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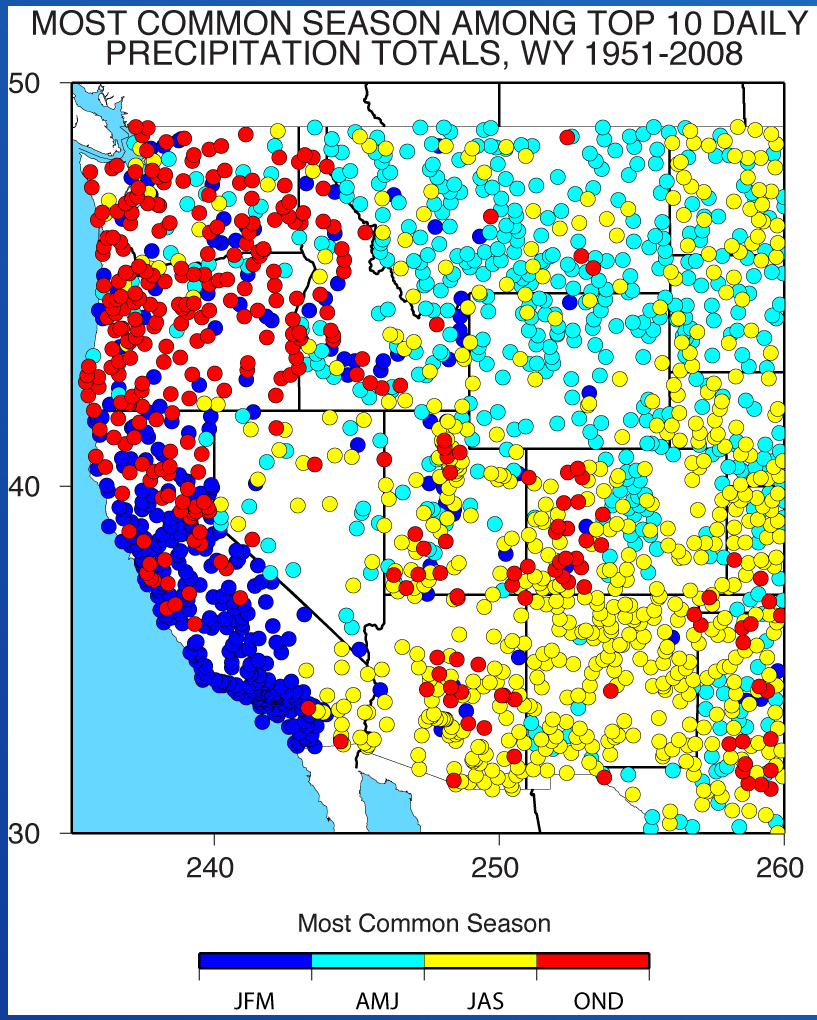
Managing Water in the West

Linking Extreme Precipitation and Floods: Implications for Climate Change Scenarios

U.S. Department of the Interior
Bureau of Reclamation

Research Question and Objective

- **Study Question**
  - **Do the largest precipitation events produce the largest floods and if not, why?**
- **Objectives**
  - **Examine basin response to extreme precipitation in regions of the western U.S.**
  - **Identify basin factors and storm conditions that produce the largest floods**
  - **Apply results to regional climate change scenarios to determine potential changes in basin response**



From M. Dettinger, USGS-SIO

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Research Strategy

Precipitation Data (Top 10 values)
1-, 3-, 5-, 7-day durations

Streamflow Data (Top 10 values)
Instantaneous annual peak discharges

Data sorting
Basins with no data
Dominant snowmelt basins

Data analysis
Ranking
Factor analysis
Rainfall runoff relationships

Implications for climate change scenarios

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Data sources

- **Precipitation (~2964 stations)**
  - **Cooperative Observer Program (COOP) network (NOAA)**
    - **Top 10 values from each gage (1950-2010)**
      - **<10% missing records**
      - **1-, 3-, 5-, 7-day durations (independent events)**
    - **Data obtained from Mike Dettinger, USGS-SIO**
- **Streamflow (~730 stations; 54 California)**
  - **Hydroclimatic data network (HCDN) (Slack et al. 1993)**
    - **Gages suitable for climate research**
    - **USGS records, accessible online**
    - **Top 10 values from each gage (1950-2010)**
      - **Annual instantaneous peak discharges**
      - **<10% missing records**

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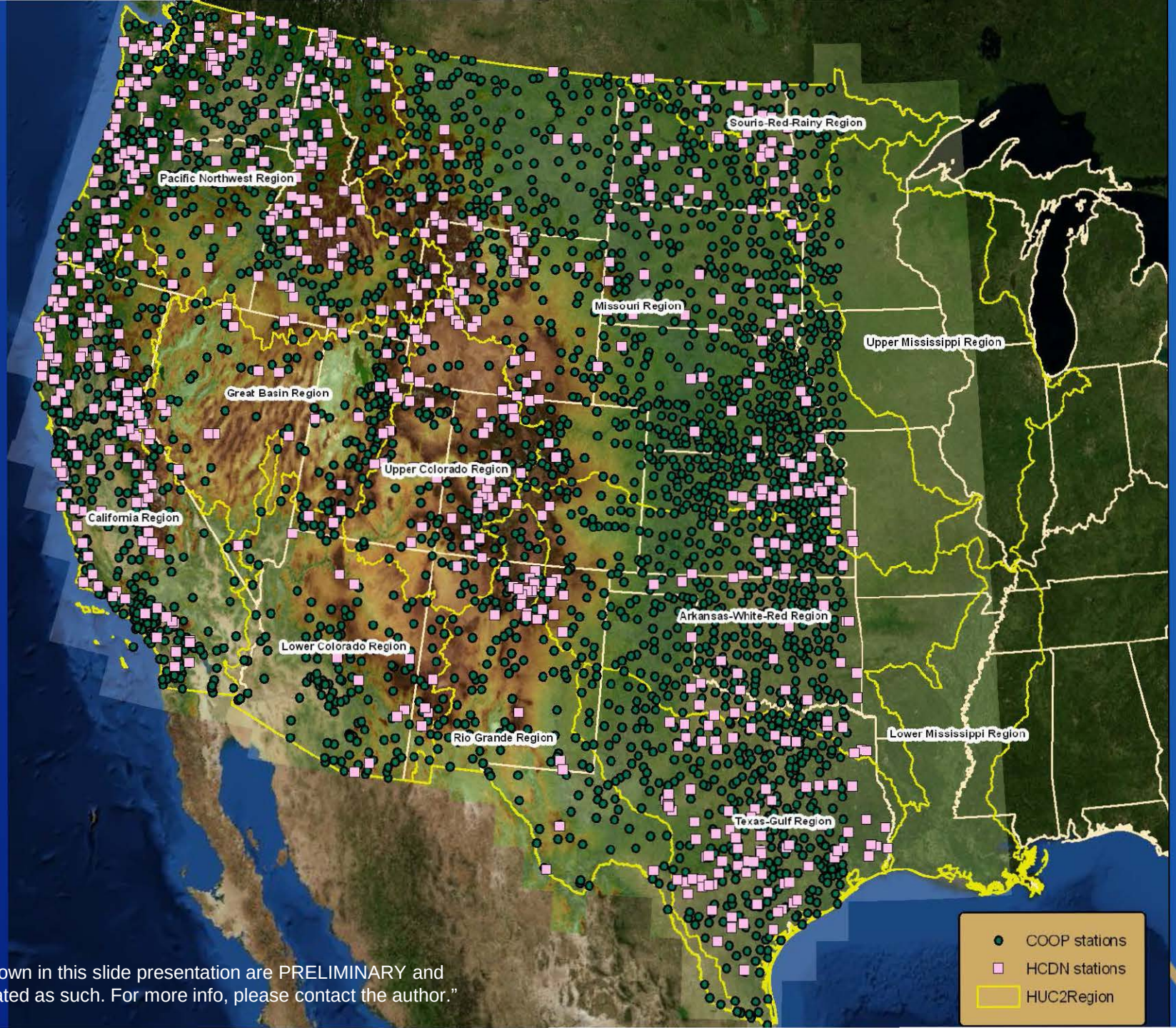

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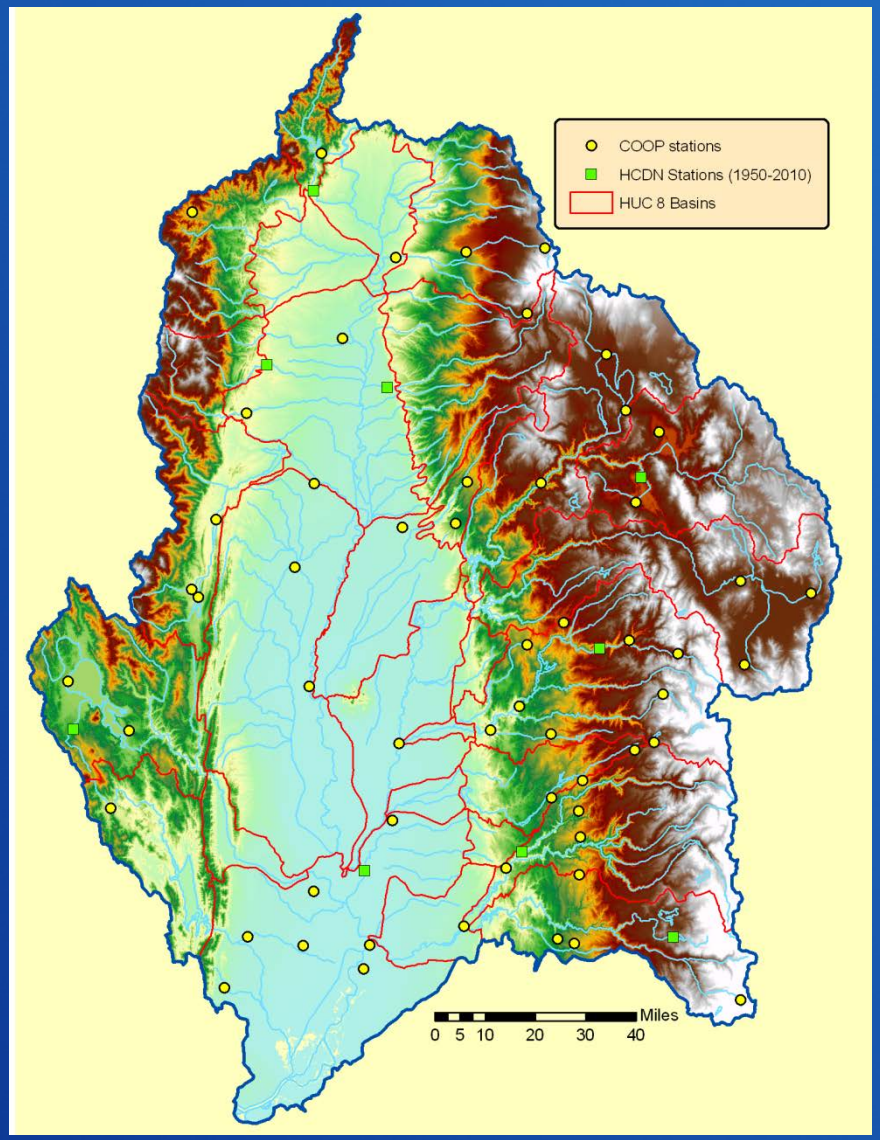
Methods

- Compare top 10 precip and streamflow records for stations in each basin
  - Selected HUC6 basins to analyze based on resolution of available data
- How many dates match between the extreme rainfall events and the extreme flood events ?
  - (i.e., is there an extreme rainfall in the top 10 records that is also recorded as an annual peak in the top 10 records)?
  - 1-day, 3-day, 5-day, and 7-day windows

Lower Sacramento Basin



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Example Matrix for 1Day Rainfall values

USGS #11132500

Date	Peak Discharge (ft^3/s)
3/15/1952	11400
1/18/1973	8280
3/18/1991	7890
3/10/1995	7850
1/27/1983	7740
2/3/1998	7470
2/9/1962	7400
1/24/1967	7090
3/4/1978	7040
2/14/1986	6270

COOP #42500044555

Date	Precipitation (mm)
1/31/63	84.3
3/10/95	76.2
2/3/98	68.6
12/23/55	61.2
1/7/74	61.2
3/16/86	58.4
12/5/97	57.4
2/15/86	55.1
12/3/74	53.6
2/25/04	52.1

MAX 1DAY	Top 10 rainfall events										
Top 10 Runoff Events	DATES	1/31/63	3/10/95	2/3/98	12/23/55	1/7/74	3/16/86	12/5/97	2/15/86	12/3/74	2/25/04
	3/15/1952	0	0	0	0	0	0	0	0	0	0
	1/18/1973	0	0	0	0	0	0	0	0	0	0
	3/18/1991	0	0	0	0	0	0	0	0	0	0
	3/10/1995	0	1	0	0	0	0	0	0	0	0
	1/27/1983	0	0	0	0	0	0	0	0	0	0
	2/3/1998	0	0	1	0	0	0	0	0	0	0
	2/9/1962	0	0	0	0	0	0	0	0	0	0
	1/24/1967	0	0	0	0	0	0	0	0	0	0
	3/4/1978	0	0	0	0	0	0	0	0	0	0
	2/14/1986	0	0	0	0	0	0	0	0	0	0

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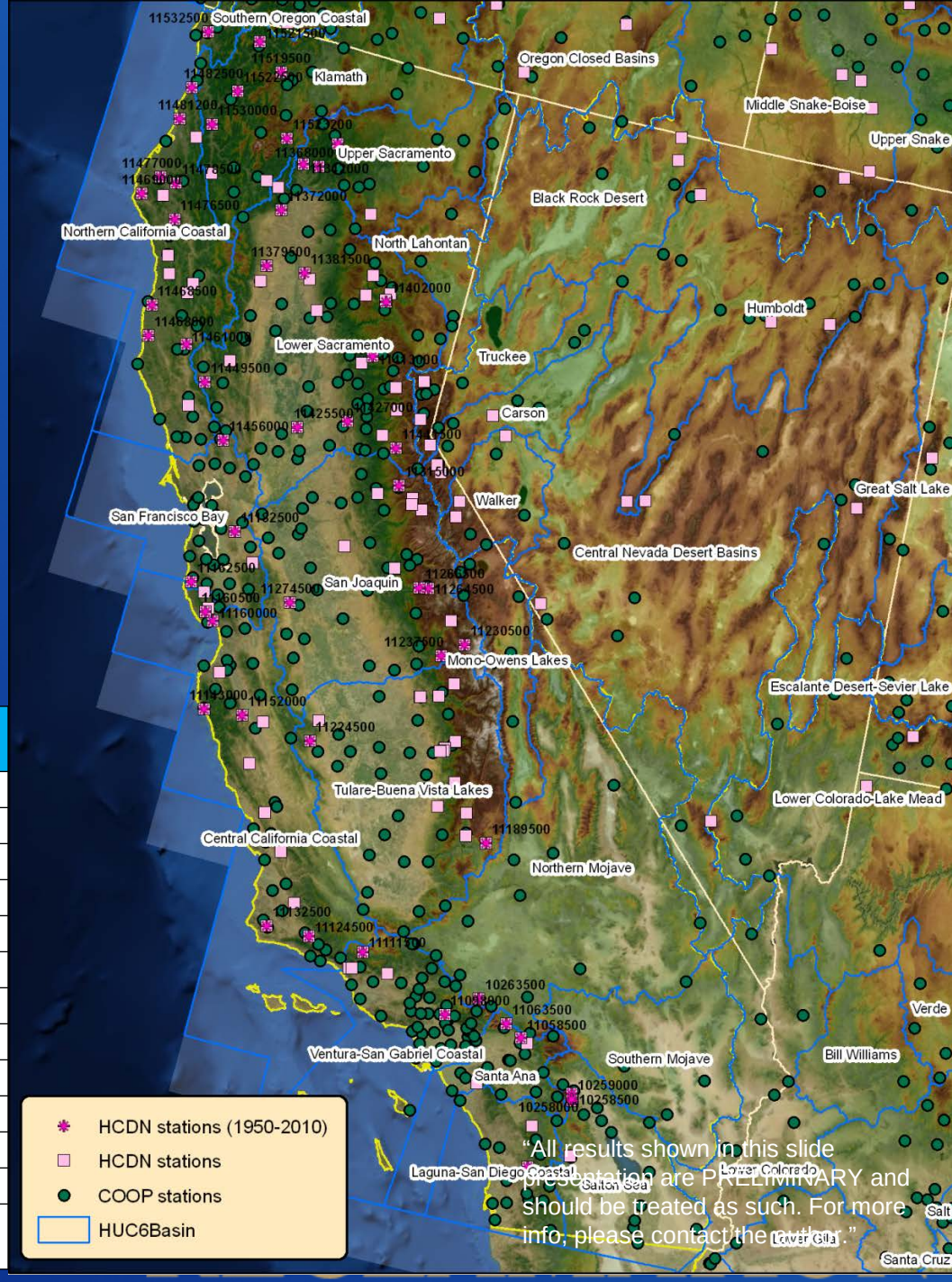
California Region

- **Subbasins with no HCDN data:**
  - **North Lahontan**
  - **Mono-Owens Lakes**
  - **Southern Mojave**
  - **Lower Colorado**
- **13 subbasins examined**

HUC 6 Basin	Number of COOP stations	Number of HCDN stations
Central CA Coastal	33	6
Klamath	22	6
Laguna San Diego Coastal	16	1
Lower Sacramento	57	9
Northern CA Coastal	23	10
Northern Mojave	14	1
Salton Sea	15	3
San Francisco Bay	27	3
San Joaquin	34	6
Santa Ana	14	2
Tulare Buena Vista Lakes	28	3
Upper Sacramento	12	3
Ventura San Gabriel Coastal	42	2



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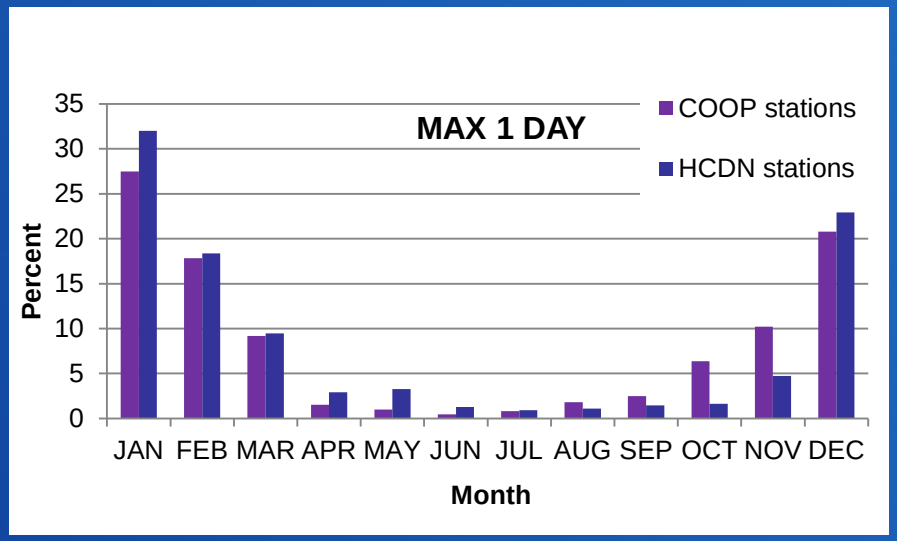
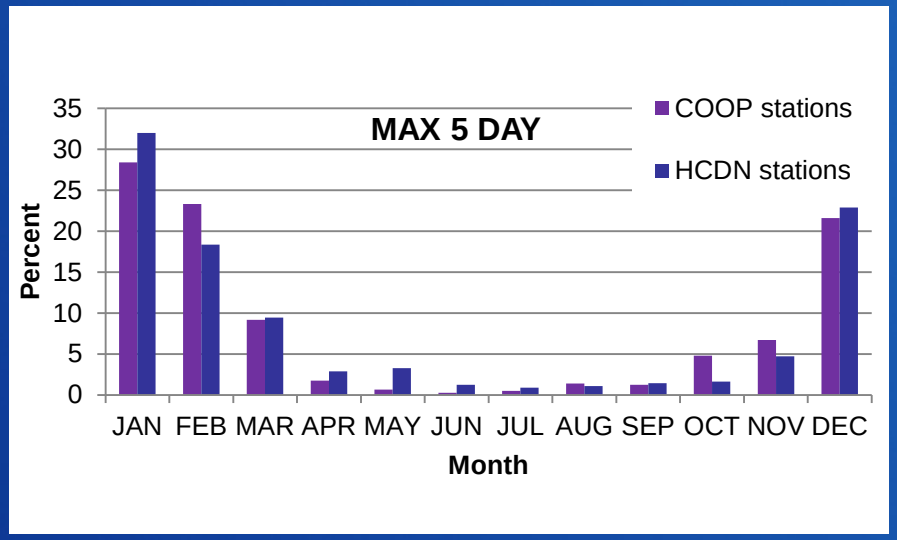
Seasonality of COOP and HCDN data (CA)

- DEC-MAR
  - Extreme rainfall and streamflow have similar percentages
- APR-JUN
  - Minor snowmelt component in streamflow
- SEP-NOV
  - Dry conditions preceding rainfall, few extreme flood records





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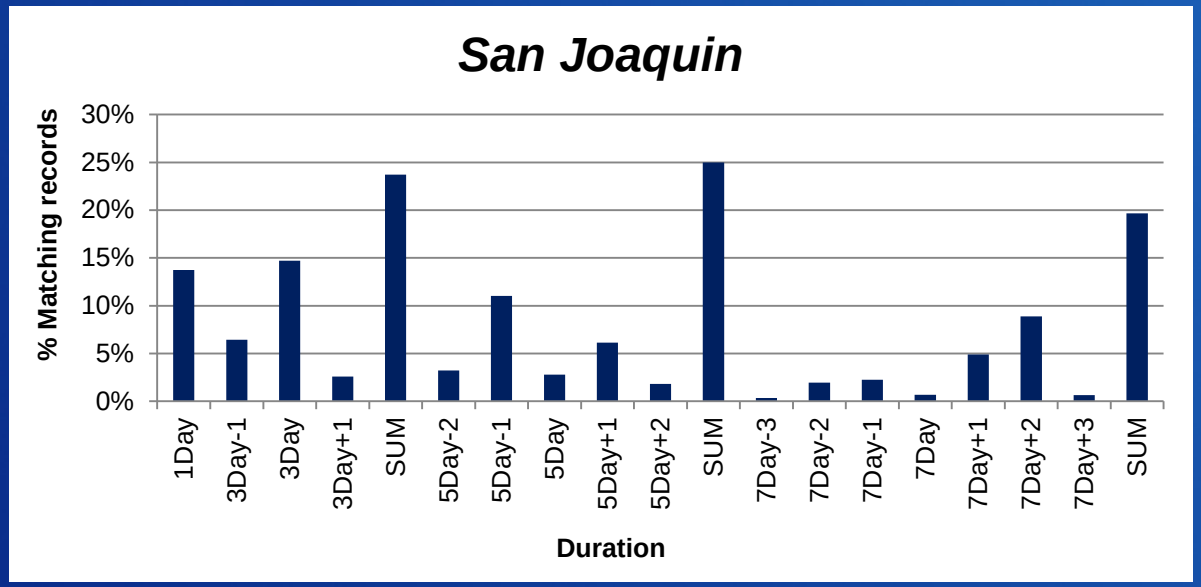

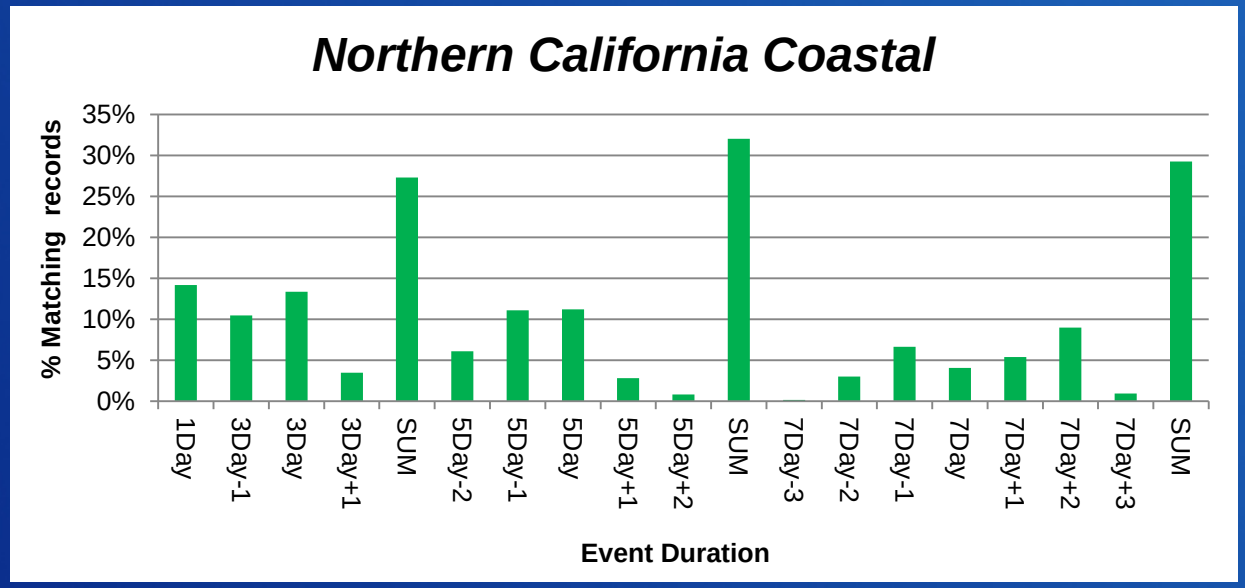

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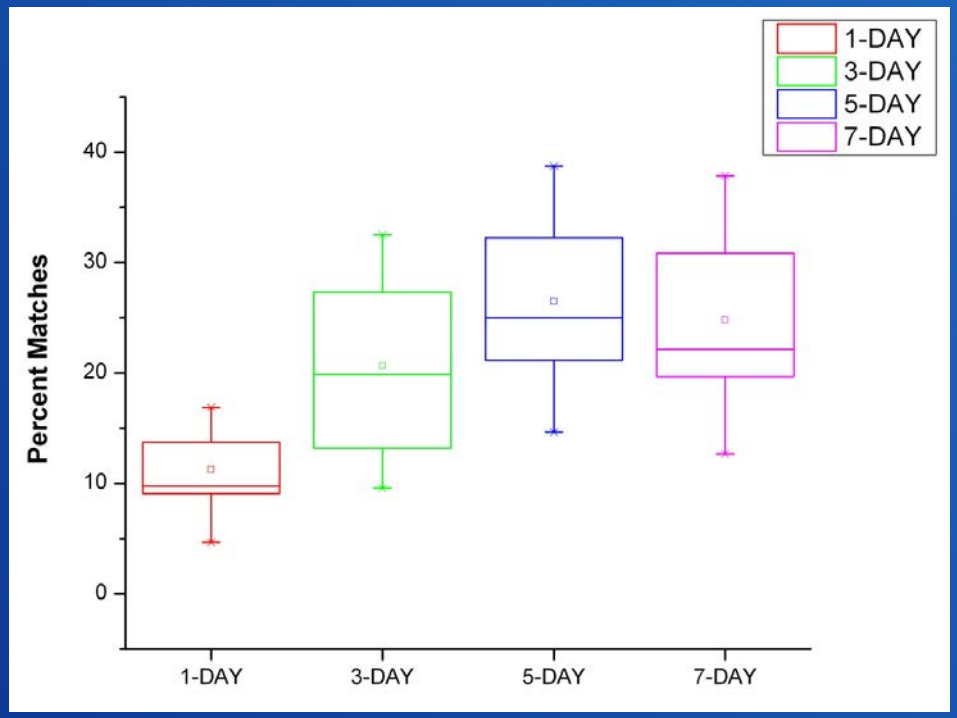
Summary of subbasin analysis

- **5-day duration appears to be most important in the generation of extreme floods from extreme rainfall**
  - **Implies that back to back storms/stalling storm patterns, antecedent conditions play a critical role**
- **1-day duration is least important, suggests that short intense rainfall produces fewer extreme basin responses (based on current dataset)**

California Region



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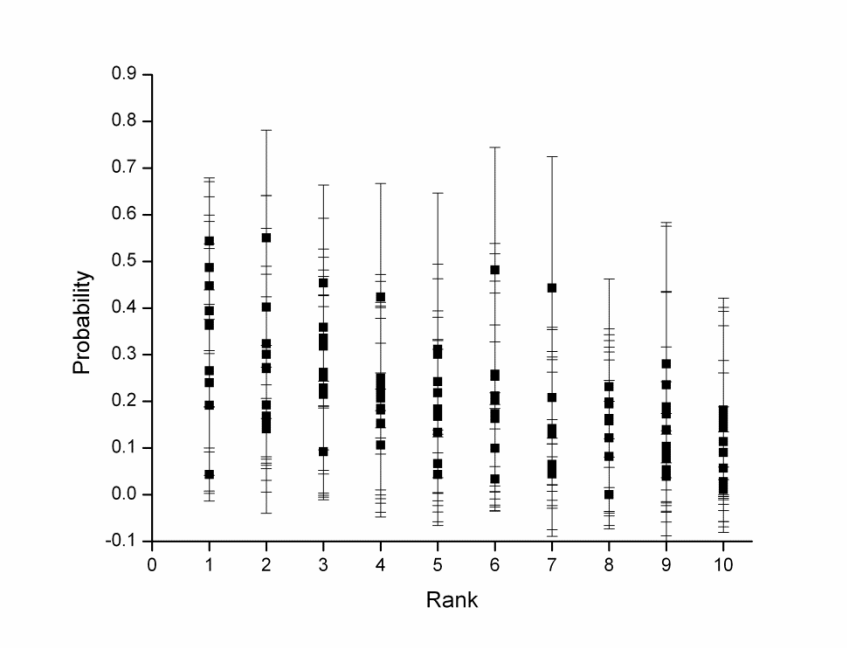
General patterns in rainfall-runoff relationships

- **What is the probability that the top 10 ranked annual peak discharges will match a top 10 precipitation value?**
  - **Includes all durations (1-,3-,5-,7-day durations)**
  - **General decreasing probability from the top ranked peak discharge to the 10th ranked peak discharge**

California Region



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Summary of California results

- **5-Day duration most important for generating extreme floods within the California Region**
  - **Antecedence is important factor**
- **1-Day duration is the least important for flood generation, indicates that more than just high intensity storms are needed to generate extreme floods**
- **Largest peak discharge (Rank=1) is more often recorded by extreme rainfall while the smallest peak discharge (Rank=10) is less often recorded by extreme rainfall**

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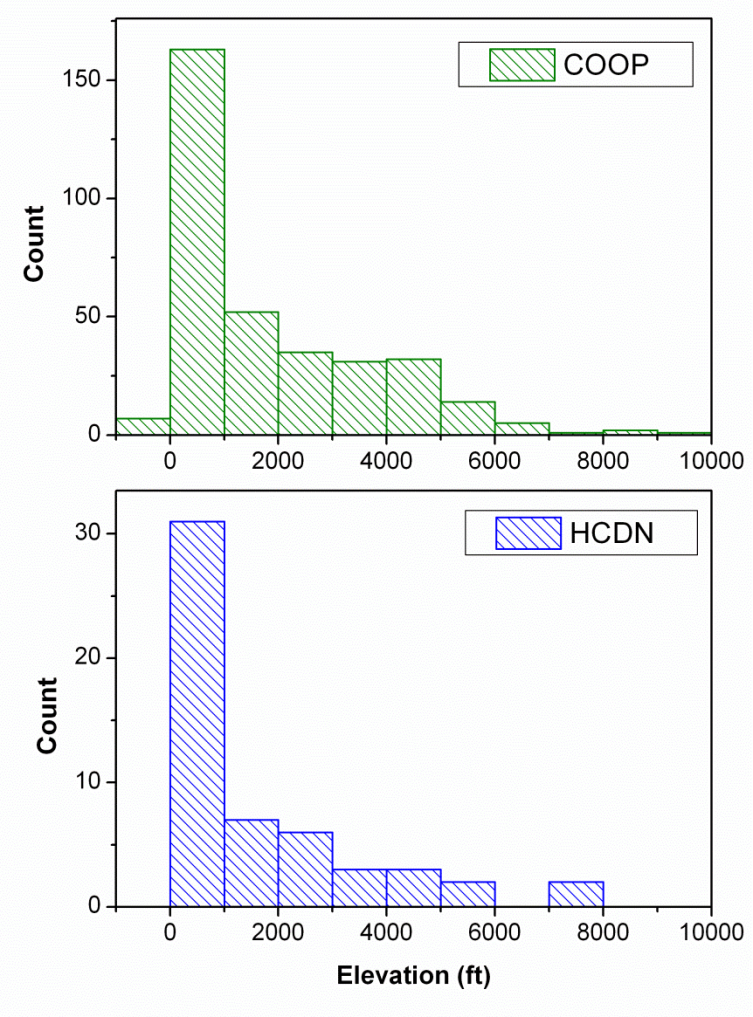
Study Limitations

- Only Top 10 Annual peaks of record used
  - Extreme rainfall values could be recorded in peaks that were not the annual extreme
- Gage locations
  - Many COOP stations located in different subbasins or downstream (at lower elevations) from streamflow data
    - Limits conclusions regarding rainfall-runoff relationships

Gage elevations for California Region



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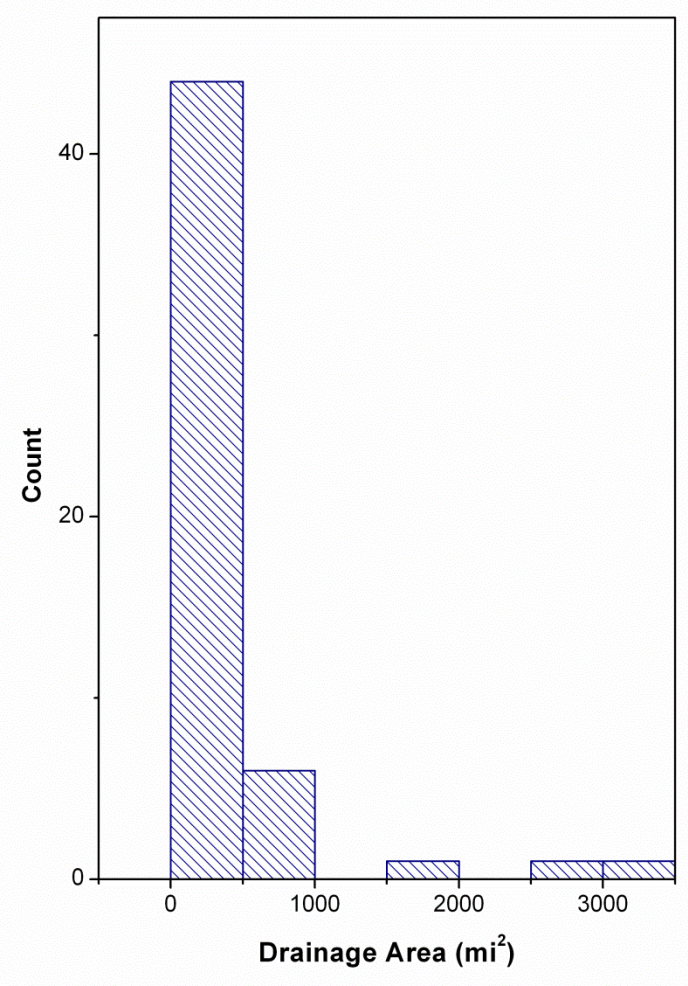
Study Limitations (cont.)

- **Availability of streamflow data**
  - Regulation/human manipulation limits the number of acceptable gages for analysis
  - Length of record (60-year requirement), online availability also limited the number of gaging stations in the analysis
- **Drainage area**
  - Acceptable stations are typically located in smaller drainage areas due to downstream regulation in larger basins



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Implications for climate change

- Dettinger et al. (2011)
  - Increases in:
    - Number of years with higher numbers of AR events
    - ARs with greater than historical water vapor transport
    - Temperatures associated with ARs
    - Peak season length for ARs
- Das et al. (2011), Sierra Nevada (some conflicting results)
  - Frequency and size of storms expected to increase
  - More precipitation as rain versus snow
- Implications for floods (from above studies):
  - More winter rainfall floods vs. snowmelt floods
  - Increase in the frequency of floods and in 3-day flood magnitude

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Implications for climate change (cont.)

- **This study**
  - **Longer duration events (5-, 7-day durations) have produced a greater number of extreme floods in the historical record**
  - **Suggests that investigating longer durations (>3-day duration) of extreme precipitation are important for simulations of projected changes in floods due to climate change**
  - **Further analysis of basins would help to define factors important in basin response to extreme precipitation and to help inform rainfall-runoff modeling in various regions.**

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Further work

- Detailed data analyses for each region (HUC2)
- Detailed data analyses for subbasins (HUC6 or HUC8) or for individual storms across subbasins
  - Rainfall-runoff relationships in individual basins, spatial variability across subbasins
- Additional gages
  - Precipitation: higher elevation gages
  - Streamflow: add gages not online, allow record length to vary (?)
- Analyze for flow volumes (long duration flows compared to high magnitude flows)
- Analyses to link extreme floods with Atmospheric River events

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Acknowledgements

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