Living on the Edge: Climate Change and Extremes in California
Talk Overview

• Nature of Extremes

• Monitoring and Tracking Extremes

• Future Projections and Extremes
Nature of Extremes

• Edges of Distributions of Observations

• Not Necessarily Rare Occurrences

• Space and Time Scales are Important
Climate Perspective: Precipitation/ Temperature Distribution Plot

As distribution shifts, new extremes possible

Some extremes are unique – need to diagnose why

Climate system plays a role in what extremes are possible

Standard Variate Precipitation

Standard Variate Temperature

Cold/Wet

Cold/Dry

Hot/Wet

Hot/Dry

Event Perspective as Viewed on Climate Scales
Year to Year Precipitation Variability

California precipitation is uniquely variable

Climate change will likely impact mean and variance

Adapted from Dettinger et al, 2011
4 Things to Remember with Extremes

- Scales
- Thresholds
- Boundaries
- Impacts
Monitoring and Tracking Extremes
Monitoring and Tracking Extremes

- Observations of Temperature and Precipitation
- Other Observations (e.g. streamflow)
- Monitor by Impacts
Sierra Region
Minimum Temperature Departure Oct-Sep

Black Line Denotes 11-year Running Mean Departures from 1949-2005 Base Period

YEAR

- Linear Trend 1895-present: $+2.17 \pm 0.54^\circ F/100yr$
- Linear Trend 1949-present: $+3.73 \pm 1.24^\circ F/100yr$
- Linear Trend 1975-present: $+4.61 \pm 3.06^\circ F/100yr$

- Warmest Year: $39.1^\circ F (+2.5^\circ F)$ in 1992
- Coldest Year: $33.5^\circ F (-3.1^\circ F)$ in 1917
- Oct-Sep 2011: $36.7^\circ F (+0.1^\circ F)$

MEAN 36.6^\circ F
STDEV 1.12^\circ F
RANK 88 of 116
California Statewide
Maximum Temperature Departure Oct-Sep

Black Line Denotes 11-year Running Mean Departures from 1949-2005 Base Period

YEAR
Linear Trend 1895-present  + 1.06 ± 0.63°F/100yr
Linear Trend 1949-present  + 1.58 ± 1.76°F/100yr
Linear Trend 1975-present  + 3.19 ± 4.53°F/100yr
Warmest Year 72.4 °F (+3.4 °F) in 1934
Coldest Year 66.8 °F (-2.2 °F) in 1983
Oct-Sep 2008 69.5 °F (+0.5 °F)

Mean 69.0 °F
STDEV 1.18 °F
Rank 80 of 113
Sierra Region
Maximum Temperature Departure Oct-Sep

Black Line Denotes 11-year Running Mean
Departures from 1949-2005 Base Period

YEAR

Linear Trend 1895-present  
+ 0.48 ± 0.80°F/100yr

Linear Trend 1949-present  
- 0.15 ± 2.03°F/100yr

Linear Trend 1975-present  
+ 0.44 ± 5.05°F/100yr

Warmest Year  
66.4°F (+ 4.9°F) in 1934

Coldest Year  
58.2°F (- 3.3°F) in 1901

Oct-Sep 2011  
59.1°F (- 2.4°F)

MEAN 61.5°F
STDEV 1.41°F
RANK 7 of 116
California Statewide
Precipitation Oct-Sep

Orange Line Denotes 11-year running mean

YEAR

| Linear Trend 1895-present | + 3.52 ± 3.30 in. | (+ 15 ± 14%) per 100 yr |
| Linear Trend 1949-present | + 0.96 ± 10.13 in. | (+ 4 ± 44%) per 100 yr |
| Linear Trend 1975-present | - 1.97 ± 28.49 in. | (- 8 ± 124%) per 100 yr |
| Wettest Year | 40.44 in. (176%) in 1983 |
| Driest Year | 9.23 in. (40%) in 1924 |
| Oct-Sep 2008 | 16.40 in. (71%) |

Western Regional Climate Center

INCHES
## Sierra Region
### Precipitation Oct-Sep

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Linear Trend</th>
<th>11-Year Running Mean</th>
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</thead>
<tbody>
<tr>
<td>1895-present</td>
<td>+ 5.19 ± 5.85 in.</td>
<td>(+ 13 ± 14%) per 100 yr</td>
</tr>
<tr>
<td>1949-present</td>
<td>+ 2.06 ± 17.53 in.</td>
<td>(+ 5 ± 44%) per 100 yr</td>
</tr>
<tr>
<td>1975-present</td>
<td>+ 4.76 ± 45.05 in.</td>
<td>(+ 12 ± 115%) per 100 yr</td>
</tr>
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</table>

**Wettest Year:**
67.79 in. (173%) in 1983

**Driest Year:**
14.89 in. (38%) in 1924

**Oct-Sep 2011:**
55.89 in. (142%)

**Statistics:**
- **Mean:** 39.15 in.
- **STDEV:** 12.33 in.
- **RANK:** 111 of 116
Monthly Average Runoff in San Joaquin River System

Runoff (million acre-ft)

Month

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

1901-1955
1956-2007
Event Above Threshold Tracking
Ukiah Tmin below 32 °F

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<tr>
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<tr>
<td>120</td>
<td>100</td>
<td>80</td>
<td>60</td>
<td>40</td>
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</table>
Event Above Threshold Tracking Healdsburg Precipitation Above 1 inch/day
Cascading Time Scales

- Single Event – Hours to Days
- Timing of Event with Respect to Months
- Seasonal Accumulation and Averaging of Months
- Annual Accumulation and Averaging of Seasons
- Decadal Accumulation and Averaging of Annual Info
Climate Change Projections
Climate Change Effects on Water Resources

- Increased air temperature
- Less snowpack
- More precipitation as rain than snow due to higher temperatures
- Earlier runoff from snow melt
- Changes in timing and amount of river flows
- Changes in water resource system operations
- Sea level rise
Climate Change and Extremes

• What is the space and time scale of interest?
• What metrics are needed? Are there projections of these metrics in climate model simulations?
• What processes come together to create extreme event?
• What information can be extracted on the frequency of the event?
Planning for Extremes

• What thresholds are important and why?
• What impacts are associated with different thresholds?
• Will climate change impact magnitude, timing, or duration of extreme?
• Are there boundaries to processes that limit magnitude, duration, or timing of extreme?
• Will the proposed investment modify the threshold or impact?
Responding to Extremes

• Recognition time is key

• Are current response methods still functional under climate change conditions?

• What adaptive capacity investments facilitate response activity?
Illustrative Example - Floods
Given this history

American River

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>Average</th>
<th>Min</th>
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<tbody>
<tr>
<td>Pre-1950</td>
<td>98,000</td>
<td>27,000</td>
<td>3,200</td>
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<tr>
<td>Post-1950</td>
<td>166,000</td>
<td>39,000</td>
<td>1,500</td>
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Feather River

<table>
<thead>
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<th>Max</th>
<th>Average</th>
<th>Min</th>
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<tbody>
<tr>
<td>Pre-1950</td>
<td>150,000</td>
<td>43,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Post-1950</td>
<td>245,000</td>
<td>55,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

How to anticipate, plan and operate to this
Flood Frequency Curve

- 3-Day Peak Flow Thousands of cfs
- Frequency

- Dry Years
- Snow Level Varies
- Rain to top of watershed
Key Phenomena Affecting California Water Supply/Flooding:

The most extreme CA storm would result from a rare alignment of key processes.
Take Home Points

• Extremes are multifaceted entities occurring on multiple space and time scales

• Thresholds, boundaries, and impacts are important for observing, tracking, responding to, and planning for extremes

• Understanding physical processes that lead to extreme events is important for incorporating climate change and extremes into planning process
Questions?

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