Estimating infiltration rates with temperature methods for intermittent streams in southern Arizona

Hillary D. Nicholas[1], Thomas Meixner[1], Kathleen Lohse[2], Julie Stromberg[3], John Sabo[3], Eric Moody[3], Danika Sertaro[3]

1 – Department of Hydrology and Water Resources; University of Arizona, Tucson, AZ 85721

2 – Department of Biological Sciences, Idaho State University, Pocatello, ID 83209; 3 – School of Life Sciences, Arizona State University, Phoenix, AZ 85004

Background:

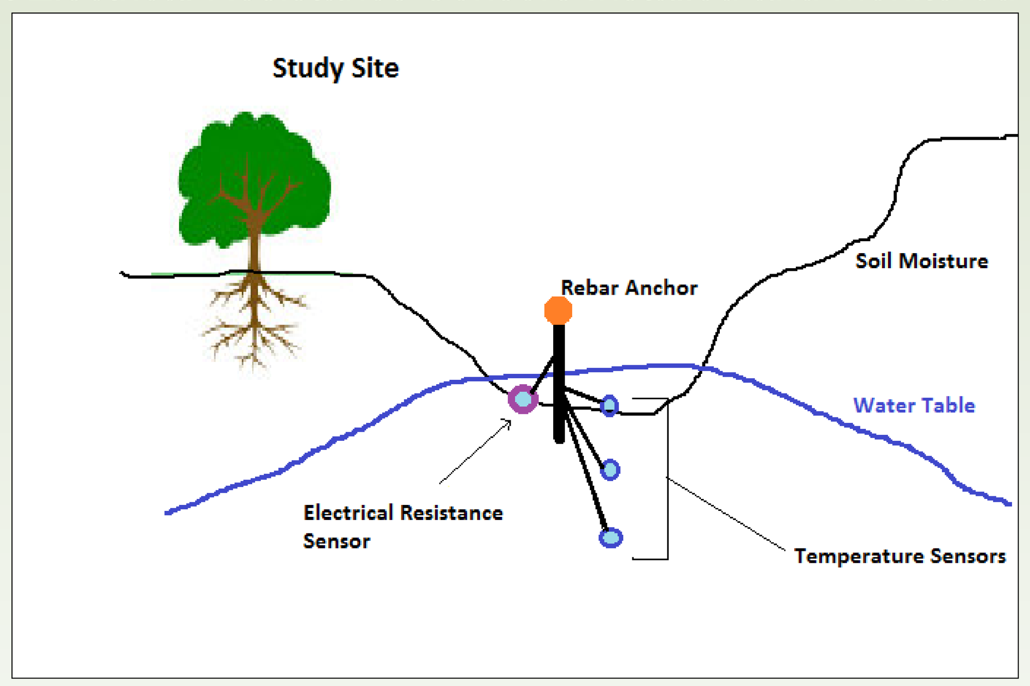
Directional climate change may lead to increased aridity and fewer precipitation events across the American Southwest. Determining infiltration flux rates during monsoonal rainstorms may be the key to predicting how changing precipitation frequency will affect groundwater percolation and potential recharge. Water is the limiting factor for ecosystem health and dynamics in the semi-arid southwest, so the value of measuring and modeling variably saturated porous media is high. Using temperature data as a proxy for water presence, we can try to estimate infiltration fluxes using medium characteristics and flow frequency. By characterizing the flow patterns in intermittent stream channels continuously to capture the onset and cessation of flow events, we can estimate the presence of water with reasonable accuracy.

Study Questions:

- Question 1 – How frequent are flow events in these intermittent streams?
- Question 2 – How much water infiltrates (and at what rates) into the earth during these flow events?
- Question 2 – How do these hydrologic flow regimes impact ecosystem processes (vegetation, entomology, nutrient cycling)?

Methods:

- iButton Temperature Sensors Installed and Monitored
- TidBit Electrical Resistance Sensors Installed and Monitored



iButton temperature sensor and protective steel housings.

TidBit electrical resistance sensor and protective PVC housing.

iButtons: These temperature sensors record temperatures at various depths (0cm, 10cm, and 30cm below the channel). When water is present, a significant drop in temperature is transferred through the soil with an amplitude and phase shift in the temperature profile.

TidBits: Specially modified to record electrical resistance, these record the onset and cessation of flow (when the two exposed leads are wet, the circuit is completed and flow is registered). This was valuable to apply the Upper Boundary Condition in HYDRUS 1-D (when flow is recorded, the top flux is estimated to be the saturated hydraulic conductivity of the site, when no flow, flux is 0).

Field Sites:

1. Santa Rita Experimental Range (2 channels)
2. Barry M. Goldwater Air Force Base (2 channels)
3. Fort Huachuca Army Base (9 channels)

Types of Sites Chosen:

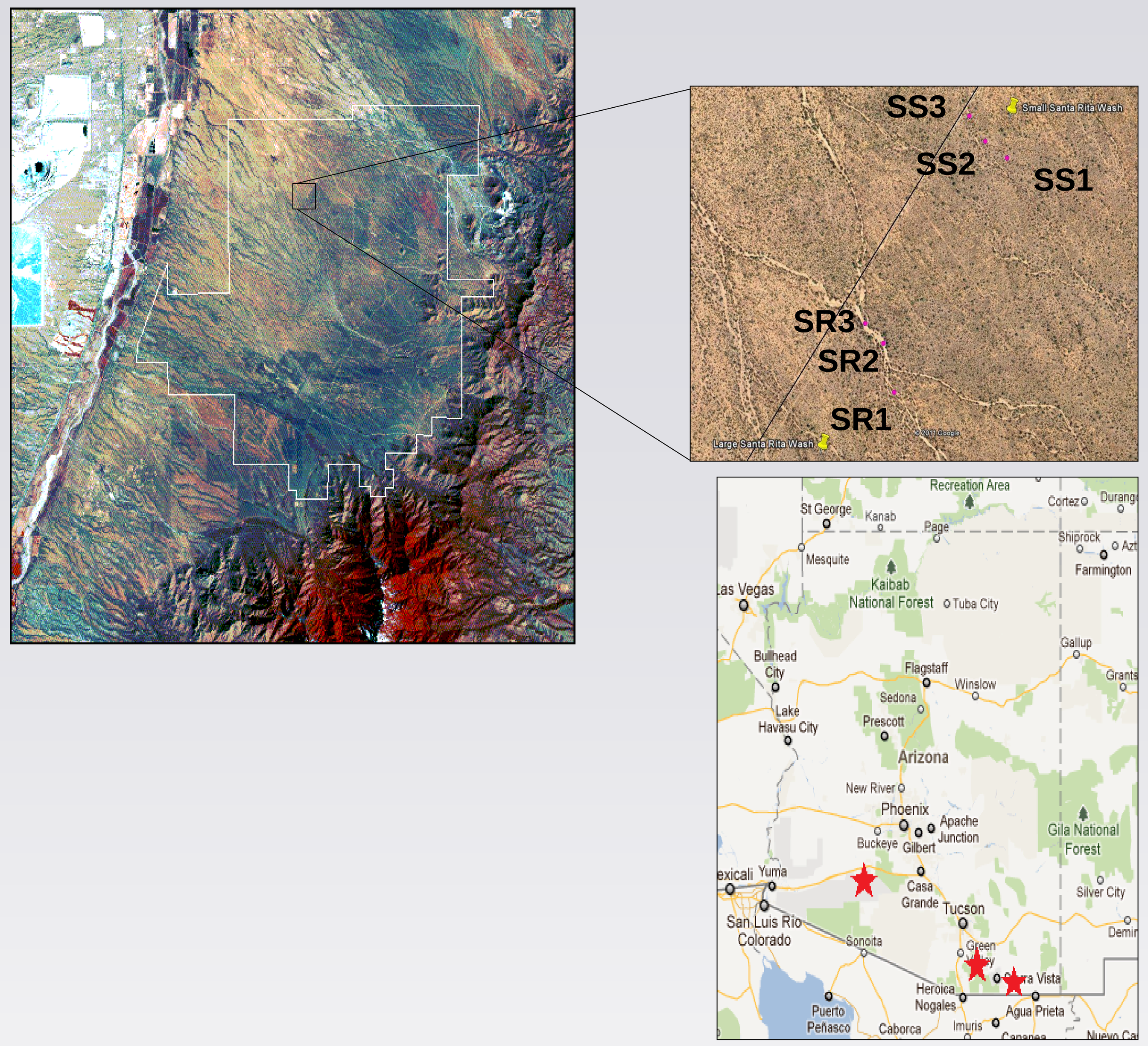
1. Intermittent-wet mountain streams and headwaters
2. Intermittent-dry streams flow during monsoon season
3. Ephemeral stream channels, no apparent headwaters

Ephemeral wash at Barry Goldwater Air Force Base (BG)

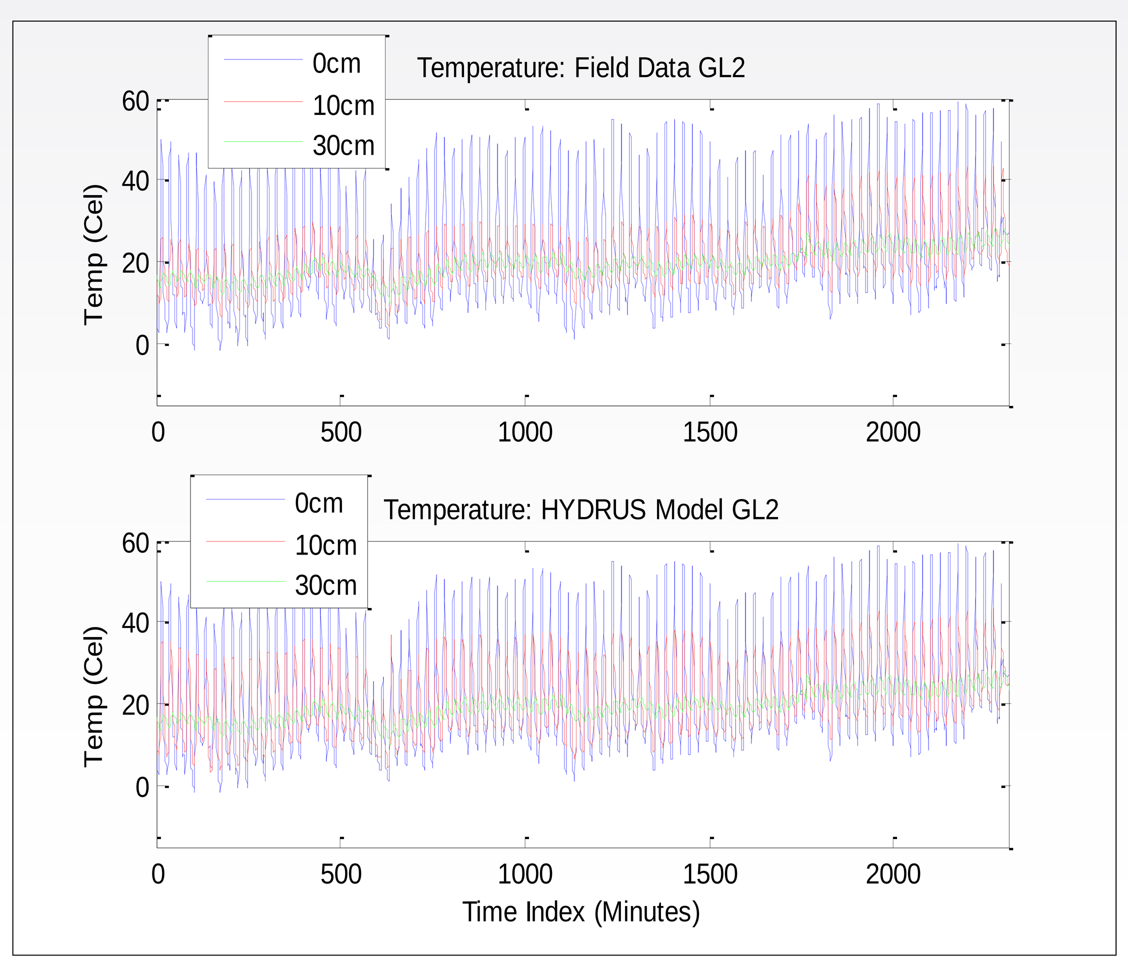
Intermittent-dry stream in Garden Canyon at Fort Huachuca (GL)

Intermittent-wet stream at Huachuca Canyon at Fort Huachuca (HU)

Site Locations and Codes at Santa Rita:



Field and Modeled Temperature Data:



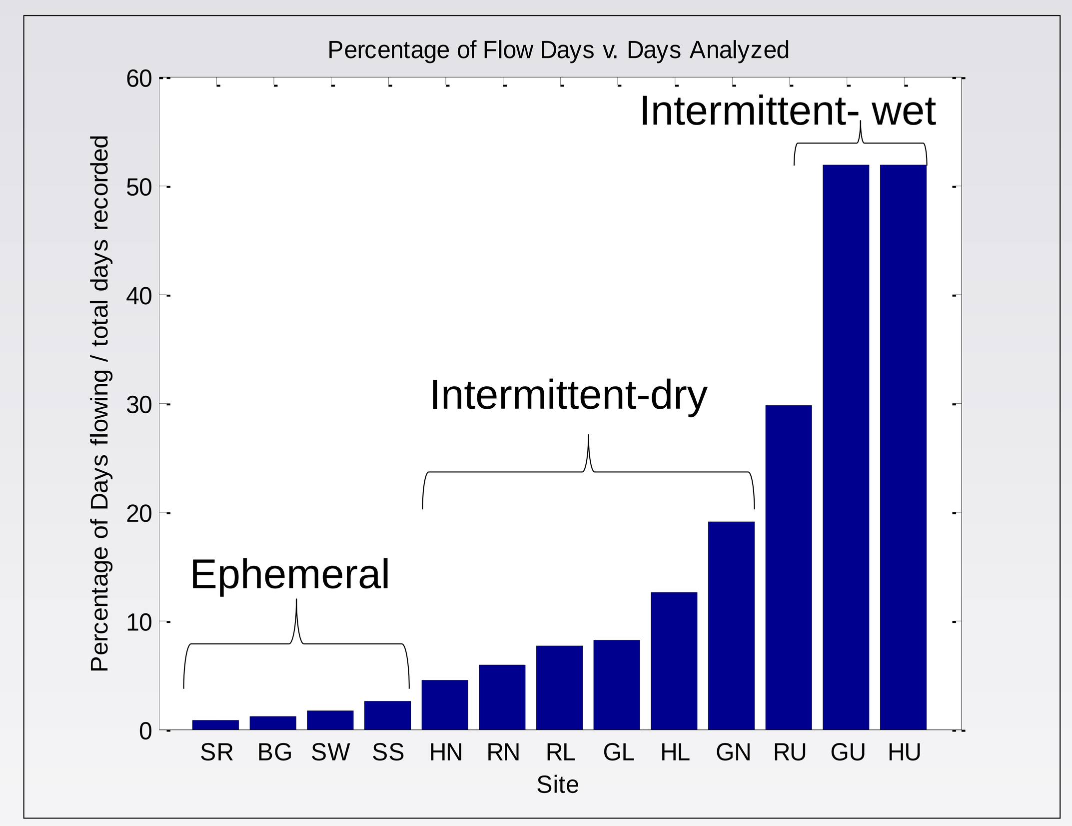
Heat and Water Transport Equations:

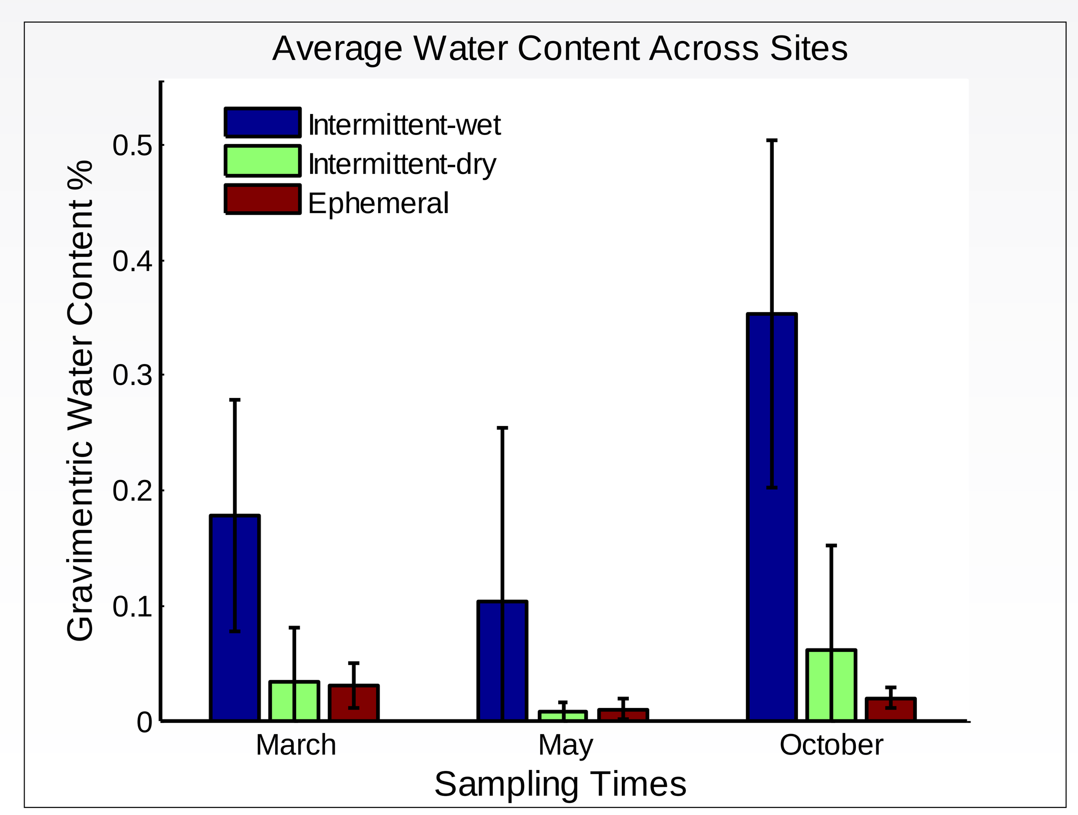
$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K\left(\frac{\partial h}{\partial z}\right)\right] \qquad \frac{\partial C_p(\theta)T}{\partial t} = \frac{\partial}{\partial z}\left[\lambda(\theta)\frac{\partial T}{\partial z}\right] - C_w\frac{\partial qT}{\partial z}$$

$$K(h,z) = K_S(z)K_r(h,z)$$

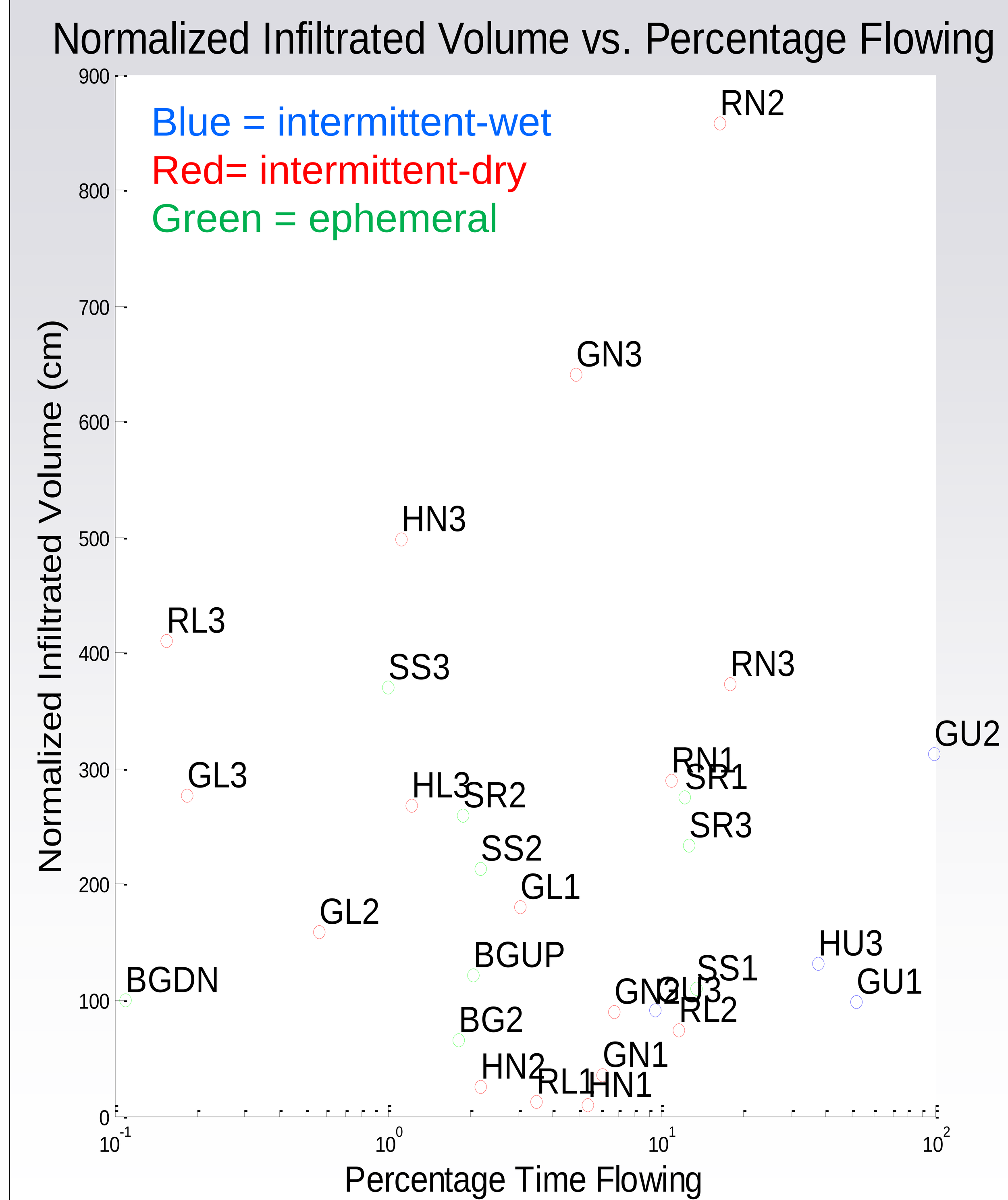
θ=water content; h=hydraulic head; z=vertical direction
t=time; q=water flux; T=temperature
Cw=volumetric water heat capacity; K=hydraulic conductivity
λ=soil thermal conductivity coefficient; Cp=volumetric medium heat capacity
Ks=saturated hydraulic conductivity; Kr=relative hydraulic conductivity

Site Classifications based on Moisture and Flow:





Preliminary Results and Conclusions:



Continuing Analysis:

- Diagnostic test for goodness of HYDRUS 1-D model temperature fits (note the differences between the 10cm field and modeled data).
- Changing HYDRUS 1-D parameters to better replicate field temperatures to improve robustness of infiltration rate estimations.
- Speculate on a different experimental design that does not allow for shifting sensors in the soil column.
- Using ground-based LIDAR to have a better understanding of the relationship between channel shape characteristics and flow regimes.
- How may flow regimes change in different climate change scenarios based on estimations on changing precipitation patterns.

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