Climate Changes and Changes in Western Water Availability

Mike Dettinger, Noah Knowles, & Dan Cayan
US Geological Survey

Sponsored by
USGS & the PIER-funded Climate-Change Research Center at Scripps Institution of Oceanography
In the near future, global-warming trends are likely to be superimposed upon ‘normal’ climate variations that our water resource systems now accommodate...
By the middle of the 21st Century, even in one of the coolest scenarios, earlier snowmelts & major reductions in snowpacks of the Sierra Nevada are projected...

With warming would come less snowfall, more rainfall...

MERCEDE RIVER RESPONSES TO PCM+SIMULATED CLIMATES
(a) Rainfall as a Fraction of Total Precipitation

Percentage of Precipitation

Historical run
Business-as-usual

Dettinger et al., 2004
… and earlier snowmelt.
Projected streamflow timings, 2080-99 vs 1951-80

resulting in earlier snowmelt runoff throughout the West,…

Iris Stewart et al., 2004
...to be added to historical trends already being observed throughout the region.

Observed CT Trends (1948-2000)

- > 20d earlier
- 15-20d earlier
- 10-15d earlier
- 5-10d earlier
- < 5d
- 5-10d later
- 10-15d later
- 15-20d later
- > 20d later

Stewart et al., 2004

Dettinger and Cayan, 1995; Cayan et al., 2001
With the timing changes will come more severe winter floods…

Dettinger et al., 2004; http://www.cgd.ucar.edu/cas/ACACIA/workshops/precip/dettinger.pdf
…and, with runoff leaving basins earlier, 
summer conditions will be much drier, 
summer streamflow will decline, 
& wildfire risks may increase.

Simulated Soil Wetness
Merced River basin abv Yosemite Valley

Water stored in soil, inches

Historical simulation (1970 1998)
Business as Usual (2020 2048)
Business as Usual (2070 2098)

Jan 1 Mar 1 May 1 Jul 1 Sep 1 Nov 1

Dettinger et al., 2004
These changes in streamflow timing may mean less “useful” water, \textit{i.e.}, less runoff captured in Western reservoirs for warm-season use.

\textbf{TOTAL RIVER DISCHARGE, APRIL-JULY}

\textit{N Fork American River at N Fork Dam}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Graph showing total river discharge from 1900 to 2100. The black line represents the observed discharge, and the red line represents the projected discharge with a 30% reduction.}\\
\textit{from ACPI Parallel-Climate model simulations,} \textit{Dettinger et al, 2004}
\end{figure}
PRECIPITATION PROJECTIONS SHOW A LOT OF SCATTER:

For California, a look at the ensemble of projections suggests moderate precipitation changes overall; Sign unknown.

Dettinger, in review, Clim. Change
Smoothing the ensemble of projections emphasizes:

- Important temperature (\& snowmelt) changes within about 20 years
- Strong tendency toward moderate precipitation change, with a hint of slightly drier
- General spreading of possibilities due to model and emission uncertainty

Dettinger, in review
Ultimately, such climate changes and uncertainties imply corresponding changes in California streamflows...

In snowmelt basins, AMOUNT sensitive mostly to PRECIP change; TIMING to combination of PRECIP/TEMPS
We generally feel more certain about the temperature projections. Therefore, for now, you may want to be asking, “Under current projections of warming,…”

...How much wetter would it have to be to retain our current spring snowmelt resource?

...How much drier to avoid increased flood risks?

...and then, How likely are such changes?”
SO, WHAT ARE
CURRENT MODELS PROJECTING?

Northern California temperature projections are broadly in consensus (+3 to +6 or more °C warmer), enough for earlier flows, more floods & drier summers.

Northern California precipitation projections are a bit more scattered, but MOST show small (drier?) changes.

How much of this applies to you?
HOW DO PROJECTIONS FOR OTHER PARTS OF THE WEST LOOK?

- Projections for Interior West NOT very different in character from California’s
  - Warming by +2 to +7ºC
  - Strong tendency toward little precipitation change
At higher resolution, western climate changes differ with altitude, with higher altitudes warming even more!

NOTE: See Snyder et al (UCSC), 2002, GRL, or various recent efforts by Miller (UCB) and/or Kim (UCLA), for more discussions of this effect.
What would warming of < +7°C (13°F) mean for your water supply?

TWO SIMPLE MINDED INDICES OF SENSITIVITY TO SNOW-STORAGE CHANGE ...

1ST:
What fraction of each year’s precipitation falls in months with average temperatures just below freezing?

More vulnerable
Less vulnerable

“Rain vs Snow”

Derived from OSU’s PRISM monthly mean climatologies, 1971-2000
2nd: What fraction of each year’s months with freezing average minimum temperatures are just below freezing?

Derived from OSU’s PRISM monthly mean climatologies, 1971-2000

“Duration of snowpack”
THUS SIGNIFICANT PARTS OF WESTERN WATER RESOURCES MAY BE VULNERABLE
(even in our cold interior regions)

Derived from OSU’s PRISM monthly mean climatologies, 1971-2000
SO, WHAT ARE CURRENT MODELS PROJECTING FOR THE WEST?

Warming by +2 to +7°C, perhaps more so at higher altitudes

Uncertain precipitation changes, maybe more maybe less

Potential significant changes in snowpack, snowmelt timing, and streamflow timing, even if only temperature changed

Not anywhere near as much time to prepare for this as you might like (not enough time to eliminate all the uncertainties)
REFERENCES


