Climate Drivers of West Coast U.S. Ecosystems

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Thanks—
Mike Dettinger
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prominent climate drivers, West Coast environment:

- Natural climate “modes"
  - ENSO
  - PDO
  - NPGO
  - Intraseasonal bursts—atmospheric rivers

- Anthropogenic changes from greenhouse gases
CHANGE IN NUMBER OF GROWING-SEASON DAYS/YEAR UNDER ASSUMED +3C WARMING

[GROWING SEASON = INTERVAL FROM FIRST TO LAST 3-DAY > 5C]
Warm and cool phase ENSO
SST, SLP, and sfc wind stress anomalies

predominant interannual coupled sea-air mode
extra-tropics involved
time scale: 2-7 years

Characteristics vary considerably within different events

Multivariate ENSO Index
Klaus Wolter, NOAA
Atmospheric Circulation during large low frequency wave episodes is similar for No Calif and Hawaii.

This pattern must produce long fetch, high westerlies many of the same cases that affect Hawaii also affect No Calif.
West Coast sea level has a strong El Nino signal. Interannual peaks at San Francisco are nearly all large El Nino years.
Enormous Changes In tropical Convection

Winter N Pacific Storms are affected
Two great El Nino’s North Pacific Basin fills with winter cyclones.

Both El Nino years had persistent storminess and a long, extended storm season.

Cyclones tracked from Asia to West Coast in 5-6 days; storm track was zonal and extended far south.
Two La Nina years

In contrast to the El Ninos, the North Pacific Basin was much less active. Propagation speed of cyclones and anticyclones is still approx 5-6 days to traverse the basin at 40N
Offshore of The California Coast, westerly Winds were much Stronger during The 1983 El Nino Than the 1989 La Nina, which had Interludes of easterly Winds, even at Longitude 138W.
Each El Nino is different. Not all El Ninos produce great storm activity along the California Coast.
El Nino favors high streamflow in the Southwest

An ensemble of daily streamflow hydrographs during several El Nino (red) and La Nina (blue) years illustrates how ENSO changes the odds of flood/drought in San Diego County streams. La Nina’s have rarely produced high flows, but El Ninos often do.

The change in flood frequency is driven by a change in U.S. winter precipitation patterns during El Nino vs. La Nina.
Pacific Decadal Oscillation

But Sierra Flows are Not reliably Linked to PDO or ENSO

Columbia is though

monthly values for the PDO index: Jan 1900–Dec 2002

Nate Mantua
Univ Wash
PDO, like ENSO, results in cross-hemispheric organization of anomalous temperature and moisture.
The North Pacific Gyre Oscillation (NPGO) is a climate pattern that emerges as the 2nd dominant mode of sea surface height variability (2nd EOF SSH) in the Northeast Pacific. The NPGO is significantly correlated with previously unexplained fluctuations of salinity, nutrients and chlorophyll-a measured in long-term observations in the California Current (CalCOFI) and Gulf of Alaska.

1 Northeast Pacific Physical-Biological Variability

PDO mode
Pacific Decadal Oscillation (PDO)

NPGO Mode
North Pacific Gyre Oscillation (NPGO)

2 California Current CalCOFI Observations

PDO
CalCOFI SSTa

3 Gulf of Alaska Line P Observations

PDO
Line P SSTa

Di Lorenzo et al., GRL 2008.
heaviest precipitation has occurred more/less frequently during warm PDO phase
Along West Coast, particularly California, there is a short seasonal window during which the year’s water supply is delivered.
And, the number of days during which most of the year’s precipitation occurs is relatively few.
THE big storms in California's arsenal...

Atmospheric Rivers!

- All 7 major floods of Russian River since 1997 have been caused by atmospheric rivers

- The 9 largest winter floods of Carson River since 1950 have been atmospheric rivers (i.e., pineapple expresses)

Corresponding precip patterns tend to be restricted mostly to Pacific coast states

Ralph et al, GRL, 2006; Neiman et al, in press; Dettinger 2004
Number of times historically when more than 40 cm (16 inches) of precipitation have fallen in a 3-day period

Mike Dettinger
West Coast sea level consistent upward trends from Seattle to San Diego

Historical tide gage observations of mean sea level at San Francisco, Seattle and San Diego exhibit secular increase of ~2cm/decade

This is consistent with estimates of global sea level rise
Two high tides and two low daily tides, unequal in amplitude.

Monthly tidal changes dominated by spring-neap cycle, with two periods of relatively high tides (springs) around full and new moon. One spring tide range per month is usually higher than the other on this coast.

The highest monthly tides in the winter and summer months are higher than those in the spring and fall as a result of lunar and solar declination effects.
Winter 1997-98 competition between fresh water inflow and ocean tides
Figure 1. IPCC SRES Emission Scenarios (Nakicenovic, N. et al. 2000). The trajectories in Figure 1 do not exactly match those in official IPCC documents because the results we report here are based on revised emissions projections subsequently made available by IPCC; these are available at http://sres.ciesin.columbia.edu/. In addition, the authors used a new version of MAGICC available from http://www.cgd.ucar.edu/cas/wigley/magicc/index.html. The differences between Figure 1 and similar figures provided by the IPCC, however, are minor and do not affect the discussion in this paper.
Projected sea levels from the B1 and A2 emission scenarios using the Rahmstorf (2007) scheme for each of the three models. Both the original Rahmstorf (dashed curves) and a version adjusted for the affect of reservoirs and dams (solid) are shown. Historical (blue) and projected simulations (red shades) are shown along with observed global sea level (aqua).
Projected sea level
San Francisco

Under projected global warming, such as in the GFDL A2 simulation, sea level rises considerably by 2100, in this scenario by approximately 0.9m.

At San Francisco high sea level events, exceeding high threshold occur increasingly often and persist for longer durations.
Regional and global surface temperatures rise markedly. This impacts Sea level rise.
Climate models project 1.5-2.0°C ocean surface warming by end-of-century.

Greater warming on land than oceans would amplify California coast-interior thermal gradient.

Summer land warming is accentuated.

GFDL CM2.1 is a medium-high sensitivity model. Other models produce less (or more) warming.
During recent history, temperature changes in west U.S. have tracked those in global temperature.
SENSITIVITY TO A +3°C WARMING...

What fraction of each year’s precipitation historically fell on days with average temperatures just below freezing?

“Rain vs Snow”
Computed by Mike Dettinger from gridded historical US weather data (from Bates et al, in rev)
Very broad winter and spring warming 1950-1997
California warmed 0.5-1.5°C
Dry & Wet days have warmed 1950-2000

less snow, more rain
earlier snowmelt
Winter (Nov-Mar) SFE/P trends at western US weather stations: symbol area is proportional to study-period changes, measured in standard deviations as indicated; circles indicate high trend significance ($p<0.05$), squares indicate lower trend significance ($p>0.05$).

More Rain Less Snow
WY 1949-2004

Noah Knowles et al. 2006 in press J. Climate
Plant bloom timing advanced by 1 wk at cooperative observer sites in the western United States 1957-1994

Cayan et al., 2001; Bull Am Met Soc
since 1985 the number of large wildfires in western U.S. increased by 4X

Anthony Westerling et al.   Science   August 2006
Large wildfire threat is aggravated by warmer springs and summers
How much snowpack will be lost?

Douglas Alden
Scripps Institution of Oceanography
Installing met station
Lee Vining, CA
We face significant losses of spring snowpack

By the end of the century California could lose half of its late spring snowpack due to climate warming. This simulation by Noah Knowles is guided by temperature changes from PCM’s Business-as-usual climate simulation. (a middle of the road emissions scenario)

- Less snow, more rain
- Particularly at lower elevations
- Earlier run-off
- More floods
- Less stored water

Knowles and Cayan 2001
Projected patterns of precipitation changes 2090-2099 versus 1980-1999

Globally, dry regions become drier?
12 AR4 GCMs, 2 emissions scenarios---an uneven consensus toward lower California precipitation
SUMMARY:

Climate warming is already occurring, projections suggest much more, along with greater impacts.

Weather, short period climate (e.g. ENSO, PDO, NPGO, ARs) and tides will continue to accentuate water level-related impacts.

Although some model simulations yield drier conditions in California over the next century, large storms continue to occur at about historical recurrence intervals.

Duration and amplitude of sea level extremes increases.

In future decades, Sierra floods would be more active as larger portions of mountain catchments are likely to produce rainfall runoff instead of snowpack.

Events having high open coast sea levels and large fresh water flows into Delta and Bay increase considerably.
Sacramento+San Joaquin Flows during High San Francisco Sea Levels simulated by Bay watershed model driven by GFDL A2 simulation showed a marked increase in number and intensity.
Annual Precipitation Projections, San Diego area
from IPCC AR4 global climate models, SRESA2 and B1

GFDL CM2.1, CNRM CM3 and NCAR CCSM3

Swarm members:
MPI ECHAM5 — NCAR PCM1 — MIROC3.2