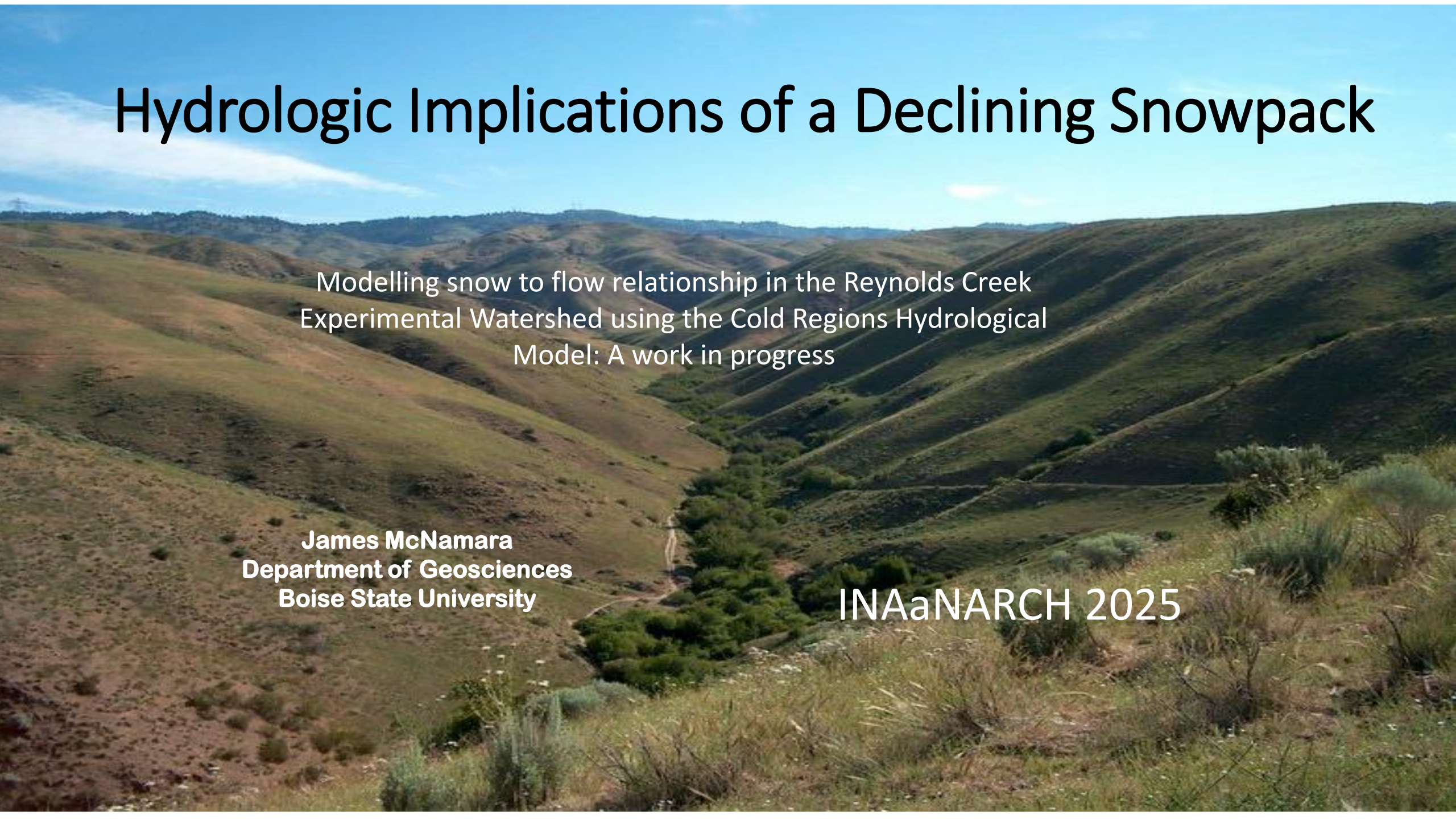
Hydrologic Implications of a Declining Snowpack

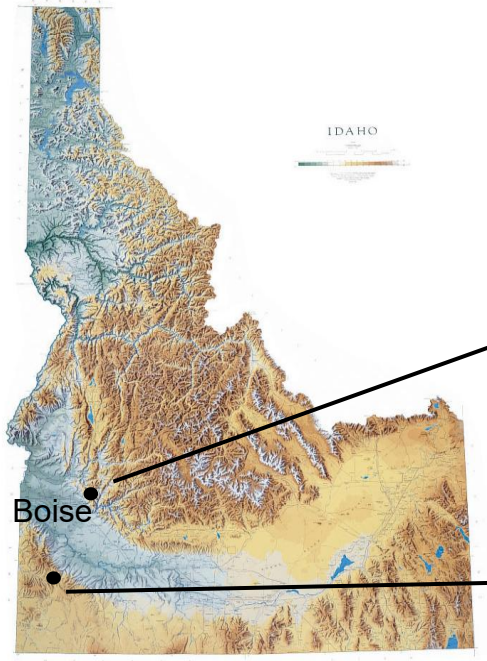
Modelling snow to flow relationship in the Reynolds Creek Experimental Watershed using the Cold Regions Hydrological Model: A work in progress



James McNamara
Department of Geosciences
Boise State University

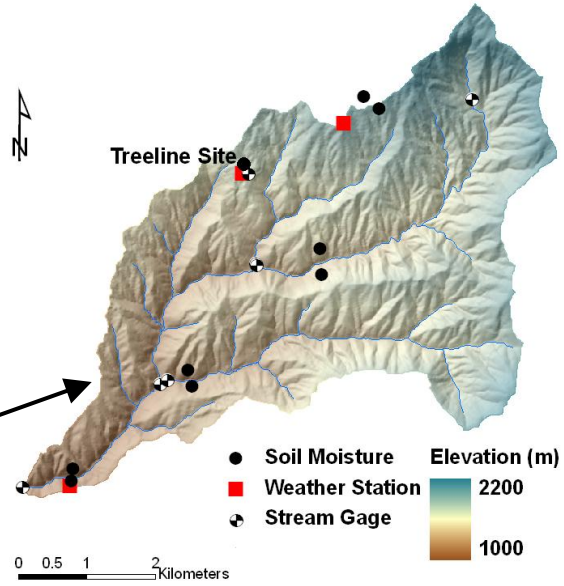
INAaNARCH 2025

Reynolds Creek and Dry Creek



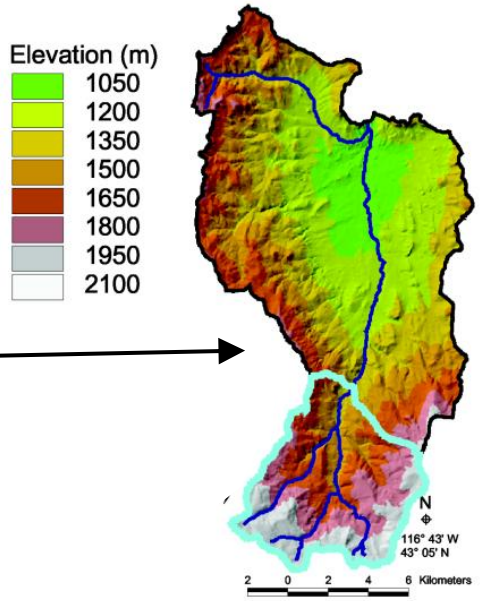
Since 1998

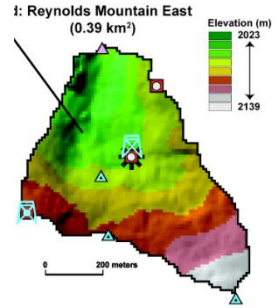
Dry Creek Experimental Watershed

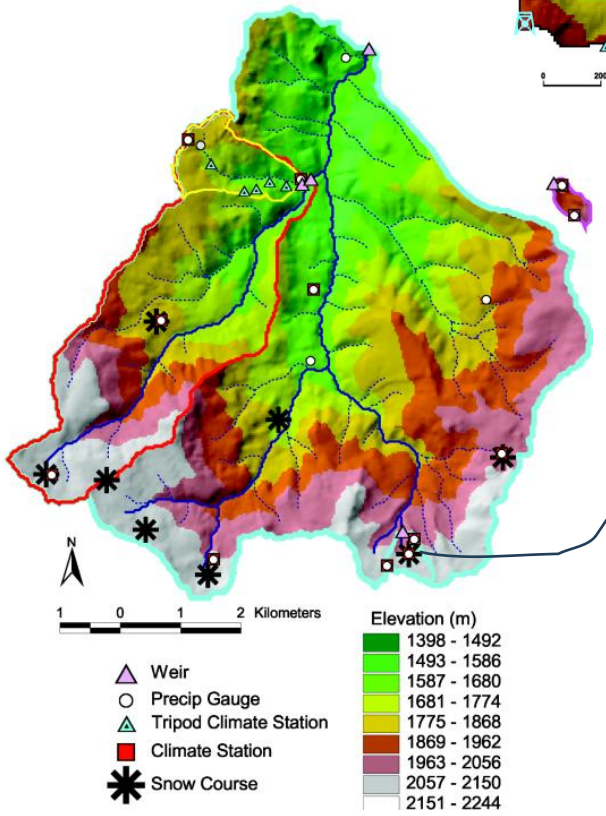


Since 1965

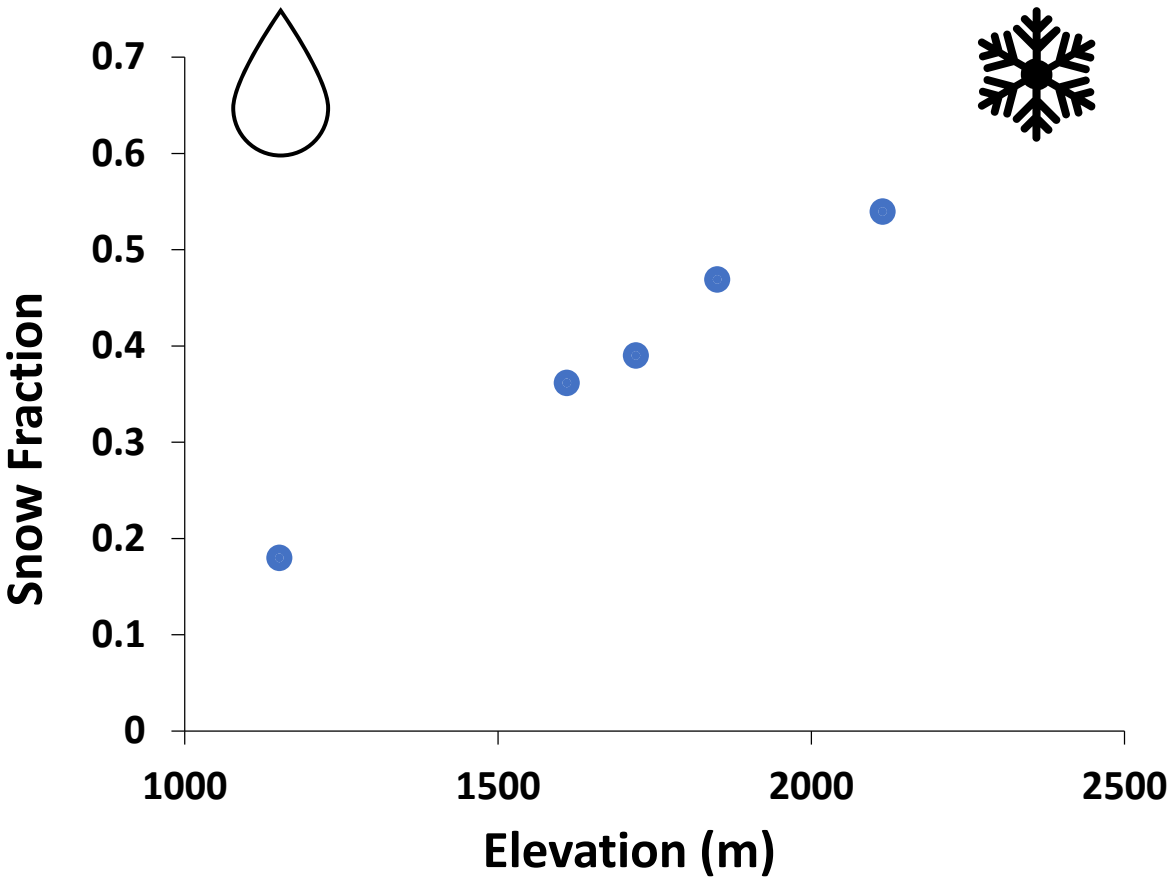
Reynolds Creek Expimental Watershed (239 km²) and Tollgate sub-basin (55 km²)

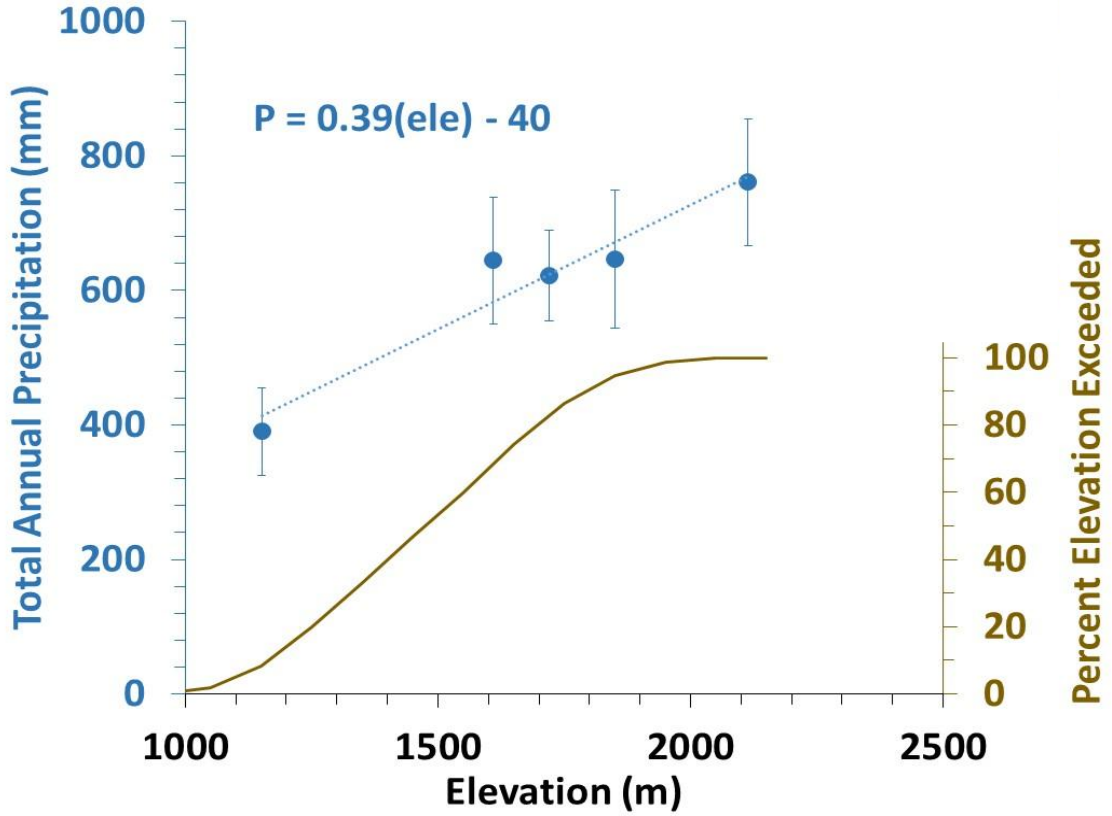




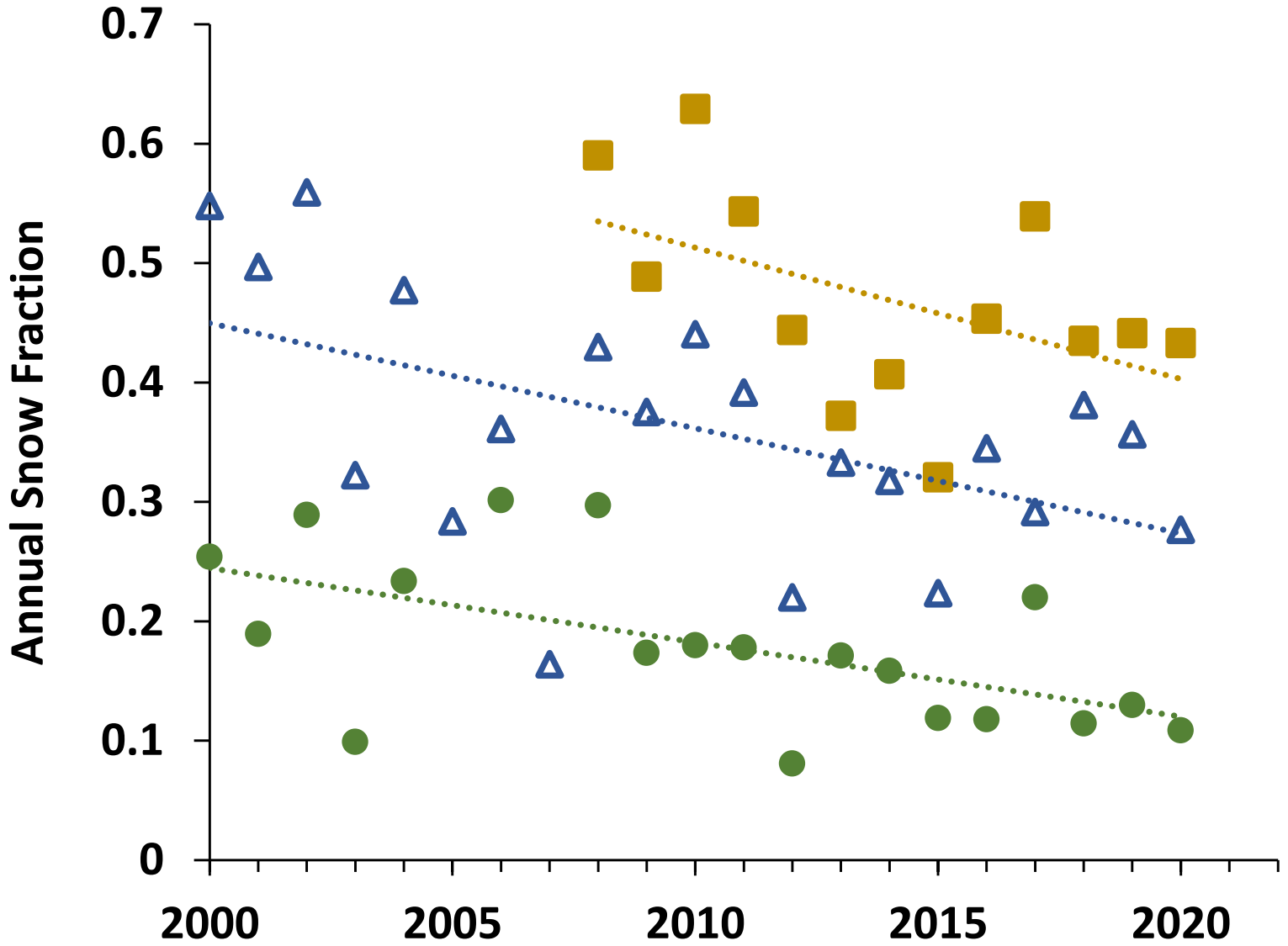


Spatial Rain to Snow





Declining Snow Fraction



Motivation

nature climate change

Explore content | About the journal | Publish with us | Subscribe

nature > nature climate change > letters > article

Letter | Published: 18 May 2014

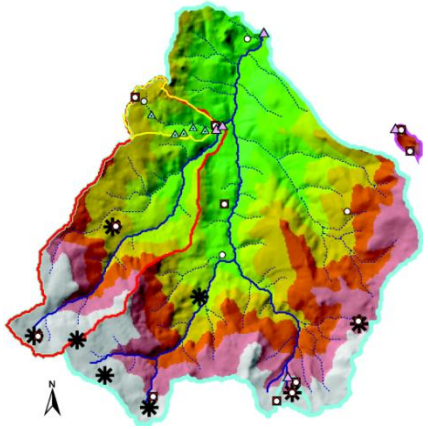
A precipitation shift from snow towards rain leads to a decrease in streamflow

W. R. Berghuijs, R. A. Woods & M. Hrachowitz

Nature Climate Change **4**, 583–586 (2014) | Cite this article

Snow-dominated catchments produce more runoff than rain-dominated catchments.

Question



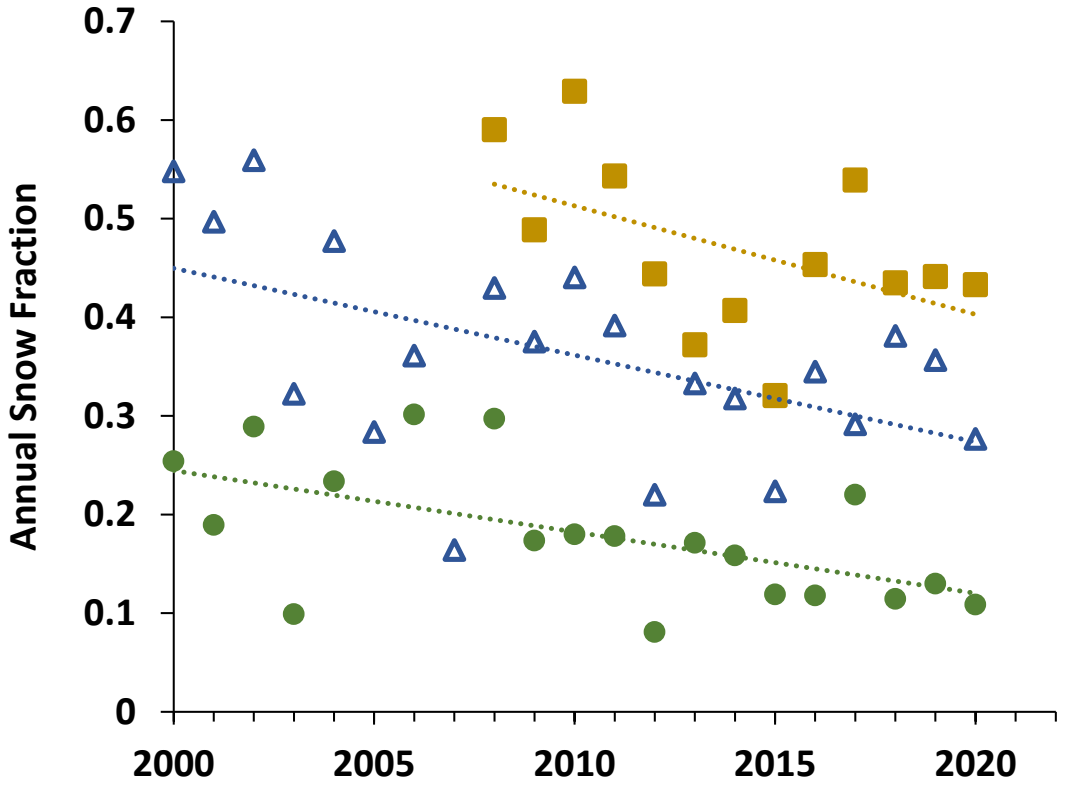
Do snow-dominated **years** produce more streamflow than rain-dominated years within a catchment?

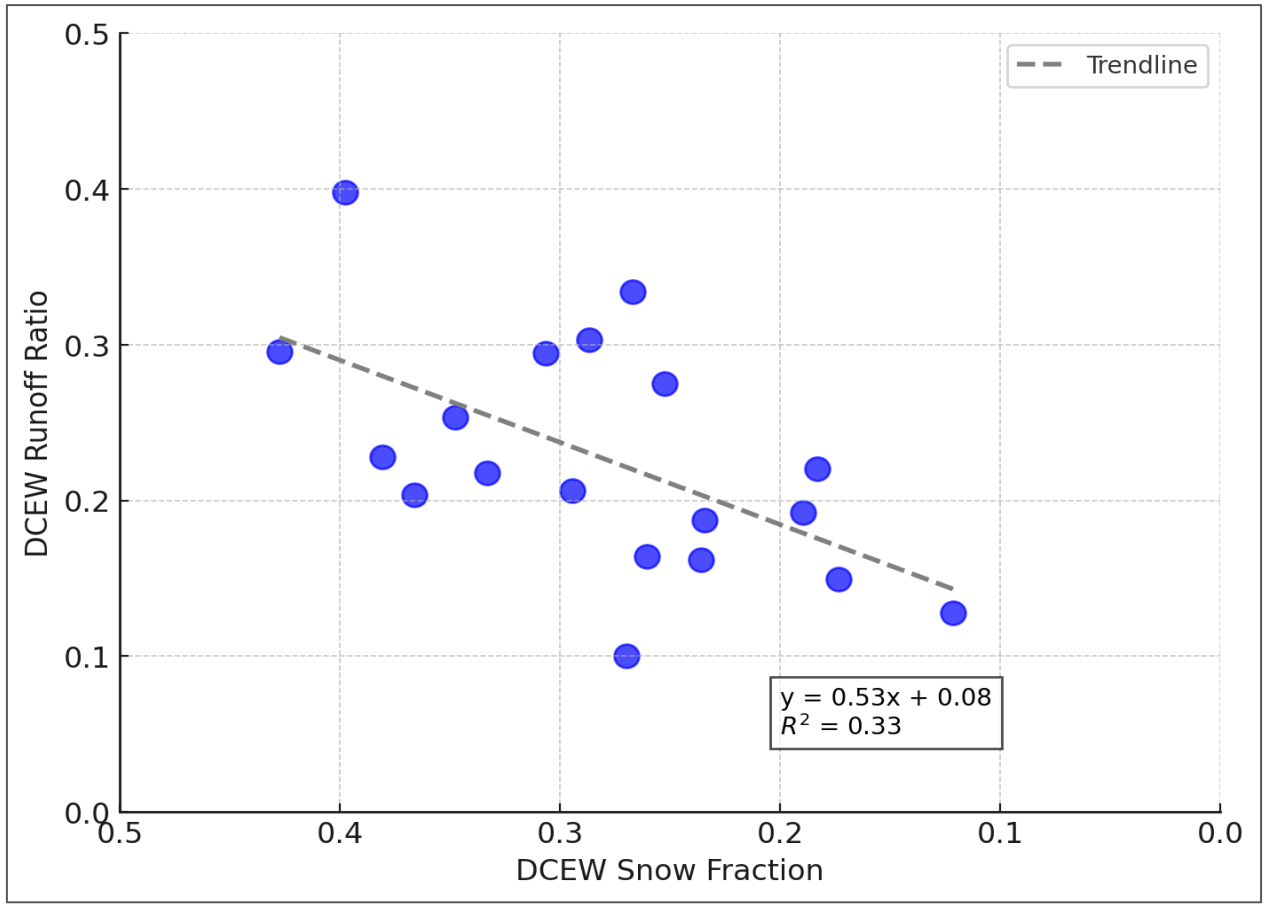
- **Analysis of Long-term observations in experimental catchments**

If so, why?

- **Models as virtual laboratories**
  - **Cold Regions Hydrology Model**

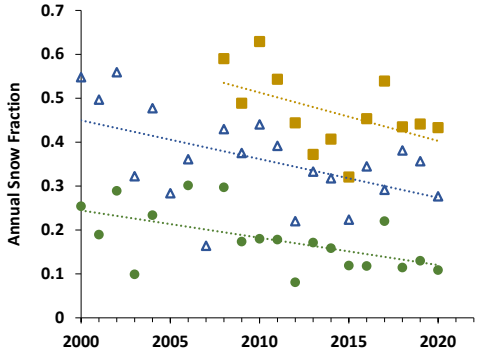
Dry Creek: Snow Fraction Snow/P) associated with Decling Runoff Ratio (Q/P)



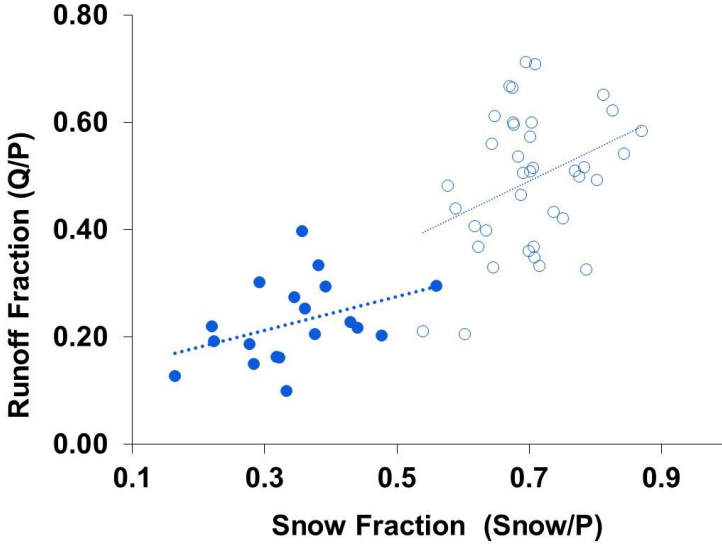


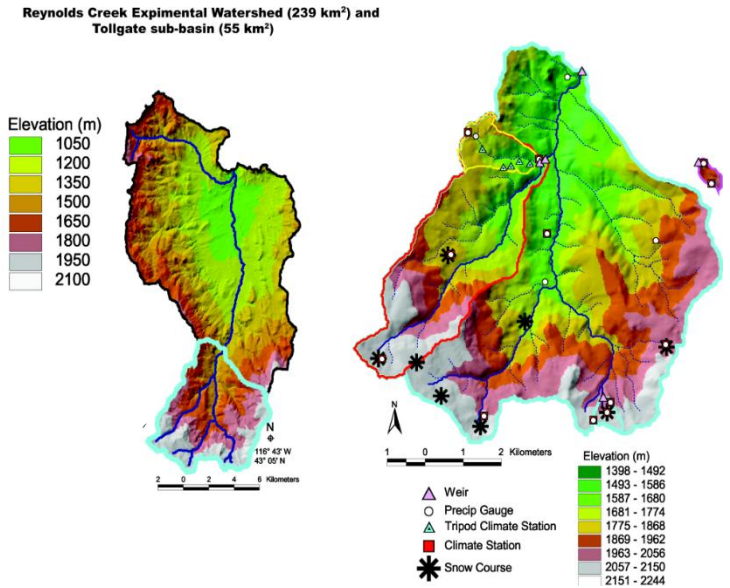
Dry Creek: Significant correlations between snow fraction and runoff ratio in all subbasins

CRHM as a Virtual Laboratory



CRHM





Can we reproduce Snow Fraction – Runoff Ratio relationship with CRHM?

What mechanisms are responsible for variability in hydrology response to declining snowpack?

The 40-year RCEW Model Forcing Dataset

- The majority of model forcing datasets lack spatiotemporal resolution and accuracy for determining precipitation phase.
- RCEW dense station network (~1 site per 6 km^2) used to distribute variables.
  - Spatial Modeling for Resources Framework (SMRF; Havens et al., 2017)
- ~35 TB stored in Zarr format, soon to be submitted for publication

Period of record: 1984 – 2023 (to be periodically updated)

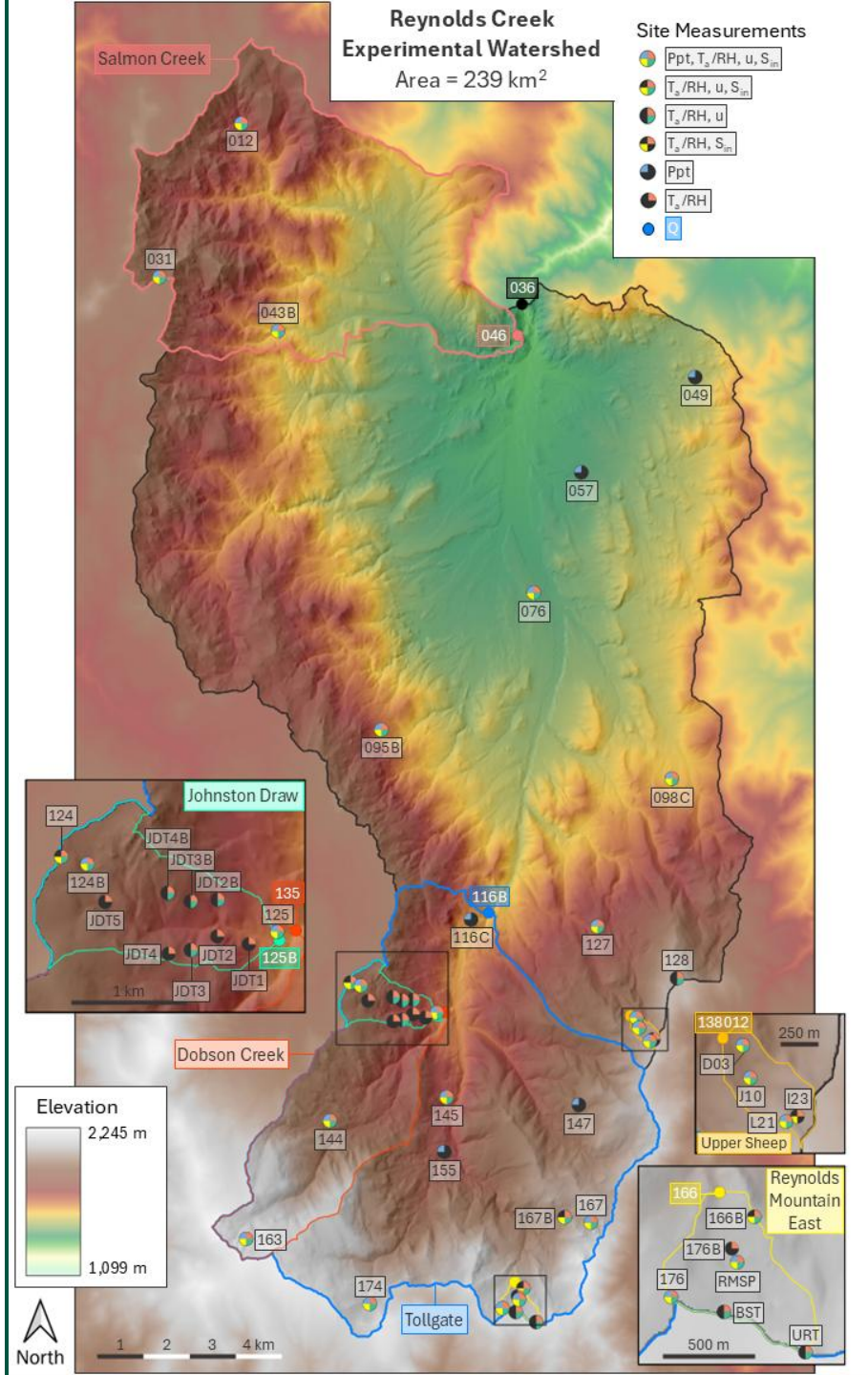
Temporal resolution: Hourly

Spatial resolution: 10-meters

Variables:

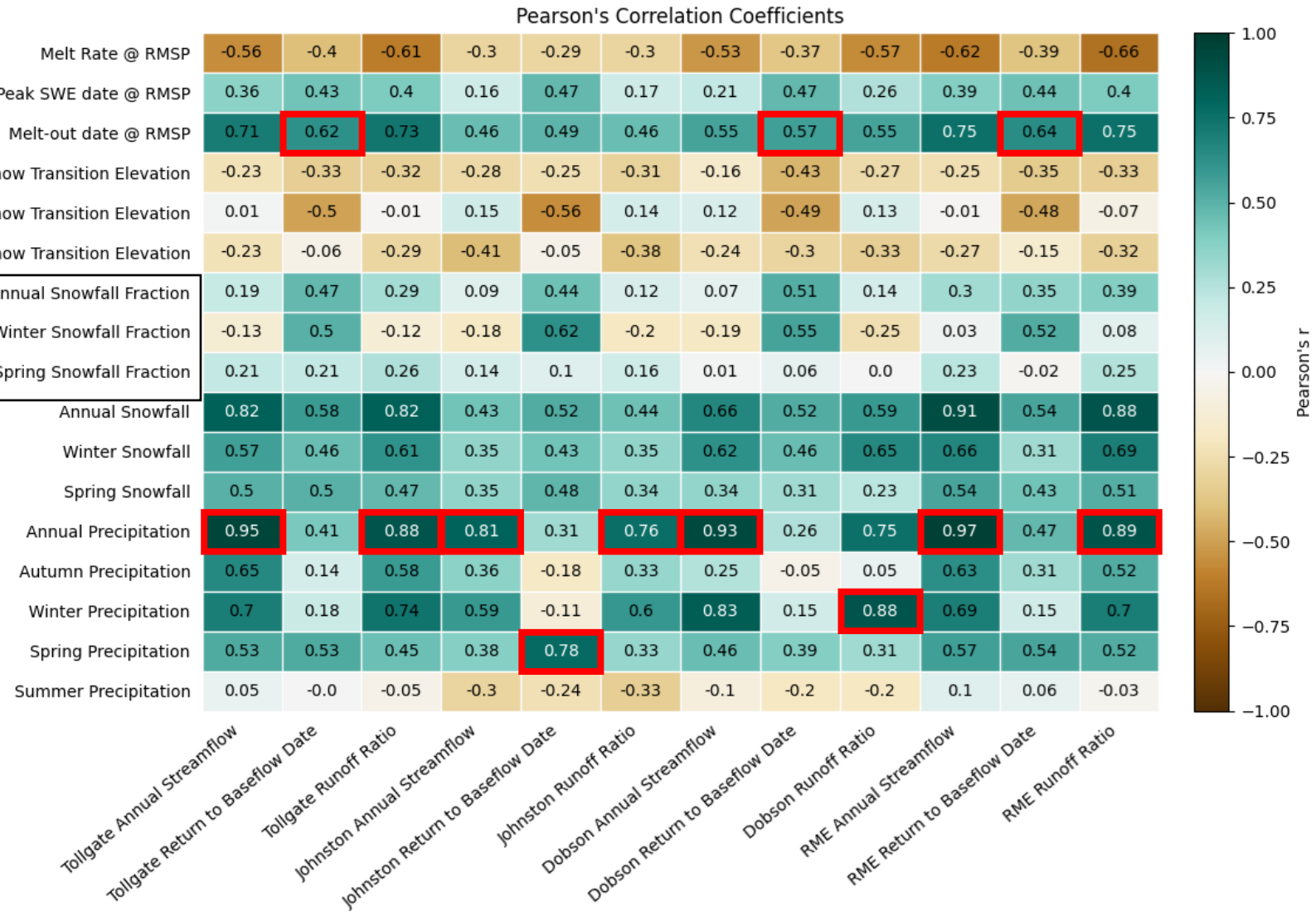
1. Air temperature
2. Vapor pressure (i.e., relative humidity)
3. Wind speed
4. Wind direction
5. Incoming shortwave irradiance
6. Incoming longwave
7. Precipitation
8. Percent snow
9. New snow density
10. Precipitation temperature (wet-bulb)

github.com/USDA-ARS-NWRC/smrf

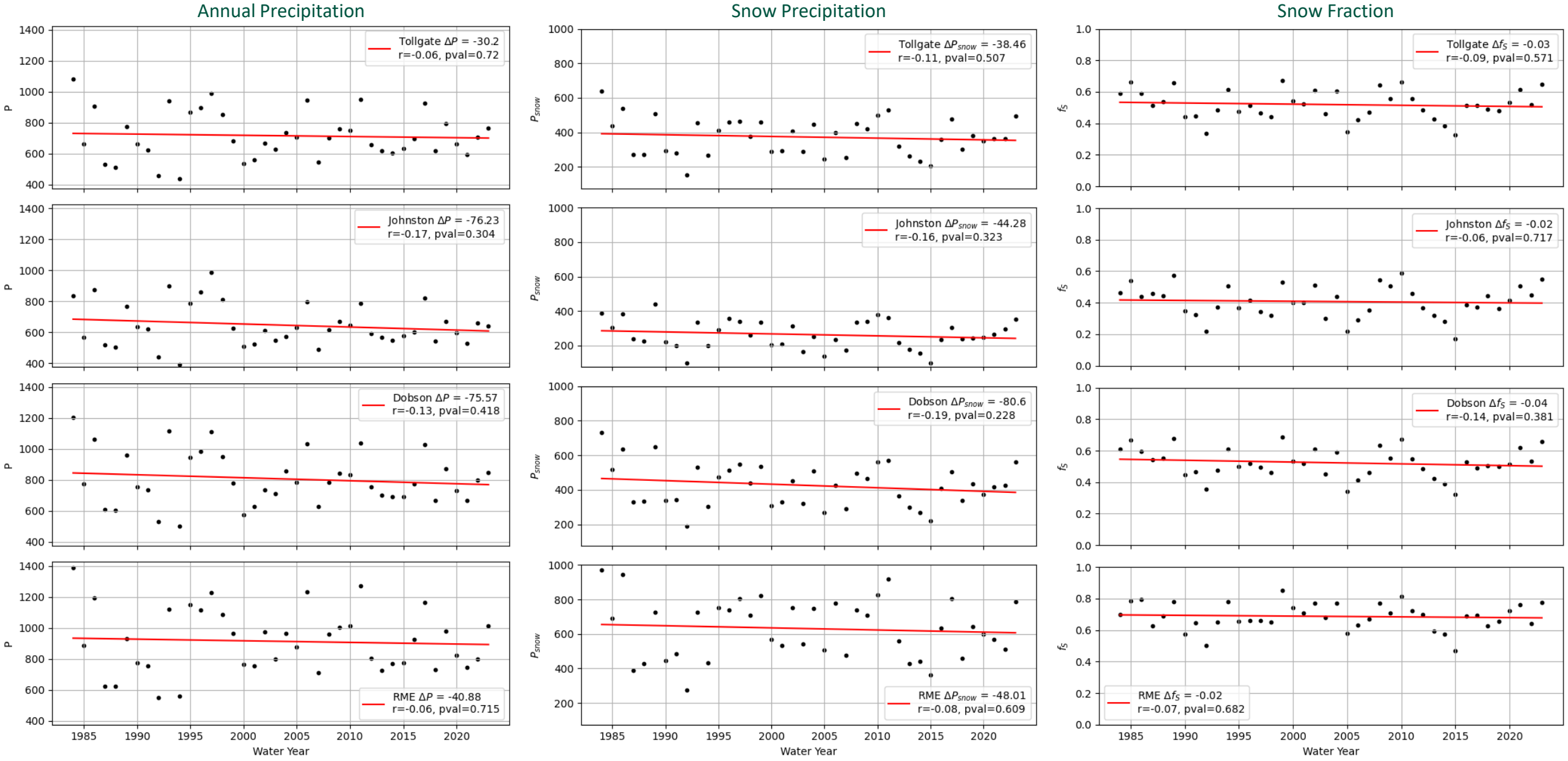


Snow Fraction doesn’t predict anything!

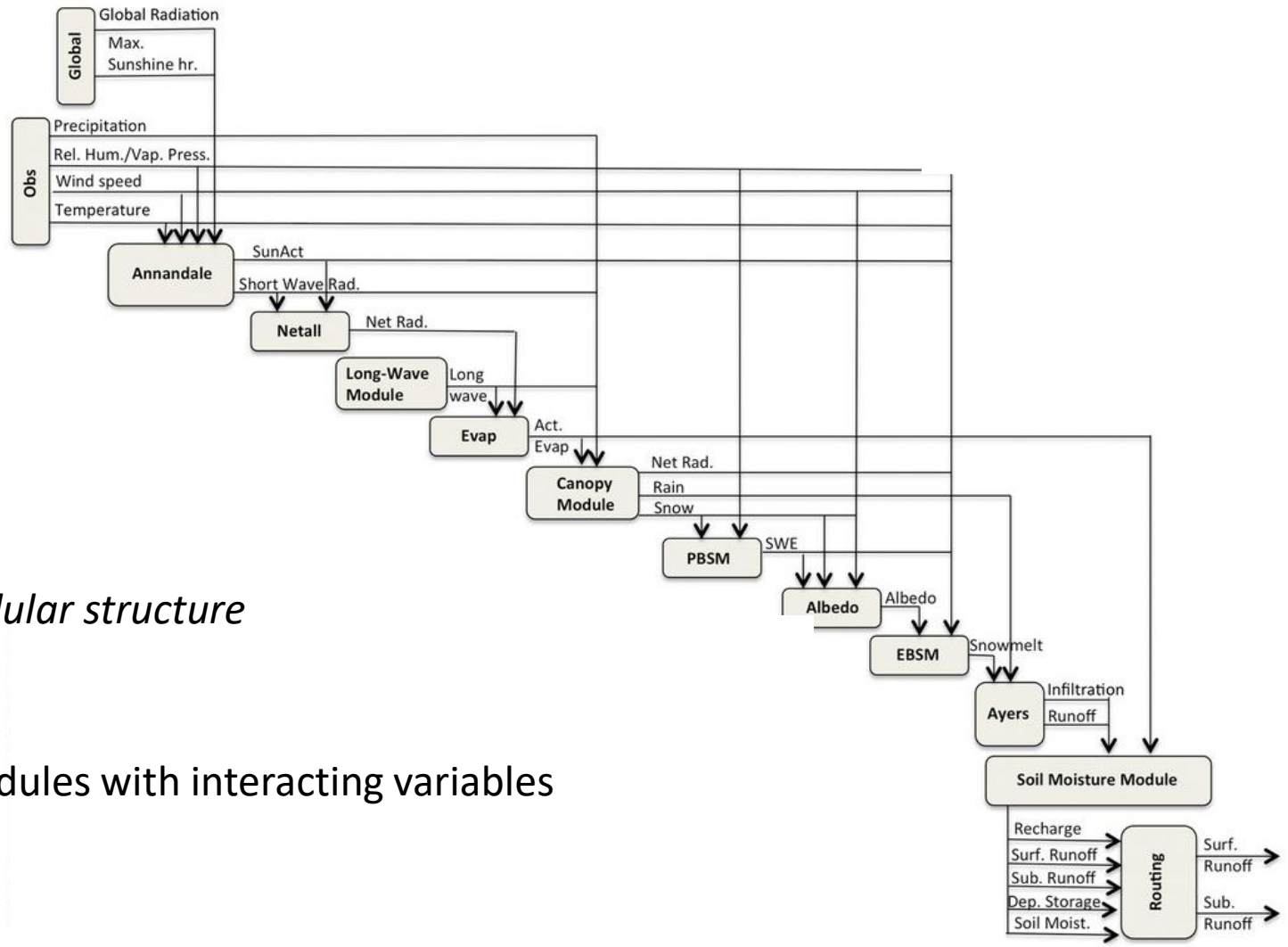
*RMSP => Reynolds Mountain Snow Pillow



Random Extra Information I



Cold Regions Hydrologic Modeling Platform (CRHM)

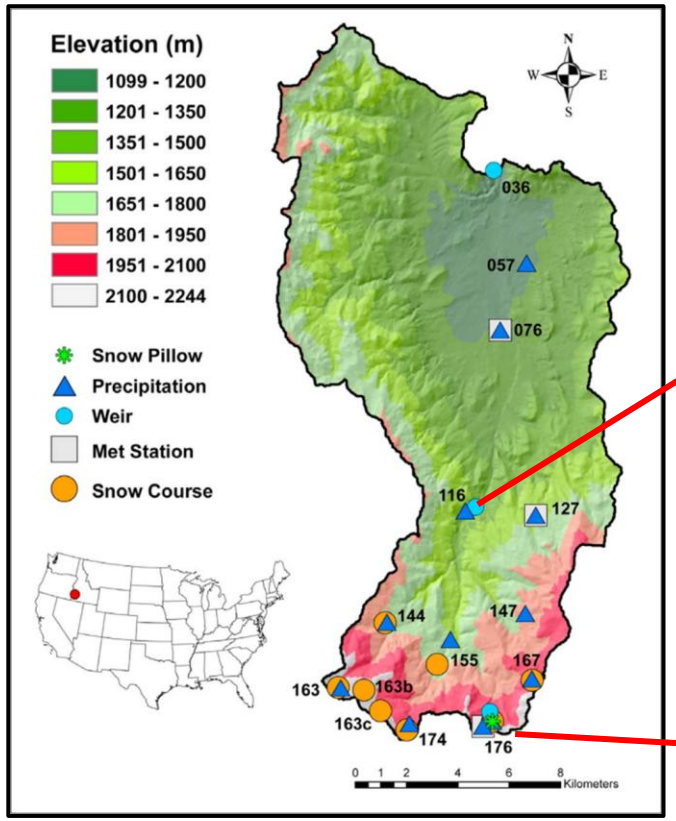


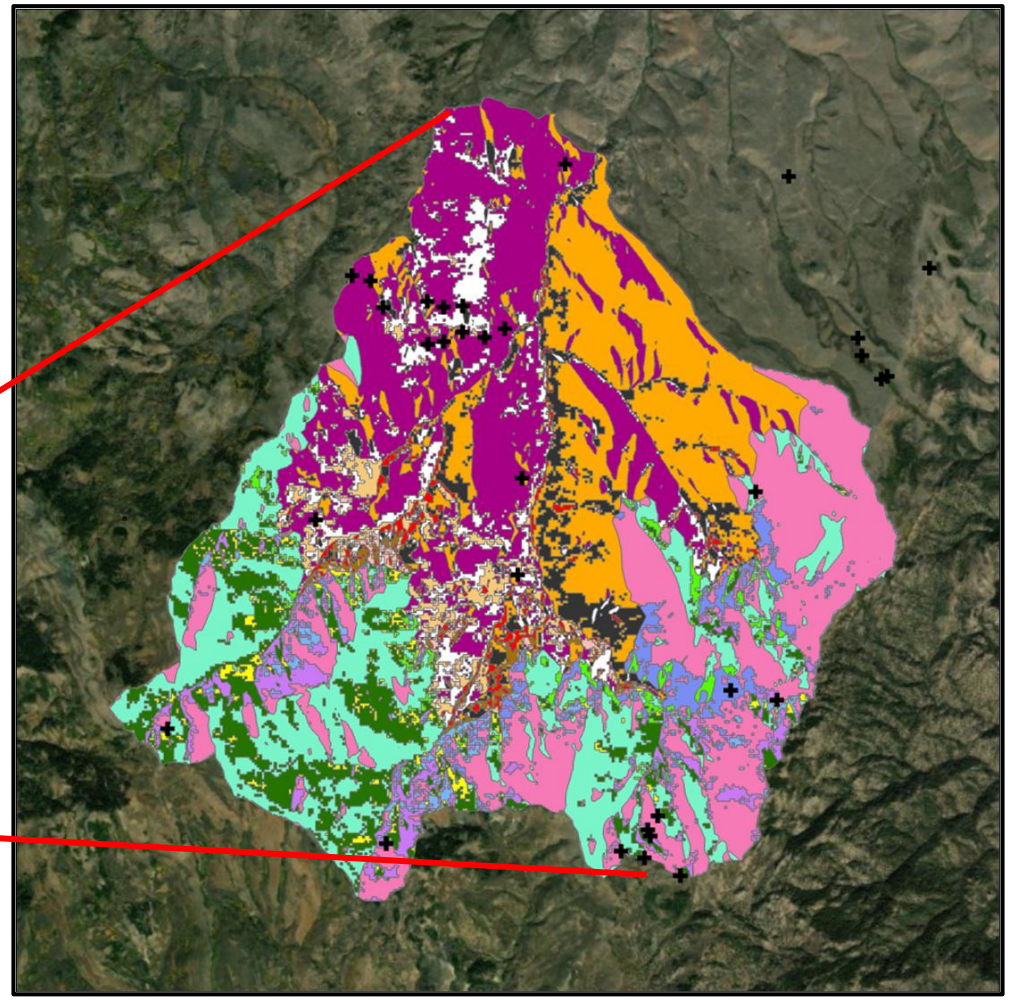
- CRHM - *Modular structure*

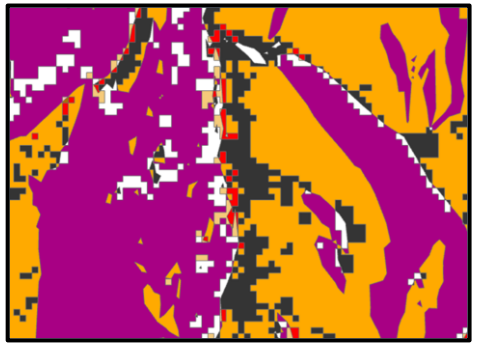
- Series of modules with interacting variables

(Pomeroy et al, 2022; Krogh et al., 2015)

Hydrologic Response Units



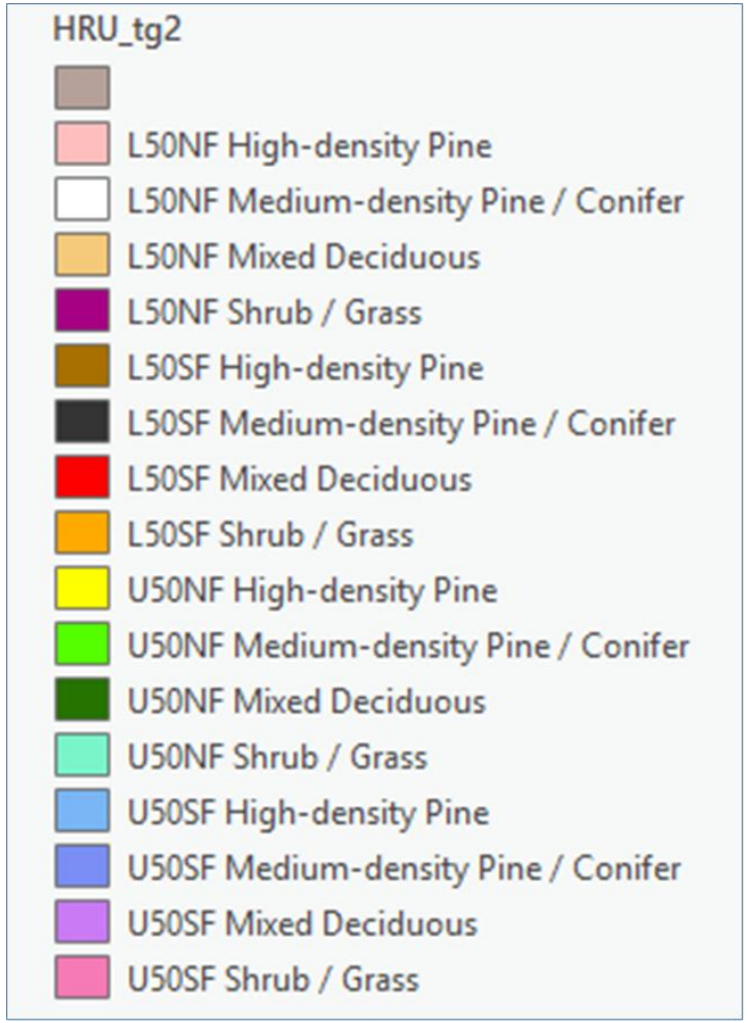




Forcing observations from stns. 125, 144, 145, 163, 167, 174, 176

Seyfried et al. 2015. Geographic database, Reynolds Creek Experimental Watershed, Idaho, United States. *Water Resources Research.* 37.11. 2825-2829.

Hydrologic Response Units - Method



- Elevation – High, Low
- Aspect – North, South
- Vegetation – Pine, Conifer, deciduous, Grass

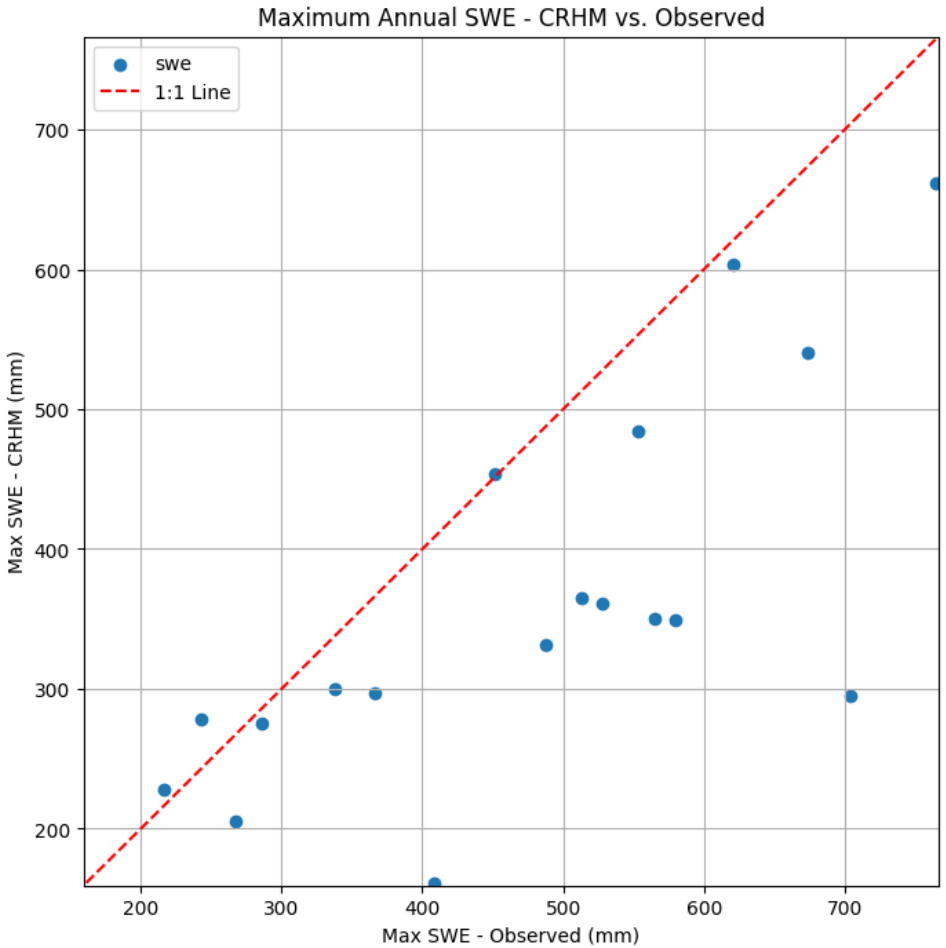
Parameters

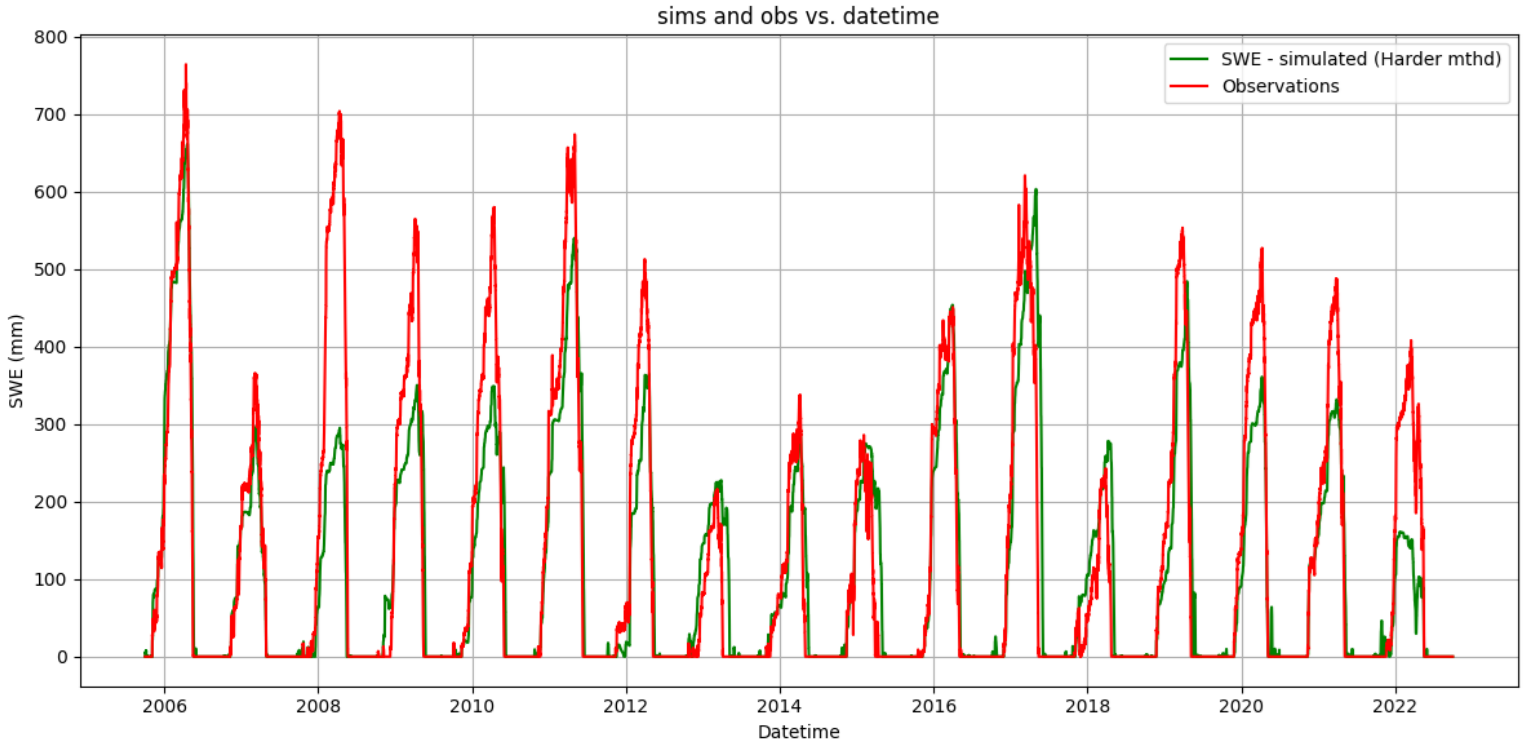
- Rain/snow partitioning accomplished using psychrometric method from Harder & Pomeroy, 2013.

- Soil storage metrics associated with vegetation classes in RME are documented in Seyfried et al., 2009.

Seyfried et al. 2009. Simulated soil water storage effects on streamflow generation in a mountainous snowmelt environment, Idaho, USA. *Hydrological Processes.* 23. 858-873. DOI: 10.1002/hyp.7211

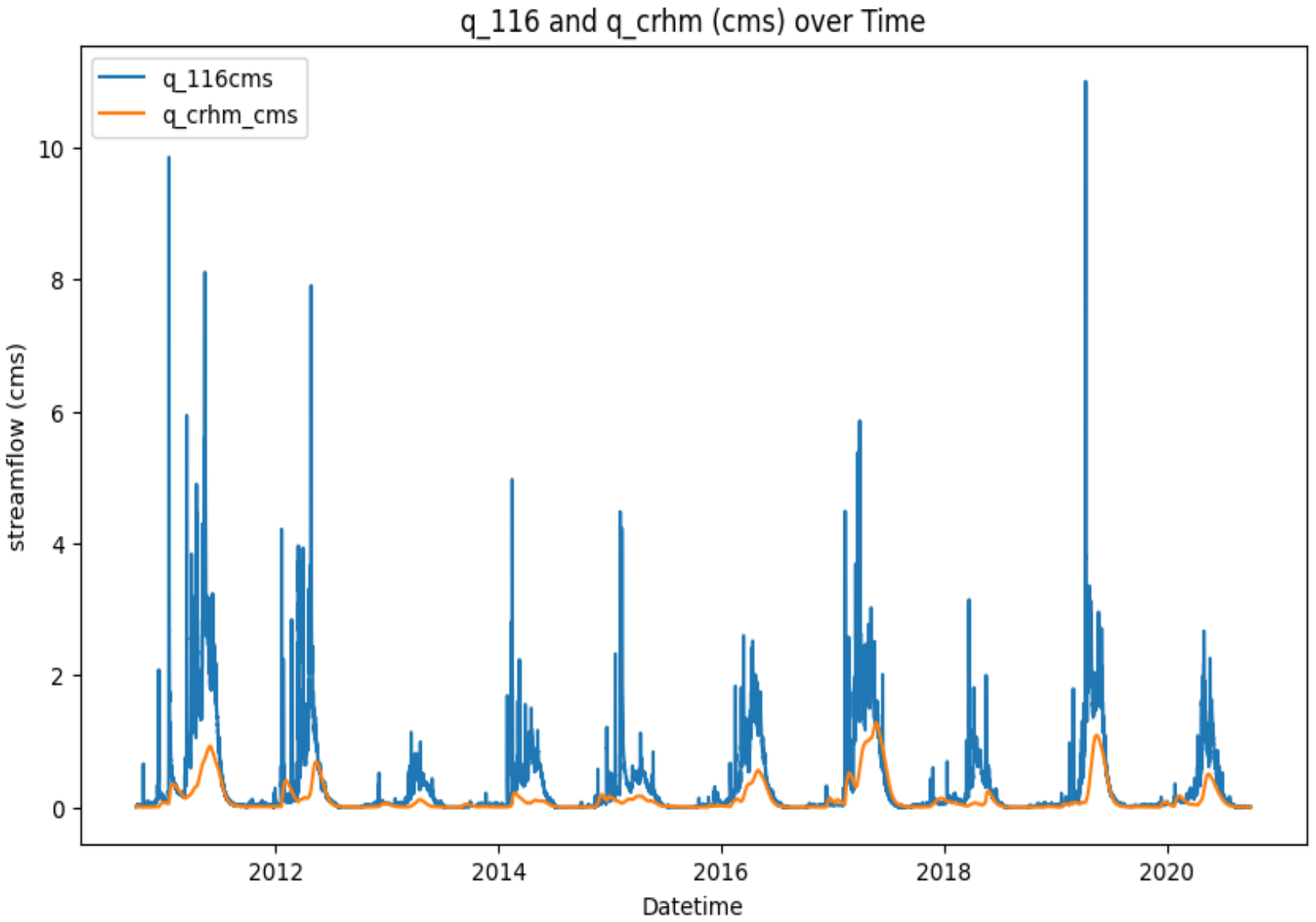
Simulation Findings - SWE (in-progress)

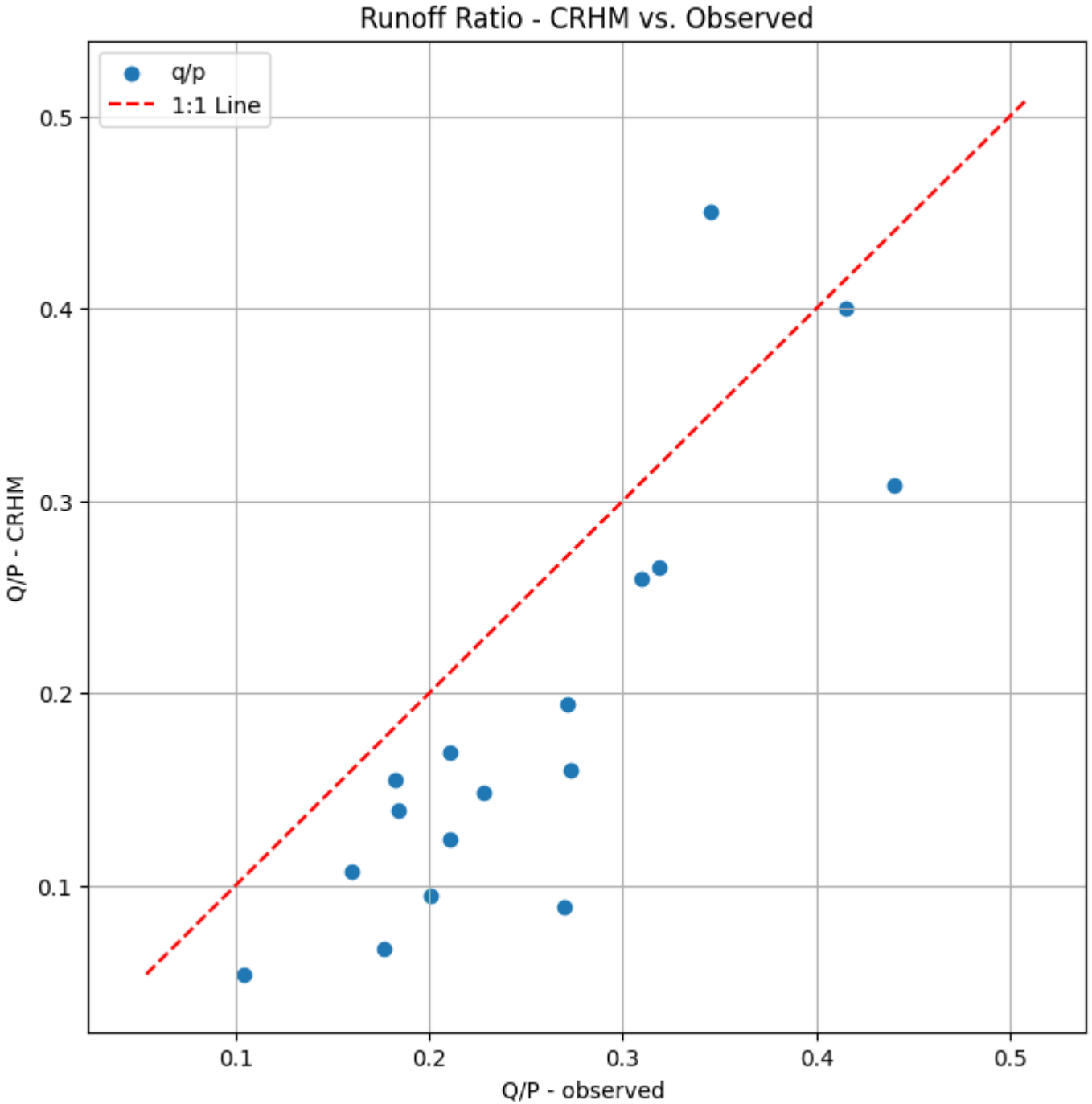




Observations from RME snow pillow (rmsp3)

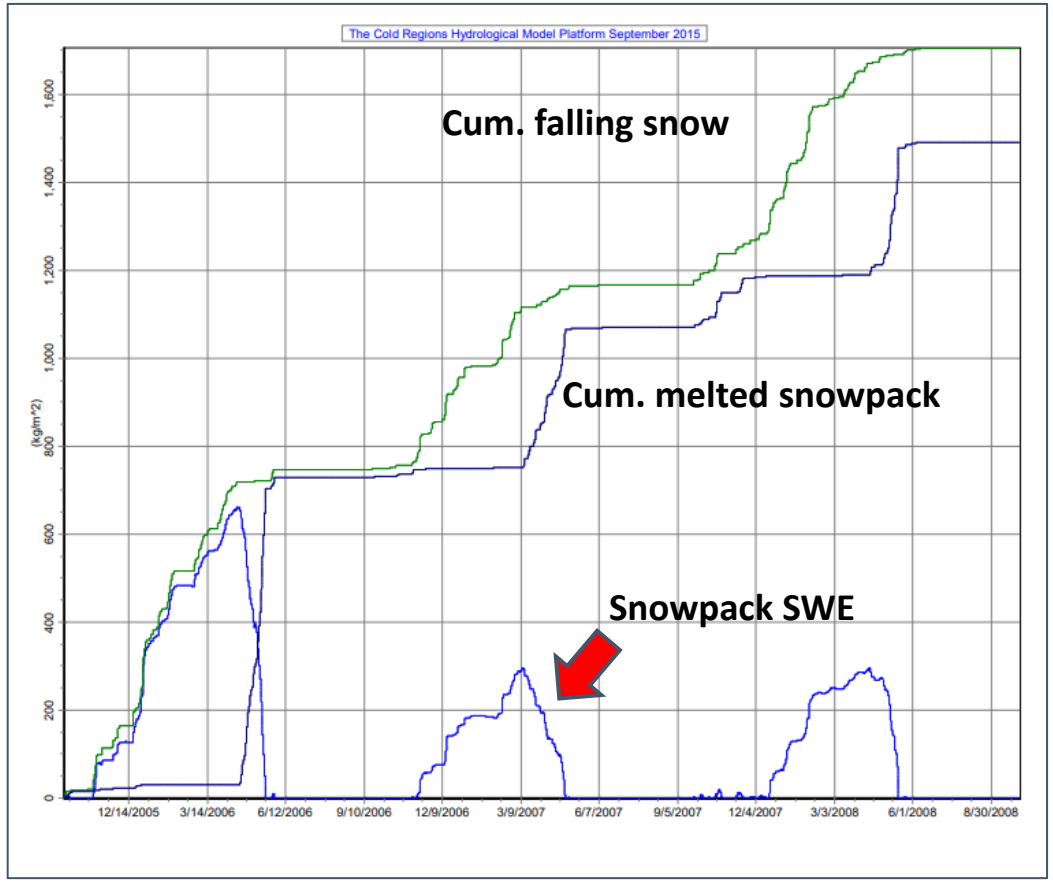
Simulation Findings - basinflow (in-progress)



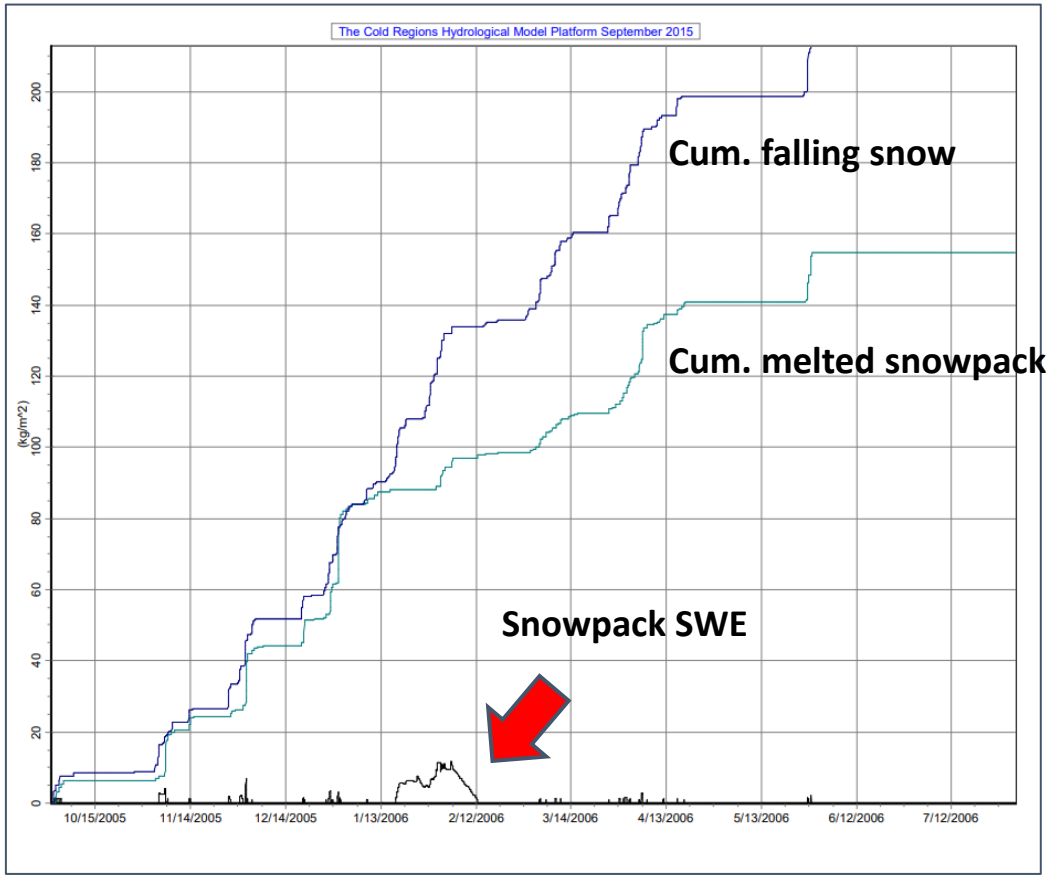

Runoff Ratio - CRHM vs. Observed
q/p
1:1 Line
0.5
0.4
0.3
0.2
0.1
Q/P - CRHM
0.1
0.2
0.3
0.4
0.5
Q/P - observed

SWE challenges cont.

Good: HRU_15 - Upper elevation, south-facing mixed-deciduous
(contains snow pillow)



Bad: HRU_13 - Upper elevation, south-facing high-density pine

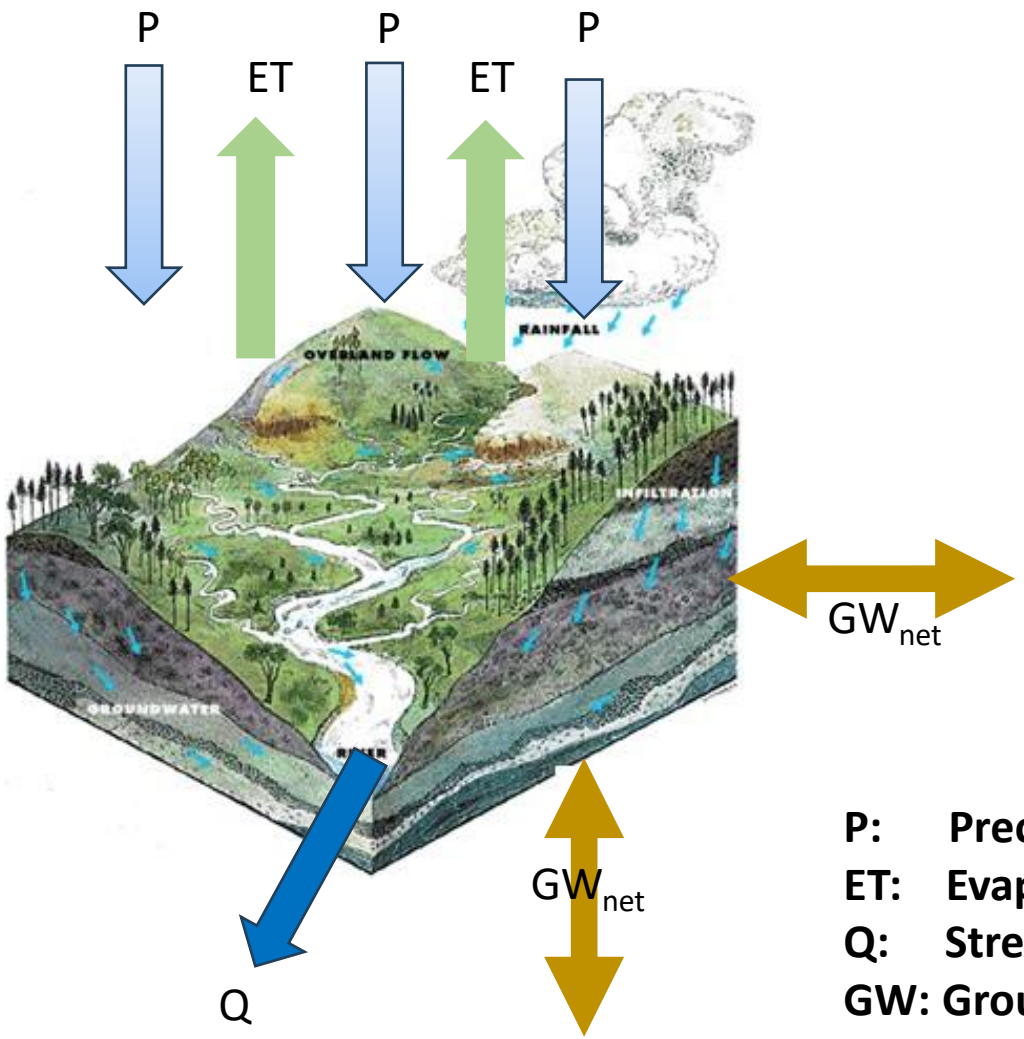


Key Points

- While average snow fraction may be associated with average runoff ratio **across catchments**, declining snow fraction **within a catchment** is not a consistent predictor of runoff ratio

- We are using CRHM to explore why, but are not yet successful

Water Balance Basics



$$P = ET + Q + GW_{net} + \Delta S$$

$$1 = \frac{ET}{P} + \frac{Q}{P}$$

Runoff Fraction

$$P = Rain + Snow$$

$$1 = \frac{Rain}{P} + \frac{Snow}{P}$$

Snow Fraction

P: Precipitation
ET: Evapotranspiration
Q: Streamflow (discharge, runoff)
GW: Groundwater

Dry Creek Experimental Watershed