Investigating Mechanisms of Cool Season Upper Colorado River Basin Precipitation

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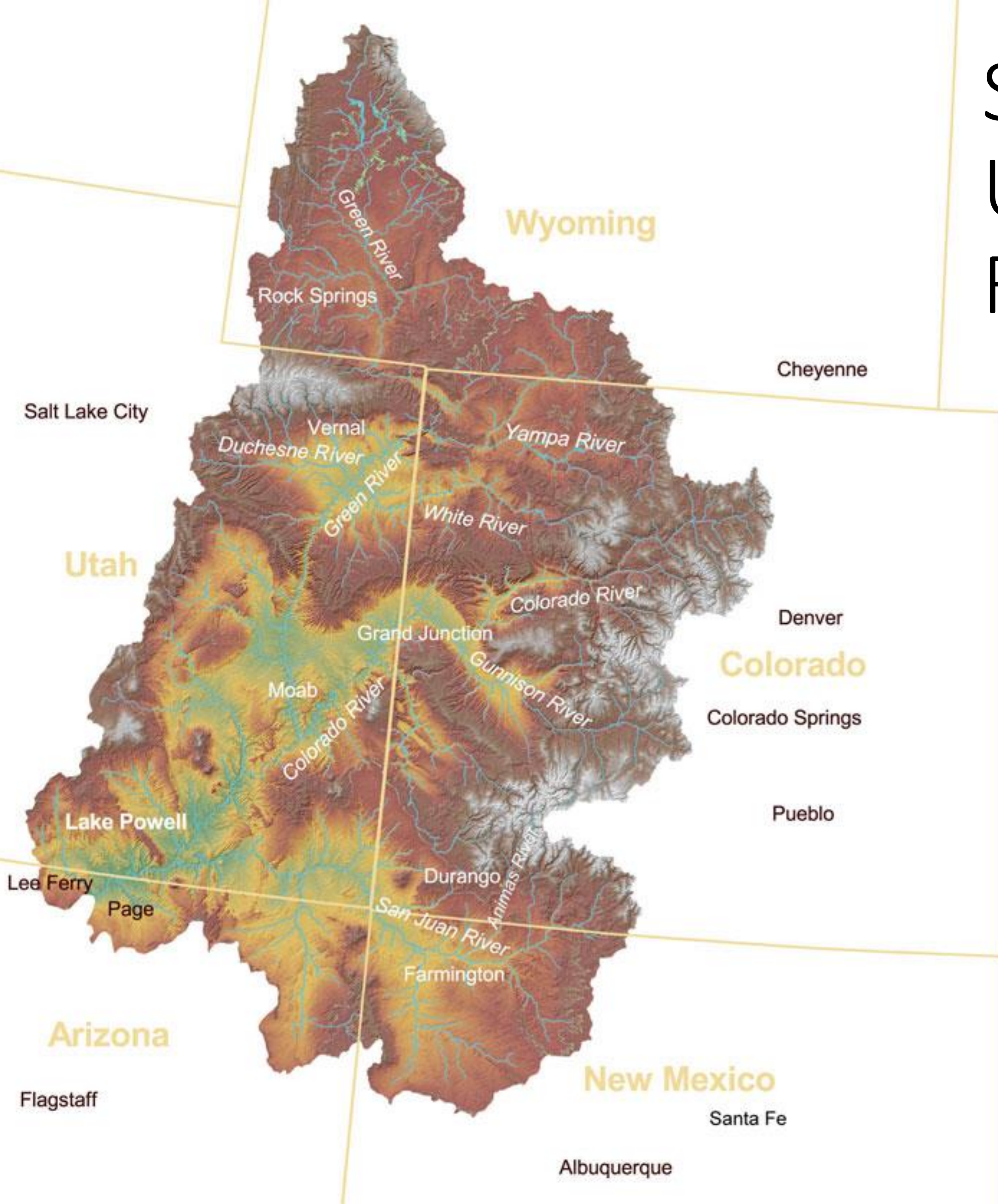
Photo: Sean Birkel



Study Area: Upper Colorado River Basin

Provides >90% of Colorado River streamflow (Christensen et al. 2004)

Snow-dominated alpine regions key for streamflow

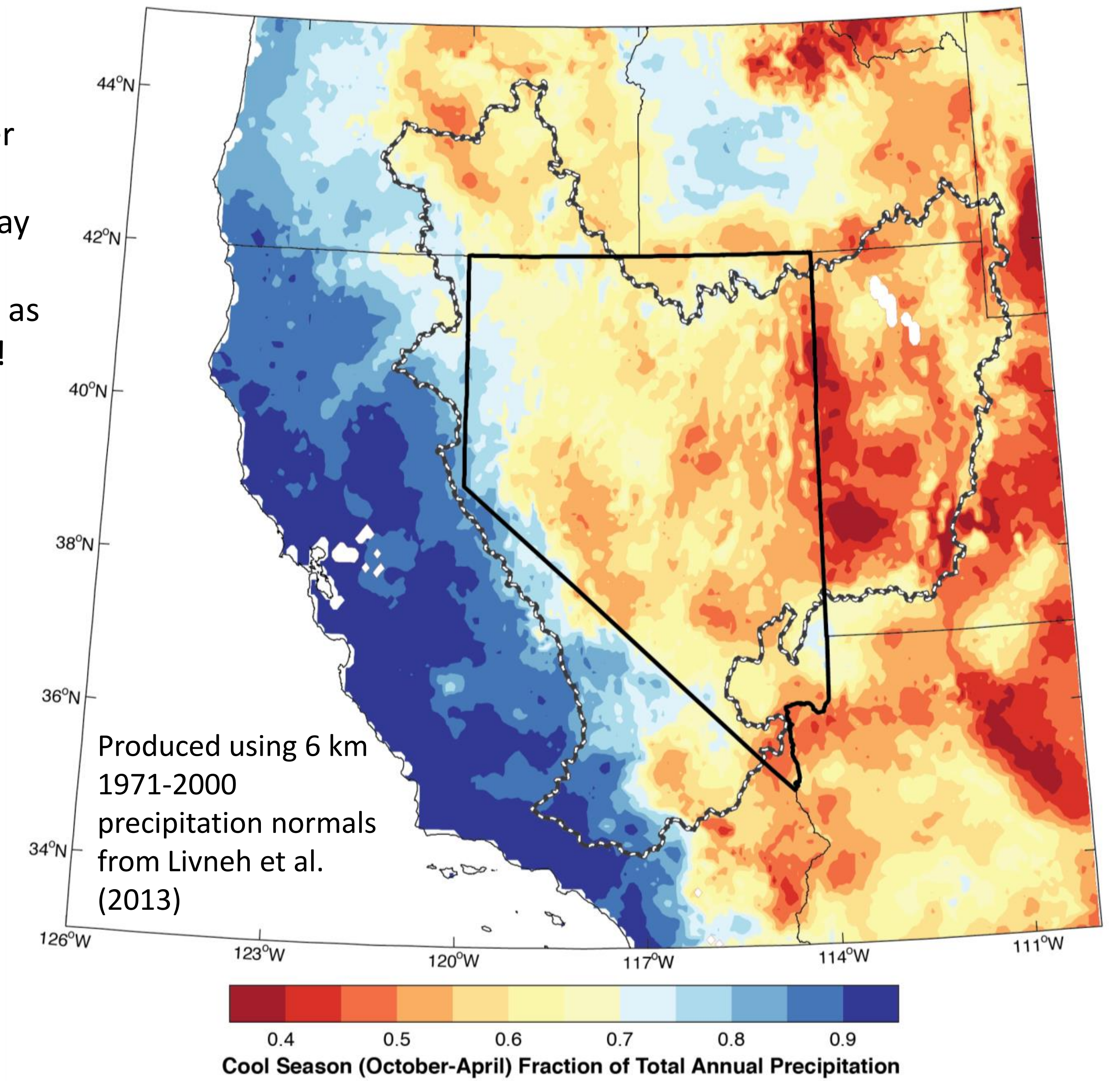
Photo: Aaron Putnam

Primary Research Questions

1. How is Upper Colorado River Basin precipitation distributed throughout the cool season, particularly in high alpine areas?
2. What dynamical mechanisms control precipitation and snowpack accumulation patterns?
3. Once 1 and 2 are addressed, we can then ask if these mechanisms be skillfully forecast at S2S timescales

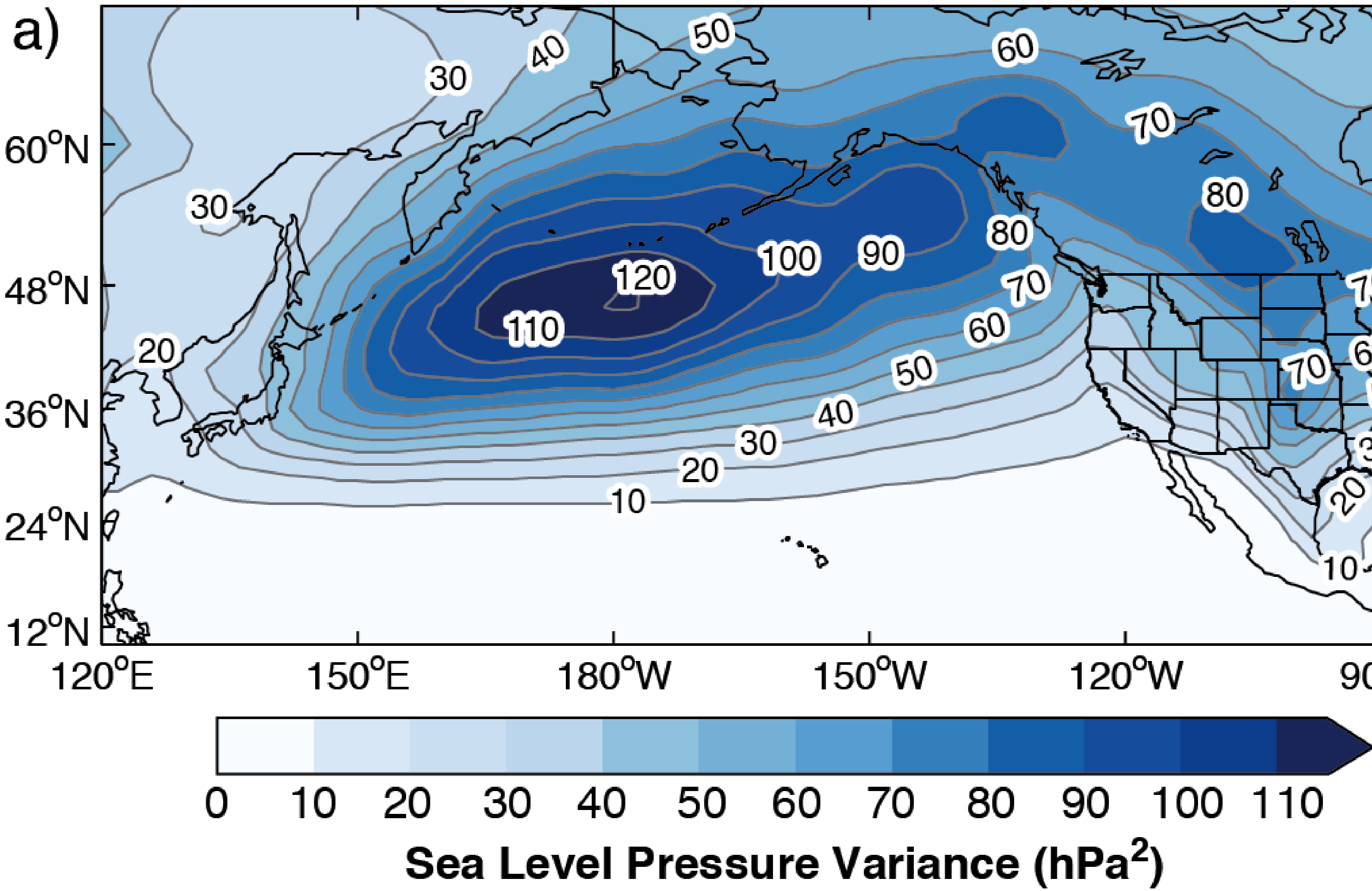
Cool season (Oct-Apr) Western US precipitation as fraction of annual

Drivers of Upper Colorado Basin precipitation may not be as straightforward as the West Coast!



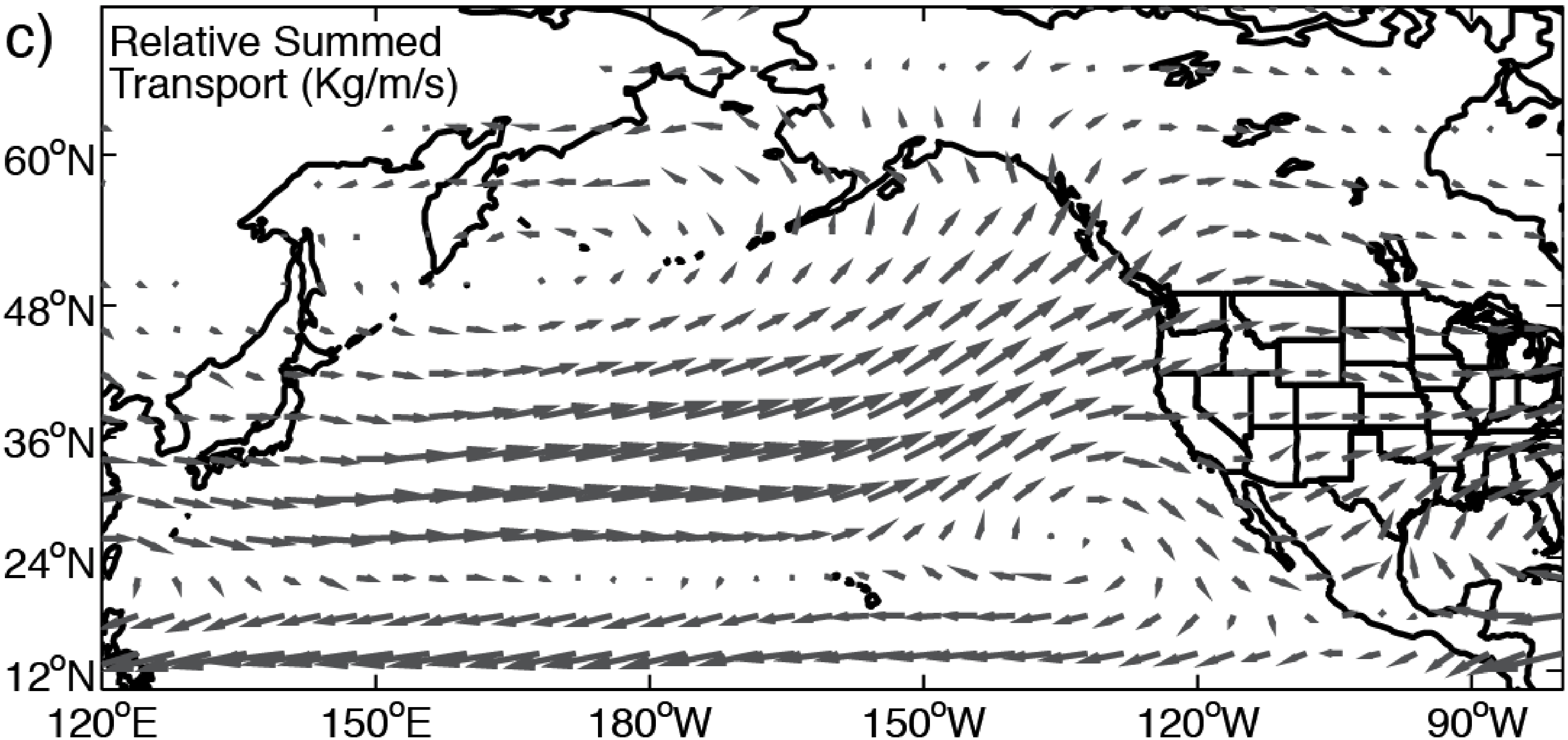
Hatchett (2016)

Potential Control: Winter Storm Track Activity

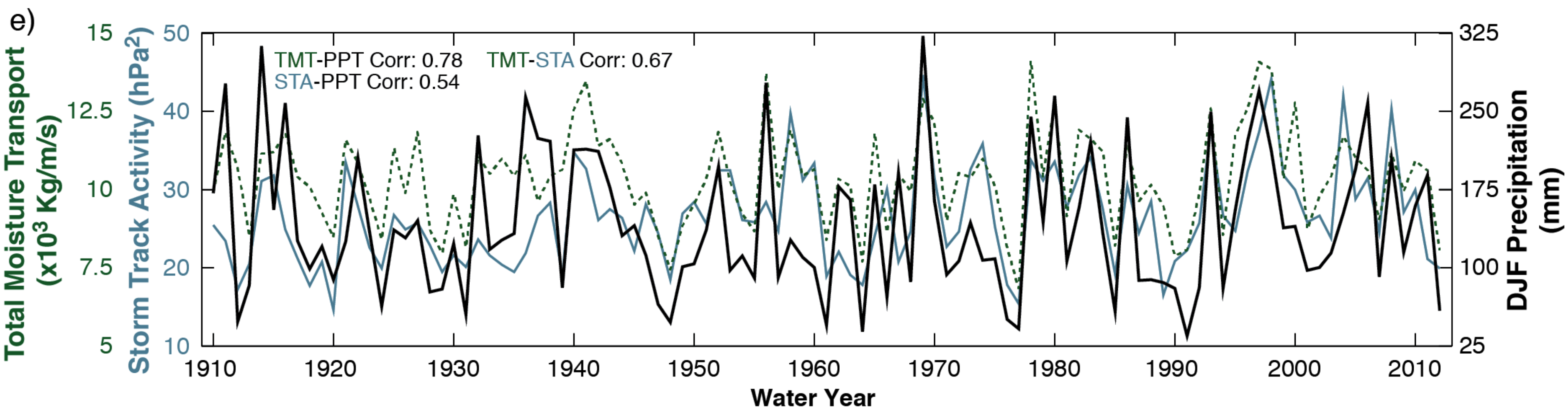


Hatchett et al. (2018)
Geol. Soc. Am. Sp. Papers

Potential Control: Moisture Transport

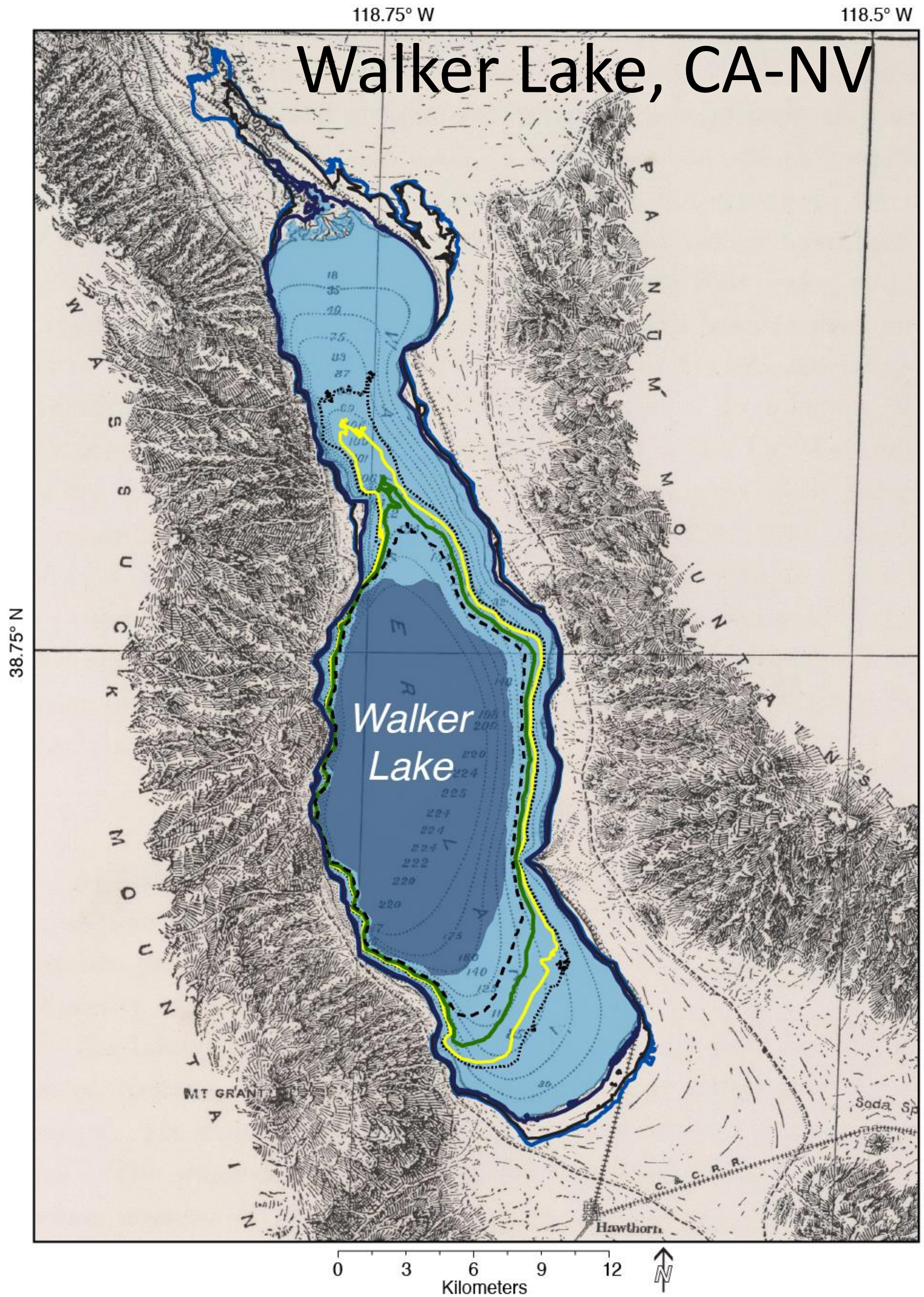


Walker Lake Basin finding: At seasonal scale, moisture transport better correlated to precipitation than storm track activity



- Moisture transport better captures precipitation signal due to:
  - Direct relation to water vapor for precipitation (upstream moisture convergence/depletion; Lundquist et al. 2010)
  - Trans-Sierra transport processes (Kaplan et al. 2009)
  - Preferential pathways through gaps and Mojave lowlands (Alexander et al. 2014; Rutz et al. 2015; Swales et al. 2016)
- Moisture transport better for forecasting precipitation events (Lavers et al. 2016).

Hatchett et al. (2018) Geol. Soc. Am. Sp. Papers



Israel Russell 1882 A.D.
1250 m

Late Holocene ca. 1890 A.D.
1252 m

March 2016 A.D.
1192 m

MCA Stine 1 (G-1)
1203 m

MCA Stine 2 (G-2)
1221 m

Baseline ≈ 1910-2012 ≈ Neopluvial

Implies 20th century as wet as any in past 3,700 years

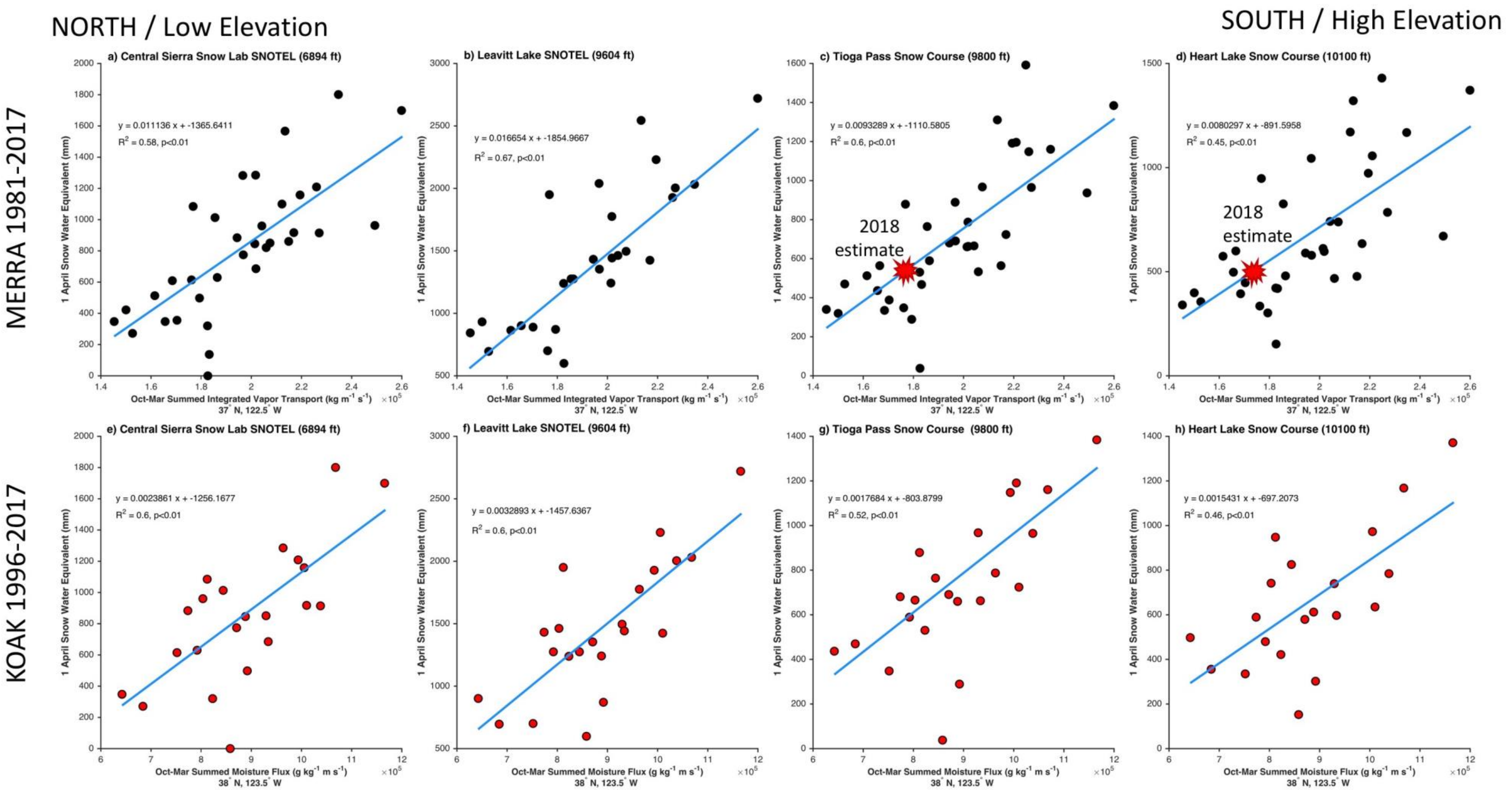
10th Percentile Storm Track
1217 m

10th Percentile Moisture Flux
1210 m

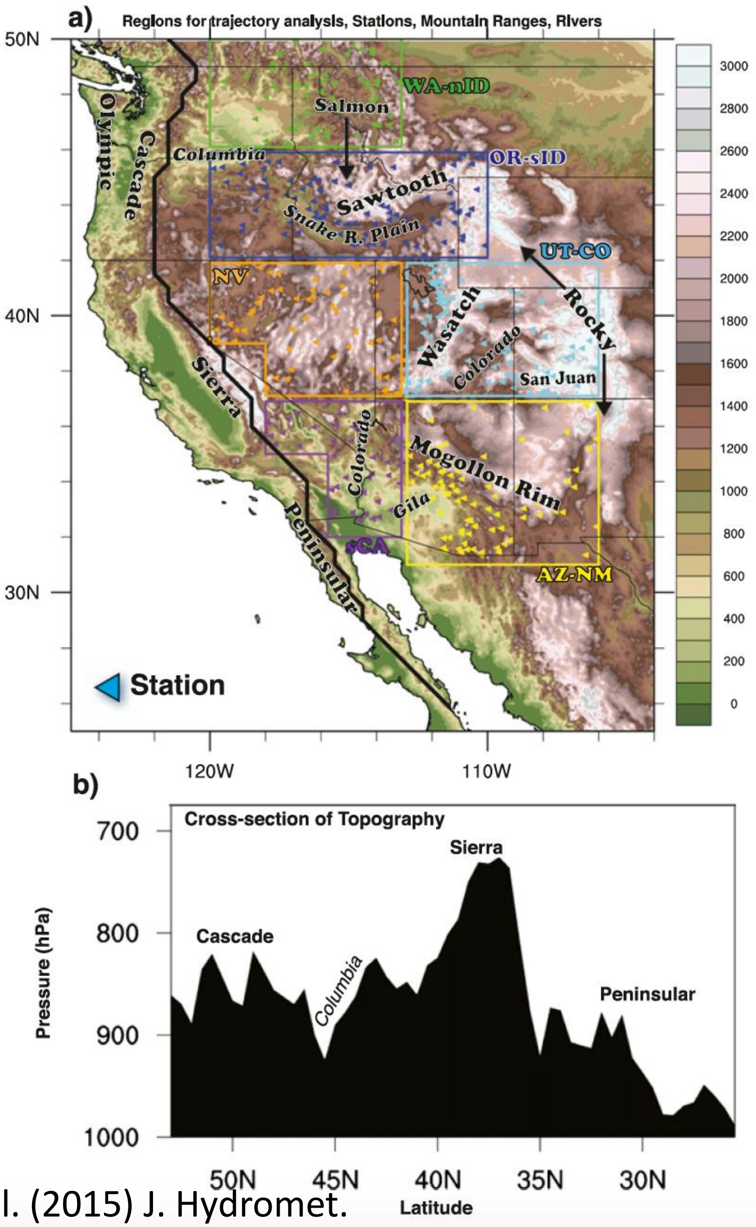
Neopluvial (ca. 3.7ka)
1261 m

Baseline 1971-2000 A.D.
1259 m

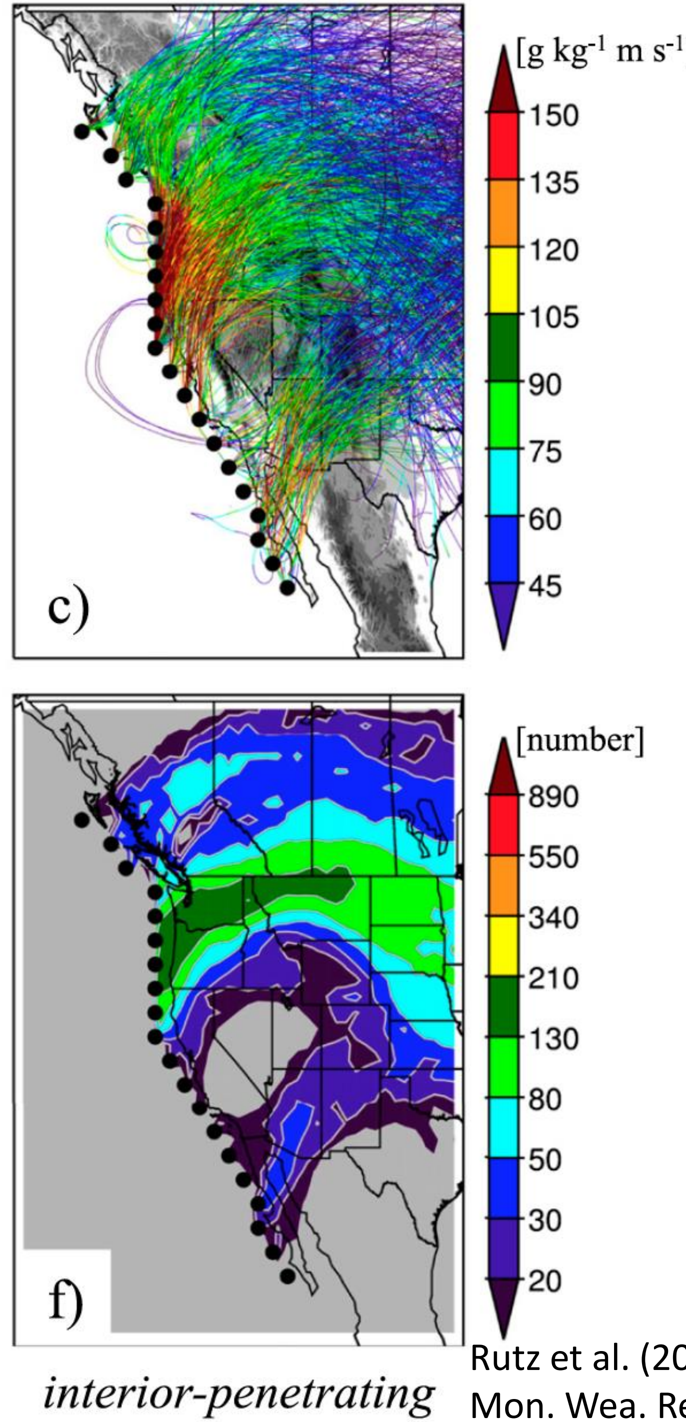
Example from Sierra Nevada: April 1 SWE estimated by Oct-Mar total upstream moisture flux



Inland Penetration of Moisture

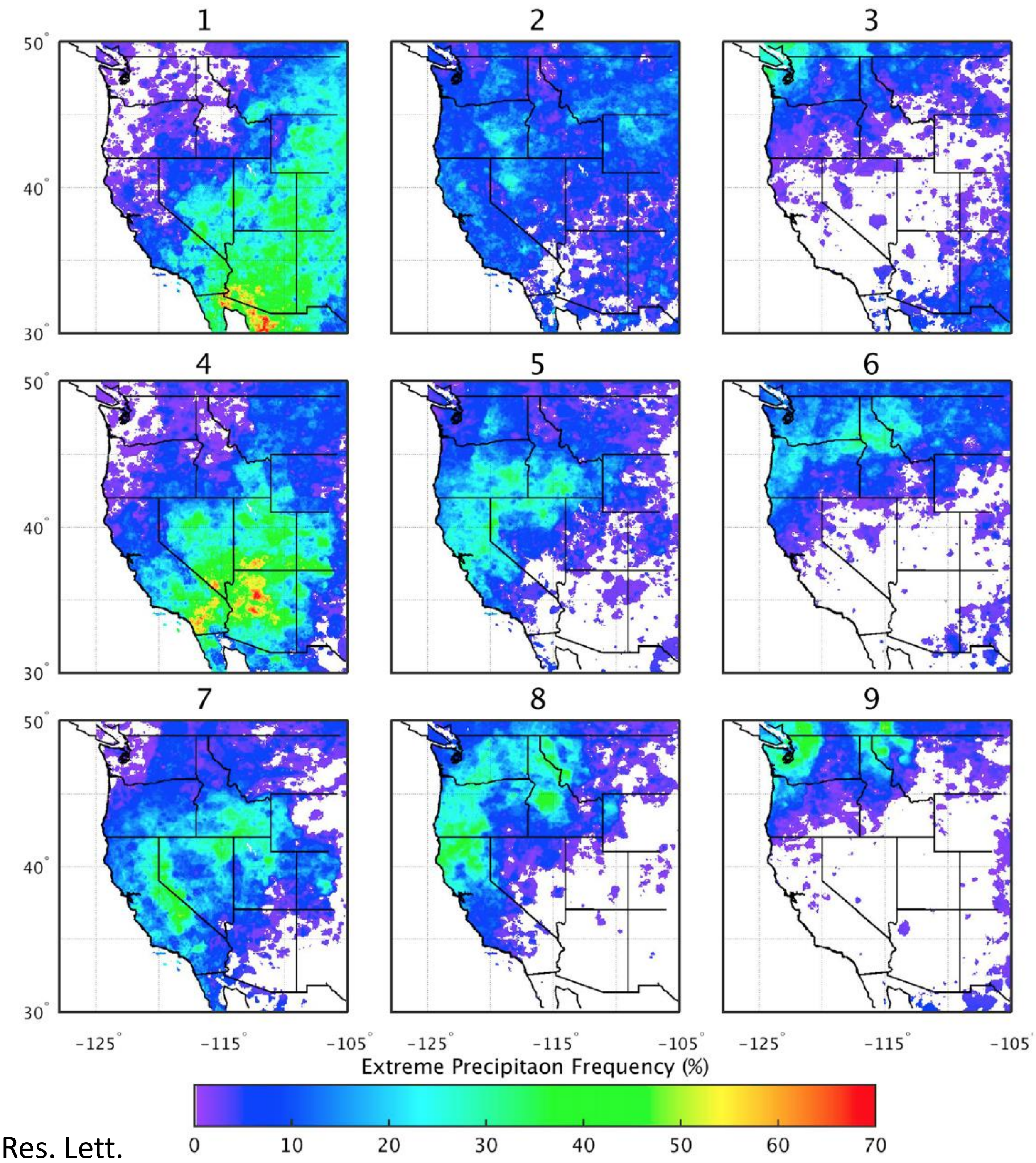


Alexander et al. (2015) J. Hydromet.



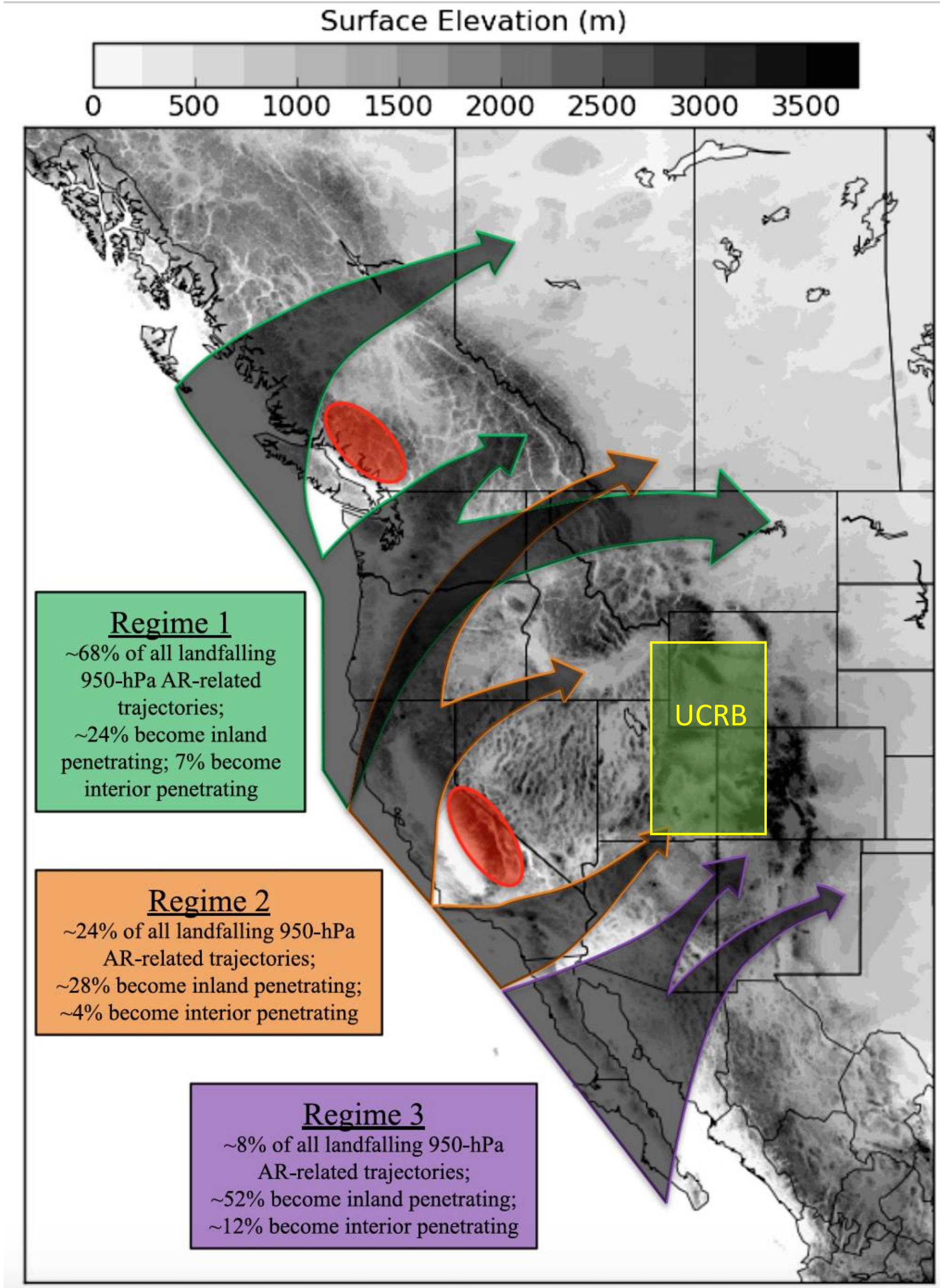
Rutz et al. (2015)
Mon. Wea. Rev.

Inland Penetration and Extreme Precipitation



Self-organizing map approach: Extreme precipitation frequency from Livneh ppt mapped onto SOM nodes

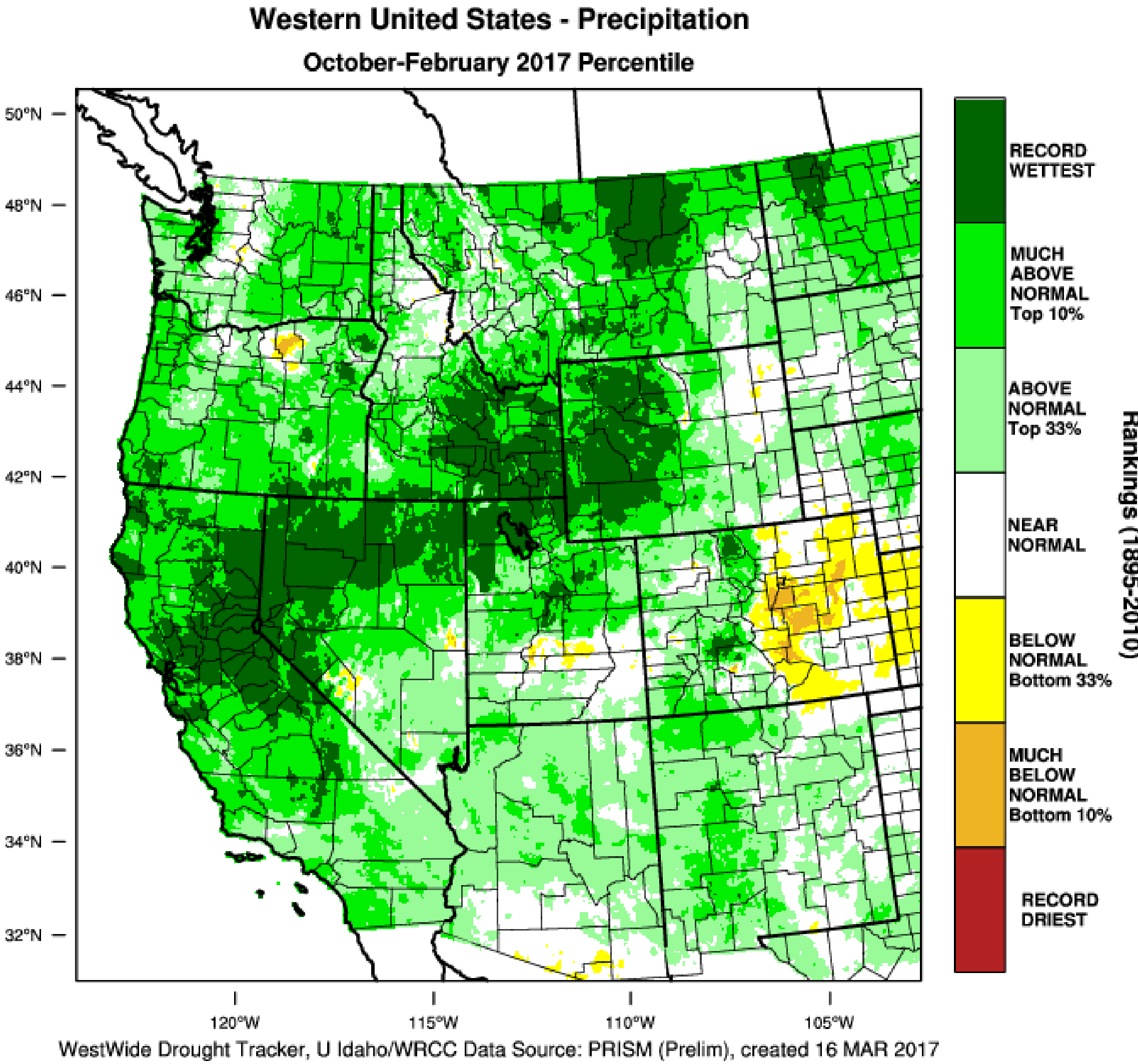
Swales et al (2016) Geophys. Res. Lett.

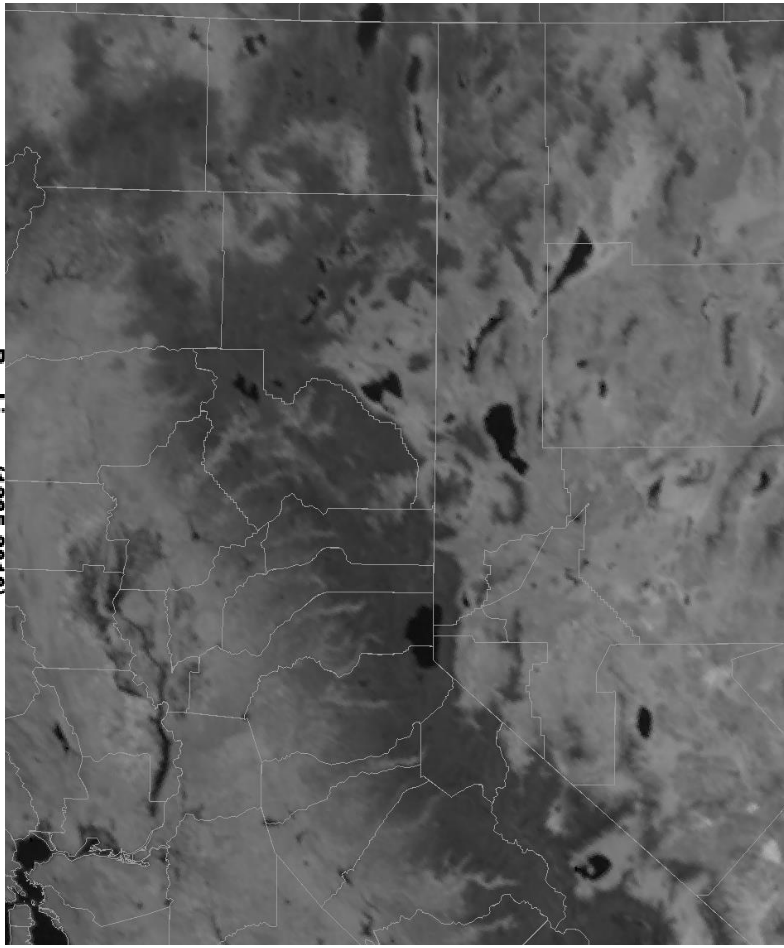


Rutz et al. (2015)
Mon. Wea. Rev.

2017 as Evidence for N. Sierra Pathway

Rutz regime 2/Swales Nodes 5&7



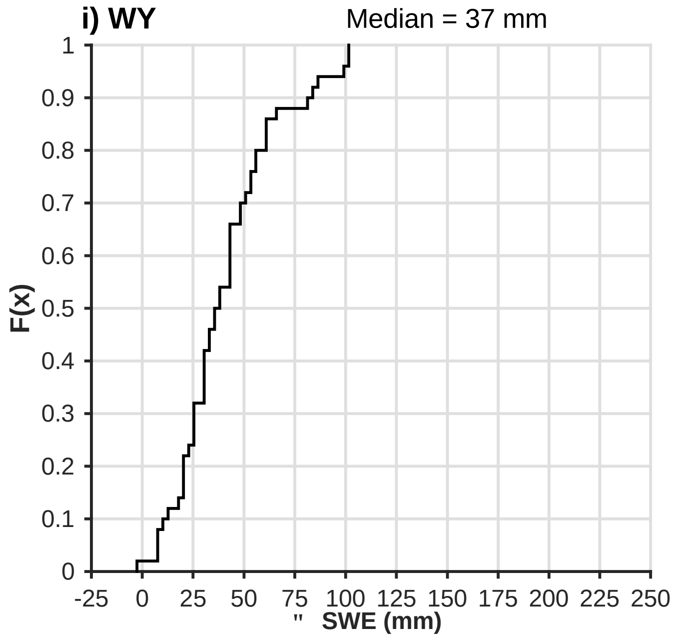


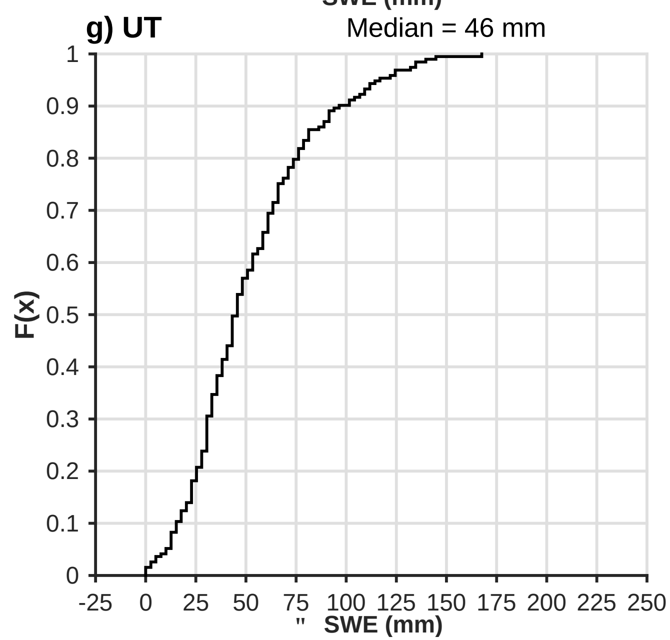
GOES-16 in early March: black = water

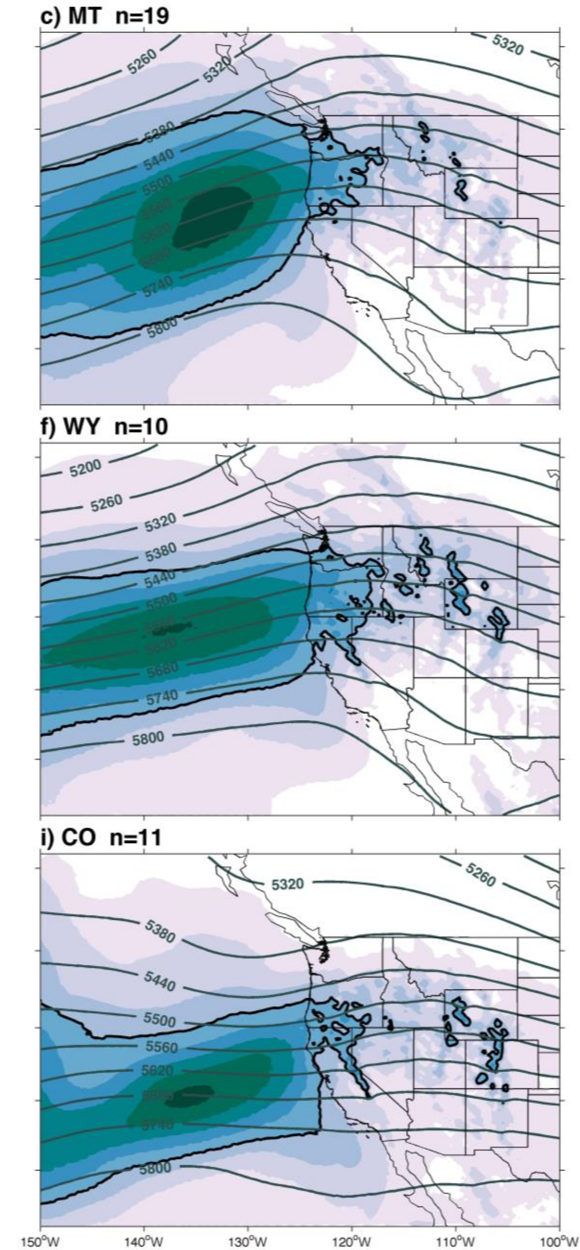
Another hint at preferential corridors for inland transport

Link between atmospheric rivers, inland penetration, and extreme snowfall (based on fatal avalanche events)

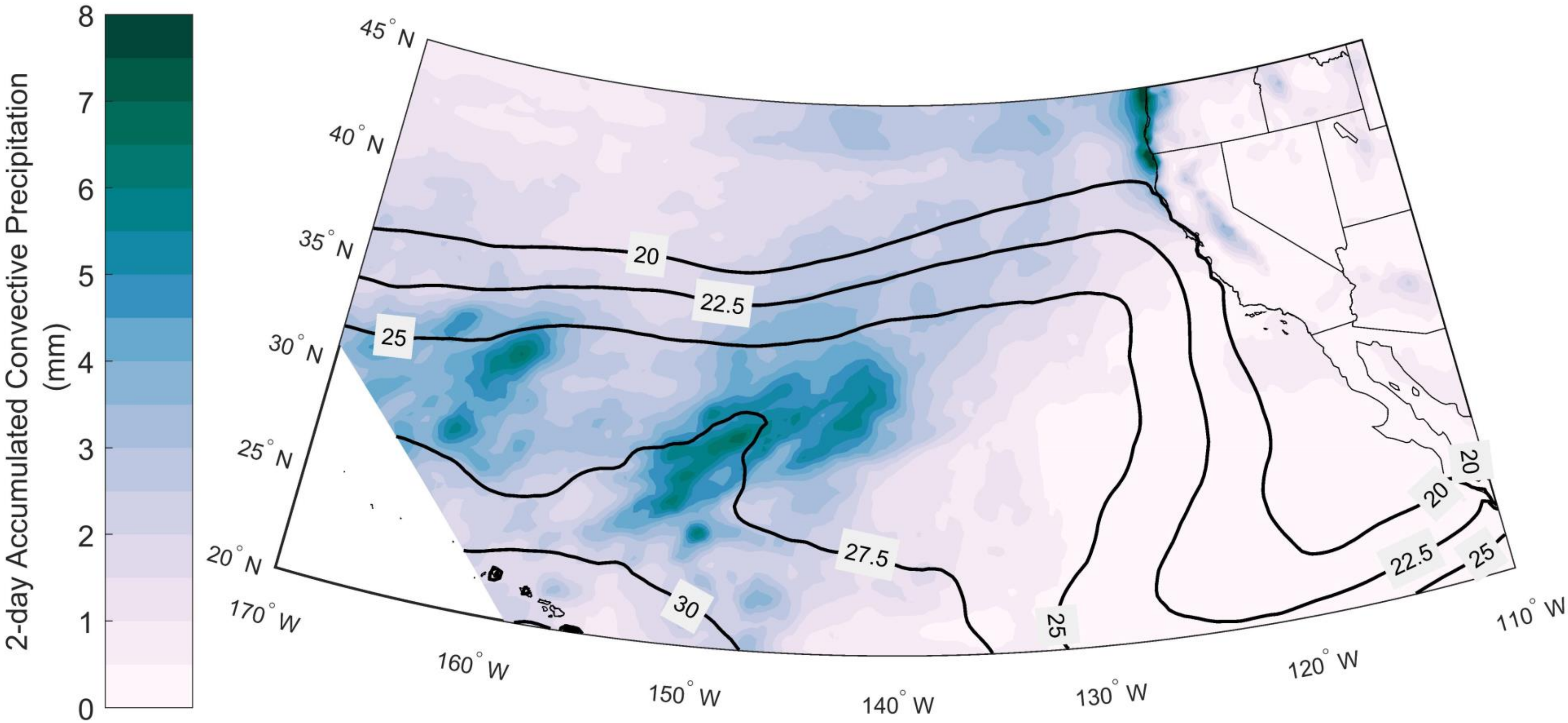
Hatchett et al. (2017) J. Hydromet







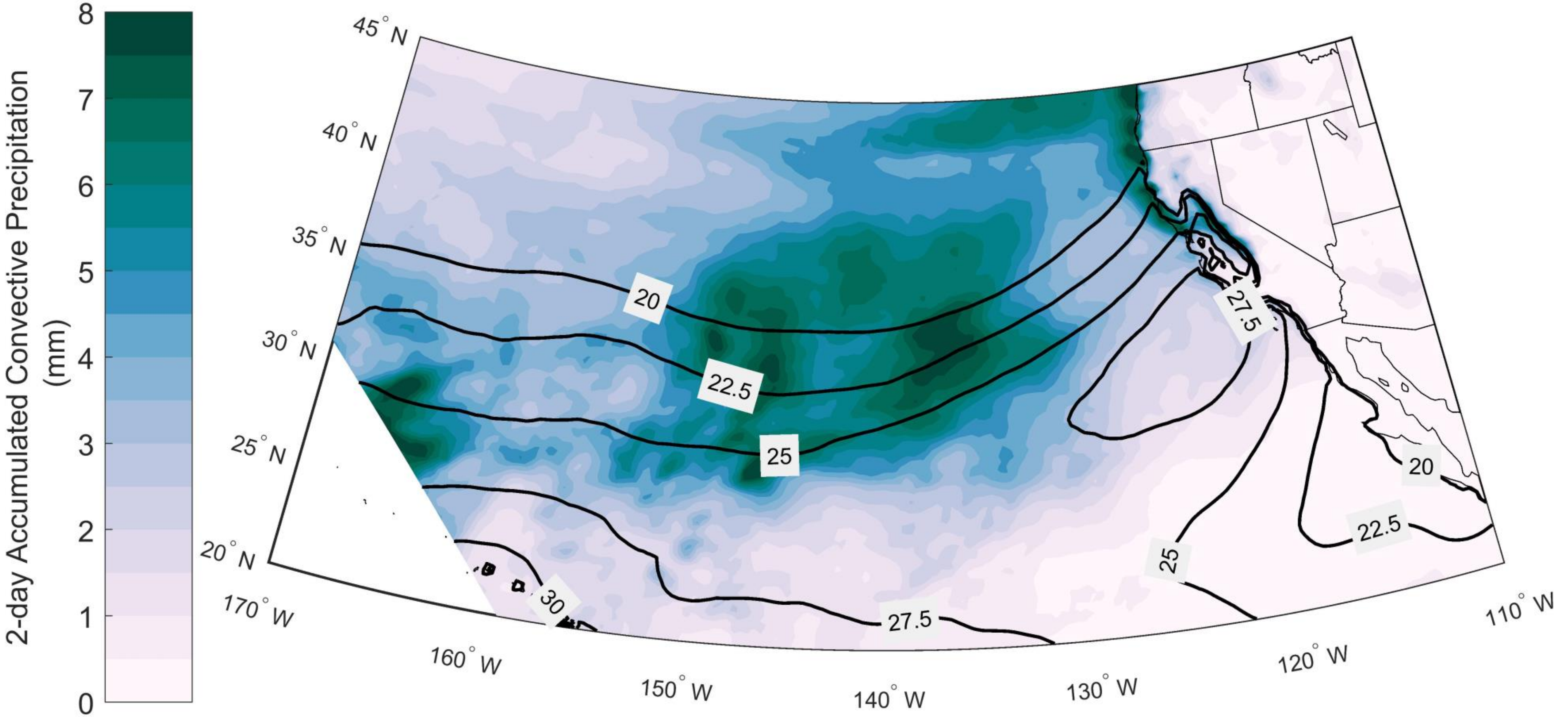
Upstream Conditions: Strong Sierra Nevada Rain Shadow



Contours show precipitable water (mm)
n = 151 days

Hatchett in prep

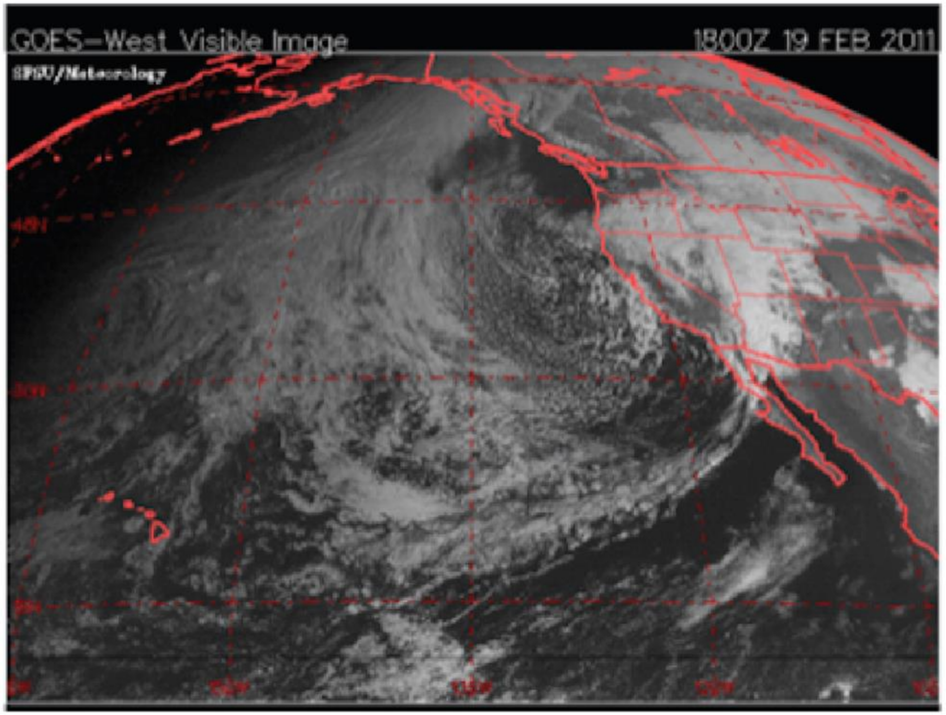
Upstream Conditions: Weak Sierra Nevada Rain Shadow

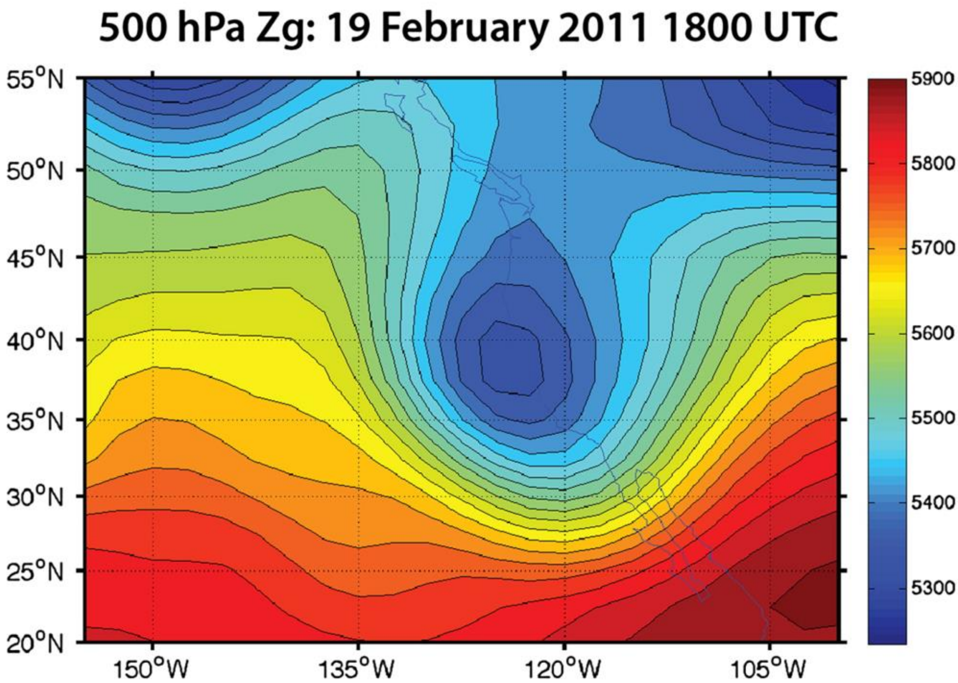


Contours show precipitable water (mm)
n = 68 days

Hatchett in prep

Closed/Cutoff Lows

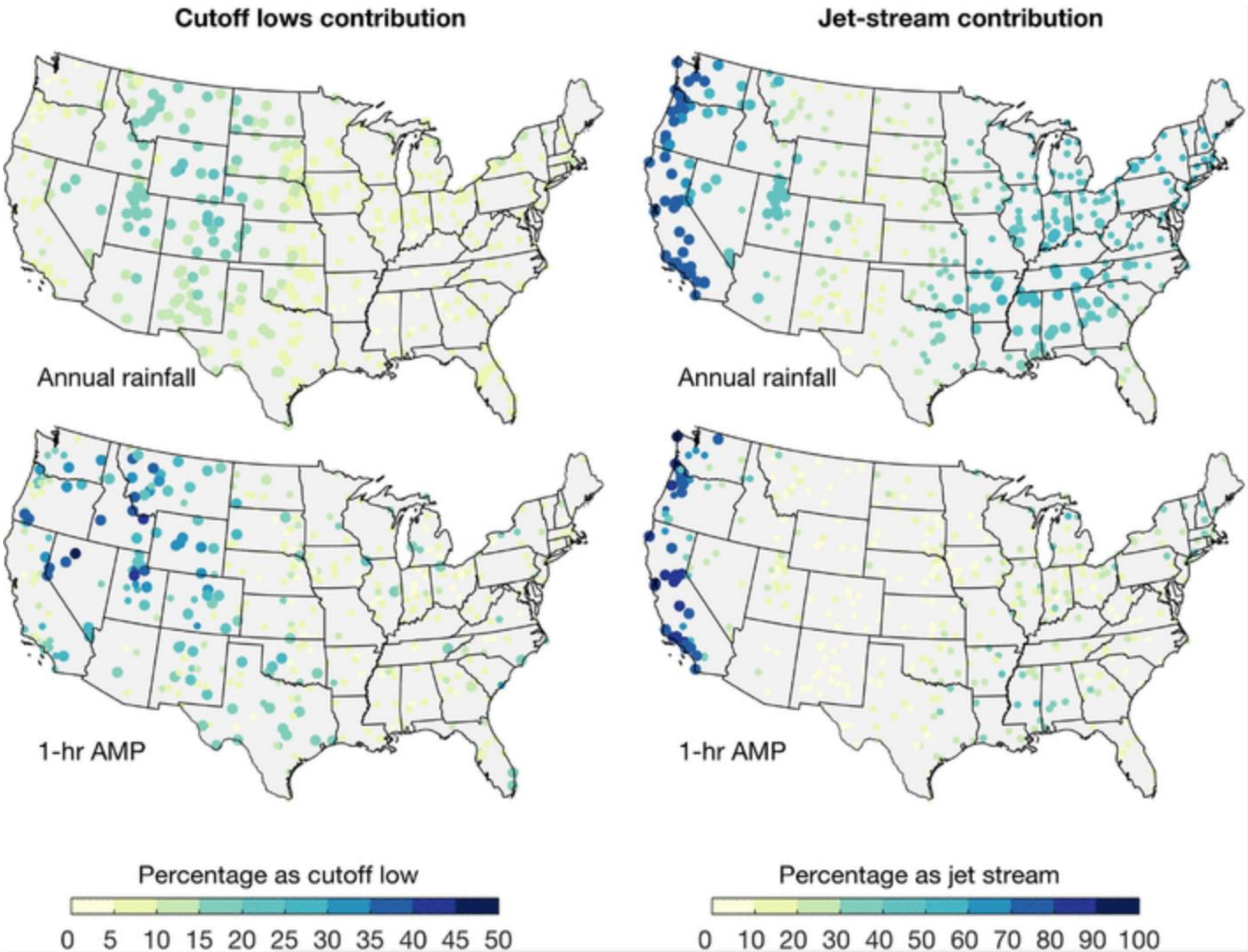




Oakley and Redmond (2014)
J. Appl. Met. Clim.

COLs contribute over 20% of annual precipitation* in interior western United States and over one-third of all 3-day precipitation extremes across parts of the semiarid western United States (Abatzoglou (2016) J. Appl. Met. Clim.)

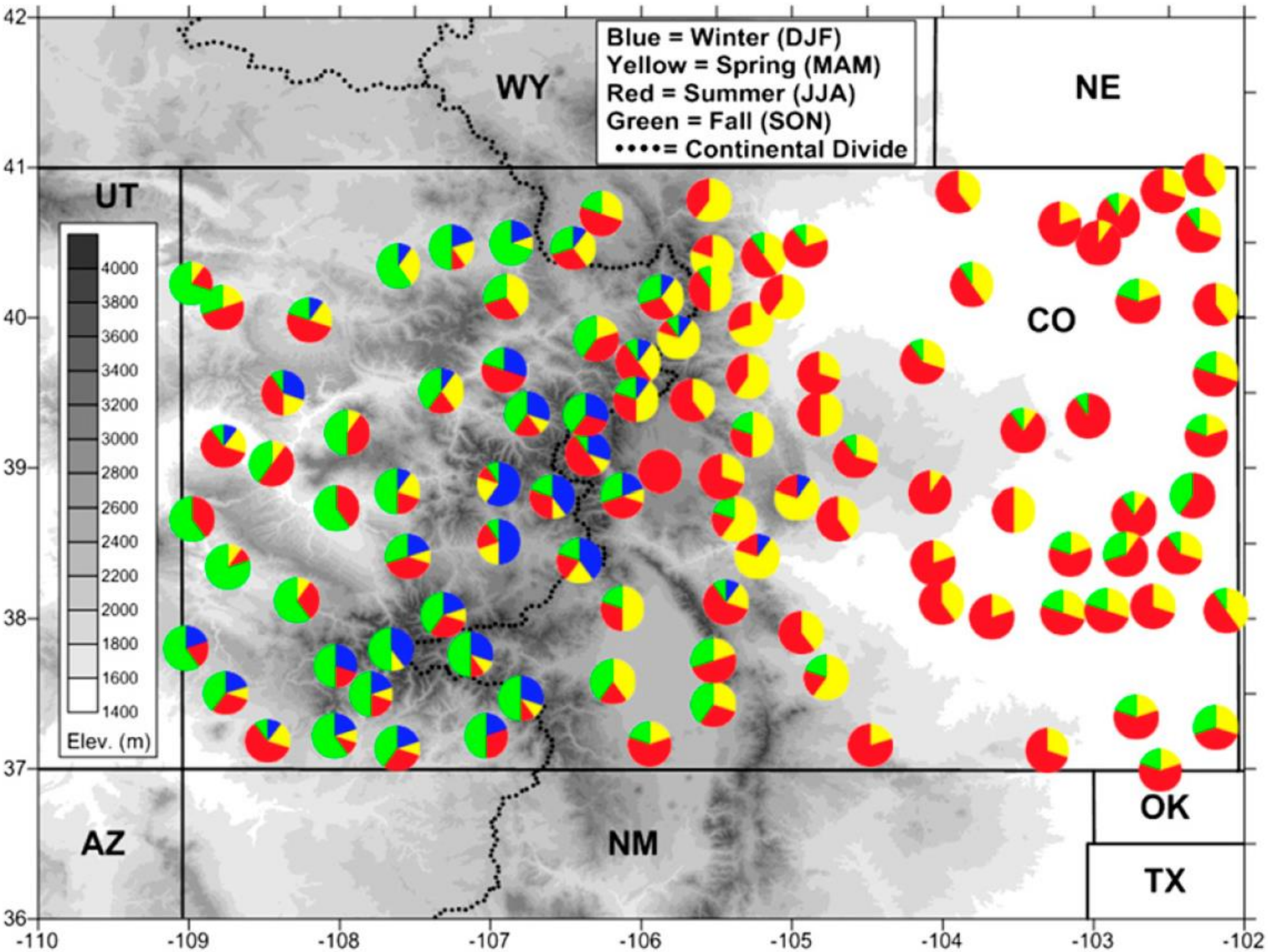
*Since only COL and not also closed lows, this is minimum estimate



Barbero et al. (2018) Clim. Dyn.

Consistent with Parker and Abatzoglou (2015) Int. Jour. Climatol.

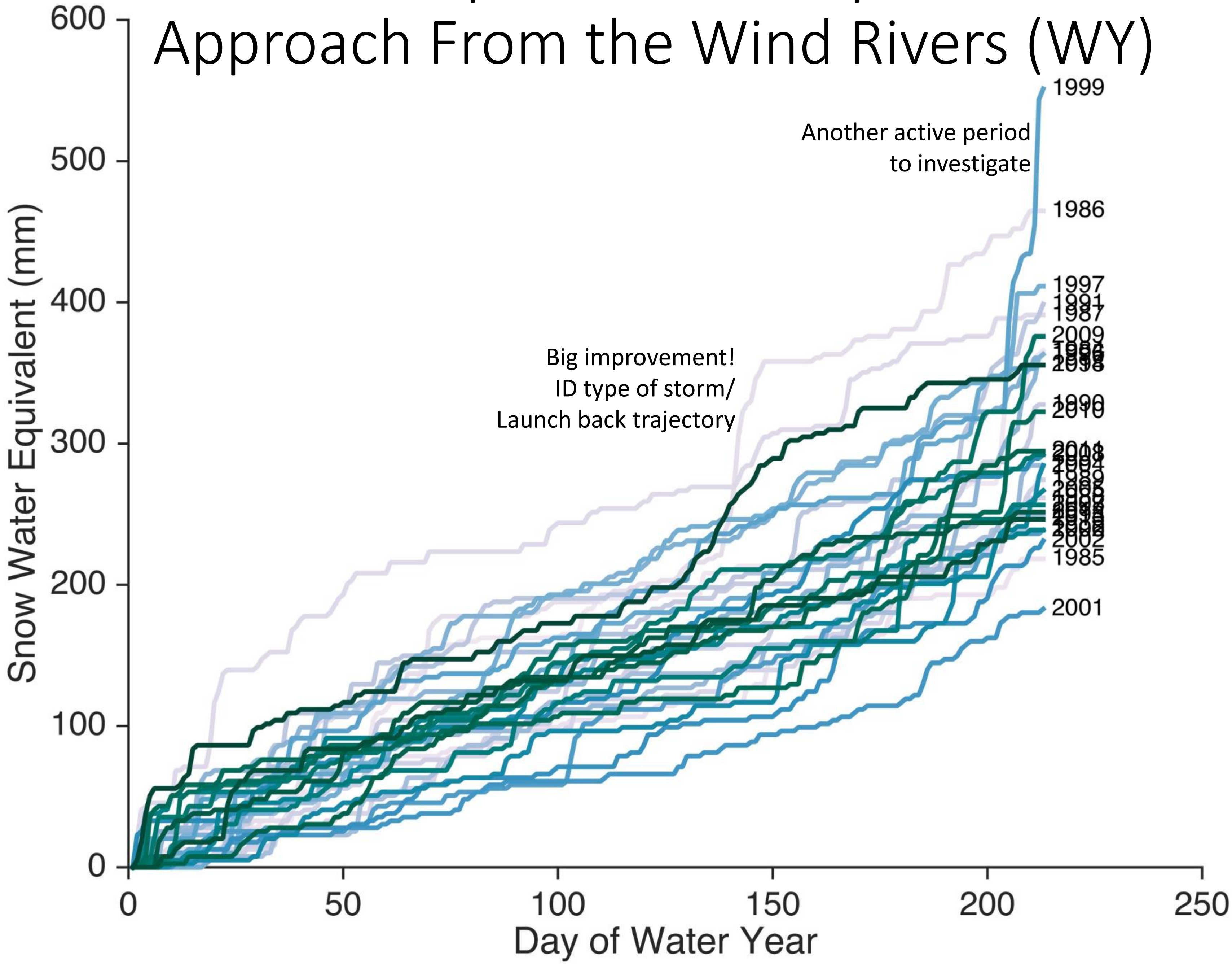
Seasonality Example From Colorado: Top 10 24-hr events show spring peak

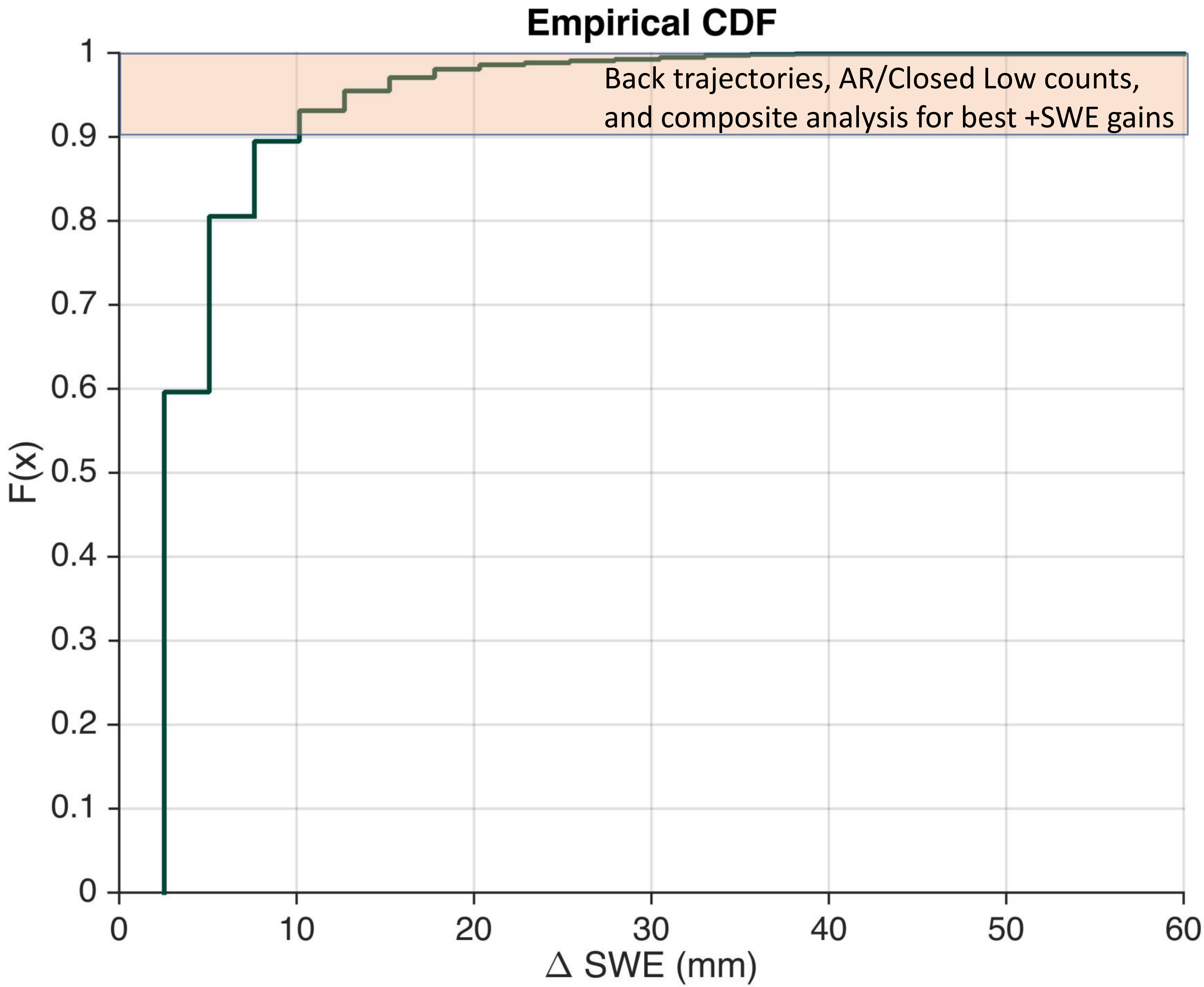


Mahoney et al. (2015) J. Hydromet

Note: longer duration extreme events in winter/spring may be missed

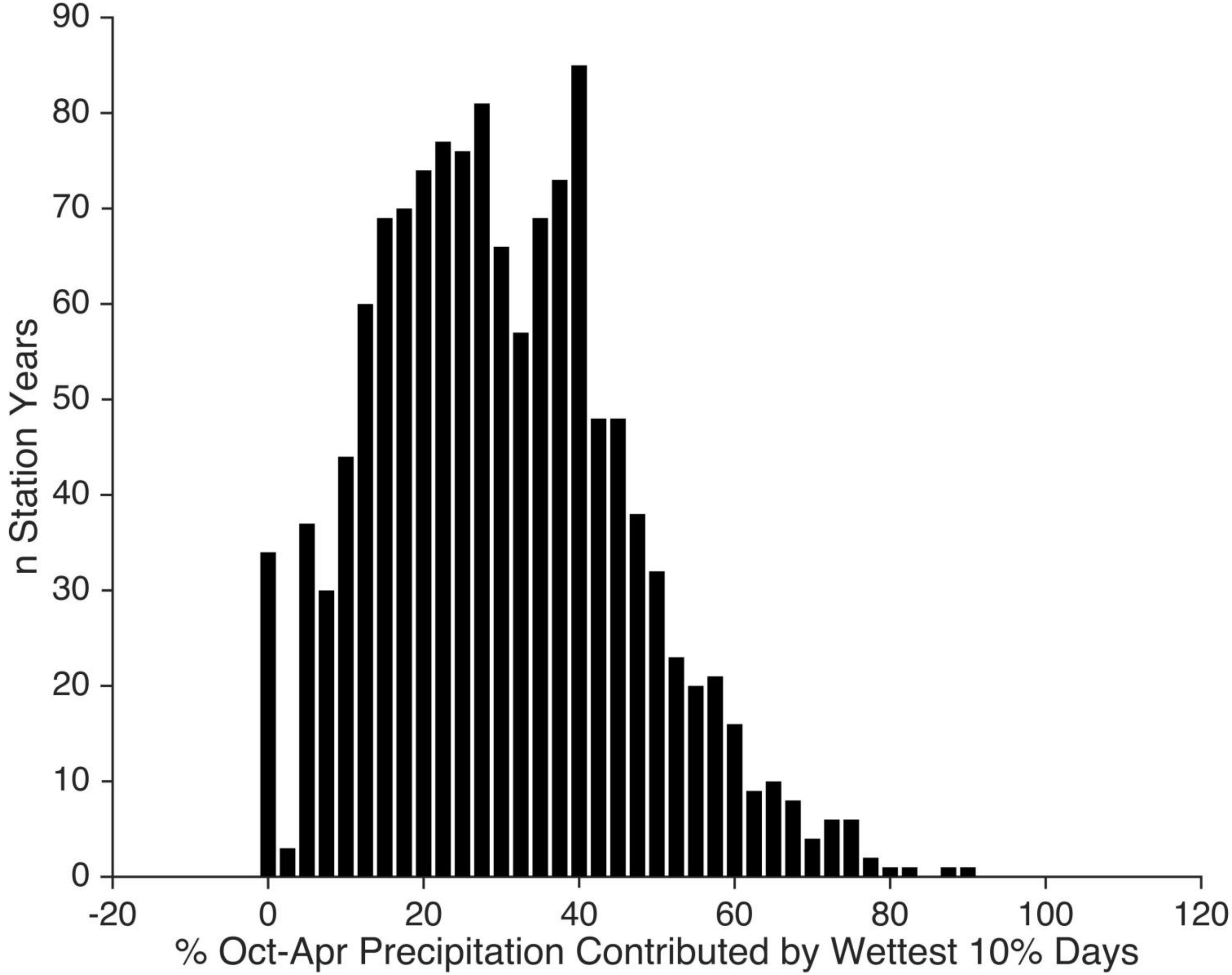
Quick Example of First Steps in Our Approach From the Wind Rivers (WY)





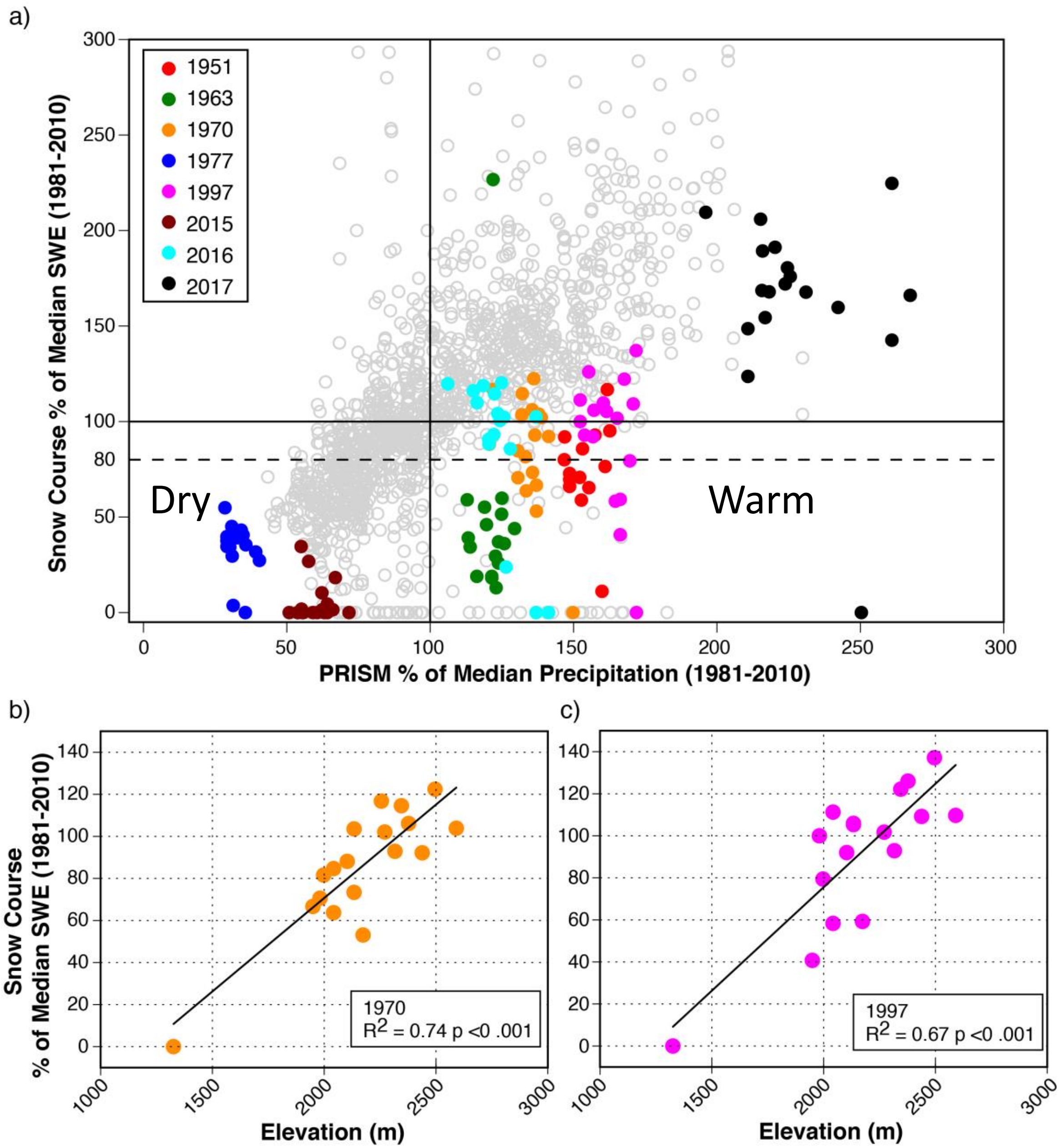
Empirical CDF
Back trajectories, AR/Closed Low counts,
and composite analysis for best +SWE gains
F(x)
Δ SWE (mm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60

Example: 48 SNOTELs in Upper Colorado
→ Top 10%-ile storms contribute ~30% cool season total precipitation



Another consideration:

Sensitivity of Upper Colorado Basin to Snow Droughts (Warm and Dry)



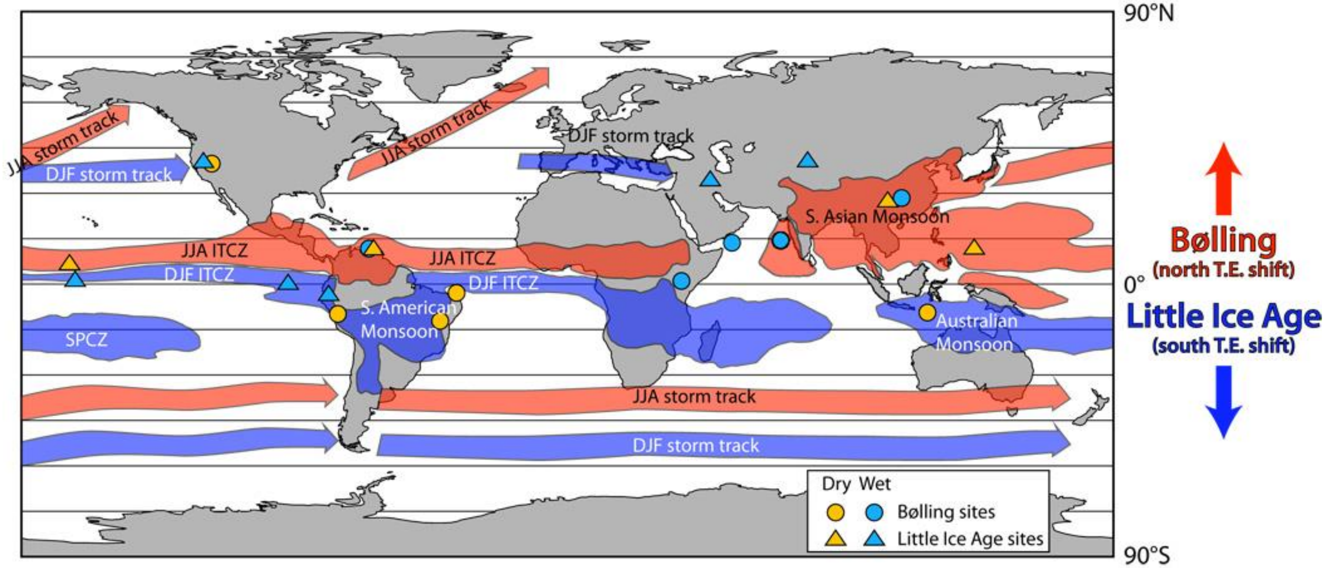
Hatchett and McEvoy (2018) Earth Int.

Tasks

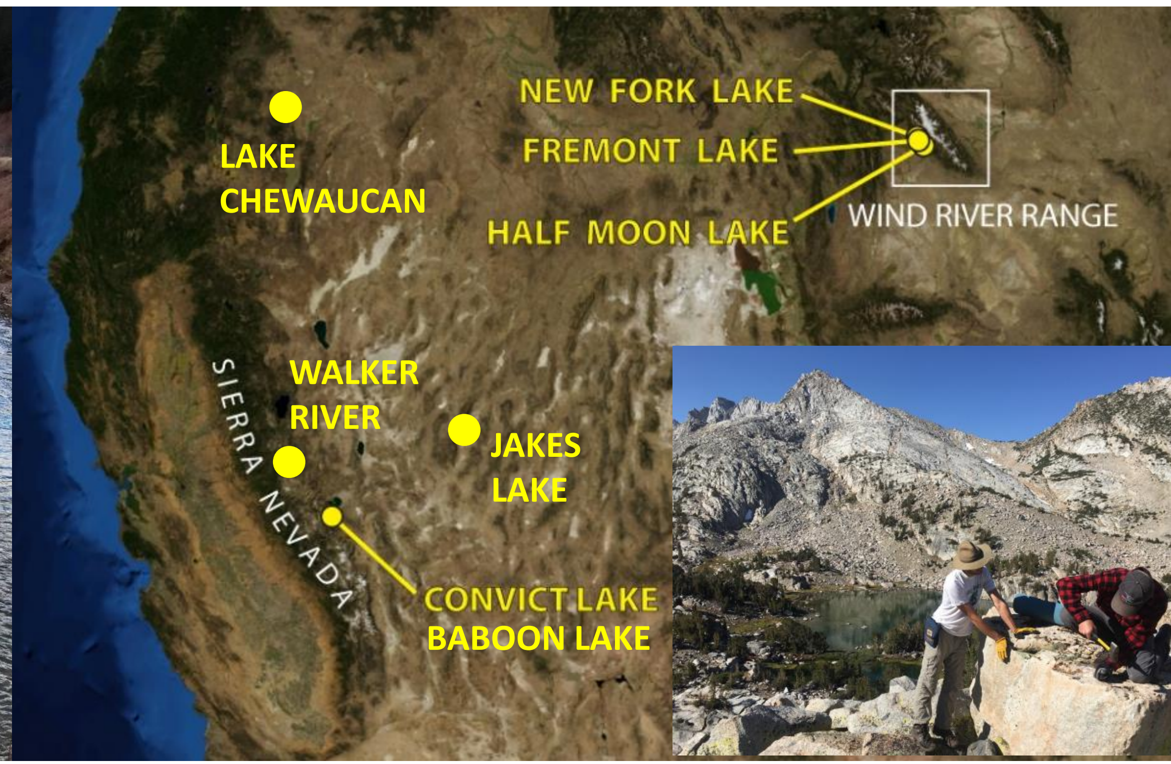
Photo: Siani Nau

- Literature review
- Station data acquisition
  - Monthly snow courses
  - Daily SNOTEL, COOP, CoCoRAHS
  - Hourly HPD?
- 'Notable' event identification (90th percentile) and quantification
- Back trajectories
  - Follow approach of Rutz et al. (2015 Mon. Wea. Rev.)
  - Explore role of model resolution for corridors
- Dynamical Associations → skill at S2S scales?
  - Closed/cutoff Lows using id/tracking algorithms (Abatzoglou et al. (2016) J. Appl. Met. Clim.; Oakley and Redmond (2014) J. Appl. Met. Clim.)
  - Atmospheric Rivers using catalog approach (Rutz et al. (2014)

Climate Application: Response of midlatitude and alpine regions to a warming world



Putnam and Broecker (2017) Sci. Adv. Broecker and Putnam (2013) PNAS



Hatchett (2018) Nature Geosci.

Birkel et al. (2012) Arc. Alp. Ant. Res., Hudson et al. submitted

Stay Tuned For Results!

Thoughts, critiques, ideas, comments appreciated!