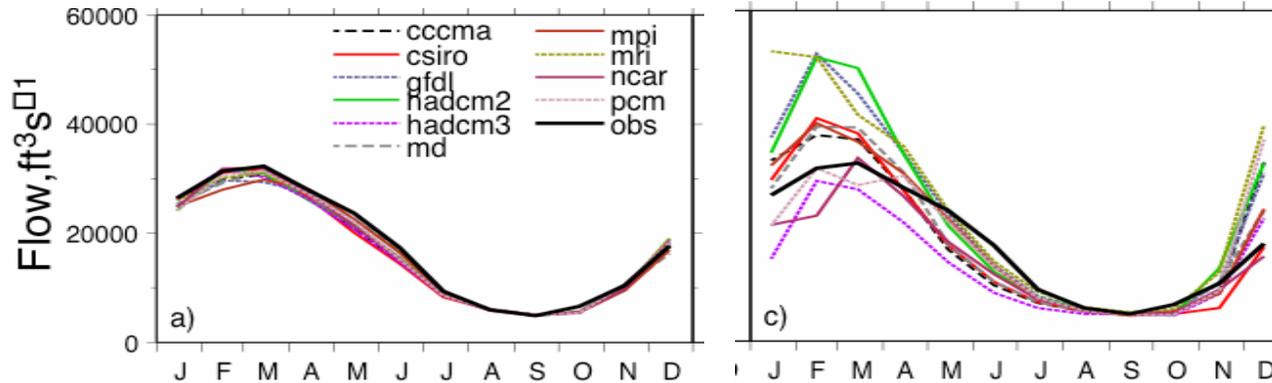
Projected snow water content in 2050-2069, as a fraction of 1949-1995 average

This is a typical projection; actual results may vary. Do not try this at home.

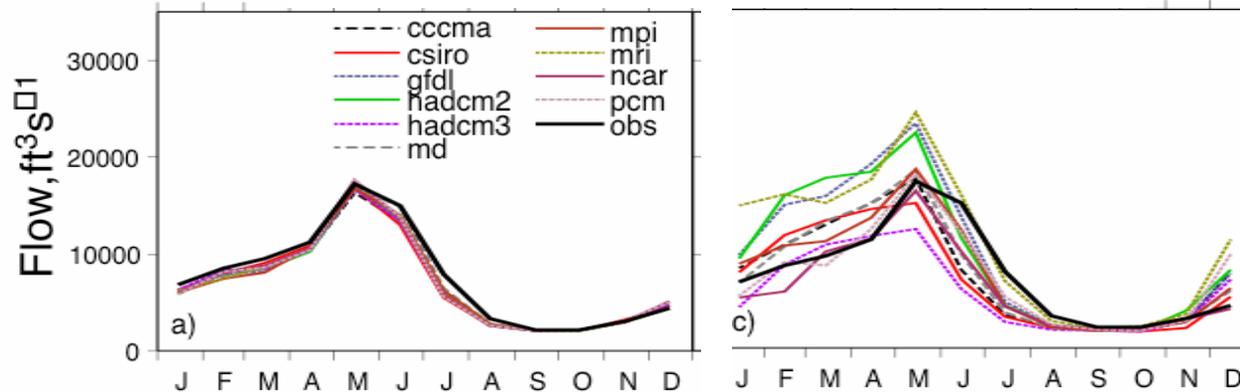
Model: PCM (low sensitivity)

Source: Knowles and Cayan, 2002, *GRL*

Warming changes timing of river flows



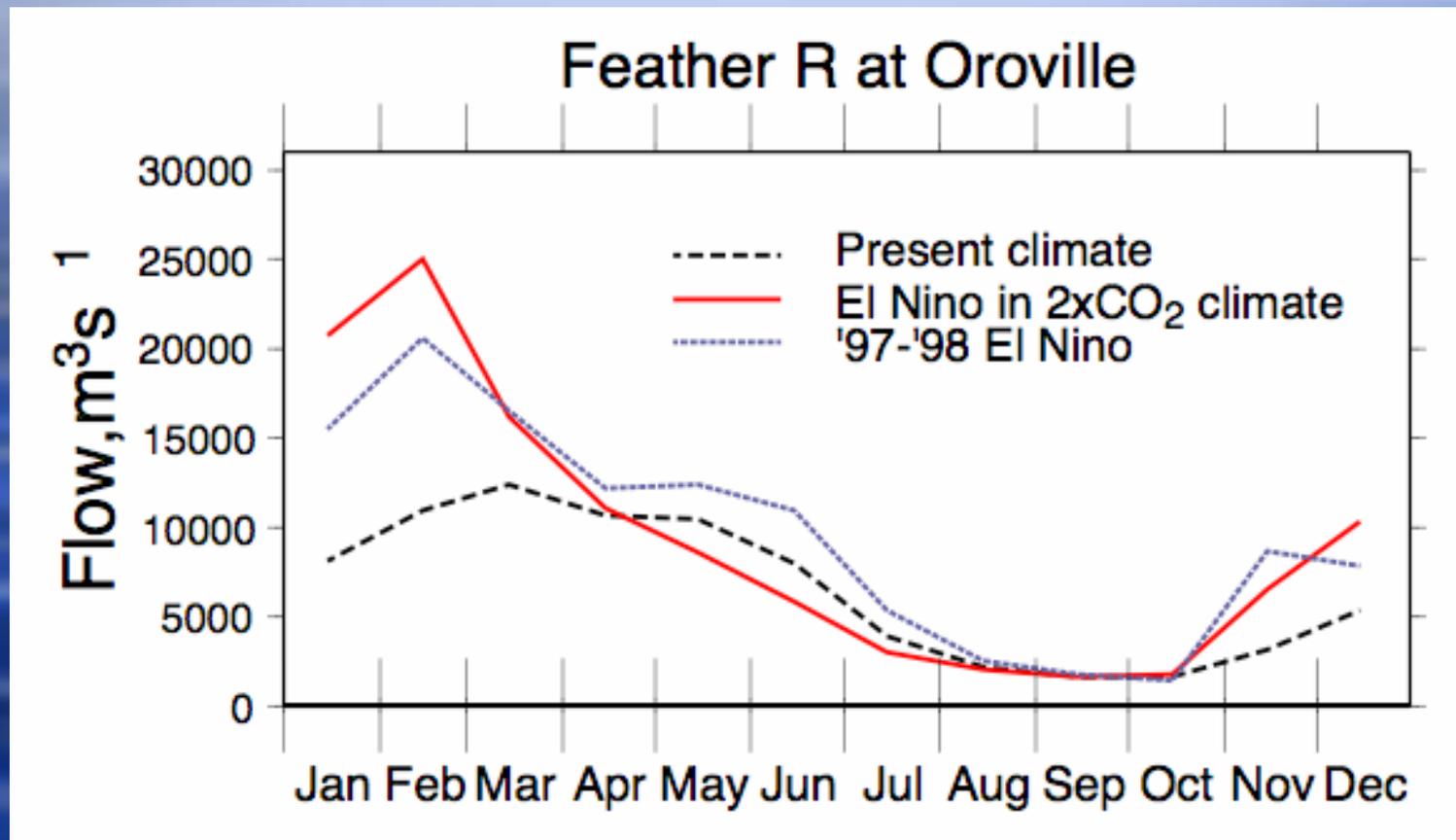
3 No. Cal. rivers



4 So. Cal. rivers

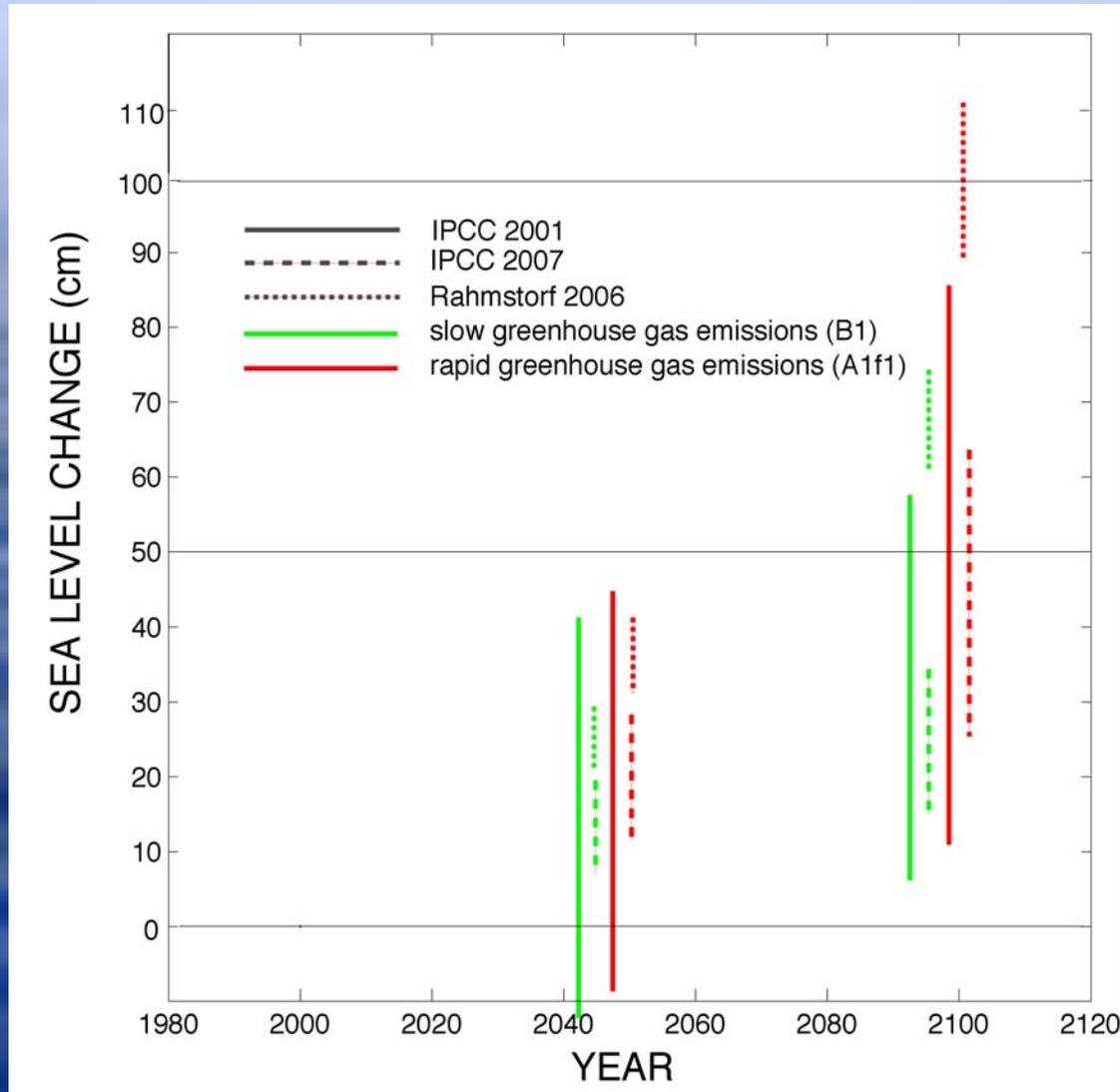
River flow simulations based on results of 10 different climate models

El Nino in a warmed climate: floods in winter, water shortages in summer



E. Maurer, S. Gibbard, and P. B. Duffy, Amplification of streamflow impacts during El Nino conditions in California under a warming climate, *Geophys Res Lett.*, Vol. 33, No. 2, L02707 10.1029/2005GL025100, 27 January 2006.

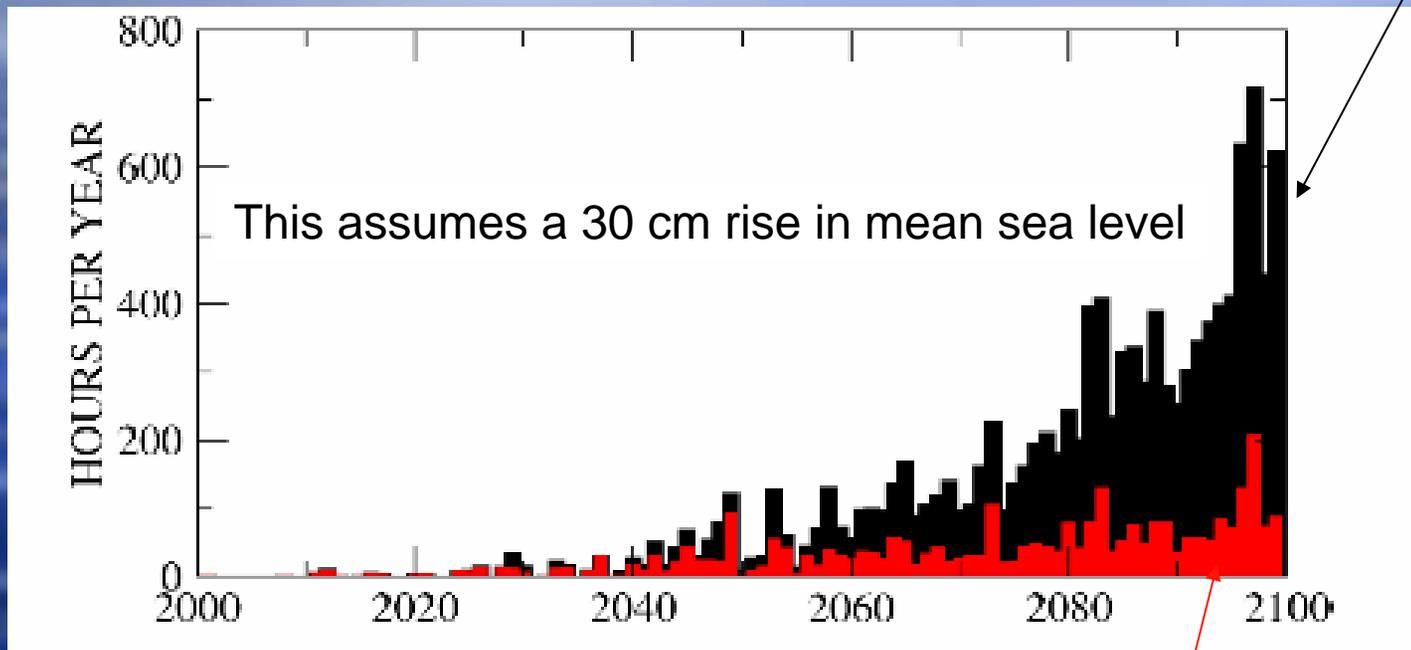
Published sea level projections are uncertain



These projections assume no significant melting of Greenland

High water levels in the Delta will occur more often

Projected hours per year with Delta water level above historical 99.99% level...



...And much below-normal atmospheric pressure

Summary: Expected climate changes

- ◆ Warmer in all seasons
- ◆ Uncertain changes in mean precipitation amounts
- ◆ More frequent extreme temperature and precipitation events
- ◆ Less snow; earlier snow melt
- ◆ Increased early-season river flows, and increased year-to-year variability in flows.
- ◆ Decreased late-season flows
- ◆ Higher sea levels (both average and extremes)
- ◆ More frequent occurrence of high water levels in the Delta

How to use this information?

- ◆ Don't expect uncertainties to be reduced much in a year (or two).
- ◆ Climate change will unfold over years (although it will be punctuated by events such as floods), so you will have some time to adapt.
- ◆ If adaptation requires many years (e.g. if it requires building infrastructure) you should consider the more pessimistic scenarios.

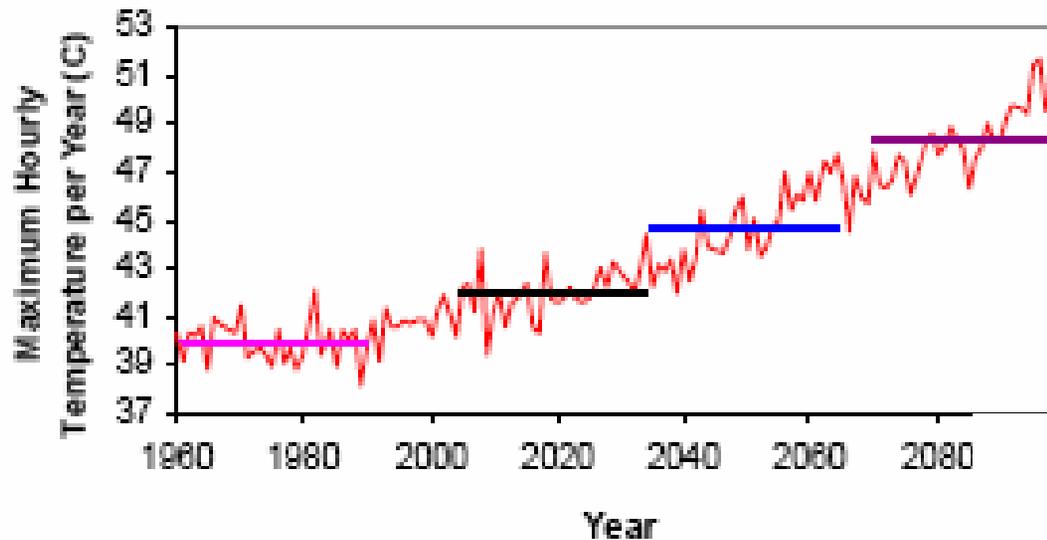
That's all Folks!



Cartoon Songs From

MERRIE MELODIES & LOONEY TUNES

Temperature extremes are projected to increase, *a lot*



CLIMATE CHANGE AND ELECTRICITY DEMAND IN CALIFORNIA

A Report From:
California Climate Change Center

Prepared By:
Guido Franco and Alan H. Sanstad

DISCLAIMER

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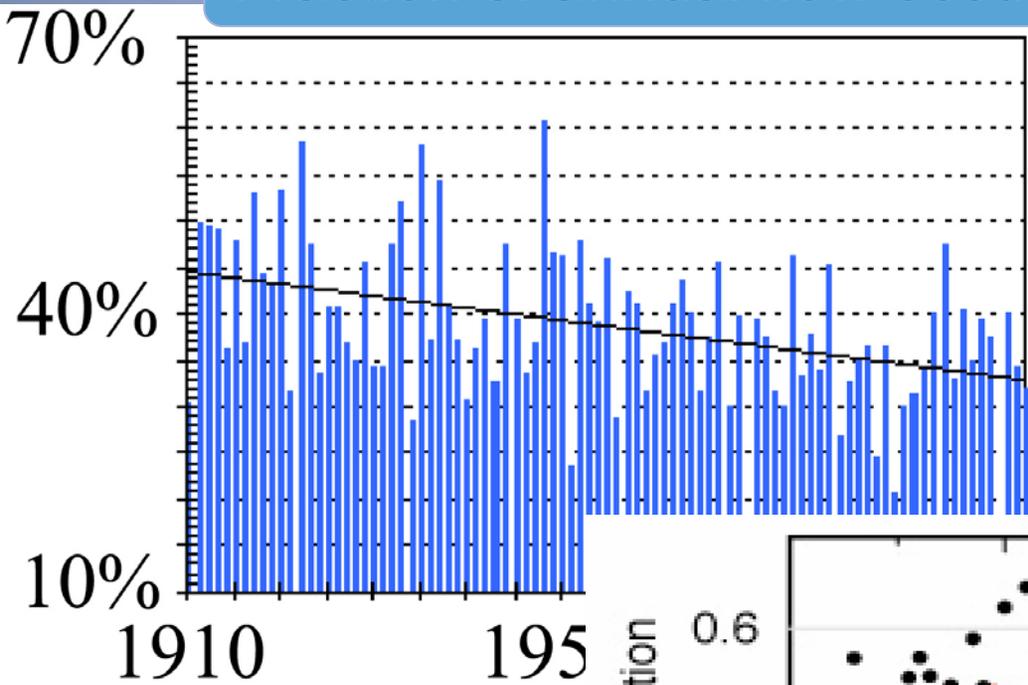


Arnold Schwarzenegger, GOVERNOR

Source:

Late-season river flows are decreasing, due to warming

Fraction of annual flow occurring in April - July



← Sacramento river system

8 major rivers →

