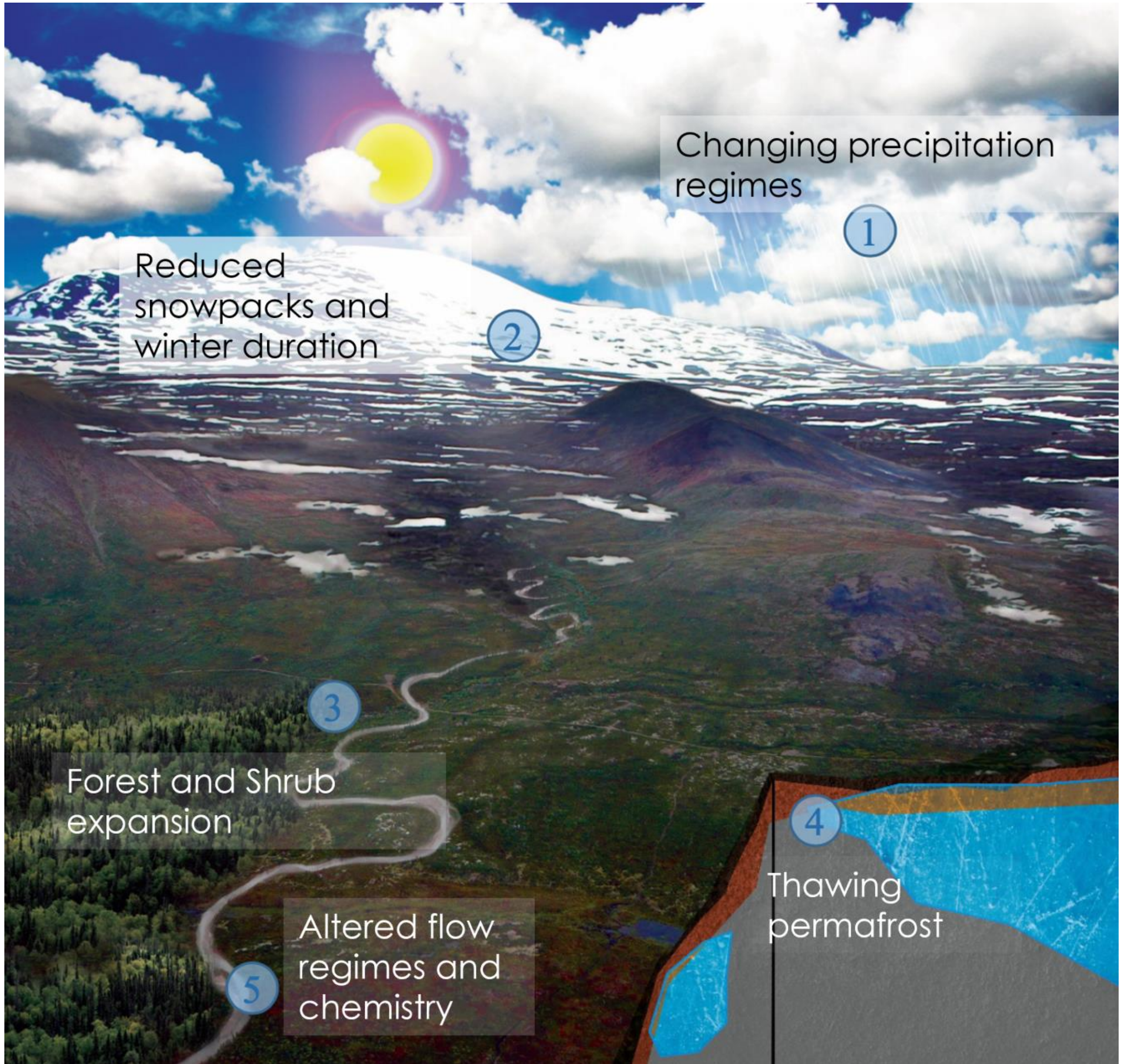
New insights of water sources and pathways across a latitudinal and altitudinal gradient, Yukon, Canada

Sean K. Carey & Arsh Grewal

School of Earth, Environment and Society, McMaster University

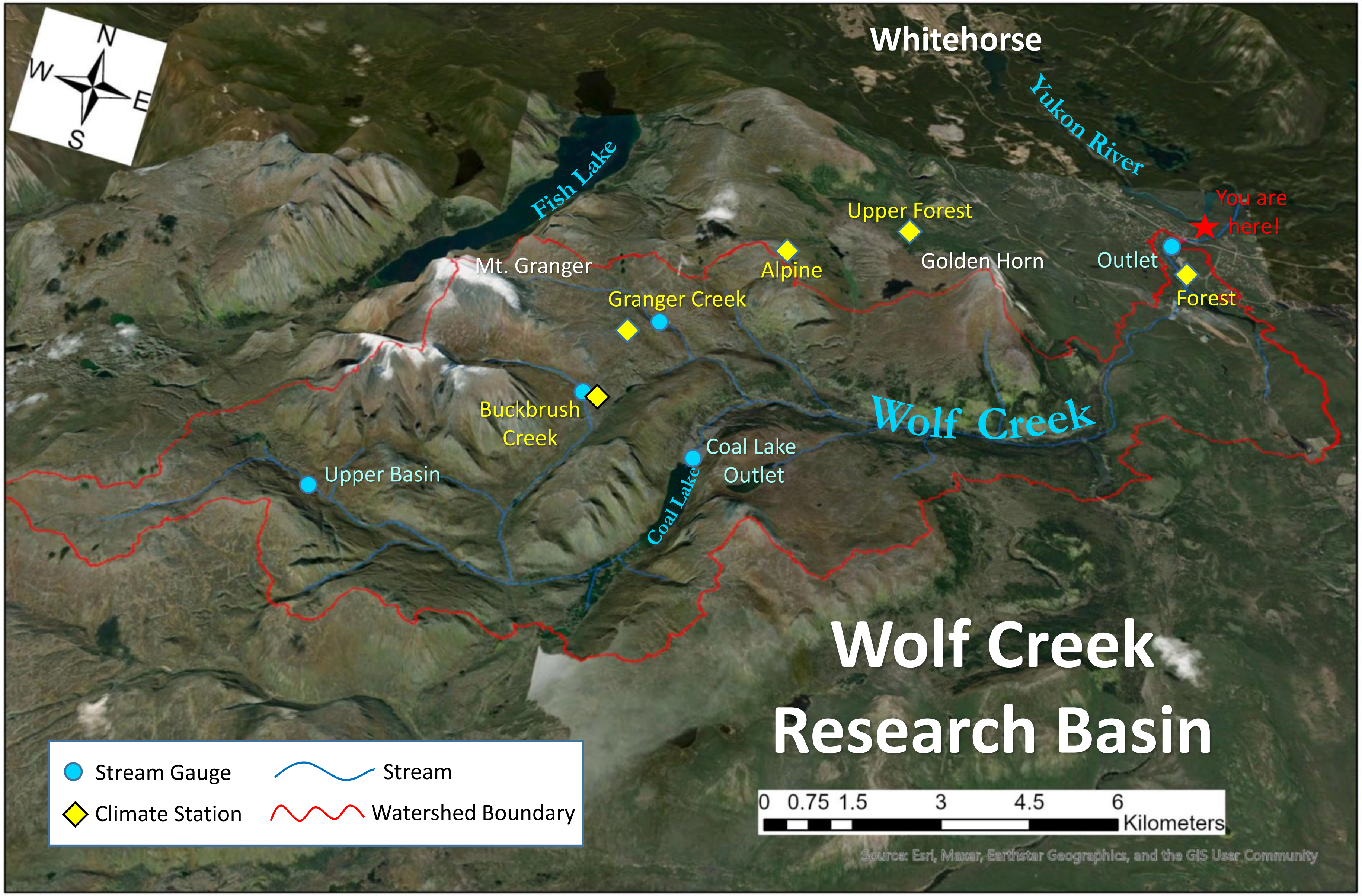
Rapidly changing cold mountains of Yukon



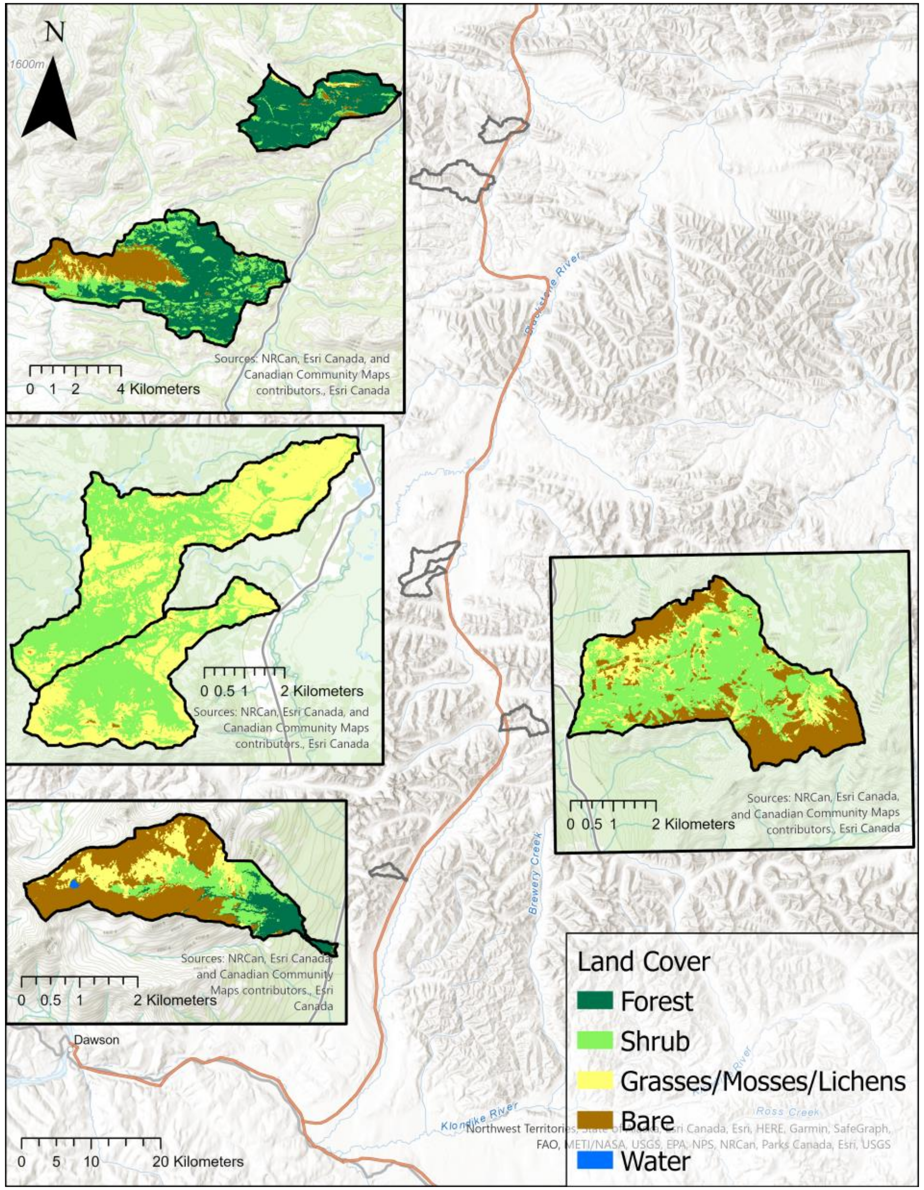
Research Questions

- What is the role of ecosystem and seasonality on the major of sources and sinks of water and solutes?
- How do runoff processes vary across a latitudinal/thermal gradient of alpine catchments?

Wolf Creek Research Basin



Tombstone Waters Observatory



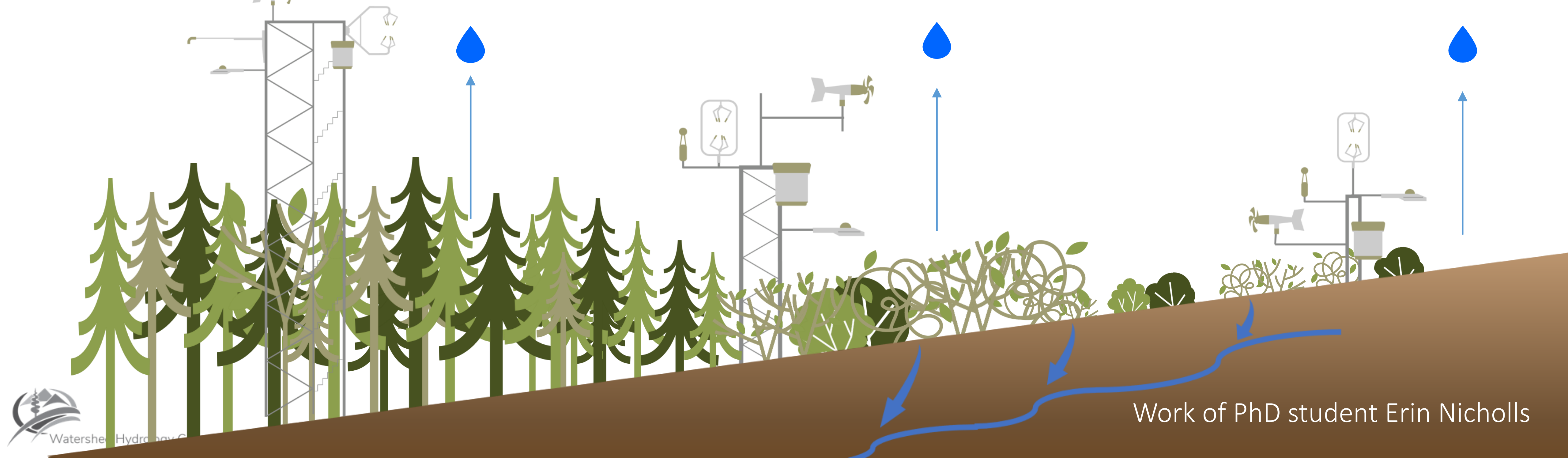
Watershed Hydrology Group - McMaster University

Last year……The EvapoTranspiration question

Forest
750 masl
White Spruce ~12-20 m

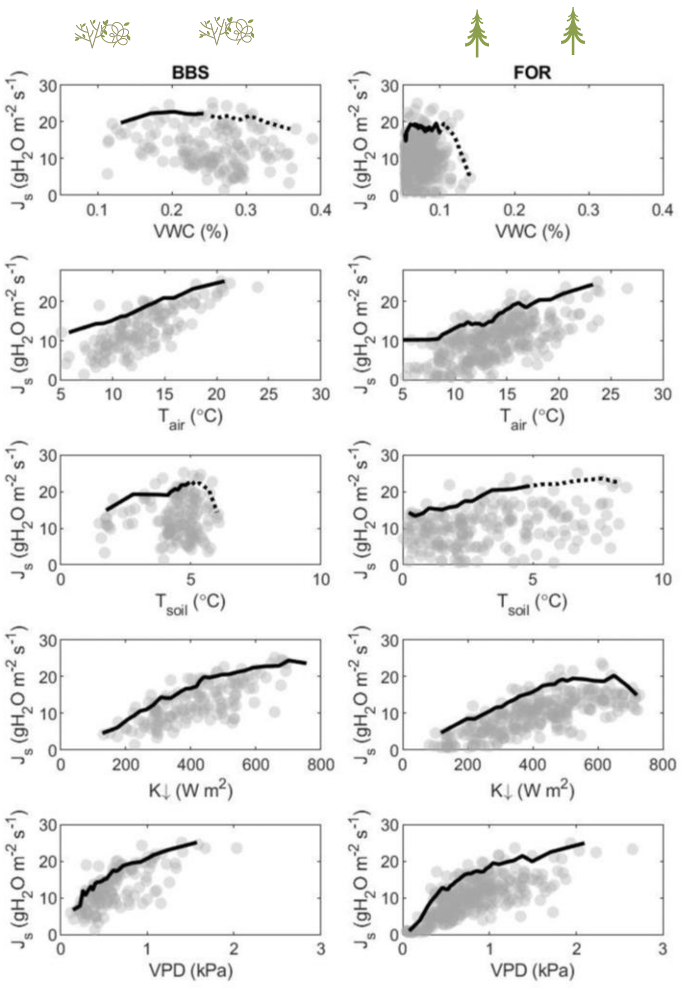
Buckbrush
1250 masl
Willow and Birch Shrubs <~1-3 m

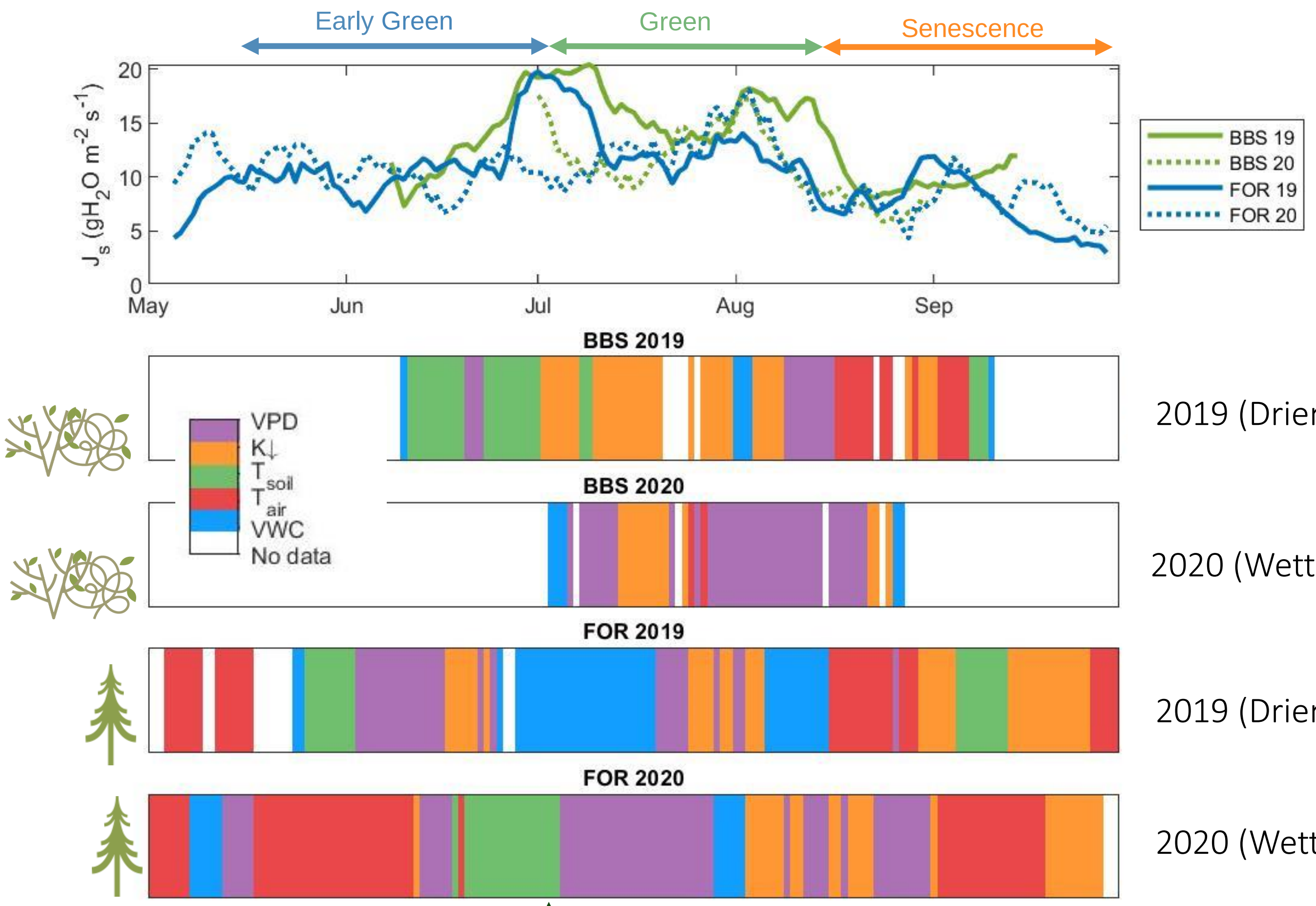
Sparse Shrub
1450 masl
Willow and Birch Shrubs <~0.5m



Work of PhD student Erin Nicholls

Environmental Drivers and Limits on Transpiration





2019 (Drier, Warmer)

2020 (Wetter, Cooler)

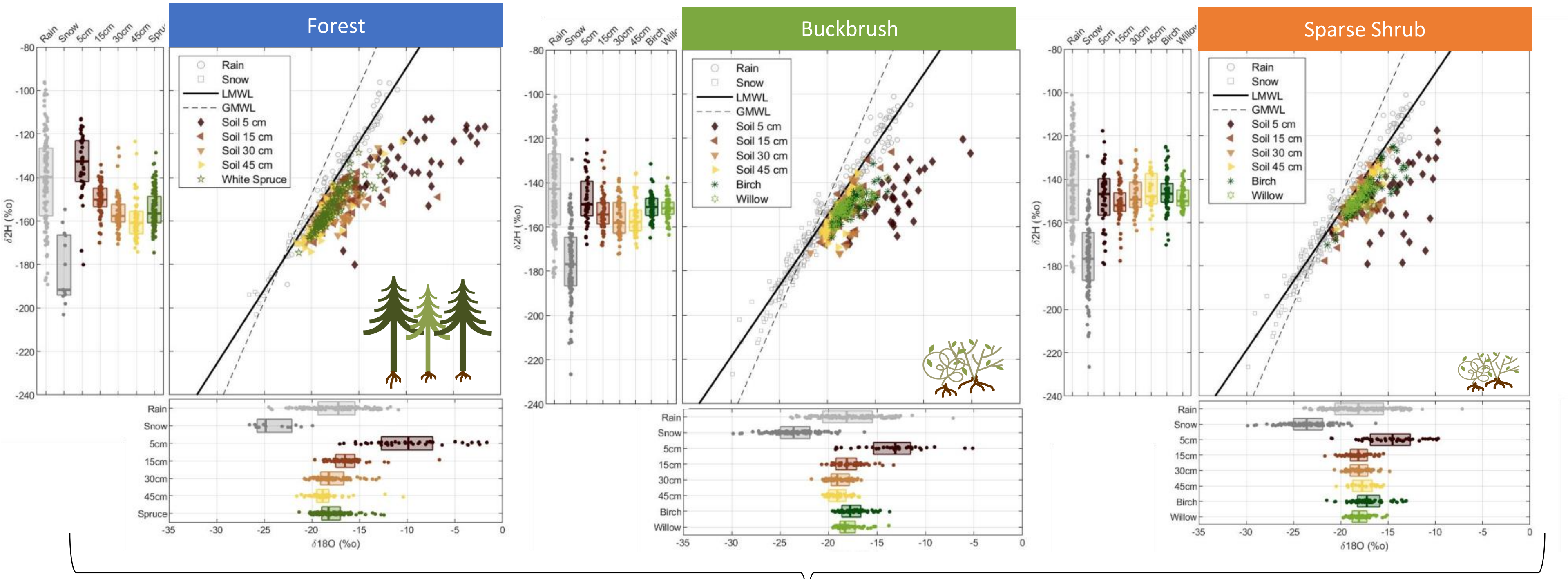
2019 (Drier, Warmer)

2020 (Wetter, Cooler)

Boundary Line Analysis

Nicholls et al, 2023, HP

Soil and Vegetation Stable Water Isotopes

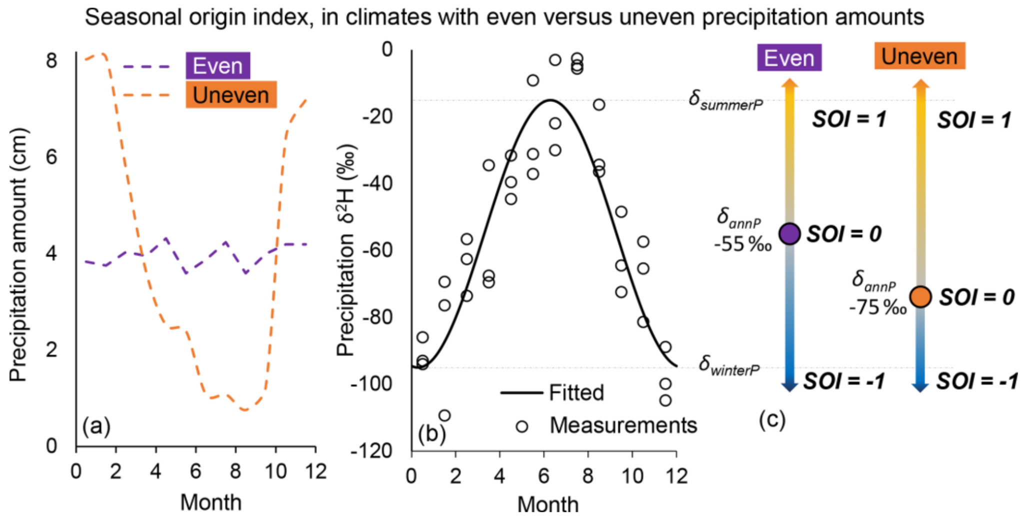


Evaporative Partitioning

Species – Specific Differences

Seasonal sources of plant water uptake

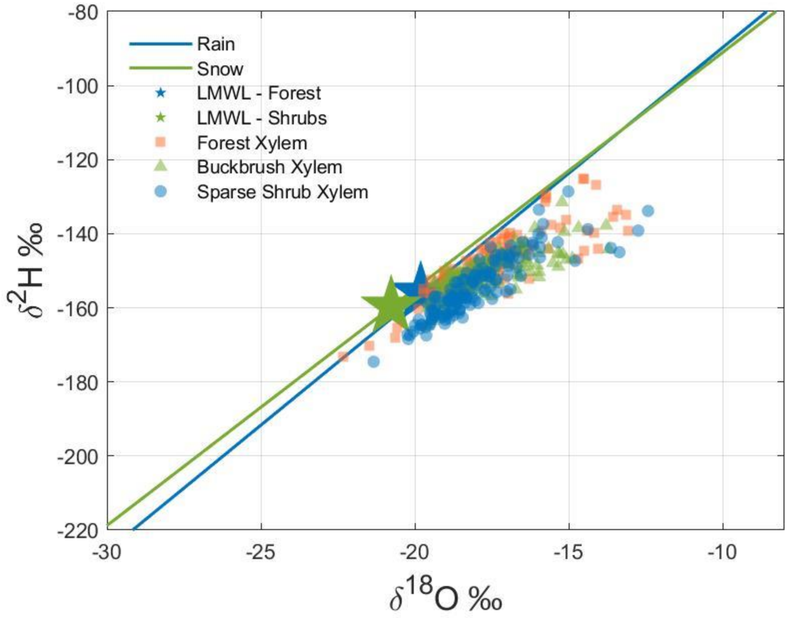
What water is being utilized: Seasonal Origin Index (SOI)



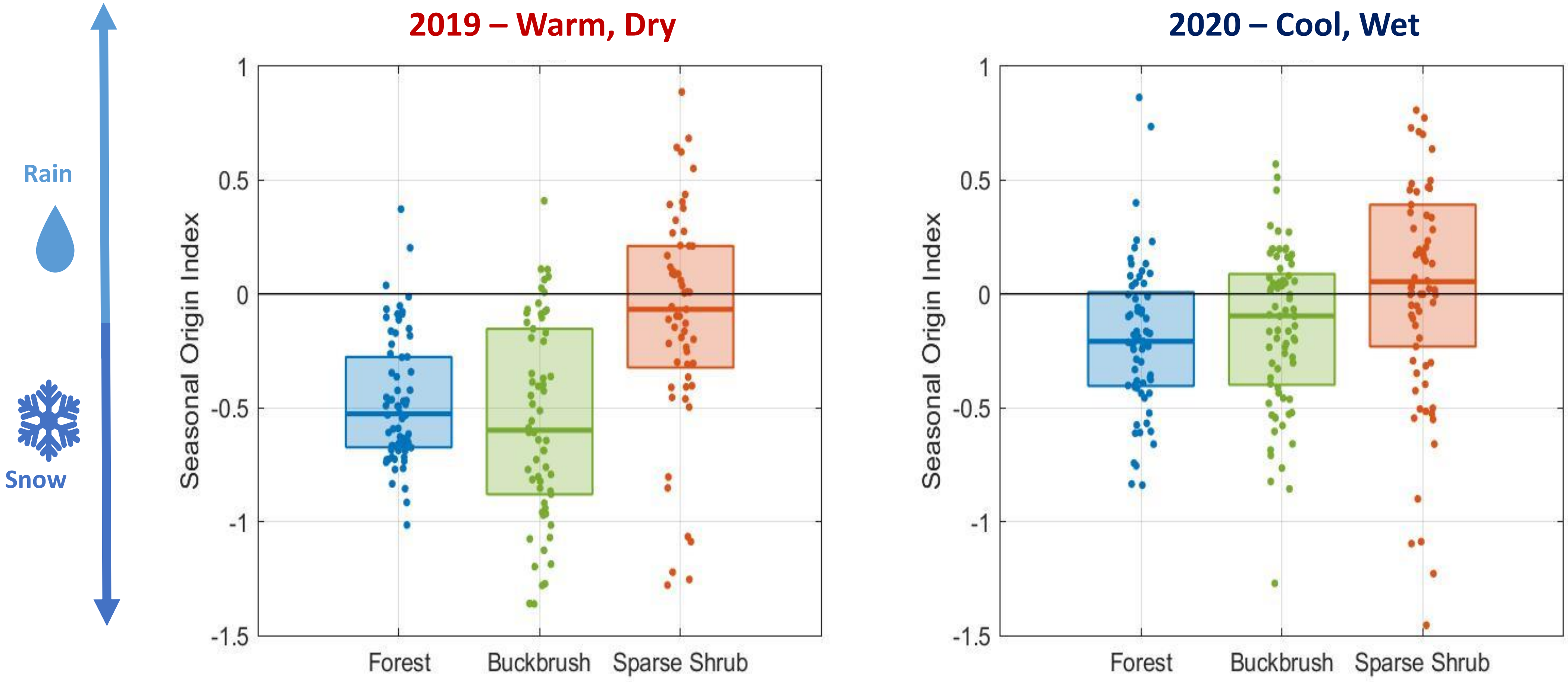
Method of Allen et al. (2019). *HESS*

$$\mathrm{SOI} = \begin{cases} \dfrac{\delta_x - \delta_{\mathrm{annP}}}{\delta_{\mathrm{summerP}} - \delta_{\mathrm{annP}}}, & \text{if } \delta_x > \delta_{\mathrm{annP}} \\ \dfrac{\delta_x - \delta_{\mathrm{annP}}}{\delta_{\mathrm{annP}} - \delta_{\mathrm{winterP}}}, & \text{if } \delta_x < \delta_{\mathrm{annP}} \end{cases},$$

Site and Year Specific Evaporation Line



Seasonal Origin Index (SOI)



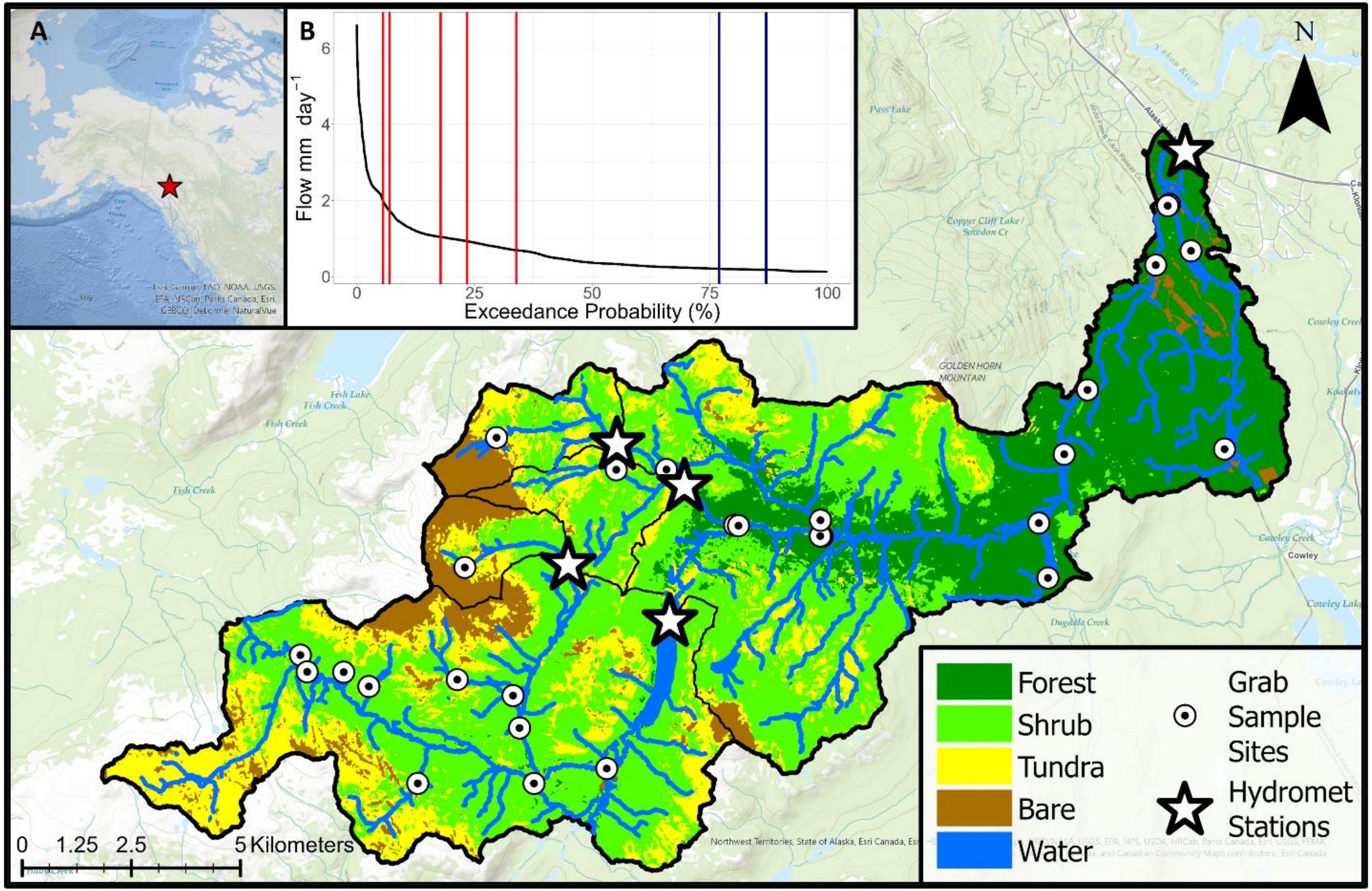
Take home points

- forests are reliant on snow water inputs with the potential to become moisture stressed

- Species matter.

Ecosystem controls on runoff and solute generation

Ecosystem controls on runoff and solute generation





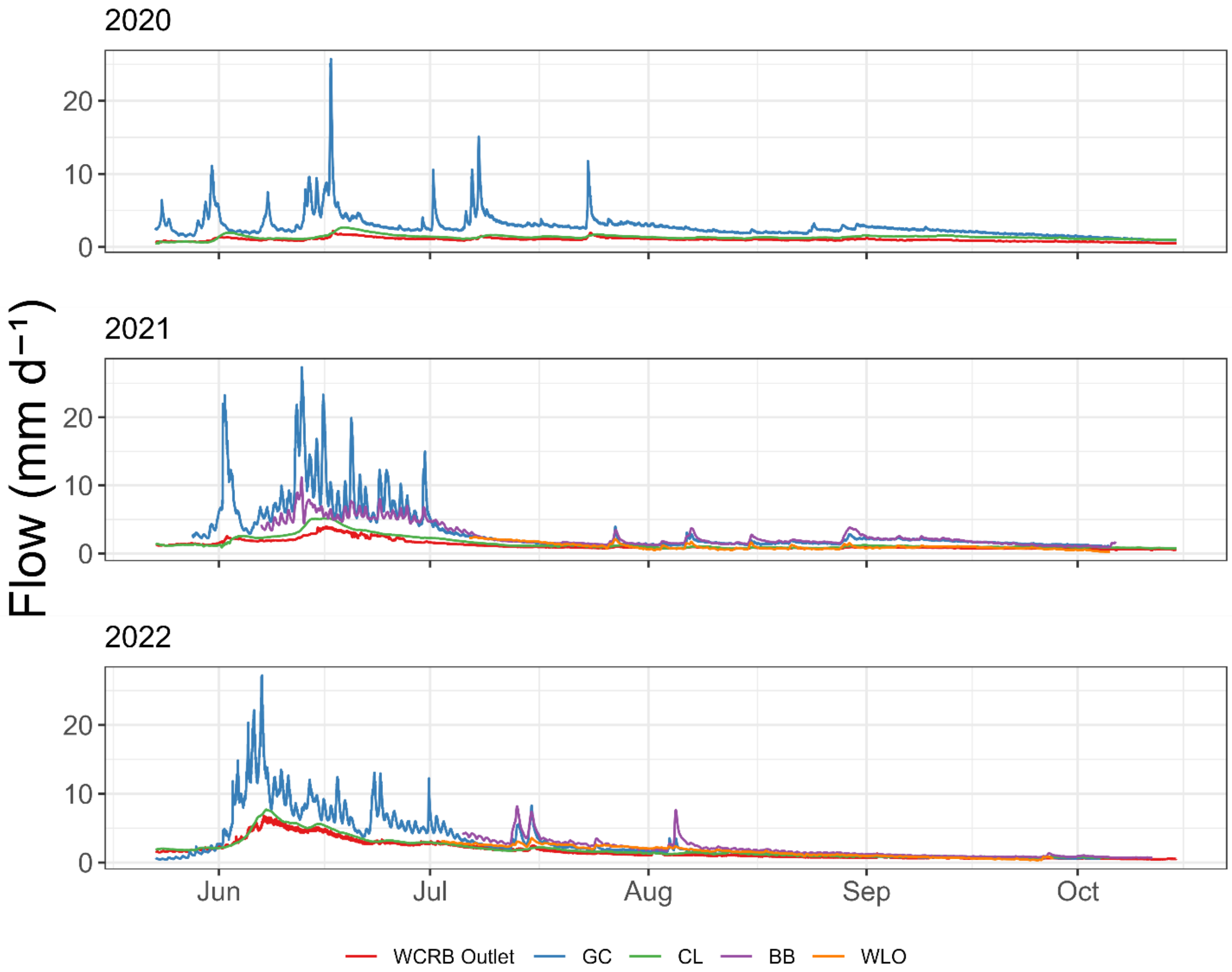







Watershed Hydrology

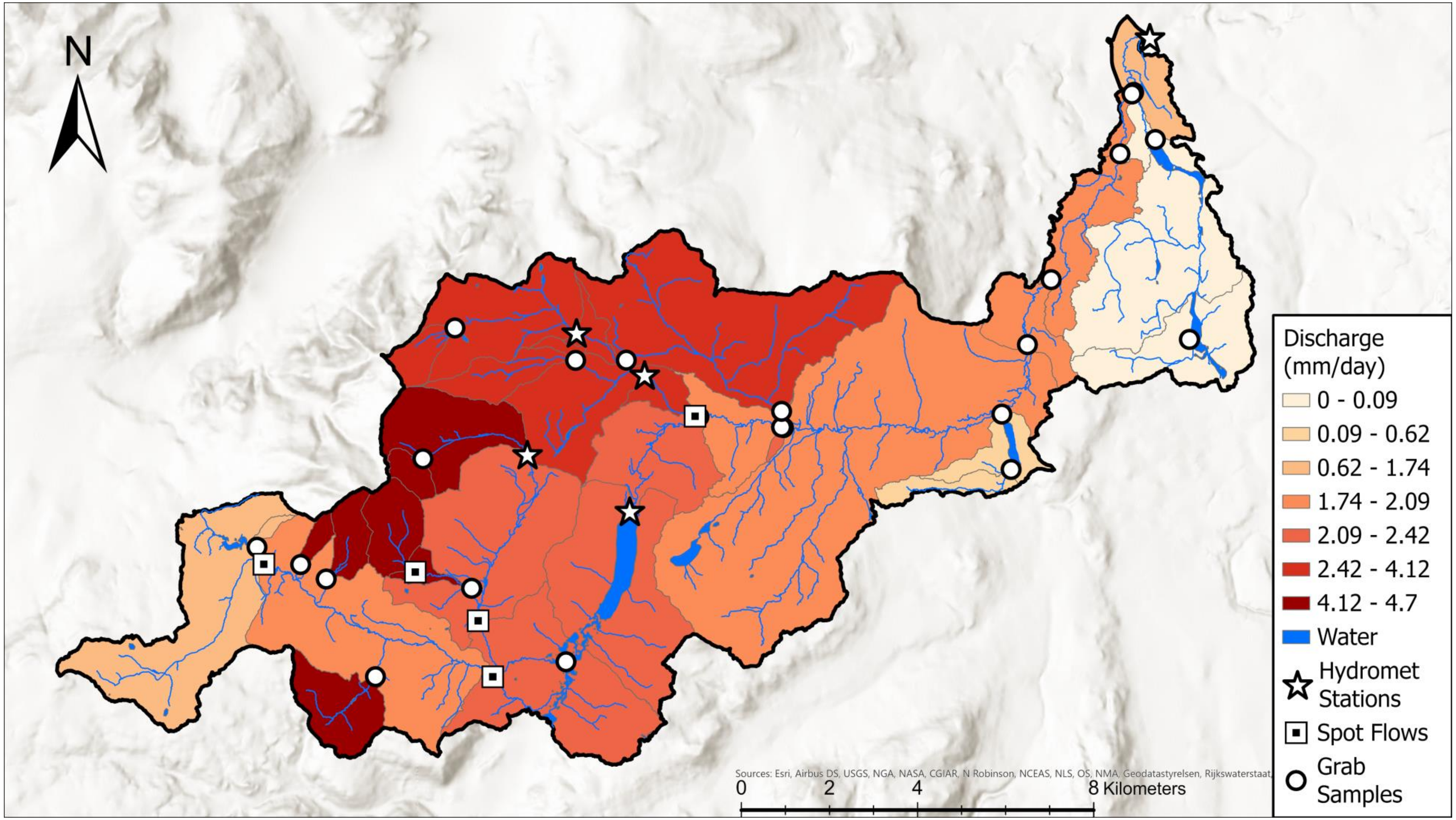
Wolf Creek Runoff



- Greater runoff generation in alpine ecozones
- Considerable inter-annual variation
- Things get boring for the most part after freshet, but there are some curious patterns.

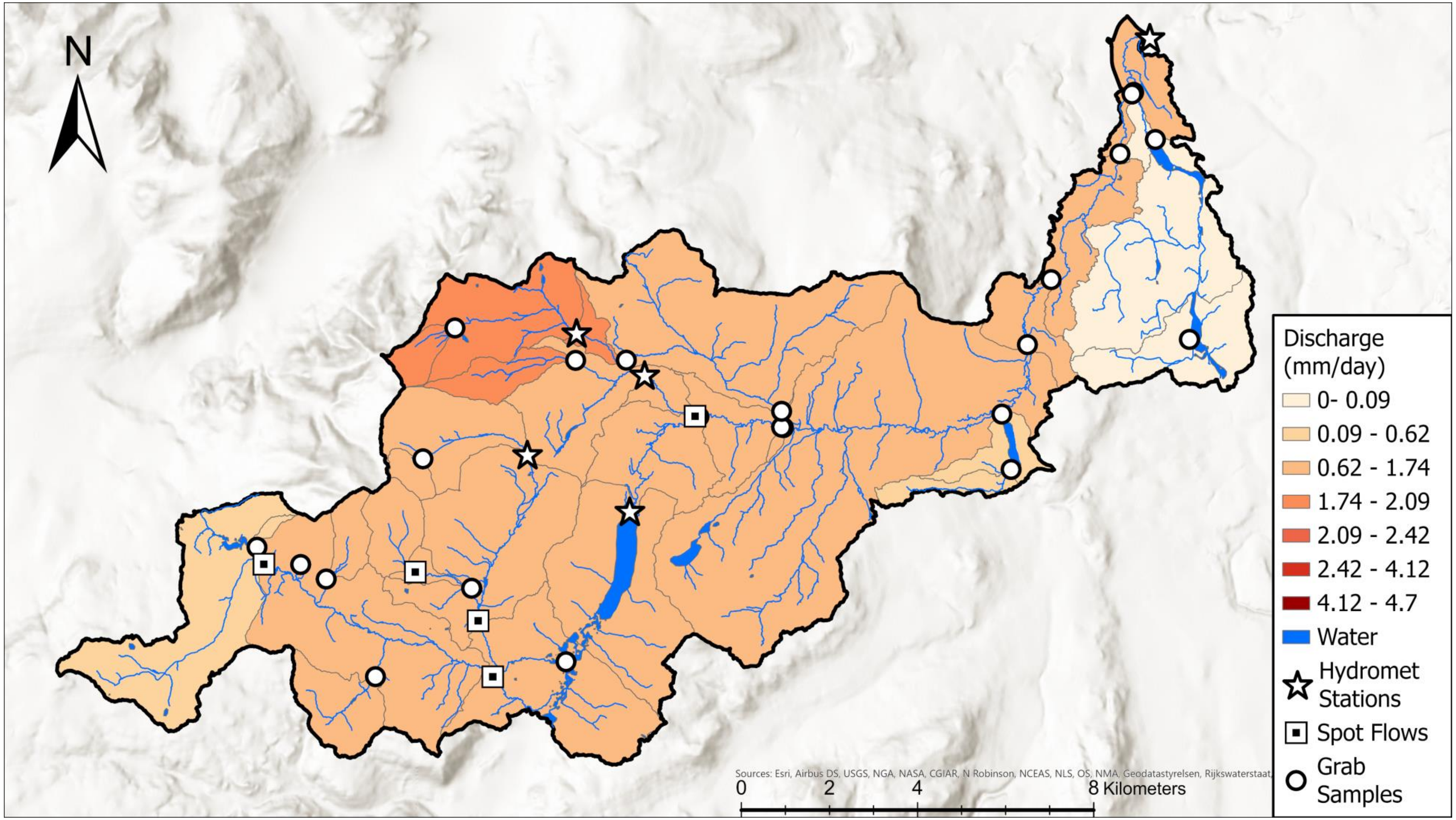
Measured variability in flows

Spring 2021

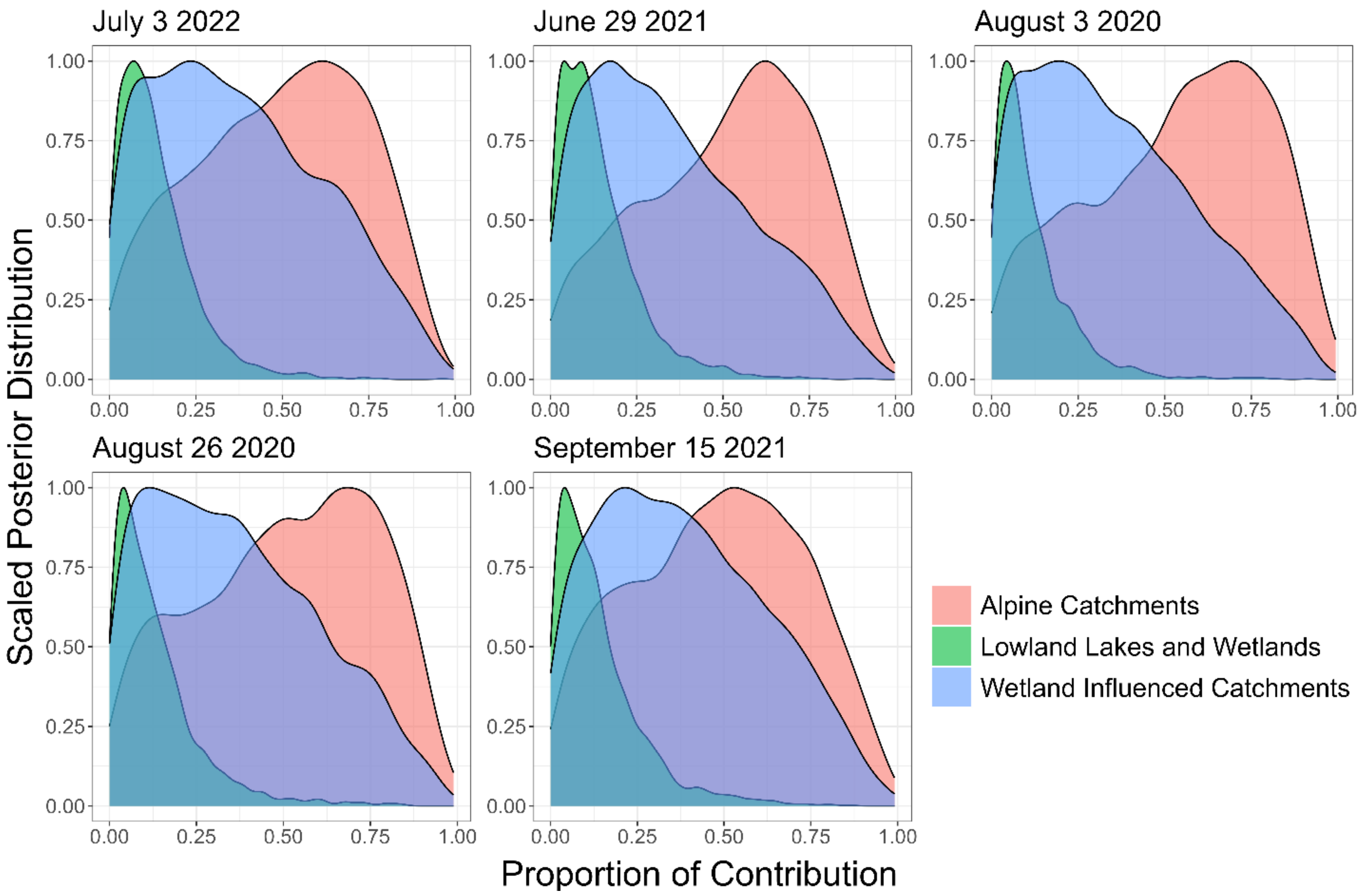


Measured variability in flows

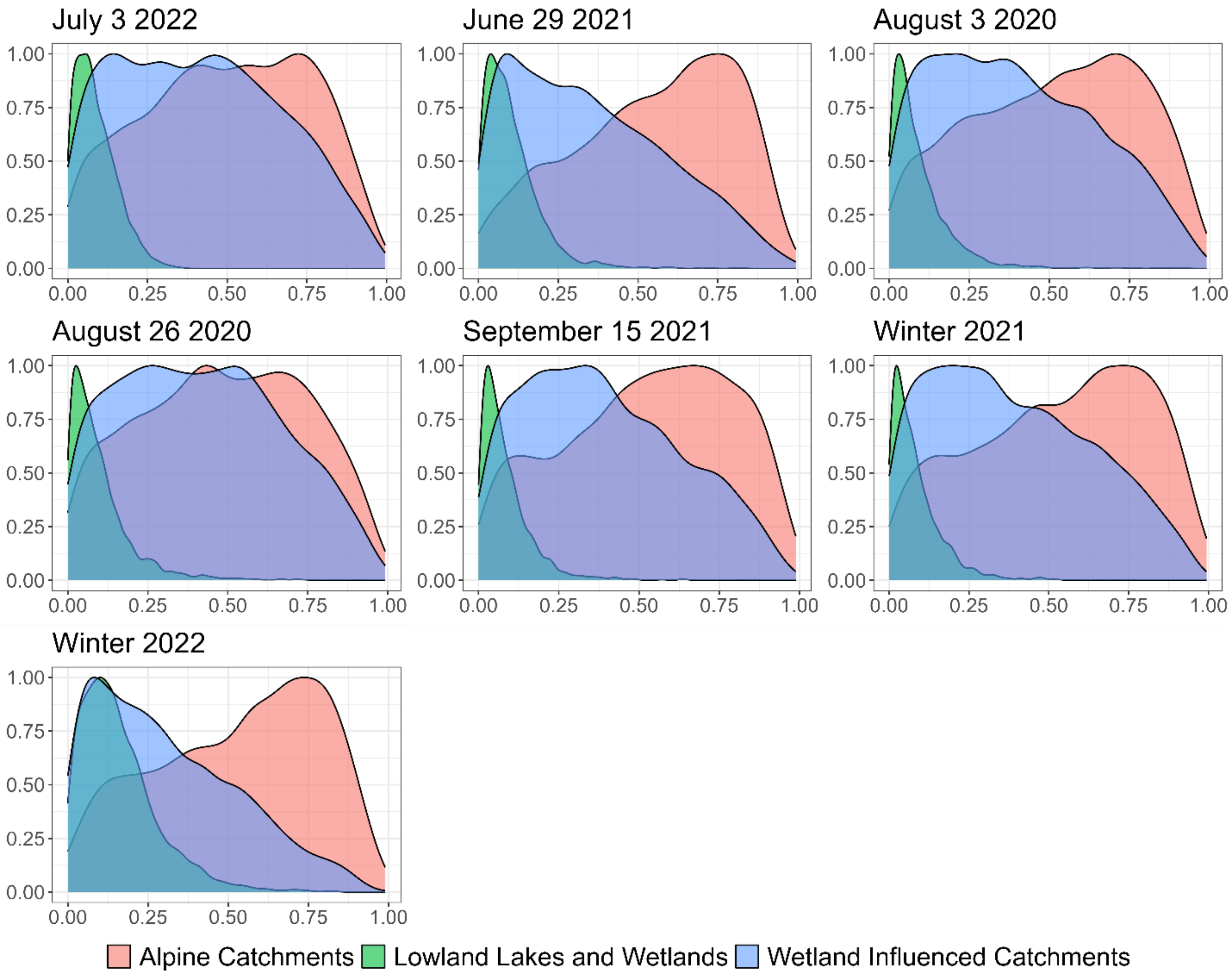
Fall 2021



Proportional Contributions by Sampling Event

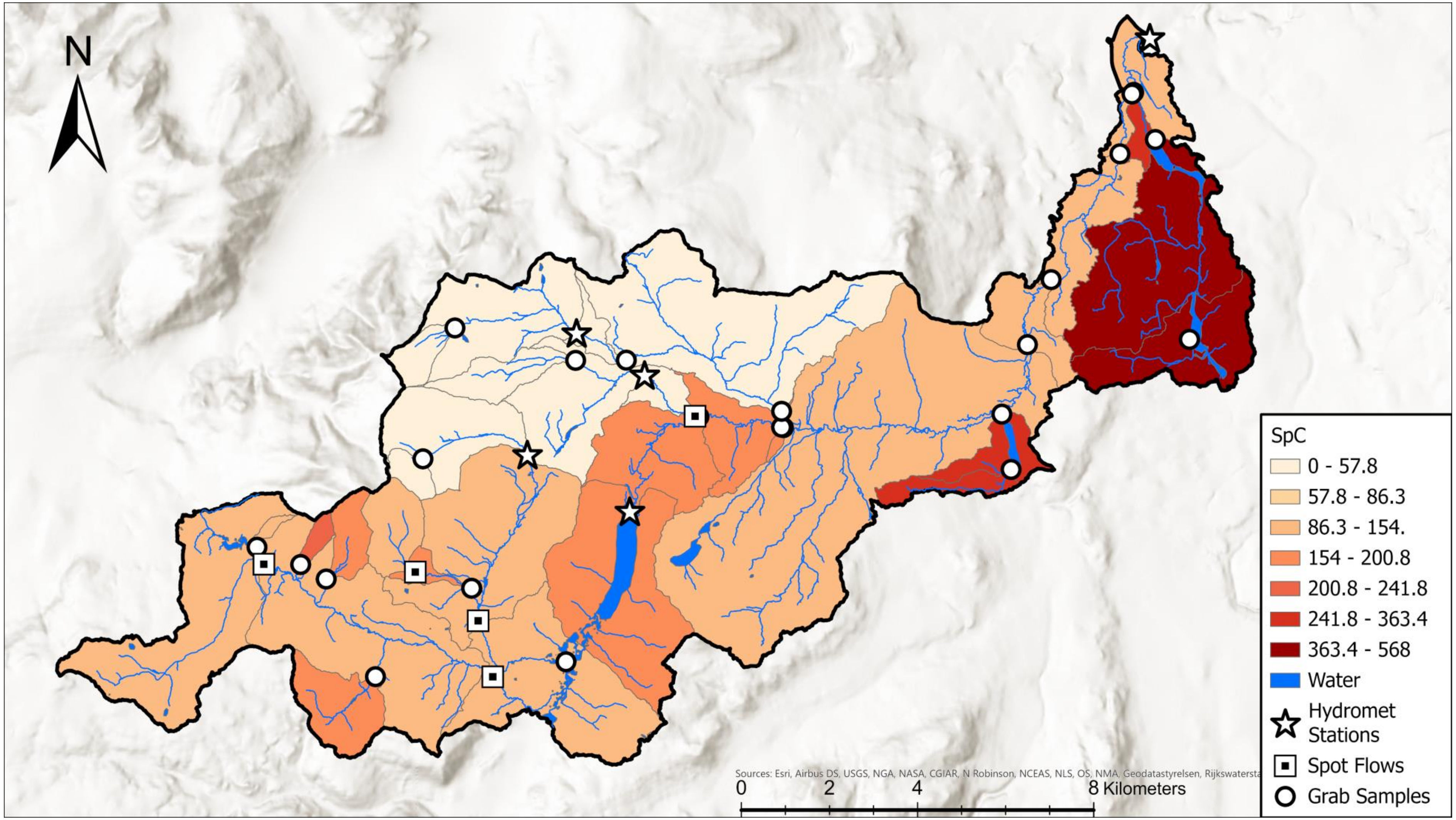


Proportional Contributions by Sampling Event



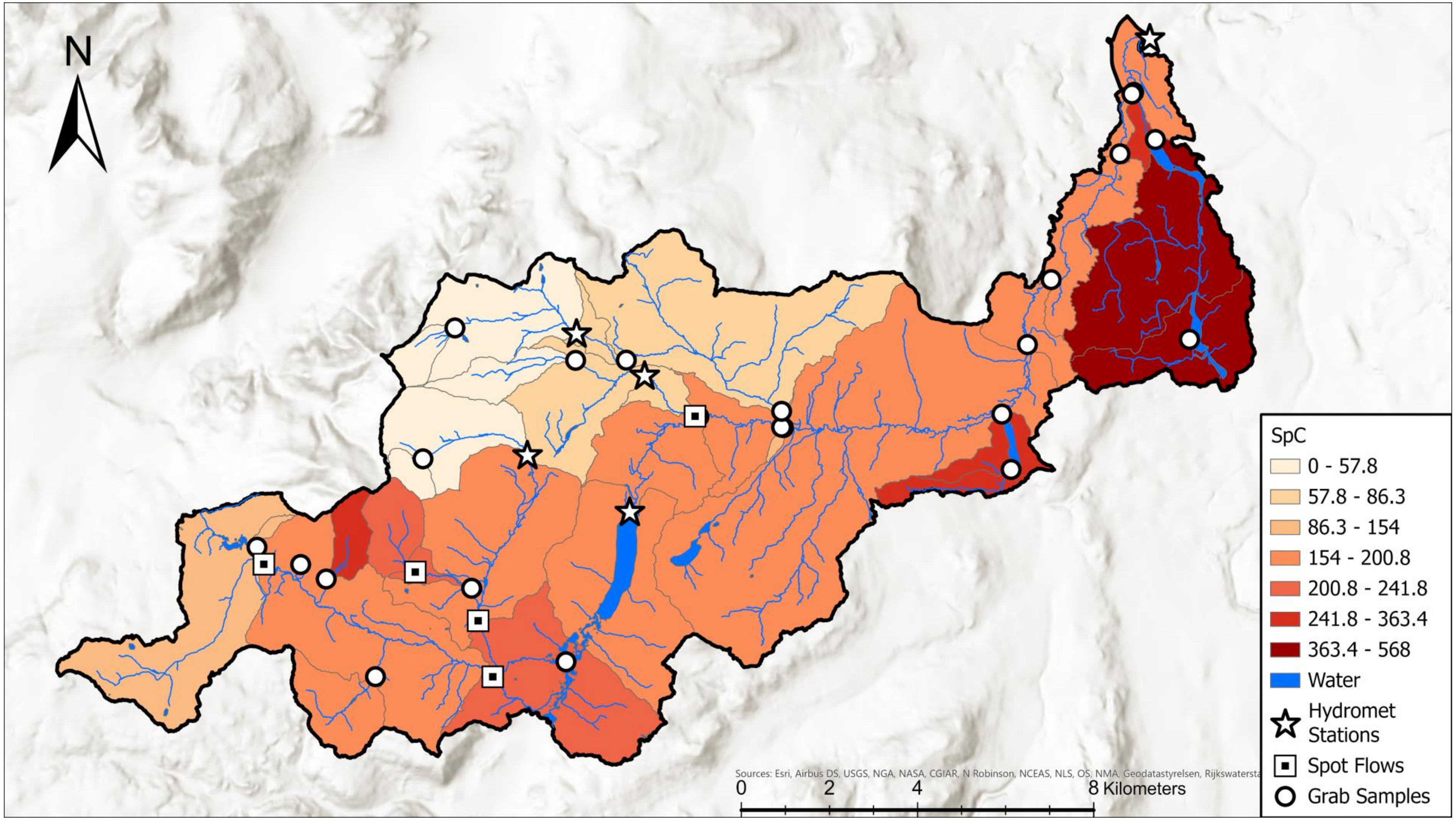
Measured variability in salinity

Spring 2021



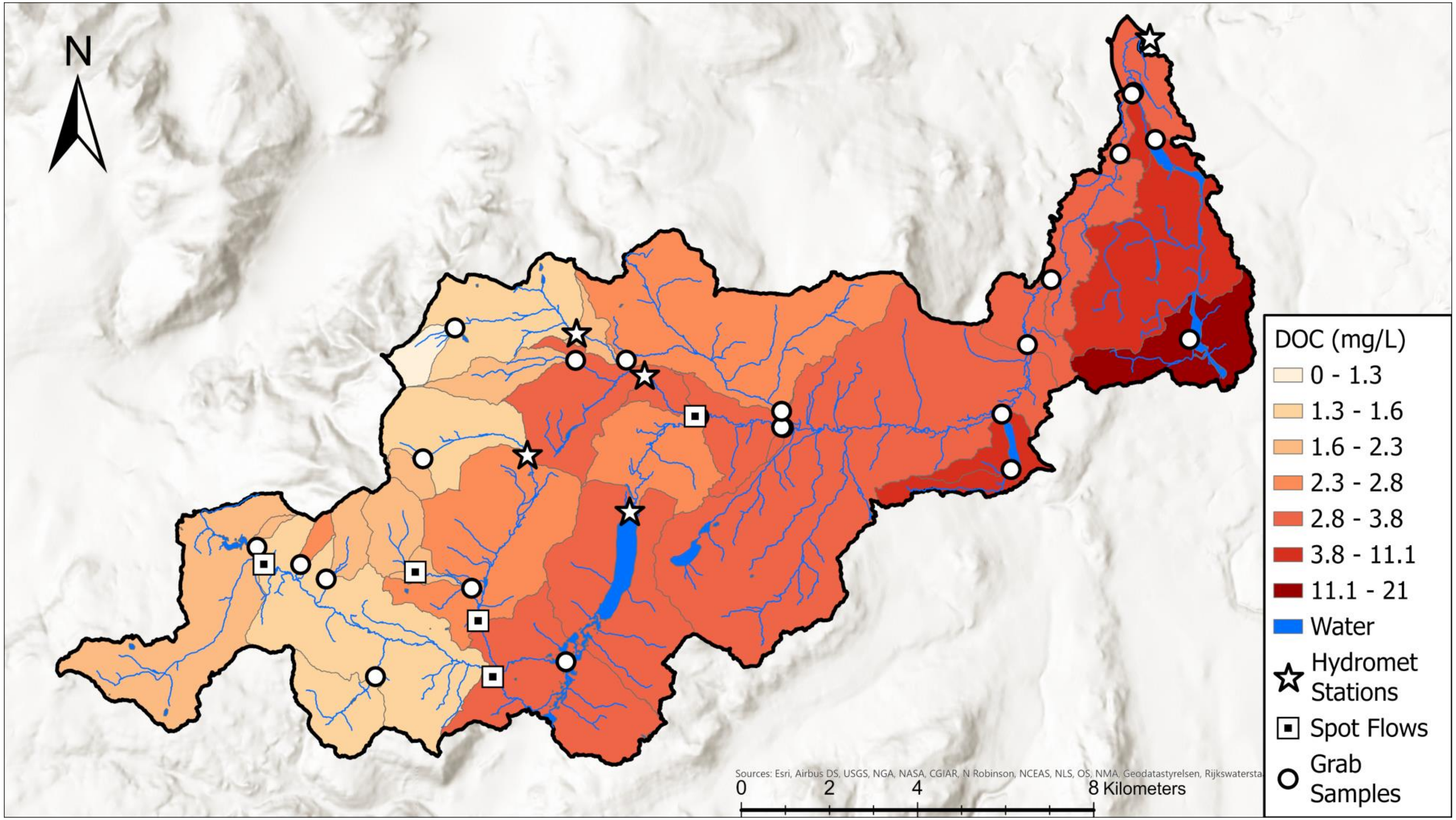
Measured variability in salinity

Fall 2021



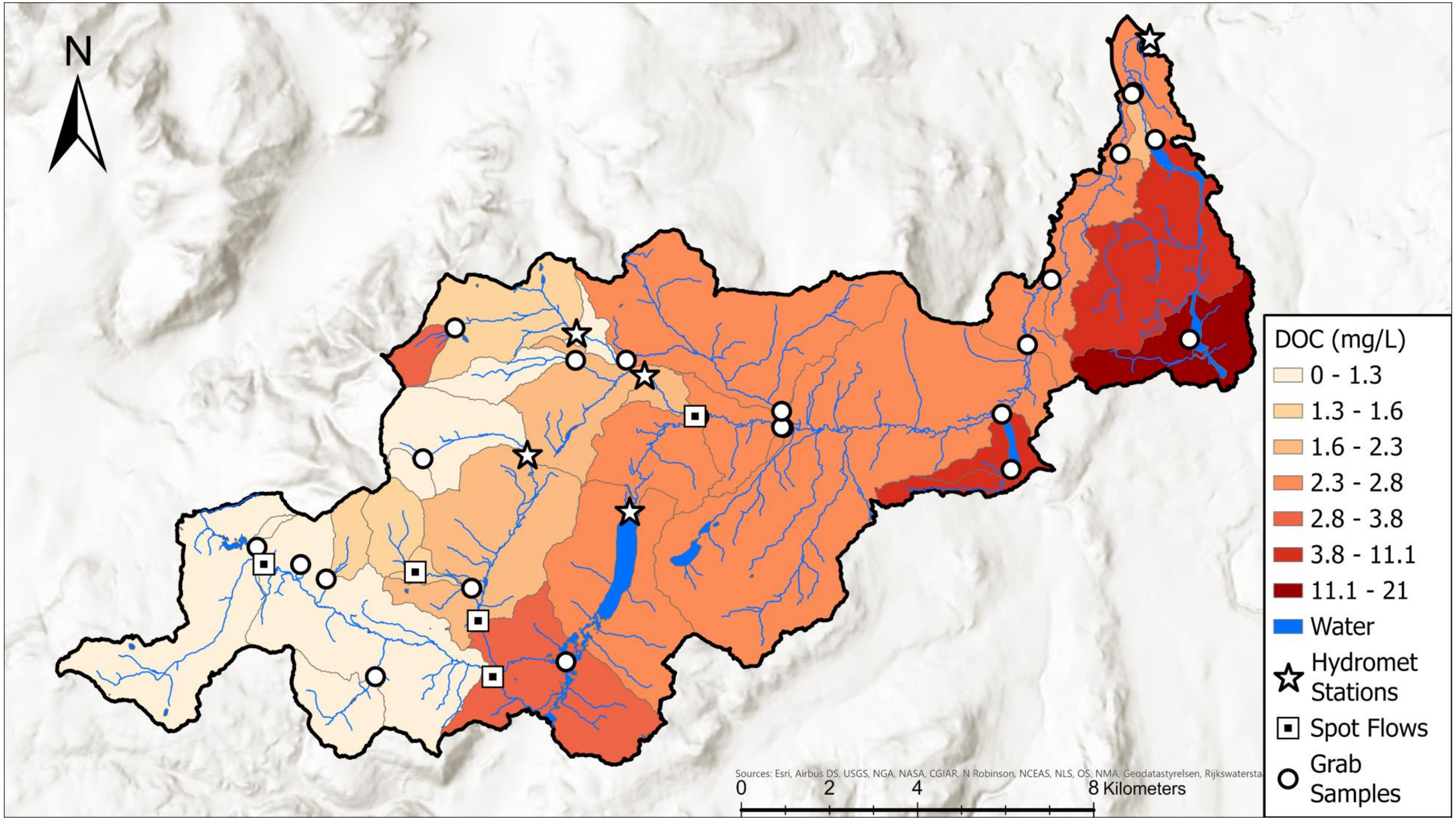
Measured variability in dissolved organic carbon

Spring 2021

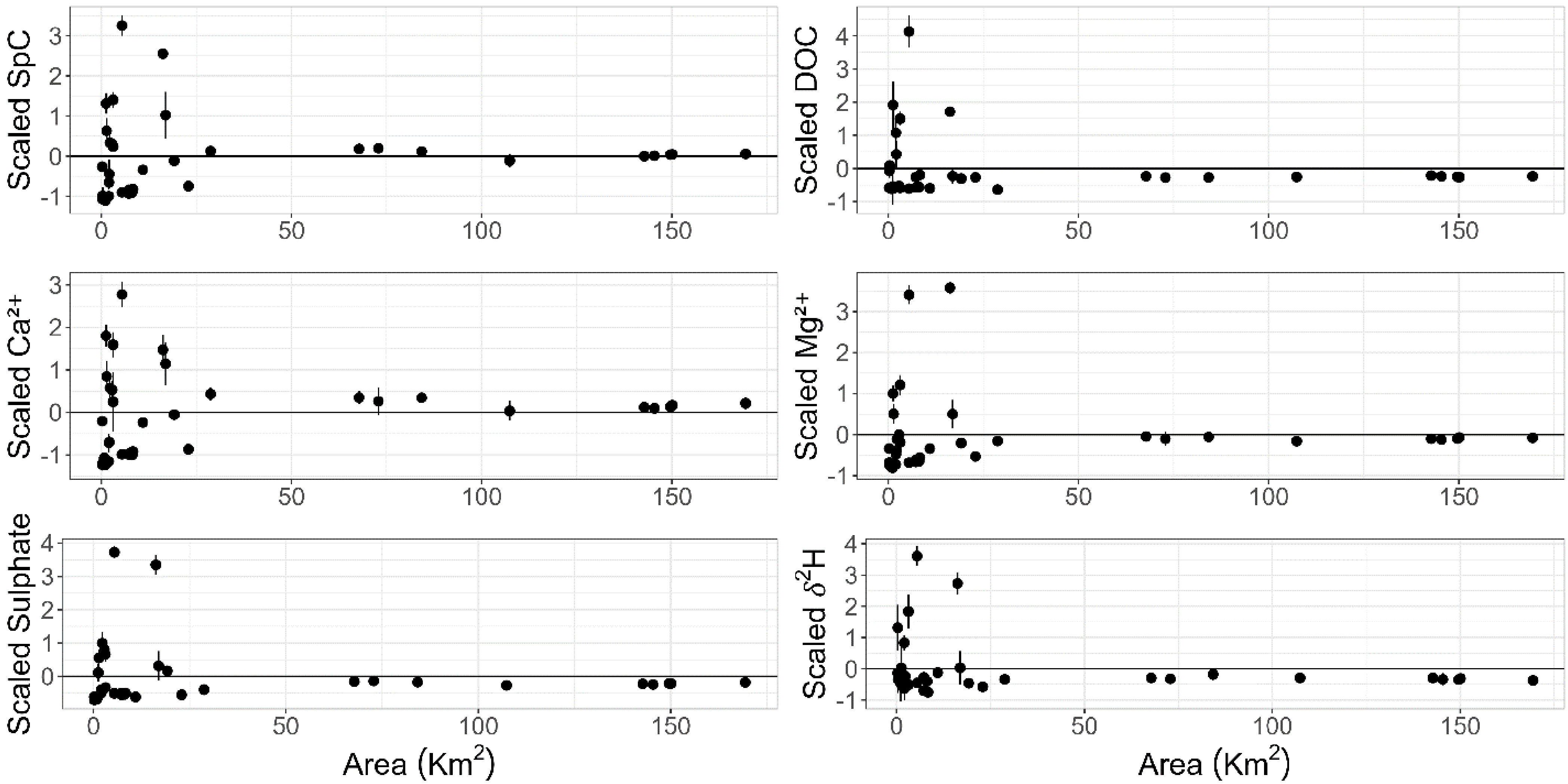


Measured variability in dissolved organic carbon

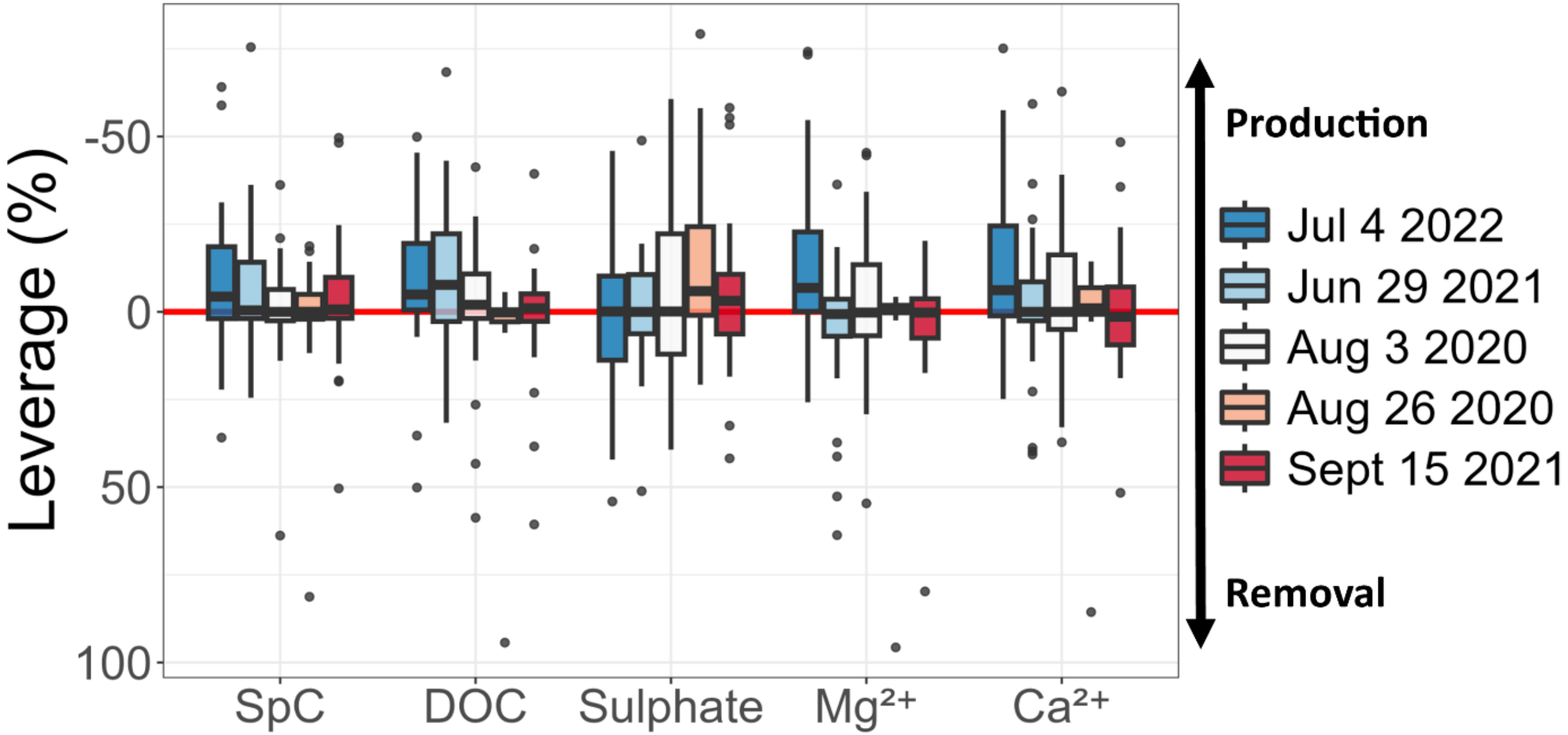
Fall 2021



Scaled concentrations of solutes per catchment area



Subcatchment Leverage

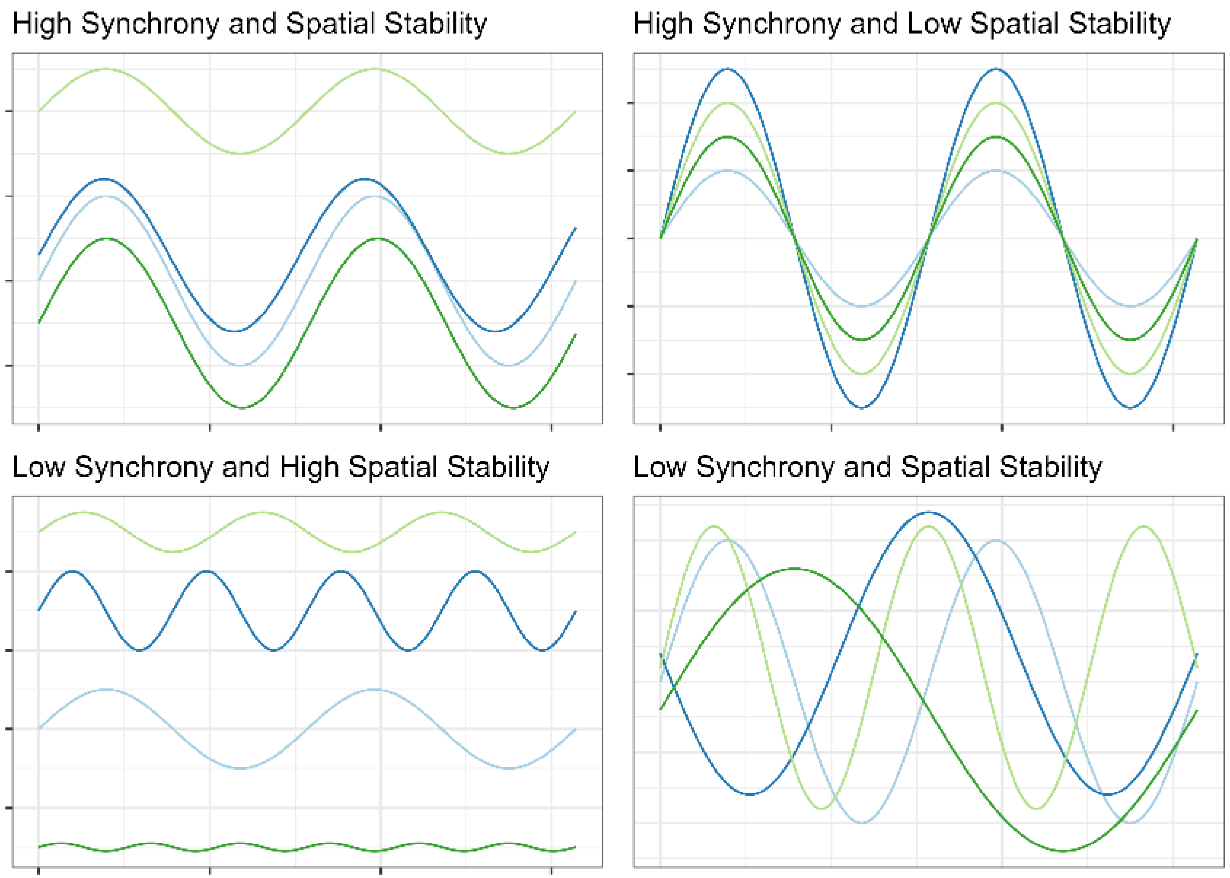


Subcatchment leverage is a spatially distributed mass balance for a particular solute.

$Leverage = (C_S - C_O) \times \frac{A_S}{A_O} \times \frac{Q_S}{Q_O}$ (1)

Where the concentration of a solute at a subcatchment (C_S) and the outlet (C_O) is multiplied by the subcatchment:outlet ratio of; area (A) and specific discharge (Q).

Synchrony and Spatial Stability

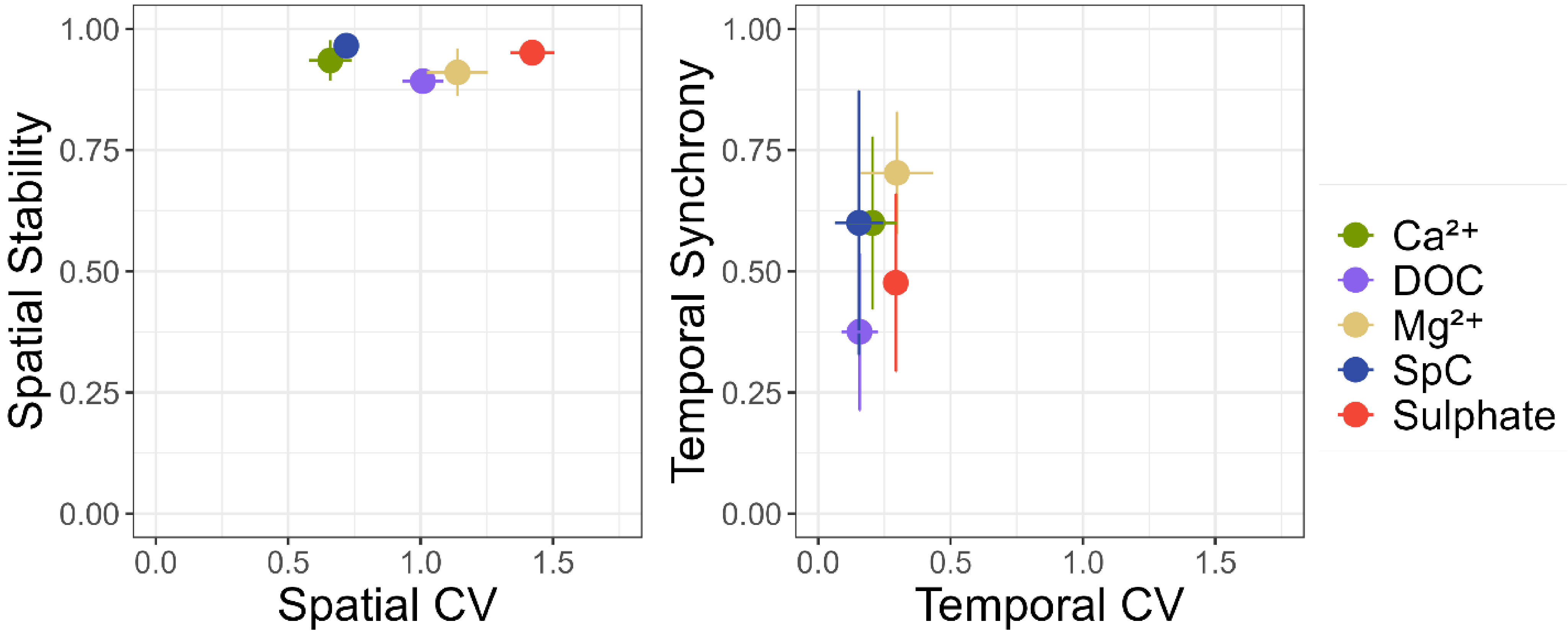


$$Spatial\ Stability = median\left[rcorr\left(C_t, C_{t_i \neq t}\right)\right]$$

$$Temporal\ Synchrony = median\left[rcorr\left(C_s, C_{s_i \neq s}\right)\right]$$

- **Spatial Stability:** Consistency of spatial patterns between surveys.
- **Synchrony:** Correlation of concentrations between subcatchments.
- Temporal and Spatial CV indicates higher variability across space than across time.
- Spatial heterogeneity drives stable patterns in chemistry.

Synchrony and Spatial Stability



High spatial stability indicates the spatial patterns of chemistry remain consistent between surveys

Temporal synchrony quantifies correlation between sites among sampling events. High synchrony represents high correlation between subcatchments over time.

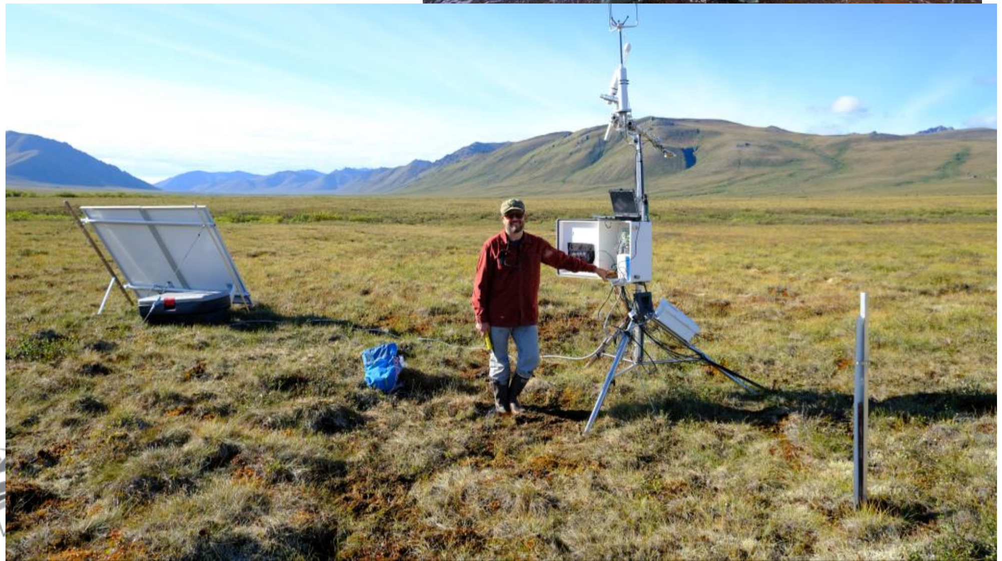
Take home points

- High similarity in relative flow contributions, and high spatial stability for stream chemistry across seasons and flow conditions.
- Higher intrinsic variability across space than across time, and high spatial stability in both flow and chemistry.
- Seasonal patterns in flow and chemistry do little to alter the spatial patterns of flow and chemistry in WCRB.
- The high spatial variability suggests that catchment biophysical heterogeneity is critical in understanding and characterizing flows and chemistry in WCRB and presumably catchments in similar environments.

Let’s move to the Tombstone Range

Let’s move to the Tombstone Range

Slavin – Km 99

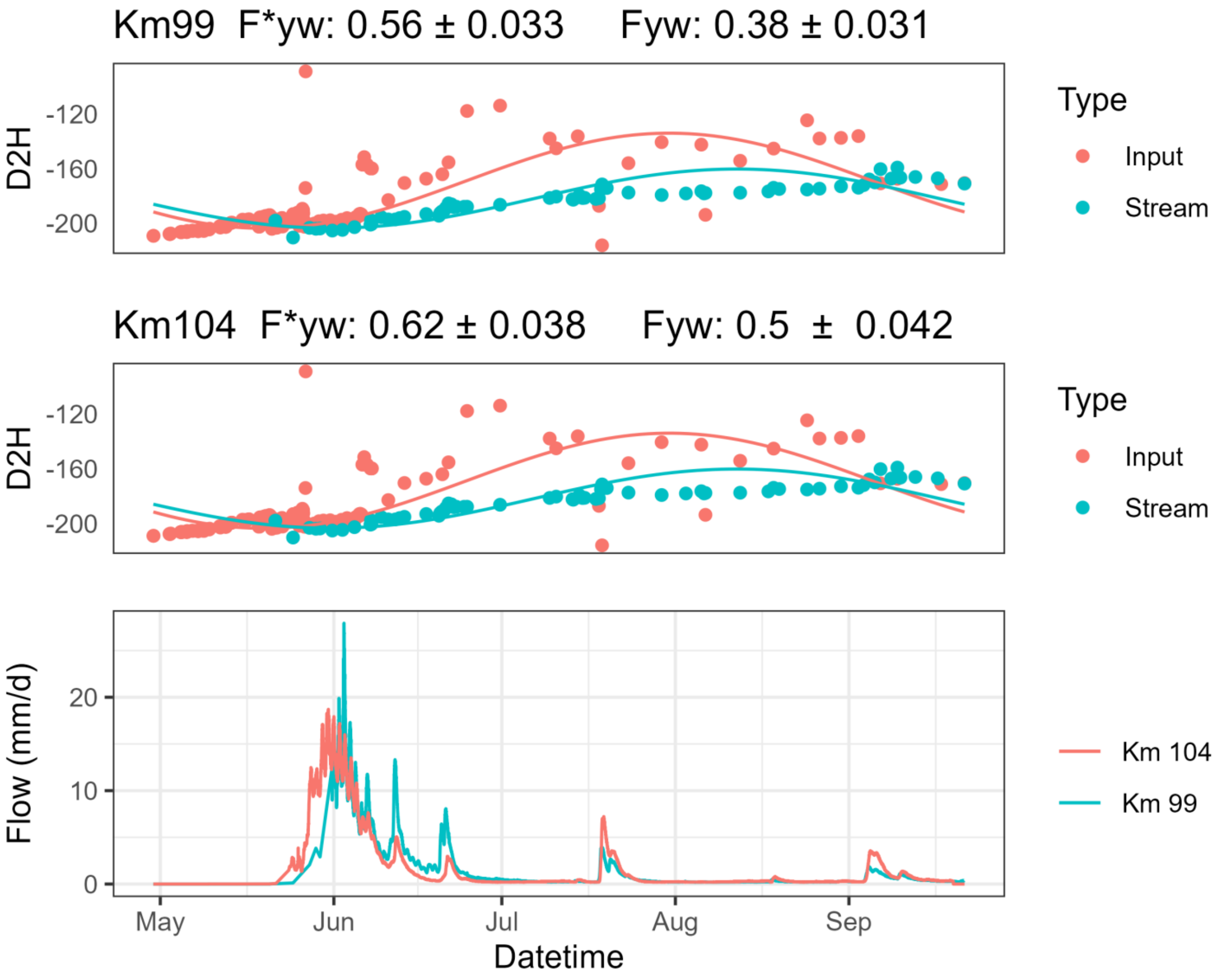



2019-05-31 10:05:07 M 1/1 12°C
HYPERFIRE 2 COVERT
RECONYX


2018-12-21 13:13:24 M 1/1 -39°C
HYPERFIRE 2 COVERT
RECONYX


2019-03-21 08:00:57 M 1/1 -4°C
HYPERFIRE 2 COVERT
RECONYX

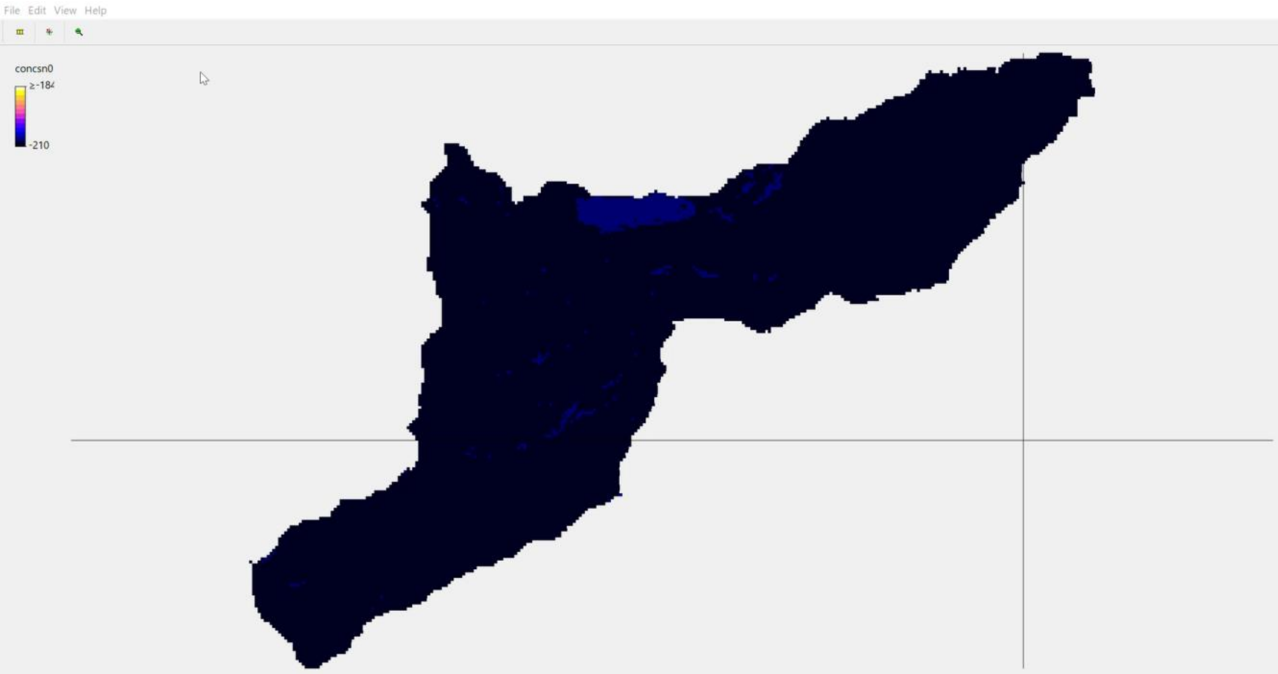
Can we utilize stable isotopes of water?



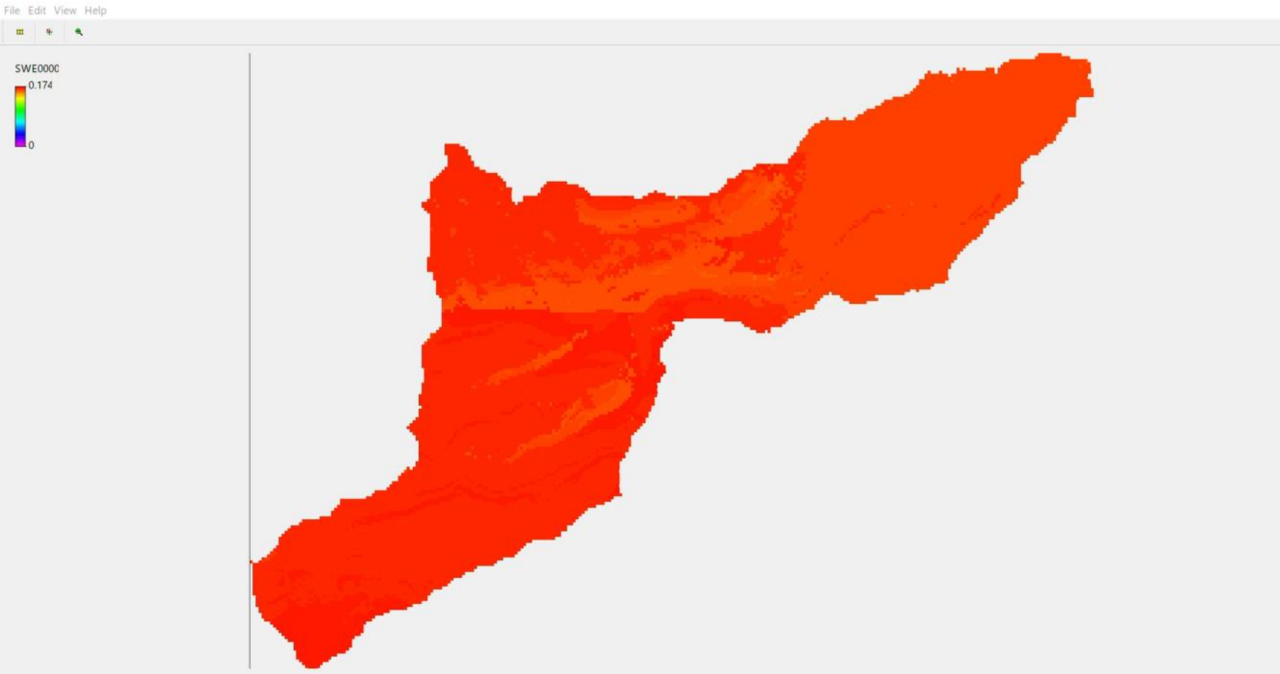
"Young Water Fractions"

Snowmelt and Snowmelt Isotopes

δ^2H

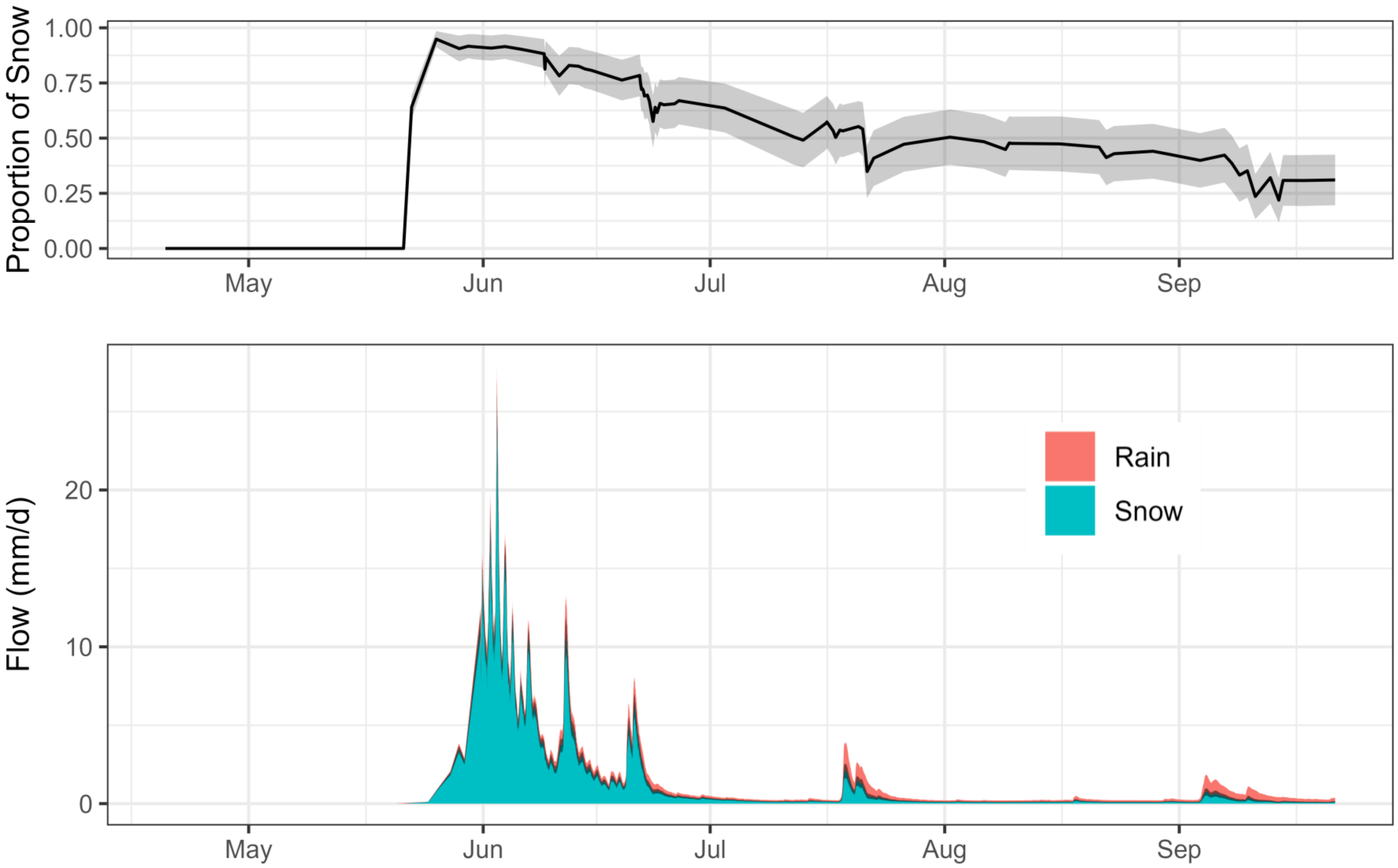


SWE



STARR model (Ala-Aho et al., 2017, HESS)

Mixing models



Storage Selection (SAS) Functions

https://doi.org/10.5194/egusphere-2022-1262
Preprint. Discussion started: 12 December 2022

mesas.py v1.0: A flexible Python package for modeling solute transport and transit times using StorAge Selection functions

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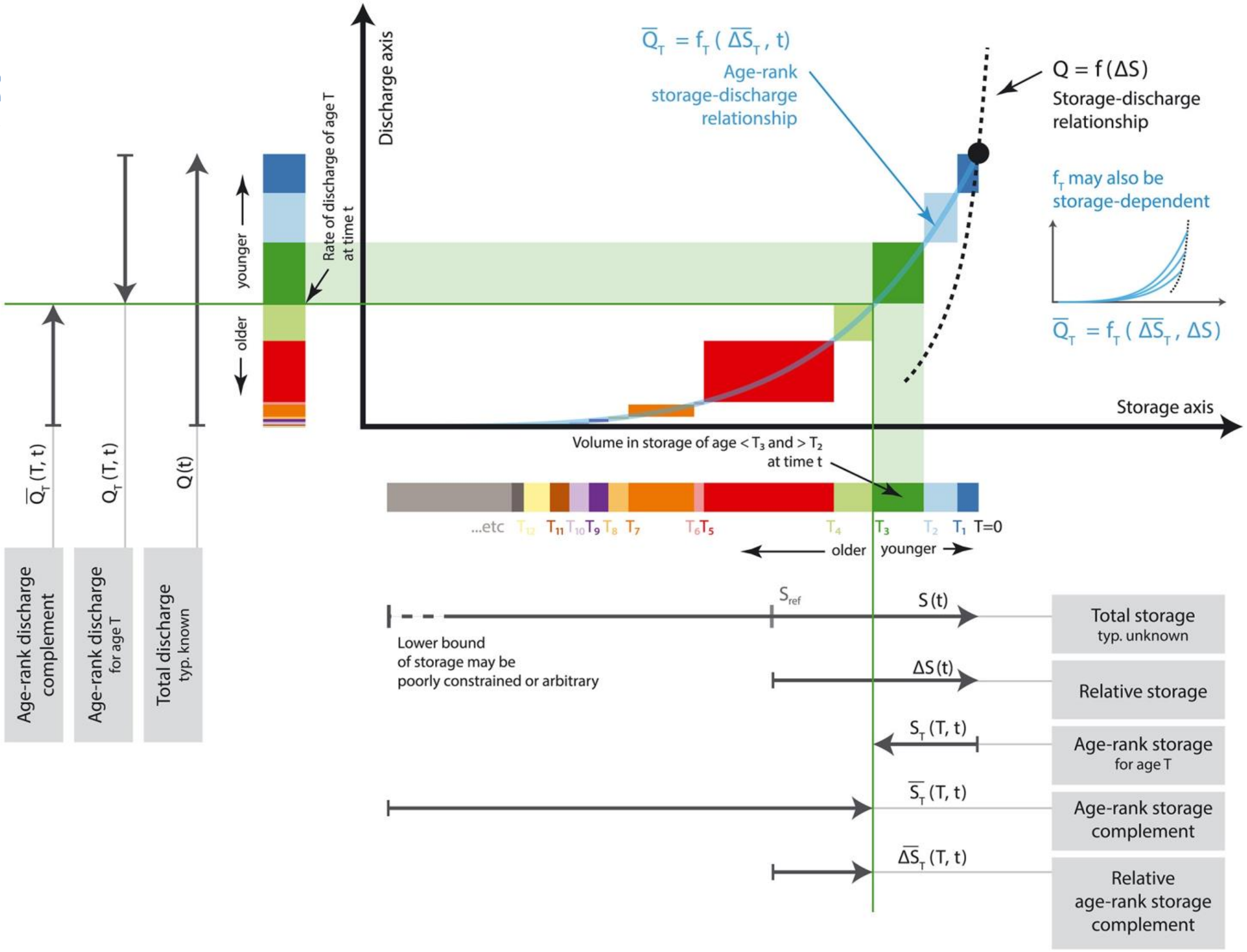
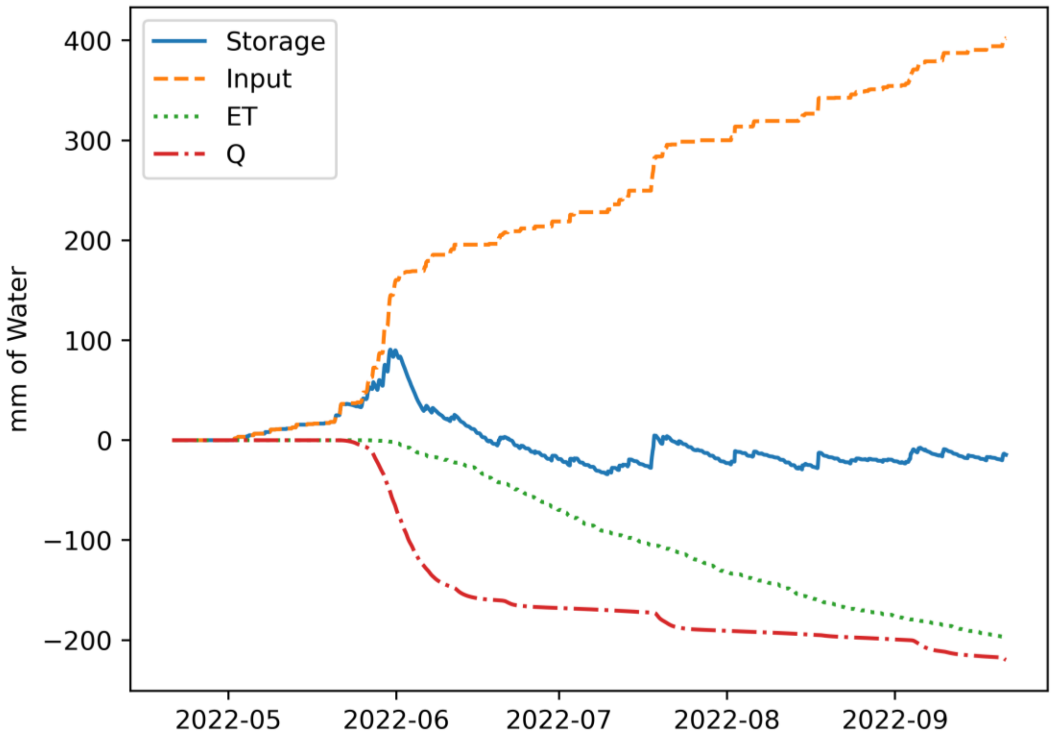
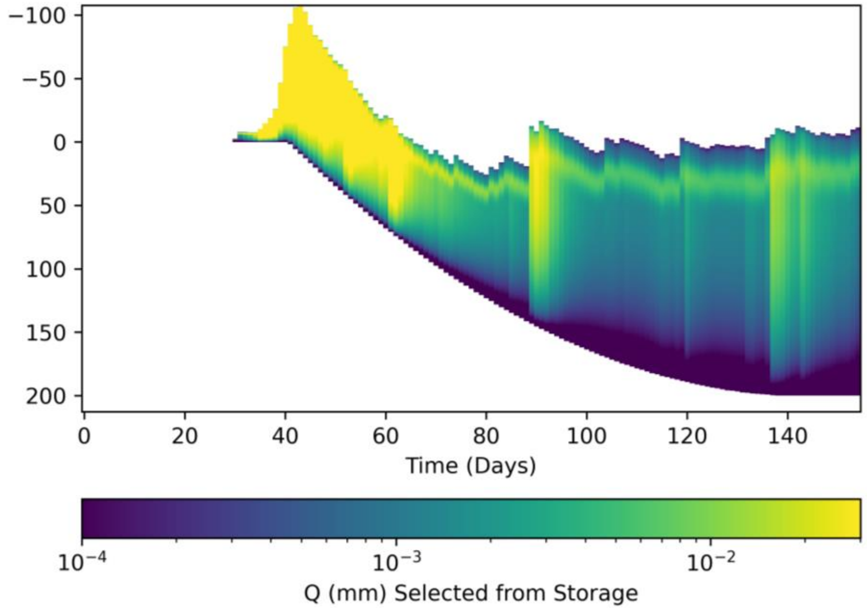
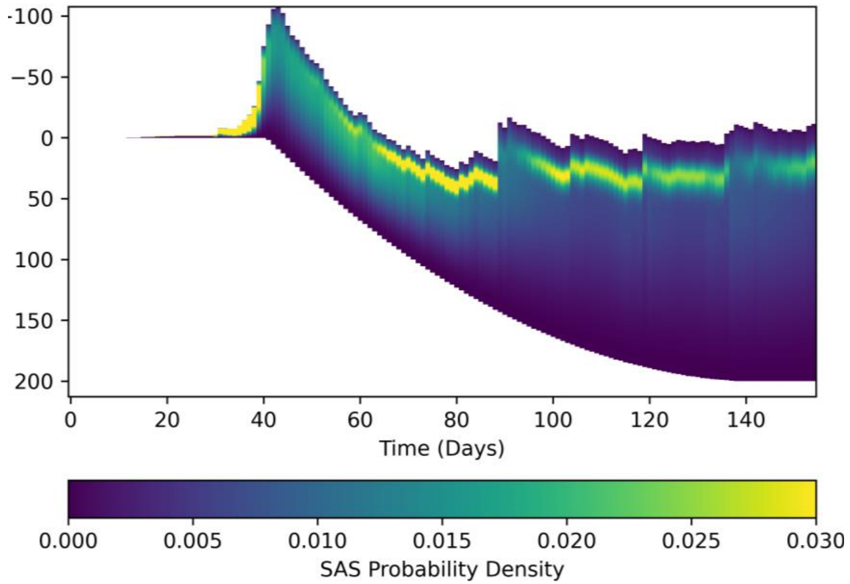
Correspondence: Ciaran J. Harman (charman1@jhu.edu)



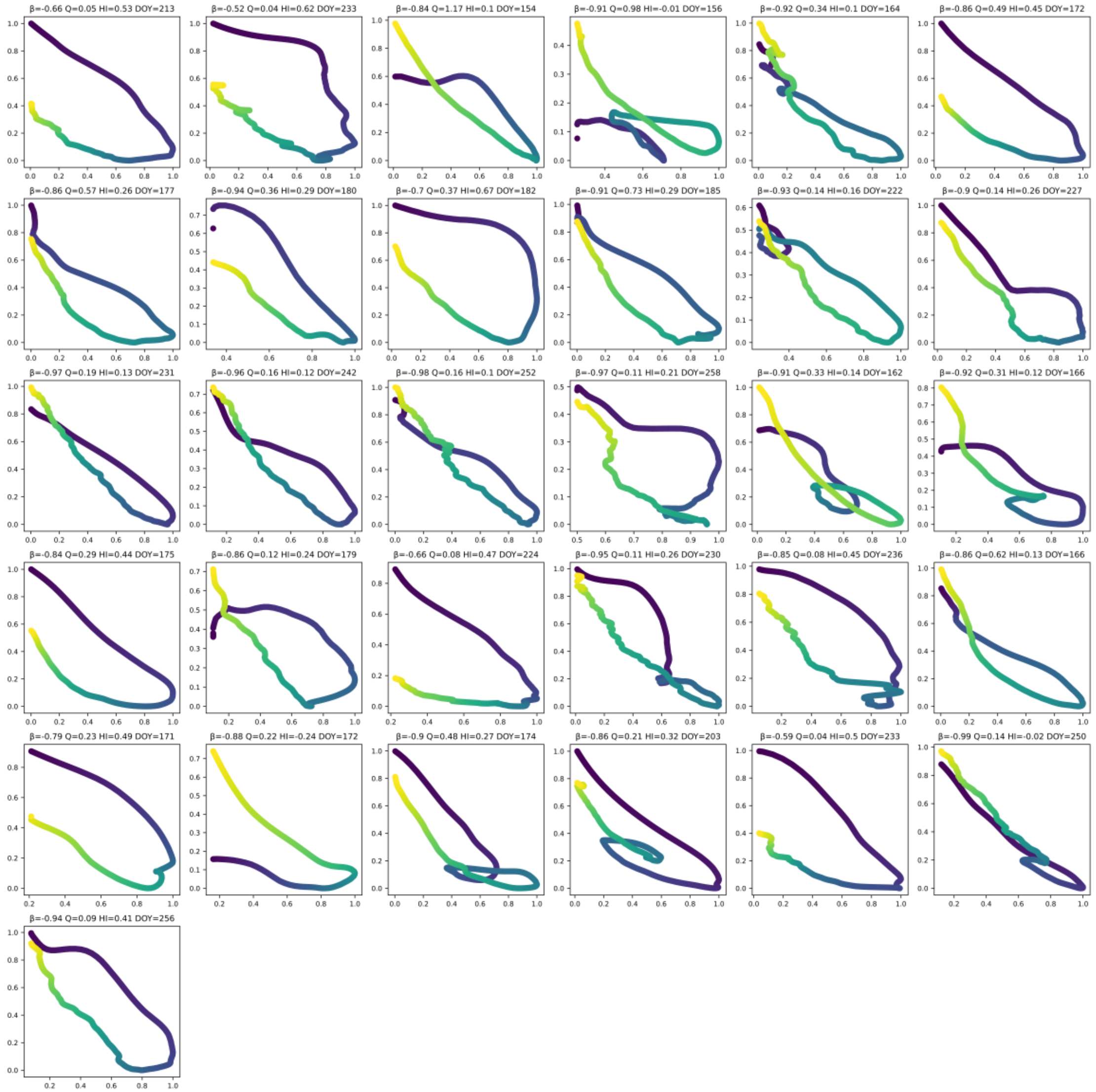
Ages and Sources of Water (from SAS functions)

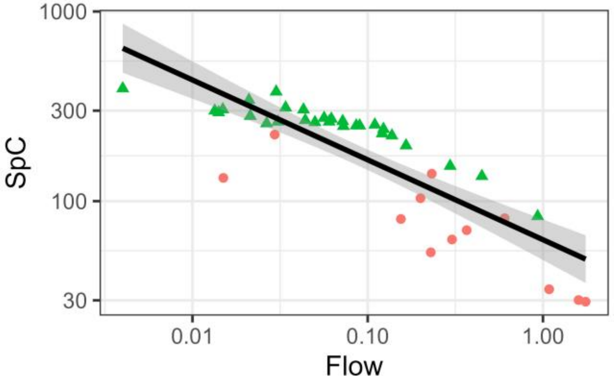


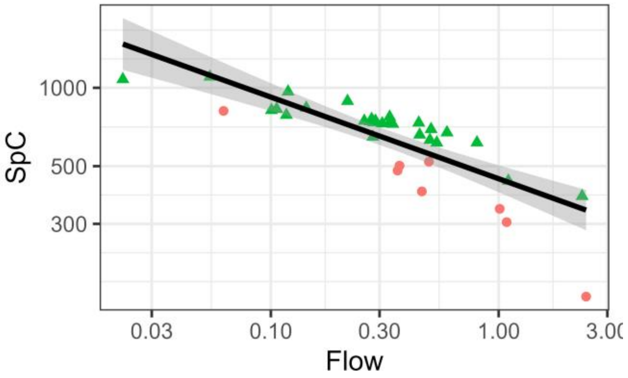


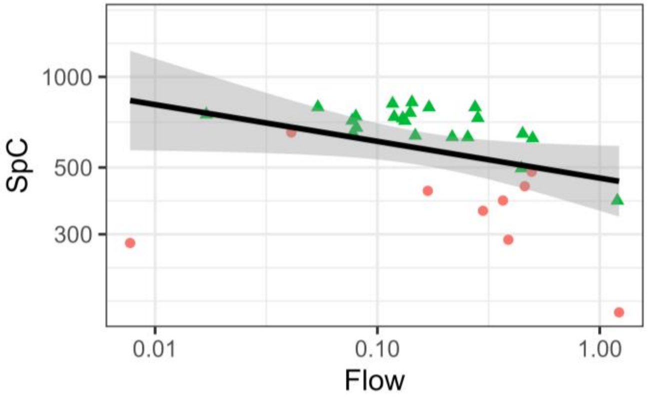


Utilize high-frequency comparative data









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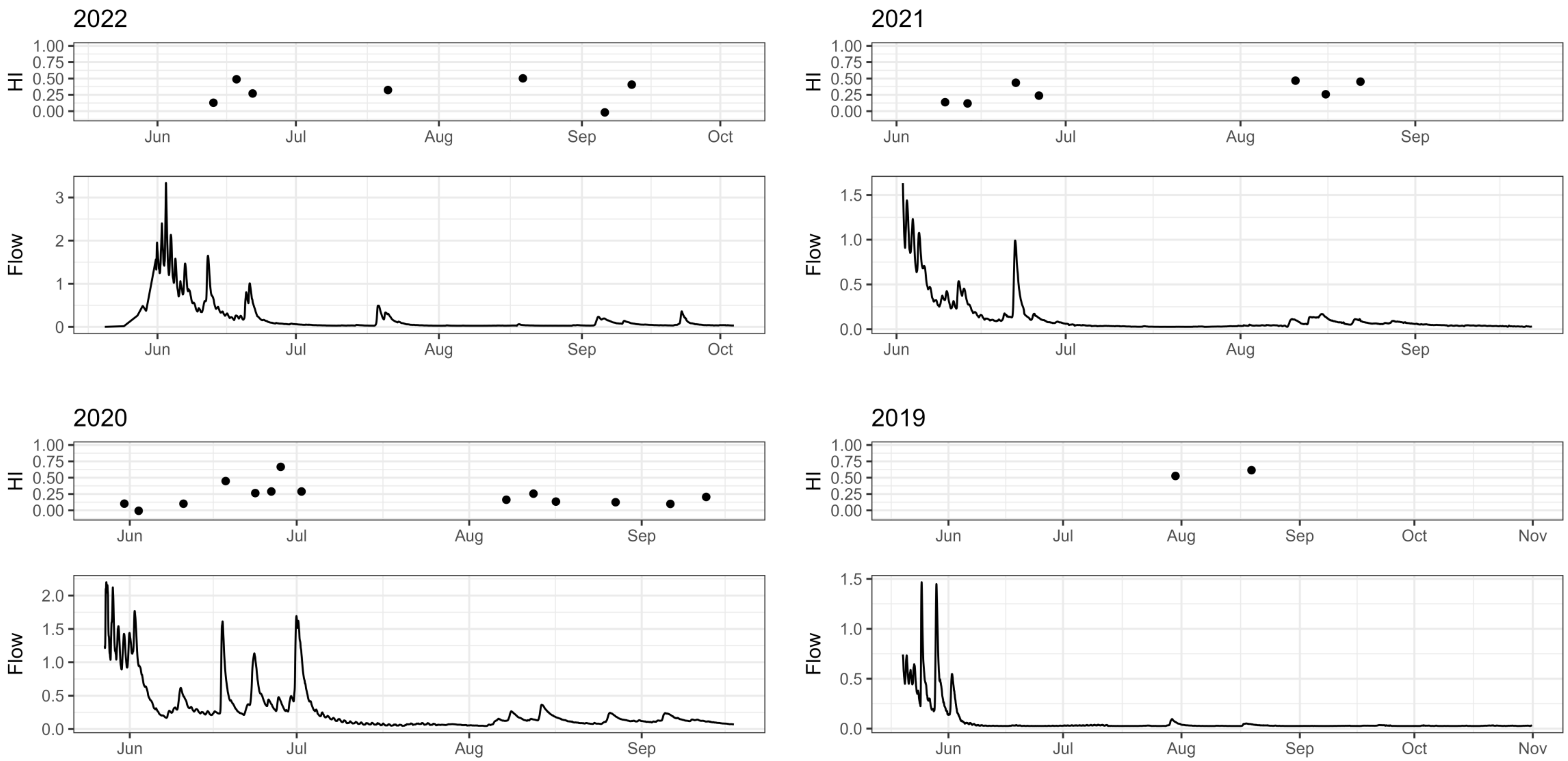

Take home points

Take home points

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