Predictive Modeling for Soil Moisture Availability and Plant Water-use in the East River Catchment, Colorado

R. J. Hess[1], N. A. Bogie[1], A. Zahori[1], M. Sprenger[2]

[1]San José State University, Department of Geology
[2]Lawrence Berkeley National Laboratory, Climate & Ecosystems Division

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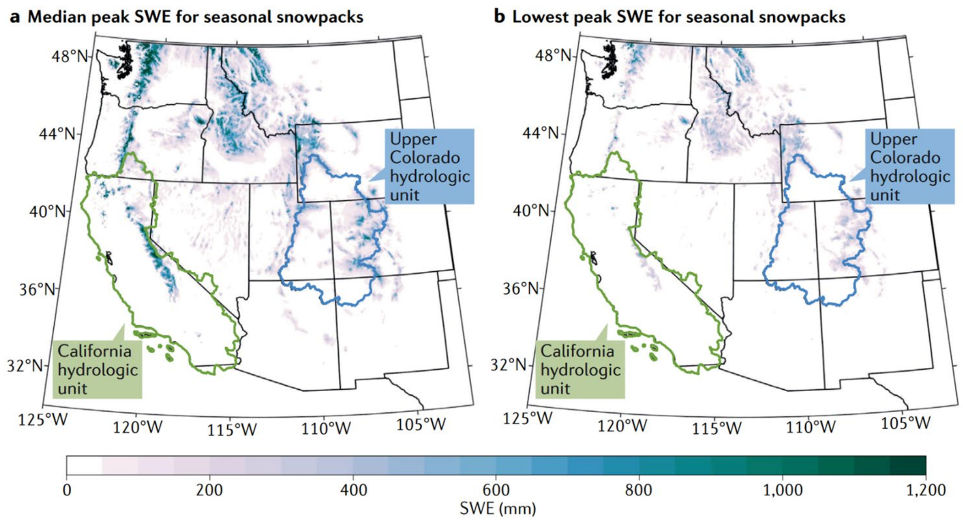
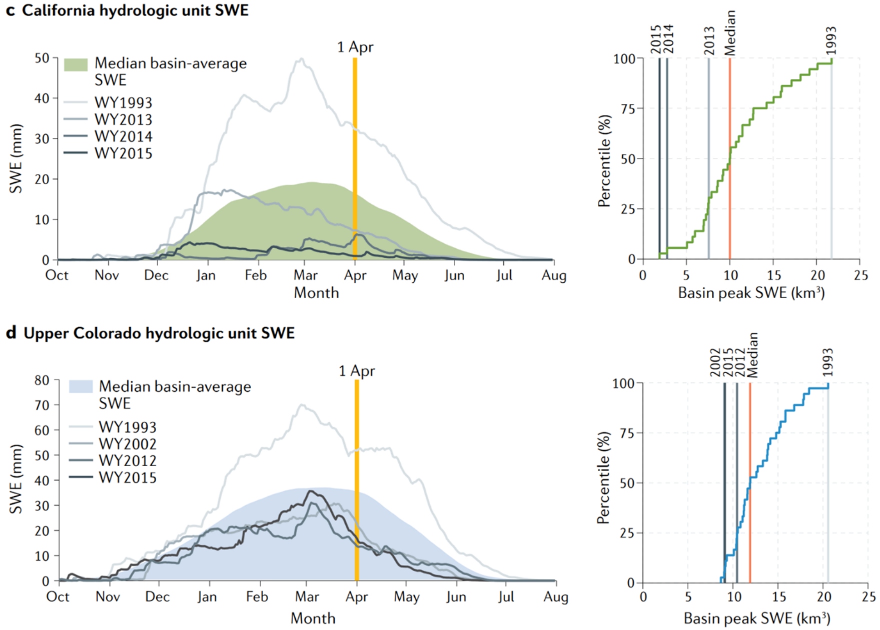
Freshwater Releases and Climate Change

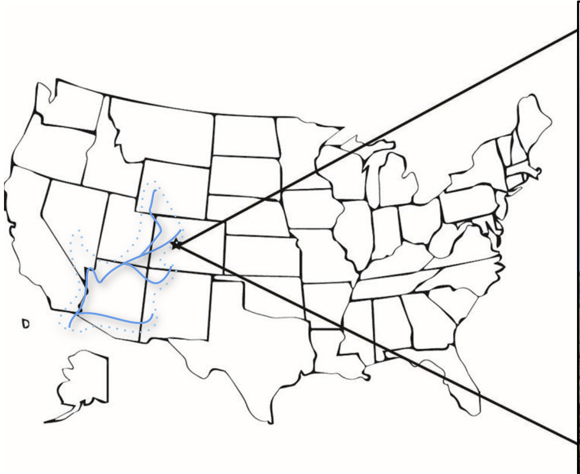


- *Snow water equivalent (SWE) across CA and CO from 1993 to 2015.*
- *Models forecast temperature increases of ~1.0 °C per 10 years in the Upper Colorado Basin (1,800 to 3,500 meters above sea level).*
- *This study aims to help quantify and predict the ecosystem response to drying conditions.*



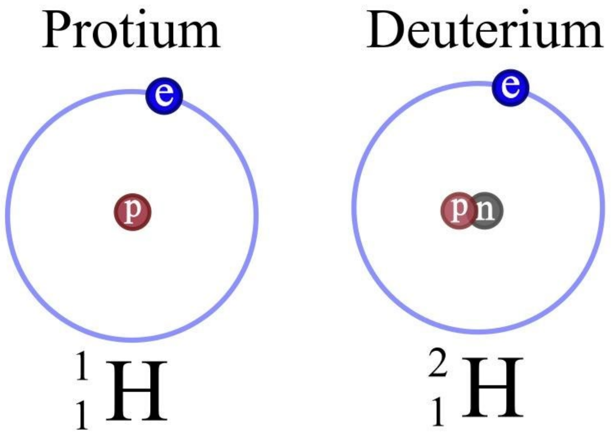
Siirila-Woodburn et al., 2021

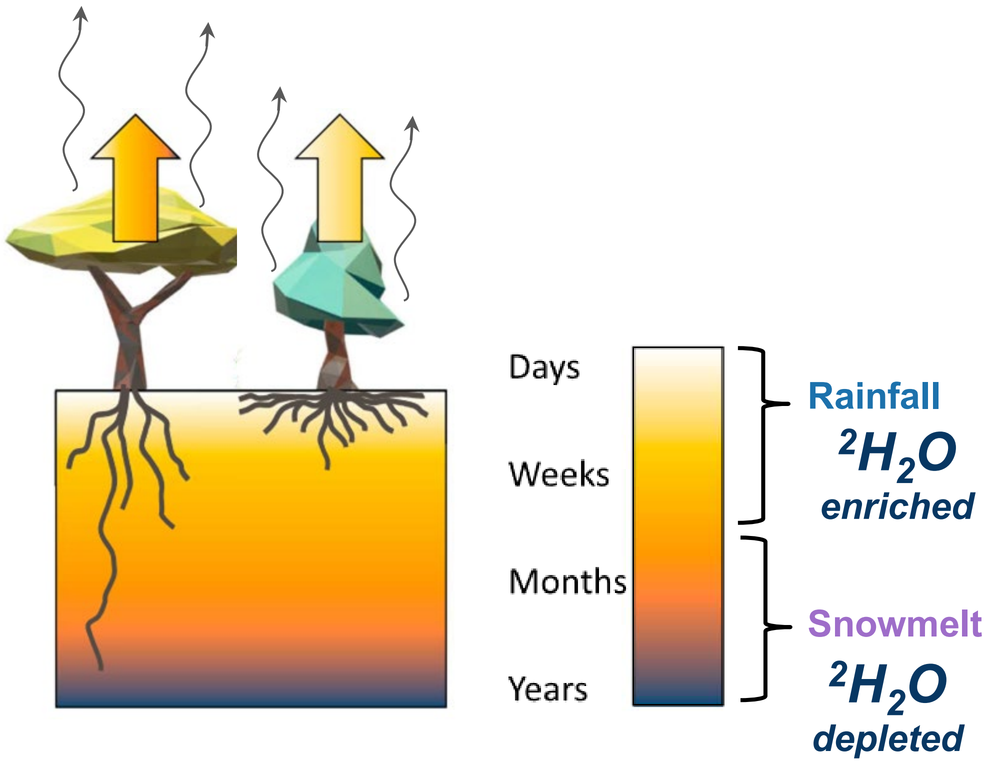
East River Watershed, Colorado



- 300 km^2 headwater catchment. (2,950 meters above sea level)
- Major tributary to the Colorado River (CR).
- CR supplies water to 40 million people across seven states.

Isotope Hydrology

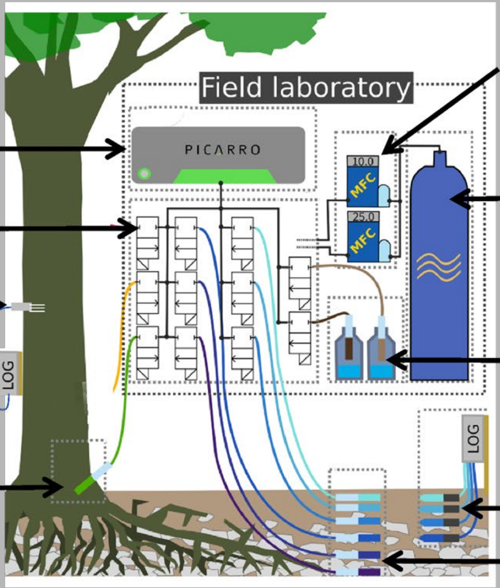




Sprenger et al., 2019

East River Field Setup (Two soil profiles)

Laser Spectrometer

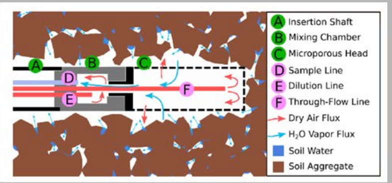


(Adapted from Seeger & Weiler, 2021)

Field Setup.

Sap flow sensor in an Aspen tree.

Vapor probe in a spruce tree.



Vapor probe schematic. (Seeger & Weiler, 2021)

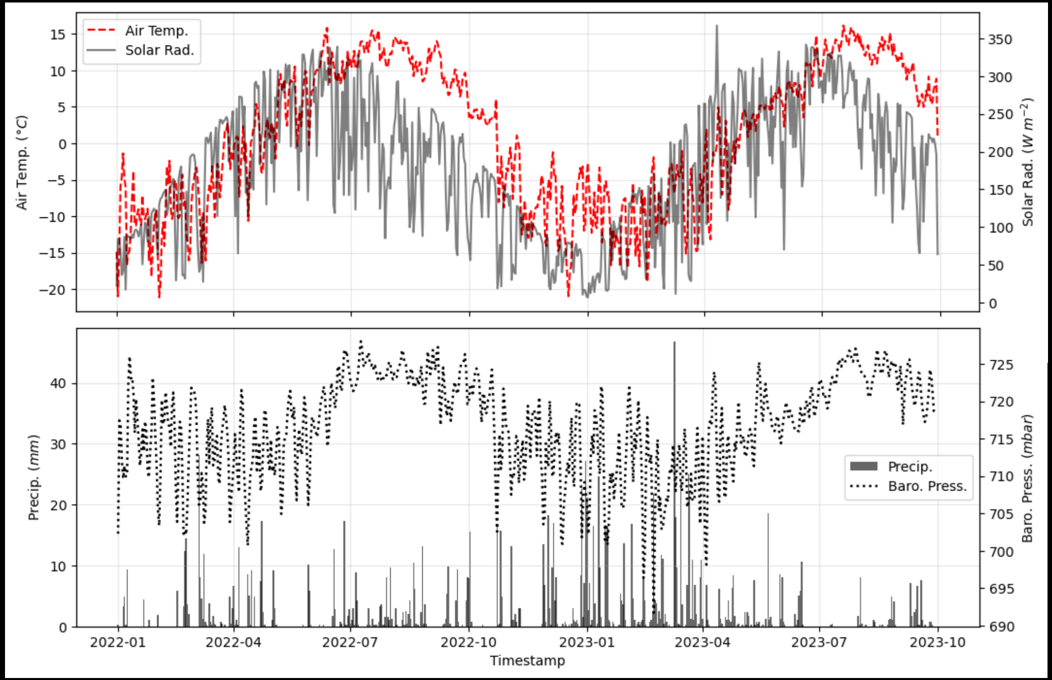
One beneath Aspen trees —

a second beneath Spruce trees

East River Field Setup

In situ isotope analyzer, measuring ^{2}H and ^{18}O vapor from probes in soil and trees

Meteorologic Data



Select Trends

Air Temperature (℃)

and

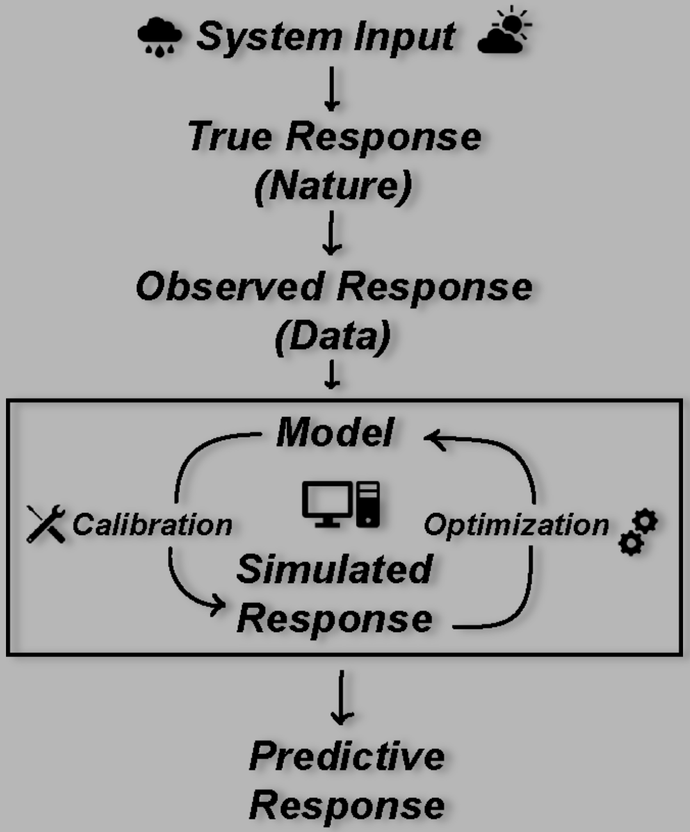
Solar Radiation ($W\ m^{2}$)

Cumulative Precip. (*mm*)

and

Baro. Pressure (*mbar*)

Conceptual Approach



- Trained the numerical model HYDRUS-1D with:

weather data
soil moisture measurements
in-situ ratios of deuterium (^2H)

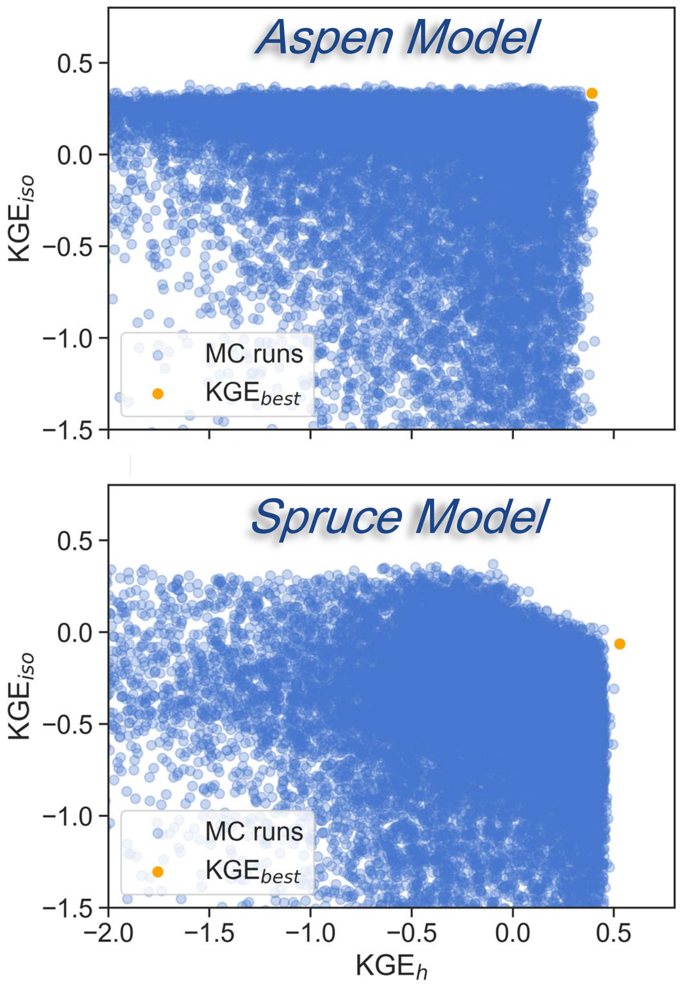
- Simulated WY-22 dynamics of soil dry down and rewetting, focusing on the driest months of the year.

Objective Function (Goodness of Fit)

Kling —Gupta Efficiency

$$KGE = 1 - \sqrt{(r-1)^2 + \left(\frac{\sigma_{sim}}{\sigma_{obs}} - 1\right)^2 + \left(\frac{\mu_{sim}}{\mu_{obs}} - 1\right)^2}$$

(*-infinity, 1*]



Parameter Optimization

Mualem — van Genuchten Equation

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha\ \psi)^n]^m}$$

θ : water content [L^3 L^{-3}]

θ_r : residual water content [L^3 L^{-3}]

θ_s : saturated water content [L^3 L^{-3}]

K_s : hydraulic conductivity [L T^{-1}]

n : pore size distribution [-]

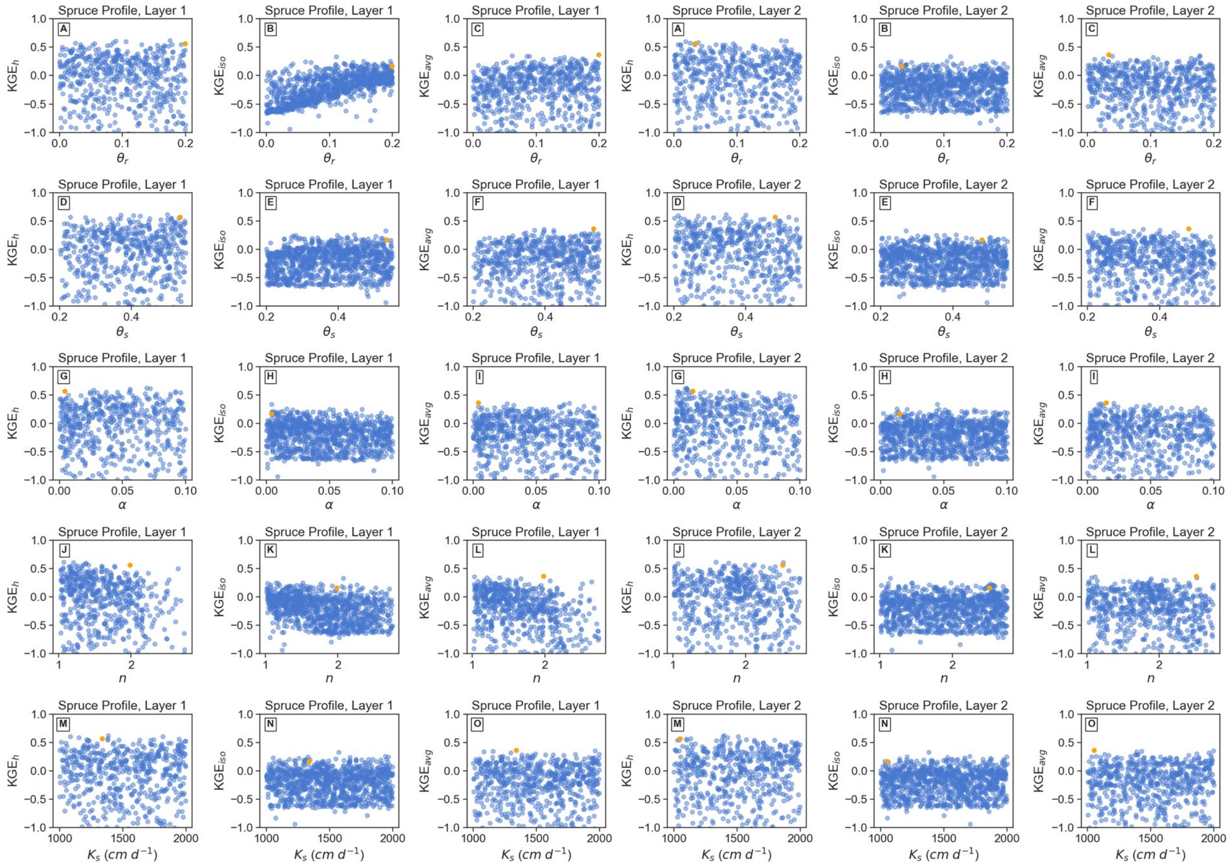
α : inverse of air entry [-]

m : shape parameter [-]

ψ : negative pressure [L]

Layer 1 (0 to 60 cm-bgs)

Layer 2 (60 to 100 cm-bgs)

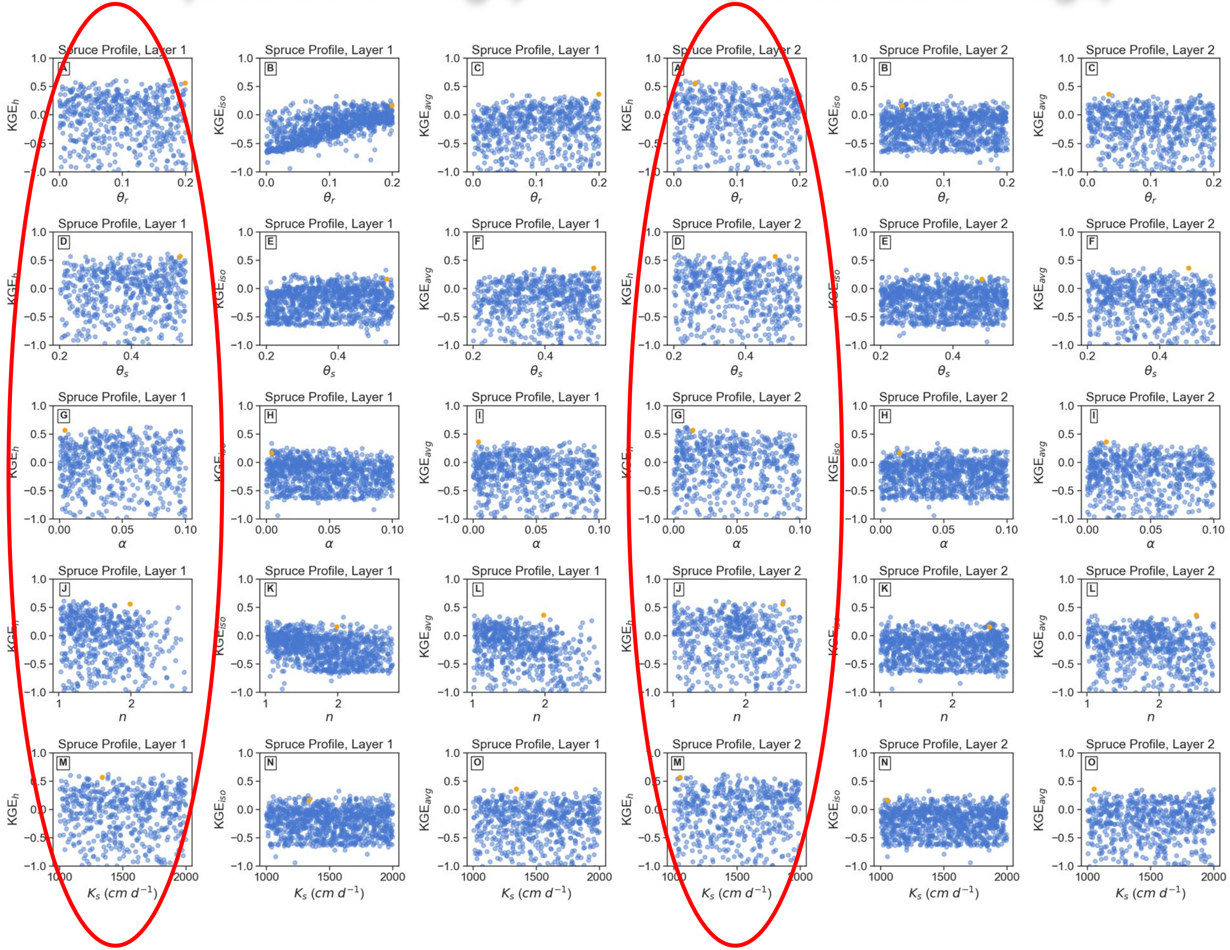


Parameter Optimization

Layer 1 (0 to 60 cm-bgs)

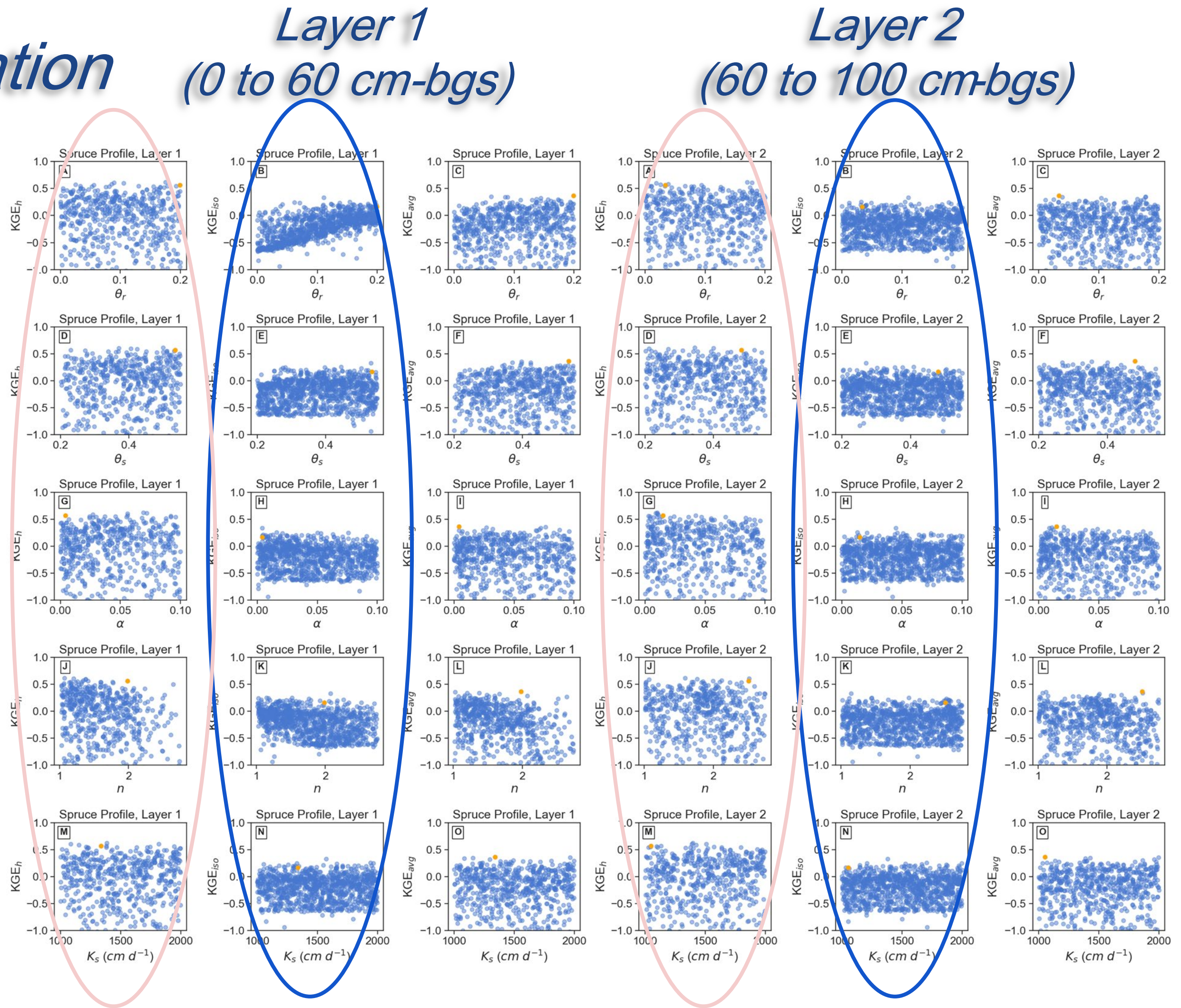
Layer 2 (60 to 100 cm-bgs)

Soil Moisture Goodness of Fit: ***KGE$_h$***



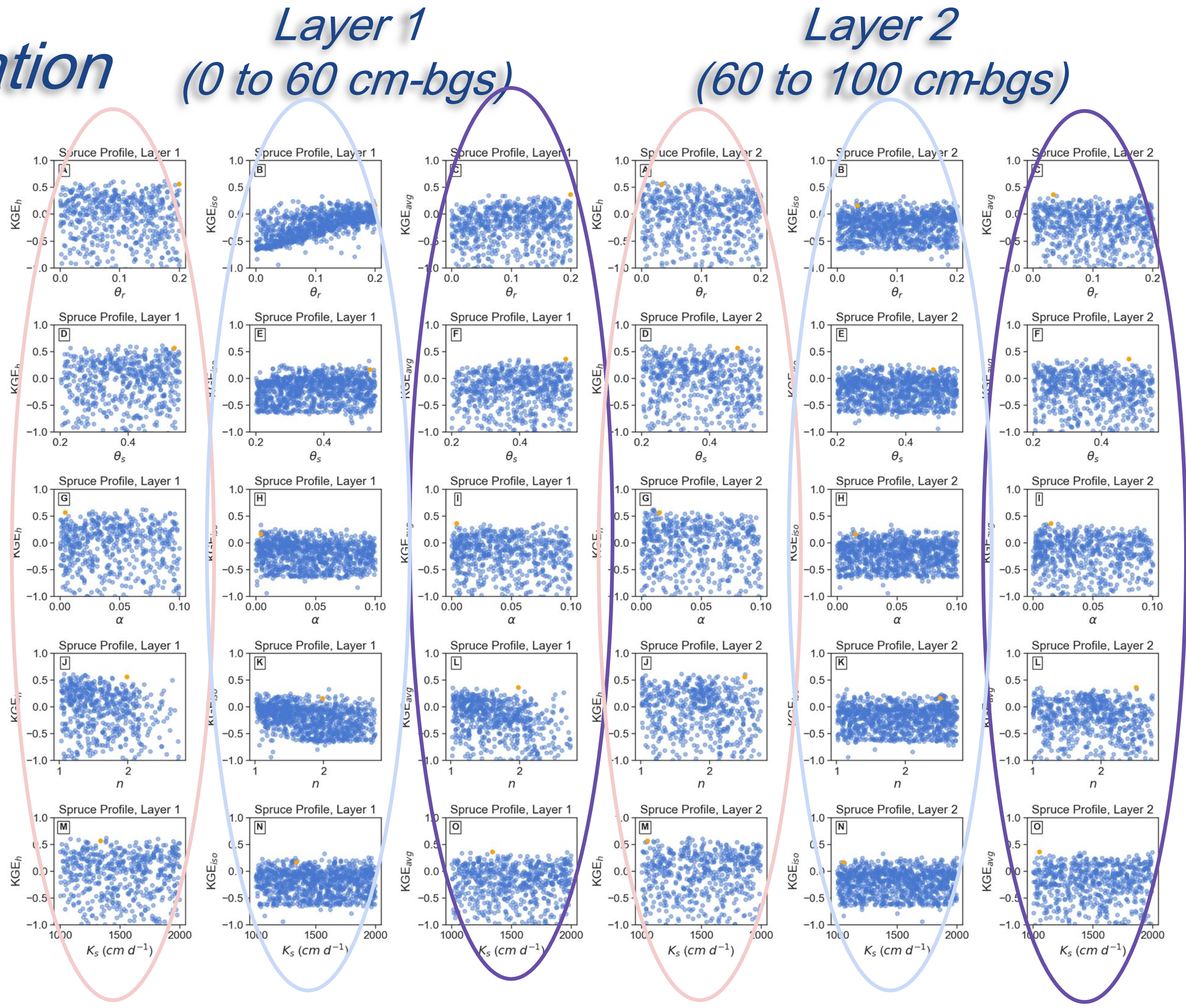
Parameter Optimization

Isotope Ratio ($^2H/^1H$)
Goodness of Fit:
KGE$_{iso}$

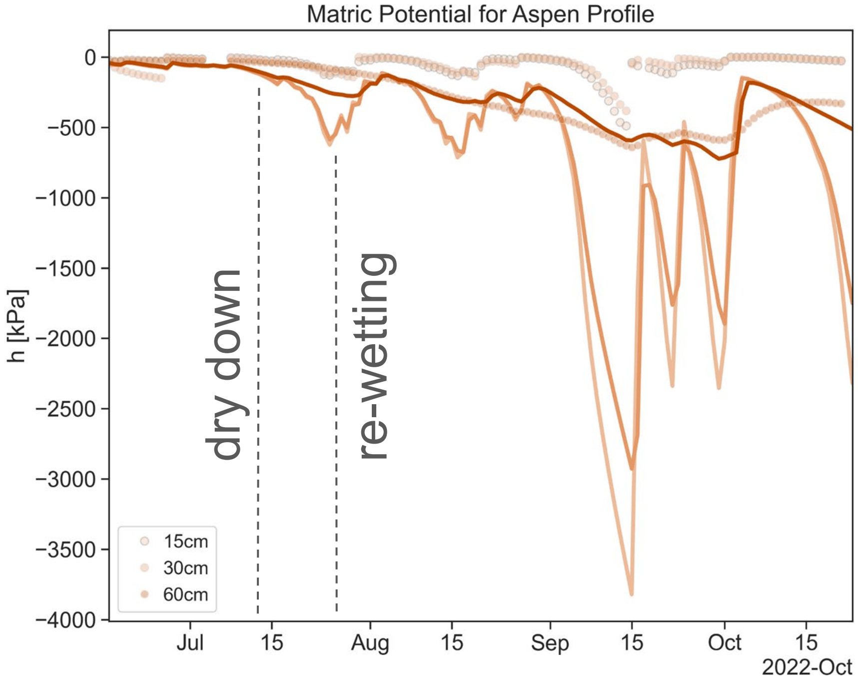


Parameter Optimization

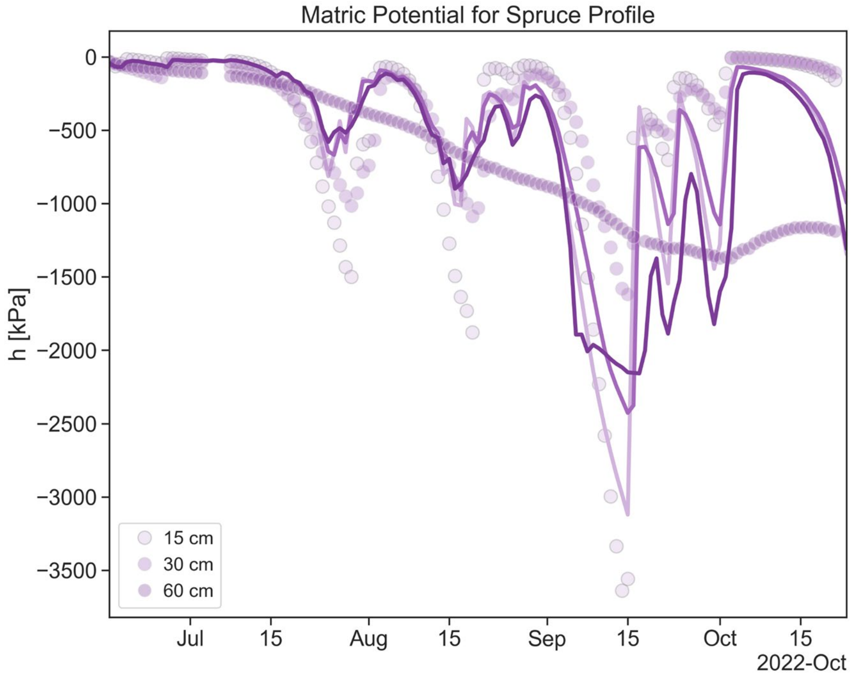
Average
Goodness of fit:
$KGE_h + KGE_{iso} = \mathbf{KGE_{avg}}$



Soil Moisture Dynamics

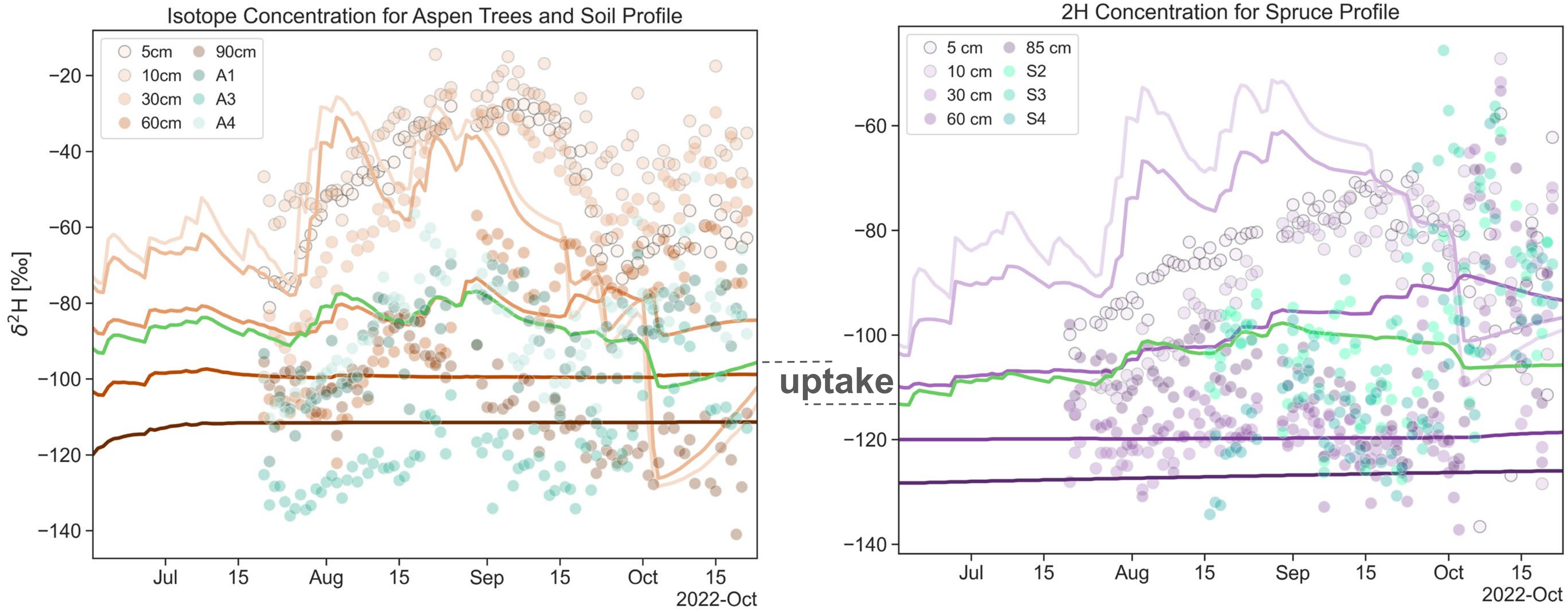


Aspen Profile [KGE_h: 0.39]



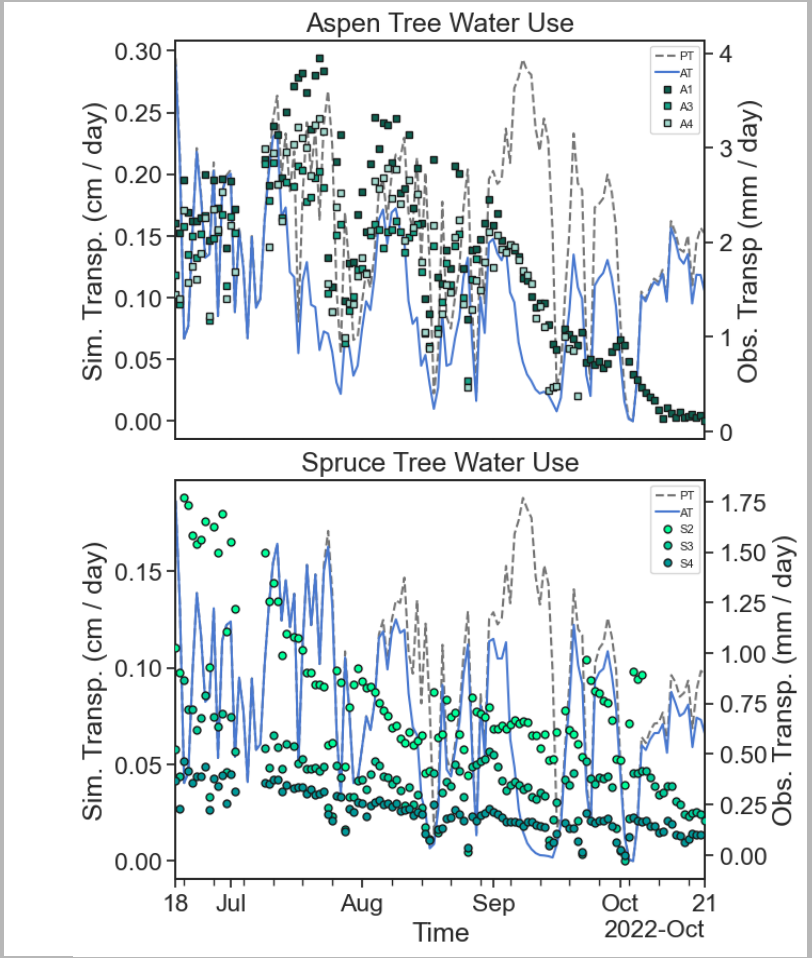
Spruce Profile [KGE_h: 0.50]

Isotope Dynamics



Aspen Profile, KGE_{iso}: 0.34

Spruce Profile, KGE_{iso}: -0.04



Plant water-use

- *Sap flow rates range 100 to 700 L d $^{-1}$*

  1 mm of water use = 1 L m^{-2} = 200 L site^{-1}

- *Aspen and spruce rely heavily on headwater snowmelt.*

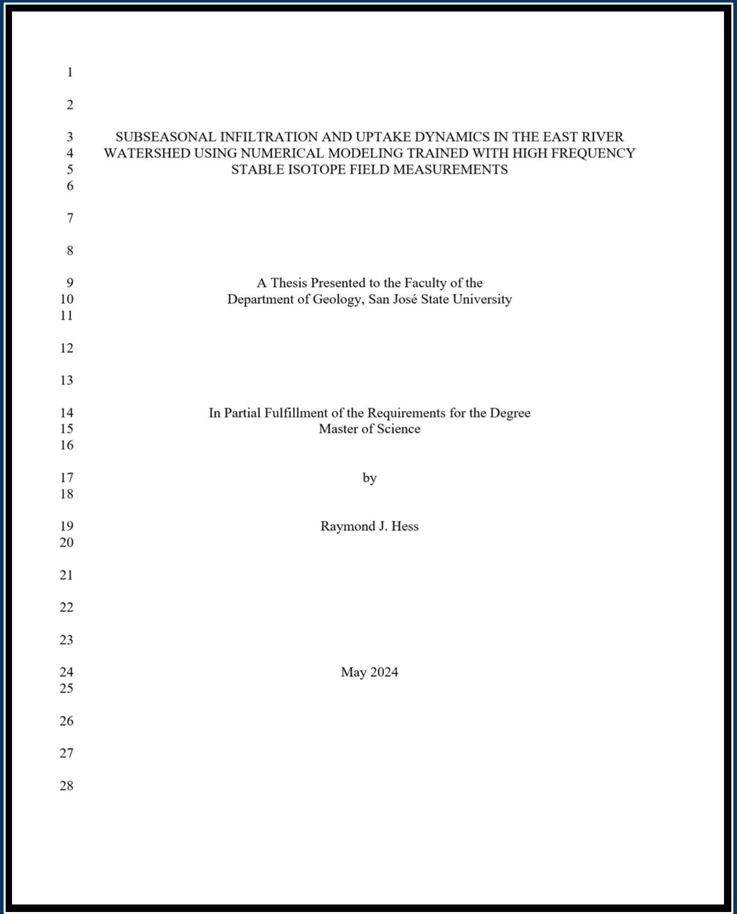
- *Changes to the timing and quantity of snowmelt will limit availability and extend the dry season.*

- *Revised management strategies for high elevation ecosystems are necessary.*

Next Steps

- *Fit WY-23 data to model simulations*
- *Perform a water balance for WY-22 and WY-23*
- *Model 5, 10, and 20 year scenarios, increasing temperature inputs and reducing rainfall inputs*

Questions?
raymond.hess@sjsu.edu



SUBSEASONAL INFILTRATION AND UPTAKE DYNAMICS IN THE EAST RIVER WATERSHED USING NUMERICAL MODELING TRAINED WITH HIGH FREQUENCY STABLE ISOTOPE FIELD MEASUREMENTS

A Thesis Presented to the Faculty of the Department of Geology, San José State University

In Partial Fulfillment of the Requirements for the Degree Master of Science

by

Raymond J. Hess

May 2024