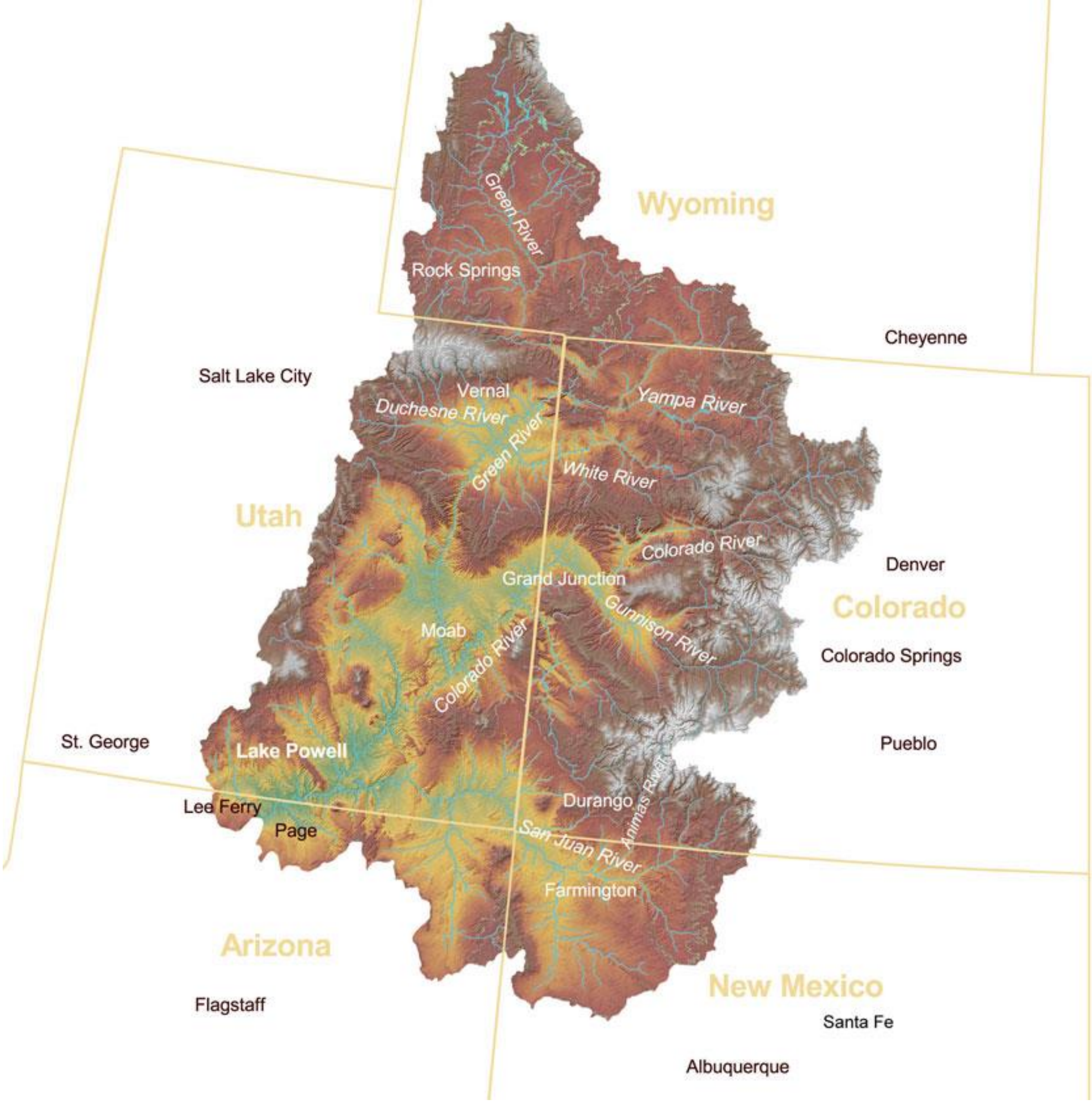
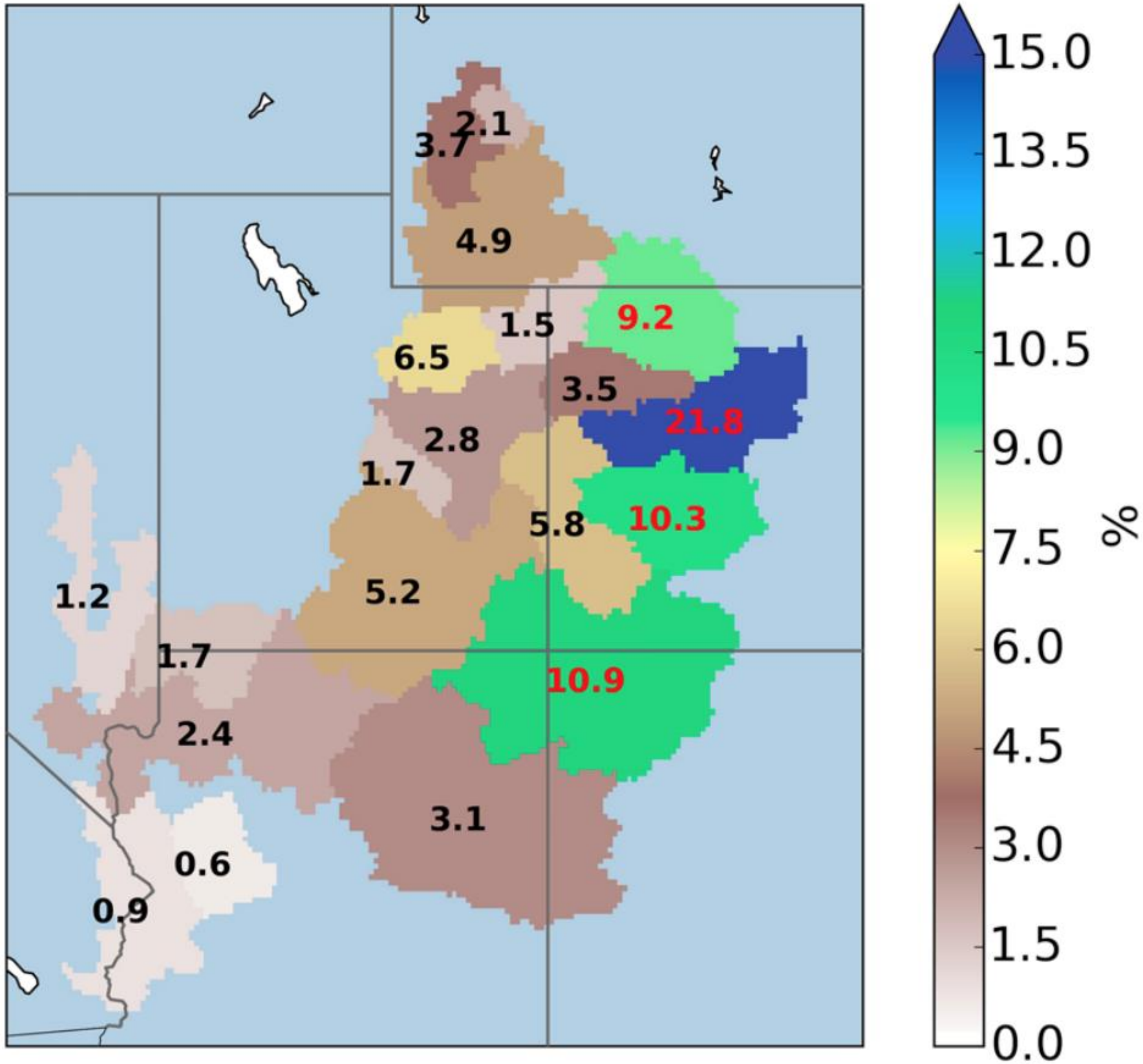
Mechanisms Responsible for Building Snowpack in the Upper Colorado River Basin

Benjamin Hatchett, John Abatzoglou, Nina Oakley, Jon Rutz, and Chris Johnston

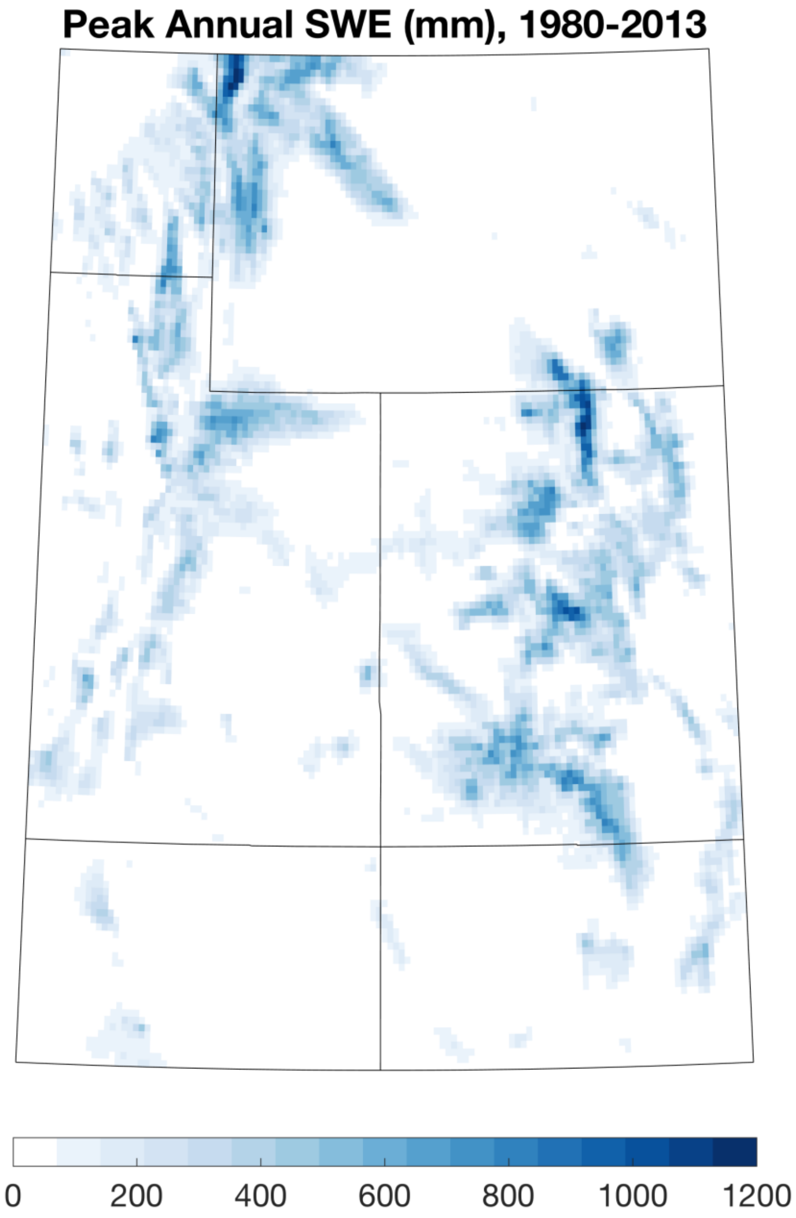
The Upper Colorado River Basin (UCRB) at a glance: Four CO Rockies sub-basins provide ~50% of the annual runoff

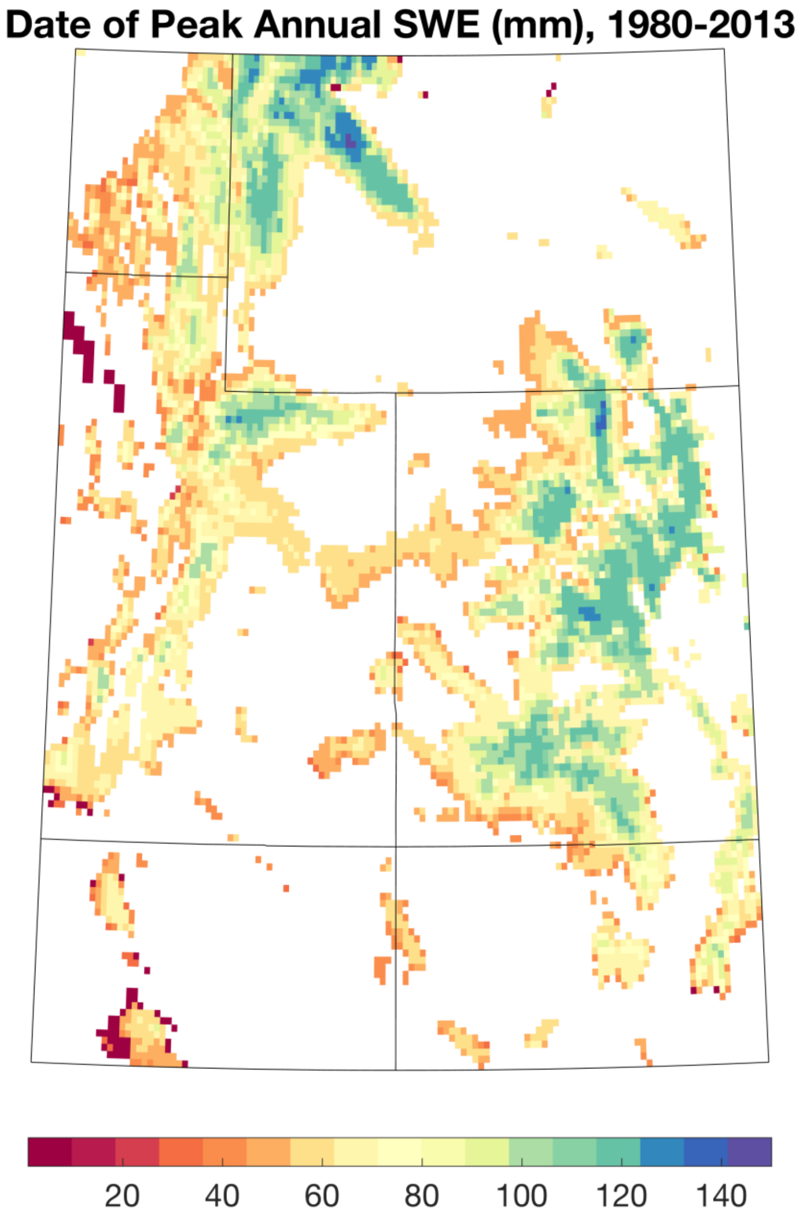




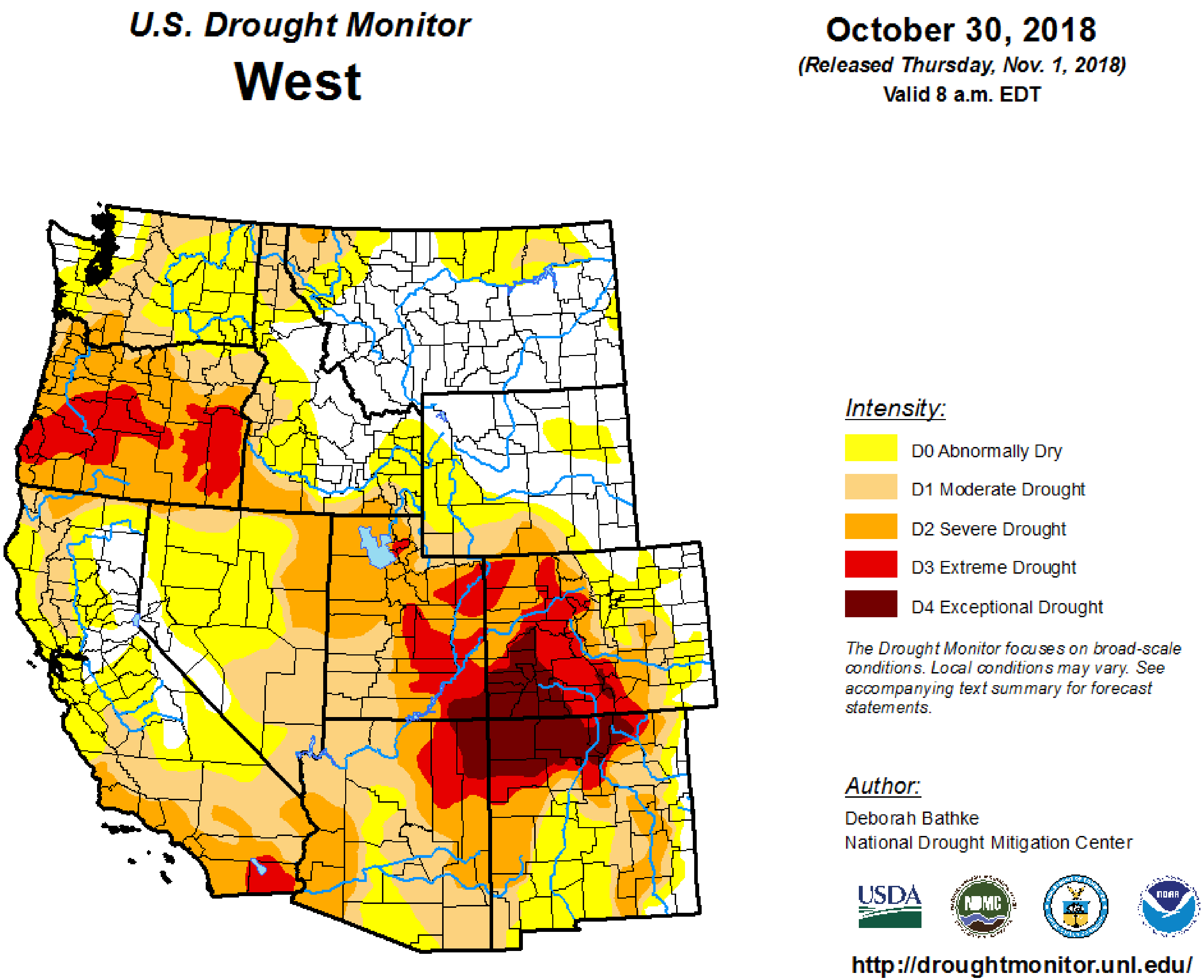
Xiao et al. (2018 WRR)

The Upper Colorado River Basin (UCRB) at a glance: Snow-dominated nature (VIC-estimated snow water equivalent)





The Upper Colorado River Basin (UCRB) at a glance: Current situation



Key Role of Temperature In Declining Colorado Streamflows

Water Resources Research
AN AGU JOURNAL

Research Article

The twenty-first century Colorado River hot drought and implications for the future

Bradley Udall, Jonathan Overpeck

First published: 17 February 2017

Geophysical Research Letters / Volume 43, Issue 5

Research Letter | Free Access

Increasing influence of air temperature on upper Colorado River streamflow

Connie A. Woodhouse, Gregory T. Pederson, Kiyomi Morino, Stephanie A. McAfee, Gregory J. McCabe

Water Resources Research
AN AGU JOURNAL

Research Article

Investigating Runoff Efficiency in Upper Colorado River Streamflow Over Past Centuries

Connie A. Woodhouse, Gregory T. Pederson

Water Resources Research
AN AGU JOURNAL

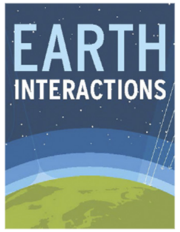
Research Article

On the Causes of Declining Colorado River Streamflows

Mu Xiao, Bradley Udall, Dennis P. Lettenmaier

First published: 30 August 2018

Earth Interactions • Volume 21 (2017) • Paper No. 10 • Page 1



Evidence that Recent Warming is Reducing Upper Colorado River Flows

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Received 18 April 2017; in final form 4 October 2017

Temperature reduces runoff efficiency, but first need something to runoff…

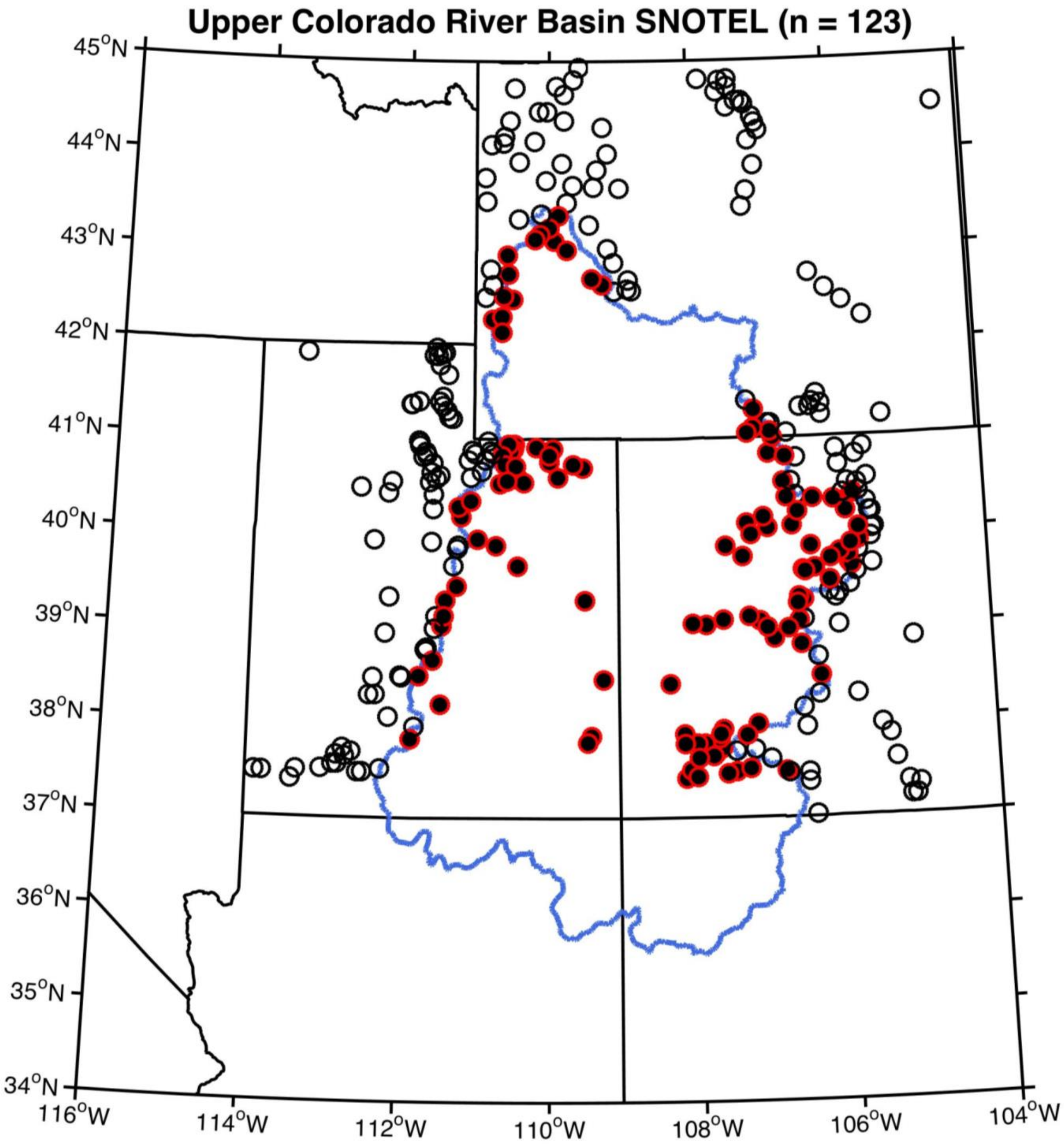
Goals of on-going study supported by DWR:

1. Summarize existing literature on UCRB precipitation, add to it, and identify additional needs with regards to S2S predictability

2. Evaluate importance of extreme/other snowfall events in interannual variability

3. Assess proximal mechanisms leading to extreme/other snowpack accumulation

Station-based Approach with SNOTEL



Blue Line = Upper Colorado River Basin

White Dots = SNOTEL outside UCRB

Black/Red Dots = SNOTEL inside (or on) UCRB

n = 123 Stations

Subset only stations with > 20 years of data

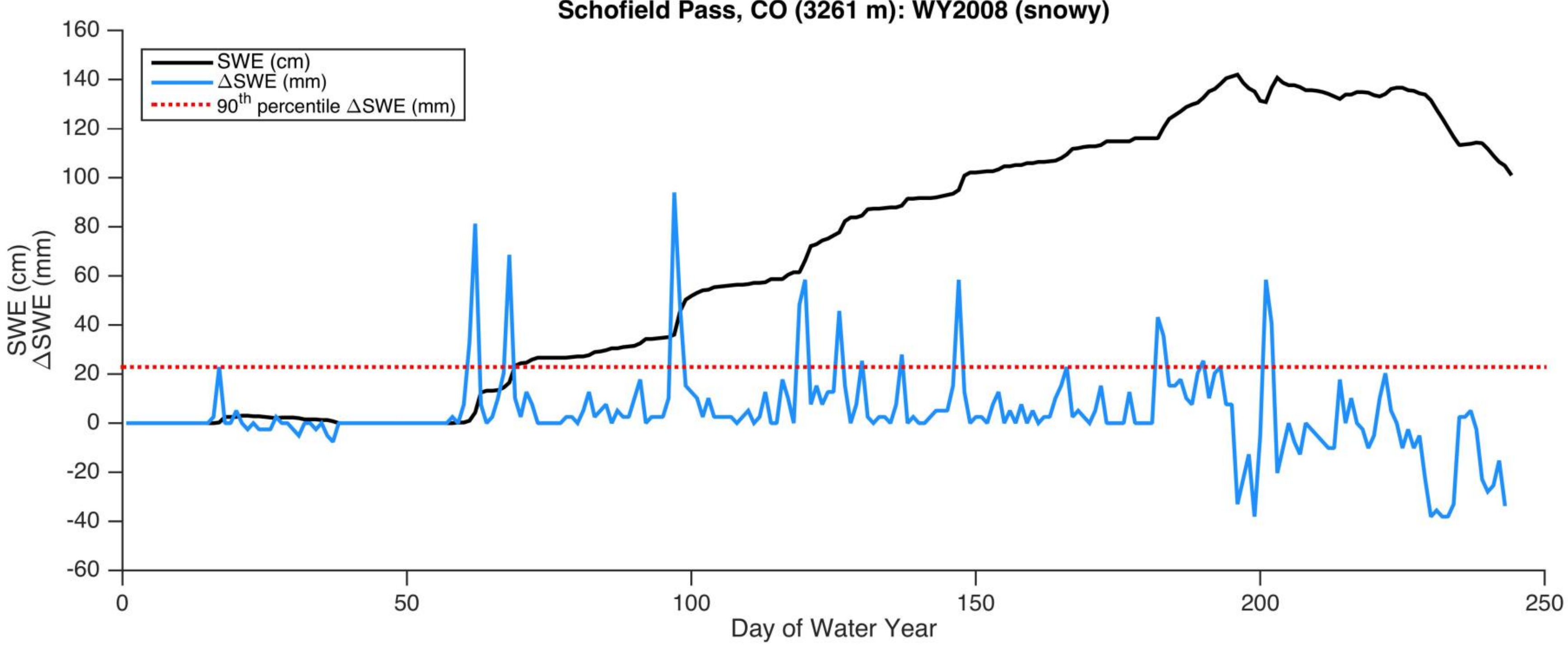
Period WY1981-2014 (will be updating through WY2018)

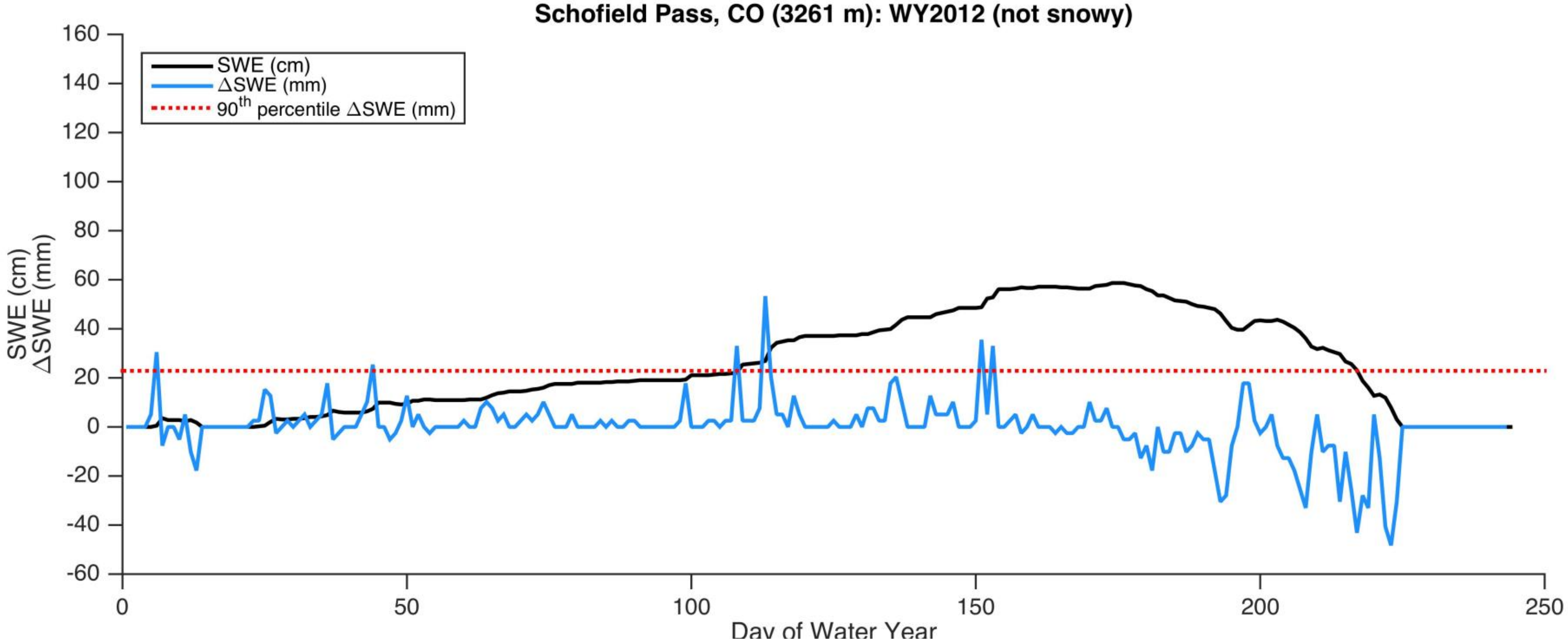
Question One:
Do extreme snow accumulation events matter?

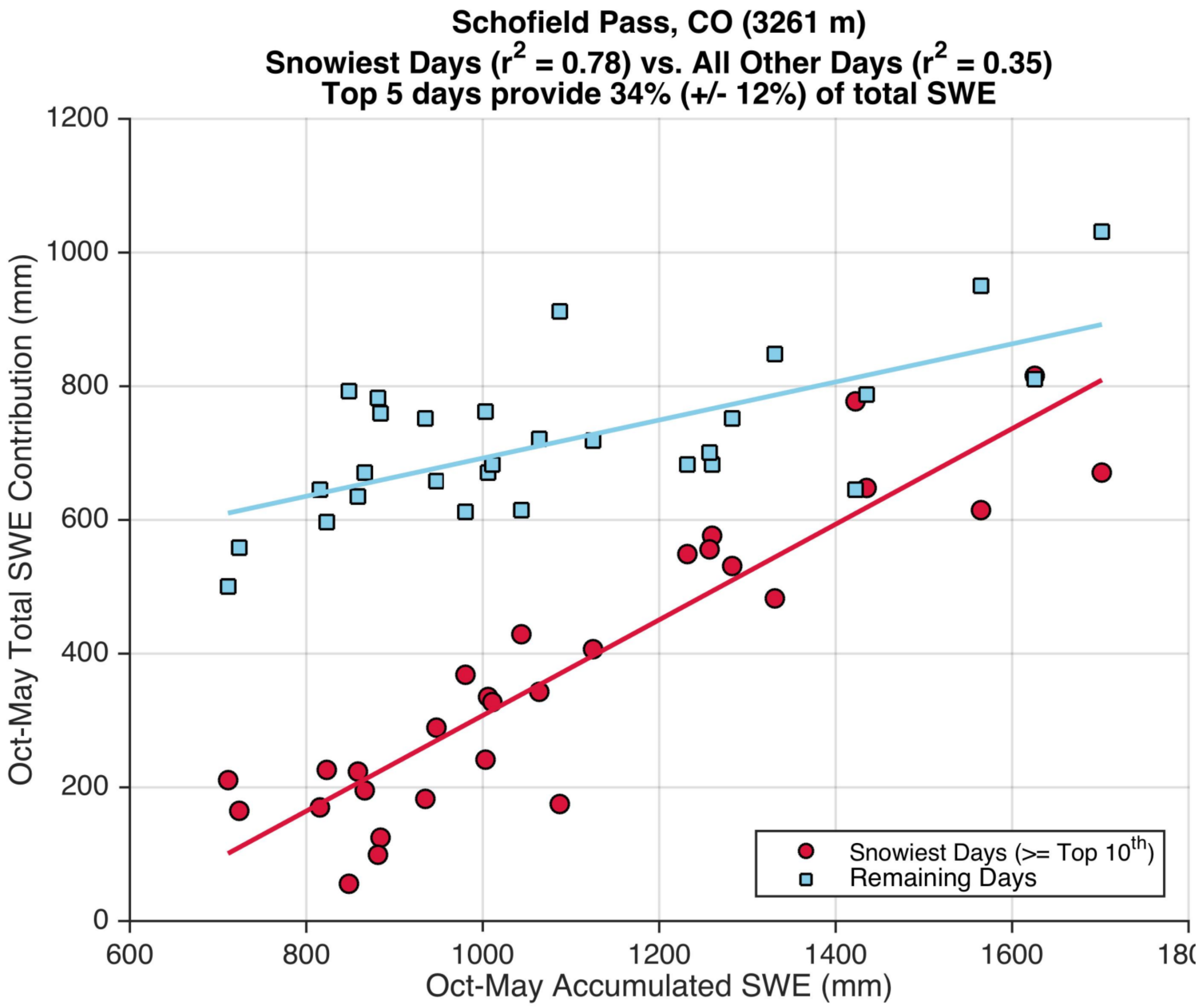
- In CA, previous work by Dettinger (2016 SFEWS) shows that extreme events contribute appreciably to the mean, but even more so to the variance
  - Lute and Abatzoglou (2014 WRR) showed this for all SNOTEL, repeating their results to check
- We'll take slightly less extreme definition (top 10^{th} instead of top 5^{th})
- Look at only daily +SWE events from Oct 1 – May 31
  - Also will look at multiday gains
- Following Dettinger, we calculate r via Spearman Rank Correlation for both top 10 and bottom 90.

Field Trip to Schofield Pass, CO

Example for Schofield Pass: A snowy year **(top)** versus a not-so-snowy year **(bottom)**







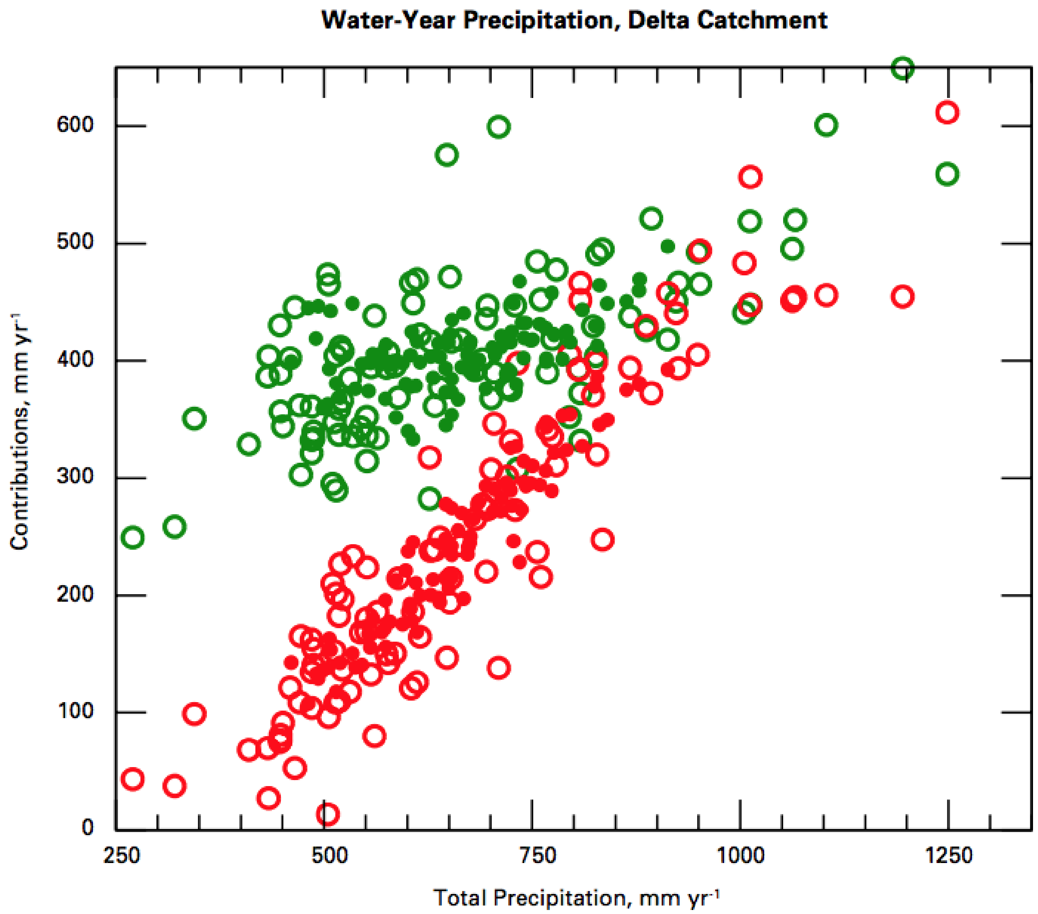


Figure 5 Comparisons of contributions to total Central Valley catchment precipitation from wettest 5% of wet days (red) and remaining wet days (green) with total precipitation, 1916–2010. Solid dots are 5-year moving averages from Figure 2 and open circles are unfiltered water-year values.

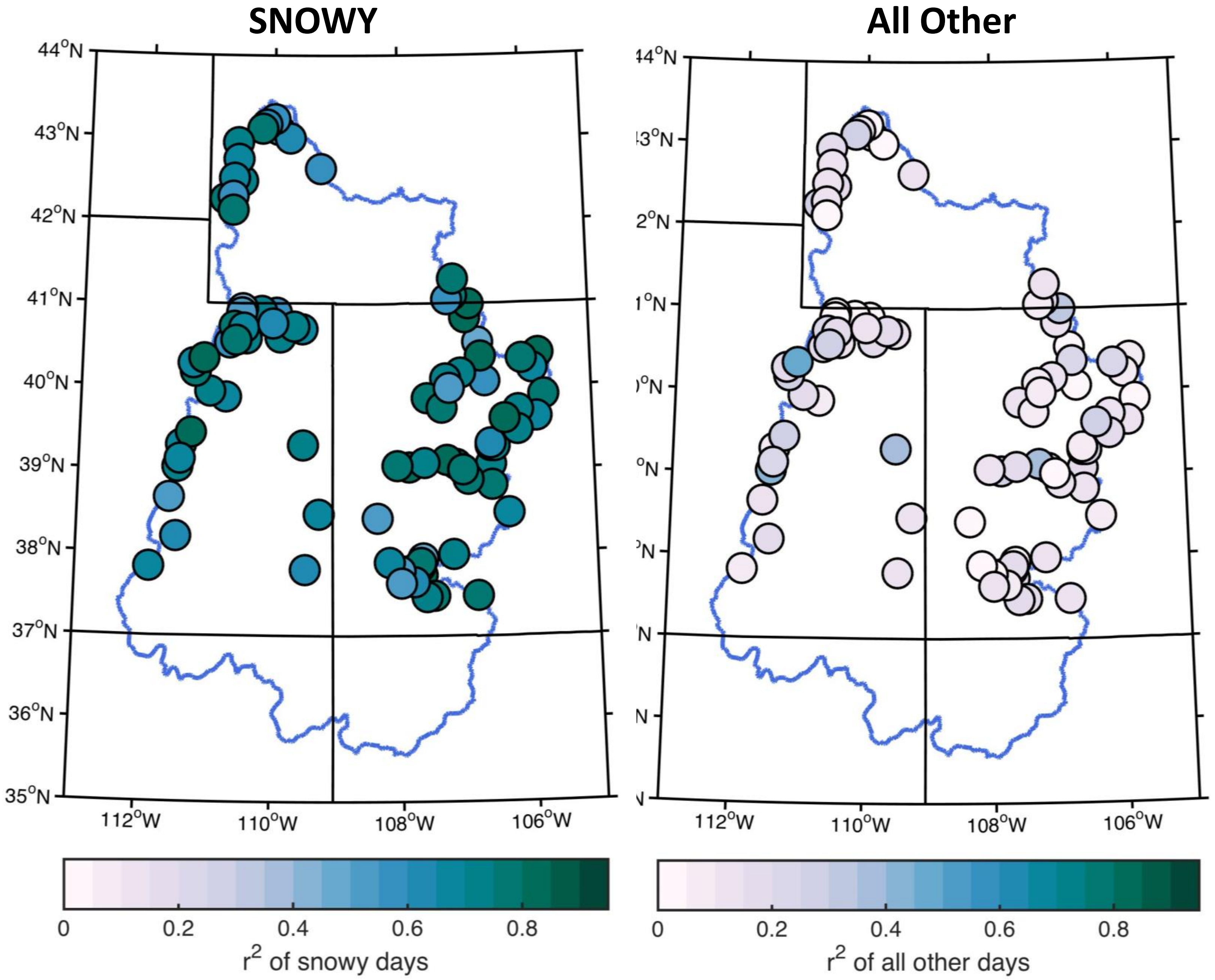
Dettinger (2016) *SFEWS*

1981-2014, note should be Top 10 days in title

UCR Basin-wide results paint a similar picture

Key Point*: *The snowiest days drive interannual variability of total snow accumulation*

*Agrees with results from Lute and Abatzoglou (2014 WRR)

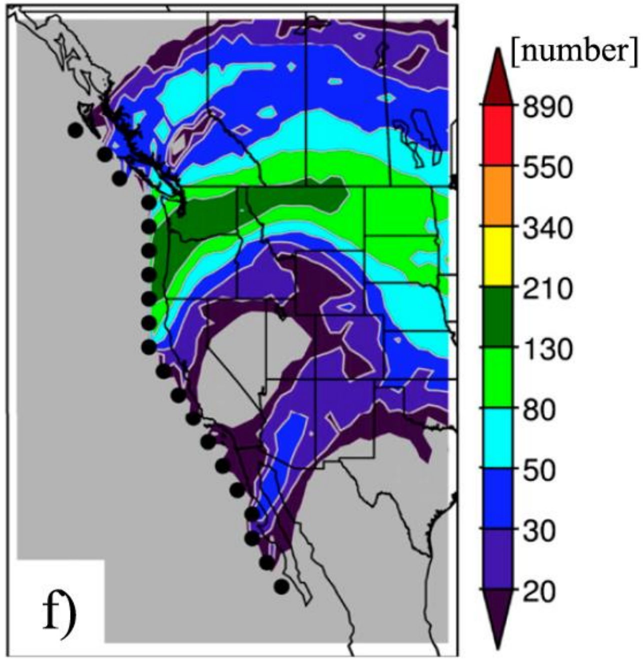


Key Point: *Contributions of extreme snowfall days to mean are typically between 30-40%*

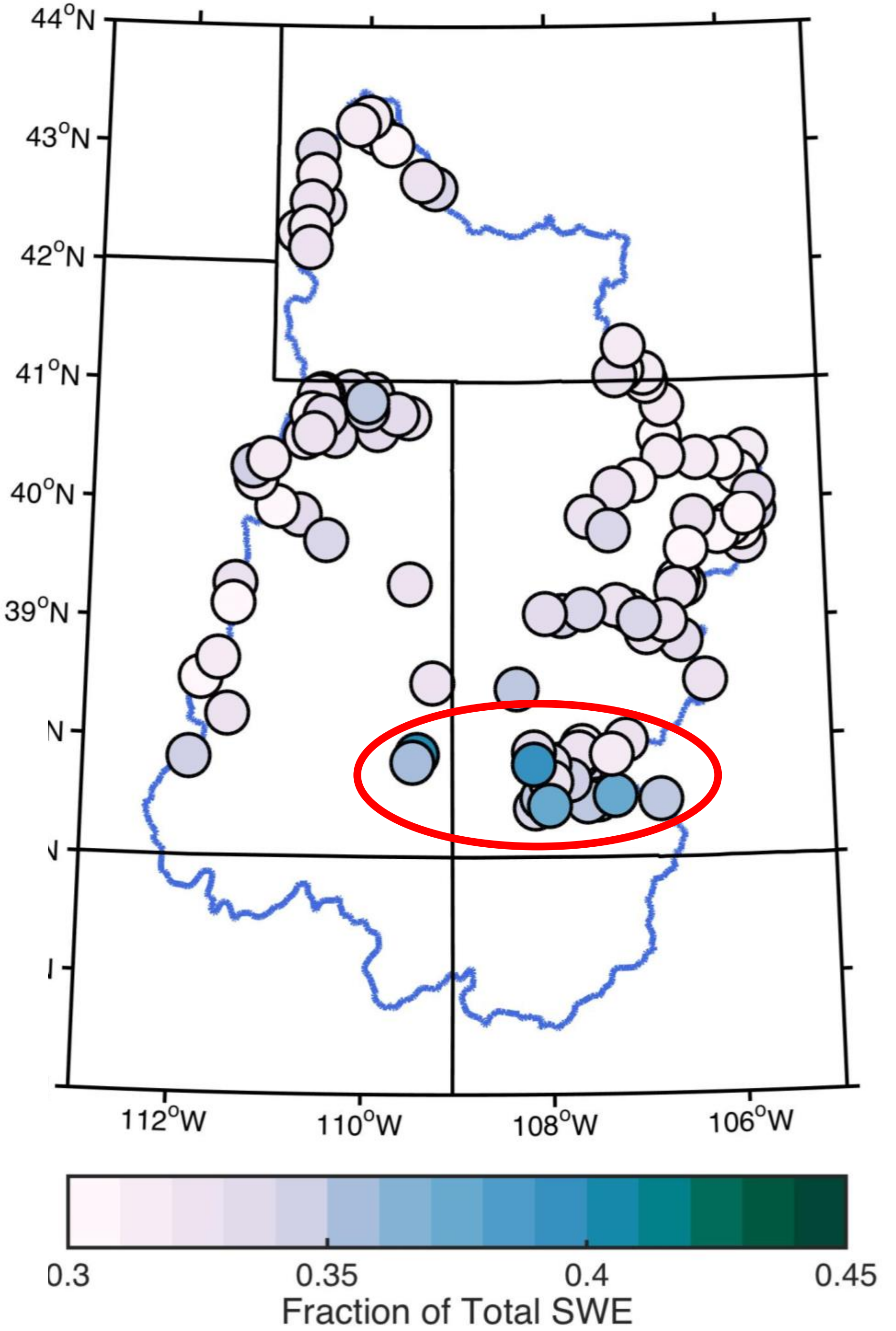
Remark 1: (Sum SWE_{top10})/(Sum +SWE)

Remark 2: Note the higher values in the San Juans/Southern Utah (red oval)

Could this be related to the southern interior AR penetration pathway shown in Rutz et al. 2015 MWR and Hatchett et al. 2017 J Hydromet?

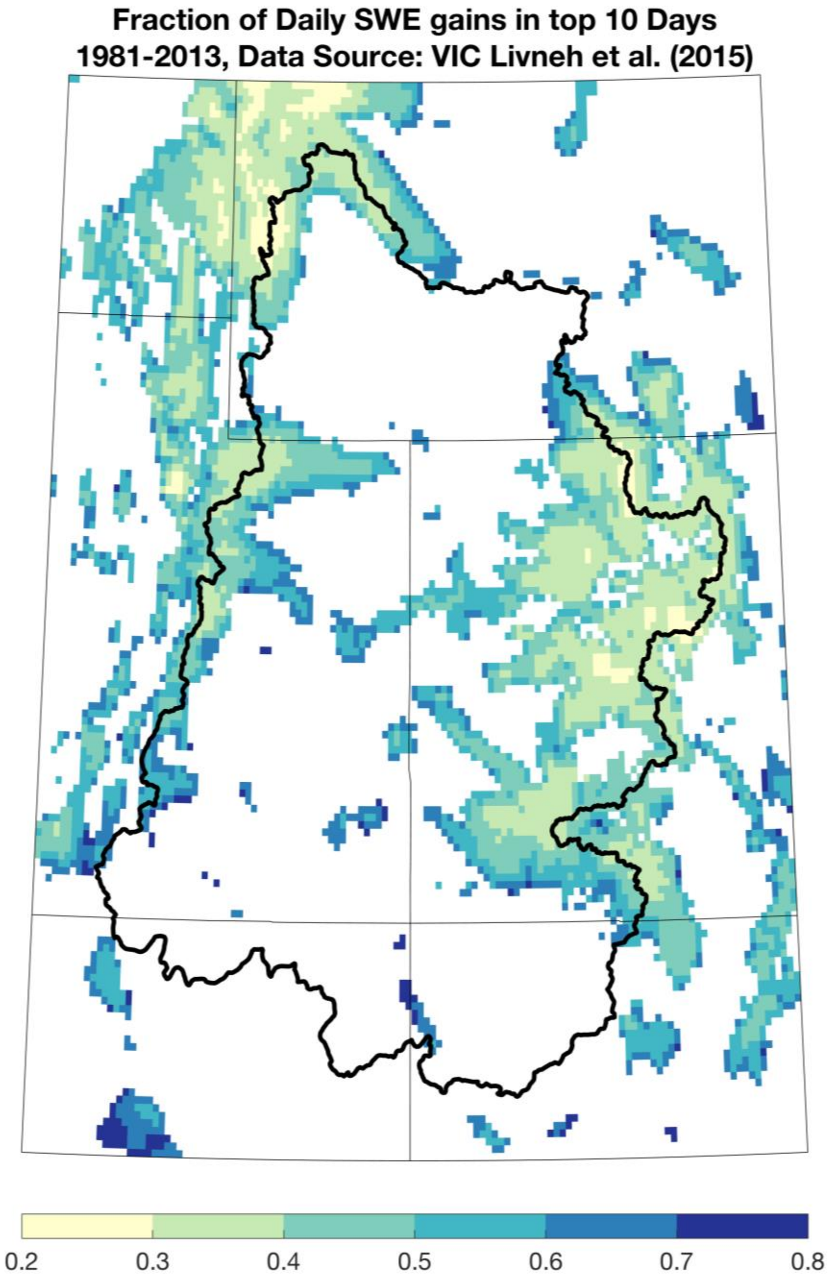


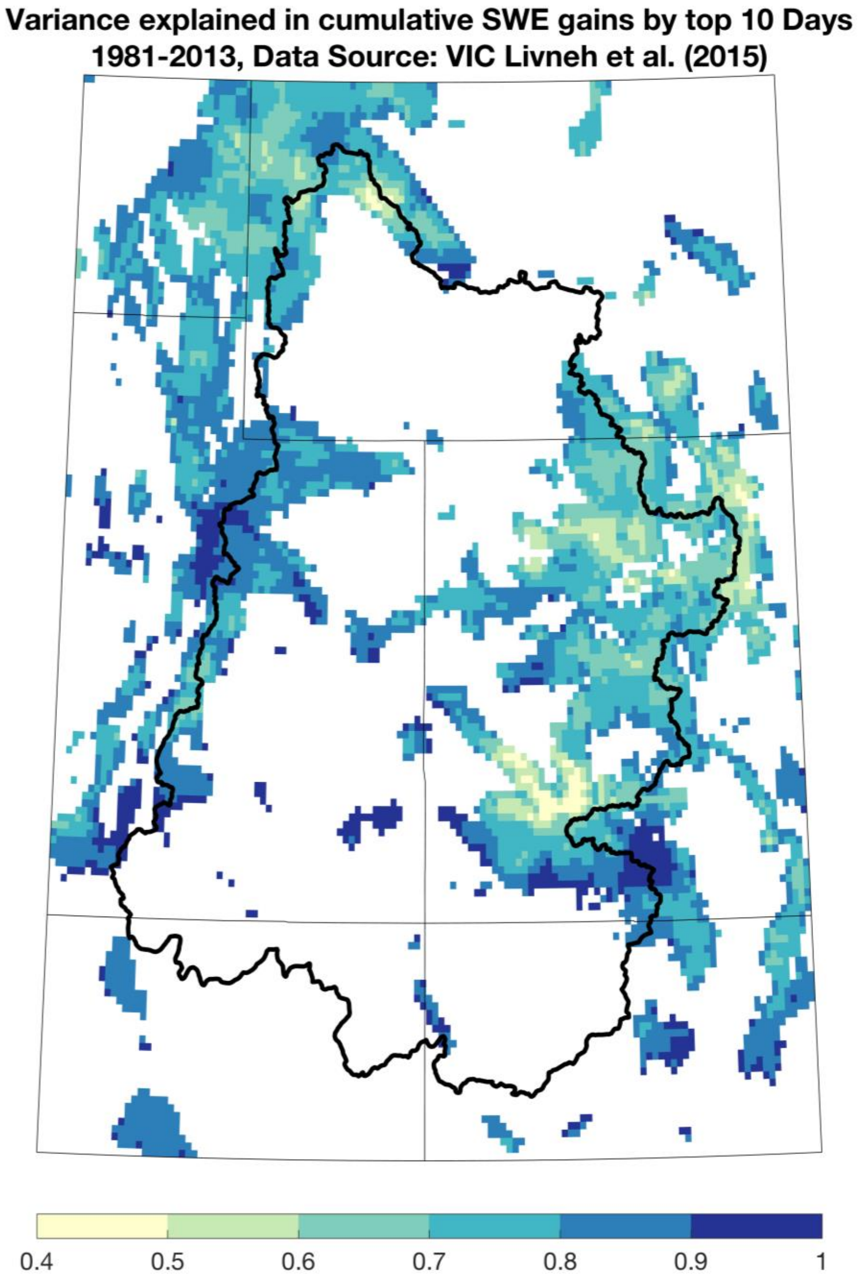
interior-penetrating



Gridded Products (VIC/Livneh) are in agreement

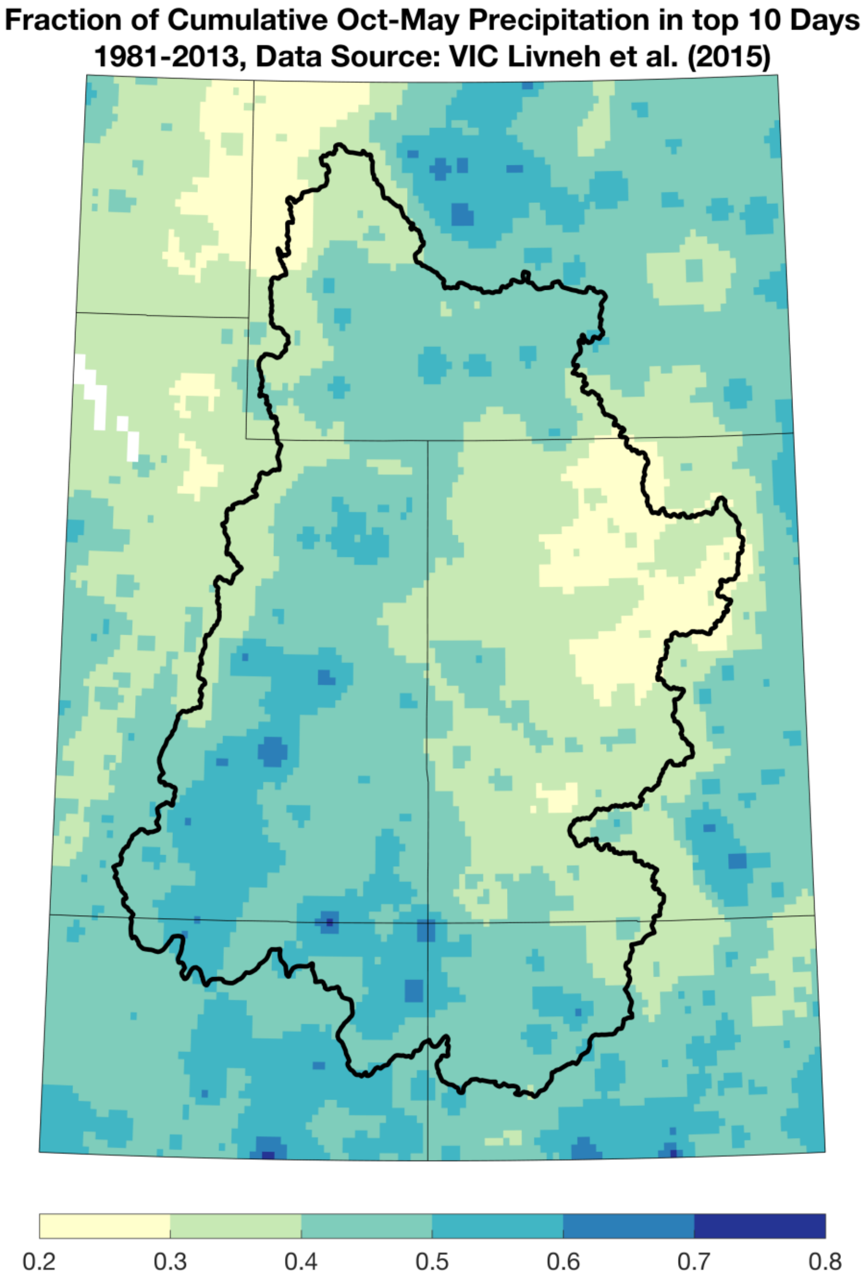
SNOTEL and Livneh are independent, but give similar results

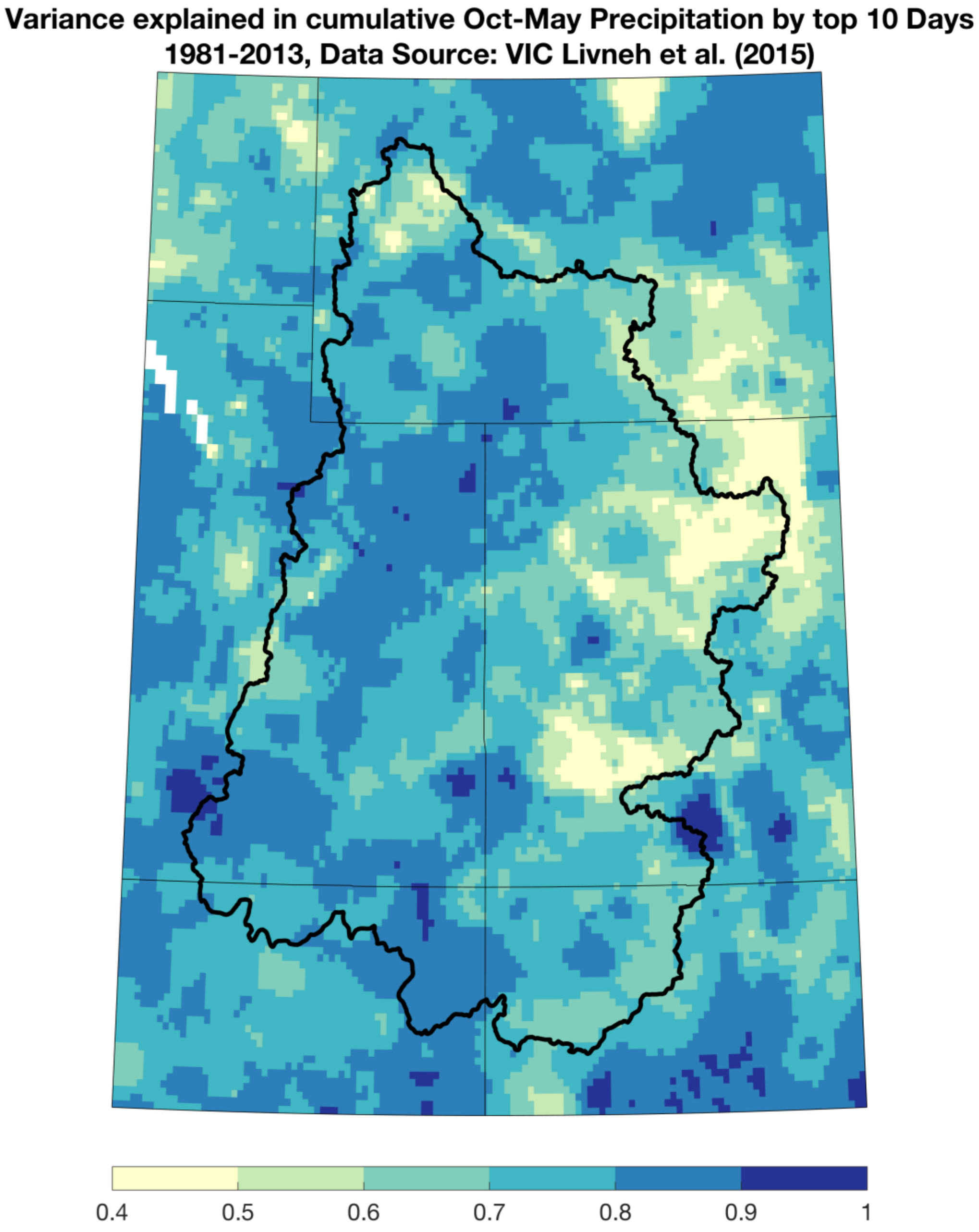




Precipitation tells slightly different story for CO Rockies…

due to station location bias?

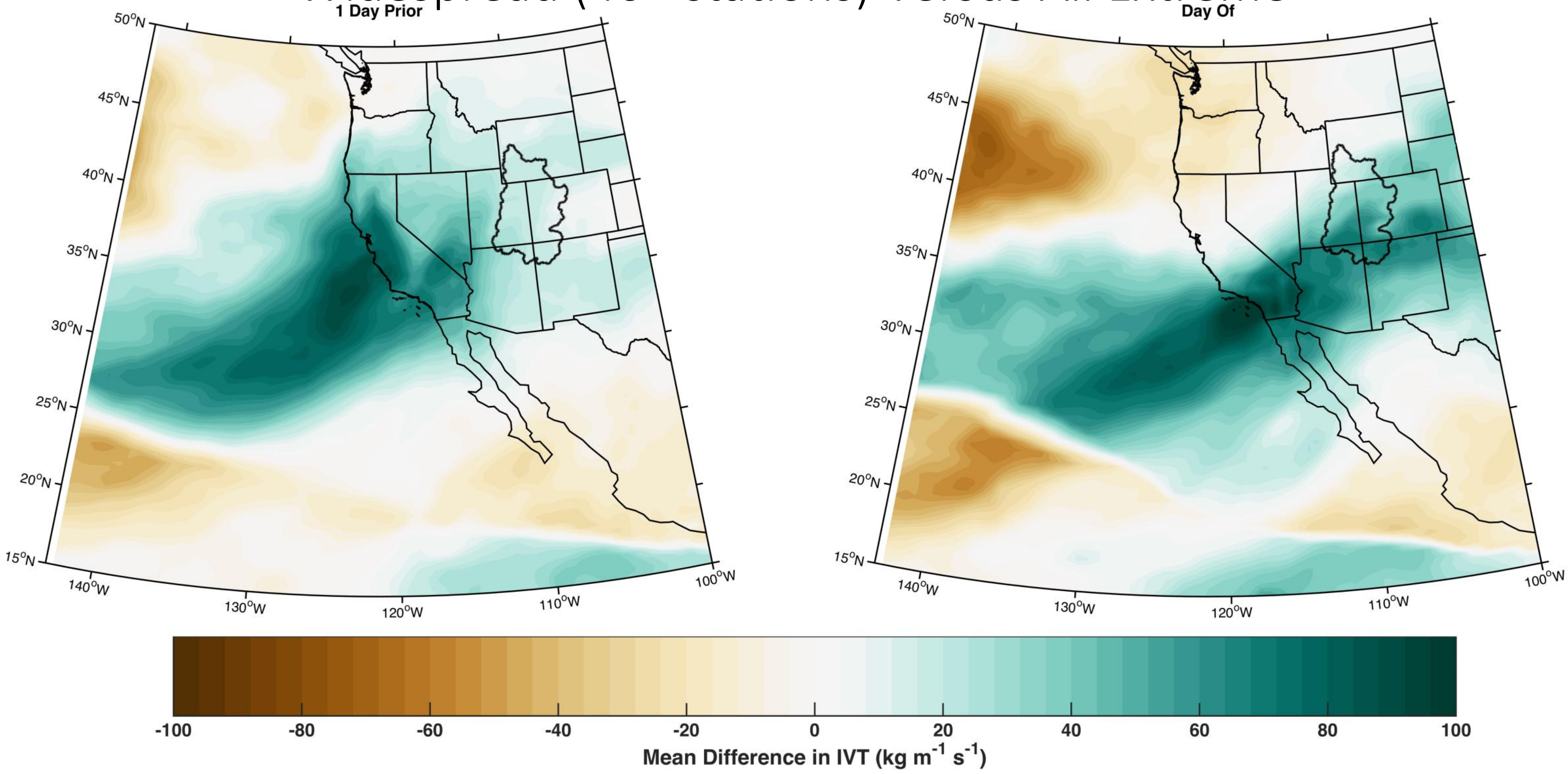




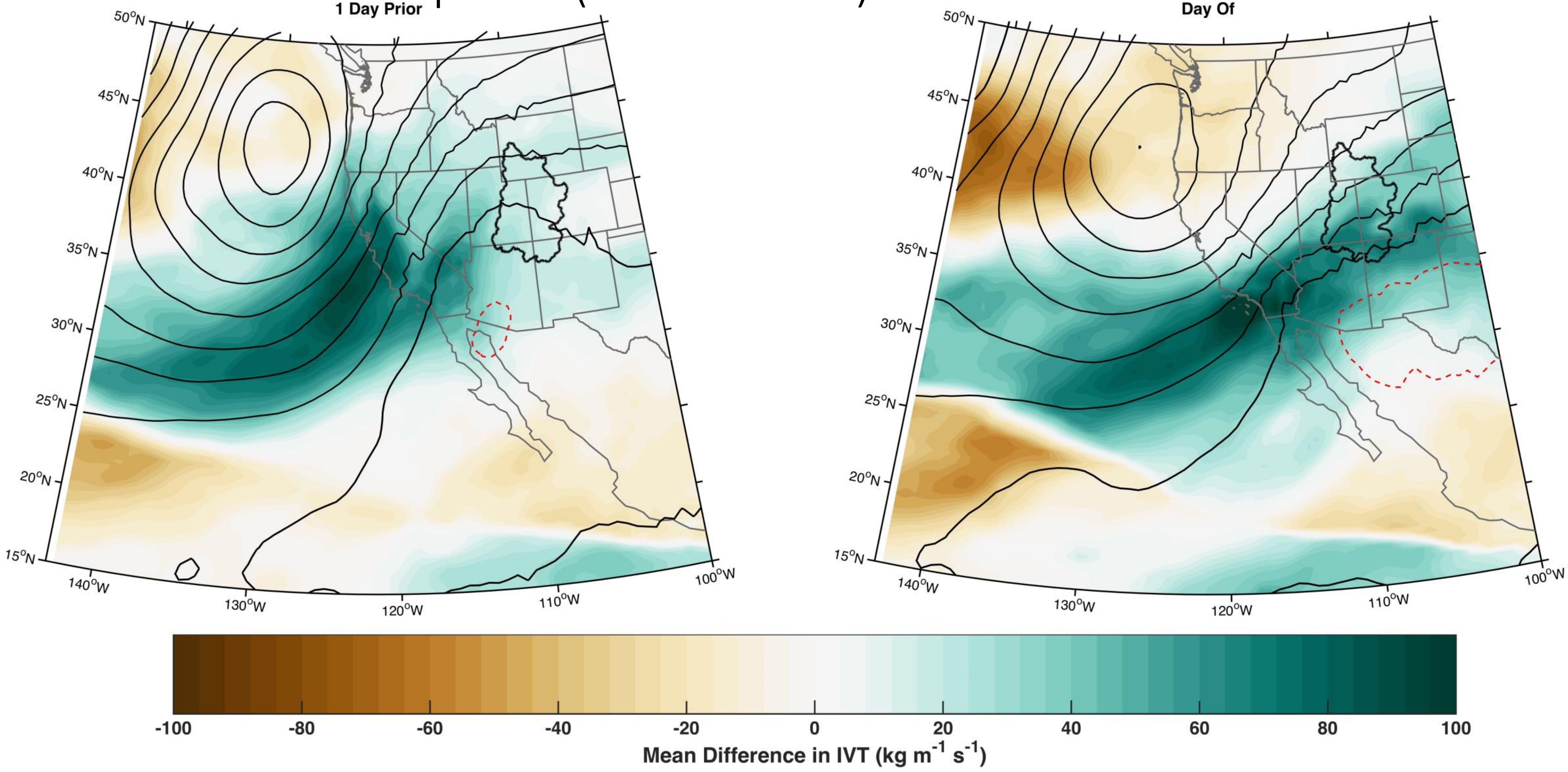
Towards the Mechanisms…

WY1981-2014 via
MERRA-2 reanalysis

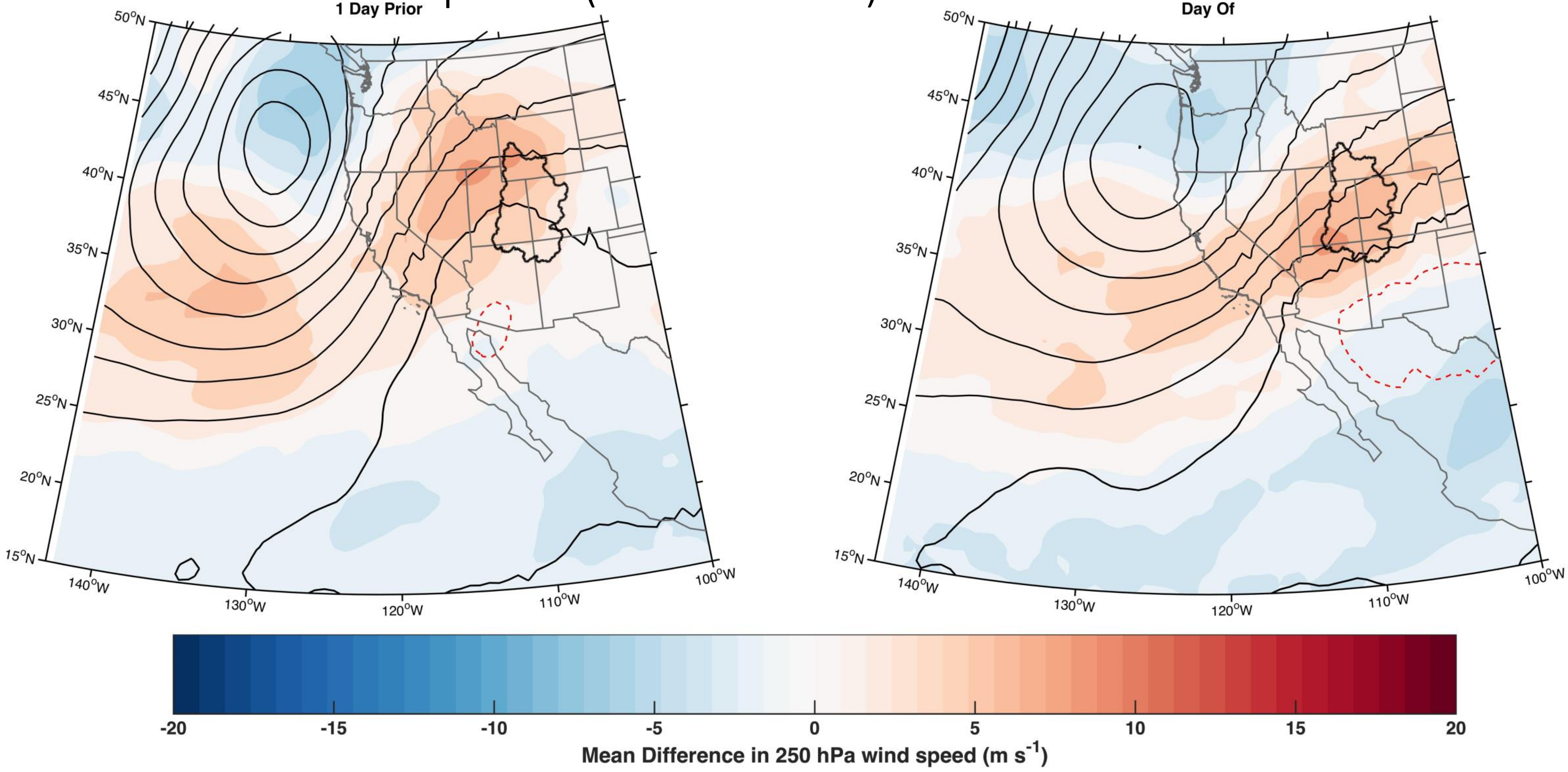
Vapor Transport Differences of Extreme Snow Accumulation Events (n = 349): Widespread (40+ stations) Versus All Extreme



Vapor Transport and 500 hPa Geopotential Height Differences of Extreme Snow Accumulation Events: Widespread (40+ stations) Versus All Extreme



250 hPa Winds and 500 hPa Geopotential Height Differences of Extreme Snow Accumulation Events: Widespread (40+ stations) Versus All Extreme



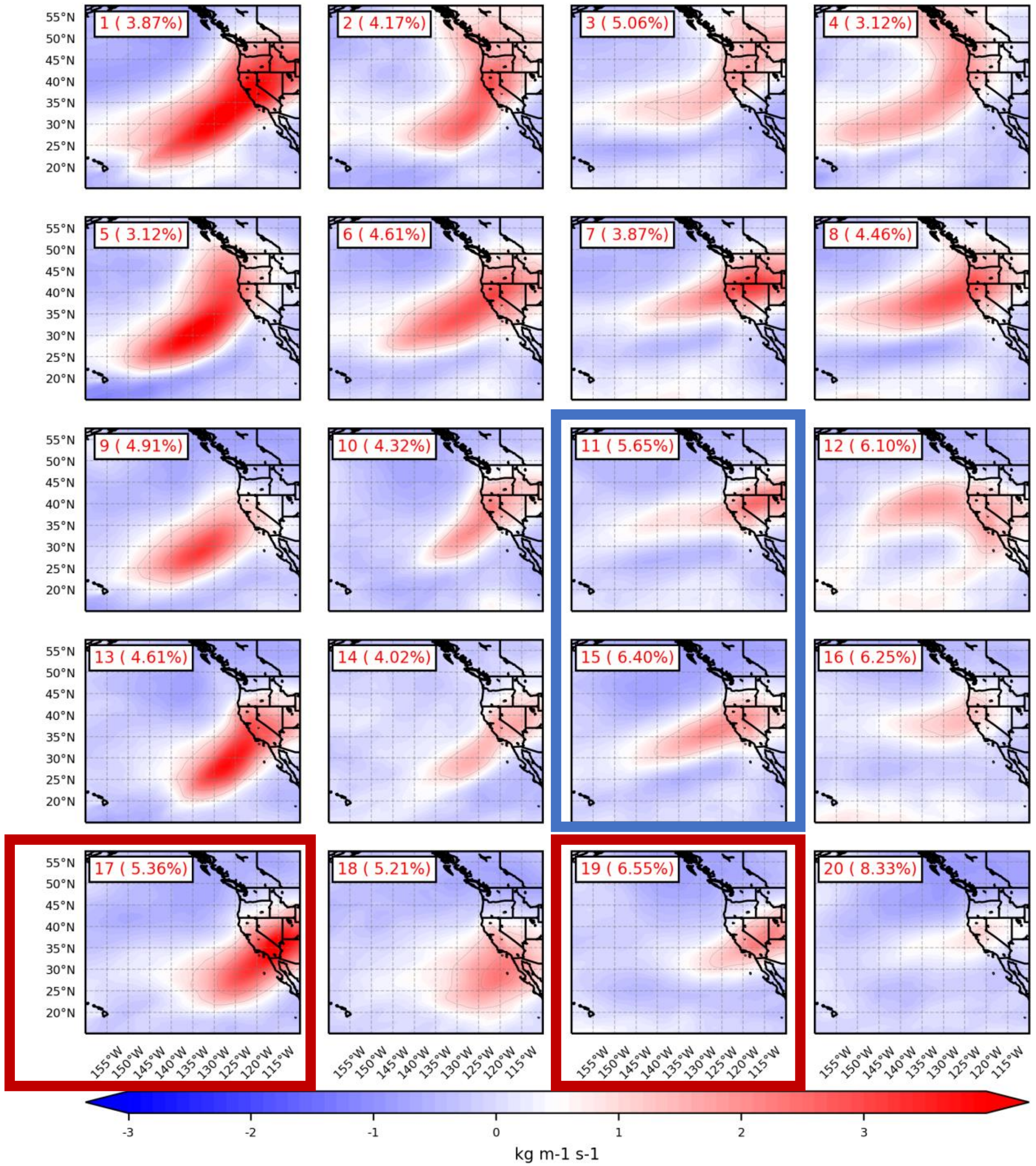
Consistent with results from self-organizing map analysis of IVT anomalies

Map Types 17, 19 (red boxes) produces inland precipitation anomalies in southern Utah/western CO

"Southern Corridor"

Map Types 11, 15 (blue boxes) produces inland precipitation anomalies in northern WY/UT/northwestern CO

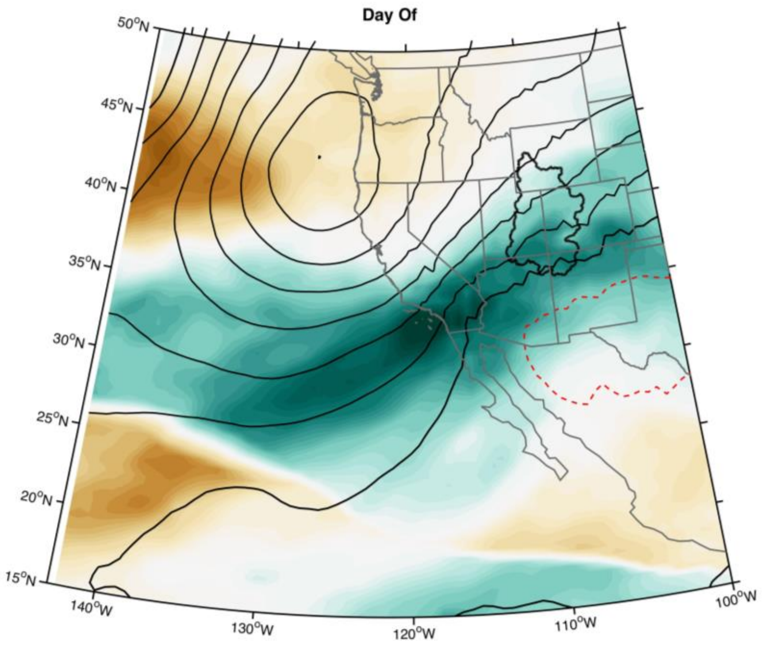
"Northern Sierra Pathway"

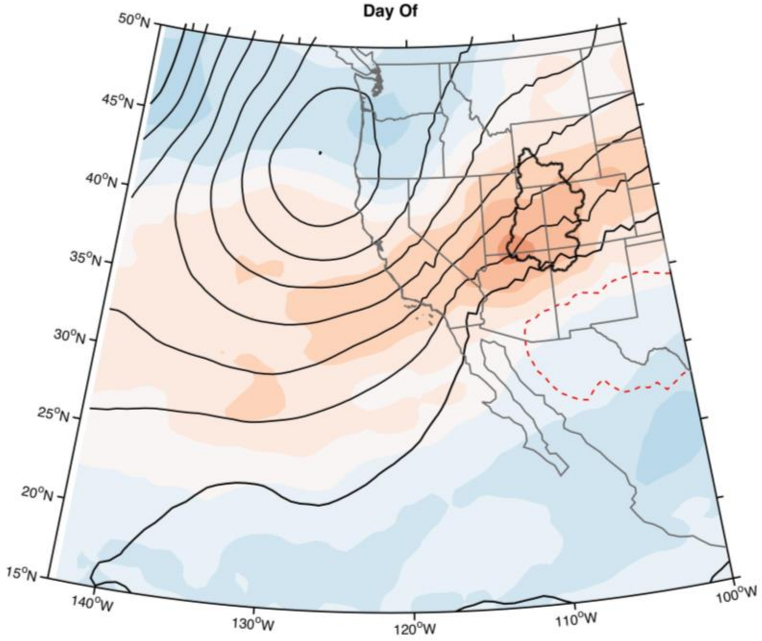


*Note: we will be extending the SOMs domain inland to 90W

Key Points on widespread accumulation events

1. Southern inland penetrating moisture transport corridor (aka ‘Mojave Sneak’) active, northern Sierra pathway active in less widespread extreme events
2. Deeper trough offshore of Oregon
3. Enhanced SW’erly upper level jet (stronger upper level divergence + forcing + transport)
4. Closed/cutoff lows occurred about 10% of cases





Next steps:

Evaluate non-extreme events (explain much less variance, but ~65% of mean)

Assess via AR catalogs/scale, vertical characteristics

Explore with Zhenhai which mechanisms lead to poor NMME results?

Similar results just published

International Journal of Climatology / Volume 0, Issue 0

RESEARCH ARTICLE

Moisture transport associated with large precipitation events in the Upper Colorado River Basin

Johnathan P. Kirk, Thomas W. Schmidlin

First published: 05 September 2018
https://doi.org/10.1002/joc.5734

headwaters. Trajectory analyses are also calculated to further characterize LPE-inducing atmospheric river pathways by subbasin in the UCRB. Results indicate that LPEs throughout the basin most commonly coincide with amplified trough patterns, which advect Pacific moisture into the UCRB from the southwest, through Southern California and the Four Corners region; patterns that are positively correlated to streamflow. LPEs occurring in

Discussion Topics:
A larger proposal…

Southerly moisture pathway:
Repeat the Mundhenk et al. (2018) analysis of change in AR frequency, but focused on CA bight/northern Baja?

Flow orientation/transport: Assess role of upstream/offshore Rossby wave breaking and subsequent downstream dynamical impacts?

At longer (i.e., subseasonal) leads, address which precipitation mechanisms models are missing that result in lower skill (a big event or several smaller events?)

Other ideas/thoughts welcome!