

Climate Change and California Water

W. Michael Hanemann

Director, California Climate
Change Center at UC Berkeley

Topics

- The Scenarios Project
- General findings
- Importance of temperature vs precipitation
- Impacts on water supply
- Implications

Two Sets of Climate Impact Studies for California

- Paper by Hayhoe et al., Proceedings of the National Academy of Sciences, August 24, 2004.
 - Group of 19 scientists
 - Private, not official, study
 - Widespread press and public attention
- Governor's Report on climate change http://www.climatechange.ca.gov/climate_action_team/reports/index.html, Draft December 2005, final February 2006.

The Governor's Study of Impacts "The Scenarios Project"

- Expanded version of Hayhoe et al. study, using similar methodology.
- Main research was conducted between July and November, 2005.
- Draws on existing, longer-run CEC research, expands its scope, brings in additional researchers, and accelerates its pace.
- About 50 researchers, 23 technical reports

The new impact studies

The new analyses contrast two global emission scenarios: (i) business as usual with continuing high rate of growth in greenhouse gas (GHG) emissions; and (ii) sustained global effort to reduce GHG emissions by 2100.

The analyses use statistical downscaling to translate the larger scale climate model results to California with finer resolution (about 12 km).

Climate forecasts developed for each location on monthly basis over 2000-2099.

Translated into impacts on various natural systems

Impacts

- Water supply
- Agriculture
- Forestry
- Fire
- Energy
- Coastal resources
- Air quality
- Public health

WHAT WE FOUND

- We are using the newest version (vintage 2003) of global climate models – the third major generation of these models.

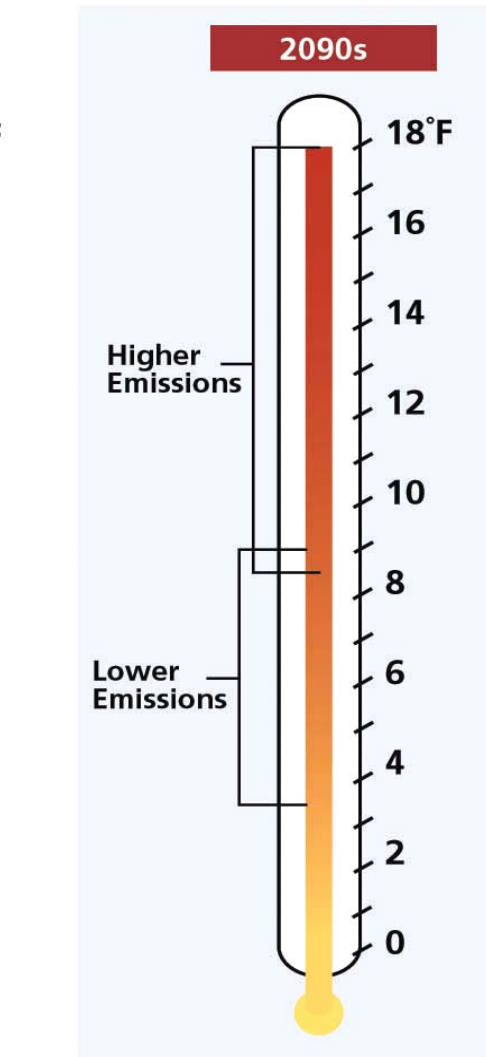
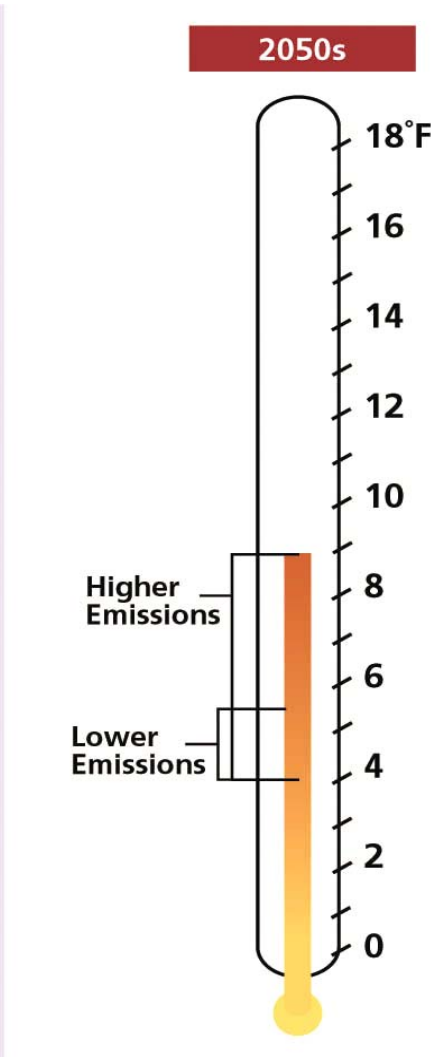
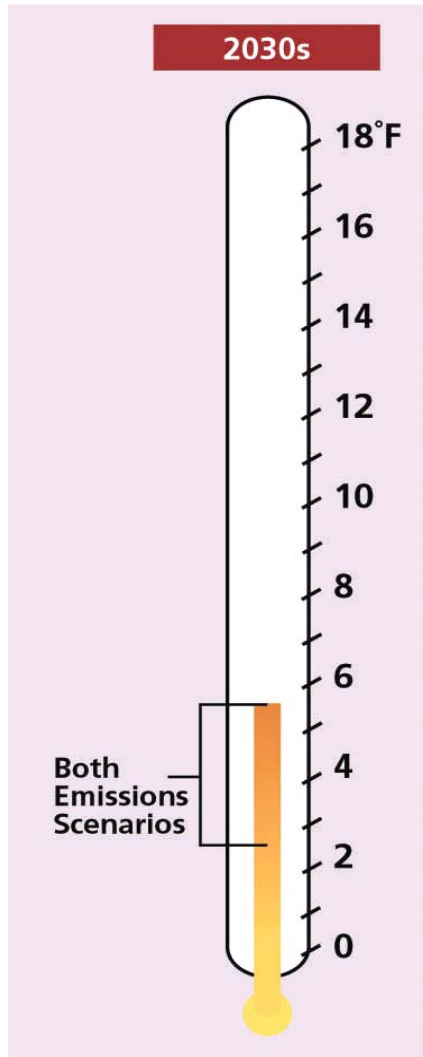
How are the new versions of these climate models different?

- The new versions of both models are somewhat more pessimistic with regard to precipitation than the previous two versions.
- The new models show about the same degree of warming in California in the winter as the previous models, but a significantly larger increase in summer-time temperature – that is new.
- The latter result may be due to improved modeling of the linkage between surface temperature and ambient air temperature.

Rising Temperatures

California statewide

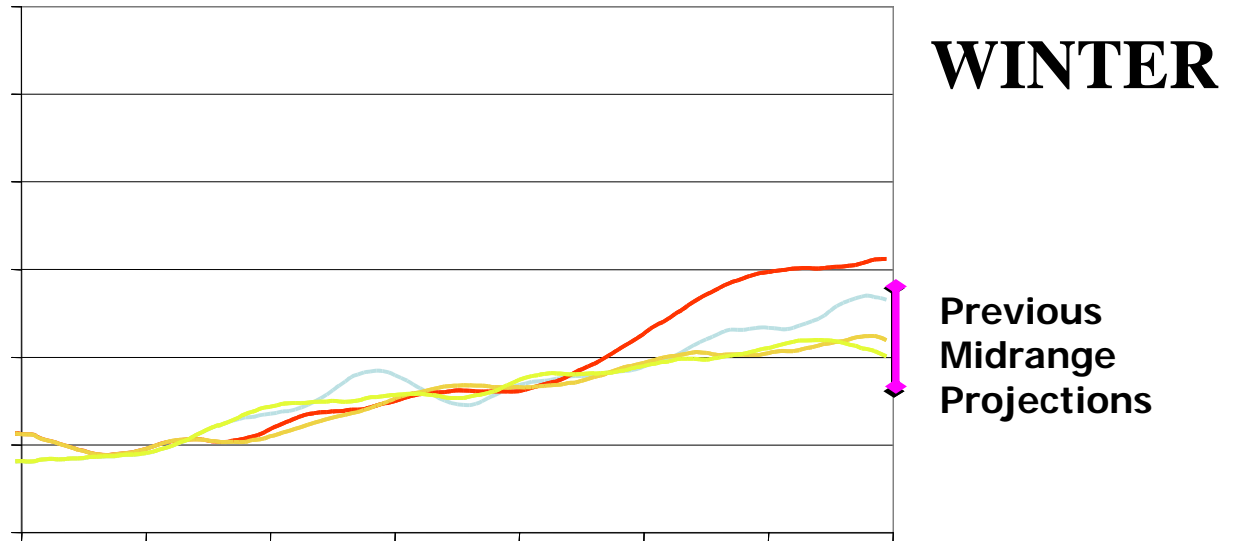
Projected average summer temperature changes



Temperature Projections

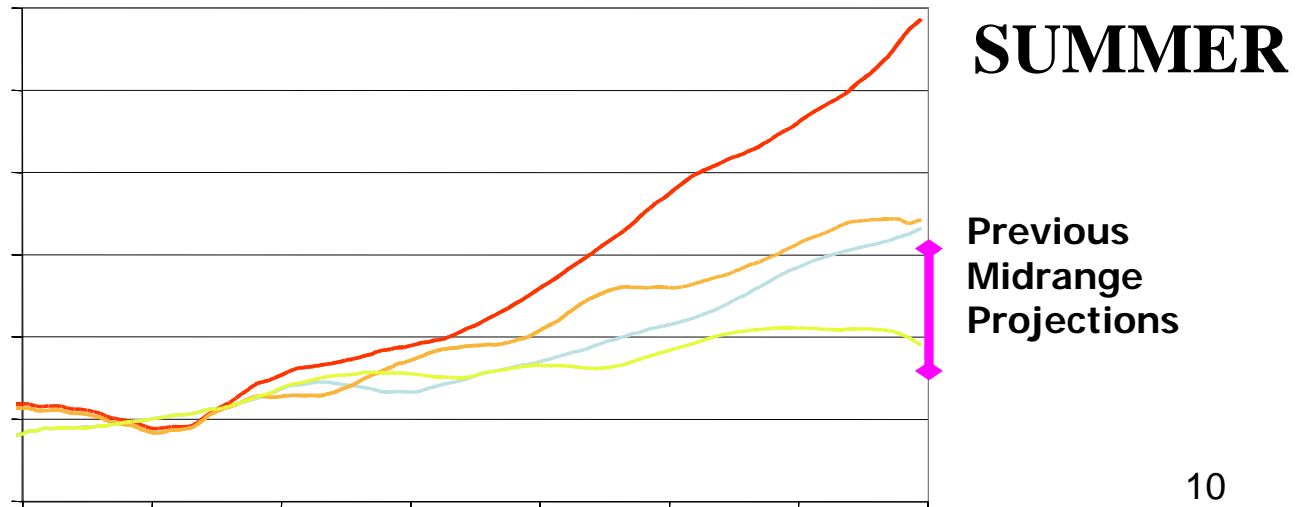
HADCM3

Low 
High 



PCM

Low 
High 



Time Lags

- The temperature trajectories for the two emission scenarios remain fairly intertwined until about 2045.
- They illustrate the fact that California's future climate for next 40 years is already determined by past emissions.
- Emission reductions initiated now show a significant effect after about 2045, with their impact increasing over time.

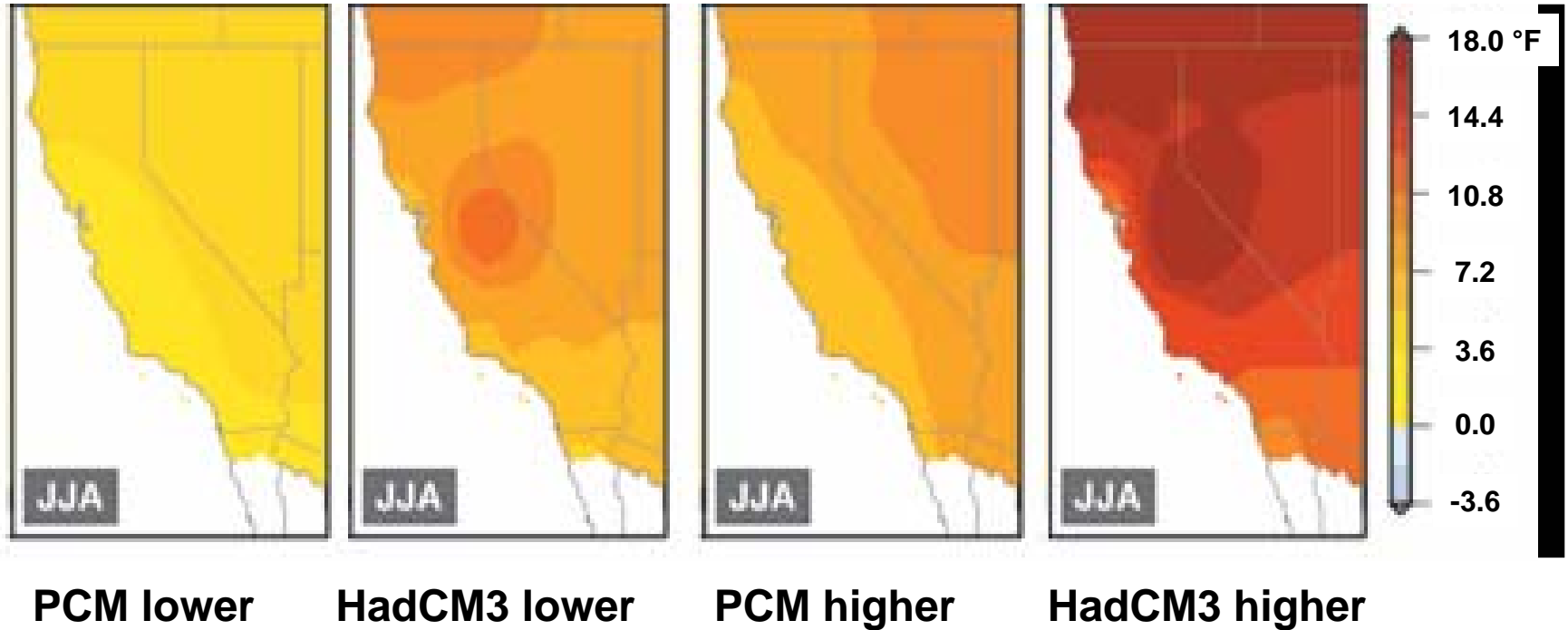
Patterns of Temperature Change

2070-2099 relative to 1961-1990

Summer

LOWER EMISSIONS

HIGHER EMISSIONS

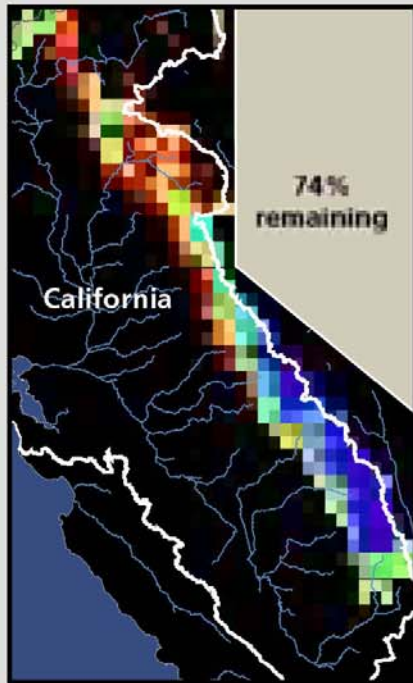


Diminishing Sierra Snowpack

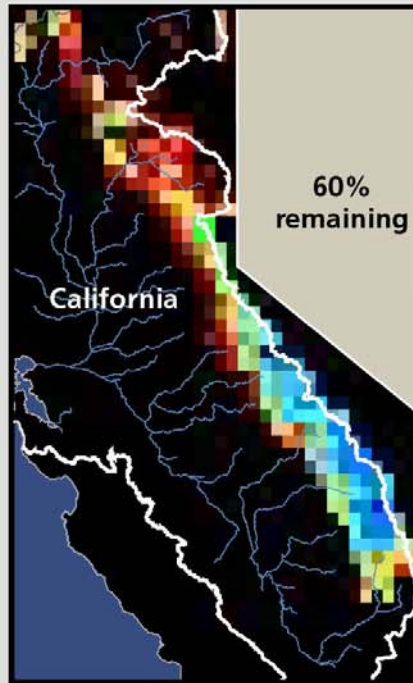
% Remaining, Relative to 1961-1990

2020–2049

Lower Emissions

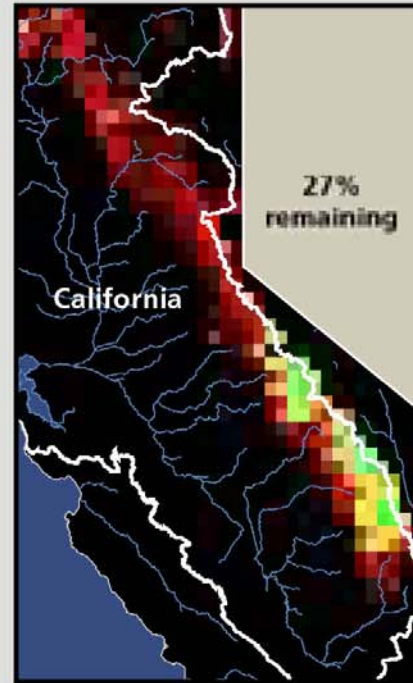


Higher Emissions

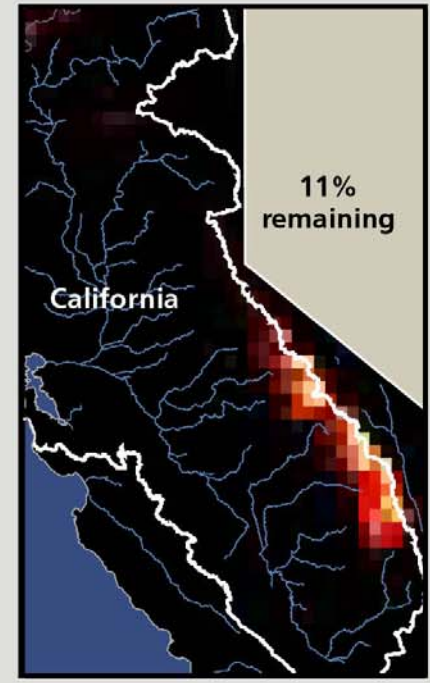


2070–2099

Lower Emissions



Higher Emissions



Remaining Snowpack (%)



Difference in effects of change in temperature versus precipitation

- Climate change will affect patterns of both precipitation and temperature.
- But, there are important differences in the nature and significance of these effects.
- First, precipitation is much harder to predict than temperature because it is inherently cyclical (El Nino/La Nina), and the precise starting and ending of a cycle are harder to model.

Differences, continued

- Second, in California, changes in winter precipitation are far less significant economically than changes in temperature.
 - Water is not a scarce resource in the winter.
 - To make winter precipitation an economically valuable asset requires an investment in some form of storage.
 - Unlike precipitation, changes in winter temperature directly affect spring and summer water supply.

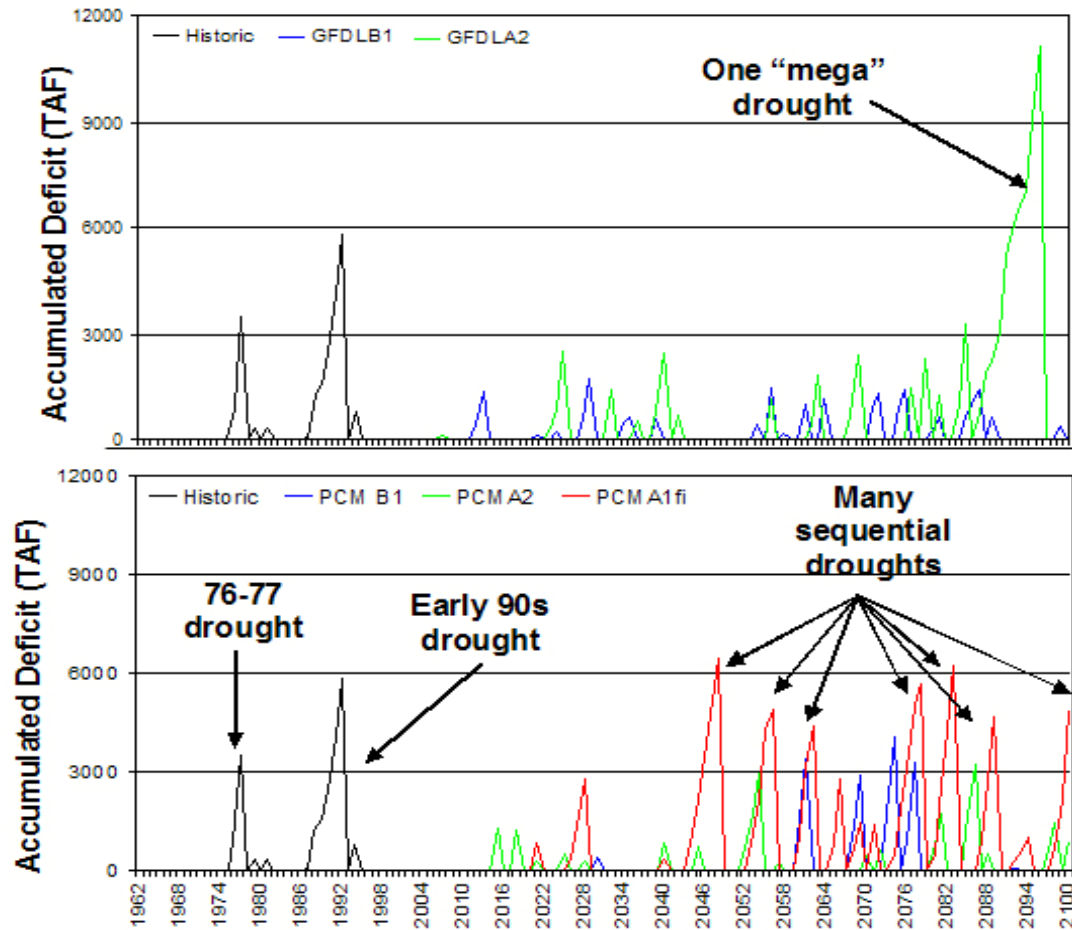
Impacts on California water

- More frequent dry years
- Drought persistence
- Reduced delivery from reservoirs
- Less stream flow in late spring & summer
- Increased crop demand for water
- Flooding from winter storms
- Flooding from sea level rise

More frequent dry years

- Over the historical period 1922–1974, 48% of the years were wet or above normal, and 40% were dry or critical.
- With the climate change scenario, there is a small shift in this distribution by 2035–2064: 46% of the years are wet or above normal, while 47% are dry or critical.
- By 2070–2099, however, only 22% of the years are wet or above normal, while 70% are dry or critical
- The increase in incidence of dry or critical years would also be accompanied by longer and more severe drought spells.

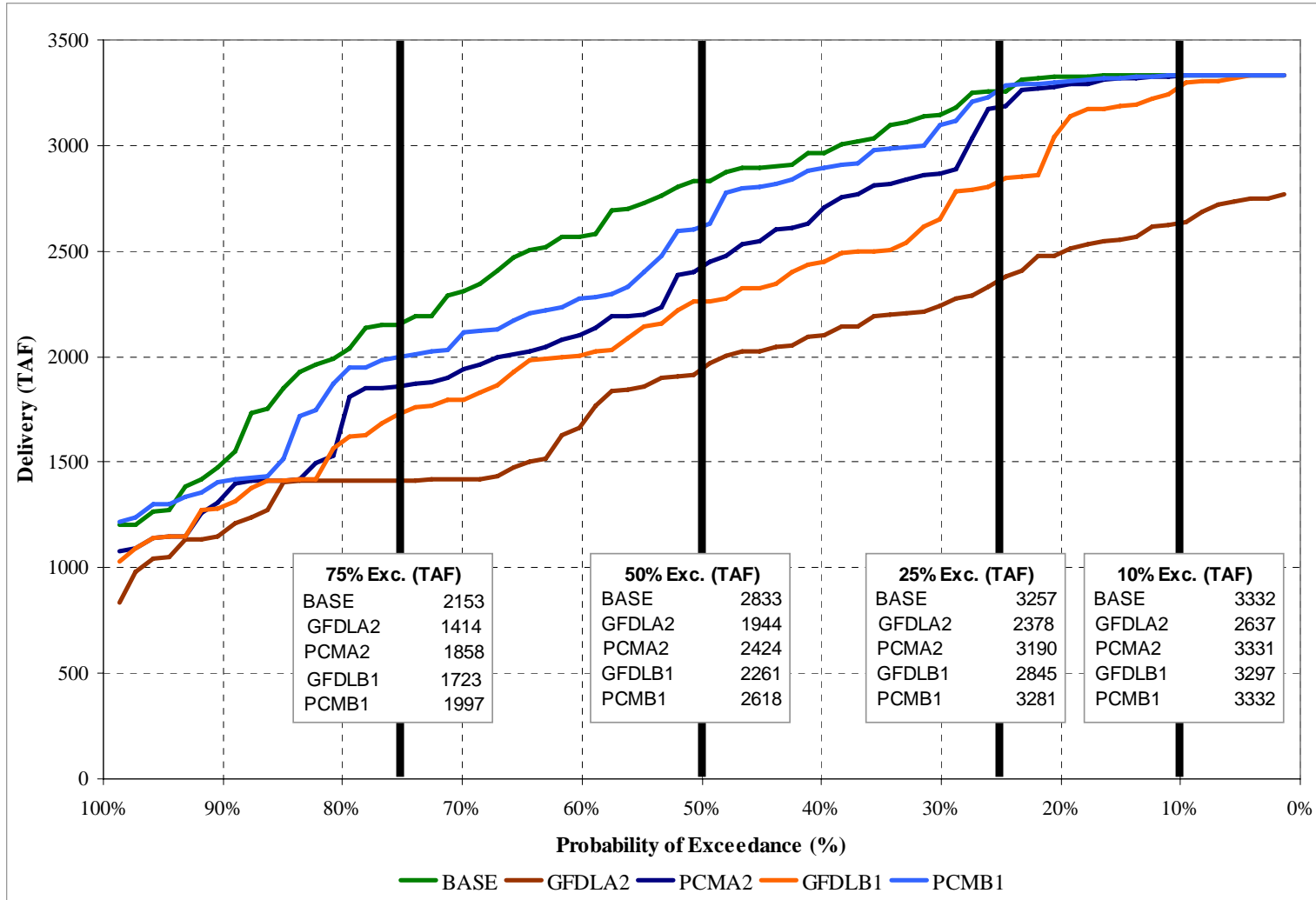
Drought persistence (WEAP)



Water deliveries

- In the Sacramento Valley over the period 2070–2099, almost no change in the amount of surface water available to agricultural users about 50% of the time; in the worst 15% of the years, there is a reduction which amounts on average to 53%.
- In the San Joaquin Valley, half the time there is a reduction in surface water availability which averages about 10%; in the next 35% of years, the reduction averages 48%; and in the worst 15% of years it averages 68%.

CVP South of Delta Annual Deliveries under climate change scenarios PCM B1-A2 and GFDL B1-A2 for 2070-2099



Impact on water supply: Less streamflow

- Spring and summer streamflow declines by 10-20% before mid-century under low emissions scenario, and 20-25% under high emissions.
- By 2100, streamflow declines by 40% under low-emissions scenario, and 45-55% under high emissions.
- ~75% of all water use in California occurs between April and September.

Some other impacts on water supply

- With higher sea level, there is greater potential for sea water intrusion into Delta.
- Also, some potential for sea water intrusion into coastal aquifers.
- Increased evaporation from surface storage.
- Greater chance of fires in watershed areas.
- More groundwater overdraft due to more frequent dry spells.
- Climate changes also affects Colorado River.

Impact on water demand

- Climate change not only affects water supply: it also affects the demand for water.
- Higher temperatures mean increased ET demand for agriculture and urban outdoor water use.
- These effects are combined with, and exacerbate, the effects of population growth

Economic impact on California agriculture – average year

- In an average year over 2070–2099, the climate change scenario leads to the fallowing of about 254,000 acres in the Central Valley, about 3.9% of the base irrigated acreage. In terms of net revenue (profit) from farming, Annual loss of \$278.5 million, or 9% of the base net revenue.
- The loss of net revenue consists of two elements: there is a loss of net revenue on land that is now fallowed, and there is also a loss of net revenue on land that is still farmed, but with more expensive groundwater.

Economic Impact: worst 15% of years

- Even without the climate change scenario some land is fallowed in these years and some revenue is lost. In the Central Valley as a whole, without climate change 147,000 fewer acres are farmed (2.2%) in the most critical years compared to the average year.
- With climate change, an additional 1.8 million acres is fallowed in the most critical years compared to the average year with climate change—a reduction of 29.1%.
- The reduction in annual net revenue from Central Valley agriculture amounts to \$803 million—a reduction of 27.7% compared to the average year without climate change.

Urban growth and climate change

- Climate change in 2070–2099 would be superimposed on an urban water system in the South Coast that, because of population growth and economic development there by 2085, may have to supply about 62% more water than it supplied in 2000.

Vulnerability of water supply to climate change

- Less vulnerable
 - Water conservations
 - Re-use of treated wastewater
 - Desalination
- More vulnerable
 - New dams and reservoirs
 - Water marketing from agriculture to cities

Two distinct consequences

- First, because of the reduction in surface water availability, climate change causes a reduction in the area's average supply, which needs to be made up by acquiring a new supply from some additional source.
- Second, climate change increases the frequency of droughts and exacerbates their duration and severity. These have different economic implications.
- The economic consequence of the first change is to raise the cost of water supply for all users *every* year, because the expenditure on a replacement for the loss in average supply contributes to the water district's "baseload" supply. Consequence of the second is shortage costs due to rationing *in droughts*.

Other severe threats from change

- Flooding in the Sacramento Valley from increased winter runoff
- Flooding of Delta from sea level rise

Implication

- These changes cumulatively amount to a considerable stress on our water system.
- The weak point in our existing system is as much institutional as physical.
- The financial and legal problems may be harder than the engineering ones.

How does this relate to existing water policy in California?

- Water rights are inadequate to accommodate climate change impacts.
- Water marketing will be important, but is slowed down in California by incomplete determination of property rights to water and disputes over these property rights. Also it is vulnerable to climate change.
- Difficulties with regulatory decision making and decision making for collective action to implement and finance infrastructure.

Water rights and timing/volume of water diversions

- Existing water rights are defined for diversions over a specific period of time – typically April – October.
- The streamflows on which these rely will be severely depleted.
- Hence a major realignment of water rights will be required.
- In many cases (other than the CVP and SWP), there are few records on actual water diversions, and in several cases water rights are not well clarified.
- Realignment of rights will be a difficult and contentious process.