Climate change, extreme precipitation, and atmospheric rivers

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Department of Water Resources Workshop
Climate Change, Extreme Weather, and Southern California Floods
California’s Wild Precipitation

a) COEFFICIENTS OF VARIATION OF TOTAL PRECIPITATION, WY 1951-2008

California precipitation is uniquely variable

Dettinger et al, Water, 2011
California’s Wild Precipitation

Just a few storms each year form the core of our water supplies

Dettinger et al, Water, 2011
California’s storms are as big as any in the country

LARGEST 3-DAY PRECIPITATION TOTALS, 1950-2008

California’s precipitation extremes are projected to increase with climate

Results from downscaled Parallel-Climate Model, BAU projections, which yields very small changes in AVERAGE precipitation

Precipitation changes mostly at the extremes

Woodfords, CA, Daily Precipitation: Observations and Parallel-Climate-Model Projections

Atmospheric Rivers are the Primary Meteorological Cause of Extreme Precipitation and Flooding in California

Atmospheric rivers and flooding

- All major floods of Russian River since 1997 have been atmospheric rivers (ARs)
- The 9 largest winter floods of Carson River since 1950 have been pineapple expresses (just a particular AR config)
- In Washington, 46 of 48 annual peak daily flows have been associated with ARs.
- Responses of daily flows in American & Merced Rivers to PEs are typically order of magnitude larger than to other storms

*Ralph et al., GRL, 2006; Dettinger, 2005; Neiman et al., 2011*
AR in AR\(^k\)Storm = Atmospheric River

...and when asked to design a really killer storm for California emergency managers, we used historical ARs strung together to do so.
Atmospheric Rivers & Climate Change

By end of 21st Century, most GCMs yield:

- More atmospheric vapor content, but weakening westerly winds

  → Net increase in “intensity” of extreme AR storms

- Warmer ARs (+1.8 C) → snowline raised by about 1000 feet on average

- Lengthening of AR seasons (maybe?)

Atmospheric Rivers & Climate Change

Water Vapor & Low-Level Winds

18 January 2100
GFDL CM2.1 GCM under A2 emissions scenario

23 December 2090
ECHAM5 GCM under A2 emissions scenario

DISTRIBUTIONS OF INTENSITIES
OF DJF AR DAYS

Days in 20 yrs

50 100 150

Intensity

1961-2000
GISS
1961-2000

2081-2100

2046-2065

1961-2000

1961-2000

2081-2100

2081-2100

GFDL

Reanalysis
Simulated historical 3-day floods in Sierra Nevada

VIC macroscale hydrologic model at 1/8 degree resolution
Projected 50-yr floods in Sierra Nevada

Changes from 50-yr flood estimated for 1951-2000 period

*Distributions from ensemble of 16 different GCMs*

Northern Sierra Nevada

- Median of A2 emissions
- Median of B1 emissions

Southern Sierra Nevada

- 75 %-ile
- 25 %-ile

Bottom line:
Projected floods in Sierra Nevada

16 GCMs, A2 emissions

Northern Sierra Nevada

Southern Sierra Nevada

Change in flood flows with various return periods

Perhaps most notably, EVEN IN PROJECTIONS WITH DRIER OVERALL CONDITIONS, FLOODS ARE PROJECTED TO INCREASE.
Projected storm sizes & frequencies in Sierra Nevada

16 GCMs, A2 emissions

**Northern Sierra Nevada**

*Changes in precip contributions above thresholds*

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<tr>
<th>Precipitation Threshold (mm/day)</th>
<th>2001-49</th>
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**Southern Sierra Nevada**

*Changes in #days above thresholds*

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**Mixed wet days**

**NSN:** Larger storms

**Fewer wet days**

**SSN:** Larger storms
Downscaling & simulating the flood consequences of climate-change projections is beginning to show that:

- Wintertime flood flows increase in both frequency & magnitudes in both Northern & Southern Sierra

- Spring-snowmelt high flows from Southern Sierra expected to decline

- Causes of these changes are mixes of larger/more storms, higher snowlines & even wetter soils, depending on river considered

Conclusions

Ensembles of projections of 21st Century climates & hydrology in California suggest:

- More years with lots of ARs, fewer with few
- Overall average AR intensities don’t change much but occasional much stronger than historical ARs
- Increased flood risks in northern & southern Sierra, combination of snowline changes & storm intensities
- Increased flash flood risks in southern California?
- Modern observational tools offer better insights & forecasts of these events
California has begun implementation of key land-based elements of a 21st Century Observations Vision.

An AR-focused long-term observing network is being installed in CA as part of a 5-year project between CA-DWR, NOAA and Scripps Inst. of Oceanography:
- Installed 2008-2012
- 93 field sites
Elements of a 21st Century Monitoring Strategy for the Western US as a whole

Enhancements to Snow & Streamflow Monitoring

Broad Monitoring of key Atmospheric Conditions that fuel Extreme Precipitation & Floods

Atmospheric River Observatories to fill largest single gap in current monitoring

Offshore Monitoring to Extend Forecast Lead Times

Ralph et al., 2011, A vision of future observations for western US extreme precipitation events and flooding: White paper to Western States Water Council, 74 p.
Western States Water solicited a vision of key land-based elements of a 21st Century Observations Vision for the West...

Ralph et al., 2011, A vision of future observations for western US extreme precipitation events and flooding: White paper to Western States Water Council, 74 p.
Heavy Precipitation and Flooding

California averaged $370 M/year in flood damages 3rd highest in the nation
