RECLAMATION

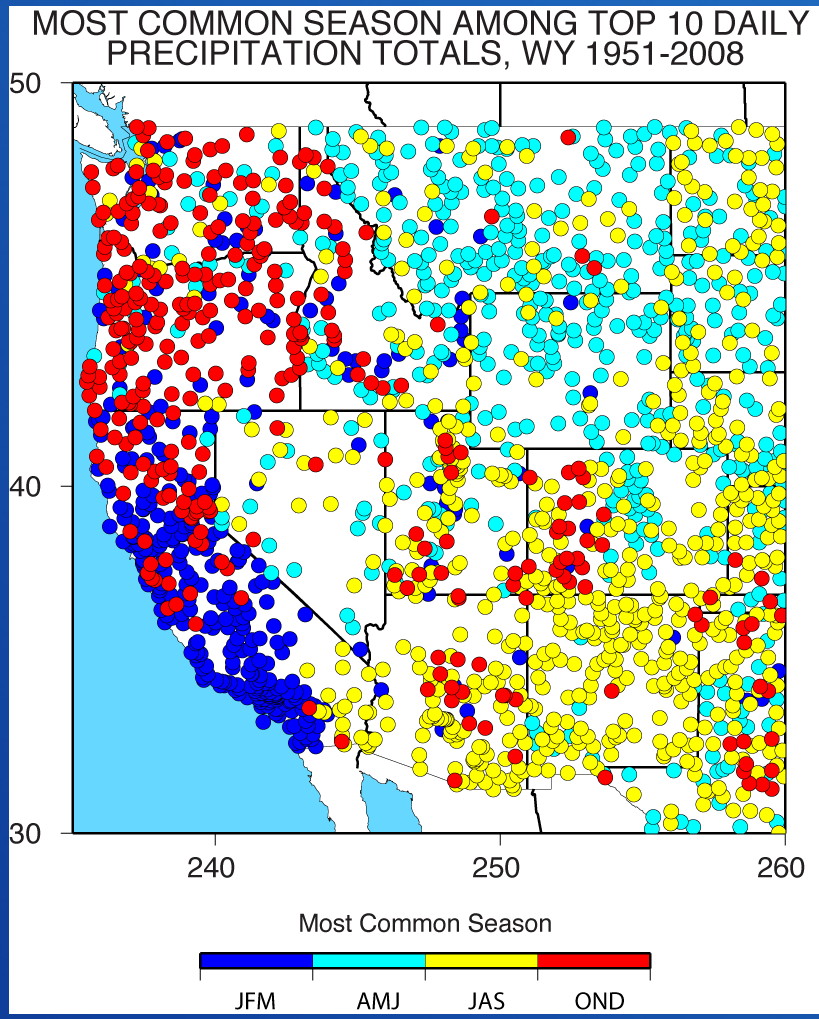
Managing Water in the West

Linking Extreme Precipitation and Floods: Implications for Climate Change Scenarios

U.S. Department of the Interior
Bureau of Reclamation

Research Question and Objective

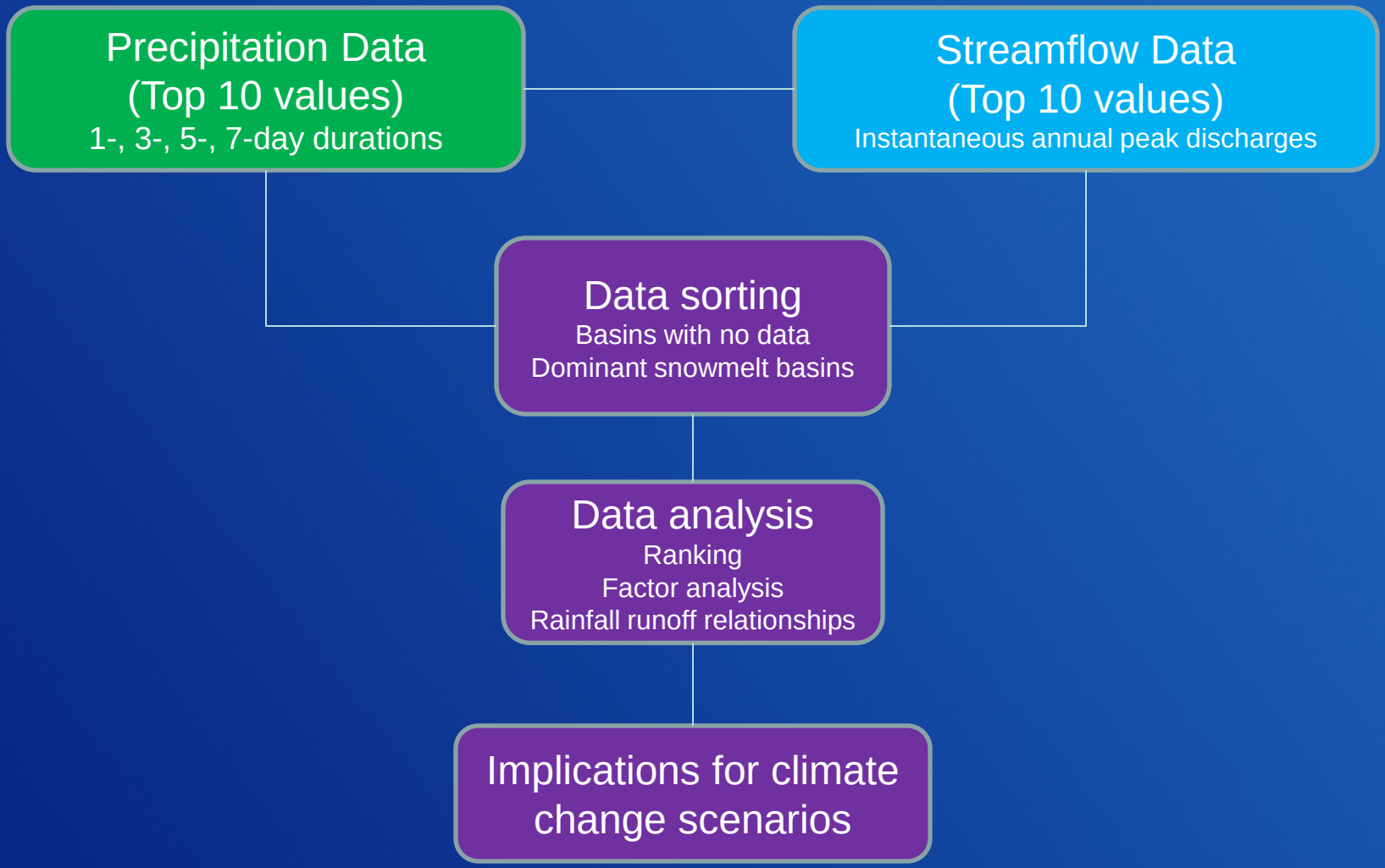
- **Study Question**
  - **Do the largest precipitation events produce the largest floods and if not, why?**
- **Objectives**
  - **Examine basin response to extreme precipitation in regions of the western U.S.**
  - **Identify basin factors and storm conditions that produce the largest floods**
  -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



From M. Dettinger, USGS-SIO

RECLAMATION

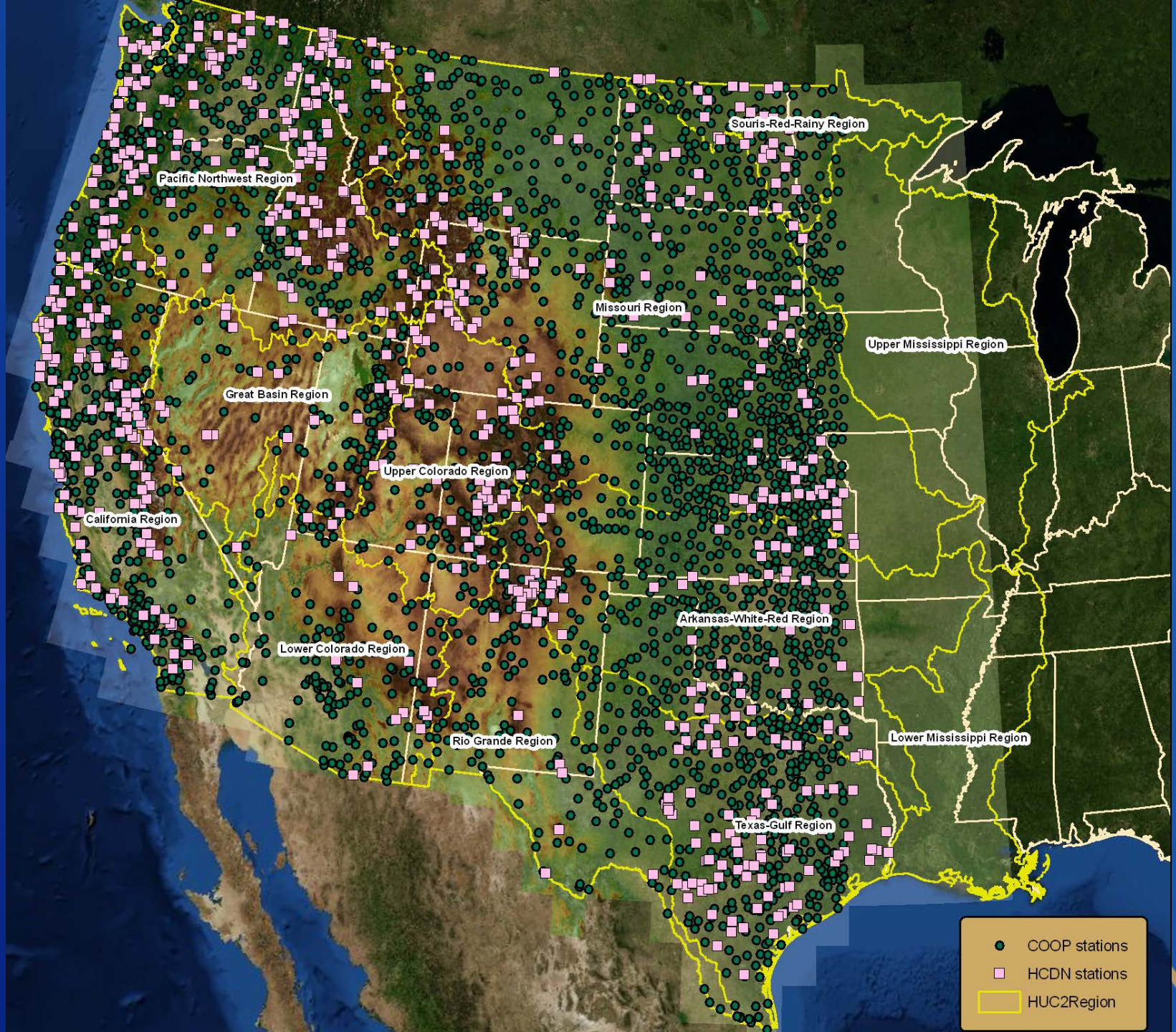
Research Strategy



RECLAMATION

Data sources

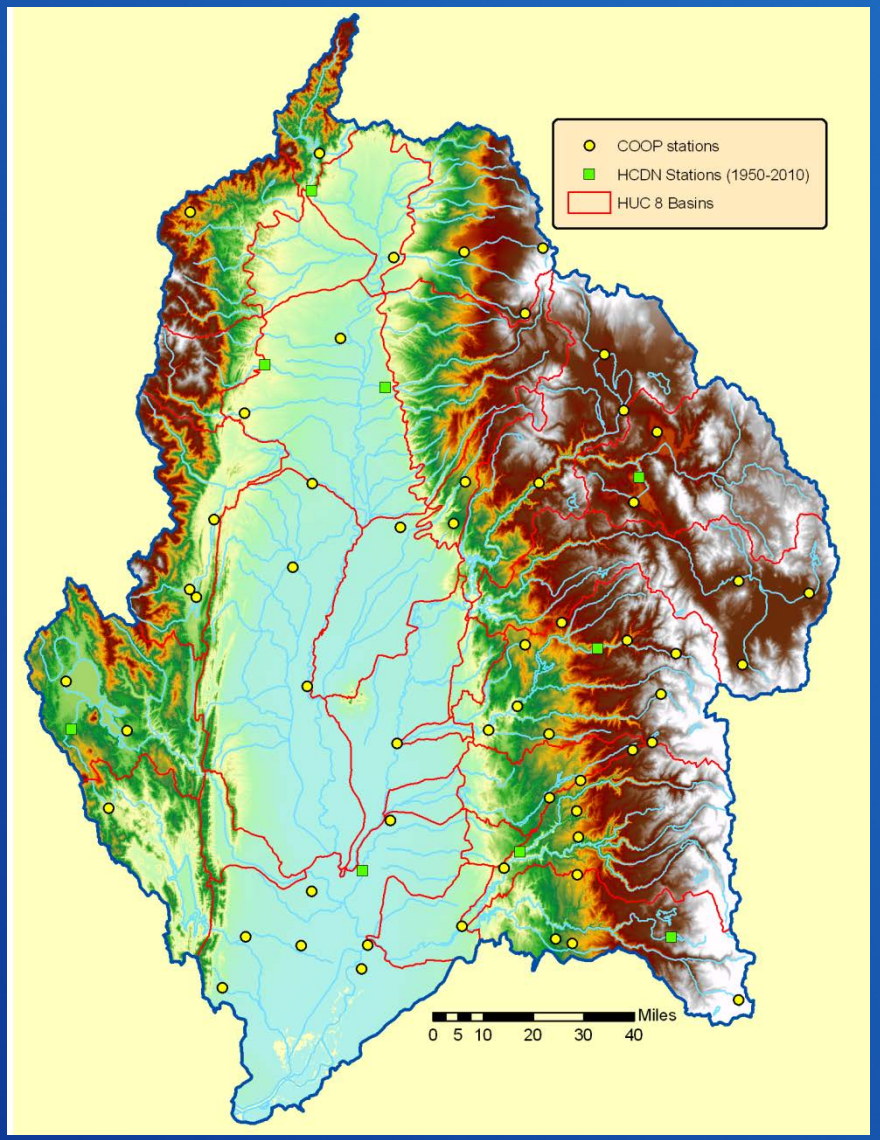
- Precipitation (~2964 stations)
  - Cooperative Observer Program (COOP) network (NOAA)
    - Top 10 values from each gage (1950-2010)
      - <10% missing records
      - 1-, 3-, 5-, 7-day durations (independent events)
    - Data obtained from Mike Dettinger, USGS-SIO
- Streamflow (~730 stations; 54 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


Souris-Red-Rainy Region
Pacific Northwest Region
Missouri Region
Upper Mississippi Region
Great Basin Region
Upper Colorado Region
California Region
Arkansas-White-Red Region
Lower Colorado Region
Rio Grande Region
Lower Mississippi Region
Texas-Gulf Region
COOP stations
HCDN stations
HUC2Region

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



RECLAMATION

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

Example Matrix for 1Day Rainfall values

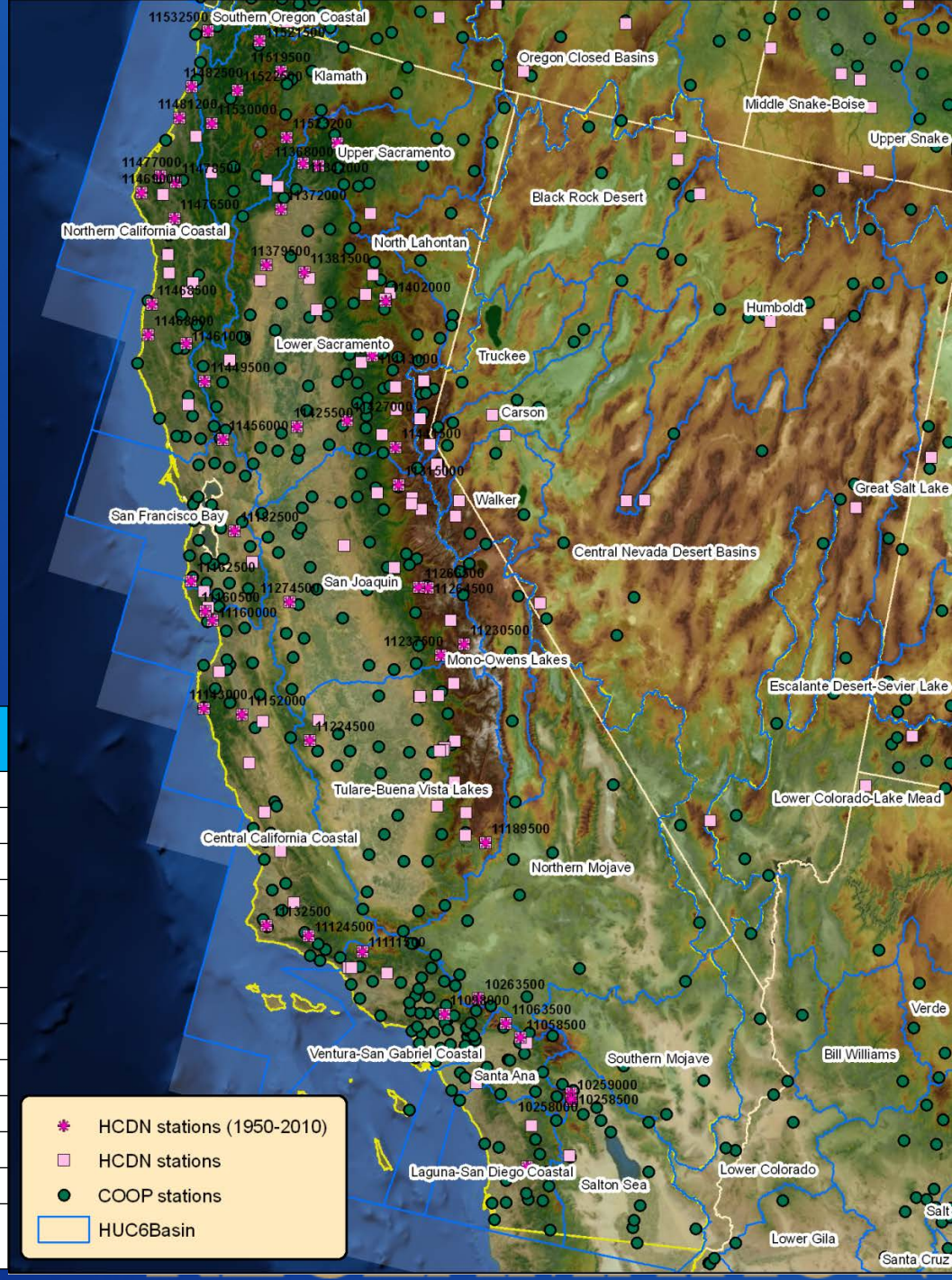
MAX 1DAY	Top 10 rainfall events										
Top 10 Runoff Events	DATES	1/31/63	3/10/95	2/3/98	12/23/55	1/7/74	3/16/86	12/5/97	2/15/86	12/3/74	2/25/04
	3/15/1952	0	0	0	0	0	0	0	0	0	0
	1/18/1973	0	0	0	0	0	0	0	0	0	0
	3/18/1991	0	0	0	0	0	0	0	0	0	0
	3/10/1995	0	1	0	0	0	0	0	0	0	0
	1/27/1983	0	0	0	0	0	0	0	0	0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

RECLAMATION

California Region

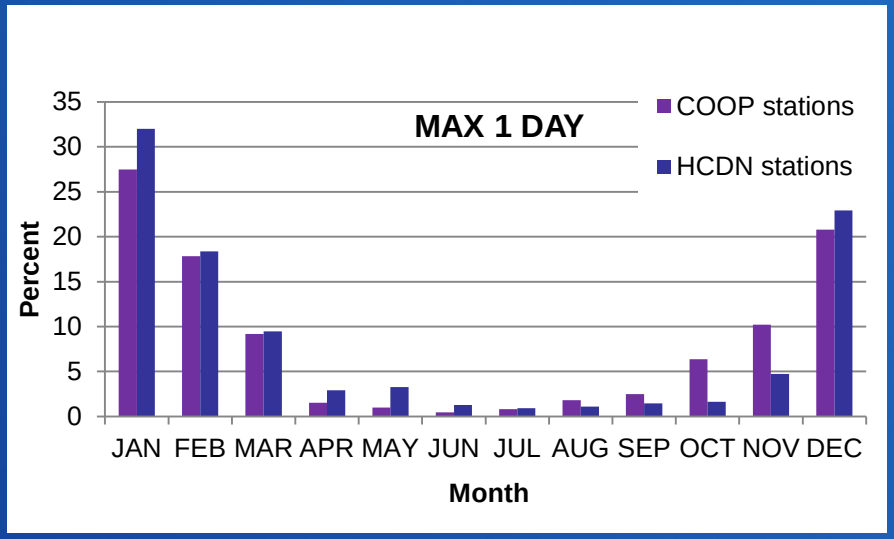
- **Subbasins with no HCDN data:**
  - **North Lahontan**
  - **Mono-Owens Lakes**
  - **Southern Mojave**
  - **Lower Colorado**
- **13 subbasins examined**

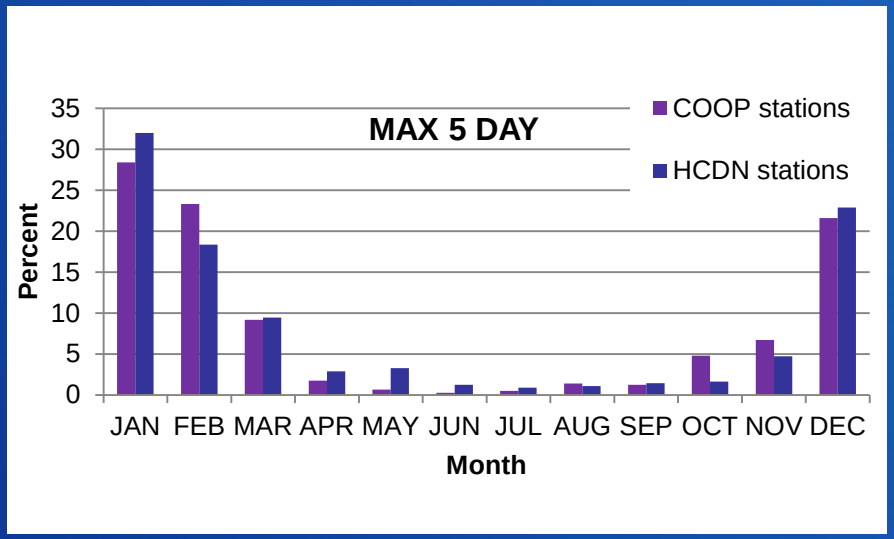
HUC 6 Basin	Number of COOP stations	Number of HCDN stations
Central CA Coastal	33	6
Klamath	22	6
Laguna San Diego Coastal	16	1
Lower Sacramento	57	9
Northern CA Coastal	23	10
Northern Mojave	14	1
Salton Sea	15	3
San Francisco Bay	27	3
San Joaquin	34	6
Santa Ana	14	2
Tulare Buena Vista Lakes	28	3
Upper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



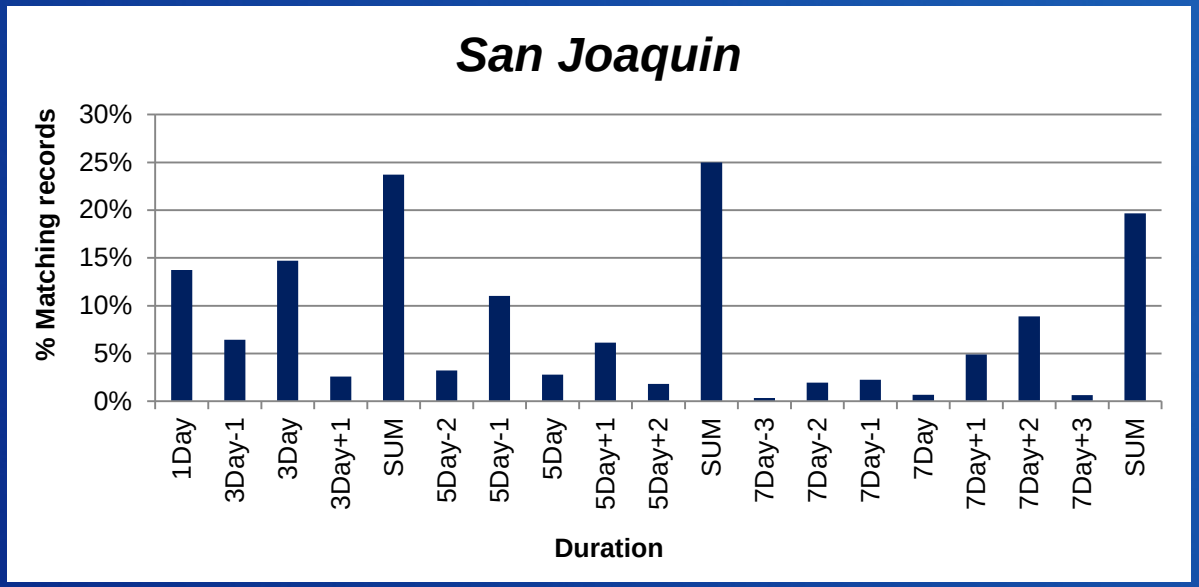
Seasonality of COOP and HCDN data (CA)

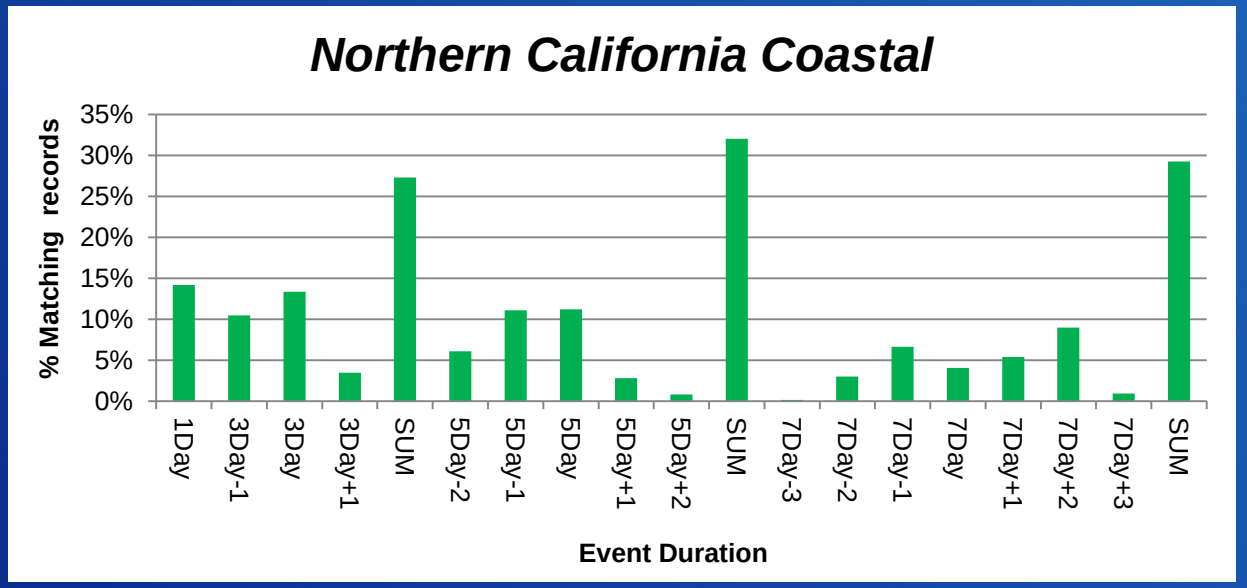
- DEC-MAR
  - Extreme rainfall and streamflow have similar percentages
- APR-JUN
  - Minor snowmelt component in streamflow
- SEP-NOV
  - Dry conditions preceding rainfall, few extreme flood records





RECLAMATION



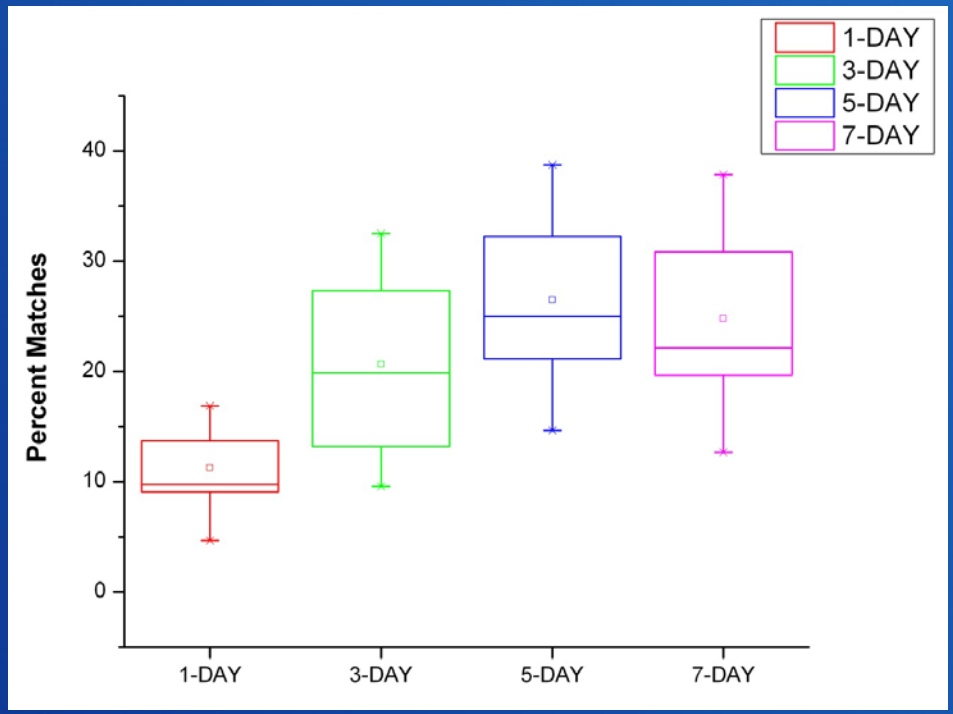


RECLAMATION

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

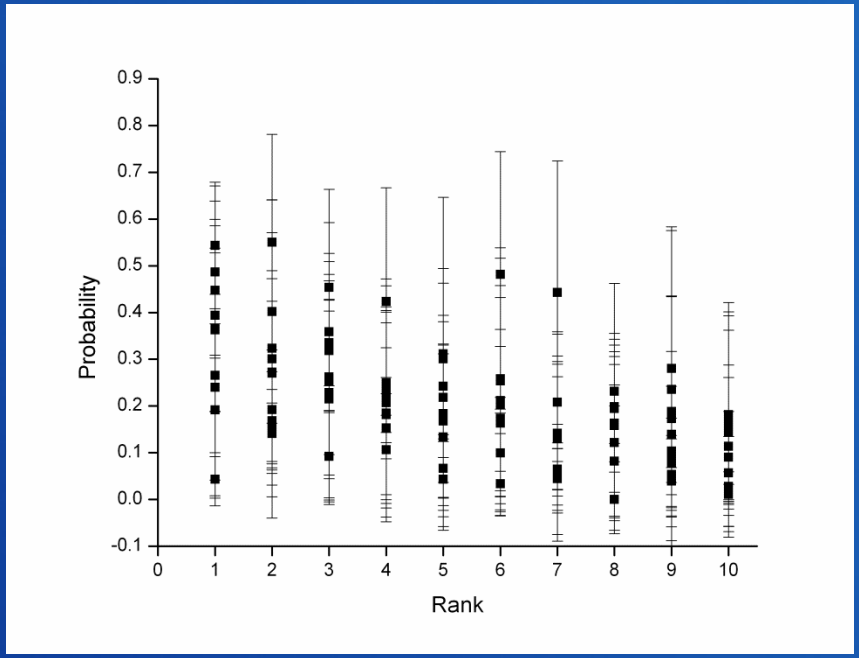


RECLAMATION

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



RECLAMATION

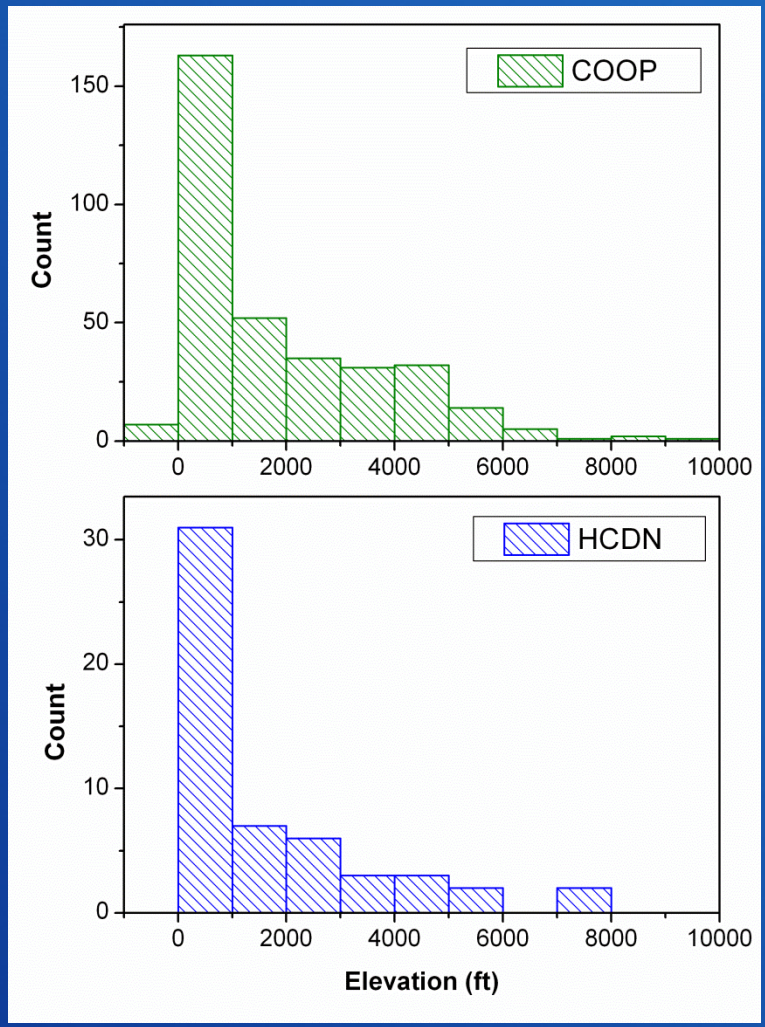
Summary of California results

- **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 an extreme rainfall event while the smallest peak discharge (Rank=10) is less often recorded by an extreme rainfall event**

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**
  - **Some COOP stations located in different subbasins or downstream (at lower elevations) from streamflow data**
    - **Limits conclusions regarding rainfall-runoff relationships**

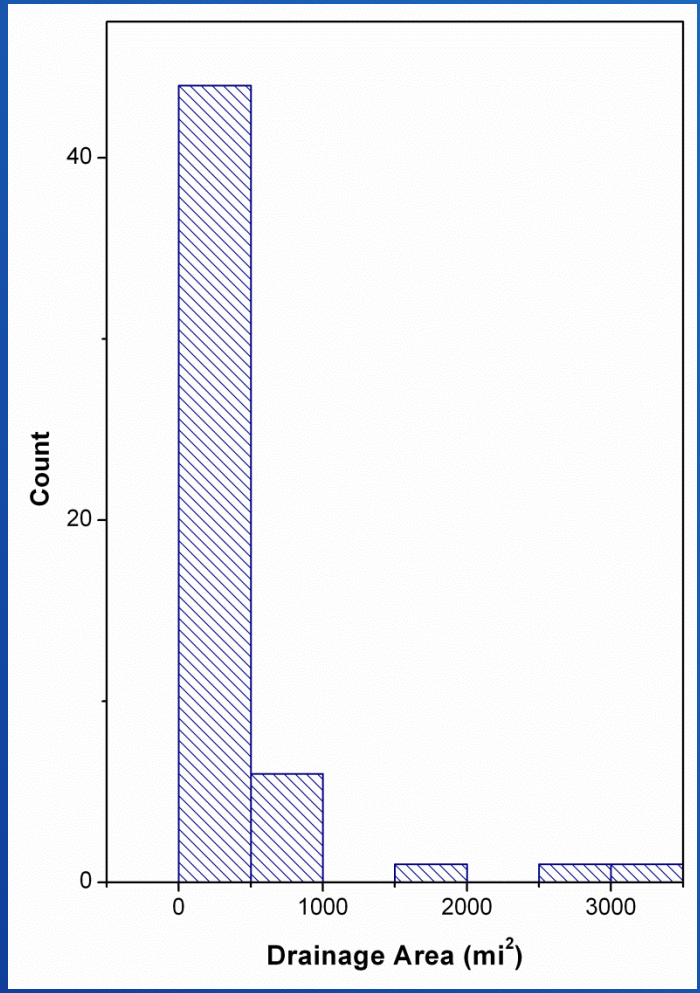
Gage elevations for California Region



RECLAMATION

Study Limitations (cont.)

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



RECLAMATION

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**

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.

Further work

- 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

Acknowledgements

- Research and Development Office, Reclamation
- Mike Dettinger, USGS-SIO (COOP data)
- Marty Ralph, NOAA-ESRL
- Frank Dworak, Reclamation, Flood Hydrology Group
- Jan Oliver, Reclamation, Sedimentation and River Hydraulics Group

Earth System Research Laboratory
Serving Society through Science

SCRIPPS INSTITUTION OF OCEANOGRAPHY

RECLAMATION