



# Climate in California: Observed Trends, Interpretation, and Future Projections

Philip B. Duffy

Lawrence Livermore National Laboratory  
and  
University of California, Merced

# Who am I?

My day jobs:

Physicist,  
Energy and Environment Directorate,  
Lawrence Livermore National Laboratory

Director, University of California  
Institute for Research on Climate Change and its  
Societal Impacts

Associate Adjunct Professor, U.C. Merced  
School of Natural Sciences



THIS TALK APPROVED FOR

**G GENERAL AUDIENCES**

All Ages Admitted 

®

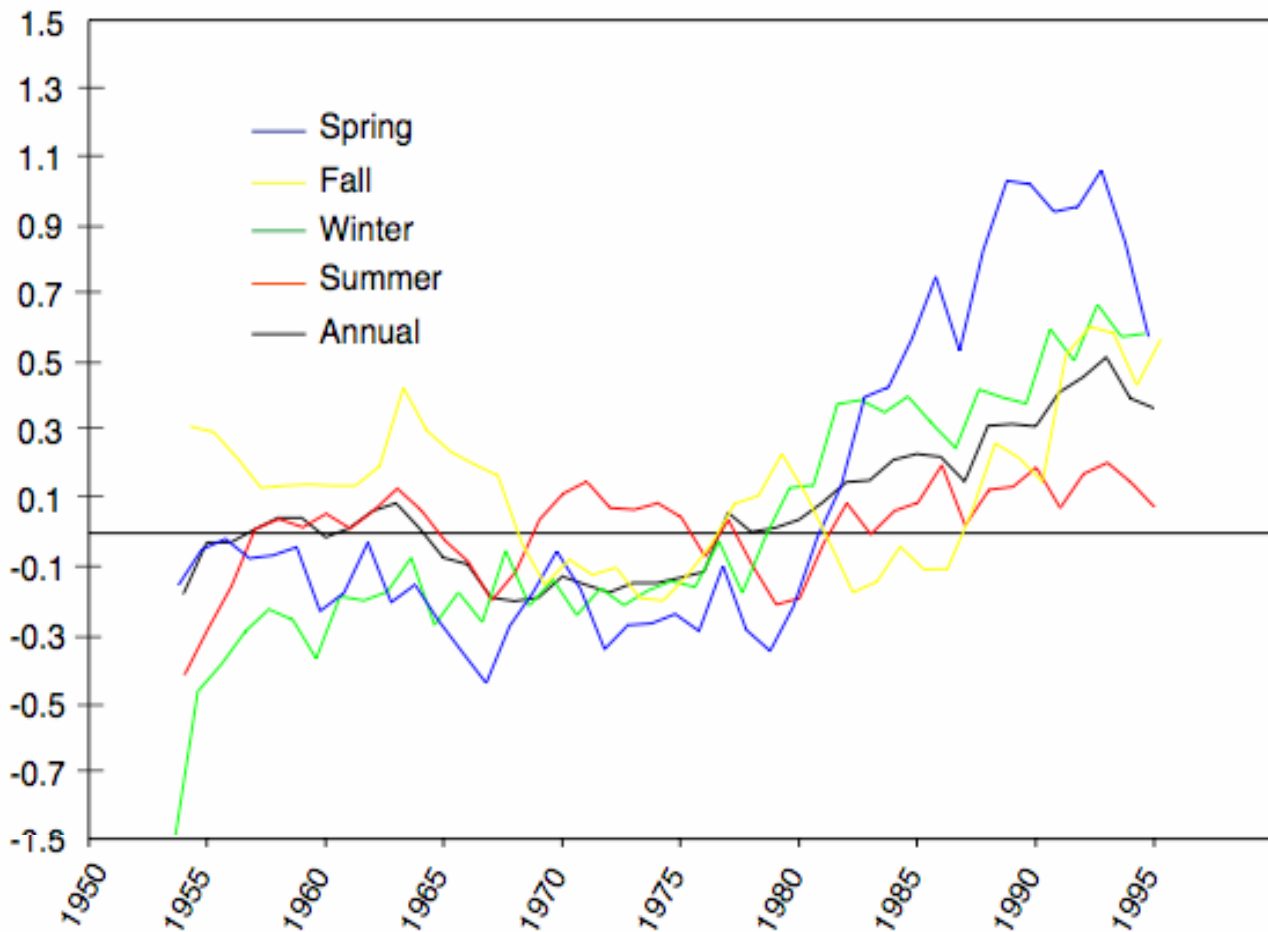
# The Past: Observed Climate Trends



# California is warming...

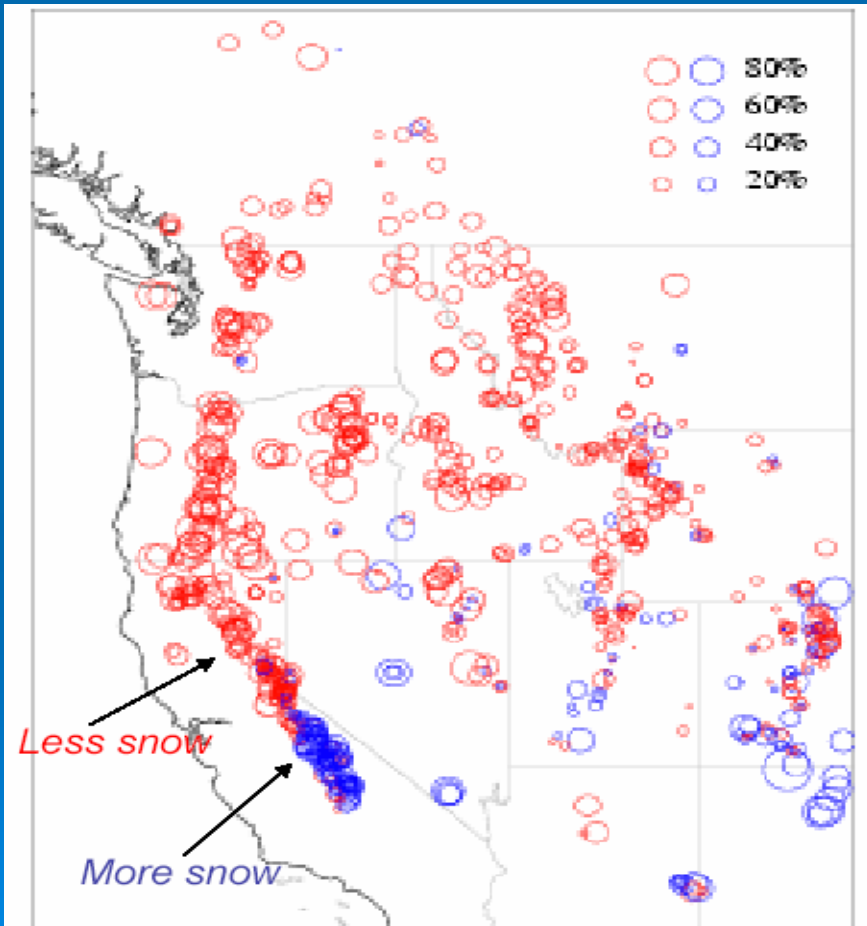
## Average temperatures, by season

Temperature Change (deg. C)

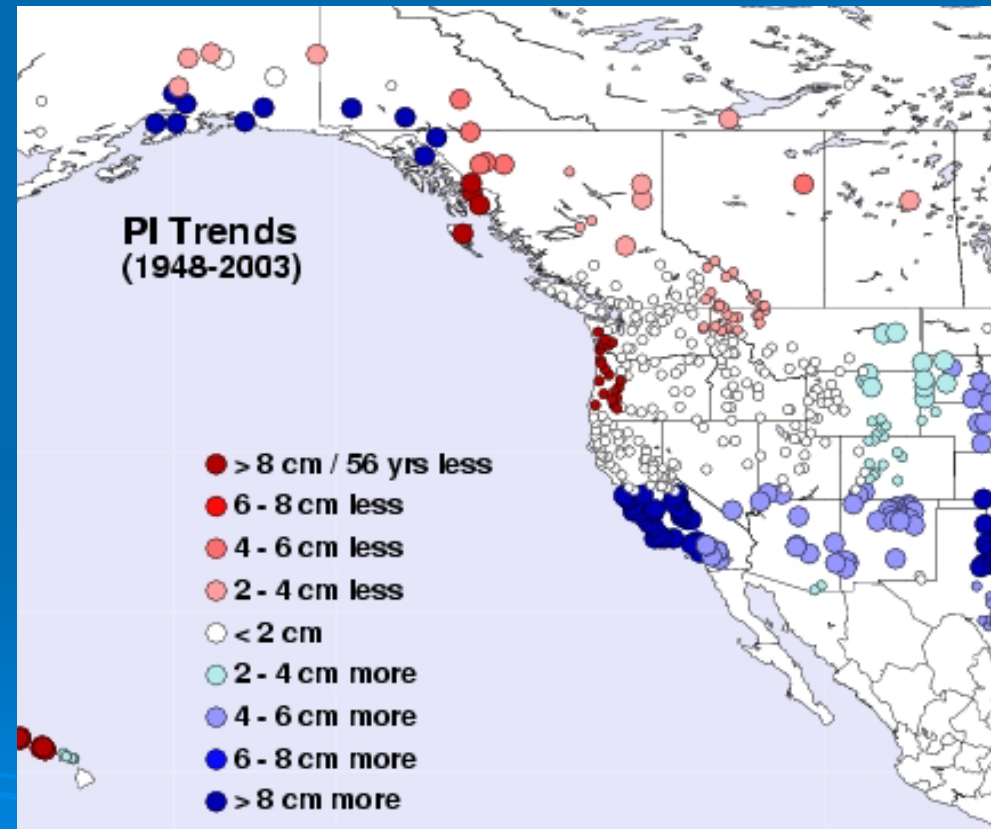


# There is less snow in most of the west

50-yr trends in snow water content



50-yr trends in precipitation

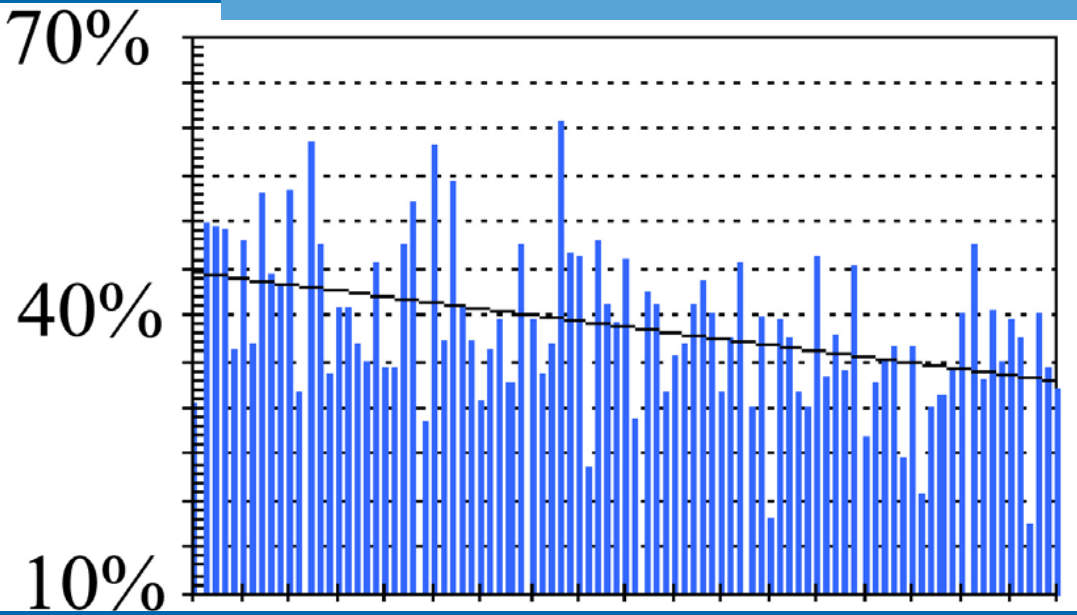


Source: P. Mote, *Bull. Amer. Meteor. Soc.*, 2005

Source: Iris Stewart, UCSD

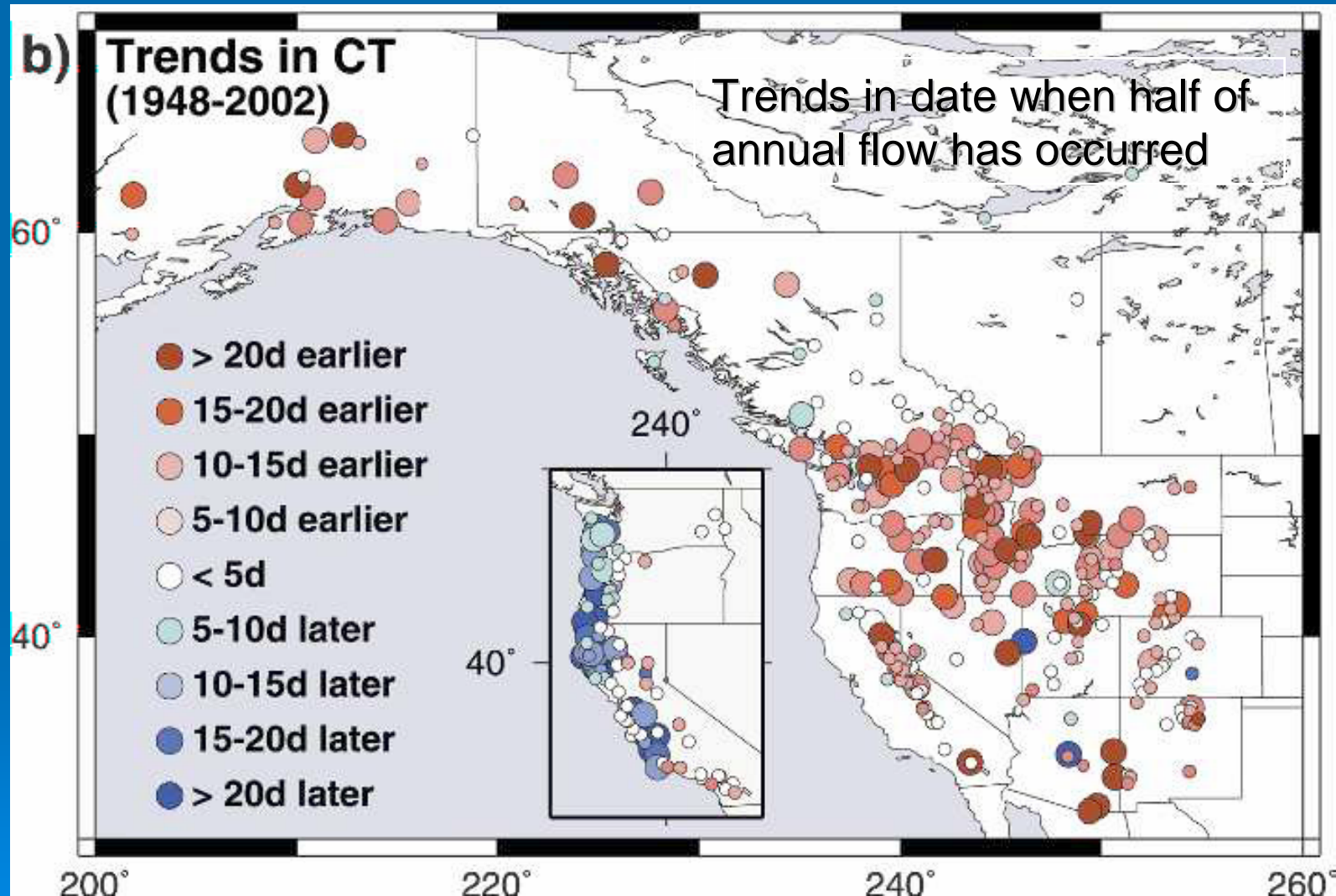
# Late-season river flows are decreasing, due to warming

Fraction of annual flow occurring in April - July



← Sacramento river system

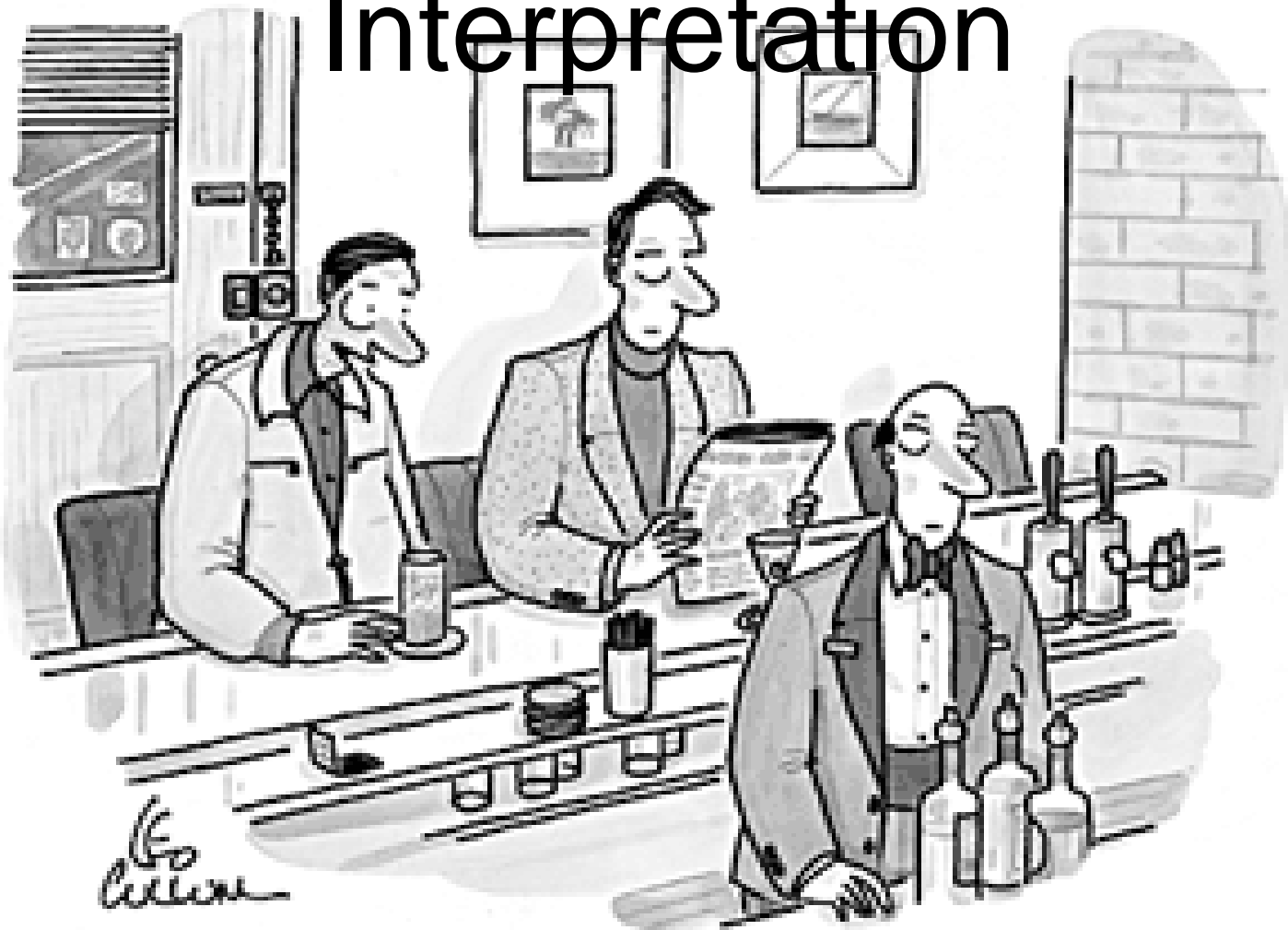
# River flow is coming earlier in the year



Source: Iris Stewart, UCSD



# Interpretation

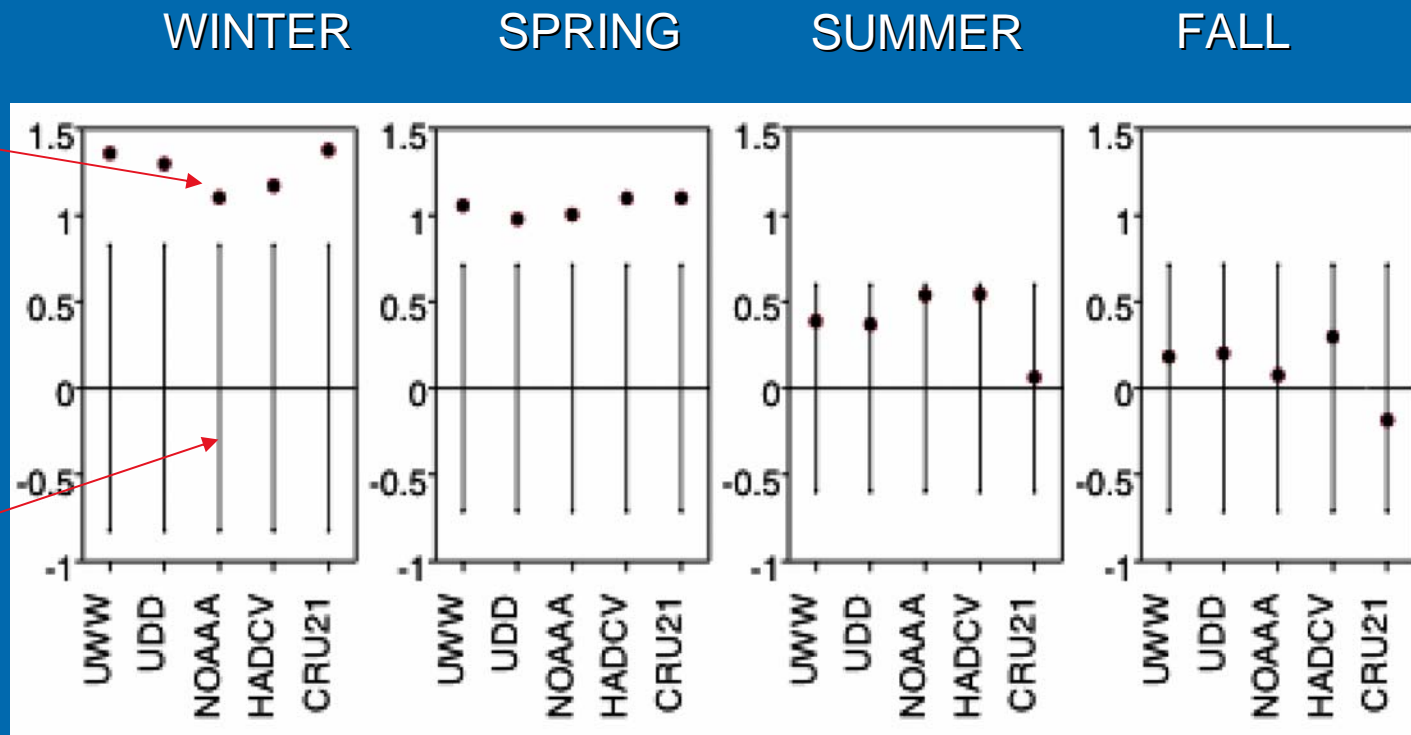


*"I don't know anything about global warming, but these ice cubes are melting like crazy."*

# Temperature changes are faster than expected from natural climate variability

Observed trends from 5 different data sets

Maximum likely trend due to natural internal variability

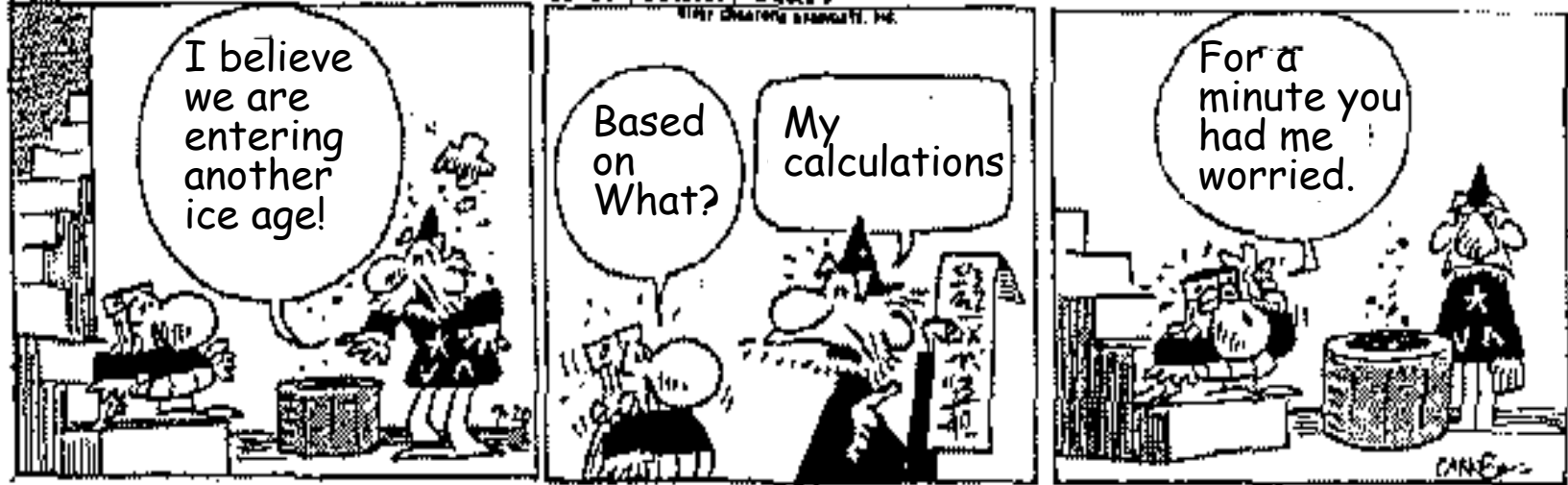


Conclusion: some external factor is contributing to winter and spring warming in California.

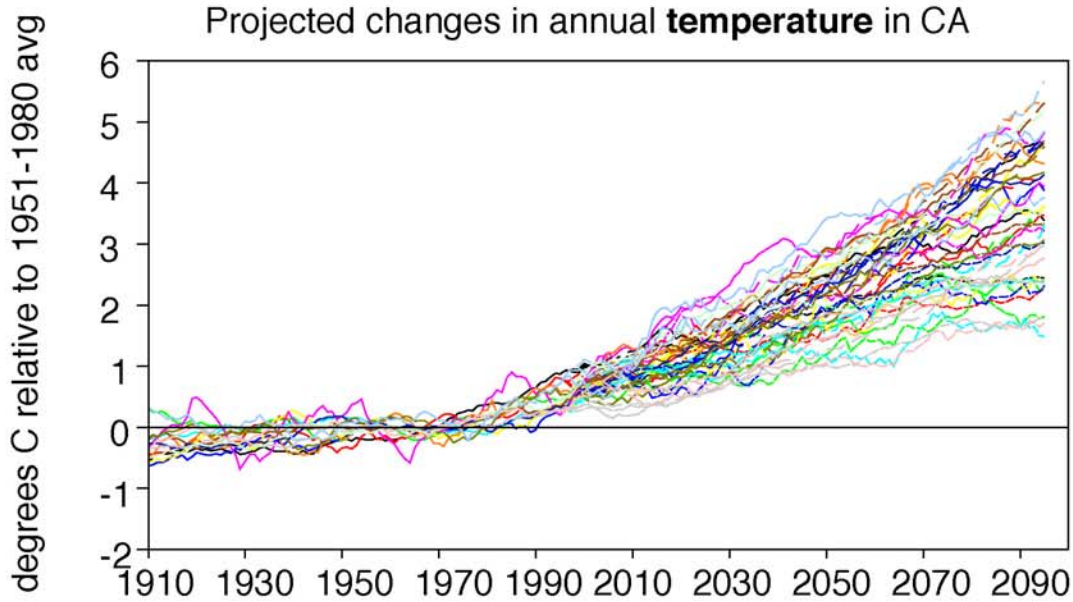
Source: Bonfils and Duffy, 2007, paper in press

# The Future

The Wizard of Id By Brant Parker & Johnny Hart

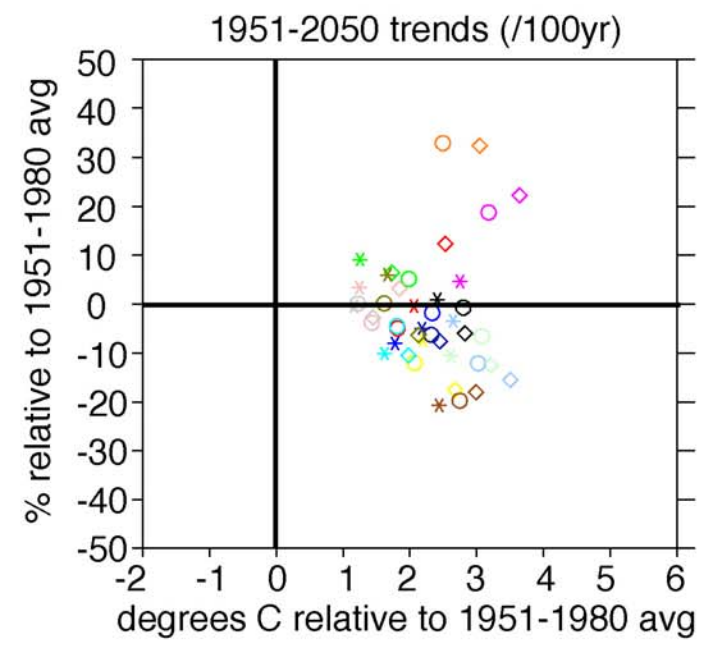
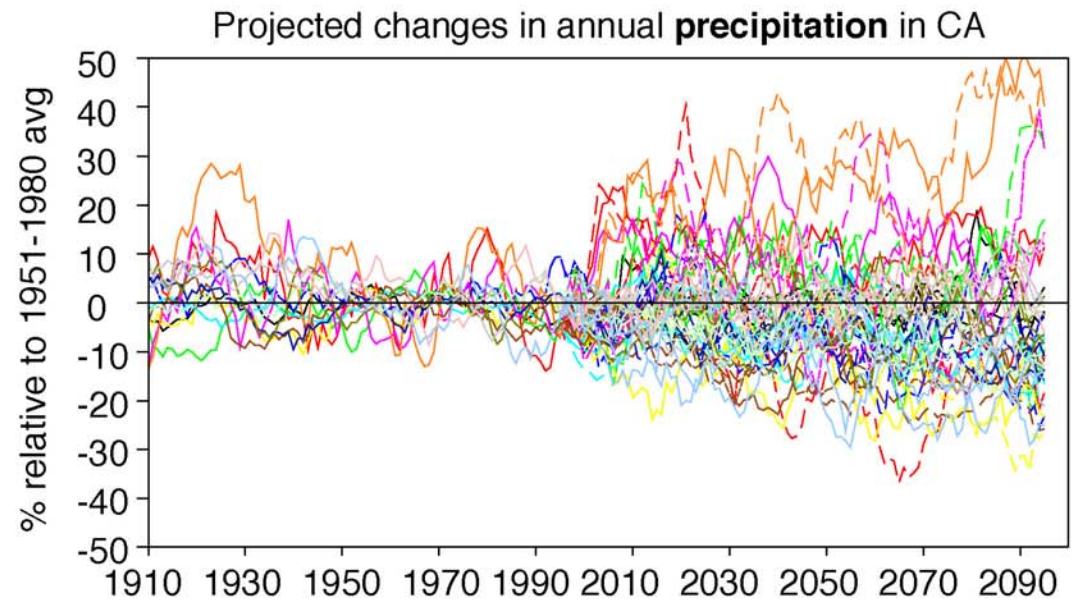


Because climate models are not perfect,  
we make projections with quantified uncertainties



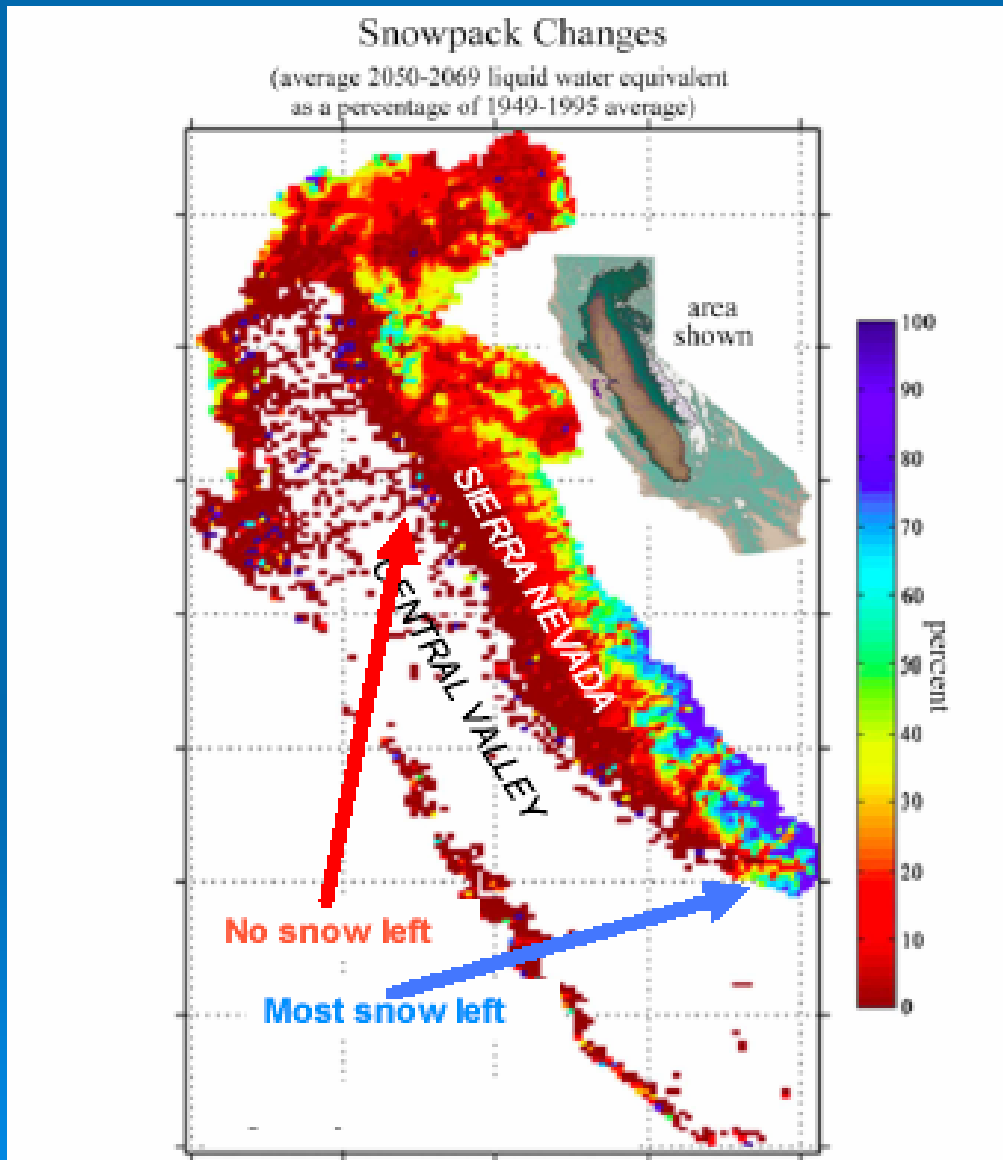
- cccma\_cgcm3\_1
- cnrm\_cm3
- csiro\_mk3\_0
- gfdl\_cm2\_0
- gfdl\_cm2\_1
- giss\_model\_e\_r
- inmcm3\_0
- ipsl\_cm4
- miroc3\_2\_medres
- miub\_echo\_g
- mpi\_echam5
- mri\_cgcm2\_3\_2a
- ncar\_ccsm3\_0
- ncar\_pcm1
- ukmo\_hadcm3

15 models  
x 3 “scenarios”



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

# California's snowpack will melt



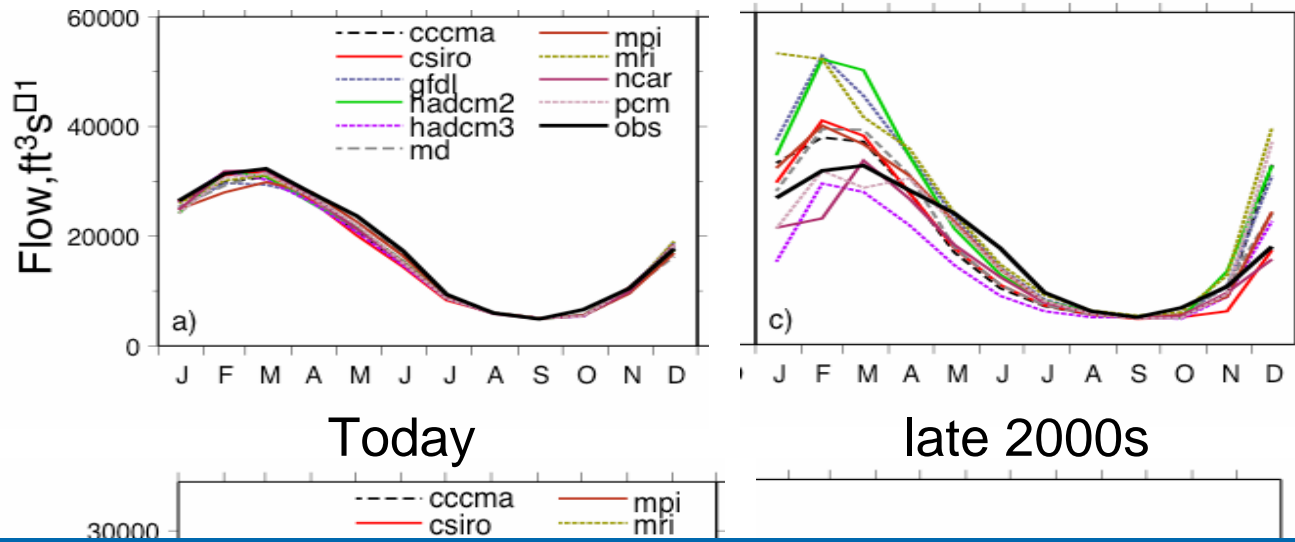
Projected snow water content in 2050-2069, as a fraction of 1949-1995 average

*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



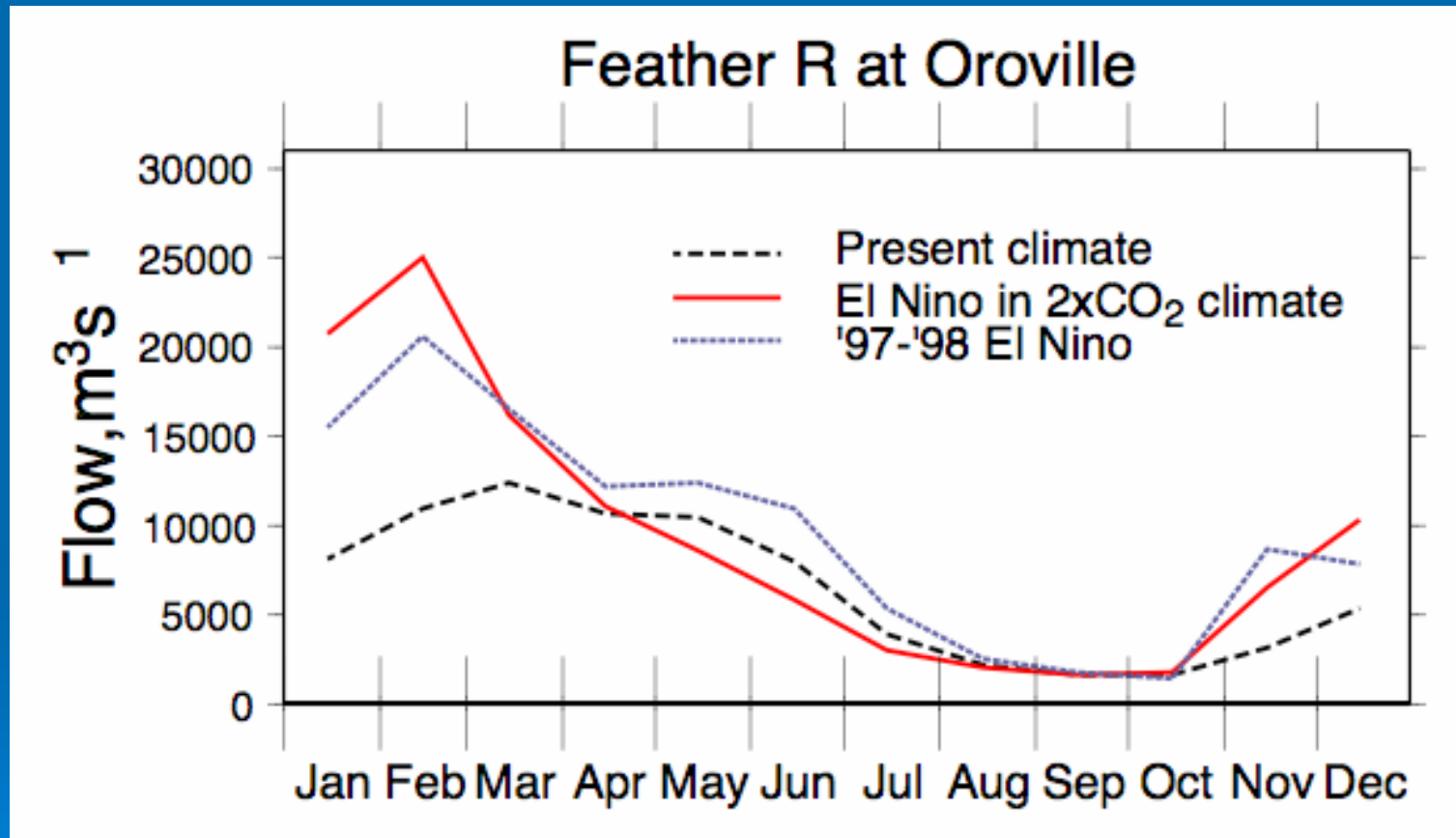
3 northern rivers

4 southern rivers

River flow simulations based on results of 10 different climate models

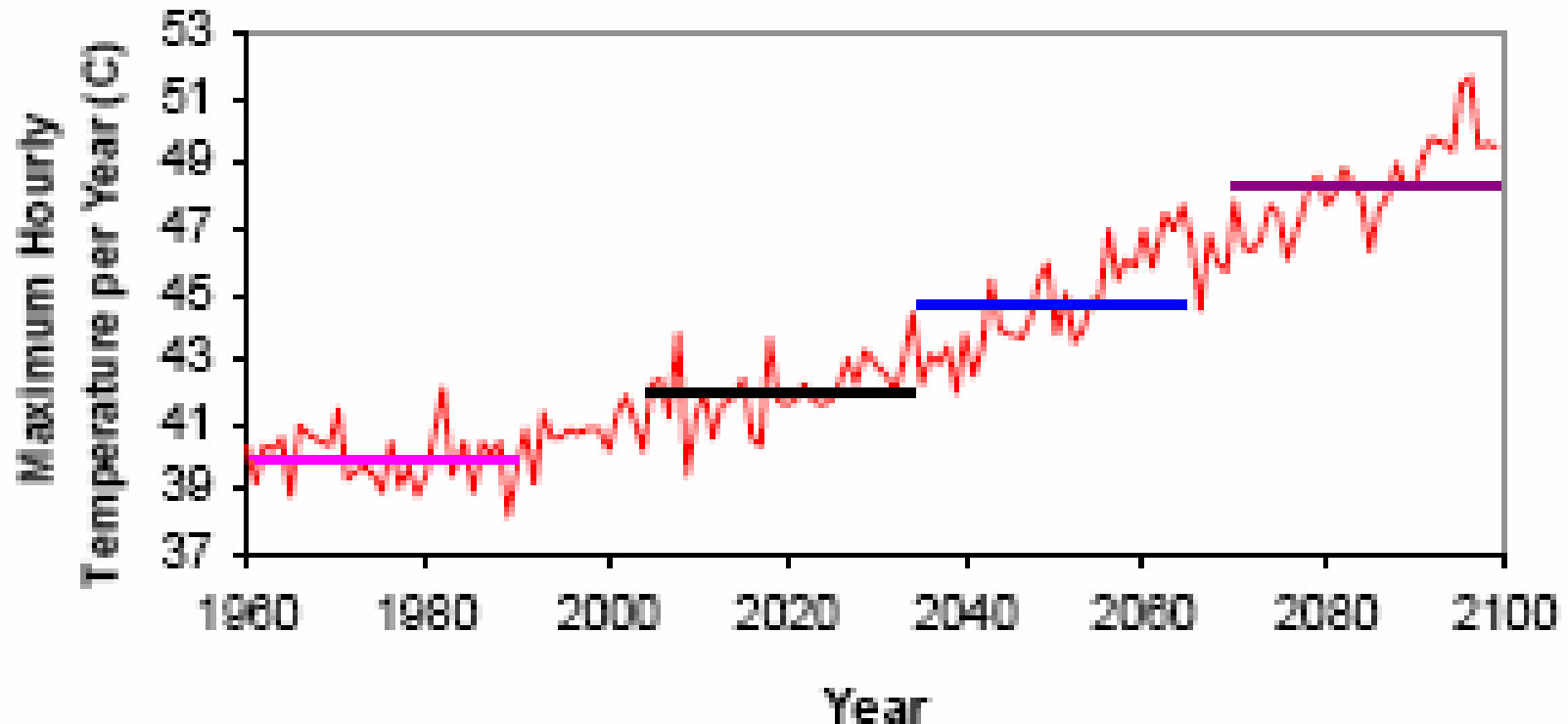
Source: E. Maurer and P. Duffy. *Geophys. Res. Lett.*, 2005

# 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.

# Temperature extremes are projected to increase, a lot



Source: G. Franco and A. Sanstad, *Climate change and electricity generation in California*, CEC Report



# Summary: Expected climate changes

- Warmer in all seasons
- Uncertain changes in mean precipitation amounts
  - But important effects on hydrological cycle result from warming, which is much more certain
- Less snow; earlier snow melt
- Increased early-season river flows, and increased year-to-year variability in flows.
- Decreased late-season flows
- Drier summer soil; greater risk of forest wildfires
- More frequent extreme temperature and precipitation events

*“That’s all Folks!”*



Cartoon Songs From

**MERRIE MELODIES & LOONEY TUNES**

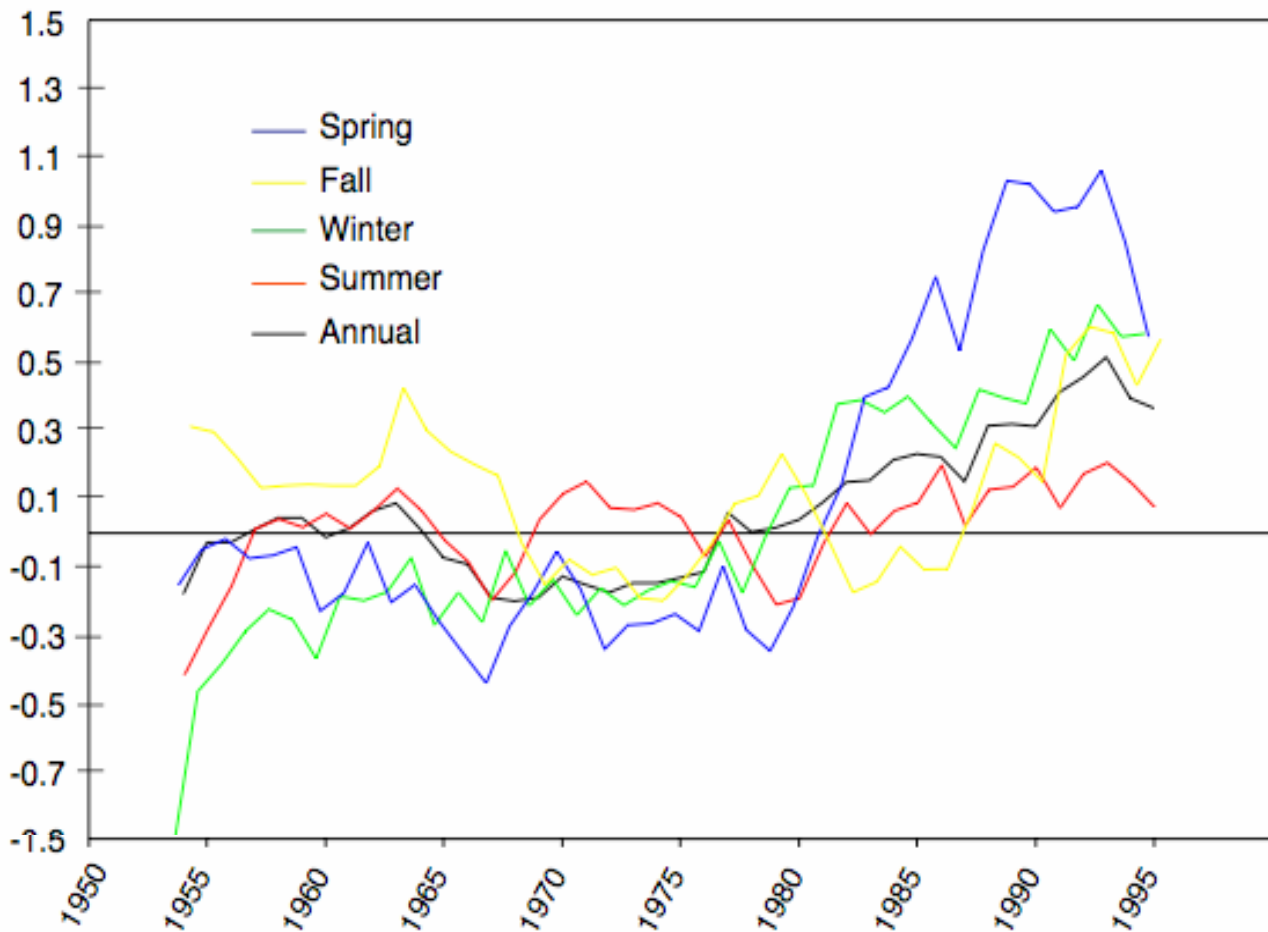
# Philip B. Duffy...

... is a Physicist at Lawrence Livermore National Laboratory, and Adjunct Associate Professor at U.C. Merced. He is also Director of the University of California's Institute for Research on Climate Change and its Societal Impacts (IRCCSI). He is an expert on the science of climate change and the societal impacts of climate change, particularly in California. He holds an AB degree *magna cum laude* in astrophysics from Harvard University, and a Ph.D. in physics from Stanford. He has published over 50 peer-reviewed papers on astrophysics, atomic physics, or climate change.

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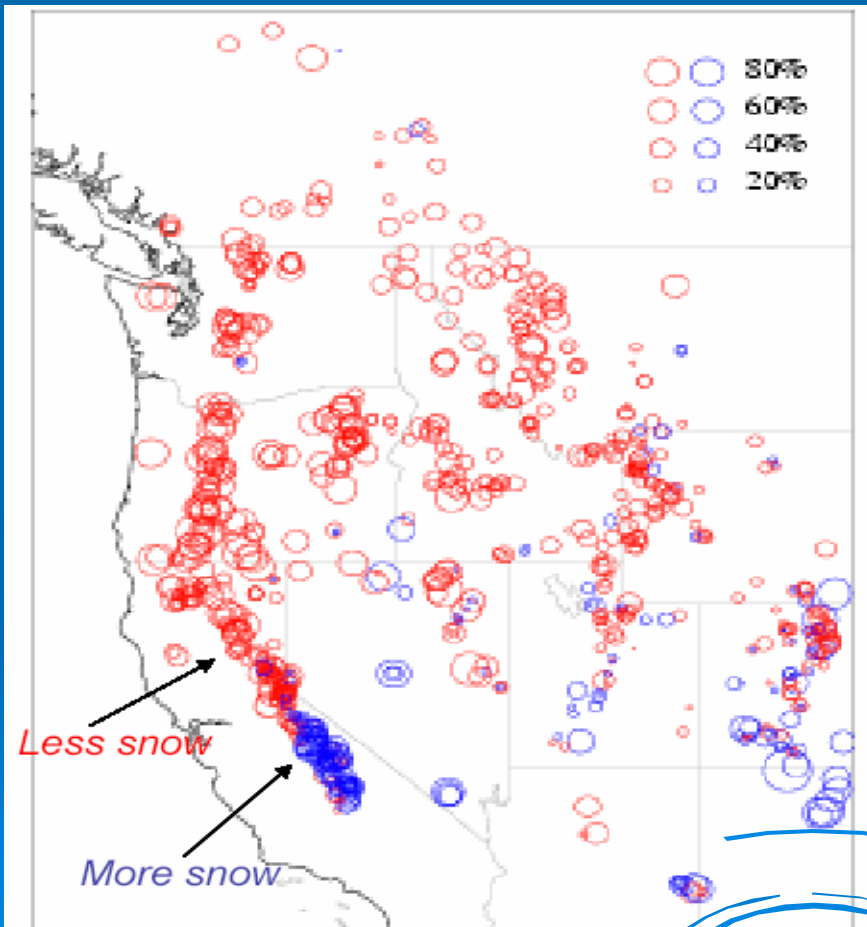
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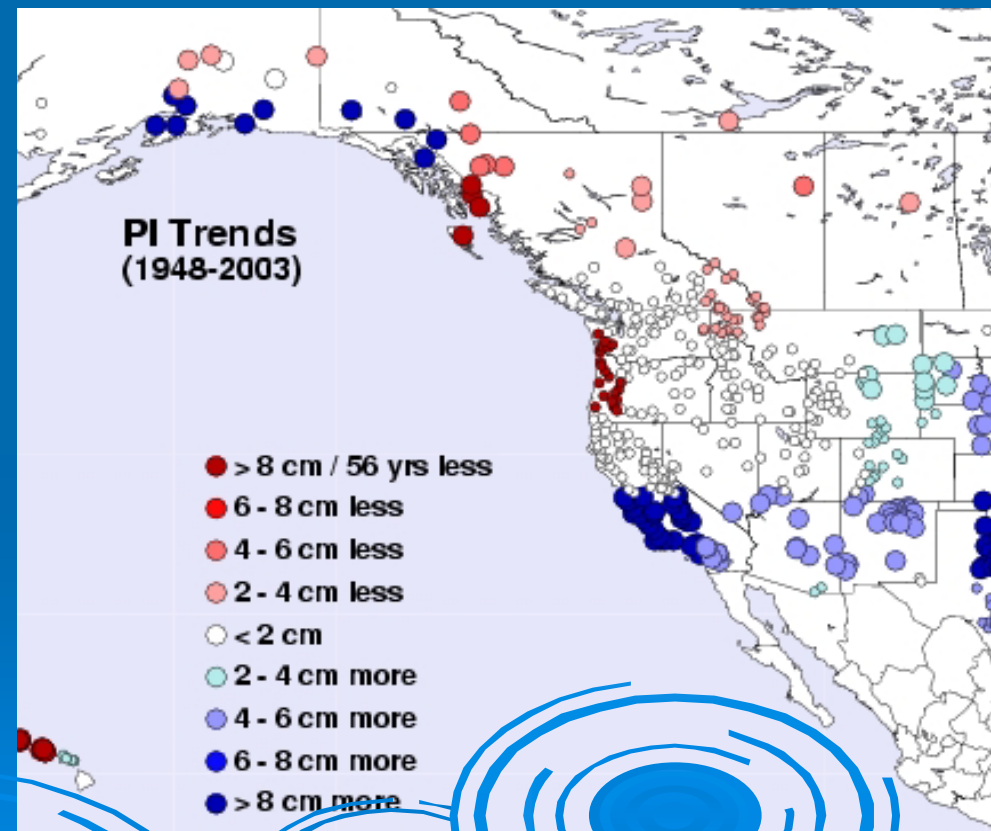


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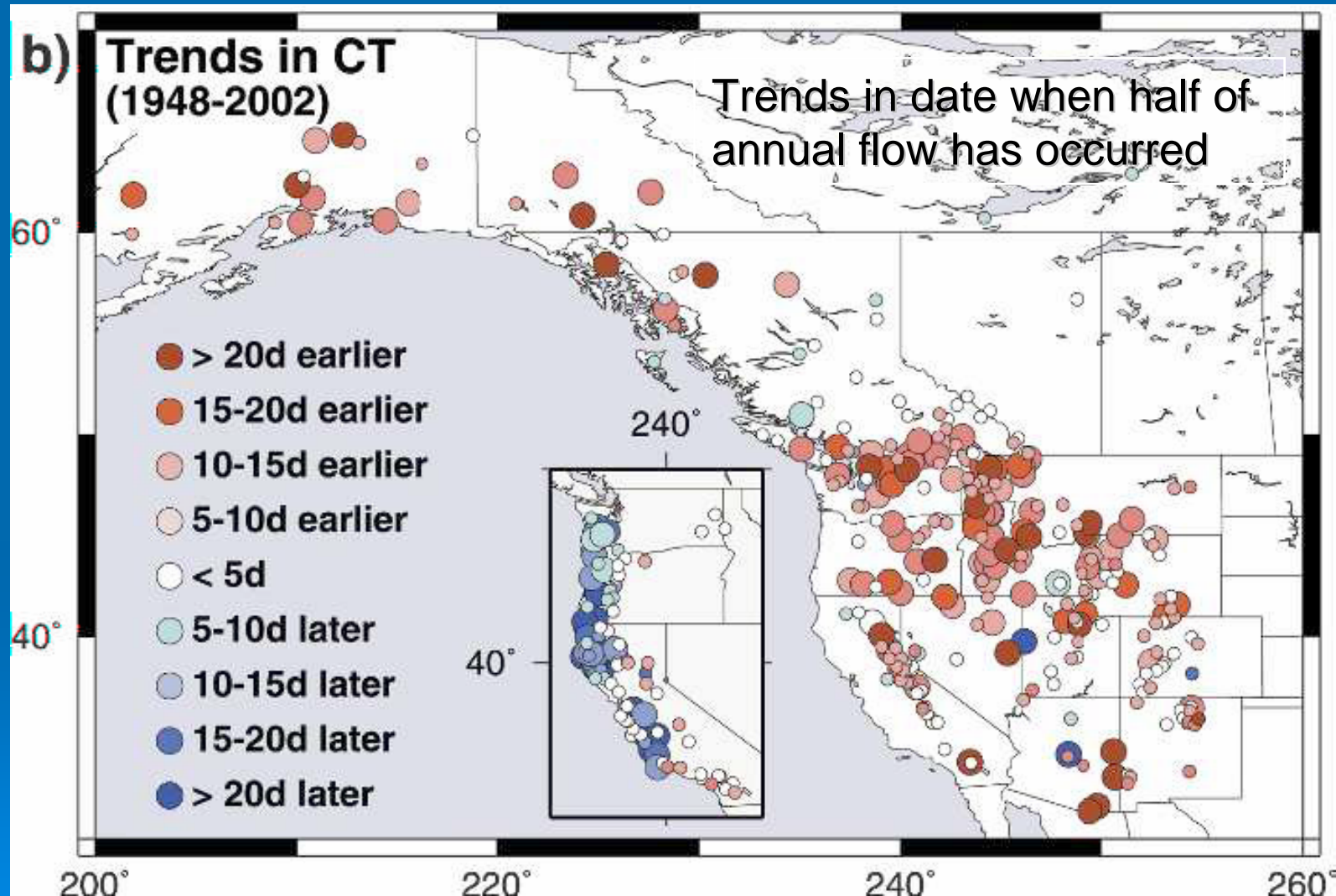
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Source: P. Mote, *Bull. Amer. Meteor. Soc.*, 2005

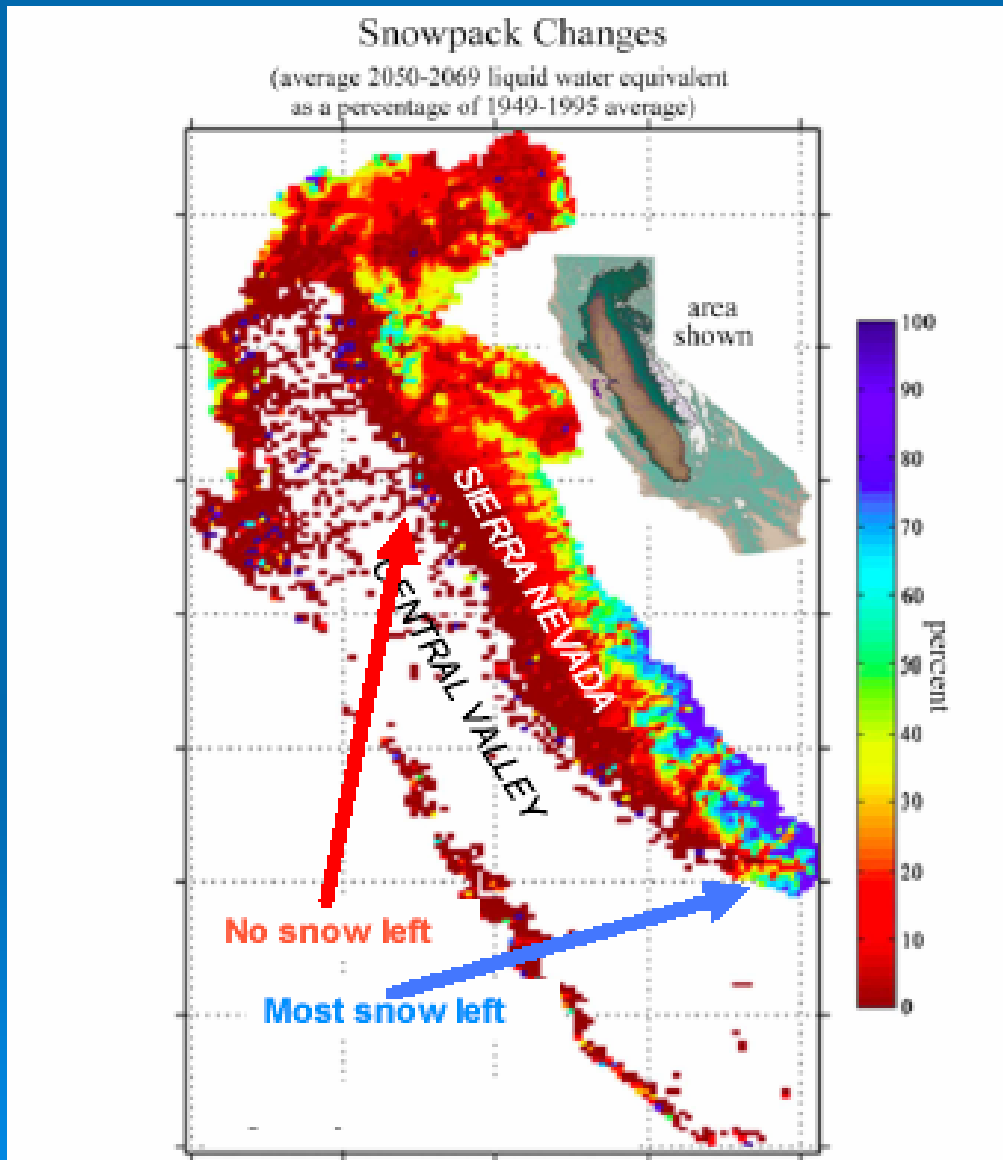
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