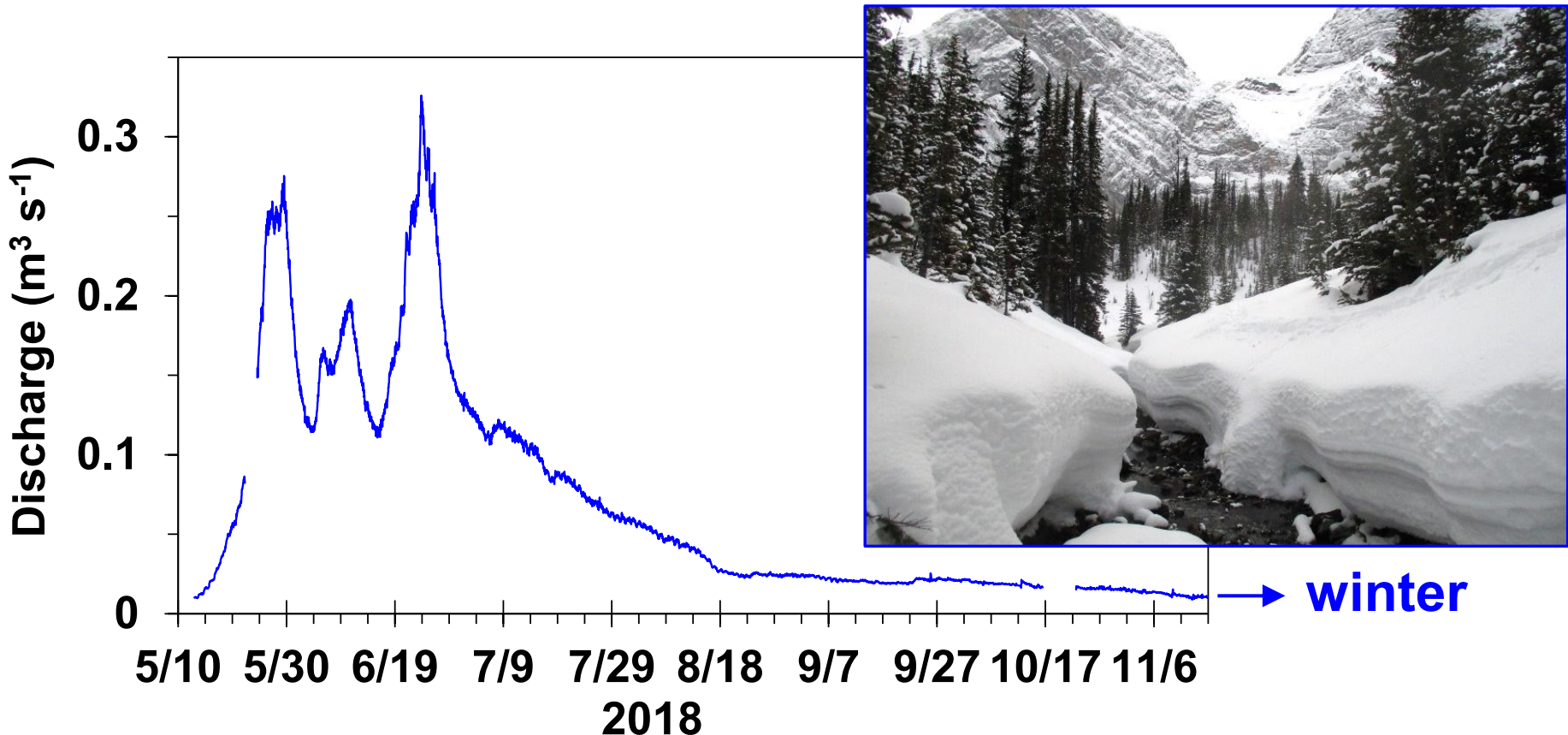


Hydrogeological Functions of Interconnected Aquifers in an Alpine Headwater Catchment



Masaki Hayashi
University of Calgary

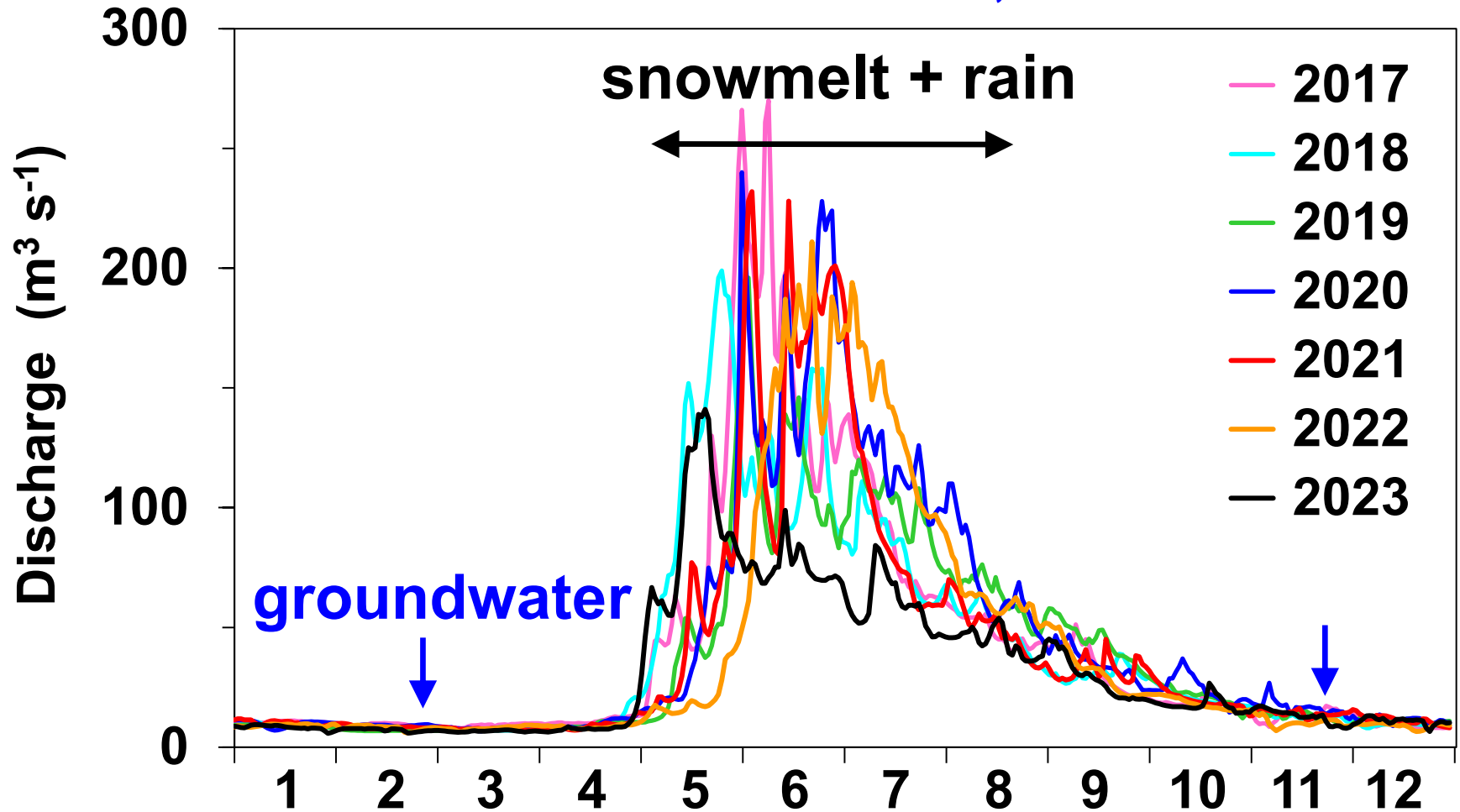
Hathataga Creek Discharge



- Groundwater discharge sustains stream flow in headwater catchments for ~8 months of the year.
- True for larger river basins?

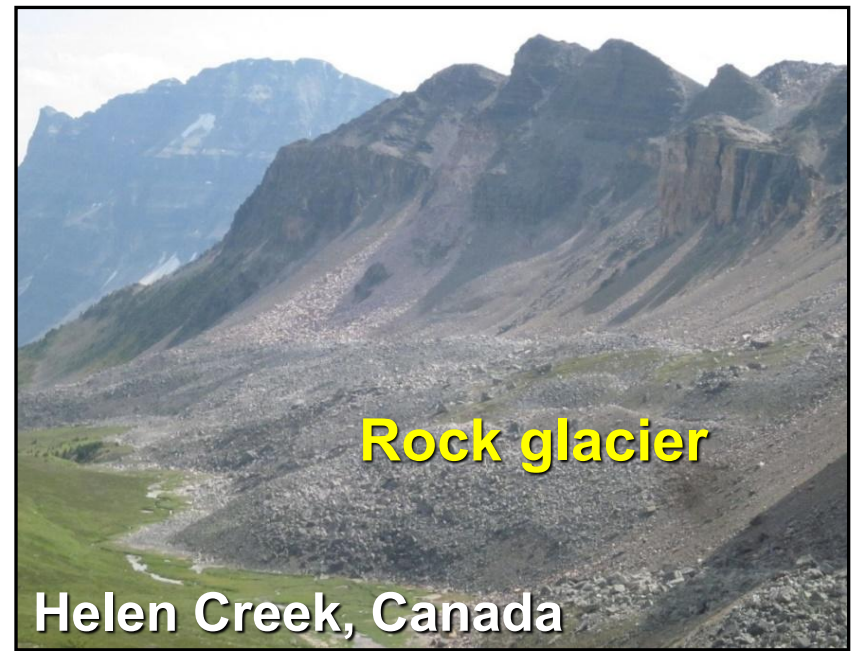
Seasonality of River Flow

Bow River at Banff (2200 km², unregulated)

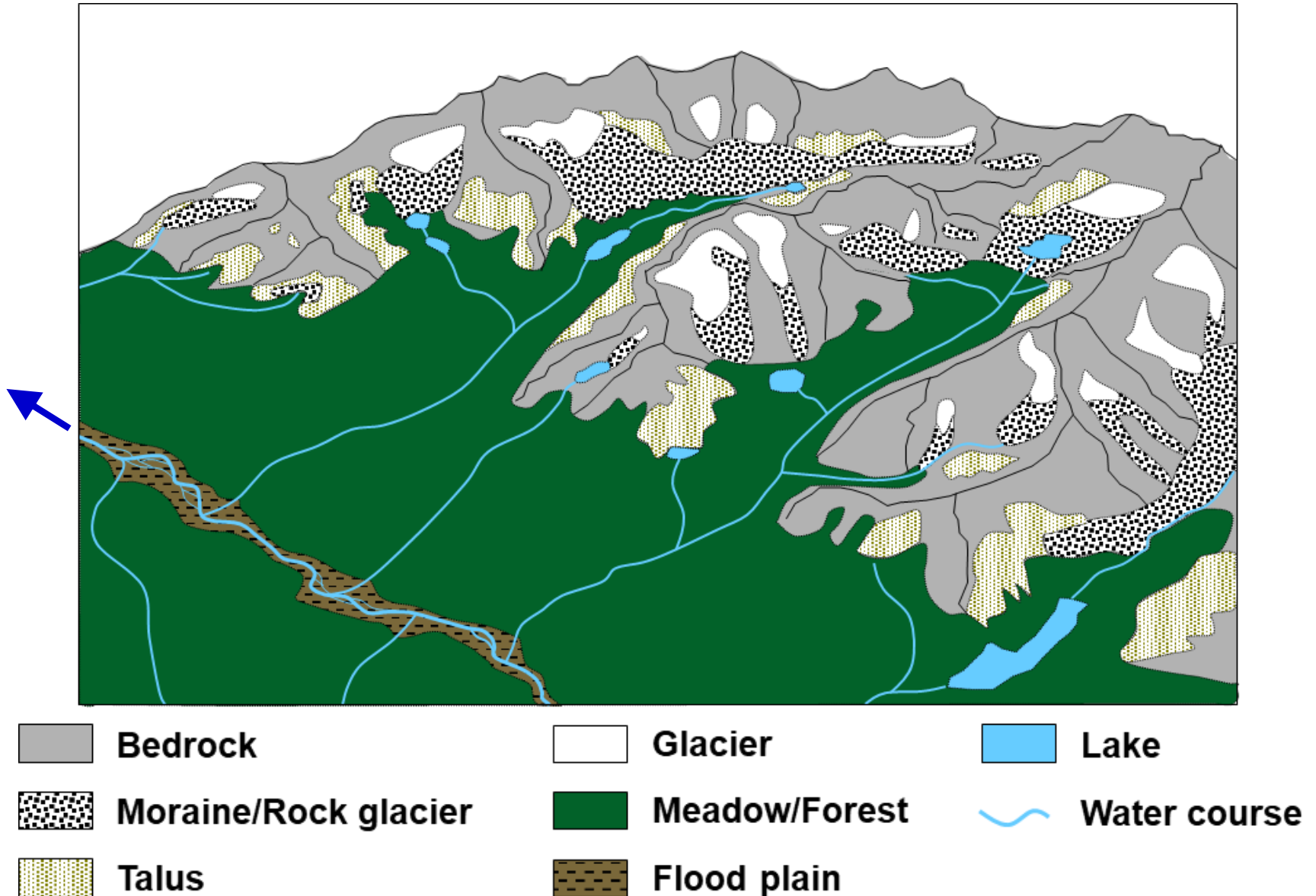


Data: Water Survey of Canada

Example of Alpine Aquifers



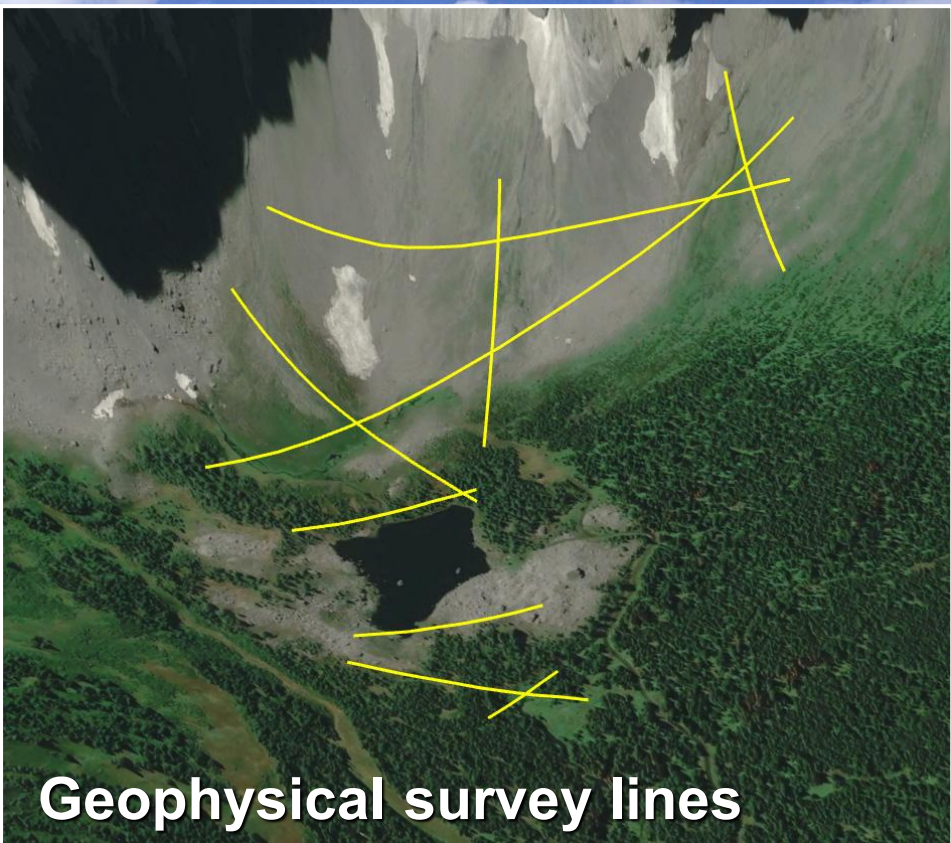
Integrated System of Alpine Aquifers



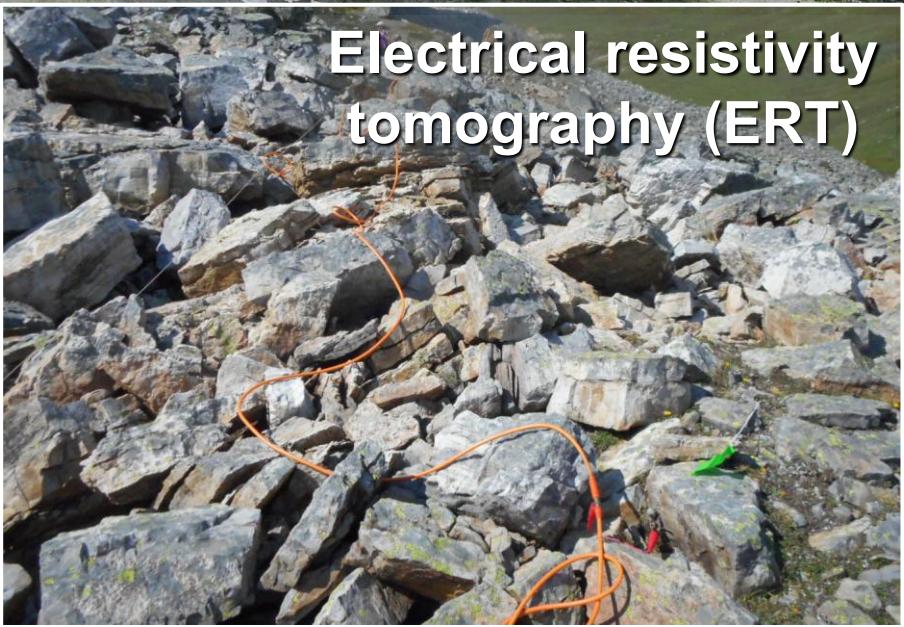
Hayashi (2020, *Groundwater*, 58: 498-510)



Seismic refraction tomography (SRT)



Geophysical survey lines

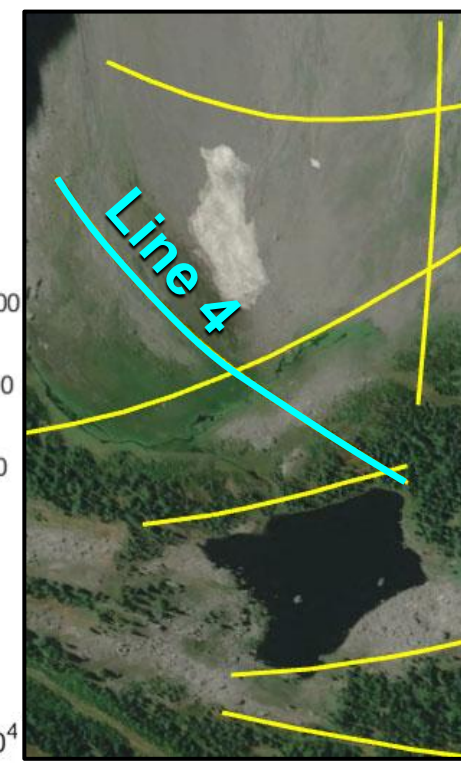
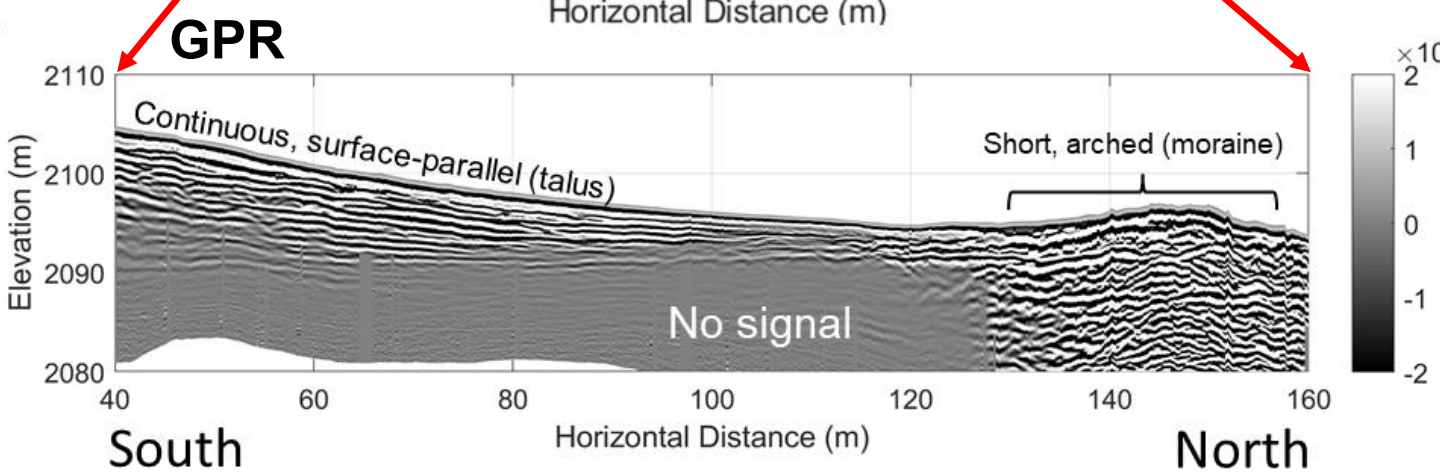
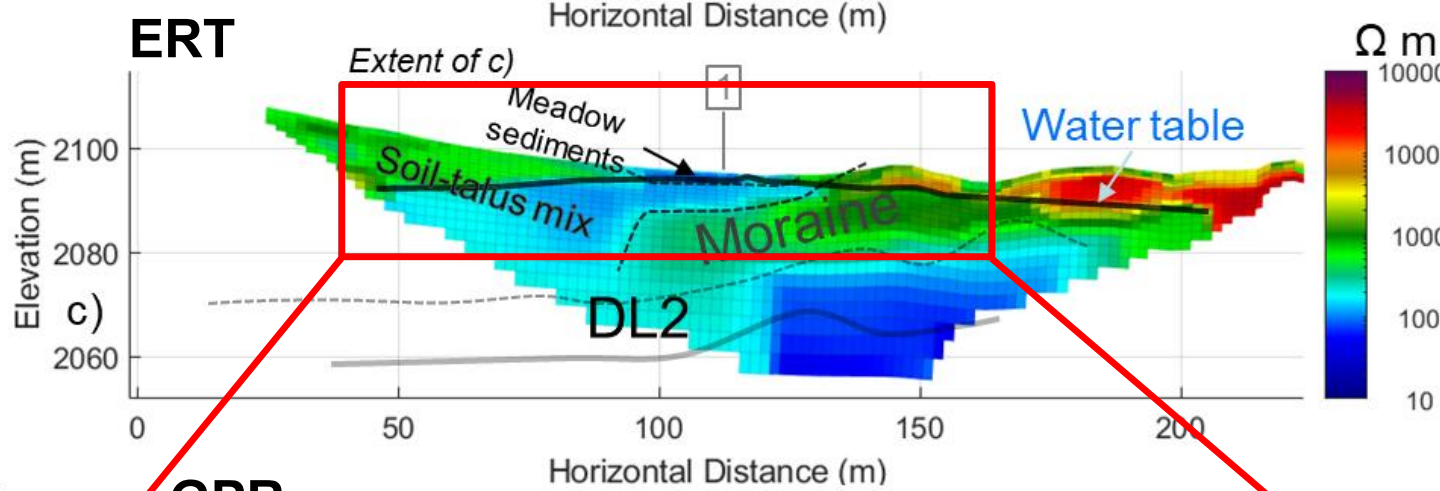
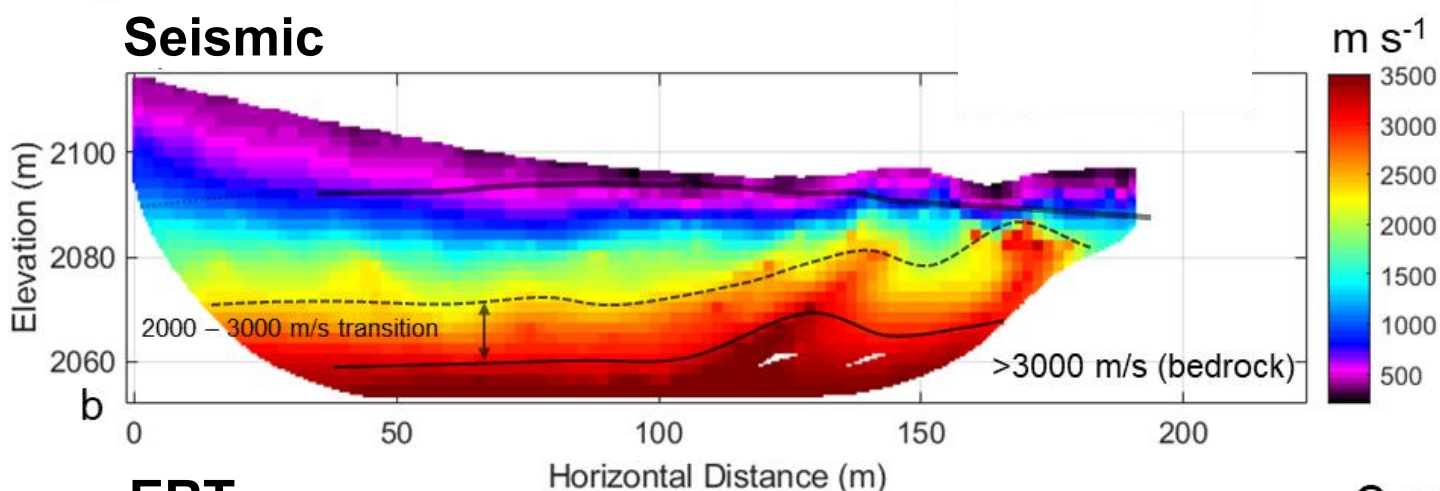


Electrical resistivity tomography (ERT)



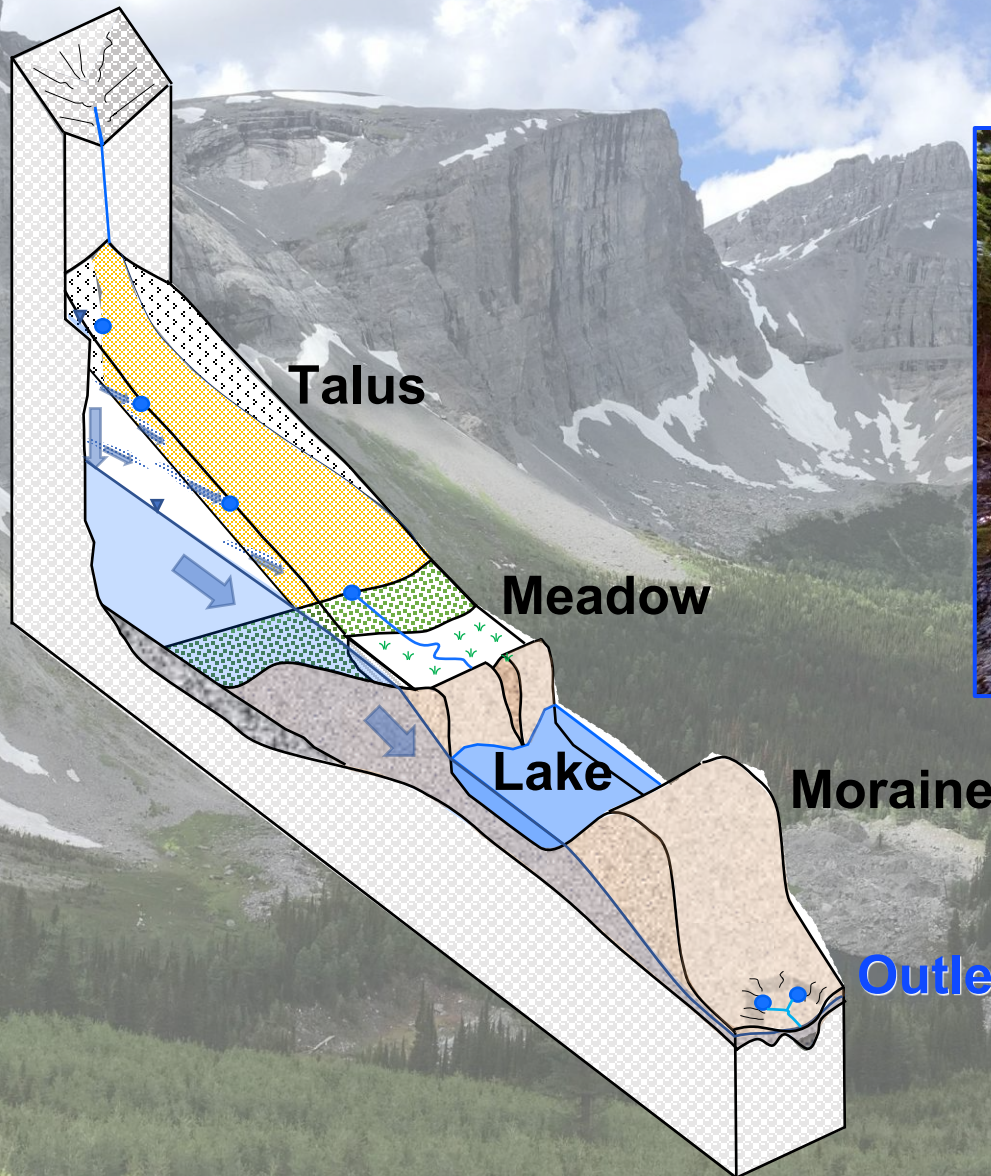
Ground penetrating radar (GPR)

Geophysical data example



Christensen et al. (2020. *Hydrogeol. J.*, 28, 1871-1890)

Alpine Aquifer Complex and the 'Gate Keeper'

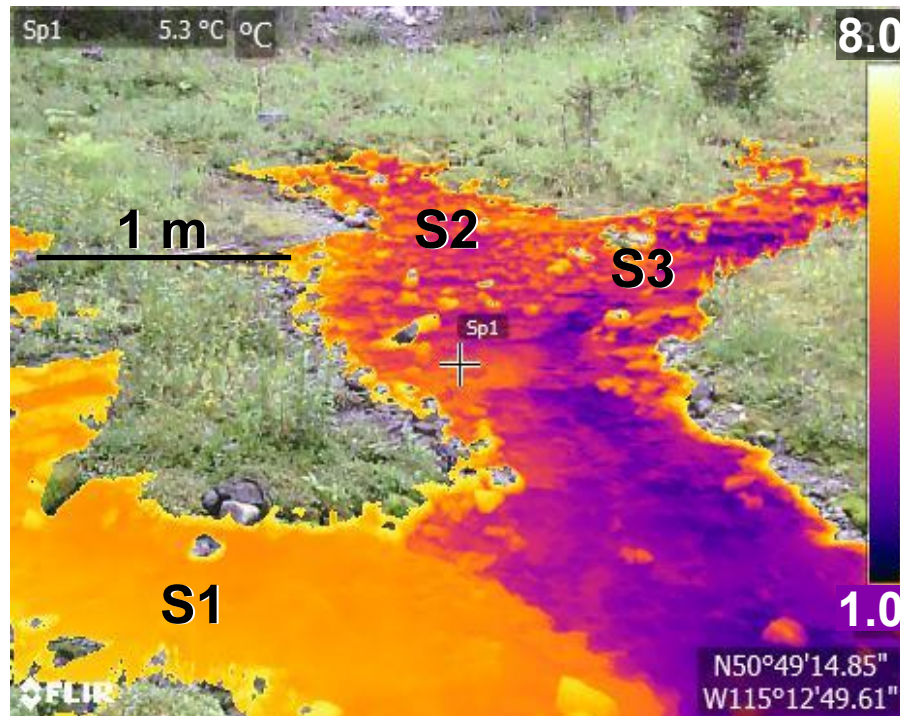


Christensen et al. (2020.
Hydrogeol. J., 28, 1871-1890)

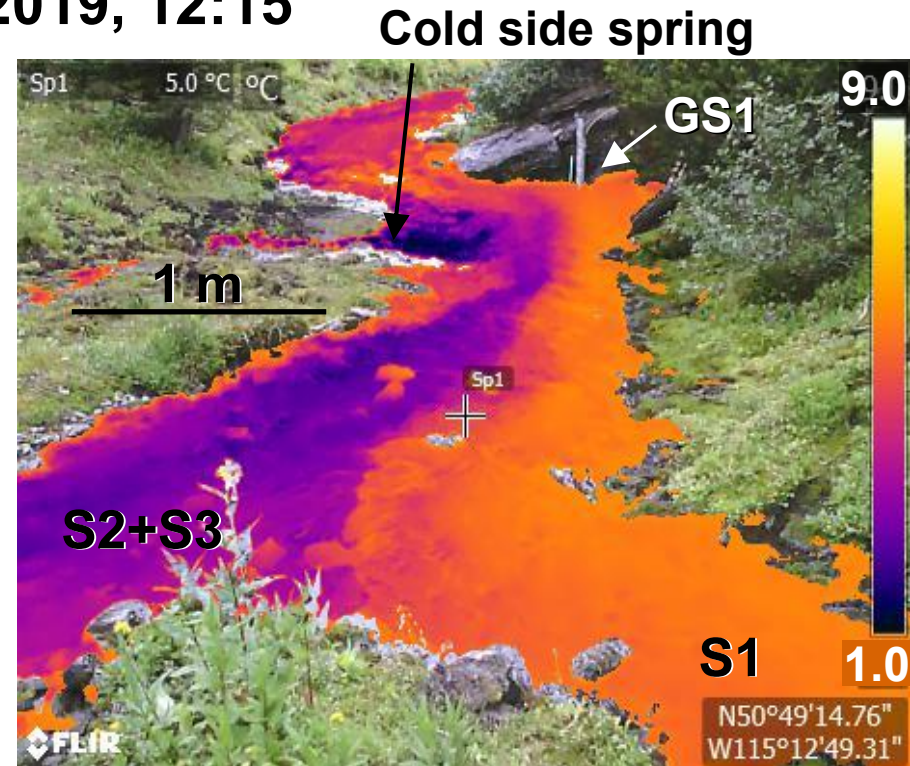
Spatial Variability of Stream Temperature

Infrared Thermal Imager (FLIR camera)

August 14, 2019, 12:15



Looking upstream

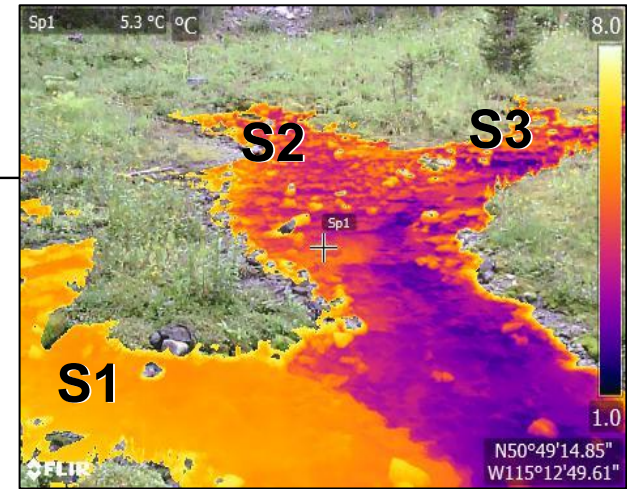
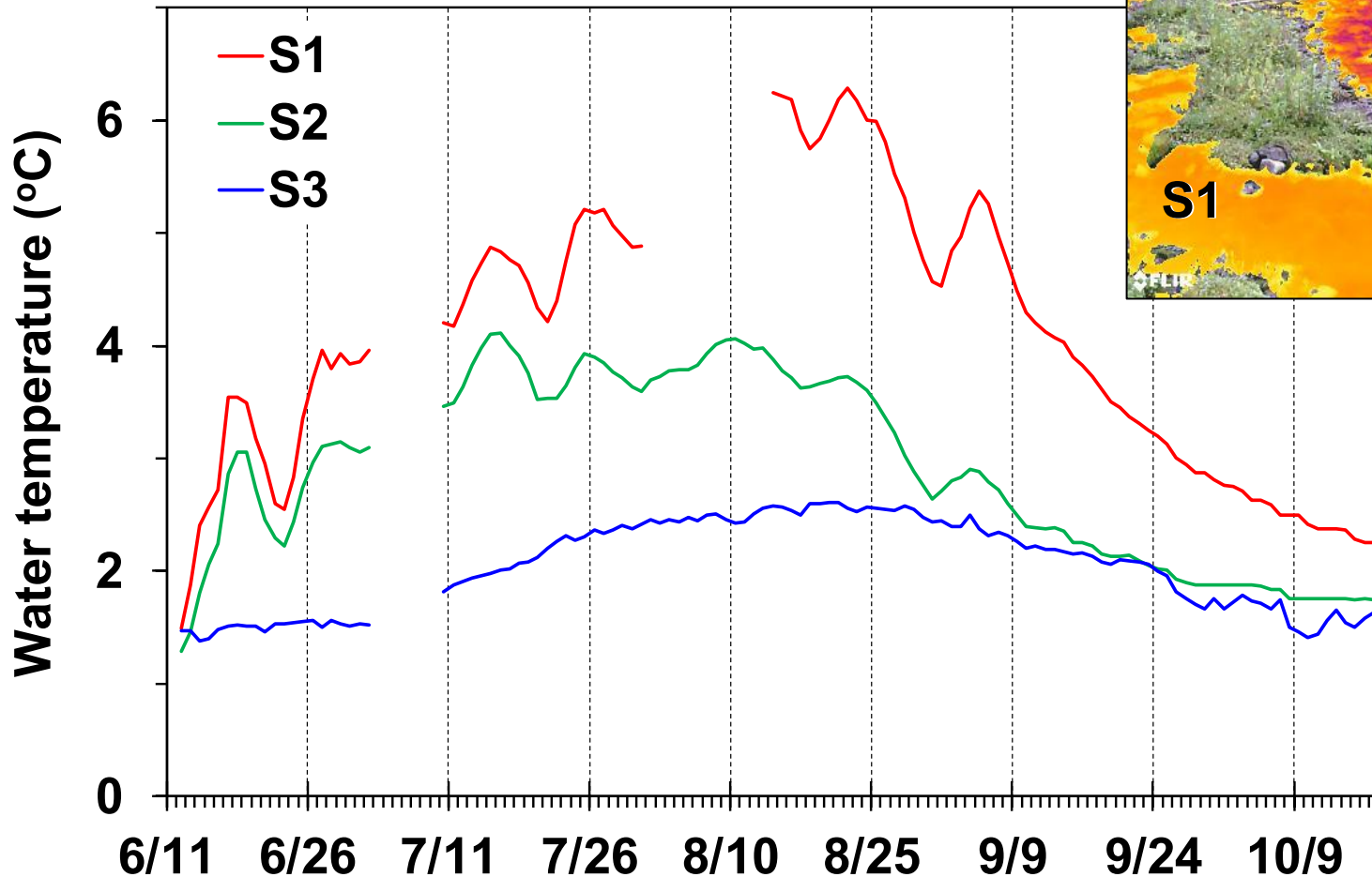


Looking downstream

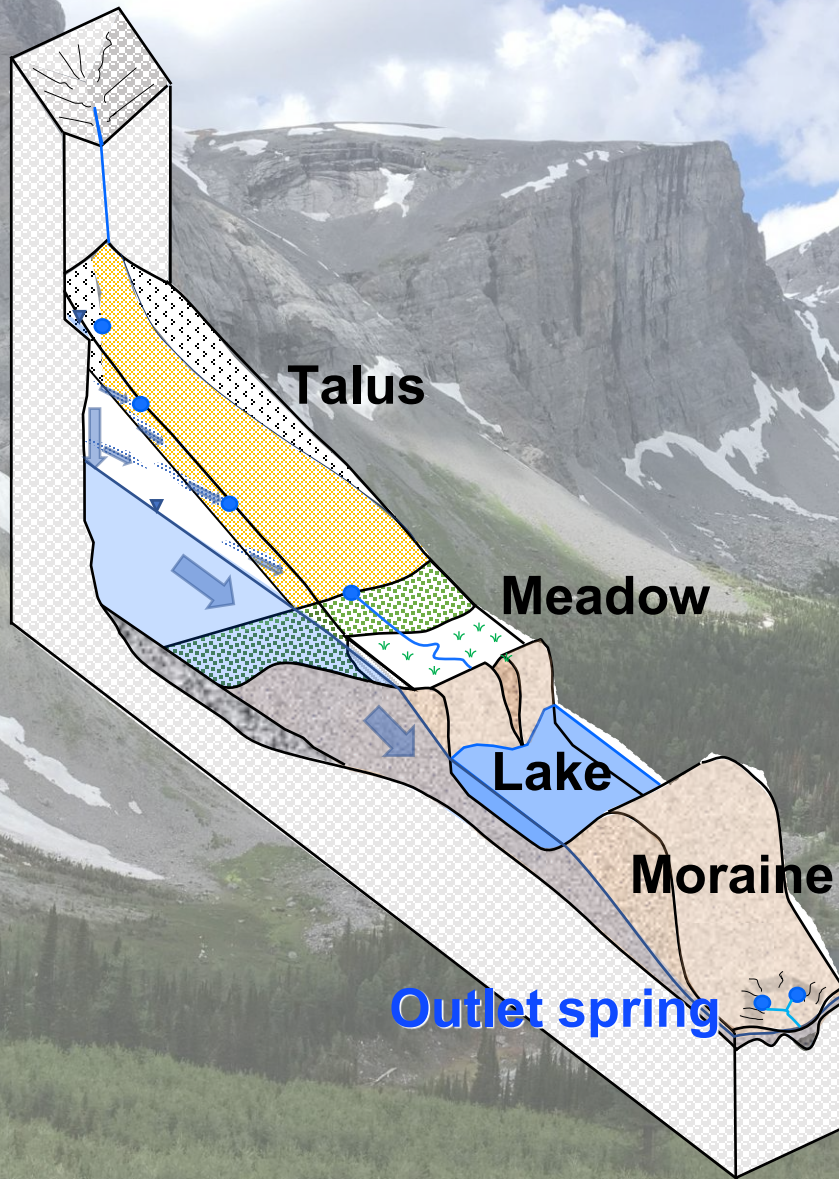
Three spring outlets have different temperatures.

Daily Average Water Temperature (2019)

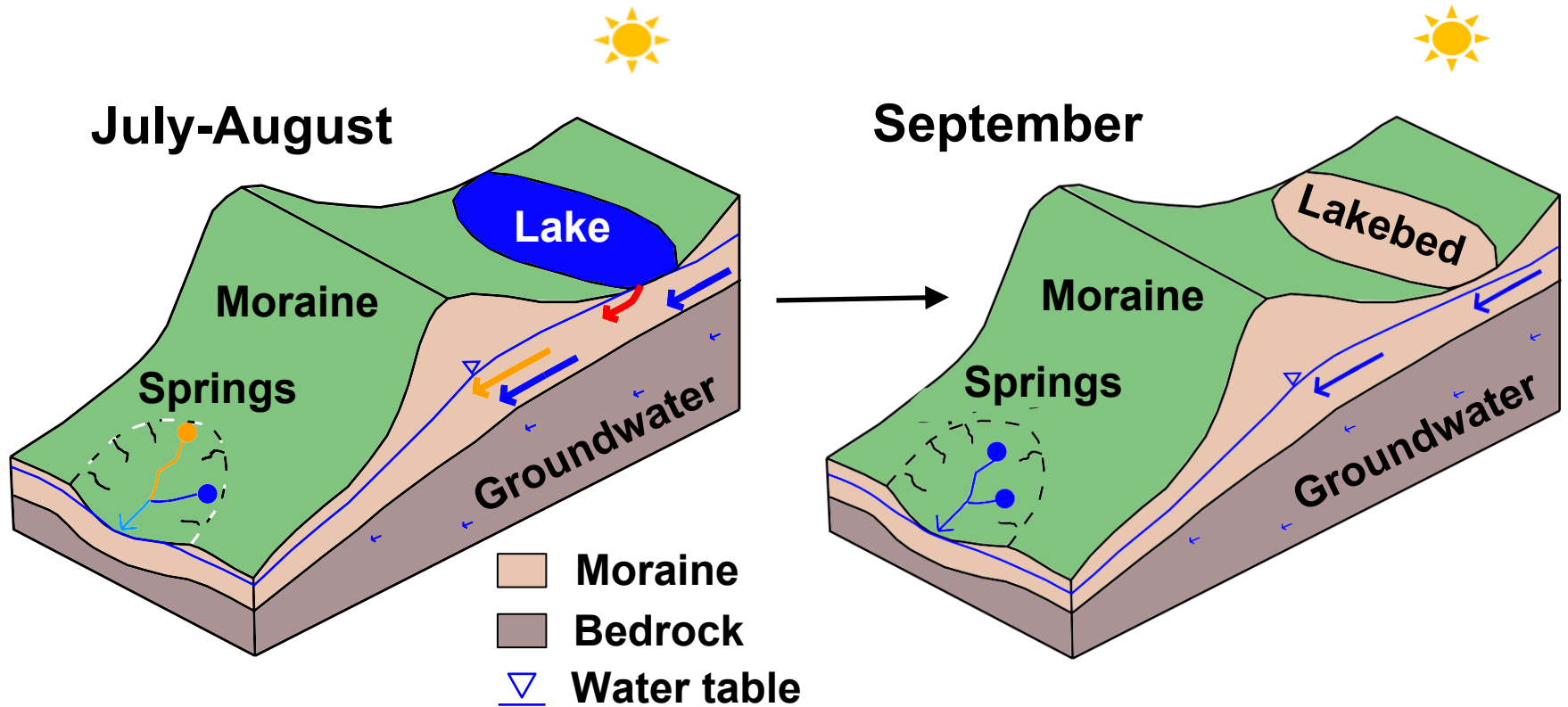
- S1 is strongly influenced by the lake.
- S3 remains cold.



Hathataga Lake: 'Outcrop' of the Water Table

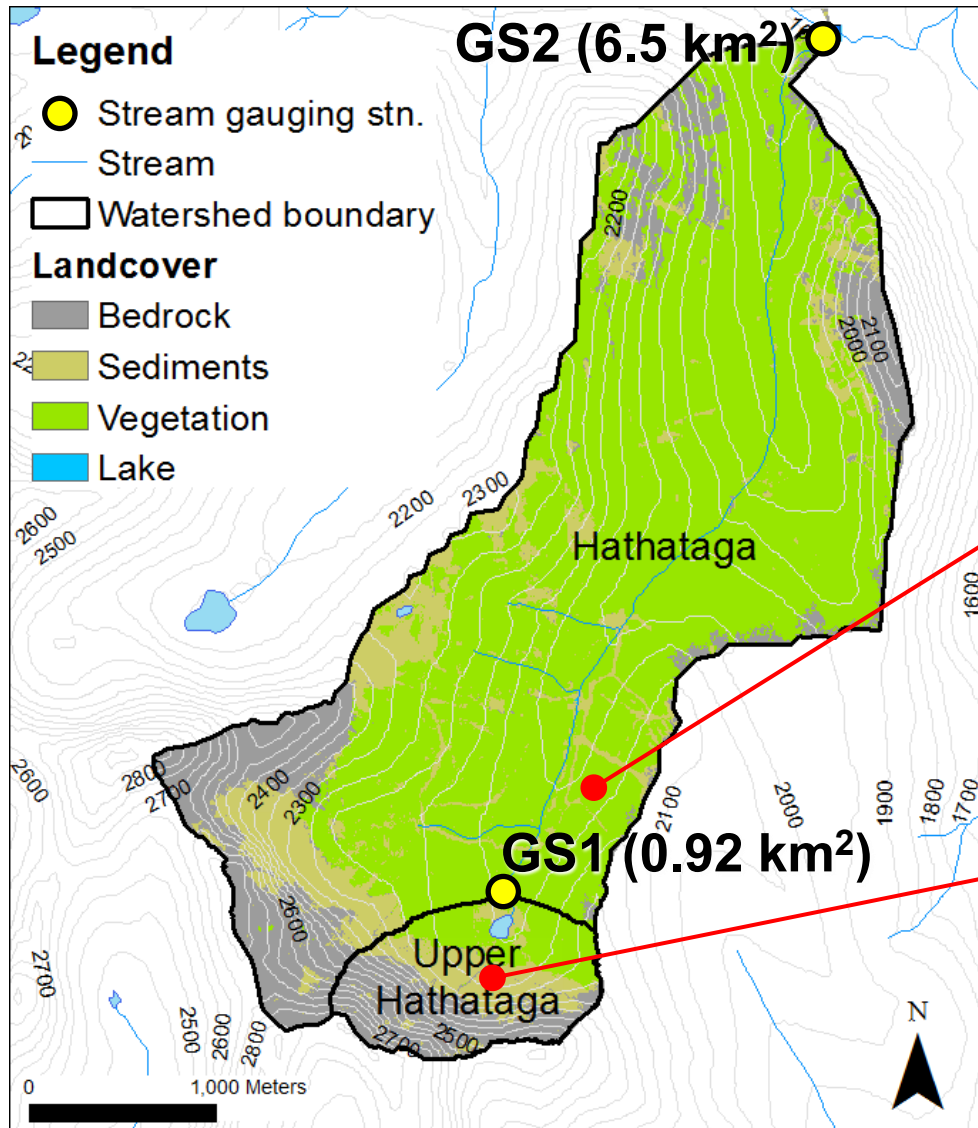


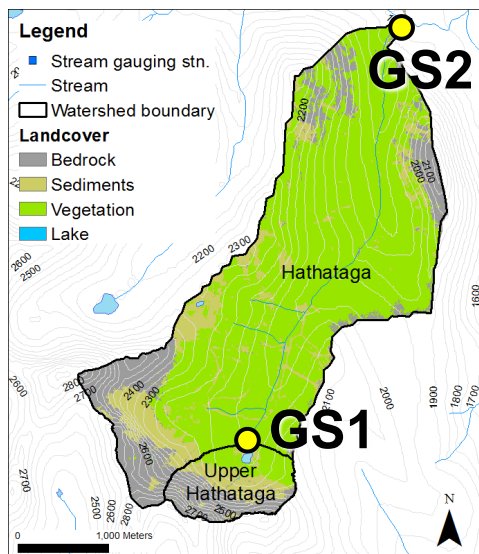
Temperature Control by Hathataga Lake



- The lake absorbs heat and generate warm groundwater.
- Cold groundwater bypasses the heat absorber.
- Warm GW contribution diminishes, and the stream temperature drops in late summer.

Upper and Lower Hathataga Watershed

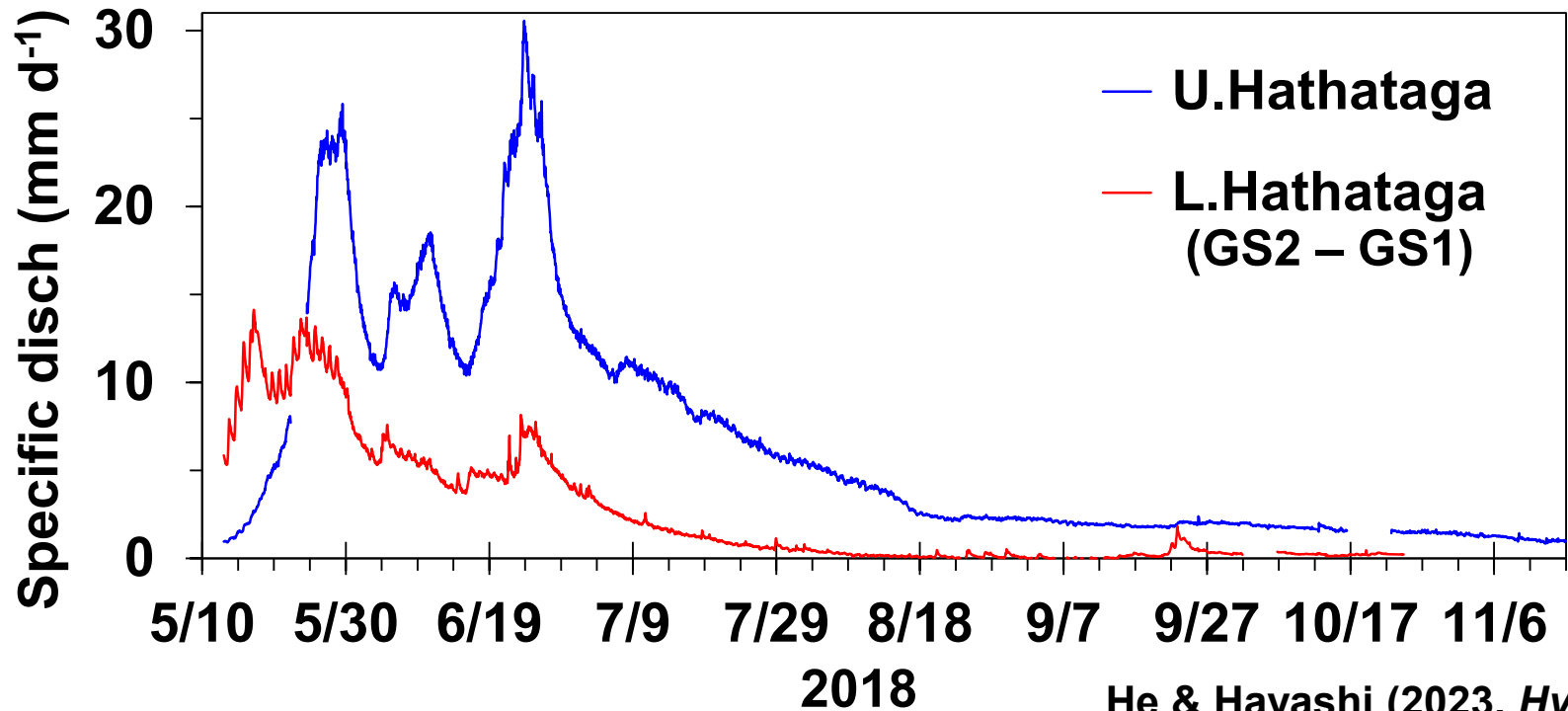




Specific Discharge (mm d^{-1})

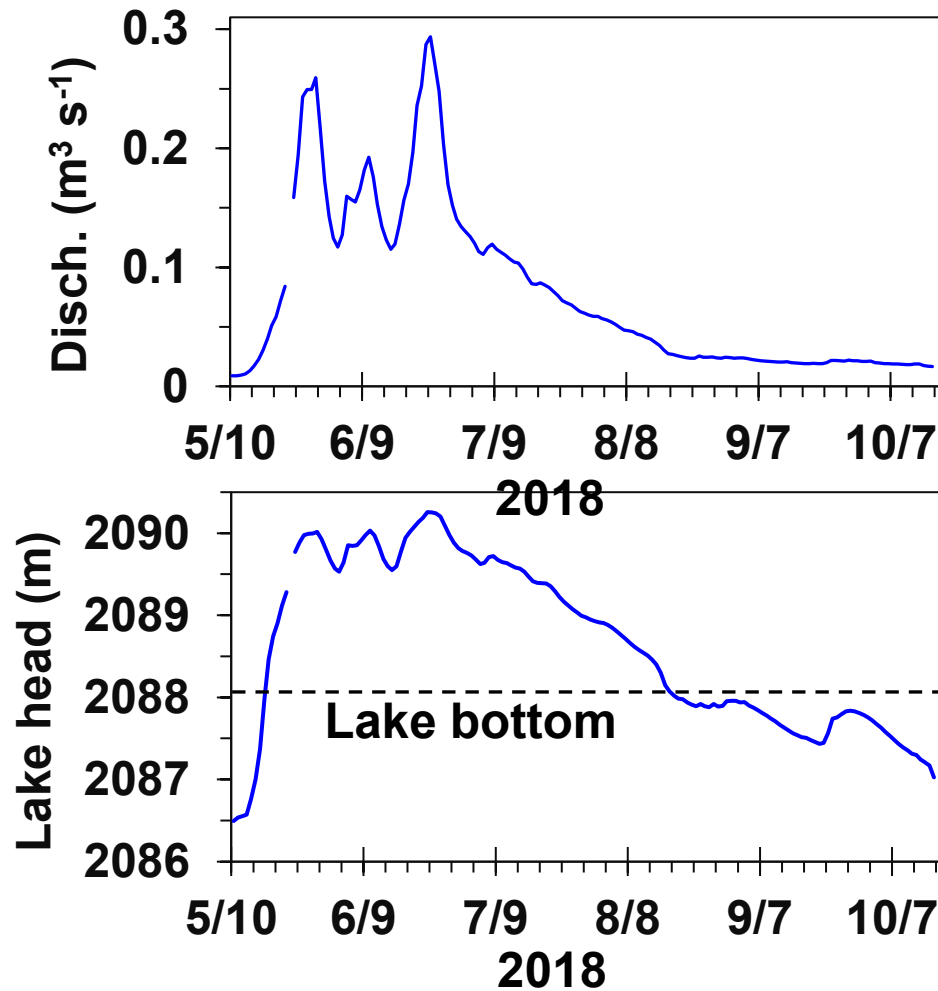
Disproportionately higher contribution from The Upper Hathataga watershed.

- High snowfall and low ET
- Alpine aquifer complex.

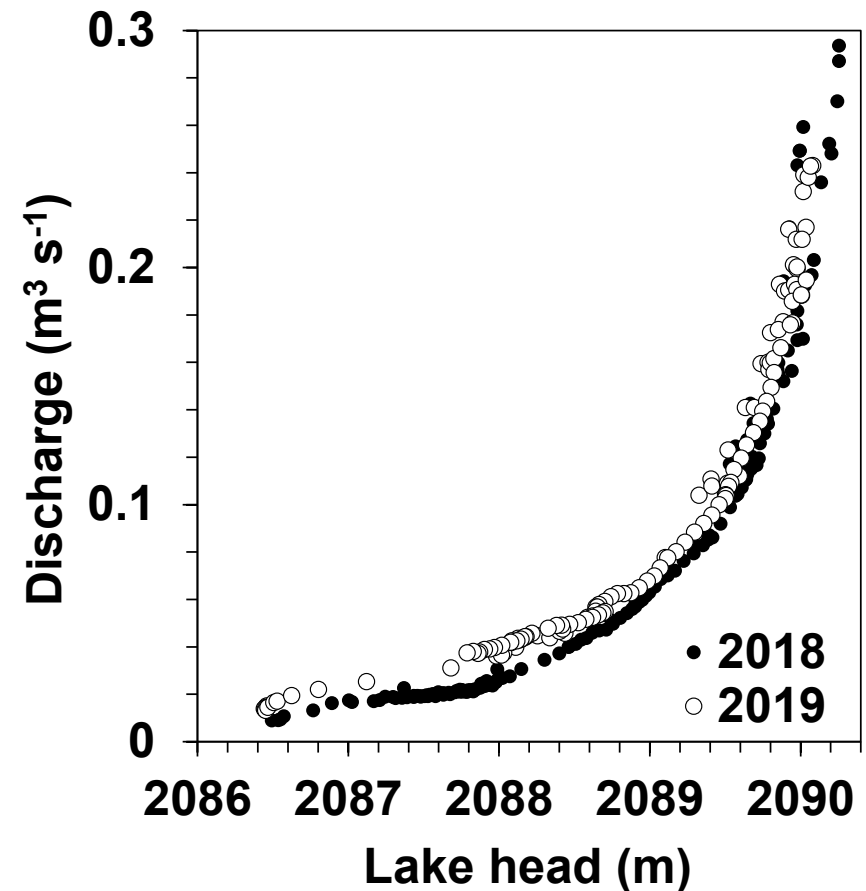


He & Hayashi (2023. *Hydrol. Process.*, 37, e14881)

Catchment-Scale Discharge-Storage Relation

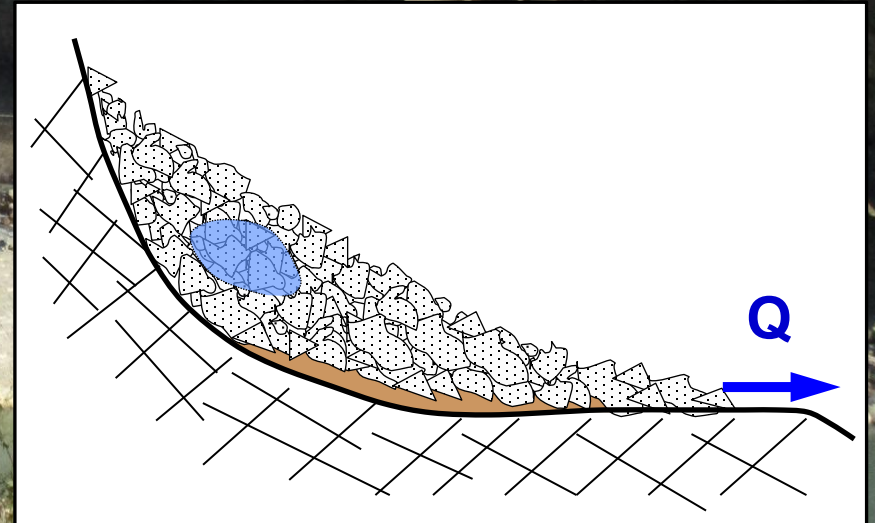
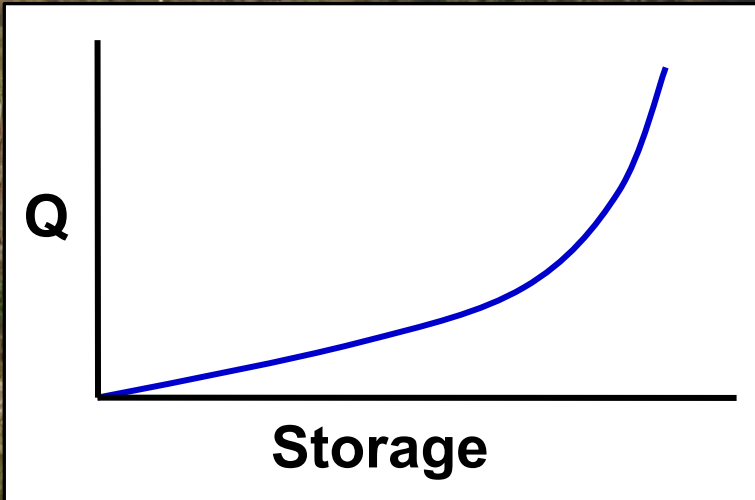
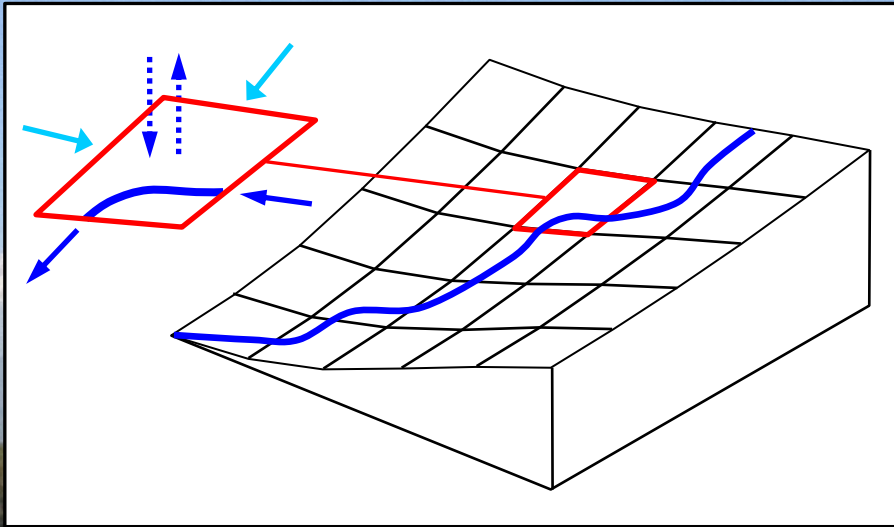


**Lake as a monitoring well
for the moraine aquifer.**



He & Hayashi (2023. *Hydrol. Process.*, 37, e14881)

Way Forward for Large-Scale Basin Models



Annapurna, Nepal

Key Points

1. **Alpine sediments are the natural reservoirs of melt water and summer rain.**
2. **Moraine in the Hathataga regulates baseflow.**
3. **Major challenge is in incorporating field-based understanding into large-scale basin models.**

Contact: hayashi@ucalgary.ca

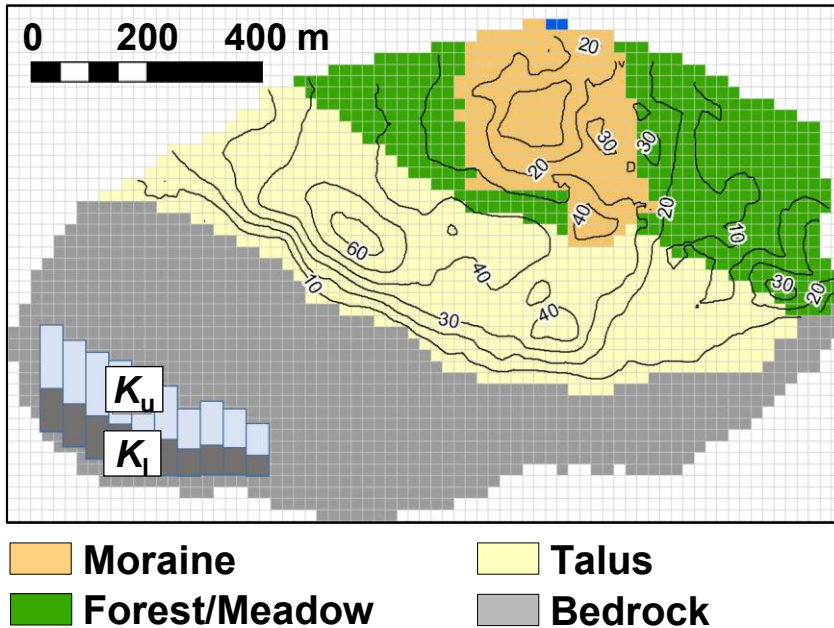
Funding and Logistical Support



**NSERC
CRSNG**



Numerical GW flow model



Dynamical system approach

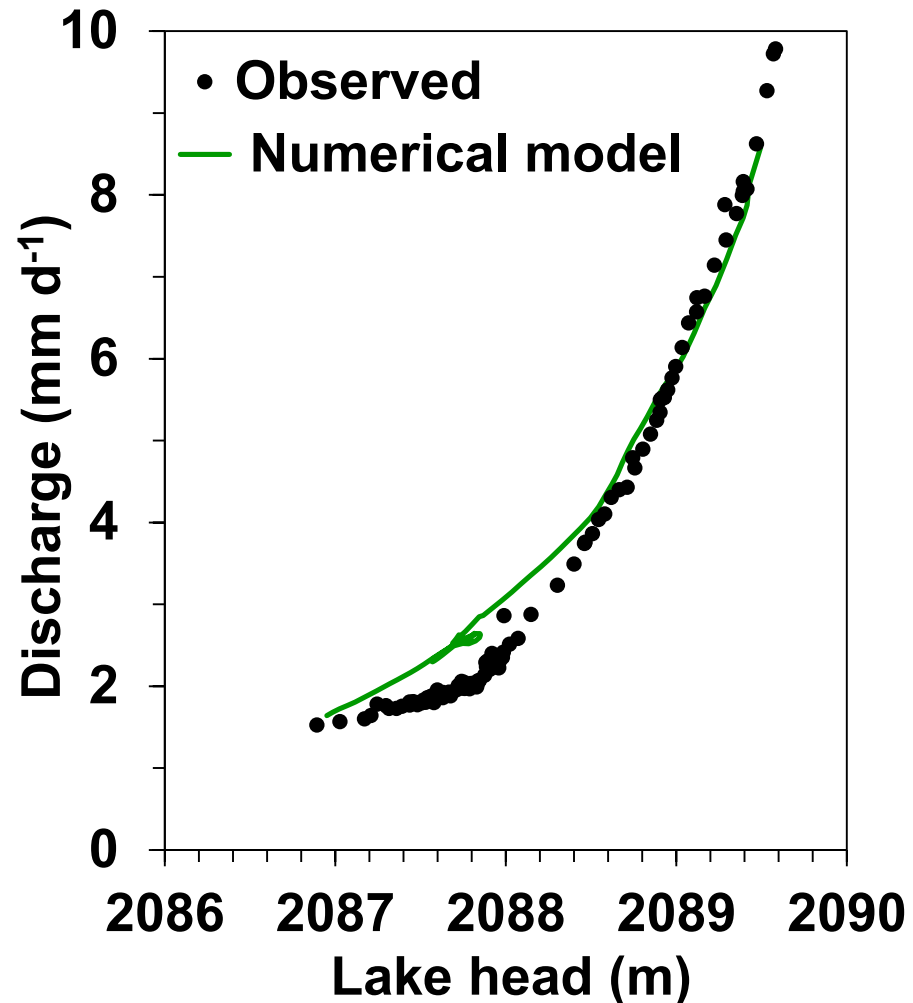
$$\frac{dS}{dt} = \frac{dS}{dQ} \frac{dQ}{dt} = \frac{1}{g(Q)} \frac{dQ}{dt} \quad g(Q) = \frac{dQ}{dS}$$

S: storage (mm)

Q: discharge (mm d⁻¹)

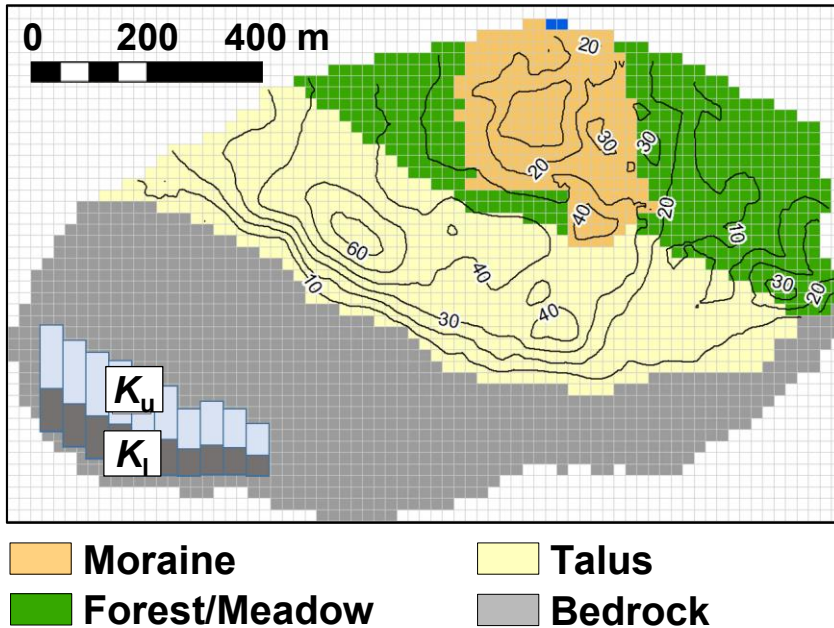
g(Q): sensitivity function (d⁻¹)

Kirchner (2009, *Water Resour. Res.*, 45, W02429)



He & Hayashi (2023. *Hydrol. Process.*, 37, e14881)

Numerical GW flow model



Dynamical system approach

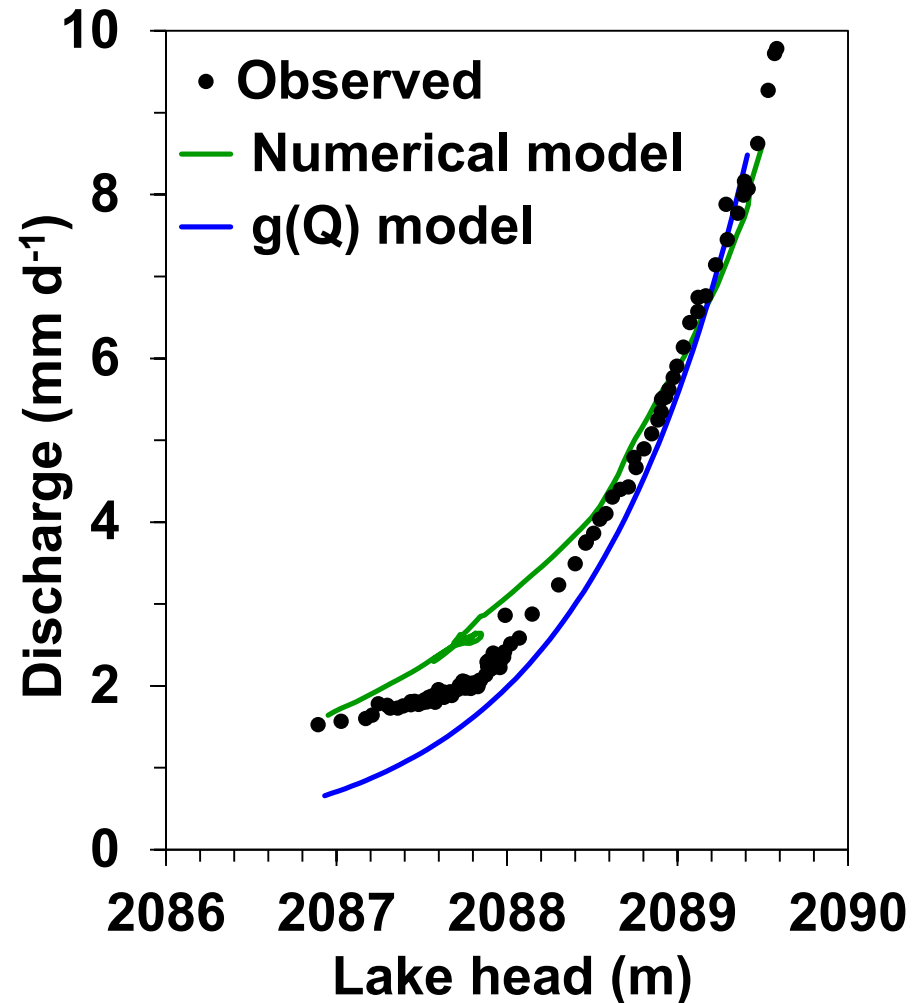
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