

Plant Water Use Across the RSTZ and other stuff

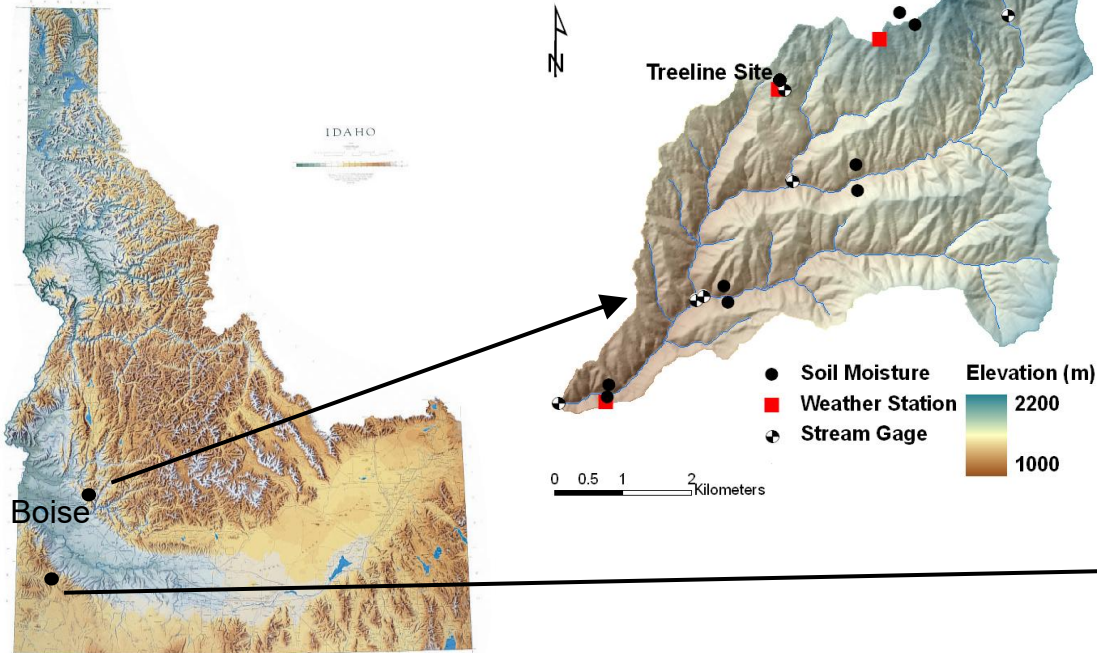
James McNamara
Department of Geosciences
Boise State University

1 MARCH 2026

Reynolds Creek and Dry Creek

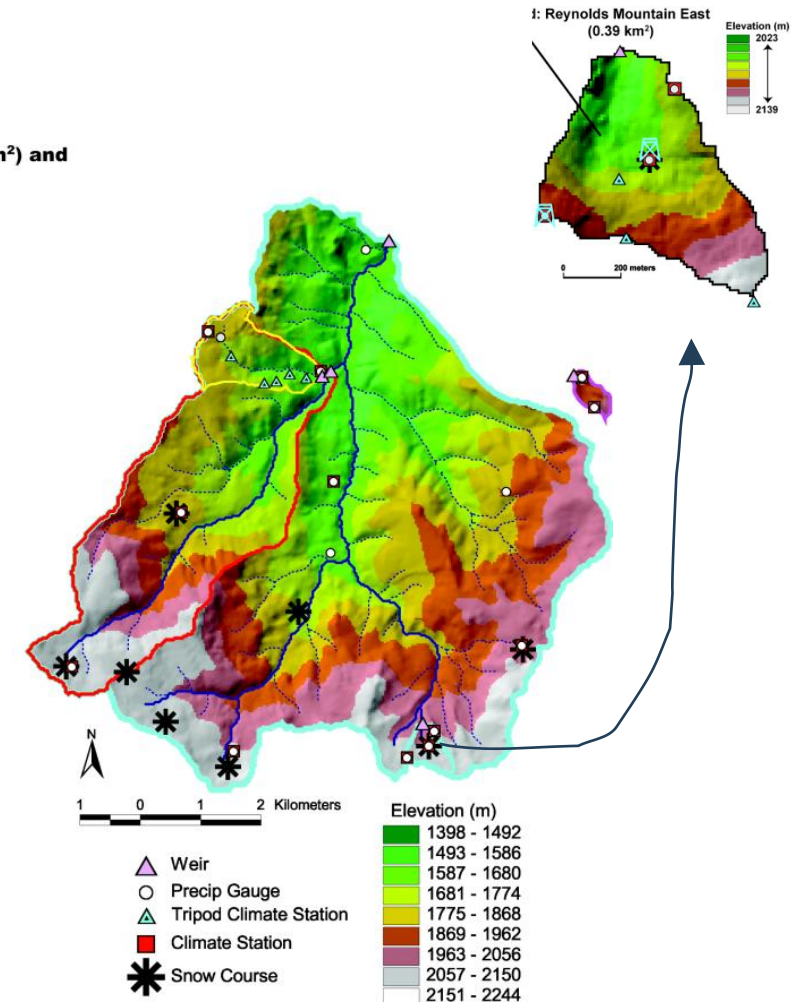
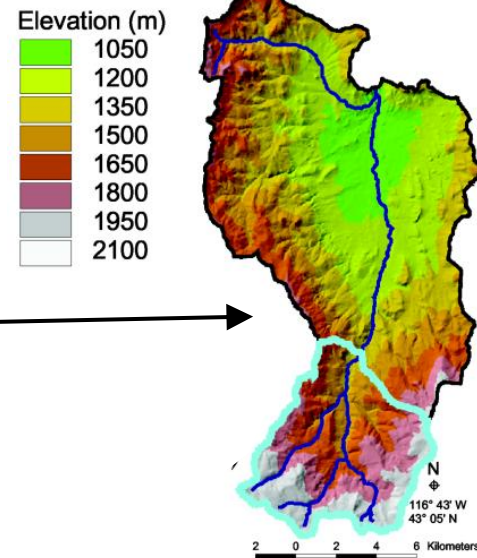


Since 1998
Dry Creek Experimental Watershed



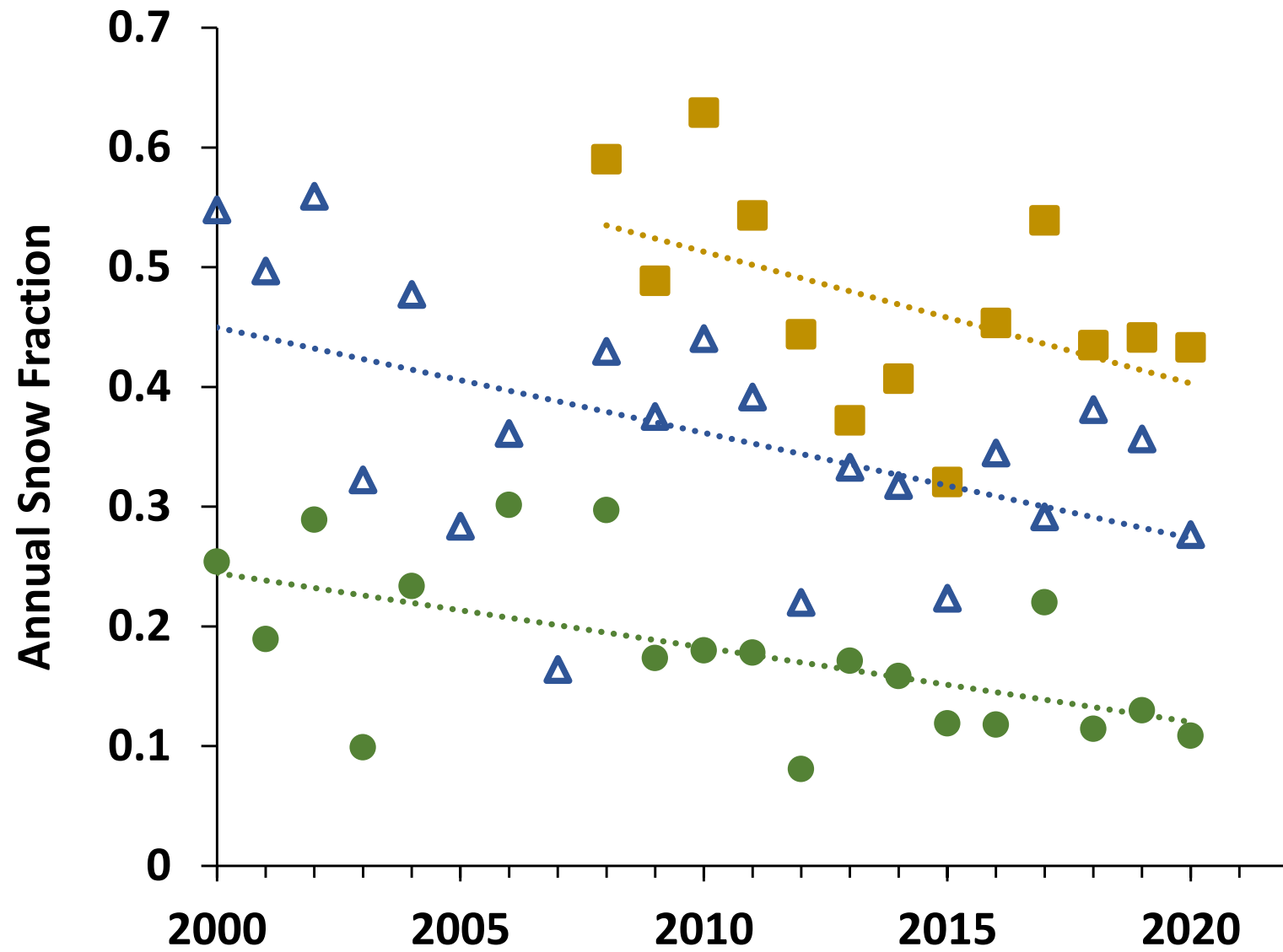
Since 1965

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





Declining Snow Fraction



Motivation



nature climate change

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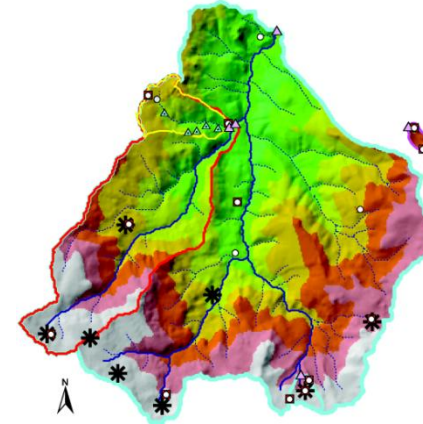
A precipitation shift from snow towards rain leads to a decrease in streamflow

[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**

Updates

- Reynolds Creek 40 year dataset – Published and available
- Reynolds Creek CRHM Modeling
- Dry Creek Snow-Flow relationships
- Dry Creek Water Uptake experiments

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 km²) 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

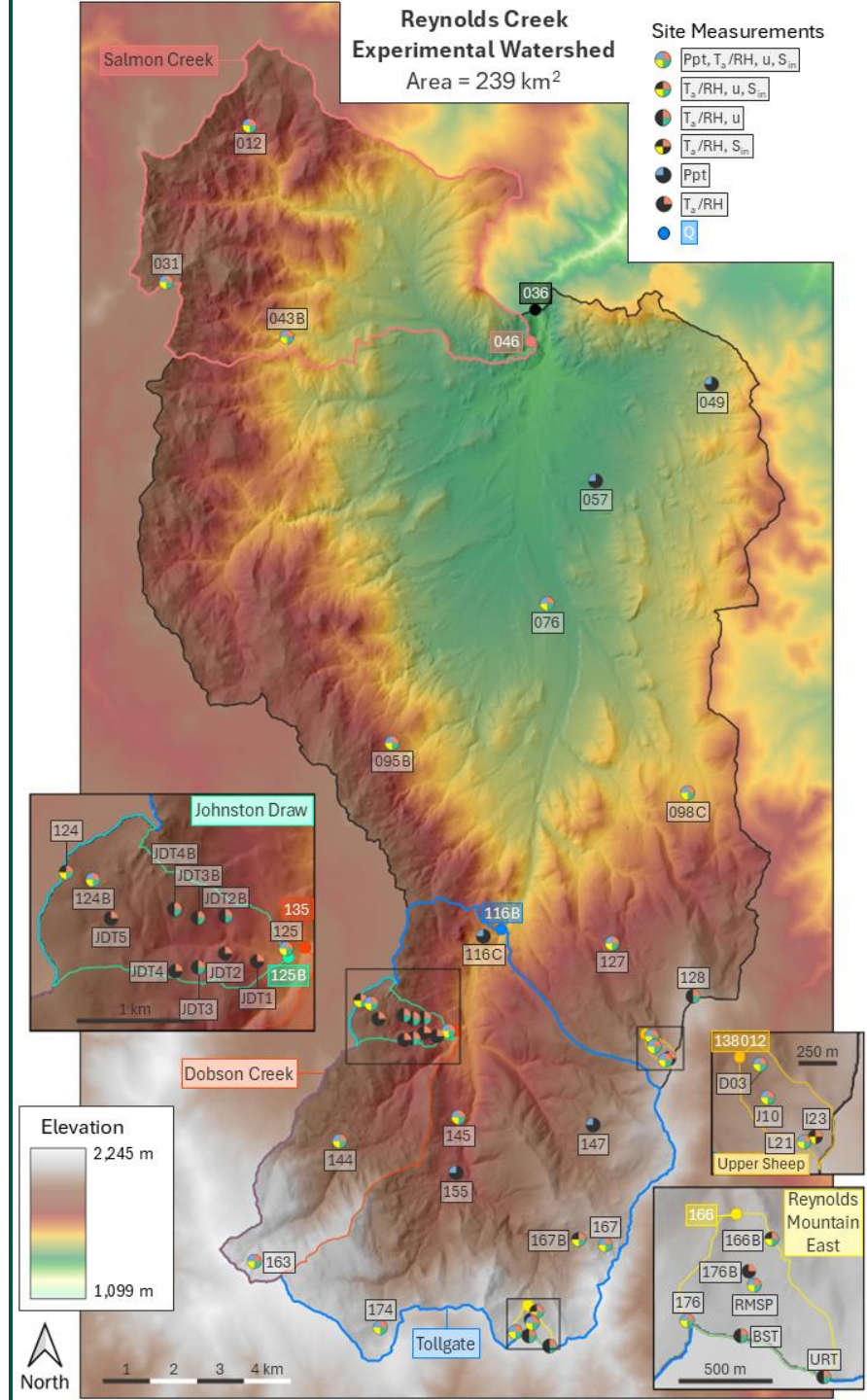
Spatial resolution: 10-meters

Variables:

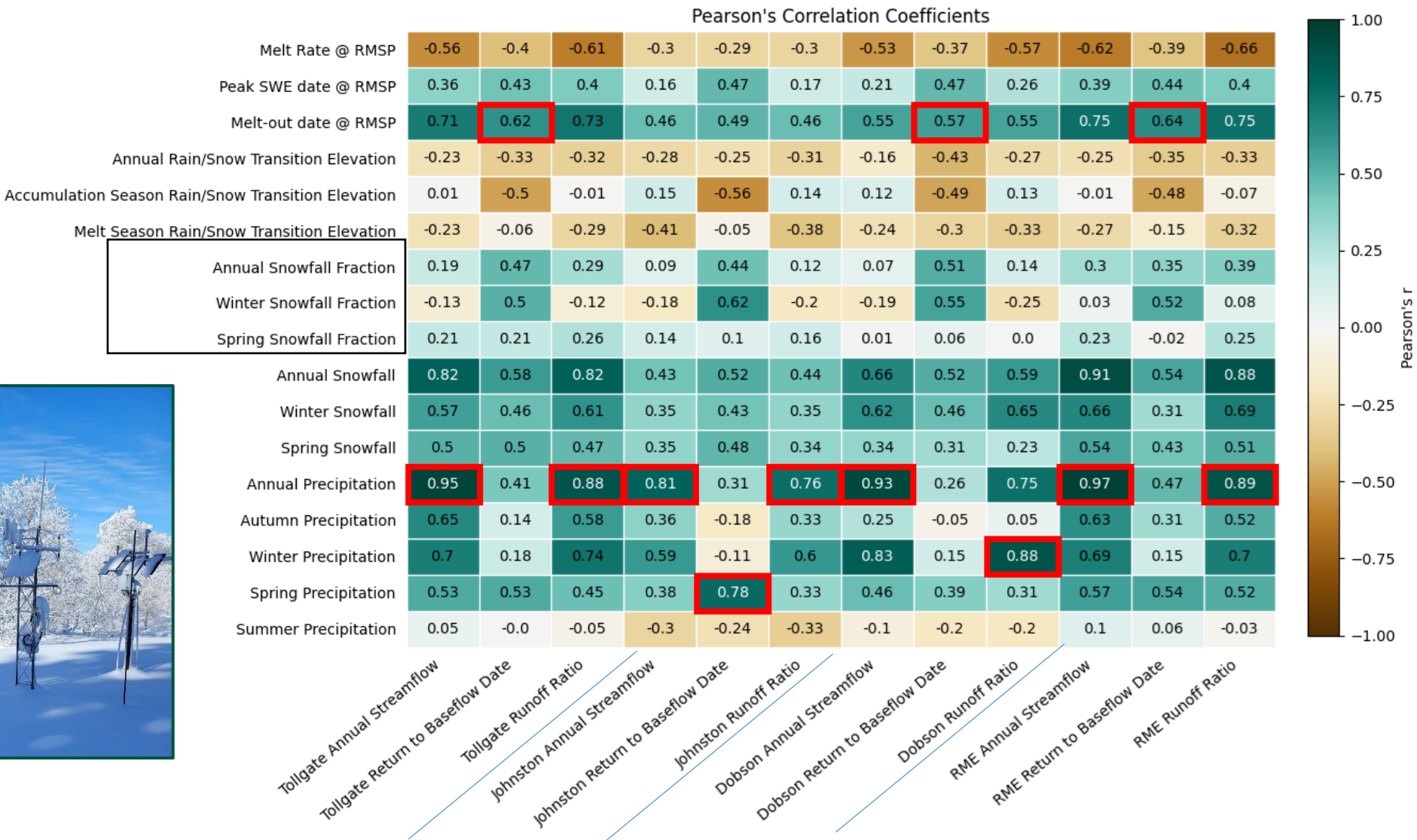
1. Air temperature
2. Vapor pressure (i.e., relative humidity)
3. Wind speed
4. Wind direction
5. Incoming shortwave irradiance
6. Incoming longwave
7. Precipitation
8. Percent snow
9. New snow density
10. Precipitation temperature (wet-bulb)



github.com/USDA-ARS-NWRC/smrf



No significant relationship between snow fraction and runoff efficiency

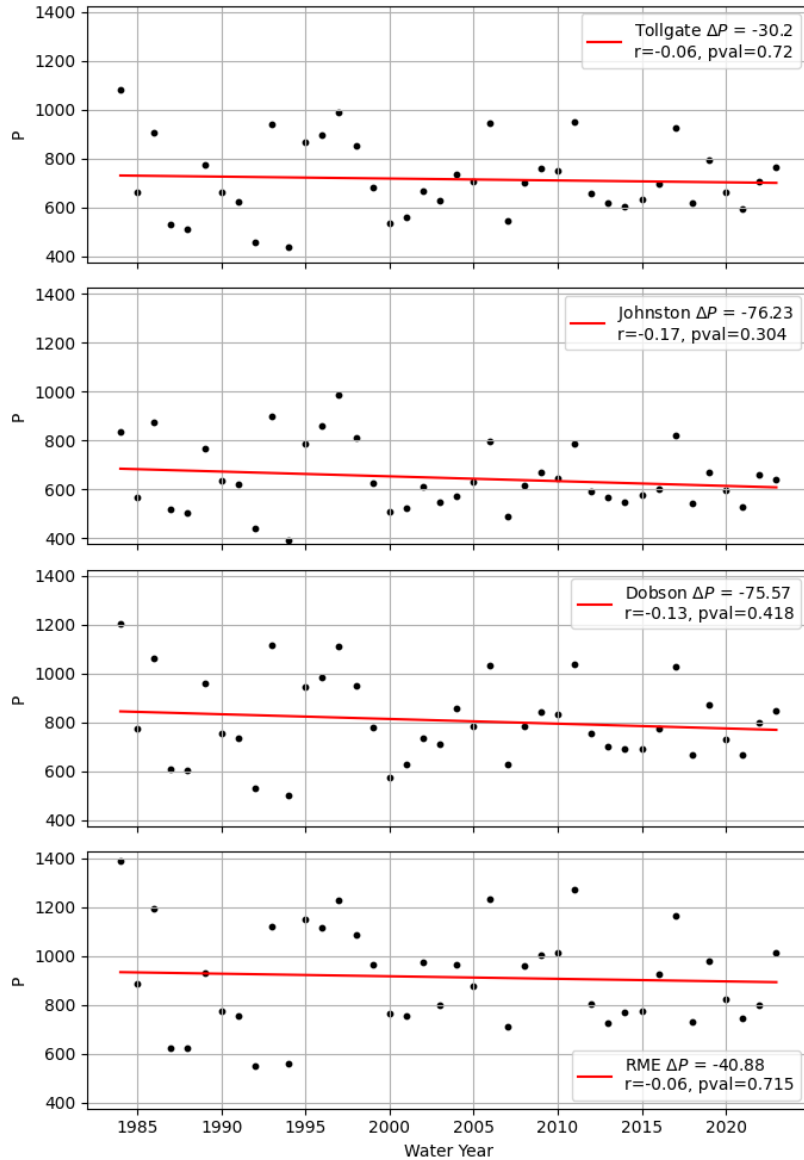


*RMSP => Reynolds Mountain Snow Pillow

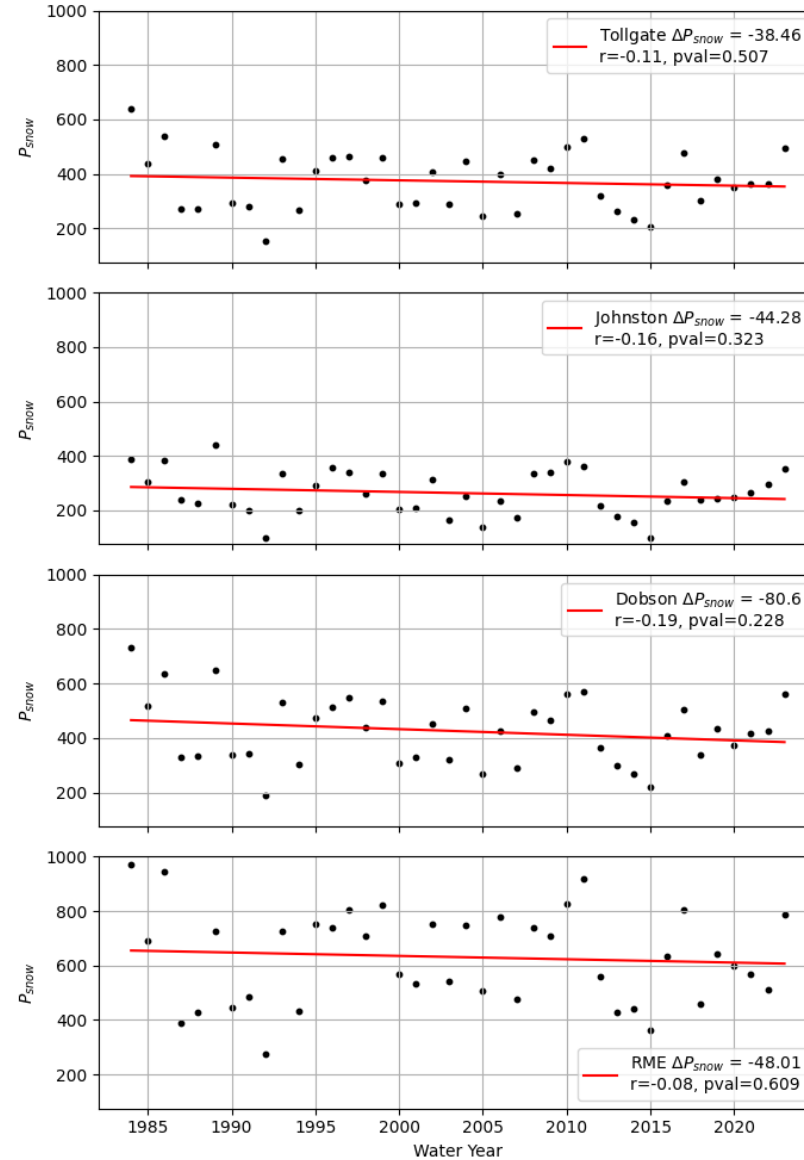


No trends in Snow Fraction

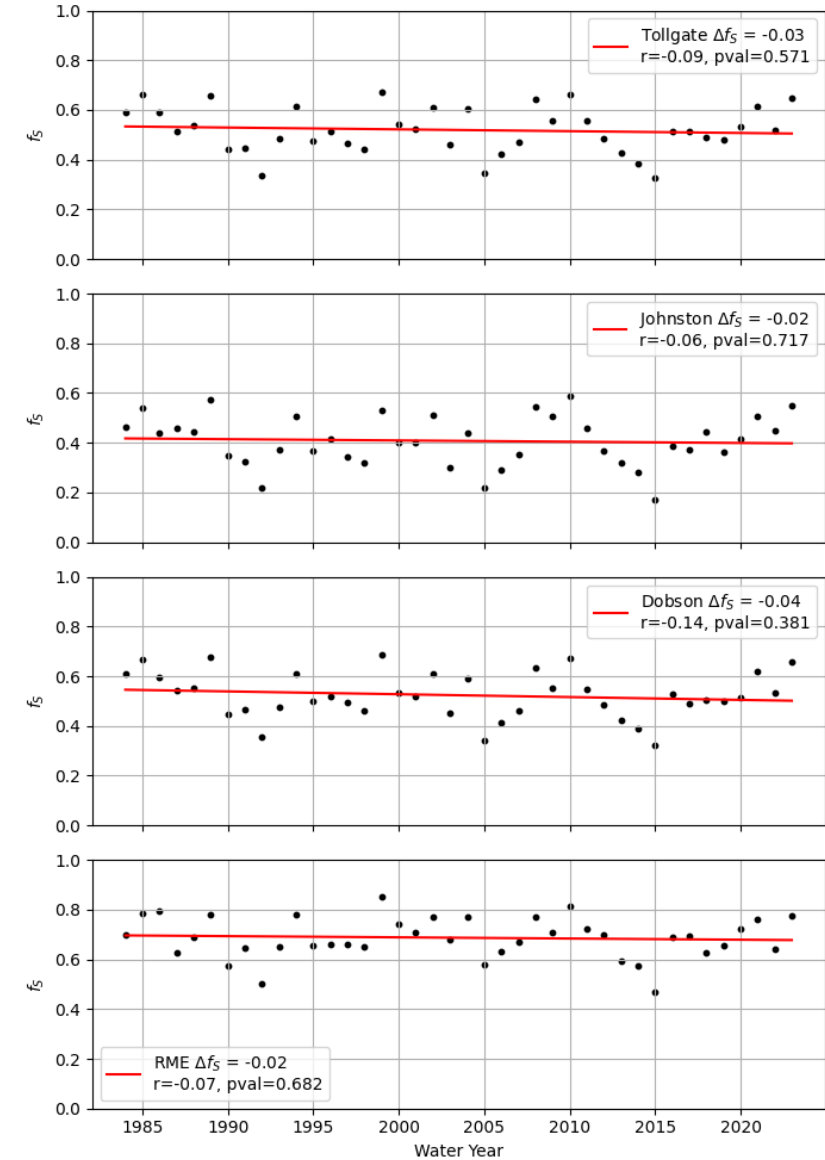
Annual Precipitation



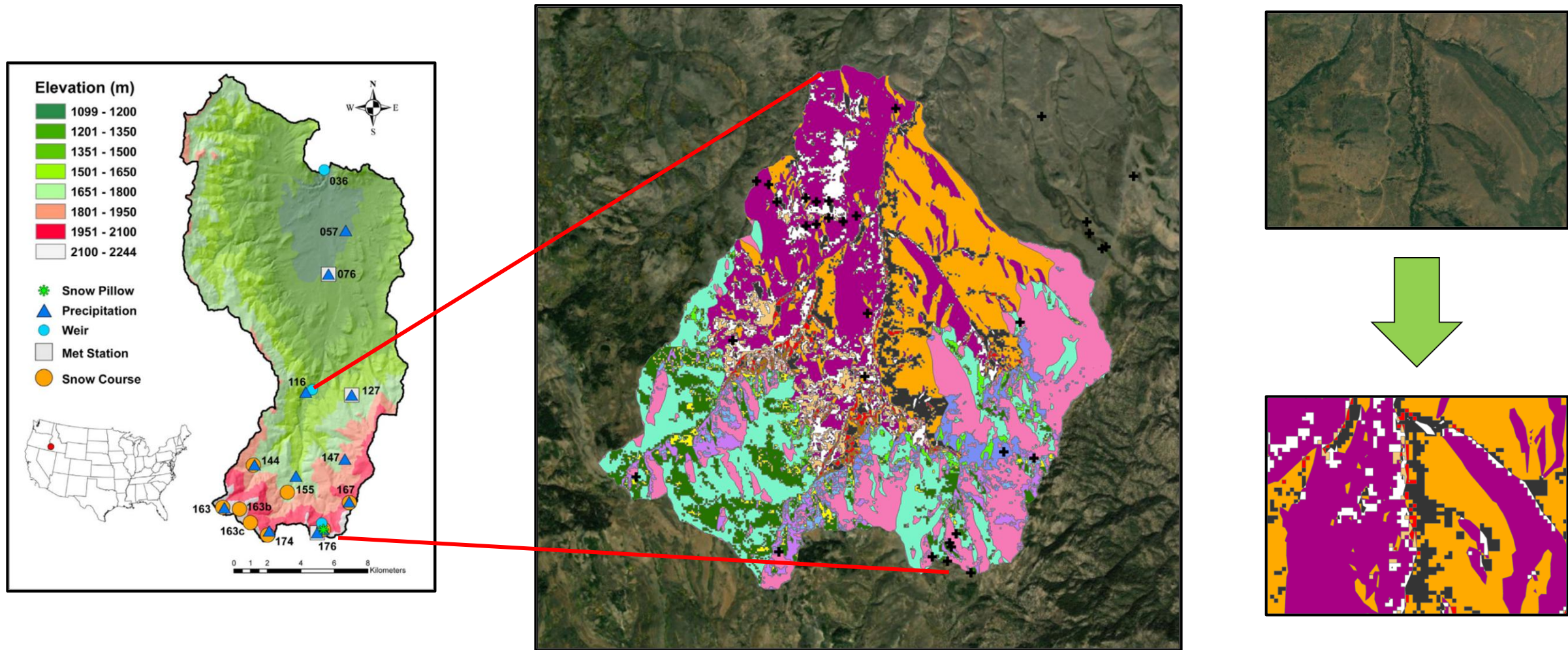
Snow Precipitation



Snow Fraction



CRHM at Tollgate – RCEW Hydrologic Response Units



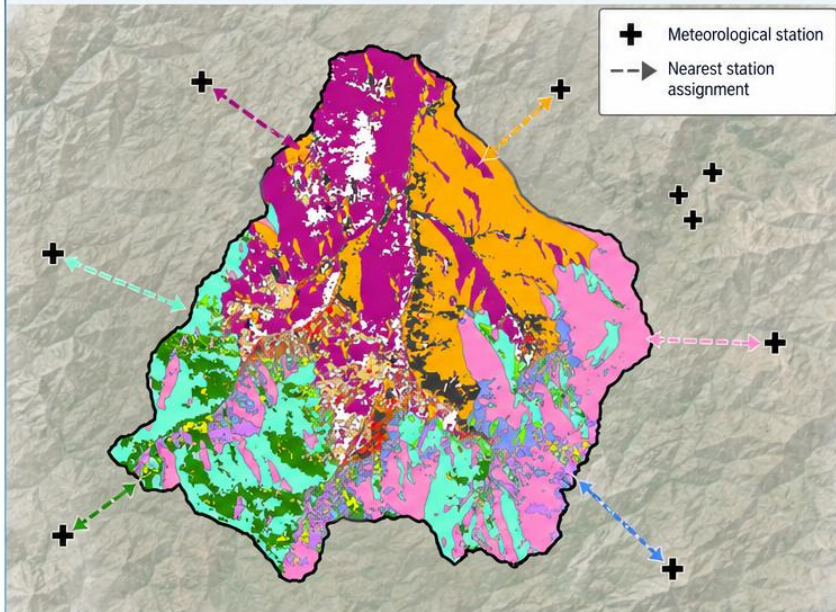
16 HRU's defined by 4 elevation zones and 4 aspects

Evaluate the value of spatially distributed inputs

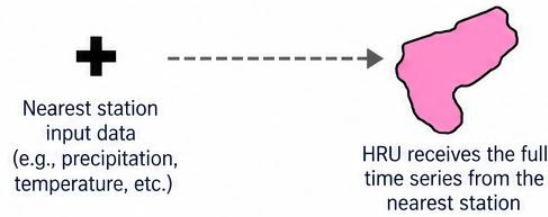
MS Student Jamie Turner

Model 1: Station Input (Nearest Station)

Each HRU inherits the input data from the nearest meteorological station.



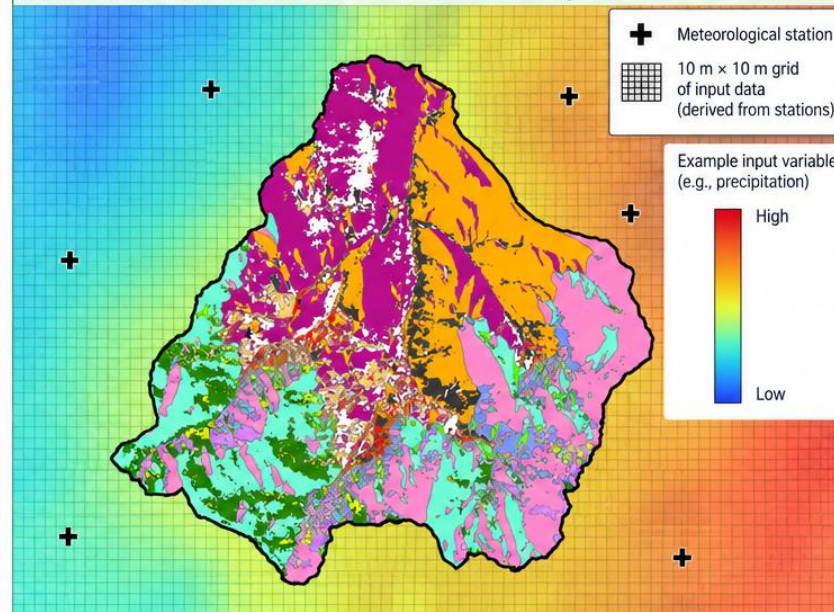
Example for one HRU (Model 1)



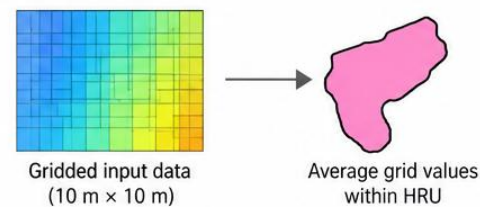
Model 1: Spatial variability is represented by assigning each HRU the input data from the nearest station.

Model 2: Distributed Input (Gridded)

Input data are estimated on a 10 m × 10 m grid using spatial statistics derived from the station data, and then averaged within each HRU.



Example for one HRU (Model 2)

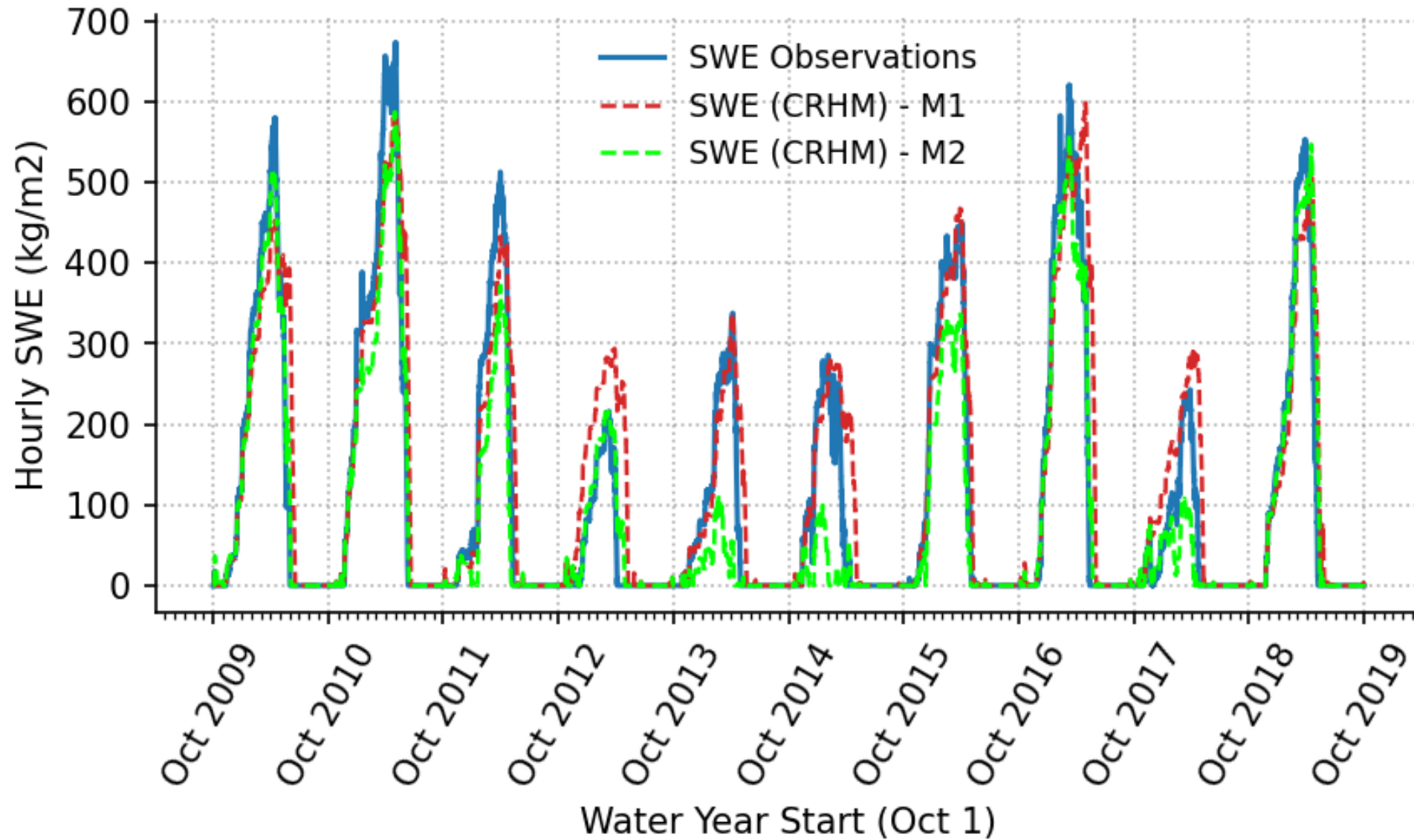


HRU input time series (spatial average)

Date	P (mm)
10/1	5.2
10/2	0.0
10/3	8.1
...	...

Model 2: Spatial variability is represented by spatially distributed input data, with HRU inputs equal to the average of 10 m × 10 m grid values within each HRU.

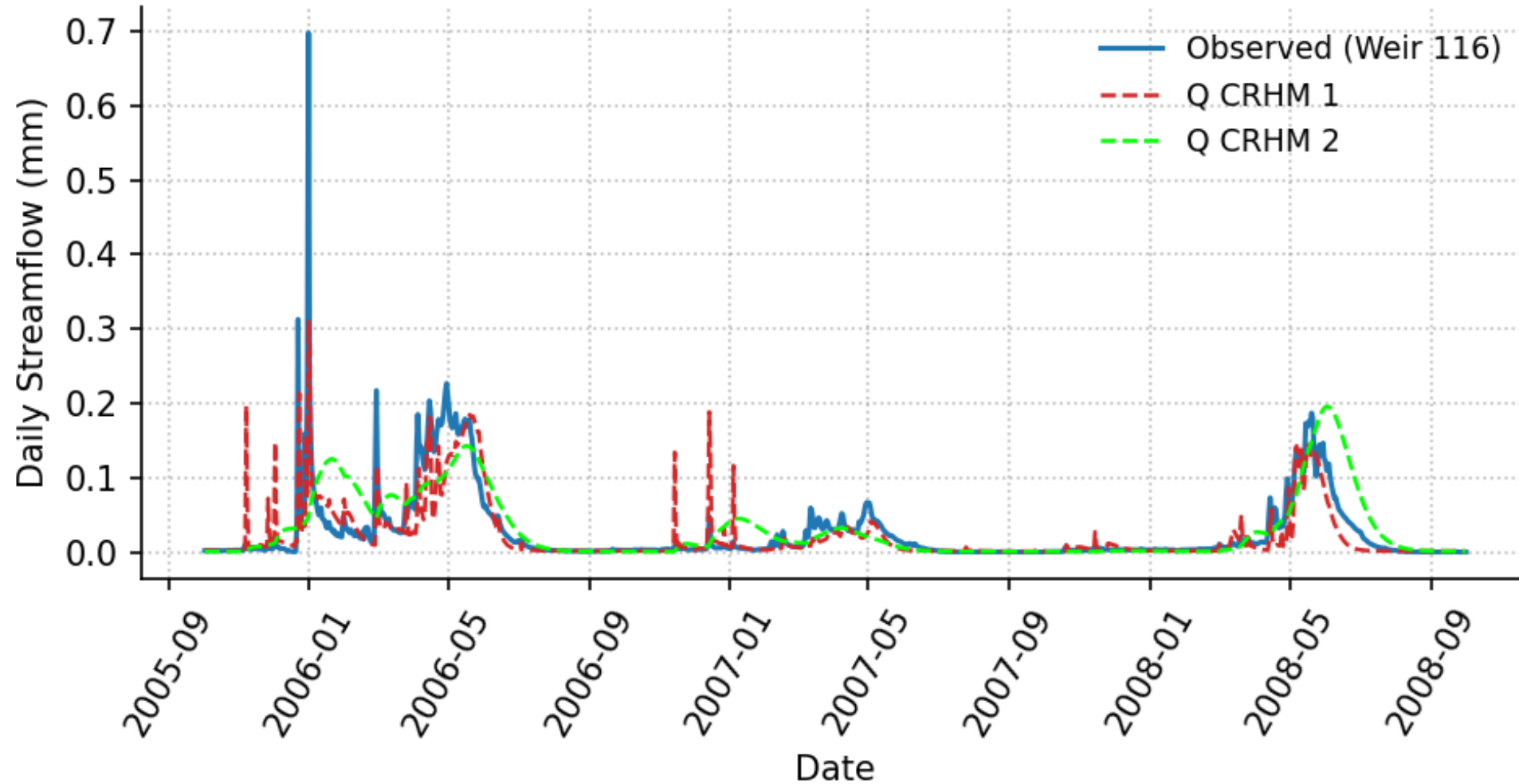
SWE - 10 yrs



**Similar performance
between models in
high SWE years**

**Station data
performed better
in low snow years**

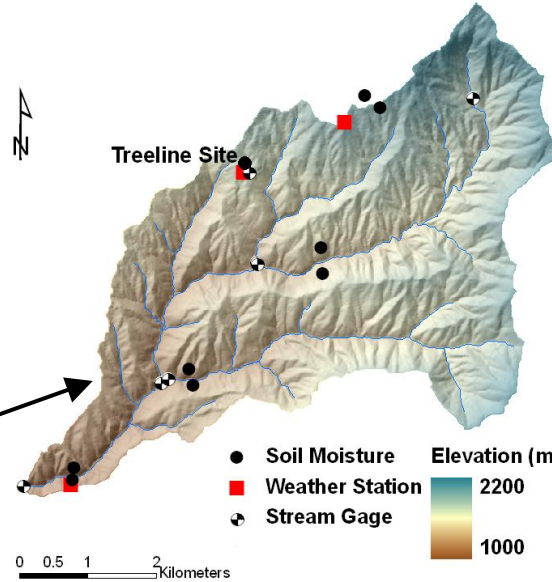
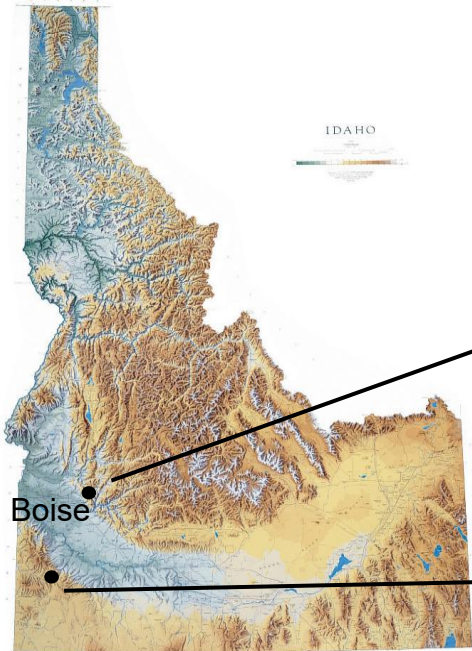
*Tollgate Q: Station data better captures short term dynamics. Neither work well in low SWE years



Reynolds Creek and Dry Creek

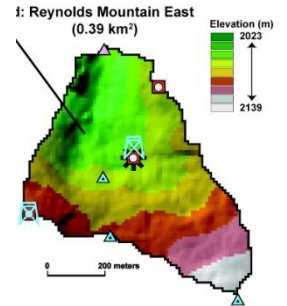
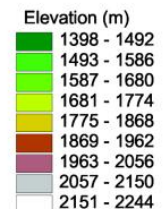
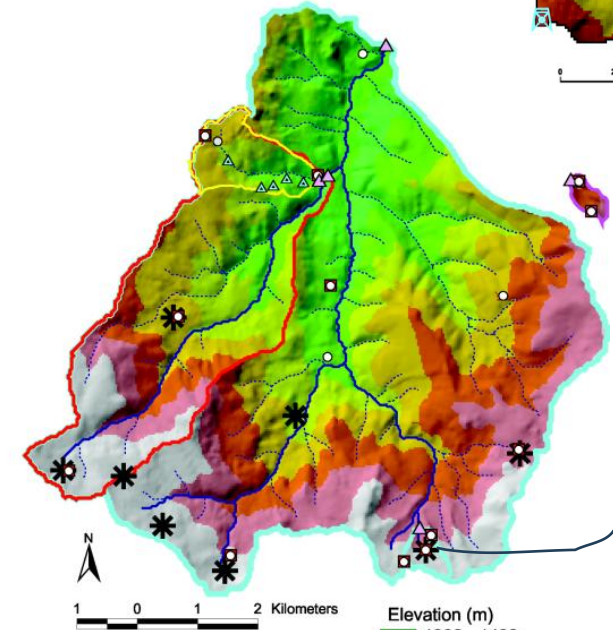
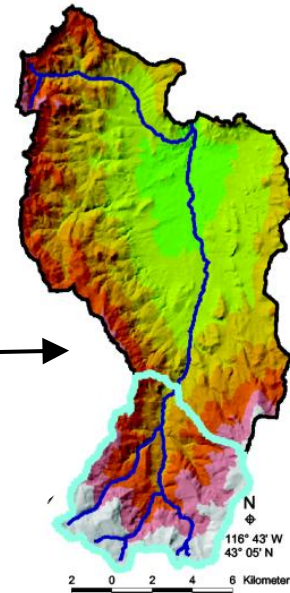
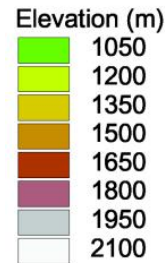


Since 1998
Dry Creek Experimental Watershed

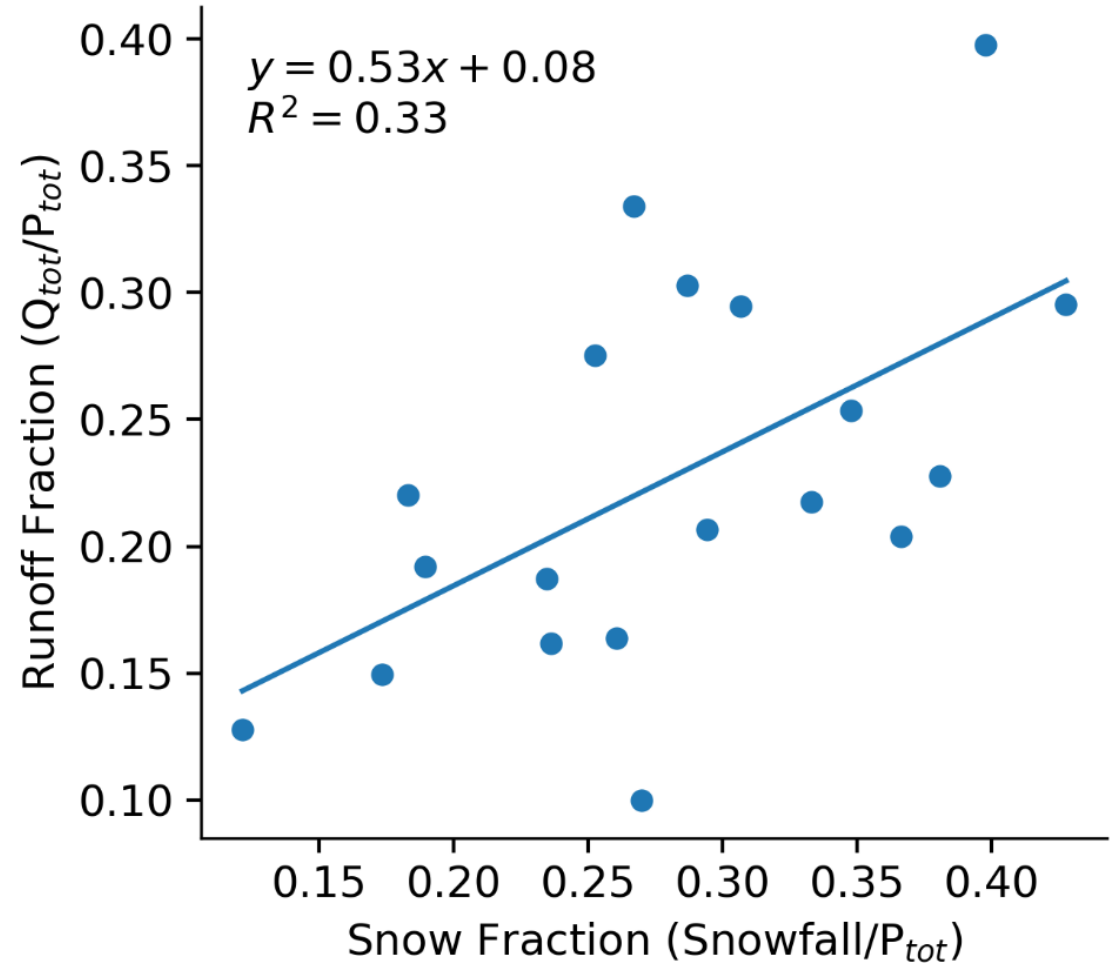
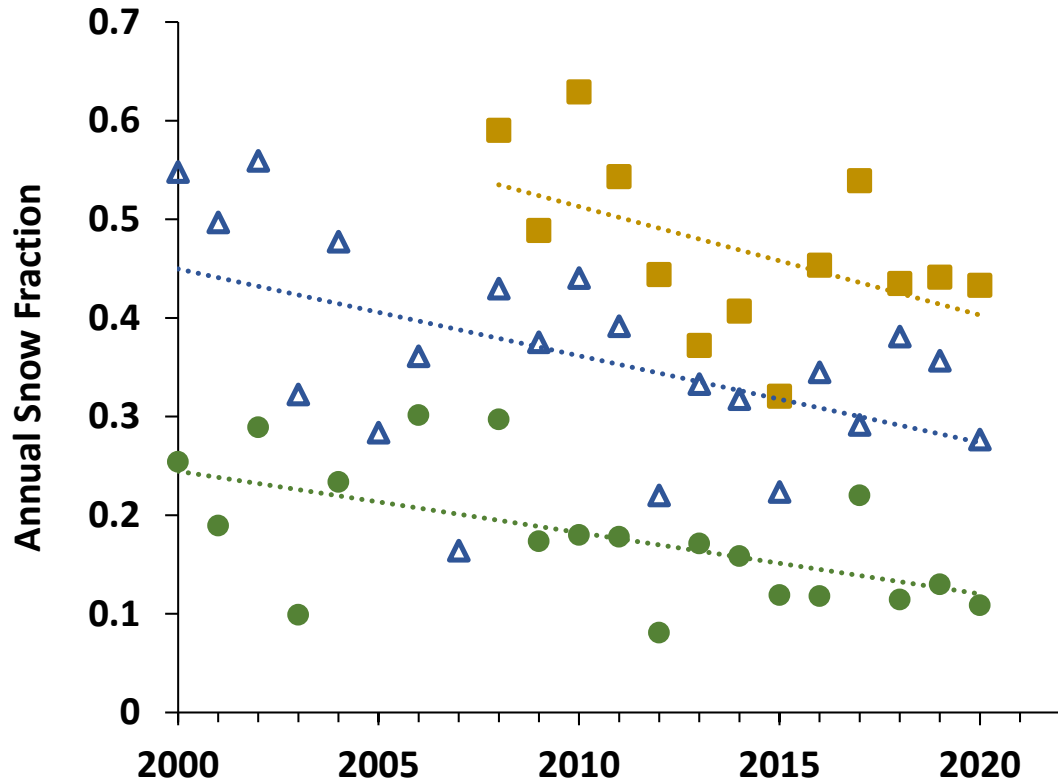


Since 1965

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



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



Snow fraction is important, but not the whole story



Proposal submitted: Impact of precipitation phase on winter carryforward storage and transpiration



Research Questions

Q1

Recharge and Carryforward Storage

How does precipitation phase shape the timing and pathways of recharge and the carryforward of plant-accessible water into the growing season across the rain-snow transition zone?

Q2

Plant Water Sources

How do the availability and accessibility of carryforward storage influence plant water sources and transpiration through the growing season across the rain-snow transition zone?

Q3

Hydrologic Partitioning

How do carryforward storage and vegetation access to stored water influence watershed-scale partitioning between transpiration and streamflow?



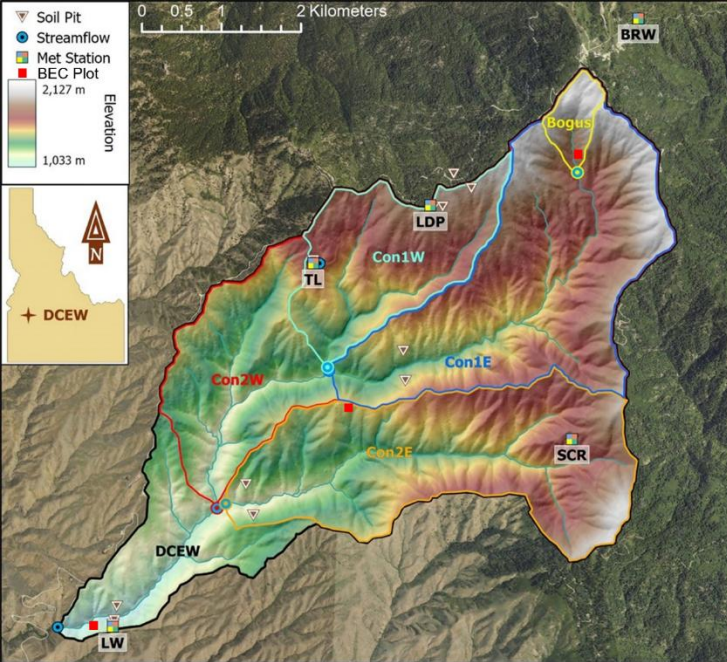
Observations

New Measurements & Analyses (This Proposal)

- Soil-water isotopes
- Xylem-water isotopes
- Groundwater & stream isotopes
- Plant-water-source attribution → *MixSIAR*
- Carryforward-storage metrics

Leveraged Existing Infrastructure

- 25+ years of hydrometeorologic monitoring
- Groundwater monitoring network (hillslope wells, riparian wells, in-stream piezometers, stilling wells, water level & temperature)
- Precipitation isotopes from Flores project (rain, snow, snowmelt)
- Qifei Niu CAREER geophysics (*subsurface properties*)
- BEC plots (riparian-hillslope pairs with sapflow and soil moisture monitoring)



Plant water use across the RSTZ

BEC PLOT

Bedrock Ecohydrologic Connectivity

Paired riparian–hillslope monitoring across a hillslope–stream continuum

HILLSLOPE ZONE

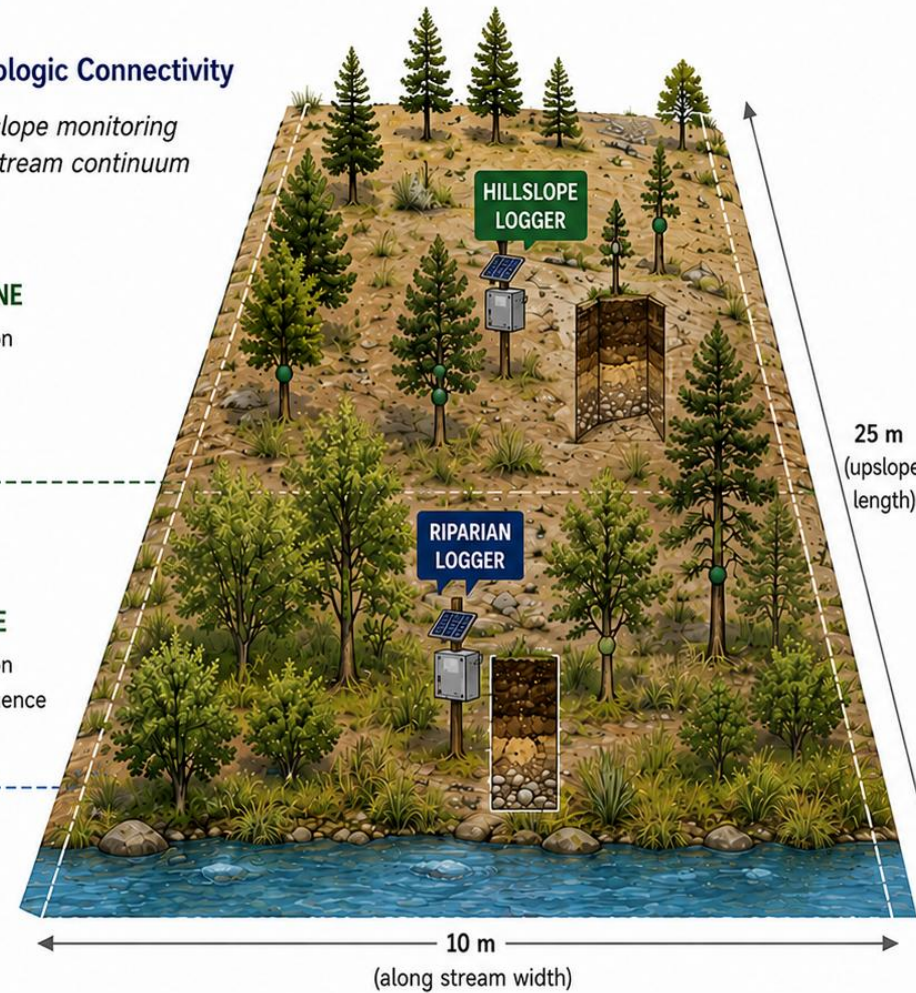
Upland vegetation
Soil to bedrock

RIPARIAN ZONE

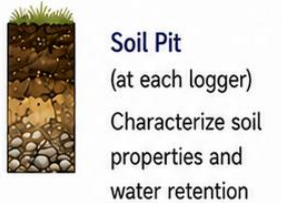
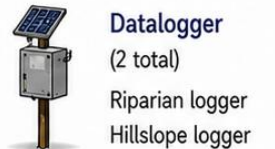
Riparian vegetation
High water table influence

STREAM

Surface water
Stream–groundwater exchange

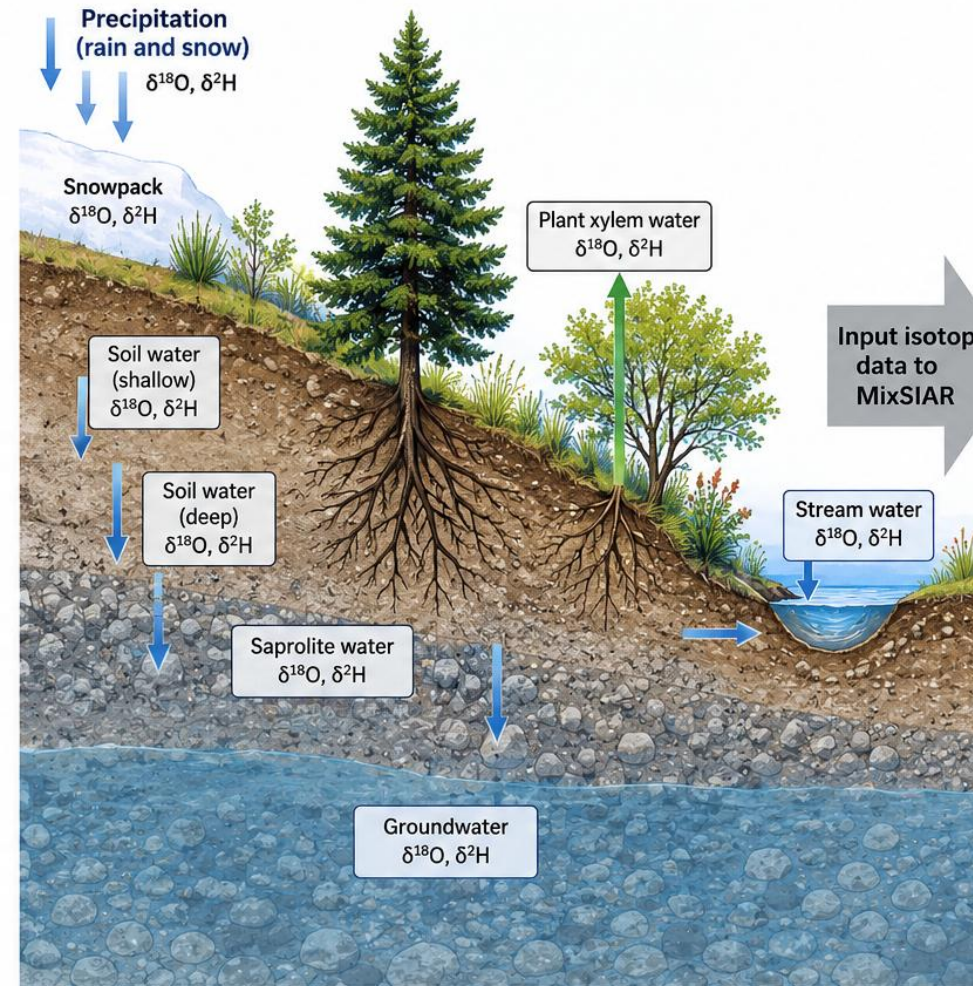


PLOT COMPONENTS



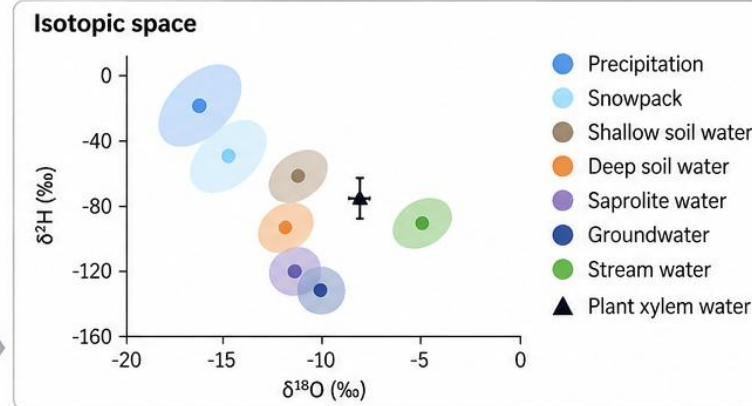
1. Potential water sources

We measure the isotopic composition ($\delta^{18}\text{O}$, $\delta^2\text{H}$) of potential water sources and plant xylem water across the hillslope-riparian transect.

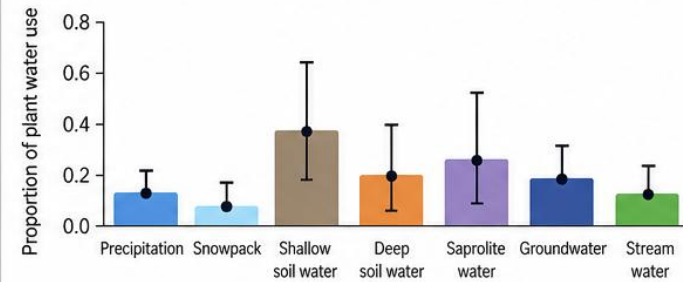


2. MixSIAR mixing model

MixSIAR uses Bayesian mixing models to estimate the proportional contributions of each water source to plant water use, accounting for source variability and uncertainty.



Estimated source contributions to plant water use



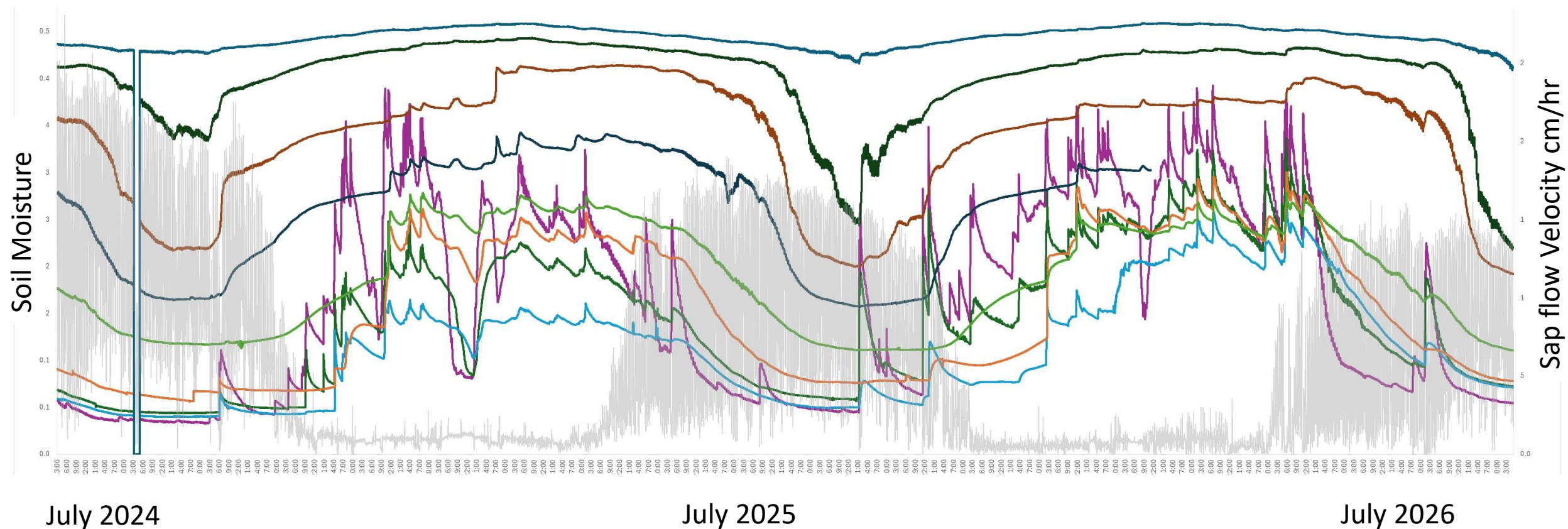
- MixSIAR estimates proportional contributions from multiple sources using Bayesian statistics.
- Results include uncertainty (credible intervals) for each source.
- We apply the model to identify how snow-to-rain transitions change plant water sources across the rain-snow transition zone.



PhD Student Avalon Johnson



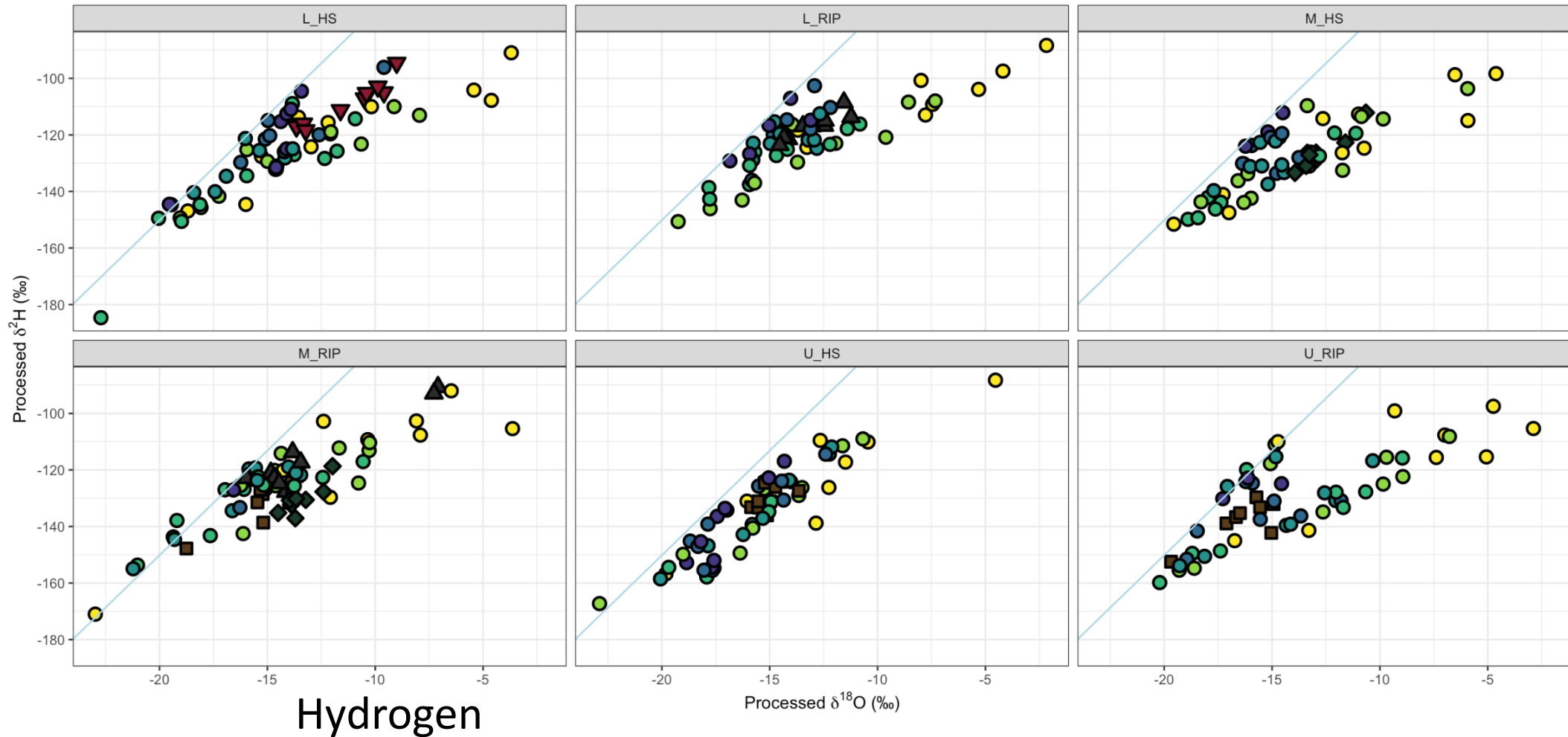
30 minute soil moisture and sapflow



Drill n Drop soil moisture sensors are amazing!

Bi-Weekly Isotope Data for Mixing Model

Oxygen



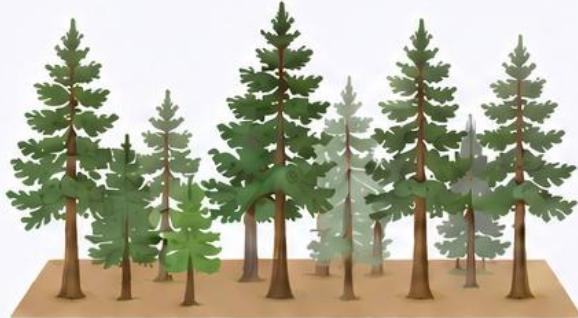
Next Steps

- Figure out why Reynolds Creek shows no declines in snow fraction
- Complete revisions on Dry Creek Snow fraction – runoff paper
- Complete mixing models to determine plant water uptake strategies by AGU

Workflow to Calculate Plot-Scale Transpiration

1 Measure diameters of all trees in plot

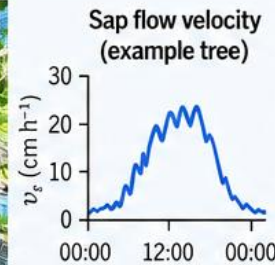
- Measure DBH for every tree in the plot.



All trees in plot

2 Measure sap flow in sample trees

- Select 6 trees per plot (3 size classes, 2 trees per class).
- Measure sap flow velocity (v_s) every 30 minutes (e.g., using heart pulse velocity probes).



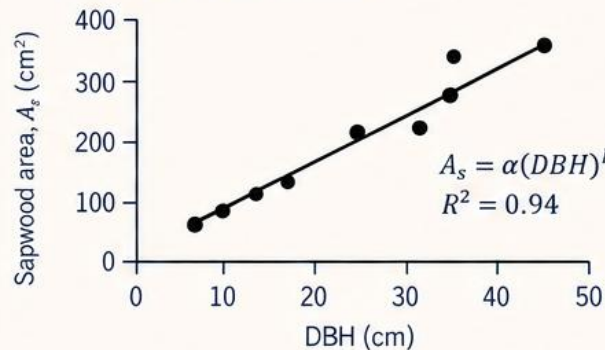
3 Determine sapwood area for sample trees

- Extract sapwood cores from the same 6 trees.
- Measure bark thickness and determine sapwood area (A_s ; cm^2) from diameter and sapwood depth.



4 Relate sapwood area to tree diameter

- Build a regression between sapwood area (A_s) and tree diameter at breast height (DBH) using the 6 sample trees.



5 Estimate total sapwood area in plot

- Apply the regression from Step 4 to estimate sapwood area for each tree in the plot.
- Sum across all trees to get total plot sapwood area ($A_{s,plot}$).

$$A_{s,plot} = \sum_{i=1}^N A_s(DBH_i) \quad (\text{cm}^2)$$

6 Calculate plot-scale transpiration

- Multiply mean sap flow velocity by total plot sapwood area to obtain plot-scale transpiration.

$$T_{plot} = \bar{v}_s \times A_{s,plot}$$

T_{plot} = plot-scale transpiration (e.g., L h^{-1} or mm d^{-1})
 $\bar{v}_s$ = mean sap flow velocity from sample trees (cm h^{-1})
 $A_{s,plot}$ = total plot sapwood area (cm^2)