WEATHER EXTREMES
IN CALIFORNIA’S
VARYING AND CHANGING CLIMATE

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Southwest Climate Science Center
Precipitation Regime Change
In Mediterranean Climate Regions

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Atmospheric Rivers

Climatology of Atmospheric River Landfalls

Contribution of ARs to total winter precipitation

Atmospheric Rivers

HISTORICAL LANDFALL INTENSITY

ENSEMBLE OF 15 GCMs

END OF CENTURY LANDFALL INTENSITY

1970-1999

ENSEMBLE OF 15 GCMs

2070-2099

IVT > 250 kg/m/s

Integrated Water Vapor (cm) Nov 30, 2012 15 UTC

NOAA
Atmospheric Rivers

CANONICAL CORRELATION ANALYSIS (CCA)
SECOND COUPLED MODE OF VAPOR TRANSPORT AND SST (JFM)

Correlation (COR) = 0.74

Graph showing the correlation between vapor transport and sea surface temperature over time from 1950 to 2010.

Map showing vapor transport and sea surface temperatures with color-coded regions indicating different values.
Heavy Rainfall and Historic Flooding in San Diego - February 27-28, 2017 towards the end of a historic drought
Precipitation Regimes and Extremes

- Precipitation is projected to become less frequent, especially in shoulder seasons
- But extremes get more extreme
- Year-to-year variability increases
- More volatility in water resources
Weather Extremes in a Varying and Changing Climate

Precipitation Regimes and Extremes
Heat Waves and Cold Spells
Marine Layer Clouds
Santa Ana Winds
Atmospheric Rivers
Droughts and Floods
Heat Waves

HUMID HEAT WAVES ARE ON THE RISE

Observed Heat wave index for California

With Kristen Guirguis

[Graph showing the observed heat wave index for California over the years, indicating an increase in humid heat waves.]
Future Heat Wave Probability Depends on the Local Climatology

a) Increase in Heat Wave Probability - Tmax

b) Increase in Heat Wave Probability - Tmin

c) Difference

d) San Francisco Tmax PDF

e) San Francisco Tmin PDF

f) San Francisco Warm Extreme Probability

g) Phoenix Tmax PDF

h) Phoenix Tmin PDF

i) Phoenix Warm Extreme Probability

j) Elko Tmax PDF

k) Elko Tmin PDF

l) Elko Warm Extreme Probability

m) Odessa Tmax PDF

n) Odessa Tmin PDF

o) Odessa Warm Extreme Probability

Legend:
- Orange: hot weather
- Red: record weather
- Tmax
- Tmin
- Model Ens Tmax
- Model Ens Tmin

Probability vs. Temperature

Temperature Range: 0°C to 40°C
Temperature Range: 0°C to 30°C
Temperature Range: 0°C to 10°C
Probability Range: 0.0 to 0.1
Probability Range: 0.05 to 0.15
Probability Range: 0.0 to 1.0
Probability Range: 0.0 to 0.1
Probability Range: 0.05 to 0.15
Probability Range: 0.0 to 1.0
Probability Range: 0.0 to 0.1
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Marine Layer Clouds


With Rachel Clemesha
Santa Ana Winds

With Janin Guzman Morales

historically:
“Cool” storms contribute immediate runoff from smaller areas of the river basin (the rest goes into snowpack for later)

In a warmer climate:
Warm storms contribute immediate runoff from larger areas of the river basin

1°C (1.8°F) warming causes snowlines to rise 500 feet
Observed warming has already driven measurable hydrologic changes.

--> Less snow/more rain

Recent trends:

-2 std devs
LESS as snowfall

+1 std dev
MORE as snowfall

This figure shows observed trends in the ratio between snow and rain: snow is decreasing relative to rain at most mountain locations. --> An expected consequence of warming.

Knowles et al., J. Clim., 2006
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
Warming and drying results in reduced Mountain Snow Pack. Cold wet extremes become progressively less frequent, while minimal spring SWE – more and more likely.

from VIC simulations of 6 GCMs A2 scenario simulations
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Sea-level rise projections for RCP 8.5 and RCP 2.6 are calculated using the methodology of Kopp et al., 2014. The shaded areas bounded by the dashed lines denote the 5th and 95th percentiles.

The H++ scenario corresponds to the Extreme scenario of Sweet et al. (2017) and represents a world consistent with rapid Antarctic ice sheet mass loss.
If recent trends continue, the contribution from the Greenland and Antarctic ice sheets will soon overtake that from mountain glaciers and ocean thermal expansion as the dominant source of sea-level rise.

The Greenland Ice Sheet (GIS) is currently losing mass at a faster rate than the Antarctic Ice Sheet (AIS), but, emerging science suggests that ice loss from the Antarctic Ice Sheet poses the greatest potential risk to California coastlines over the next 100 years.

Spatial patterns of ice mass loss (inches of water equivalent lost per year between 2003 and 2012) over Greenland and Antarctica (left), inferred from the GRACE (Gravity Recovery and Climate Experiment) satellites’ measurements of Earth’s gravitational field (Velicogna et al., 2014; Velicogna and Wahr, 2013). Note the widely distributed ice loss around much of the Greenland Ice Sheet margin. In contrast, Antarctica’s ice mass loss is concentrated in the Amundsen Sea sector of West Antarctica, where warming sub-surface ocean temperatures are in direct contact with the underside of ice shelves (figure source: NASA Jet Propulsion Laboratory).
Other impacts of climate change....

High tide at La Jolla Shores Beach and Tennis Club
December 4, 2013
SHORTER PERIOD

THREATS—
during high sea levels, the sea is often not quiescent
SUMMARY OF CLIMATE CHANGE

• CLIMATE IS THE STATISTICS OF WEATHER
• A particular storm or temperature record or any weather event cannot be clearly attributed to climate change, but its probability can be.
• In the same way, a particular home run, performance in a competition or record broken cannot be attributed to an athlete’s use of steroids, but the statistics of an athlete’s performance over a season can be.
• So, climate change can be thought of as weather on steroids.
• This analogy is explored further here https://www2.ucar.edu/atmosnews/attribution