Climatic Change Implications for Hydrologic Systems in the Sierra Nevada

Part One:

Climatic Change Background Information

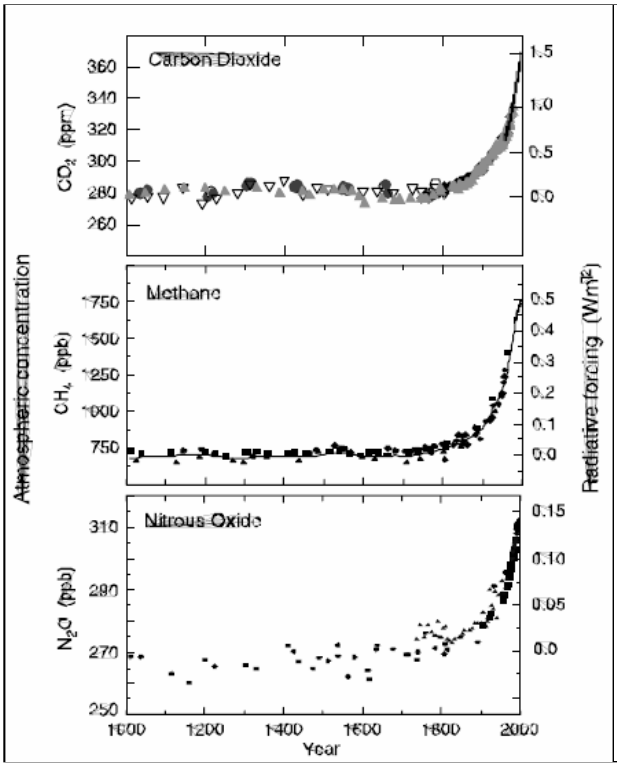
Part one presents background on climate change including some GCM results, modeling results as relates to some regional climate indicators, and recent regional trends in basic climate indicators.

Part 1 was compiled by Otis Wollan from the following presenters:

Phil

Dan Cayan

Mike Dettinger

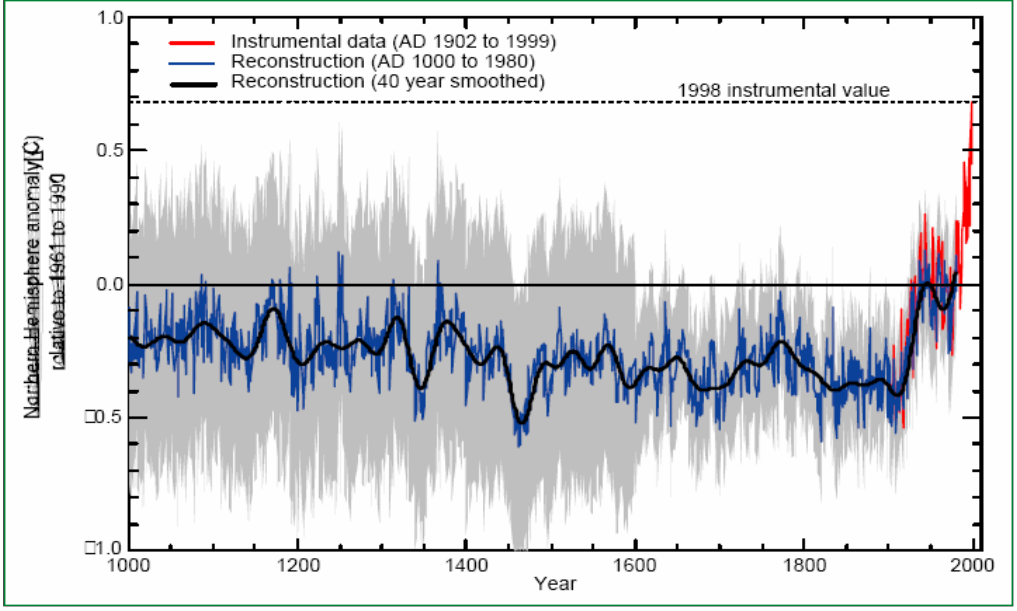


Greenhouse Gases:

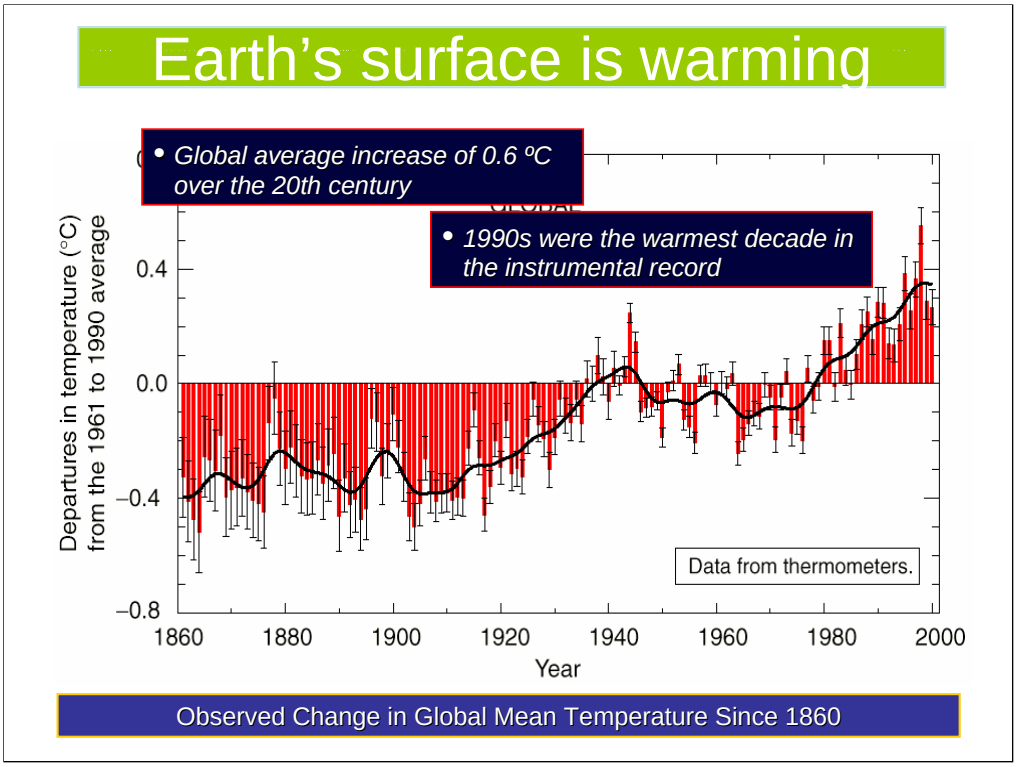
Carbon Dioxide, Methane, & Nitrous Oxide have atmospheric concentrations that are increasing dramatically.

A 1000 year summary of greenhouse gas concentrations. The dramatic increase falls within the 20th century.

Temperatures have risen as greenhouse gas concentrations have increased

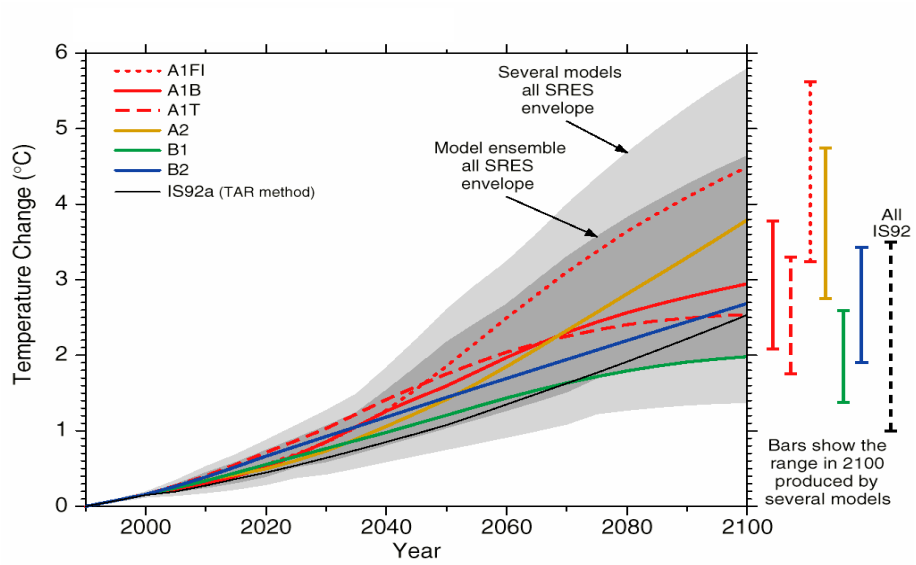


Temperature overview the past 1000 years for the Northern Hemisphere shows temperature increased dramatically in the past century, in synch with the increase in greenhouse gases.

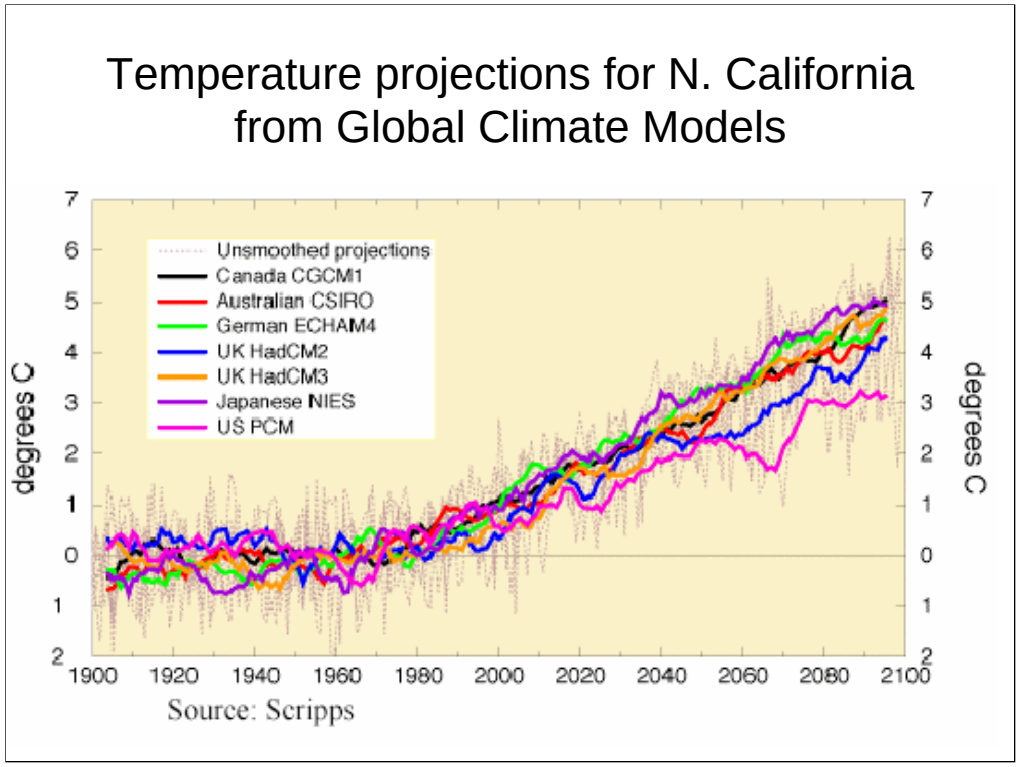


An overview of the increase in global temperatures showing the increase in temperature in the last 150 years.

Projecting into the future: Global Temperature change Models



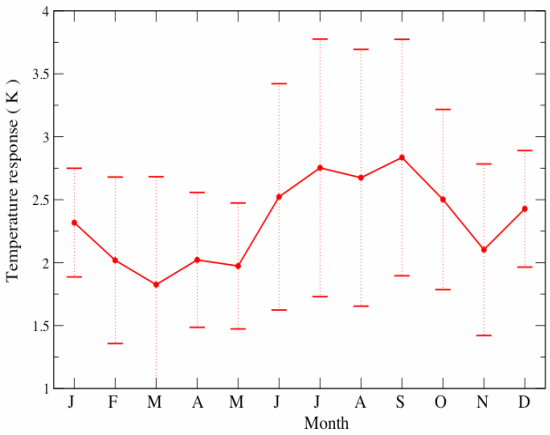
Global models project increases in temperature in the future, based on assumptions of increases in greenhouse gases and assumptions on climatic dynamics. Differences in the assumptions of both future levels of greenhouse gases and future dynamic climate reactions are reasons for varying projections. Many global climate scenario models have been generated; the above graph compares the most widely accepted scenarios as compiled by Scripps Institute.



Scripps Institute compared the global climate scenarios by selecting the model grids that affect Northern California.

For the purpose of the watershed yield calculator funded for this EPA study, the study team selected a time horizon of fifty years, and a range of possible temperature increase from 1 to 4 degrees Centigrade. Essentially, the user of the calculator can model watershed yield for any (or all) of those four degrees of change. The user choice of 1-4 degrees over fifty years is consistent with these Northern California scenarios which shows projections of up to 5 degrees Centigrade over 100 years.

Mean and Standard Deviation Of 15 Global Climate Models (GCM's) agree: Western States will get warmer, but by how much?

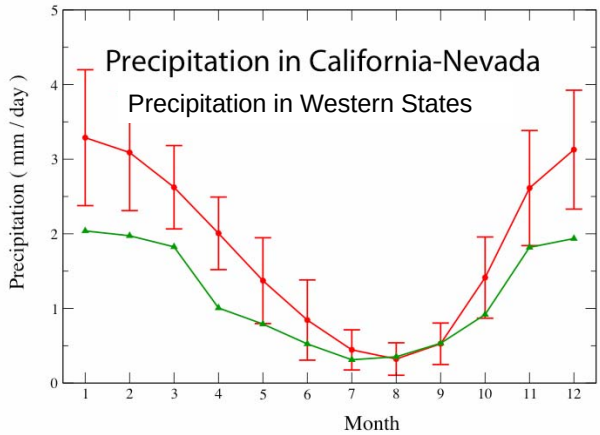


Coquard et al. "Present and Future Surface Climate in the US as Simulated by 15 GCM's" *Climate Dynamics*, 2004.

The graph shows mean and standard deviation of 15 global models in response to a doubling of CO_2 concentrations. Models agree that temperatures will rise 2-3 degrees, with greatest increases occurring in summer, then winter, with lesser changes in spring and fall.

The watershed yield calculator distributes the annual change evenly throughout the year. If that annual response were plotted in the graph on the right, it would be a straight line, placed from 1 degree to 4 degrees according to the choice of the calculator user. This could mean that ET losses in the summer and winter snowmelt are underestimated in the watershed yield calculator.

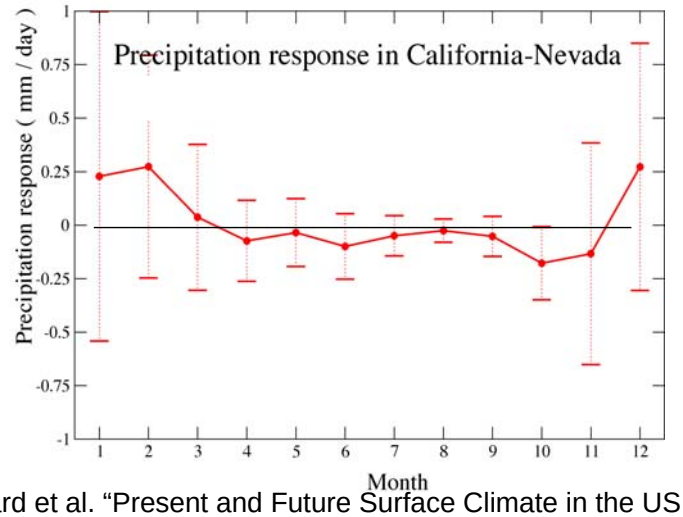
Mean & standard deviation of 15 GCM's simulated precipitation compared to observed precipitation tend to over-estimate precipitation



Coquard et al. "Present and Future Surface Climate in the US as Simulated by 15 GCM's" *Climate Dynamics*, 2004.

The global climate models generally overestimate precipitation for Western States. As shown on the mean and standard deviation of 15 global climate models, there is no clear prediction of wetter or dryer. There is little deviation in August (slightly more or less dry), but there is substantial deviation in the winter months, both wetter and dryer.

Mean and Standard Deviation of 15 GCM's do not agree on direction of precipitation response in Western States

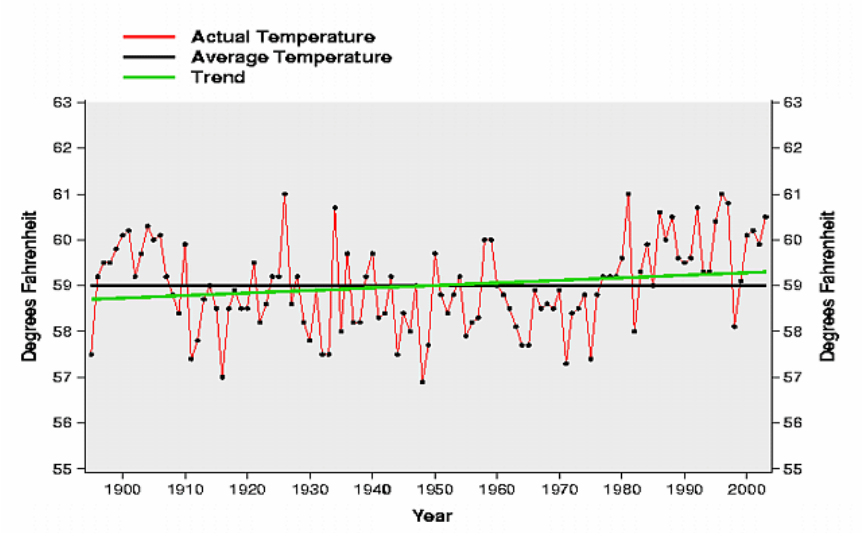


Coquard et al. "Present and Future Surface Climate in the US as Simulated by 15 GCM's" *Climate Dynamics*, 2004.

The greatest differences in model results are in the high precipitation winter months. Some project more precipitation; some project less precipitation. As GCM's have scaled down, the picture for precipitation has become even less certain. One models has shown more precipitation in the Southern Sierra Nevada with a decrease in the North. There is no agreement among the models at this point in time.

For the purpose of the watershed yield calculator, three precipitation scenarios were modeled using the HSPF program----base precipitation, plus 25% precipitation and minus 25% precipitation. The calculator then uses an interpolator to give plus and minus precipitation options in 5% increments, giving the user the choice to increase or decrease precipitation from 5-25%.

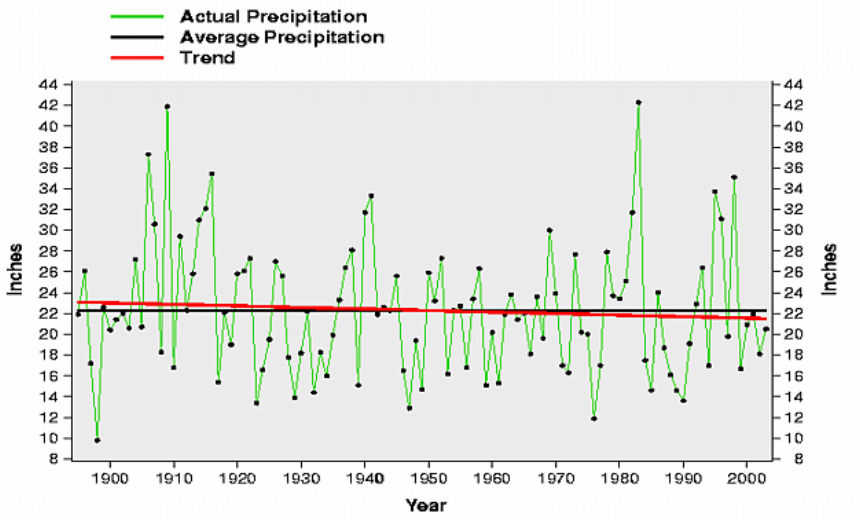
CA may be getting warmer



Source: National Climatic Data Center, NOAA

The actual trend in CA over the past 100 years is warming, approximately one degree F in one hundred years.

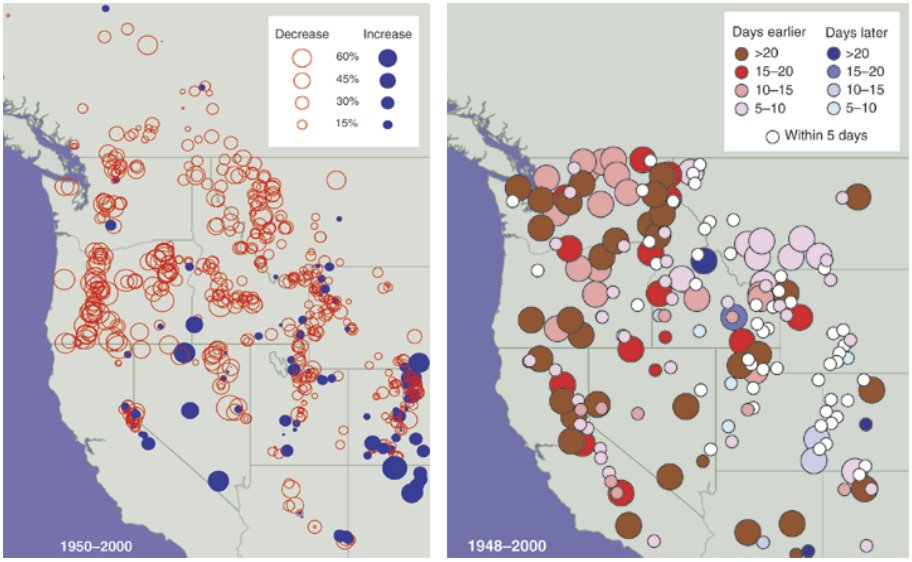
Precipitation in CA may be decreasing



Source: National Climatic Data Center, NOAA

Actual CA precipitation over the past 100 years trends toward decreasing precipitation, by as much as 5%.

A changing western snowpack?

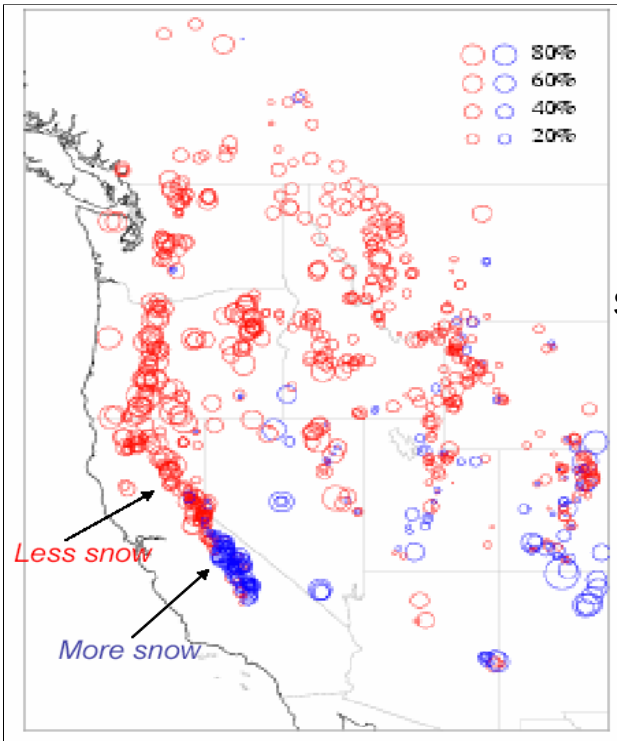


Less snow? Earlier melt?

Service, R. F., "As the West Goes Dry", *Science,* 20 Feb 2004

Left graph, from Phil Mote's work, shows stations in the SNOTEL network, operated by the USDA Soil Conservation Service. The circles show stations with decreasing and increasing snowpacks over 50 years. Note how few there are in California.

The right graph, from the work of Dan Cayan & Mike Dettinger, shows the season snowmelt at river gaging stations and their advance (earlier) or delay (later) in the timing of the initiation of the spring pulse.

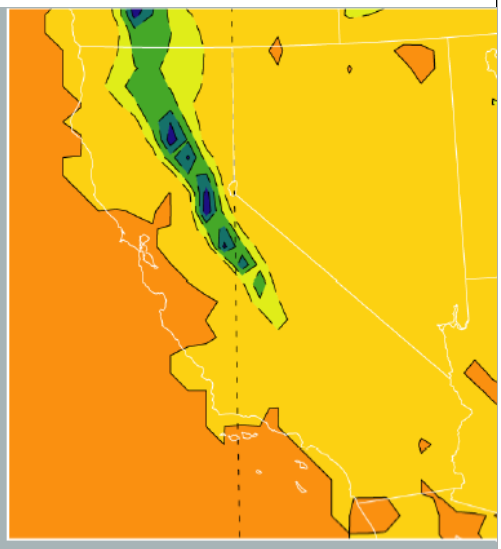


April 1 snow water content has decreased in most places. However, this study shows an increase in snowpack for the Southern Sierra Nevada.

Source: Phil Mote, *Geophys Res. Lett.*, 2003

Other studies indicate snowpack reduction Sierra-wide.

- *Snowpack is reduced everywhere in the state on an annual and monthly basis*
- *Snowpack is reduced by as much or more than 60%*

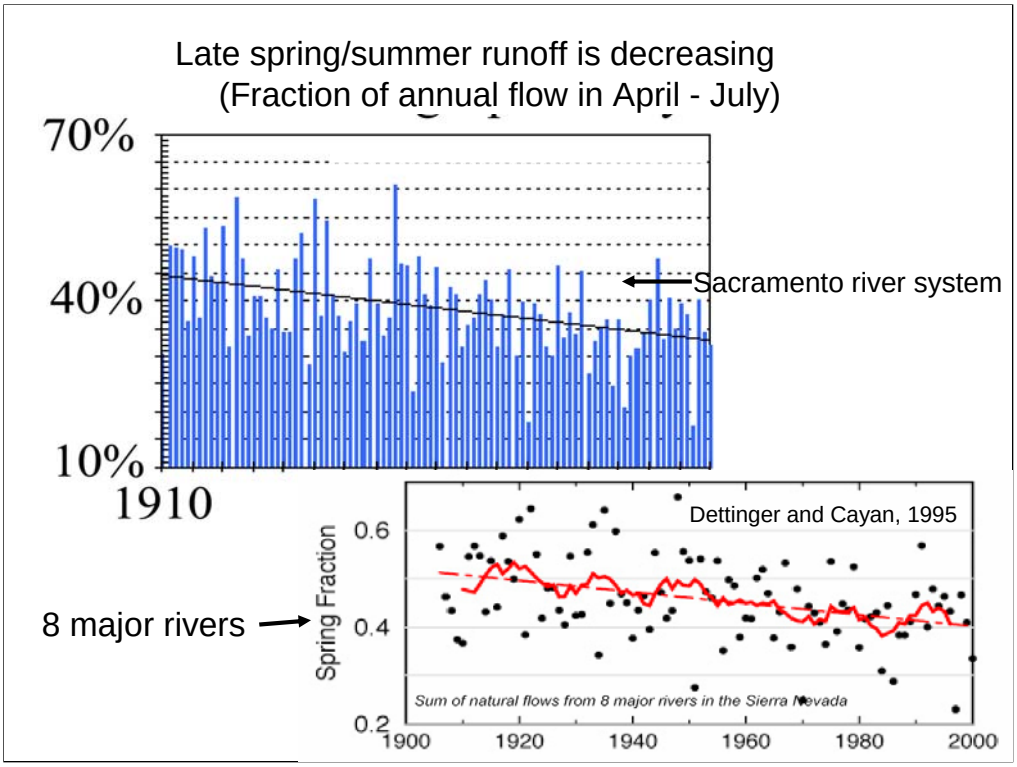


Cm water equiv

-12 -6 0 6

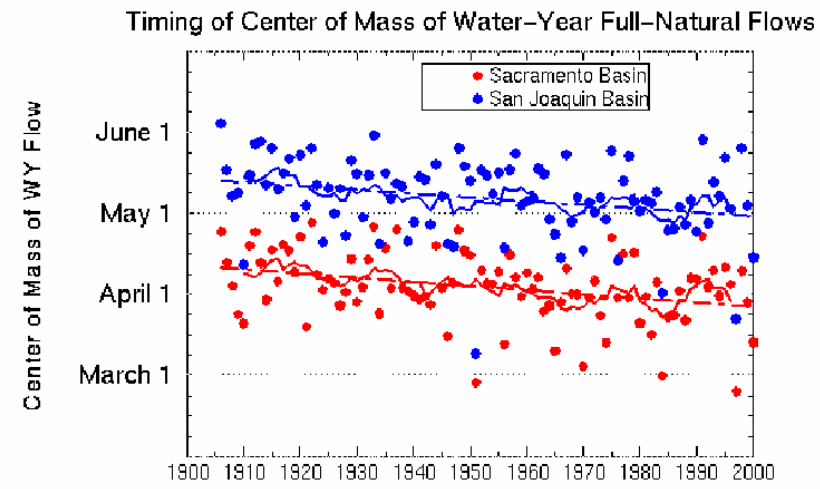
Snyder et al., 2002

A recent model from UCSC shows snowpack reduction throughout the Sierra Nevada.



Historic flows on the Sacramento river system, and on 8 major rivers in the Sierra Nevada, show the same trend of reduced late spring and summer runoff.

River flow is occurring earlier in the season



Roos, 1989, 1991; Dettinger and Cayan, 1995

A comparison of Sacramento basin and San Joaquin basin shows a similar trend toward earlier timing for the center of mass of water, approximately two weeks over the past 100 years.

Based on the best available scientific information, the watershed yield calculator was designed to give the user the option to design your own scenario for your watershed, within the temperature and precipitation change parameters of the most widely accepted models. You can choose your own scenario, with temperature increases of 1-4 degrees Centigrade, and precipitation change from plus 25% to minus 25% in 5% increments.