Hydrologic Impacts of Atmospheric Rivers in the Western U.S.

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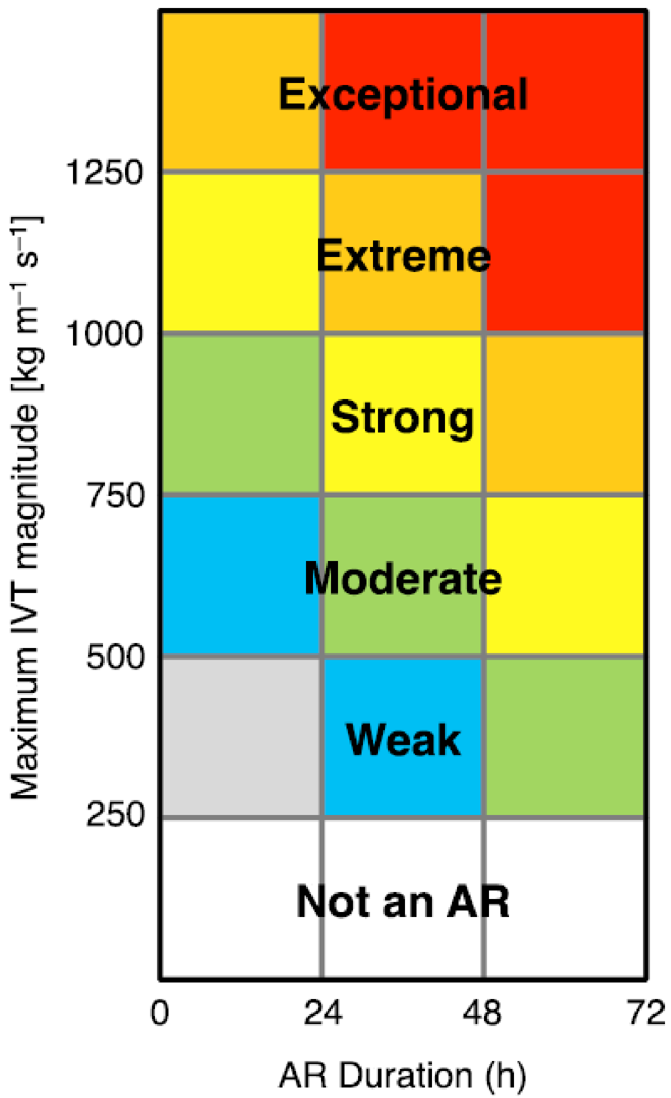
AR Impacts Range from Hazardous to Beneficial

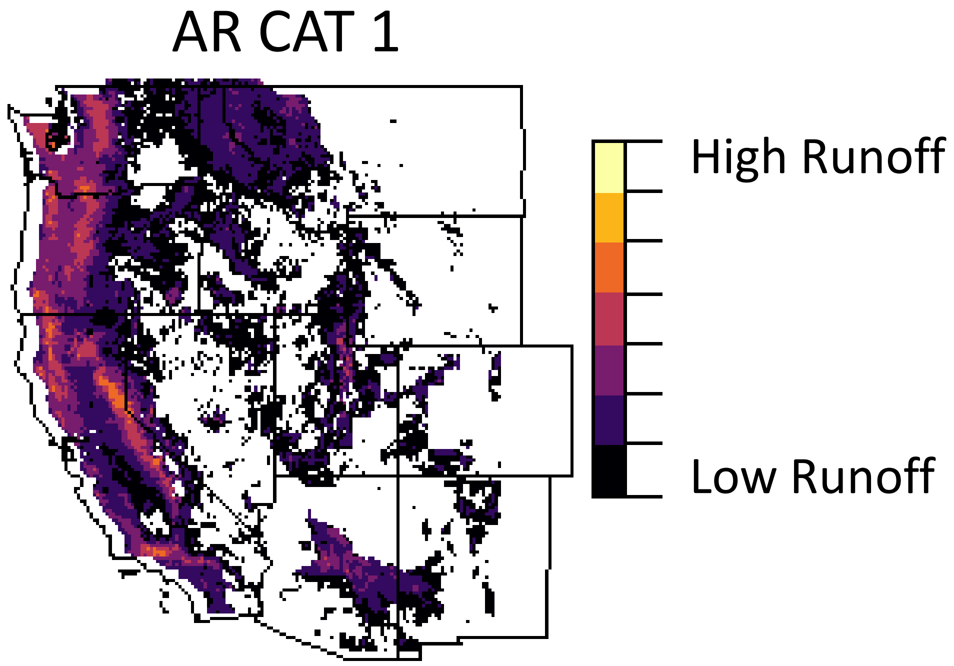


- Cat 5 – Primarily hazardous
- Cat 4 – Mostly hazardous, also beneficial
- Cat 3 – Balance of beneficial and hazardous
- Cat 2 – Mostly beneficial, also hazardous
- Cat 1 – Primarily beneficial

Ralph et al., In review

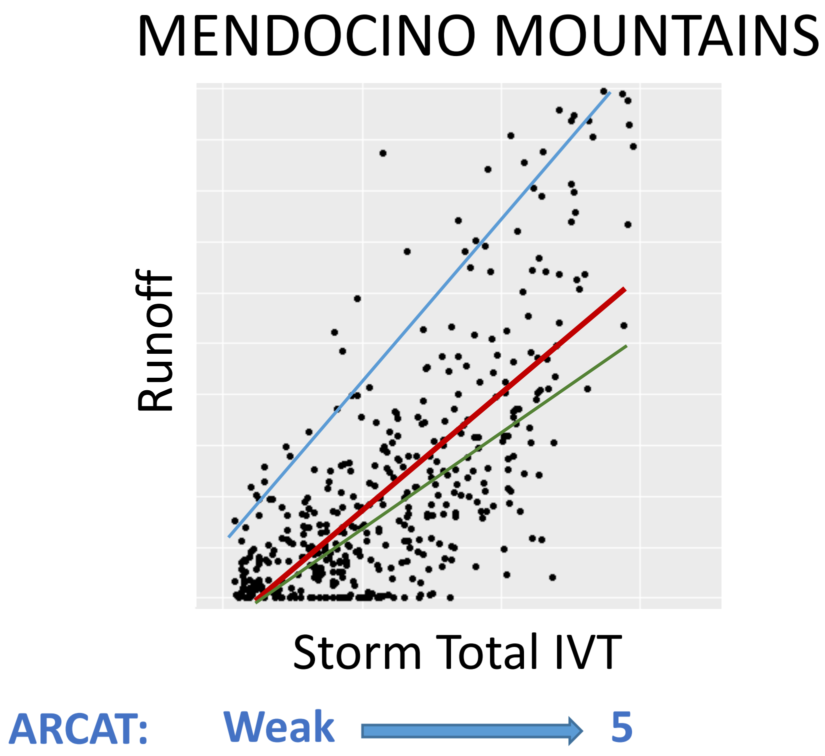
Objective: Characterize the magnitude, nature, and variability of hydrologic impacts based on the AR scale

Over Space



- Atmospheric conditions and terrain affect precipitation amounts
- Site differences affect hydrology

Over Time

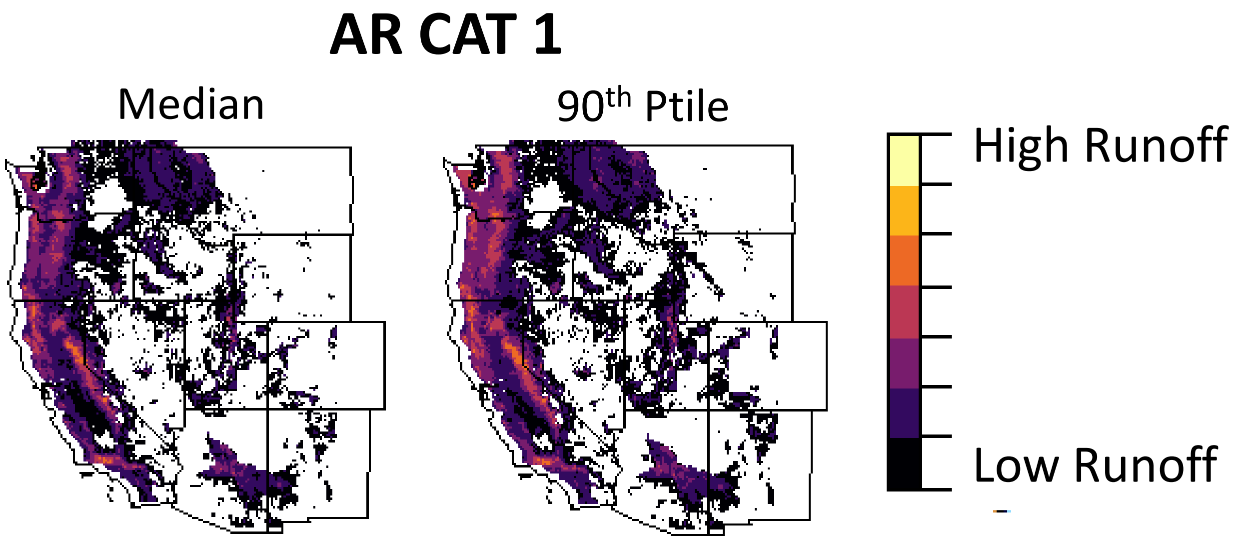


- Atmospheric conditions affect precipitation amounts
- Antecedent conditions affect hydrology

Approach: Assess probable (50th percentile) and potential extreme (90th percentile) hydrologic impacts

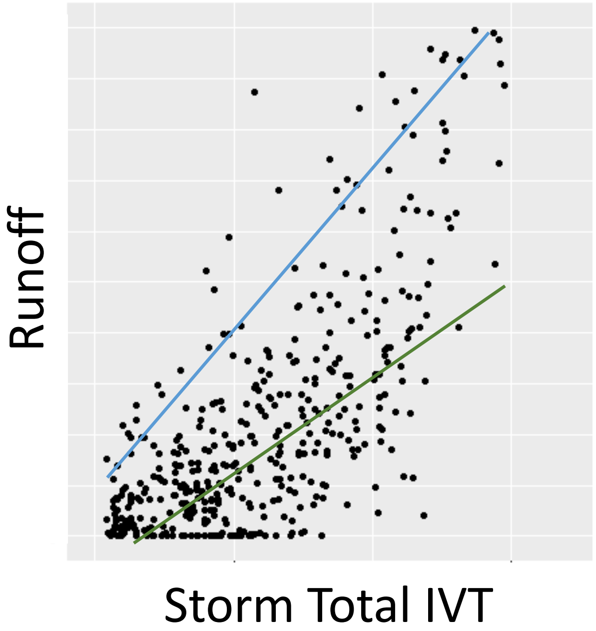
Over Space

- Composite 50th/90th percentile hydrologic responses by AR CAT
  - Runoff
  - Δ Soil Moisture
  - Δ Snow Water Equivalent



Over Time

- Quantile regression of 50th/90th percentile hydrologic responses to AR conditions from 1980-2013, by pixel



Data and Methods – Atmospheric River Event Chronology

- Rutz MERRA-2
- Winter (Oct-Apr) ARs, 1980-2013
- 3 hr → Daily → Event Scale

Composite Analysis

- Storm Total IVT Classes

STIVT 10^7(kg/m)	AR CAT
>19.44	Cat 5 – Primarily hazardous
>12.96	Cat 4 – Mostly hazardous, also beneficial
>8.64	Cat 3 – Balance of beneficial and hazardous
>4.32	Cat 2 – Mostly beneficial, also hazardous
>2.16	Cat 1 – Primarily beneficial

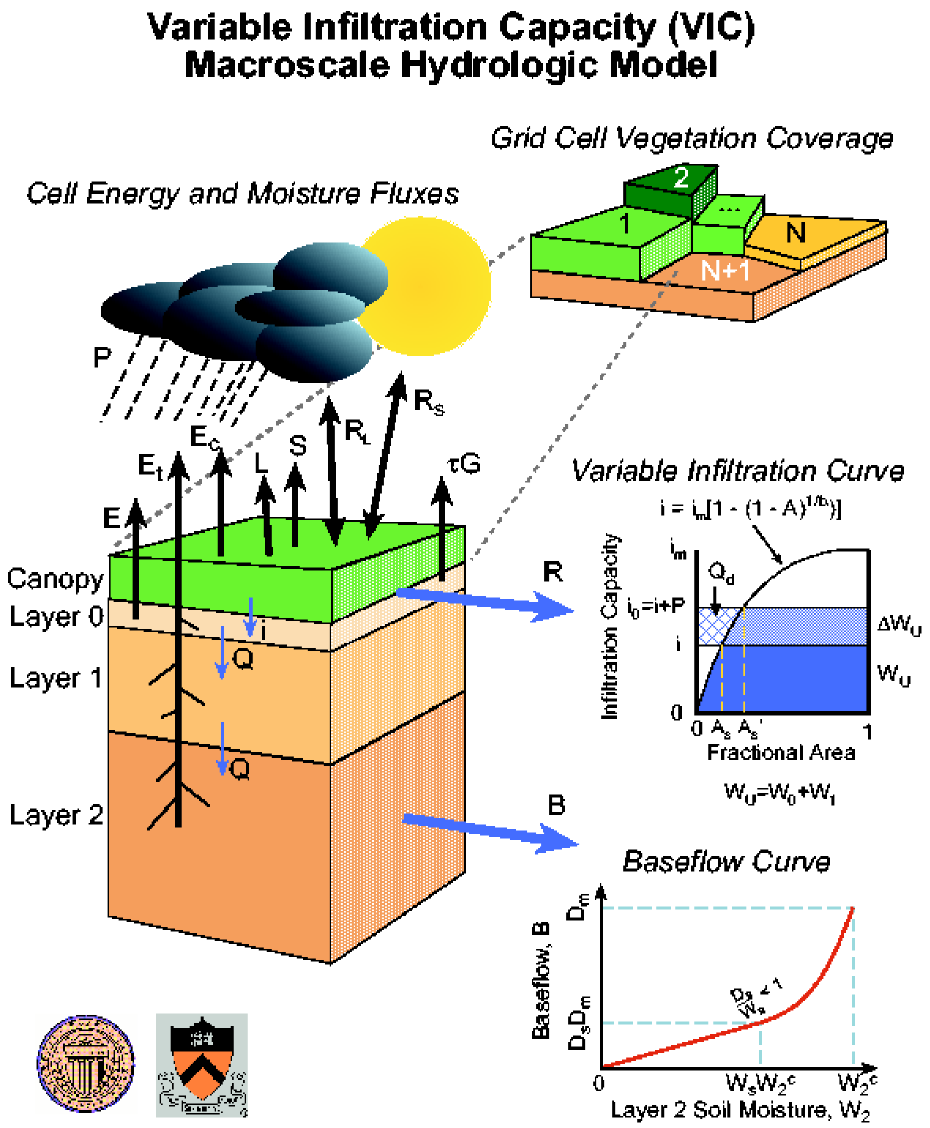
Multiple Quantile Regression

- n > 30 AR events per pixel
- Predictor Variables:
  - Storm Total IVT
  - Specific humidity-weighted
    - temperature
    - wind direction
  - Antecedent soil moisture (VIC model)

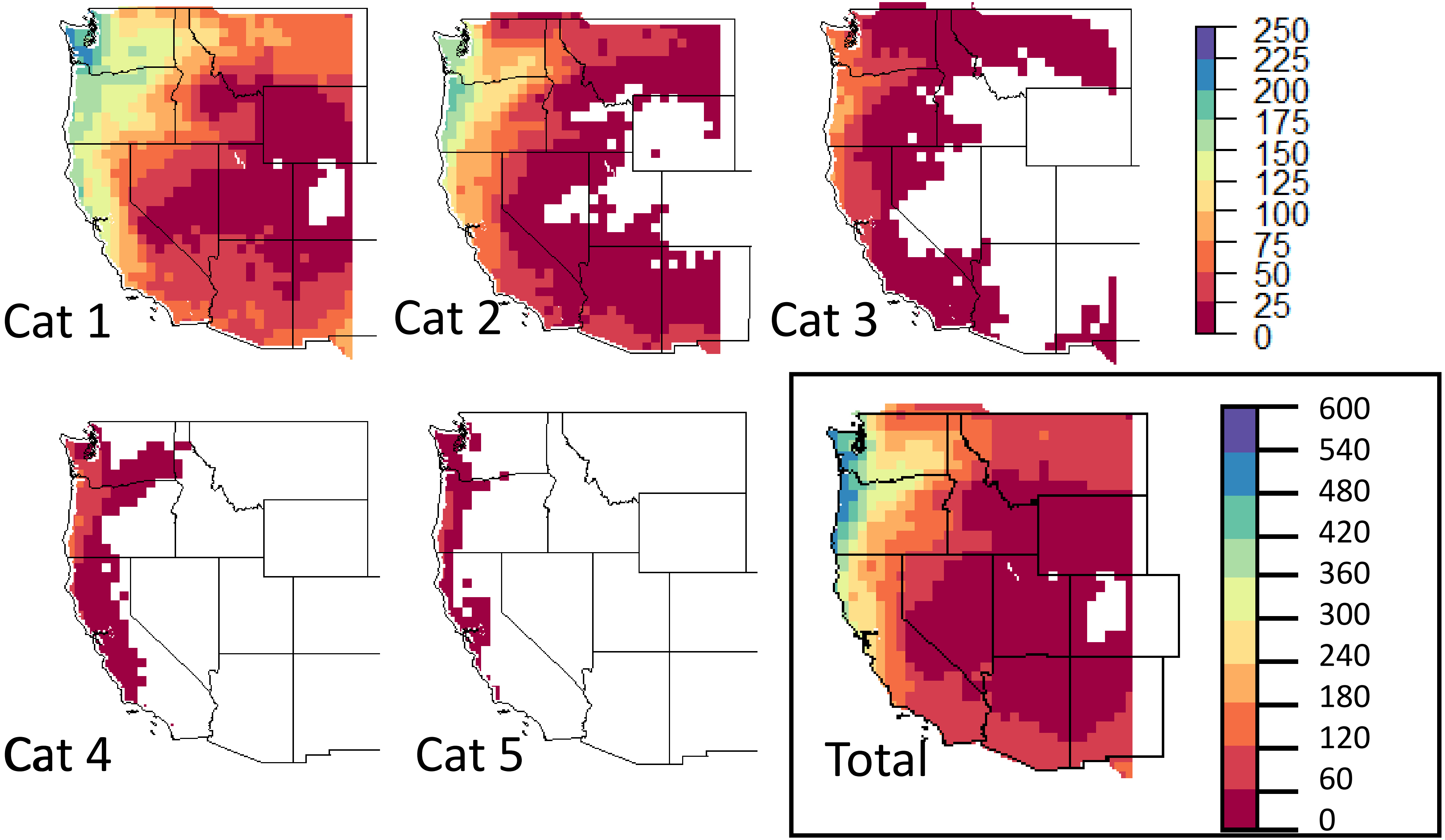
Data and Methods – Hydrologic Responses

Variable Infiltration Capacity (VIC) Model

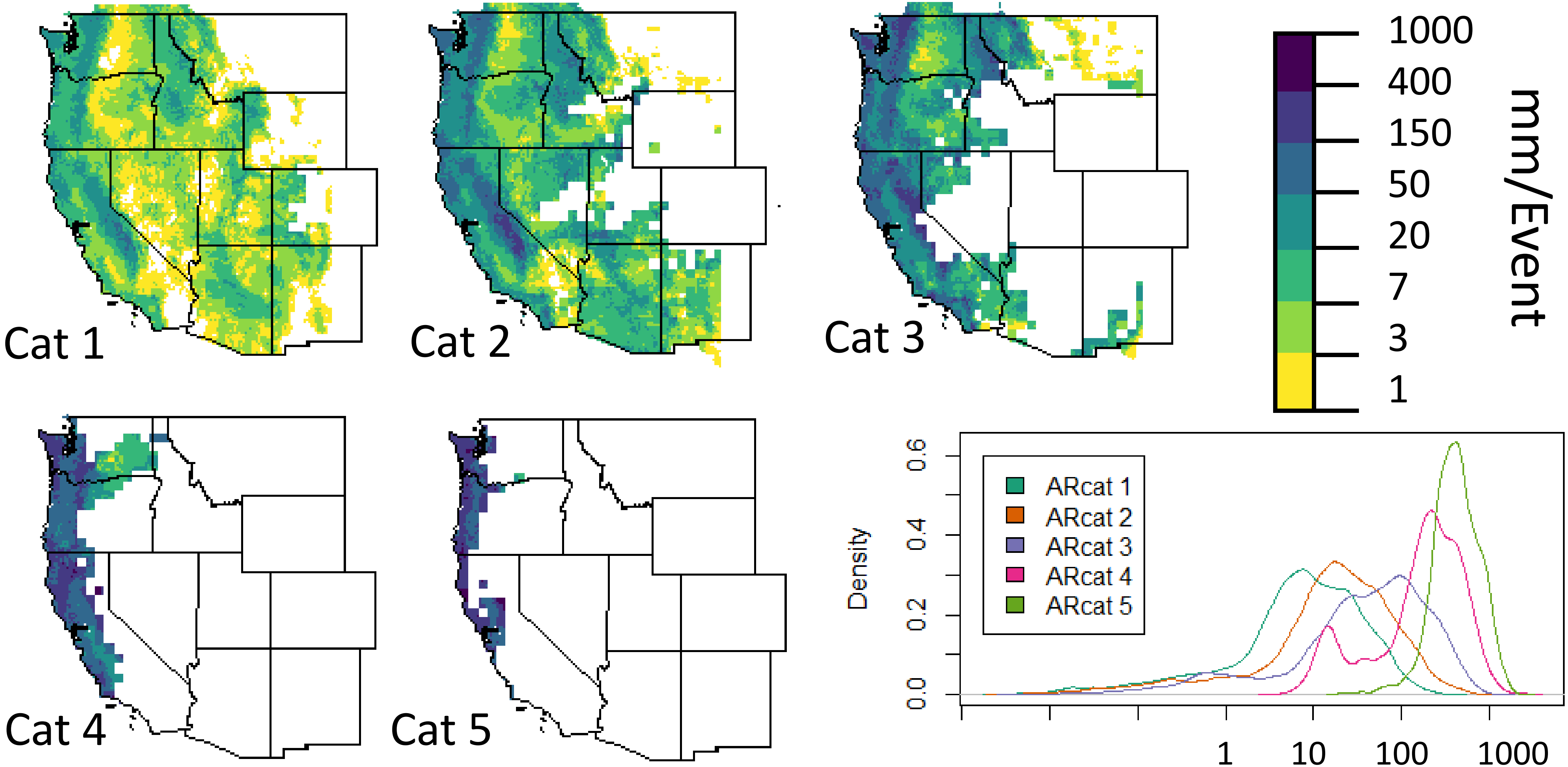
- 1/16th degree, Livneh et al. 2015
  - Antecedent Soil Moisture (Predictor)
  - Response Variables
    - Precipitation (model forcing)
    - Surface Runoff + Δ Baseflow
    - Δ Soil Moisture
    - Δ Snow Water Equivalent

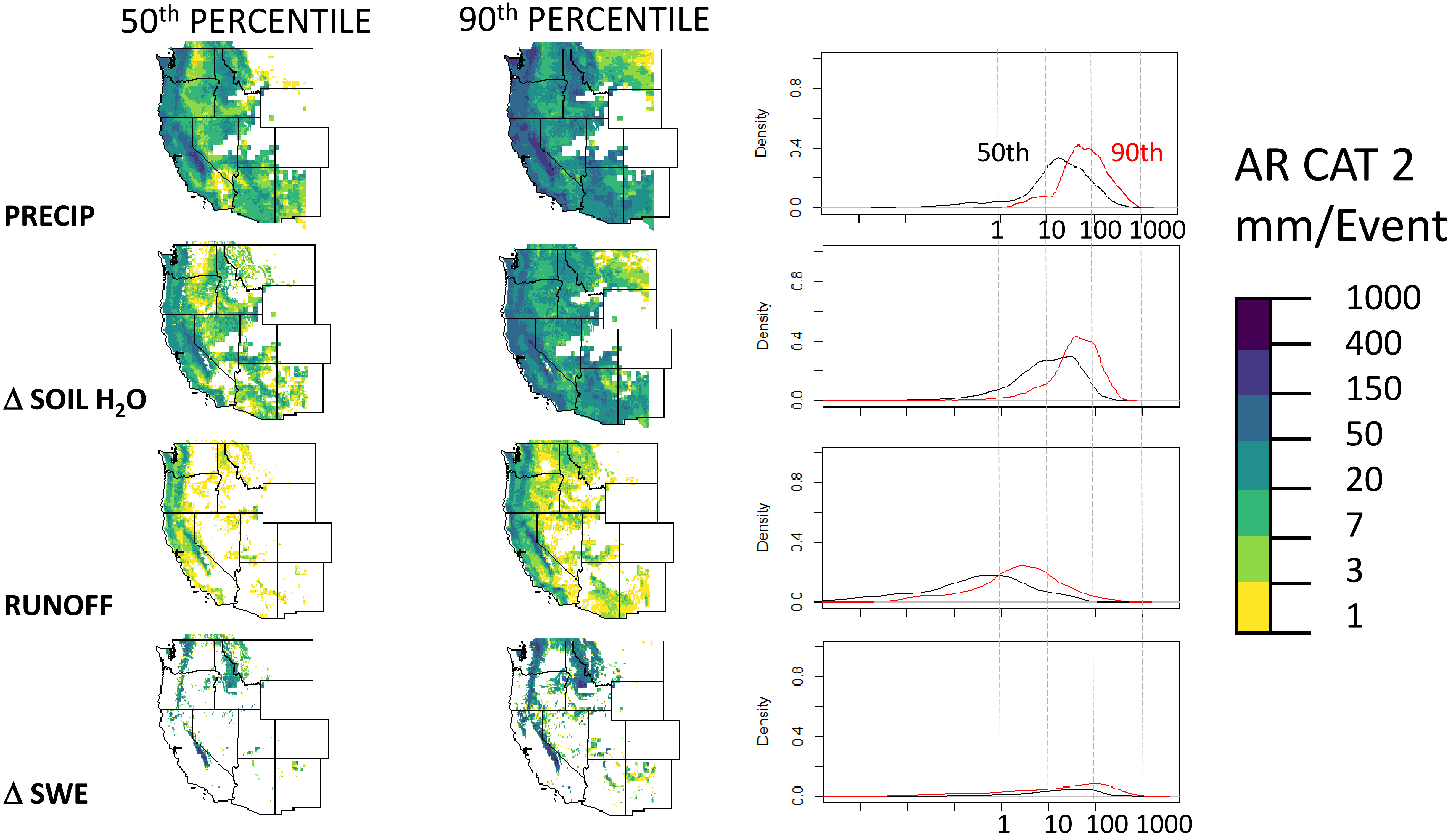


Number of AR Events by Category 1980-2013



Median Precipitation Impact by AR Category





50th PERCENTILE
90th PERCENTILE
PRECIP
Δ SOIL H2O
RUNOFF
Δ SWE
Density
0.0
0.4
0.8
1
10
100
1000
50th
90th
AR CAT 2
mm/Event
1000
400
150
50
20
7
3
1

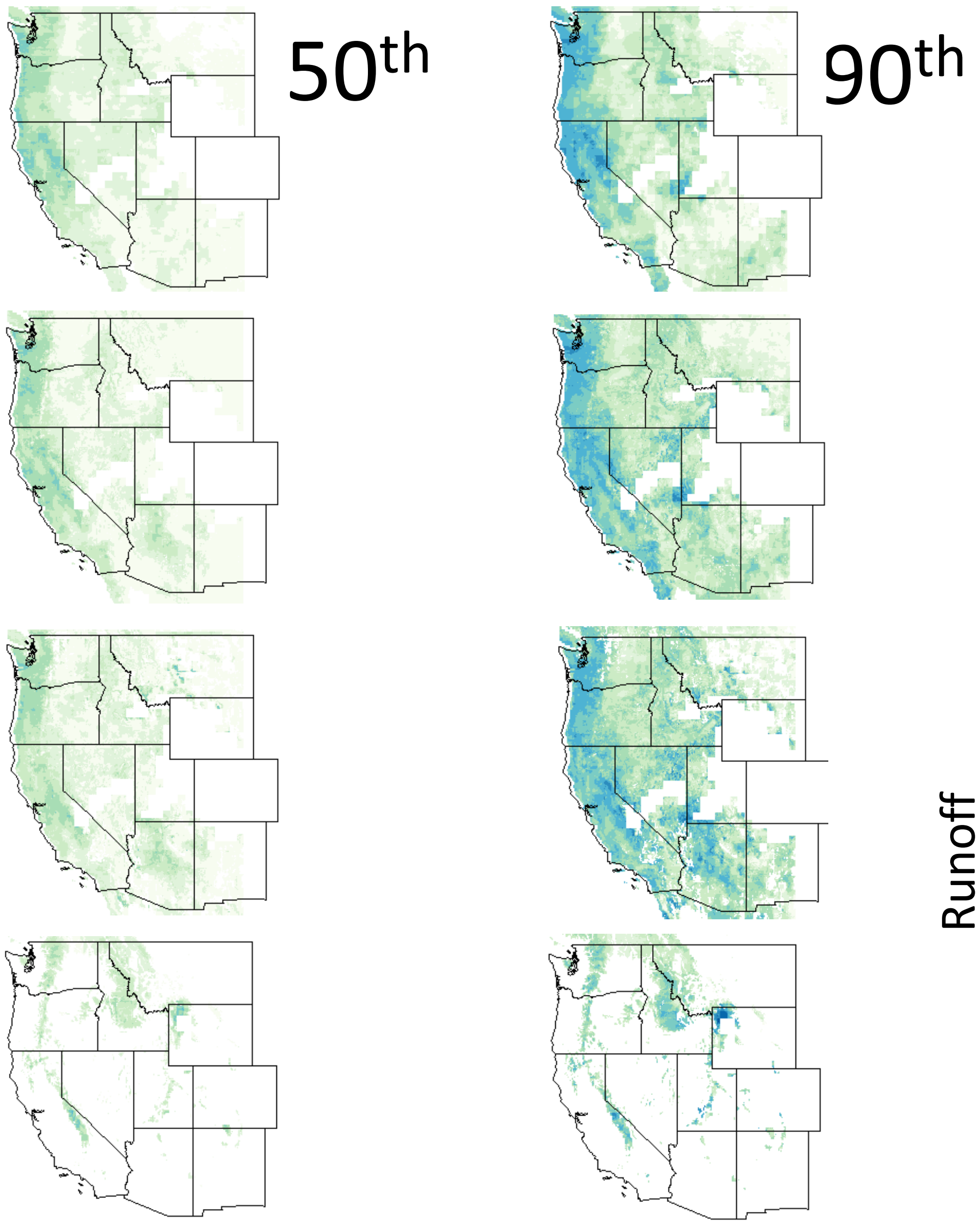
Quantile Regression Model Fits

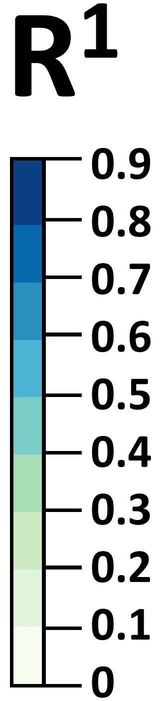
Precipitation
=STIVT + WIND DIRECTION

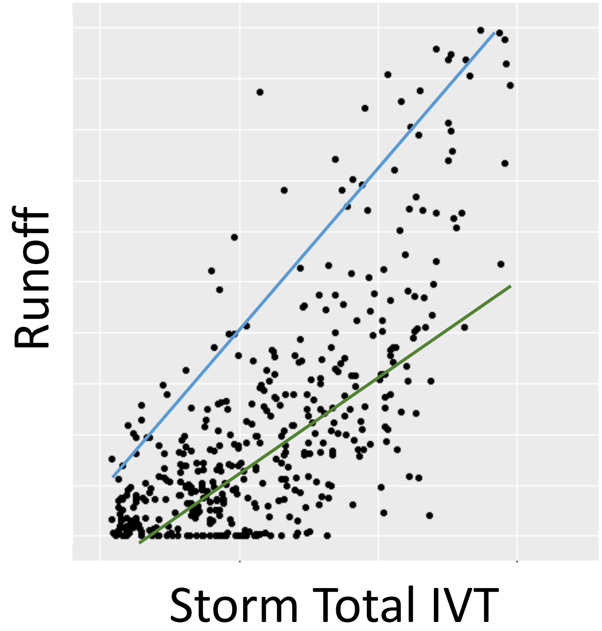
Δ Soil Moisture
=STIVT + WIND+TEMP+ ANTECEDENT SOIL

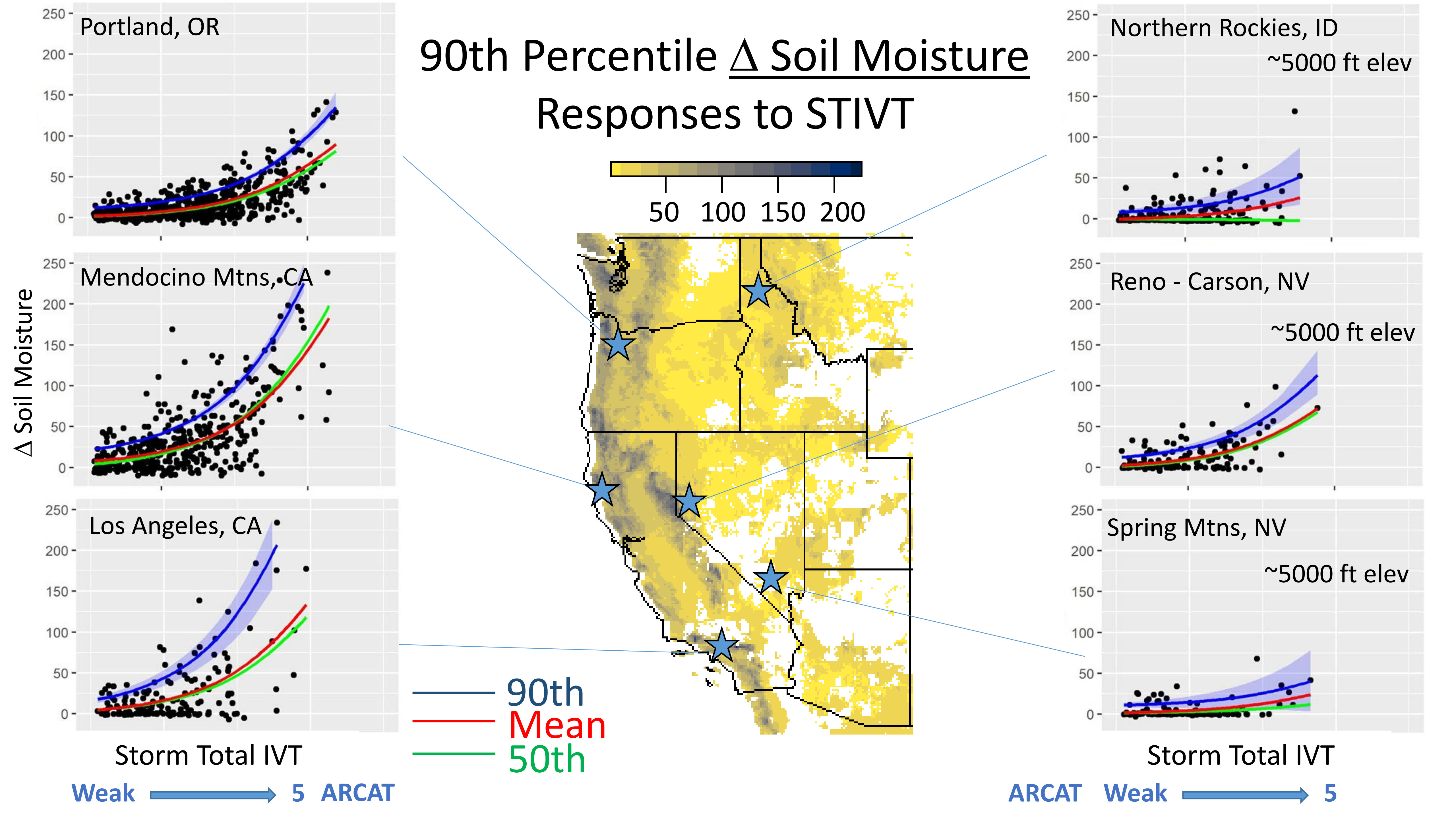
Runoff
=STIVT + WIND+TEMP+ ANTECEDENT SOIL

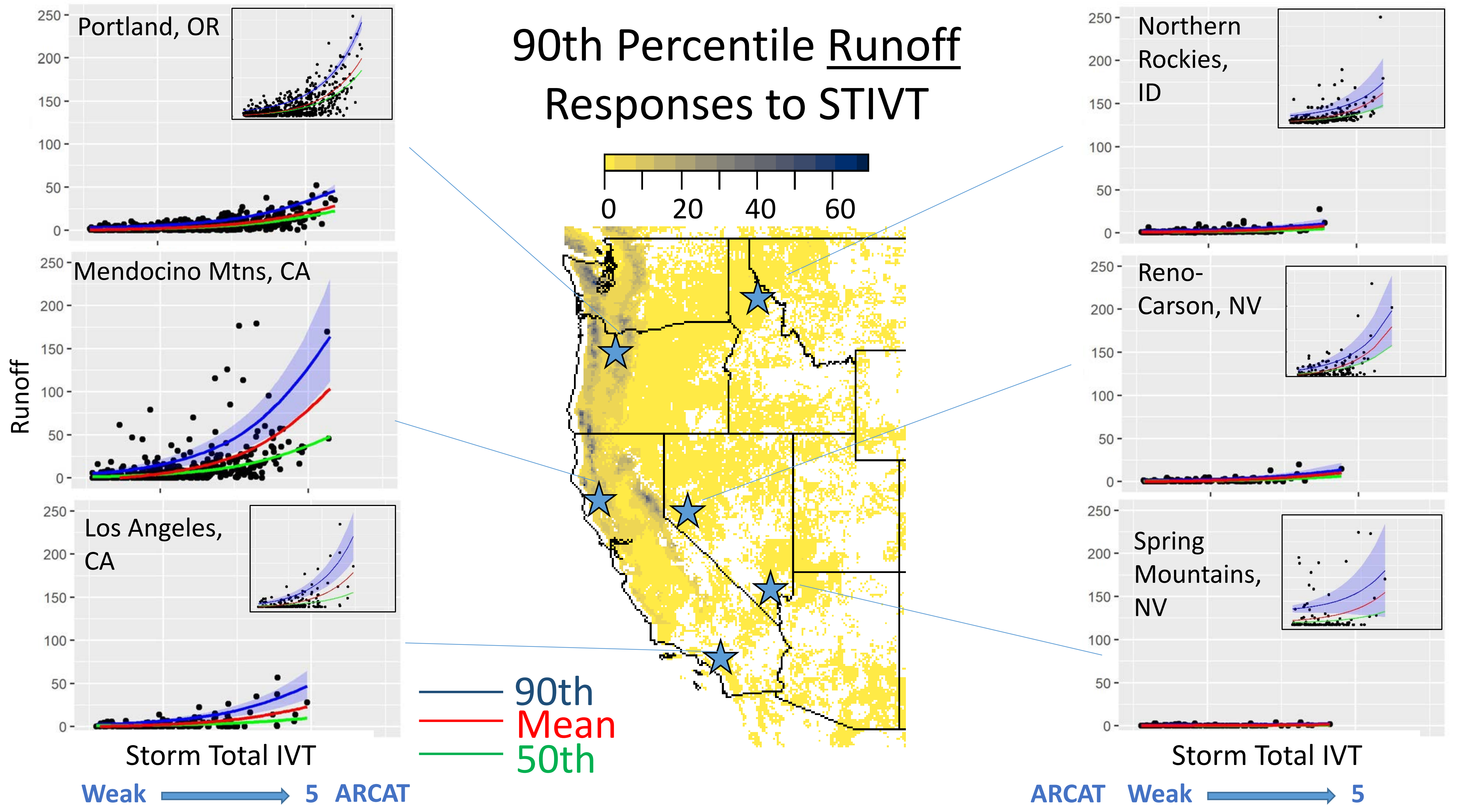
Δ SWE
=STIVT + WIND+TEMP

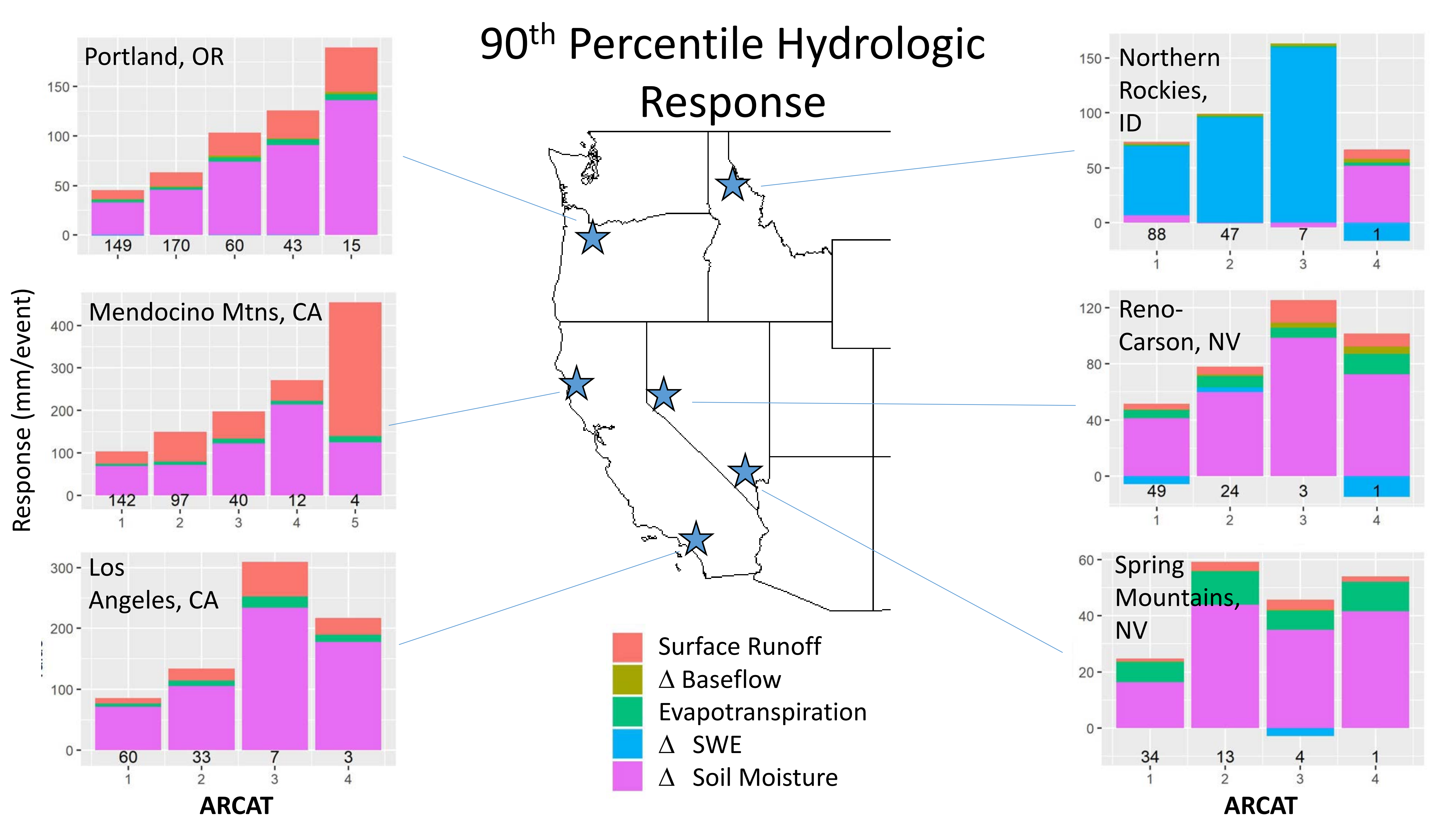




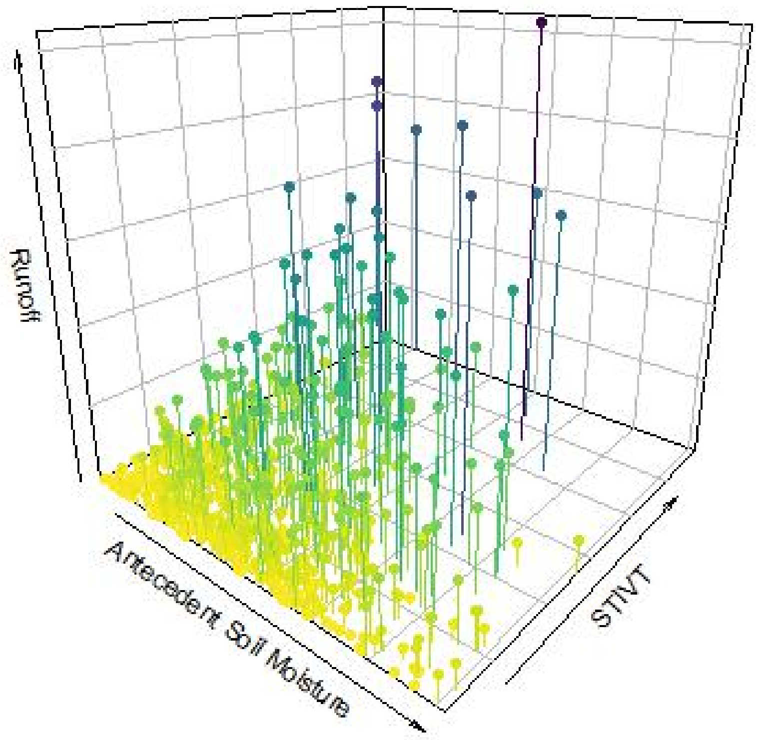



90th Percentile Δ Soil Moisture
Responses to STIVT
50 100 150 200
Portland, OR
Mendocino Mtns, CA
Los Angeles, CA
Northern Rockies, ID
~5000 ft elev
Reno - Carson, NV
~5000 ft elev
Spring Mtns, NV
~5000 ft elev
Δ Soil Moisture
250
200
150
100
50
0
90th
Mean
50th
Storm Total IVT
Weak
5
ARCAT
Storm Total IVT
ARCAT
Weak
5

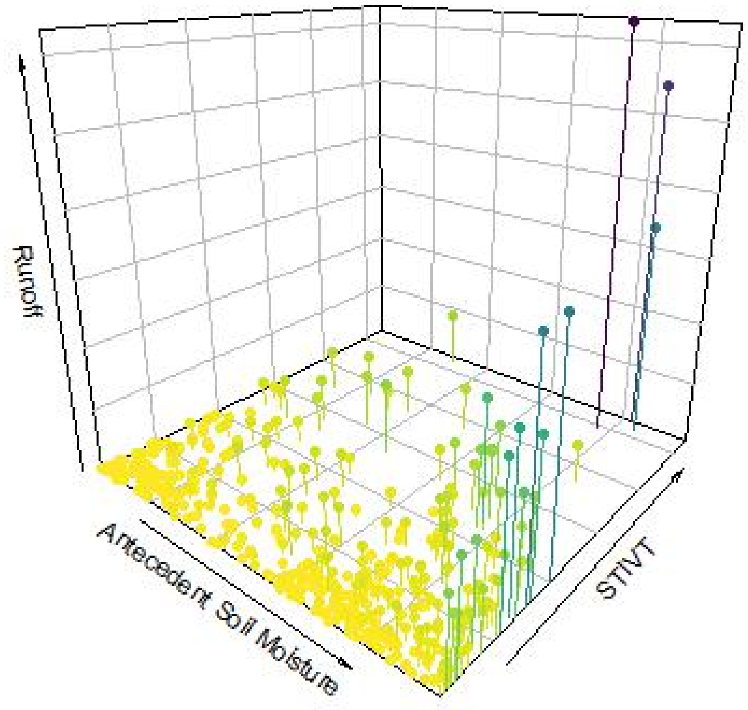

90th Percentile Runoff
Responses to STIVT
0 20 40 60
Portland, OR
Mendocino Mtns, CA
Los Angeles, CA
Northern Rockies, ID
Reno-Carson, NV
Spring Mountains, NV
Runoff
250 200 150 100 50 0
Storm Total IVT
Storm Total IVT
Weak → 5 ARCAT
ARCAT Weak → 5
90th
Mean
50th


90th Percentile Hydrologic Response
Portland, OR
150
100
50
0
149
170
60
43
15
1
2
3
4
5
Mendocino Mtns, CA
400
300
200
100
0
142
97
40
12
4
1
2
3
4
5
Los Angeles, CA
300
200
100
0
60
33
7
3
1
2
3
4
Response (mm/event)
ARCAT
Northern Rockies, ID
150
100
50
0
88
47
7
1
1
2
3
4
Reno-Carson, NV
120
80
40
0
49
24
3
1
1
2
3
4
Spring Mountains, NV
60
40
20
0
34
13
4
1
1
2
3
4
ARCAT
Surface Runoff
Δ Baseflow
Evapotranspiration
Δ SWE
Δ Soil Moisture

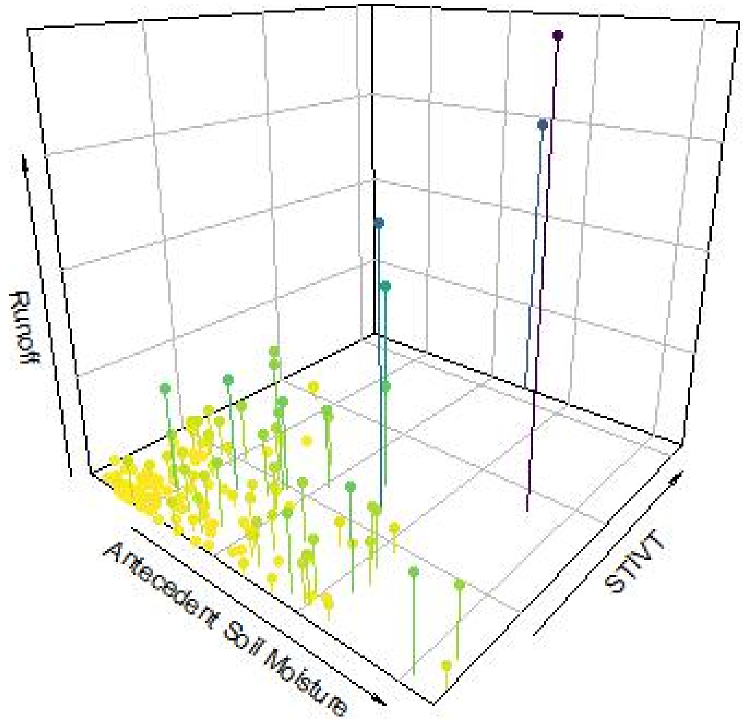
Runoff Response to Antecedent Conditions and IVT Varies among Sites



Portland, OR



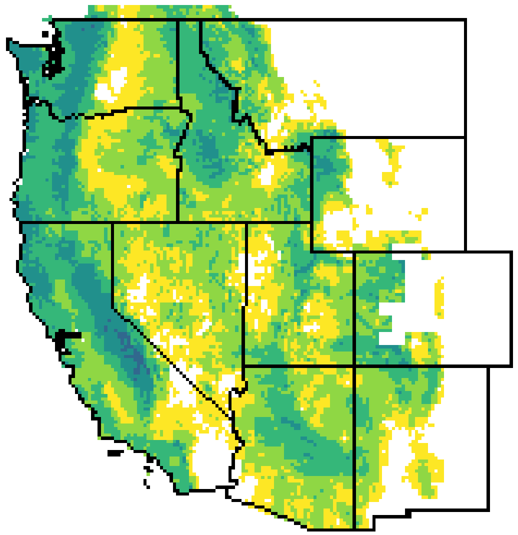
Mendocino Mtns, CA

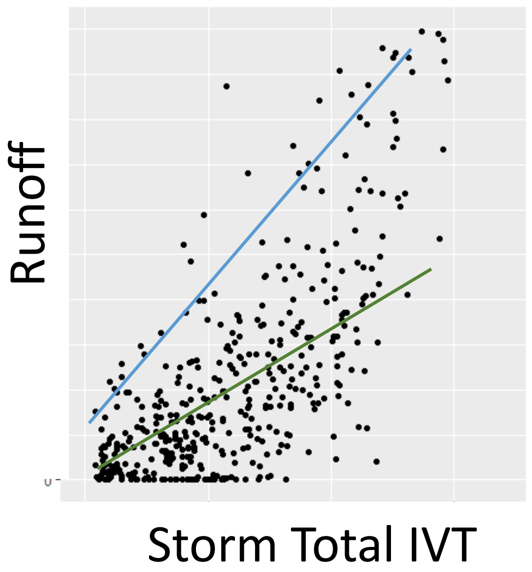


Reno, NV

Summary

- Similar AR conditions (STIVT) overhead result in different impacts over space
  - Larger response in coastal and mountainous terrain
  - Magnitude and nature of hydrologic response differs among sites
- Wide variation in impacts over time at a given location and STIVT
  - Upper limits have closer connection and are more sensitive to STIVT than central tendencies
  - STIVT has almost no association with precipitation in some places
  - Role of other drivers varies among locations





Implications

- Results provide a spatially explicit interpretation of the AR scale that can be used for communicating potential impacts
- Quantile regression may be a useful tool for linking maximum potential hydrologic impacts to AR characteristics
  - Response ‘ceiling’ varies linearly with STIVT in many locations