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

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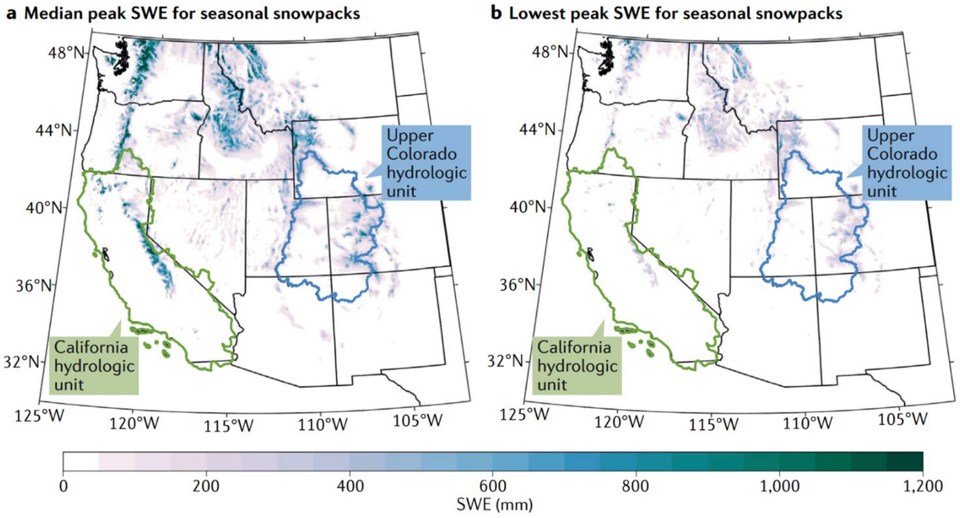
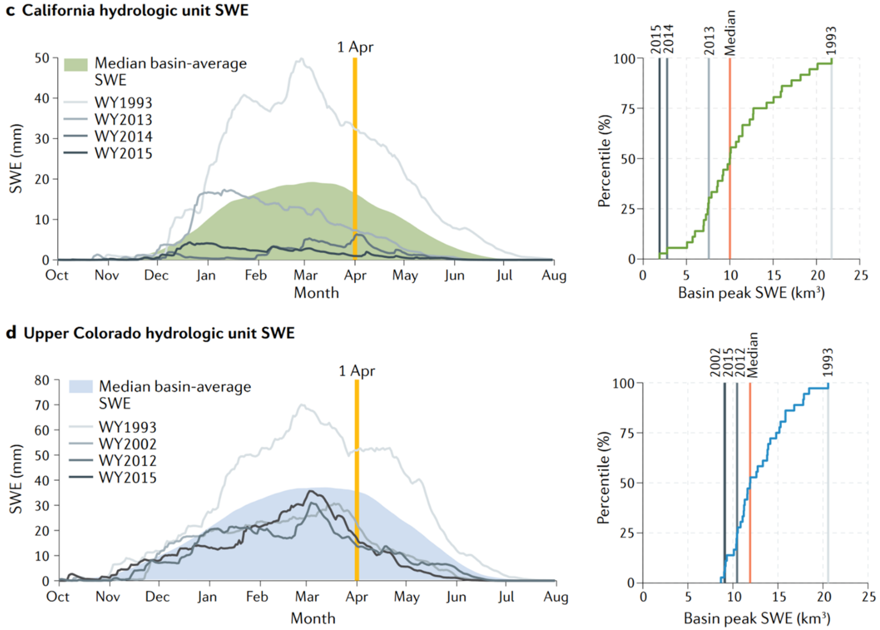


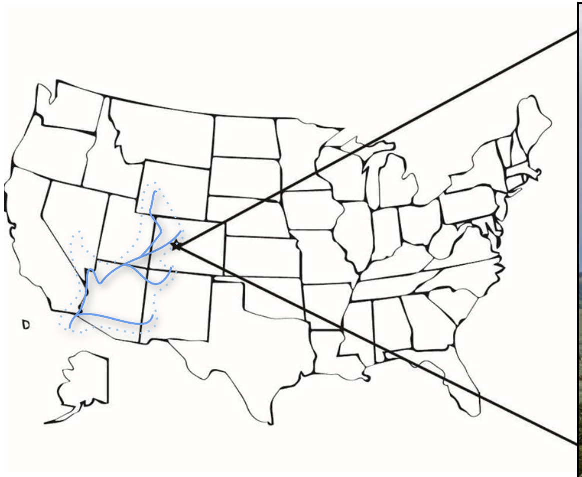
Freshwater Releases and Climate Change



- *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.*

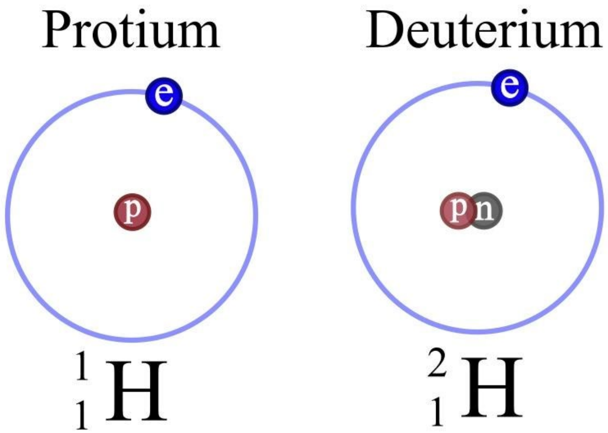
Siirila-Woodburn et al., 2021

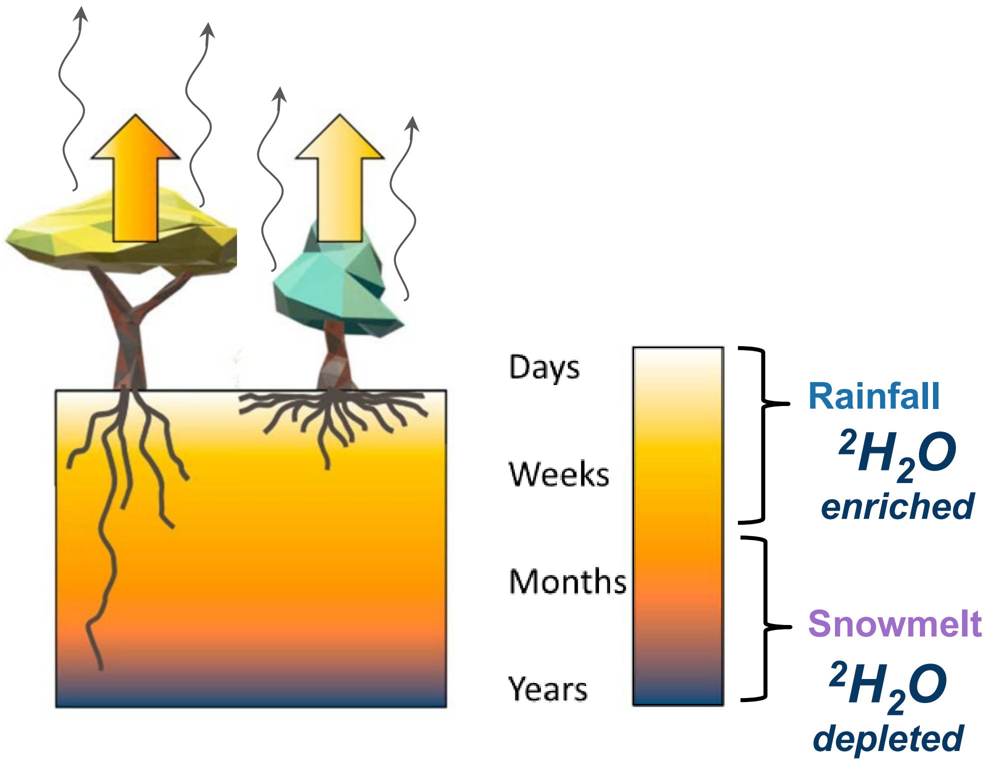
East River Watershed, Colorado



- 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.

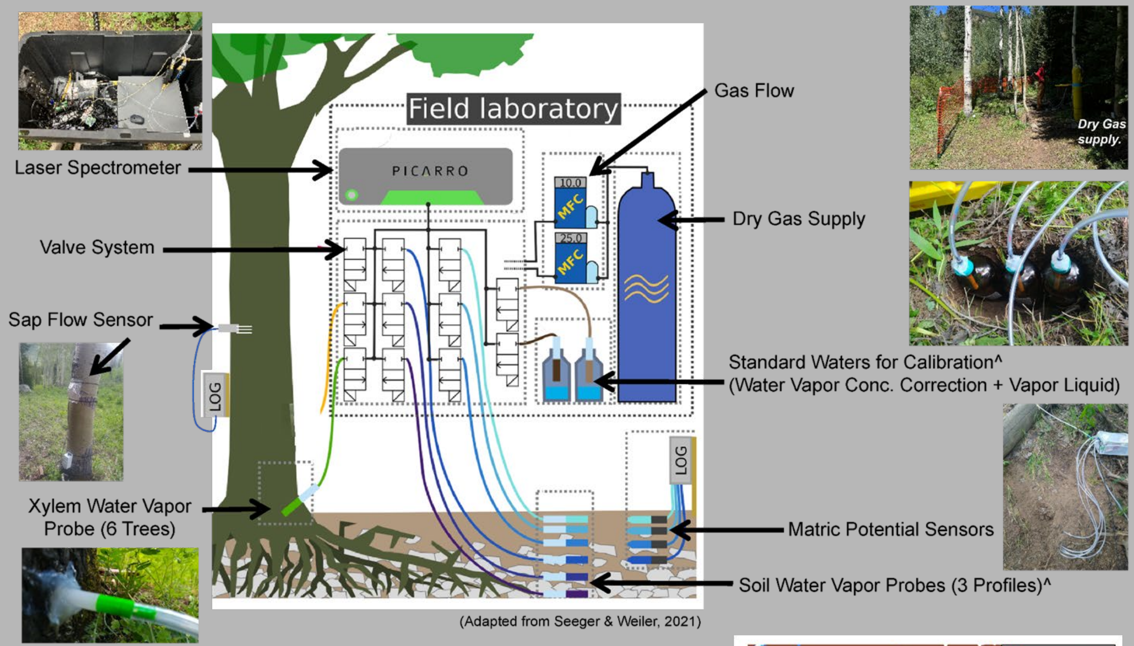
Isotope Hydrology





Sprenger et al., 2019

East River Field Setup (Two soil profiles)

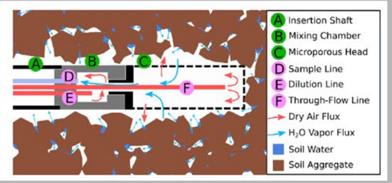


(Adapted from Seeger & Weiler, 2021)

Field Setup.

Sap flow sensor in an Aspen tree.

Vapor probe in a spruce tree.



Vapor probe schematic. (Seeger & Weiler, 2021)

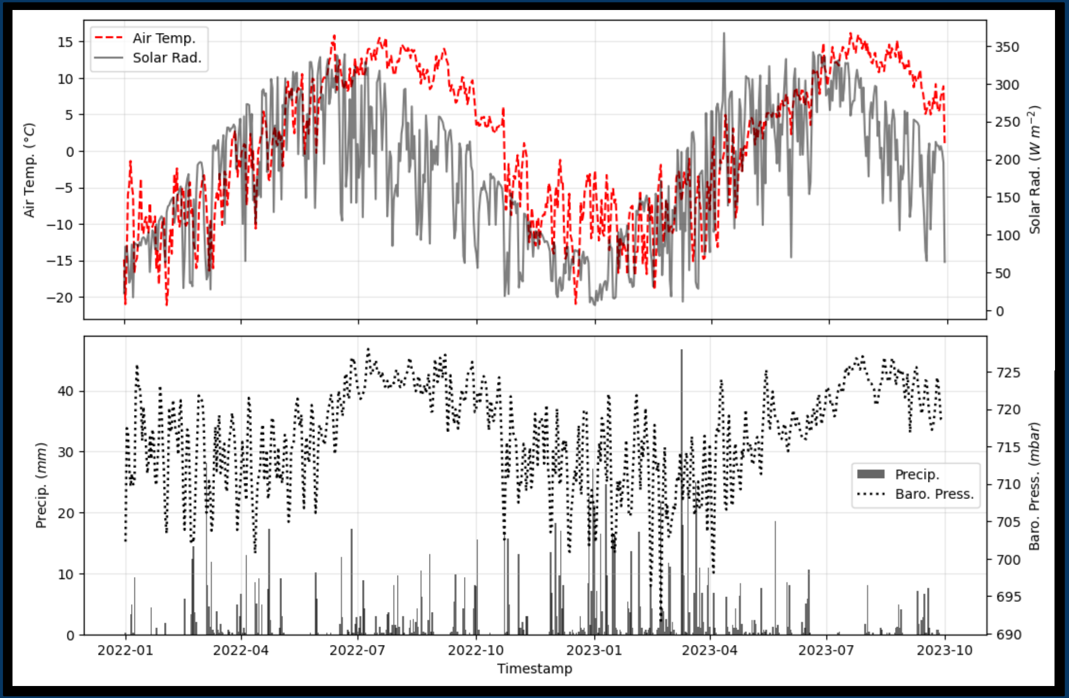
One beneath Aspen trees —

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

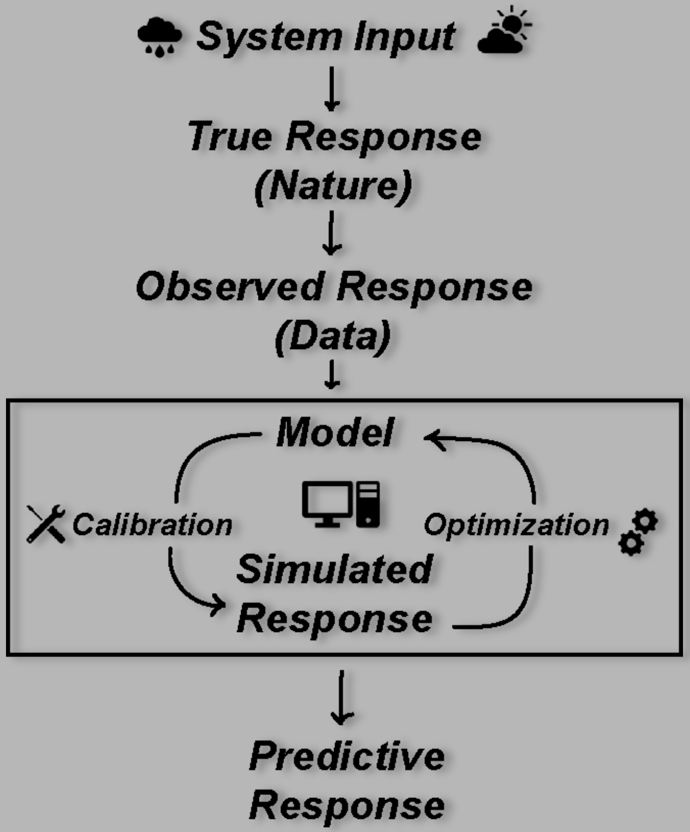


Select Trends

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)

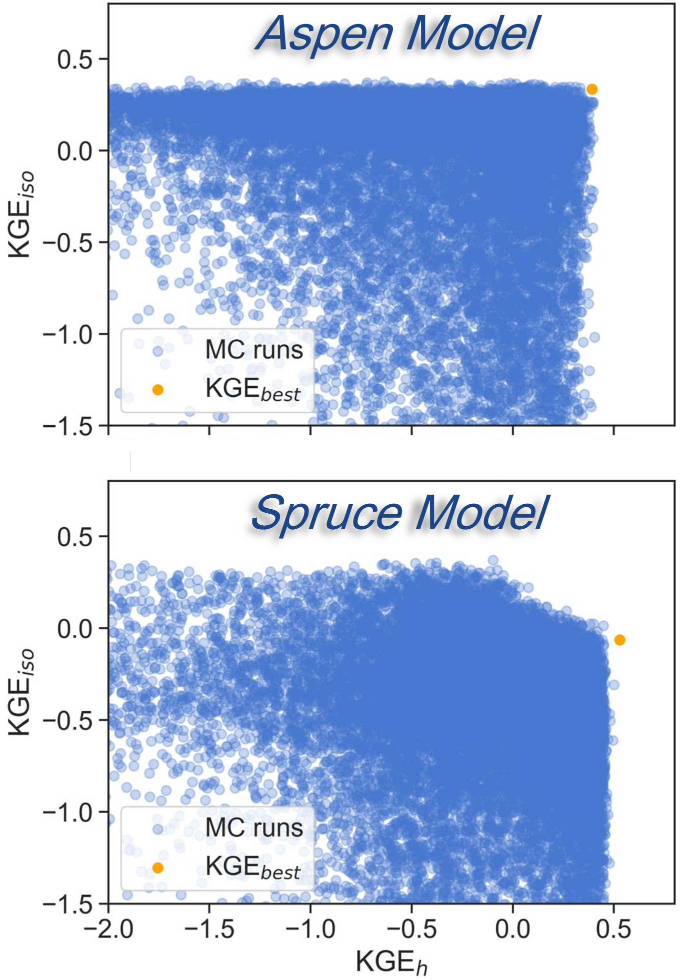
- Simulated WY-22 dynamics of soil dry down and rewetting, focusing on the driest months of the year.

Objective Function (Goodness of Fit)

Kling —Gupta Efficiency

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

(-*infinity*, *1*]



Parameter Optimization

Layer 1 (0 to 60 cm-bgs)

Layer 2 (60 to 100 cm-bgs)

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 [$L^3\ L^{-3}$]

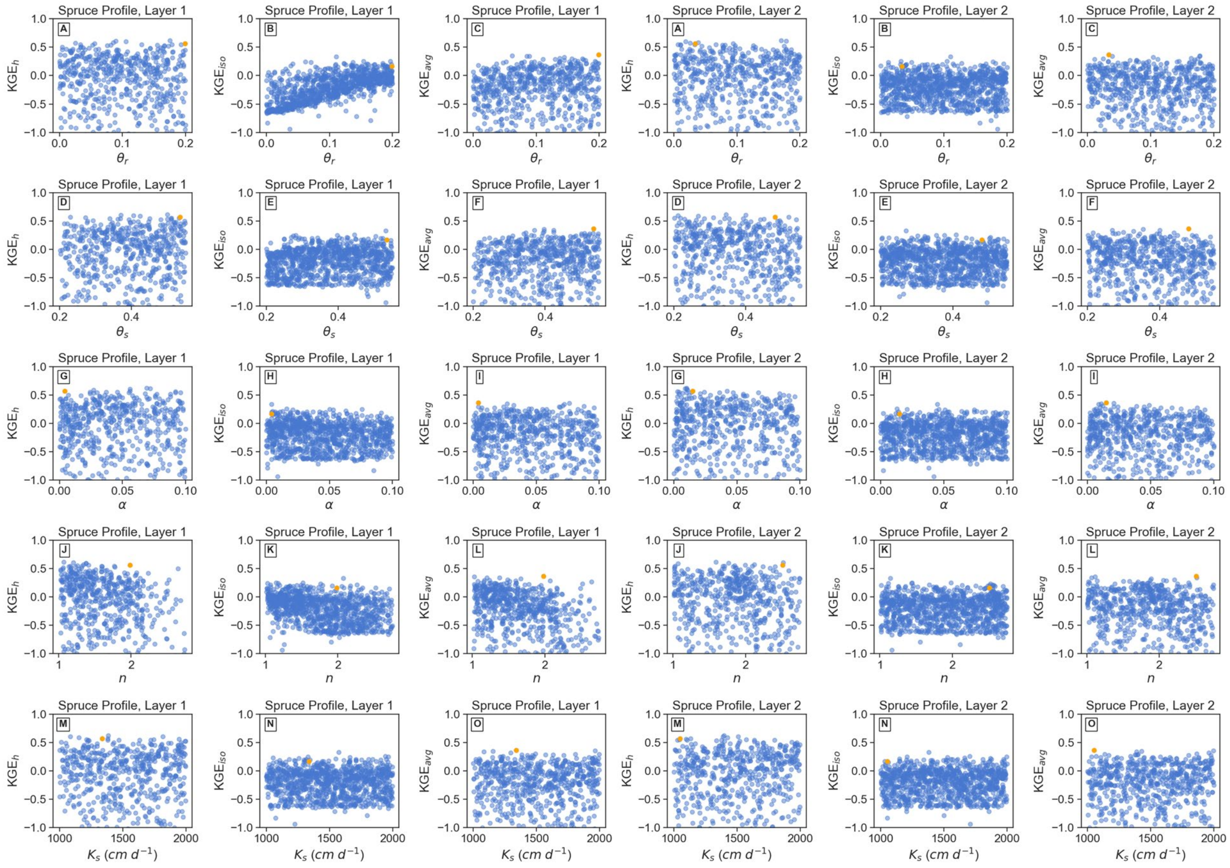
K_s : hydraulic conductivity [$L\ \ T^{-1}$]

n : pore size distribution [-]

α : inverse of air entry [-]

m : shape parameter [-]

ψ : negative pressure [L]

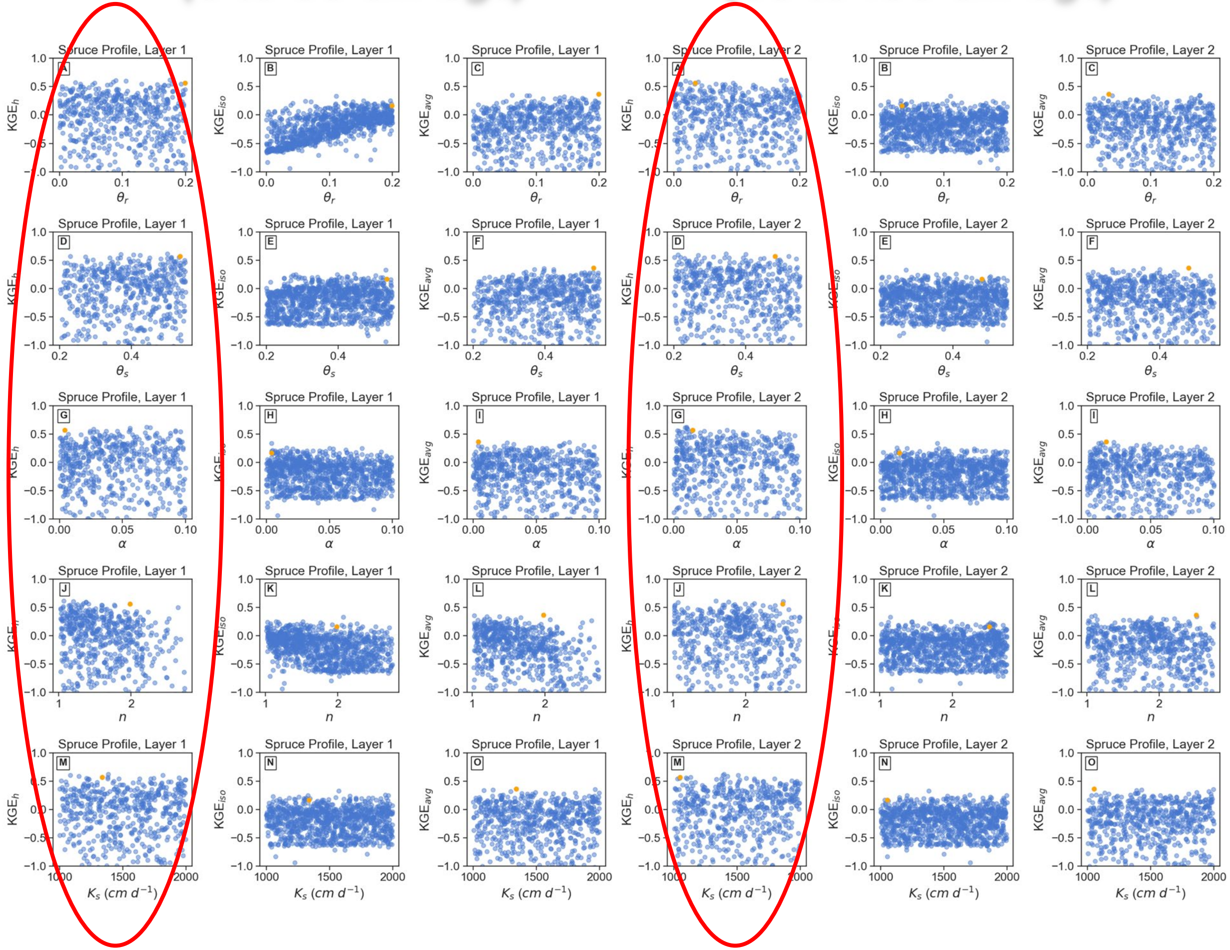


Parameter Optimization

Layer 1 (0 to 60 cm-bgs)

Layer 2 (60 to 100 cm-bgs)

Soil Moisture Goodness of Fit: ***KGE_h***

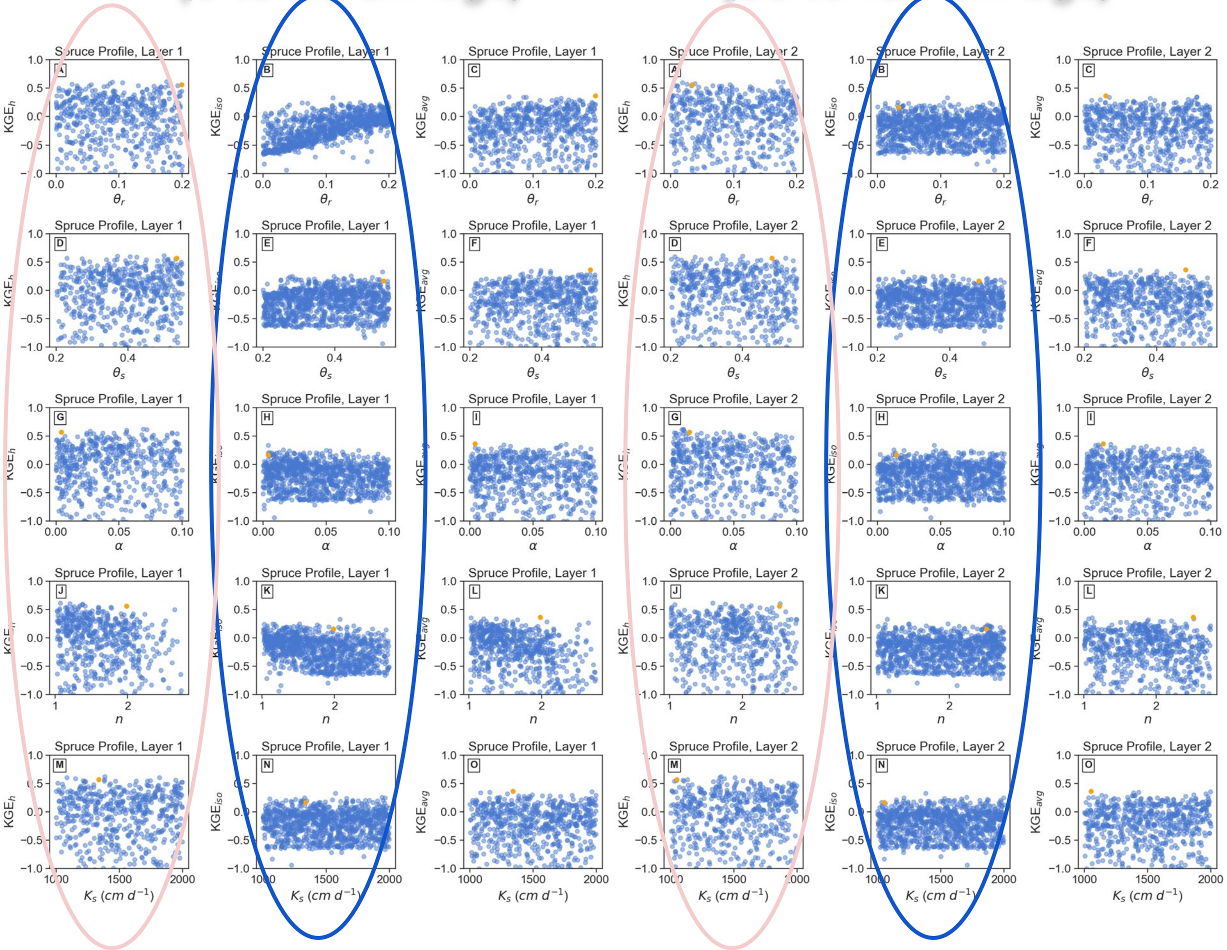


Parameter Optimization

Layer 1
(0 to 60 cm-bgs)

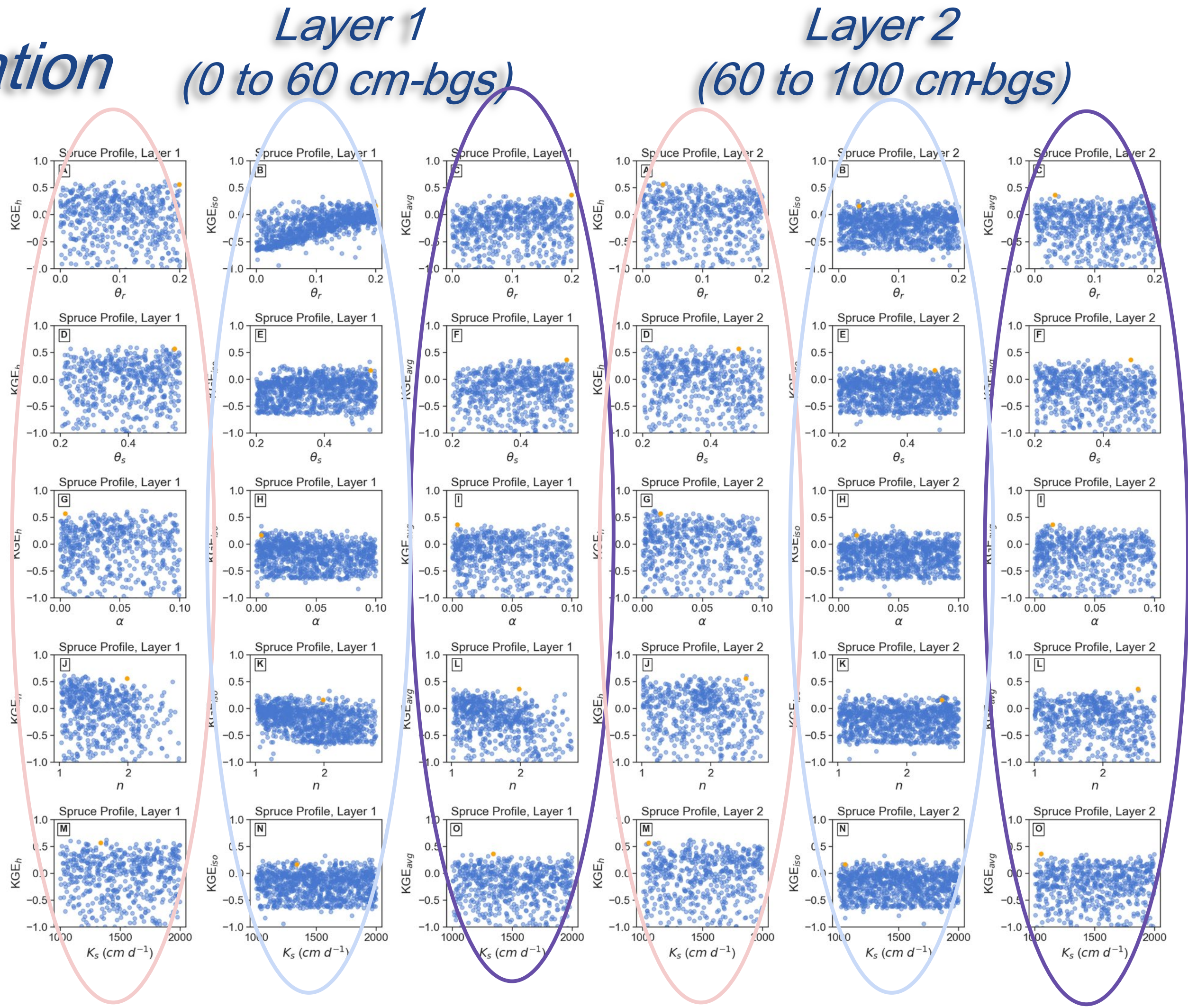
Layer 2
(60 to 100 cm-bgs)

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

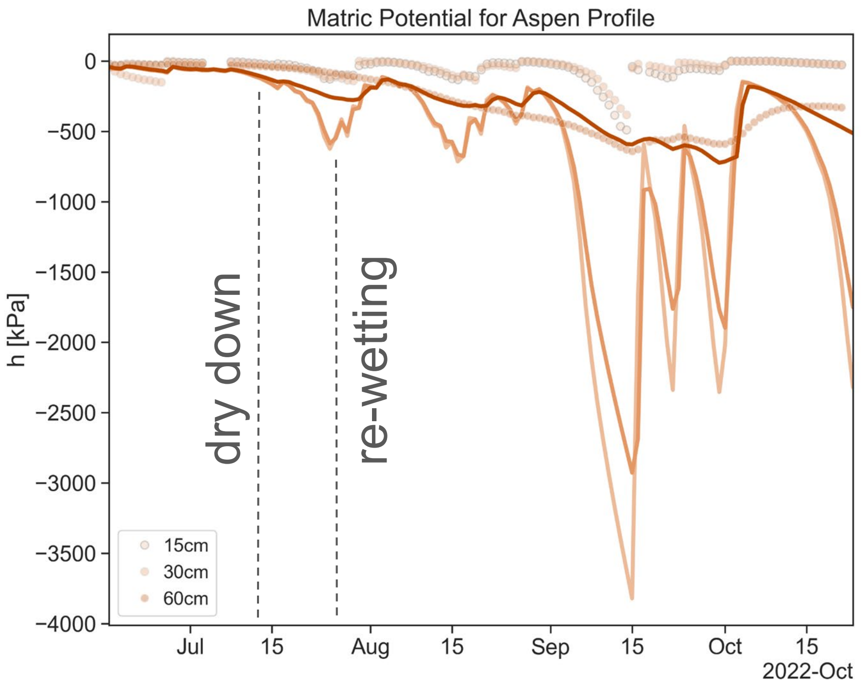


Parameter Optimization

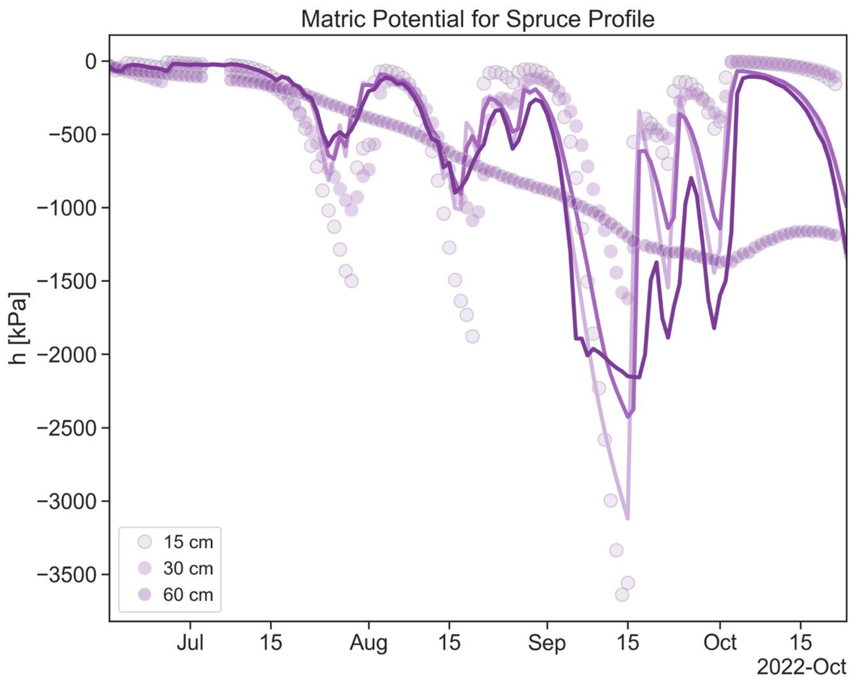
Average
Goodness of fit:
$KGE_h + KGE_{iso} = \boldsymbol{KGE_{avg}}$



Soil Moisture Dynamics

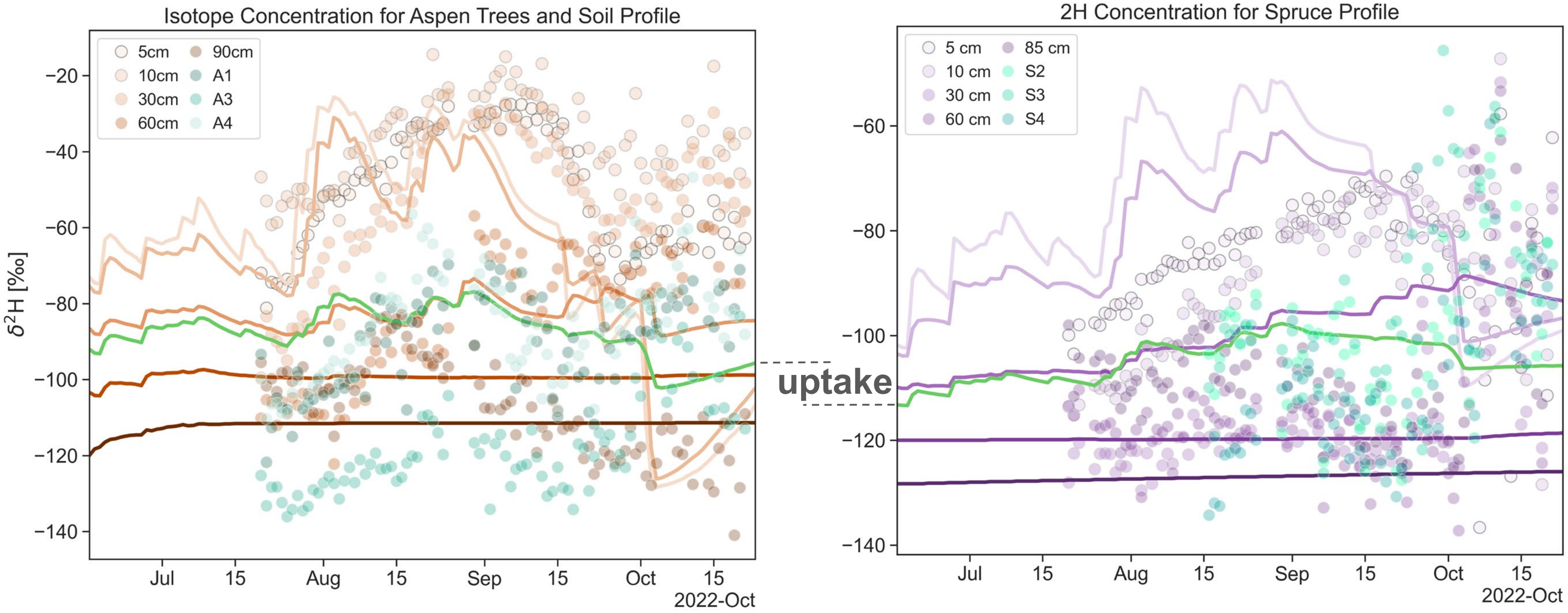


Aspen Profile [KGE_h: 0.39]



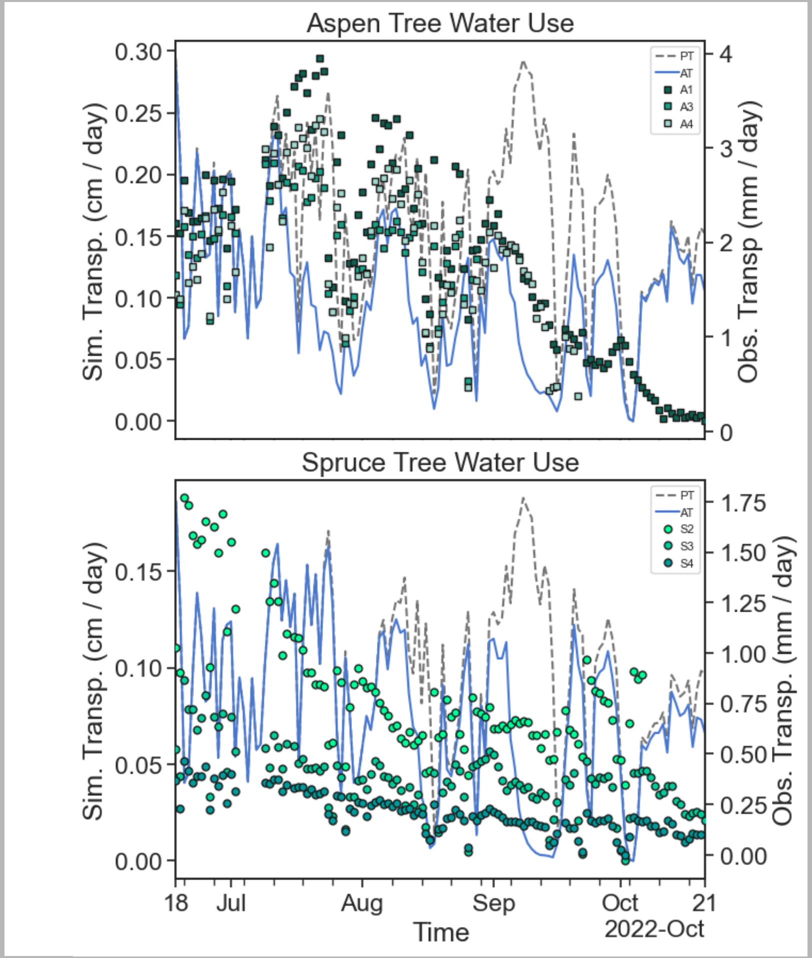
Spruce Profile [KGE_h: 0.50]

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?

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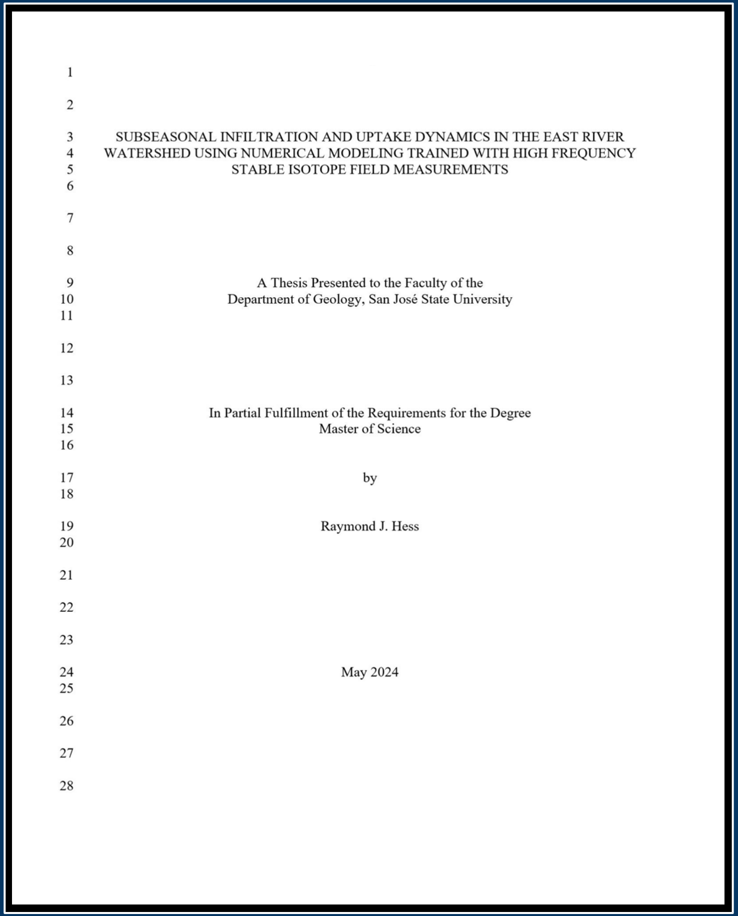

SUBSEASONAL INFILTRATION AND UPTAKE DYNAMICS IN THE EAST RIVER WATERSHED USING NUMERICAL MODELING TRAINED WITH HIGH FREQUENCY STABLE ISOTOPE FIELD MEASUREMENTS

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

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