Investigating Hillslope Hydrological Processes in the Snowy Mountains, Australia Using Physical, Chemical, and Isotopic Data

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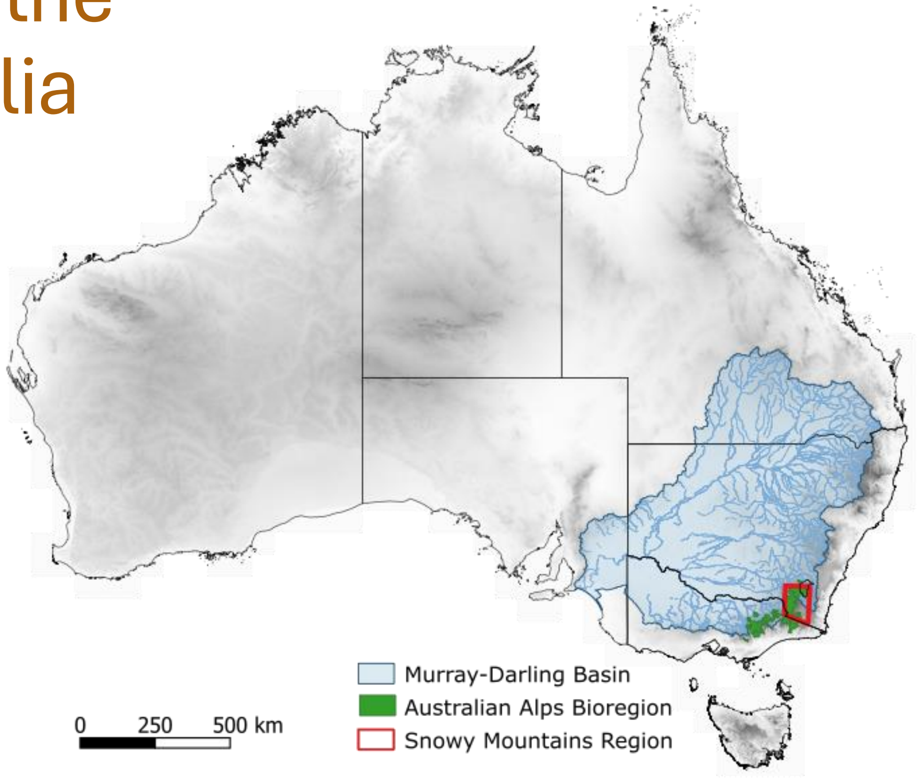
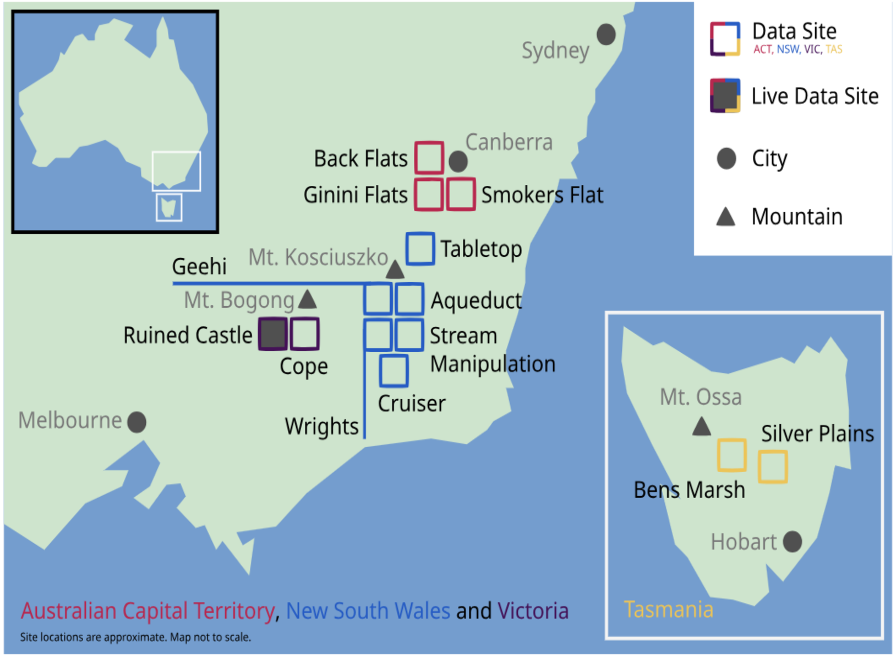
Unique Characteristics of the Snowy Mountains Australia

- ❑ Marginal Snowpack condition
- ❑ Geological history
  - Limited glacial extent (predominantly periglacial)
- ❑ Granitic (granodiorite) geology
  - Deep weathering profiles (~3-10m)
- ❑ Unique Vegetation communities
  - Snow Gum eucalypt forests



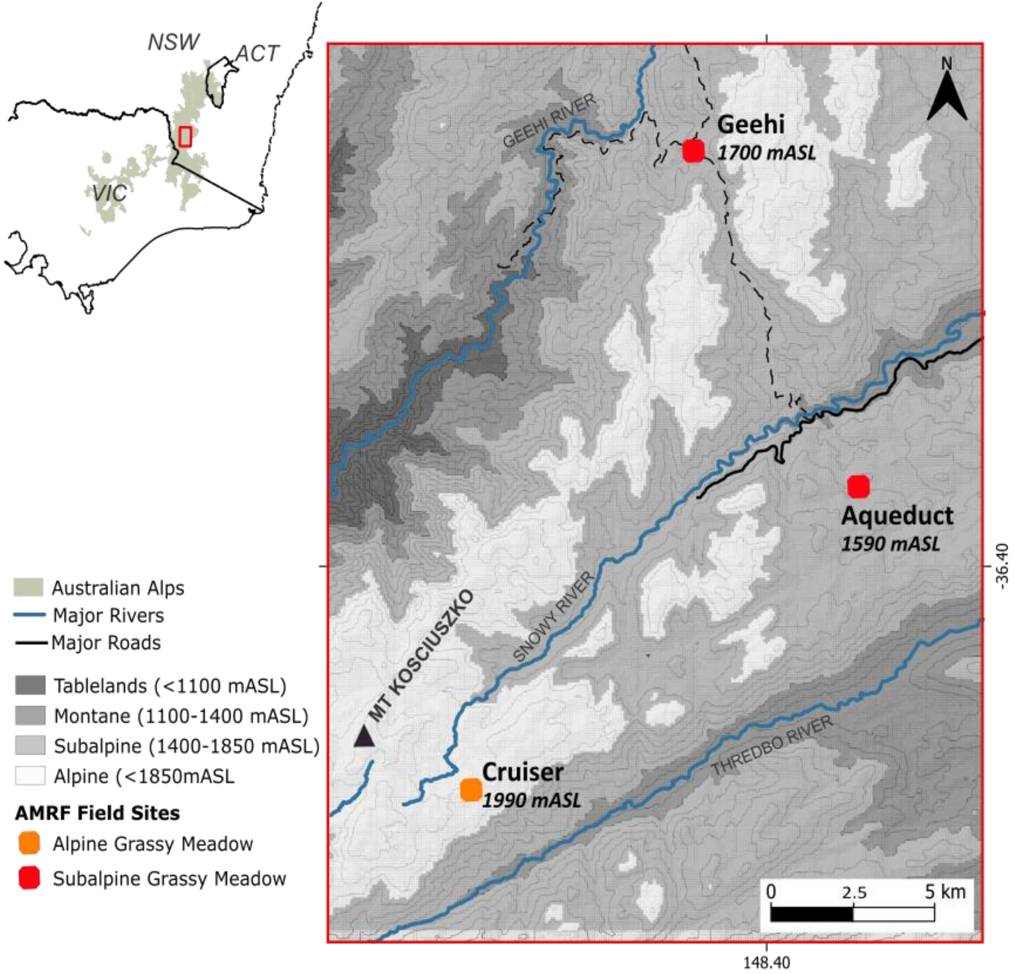
Australian Mountain Research Facility (AMRF)



Official Website: https://www.amrf.org.au/
AMRF Site Data: https://grafana.amrf.org.au/

- **AMON sensor array** (weather station)
- **Ecosystem flux** (CO_2 and water vapour) using eddy covariance.
- **DroughtNet**
- **FutureClim**
  in situ, future climate simulation experiment
- **Hydrological Monitoring Array**

“to produce world-leading ecosystem, evolutionary and biophysical science to guide adaptive management of High Mountains Australia”



Snowy Mountains AMRF Field Sites

- ❑ South-facing aspect
- ❑ Low-moderate slope angle (7 – 13°)
- ❑ Grassy Meadow vegetation
  - ❑ Heath (shrubs) is present at sub-alpine sites

MAX Snow Depths

~ 0.6m Aqueduct

~ 1.0m Geehi

~ 1.5m Cruiser
(plus, windblown snow)

Research Questions

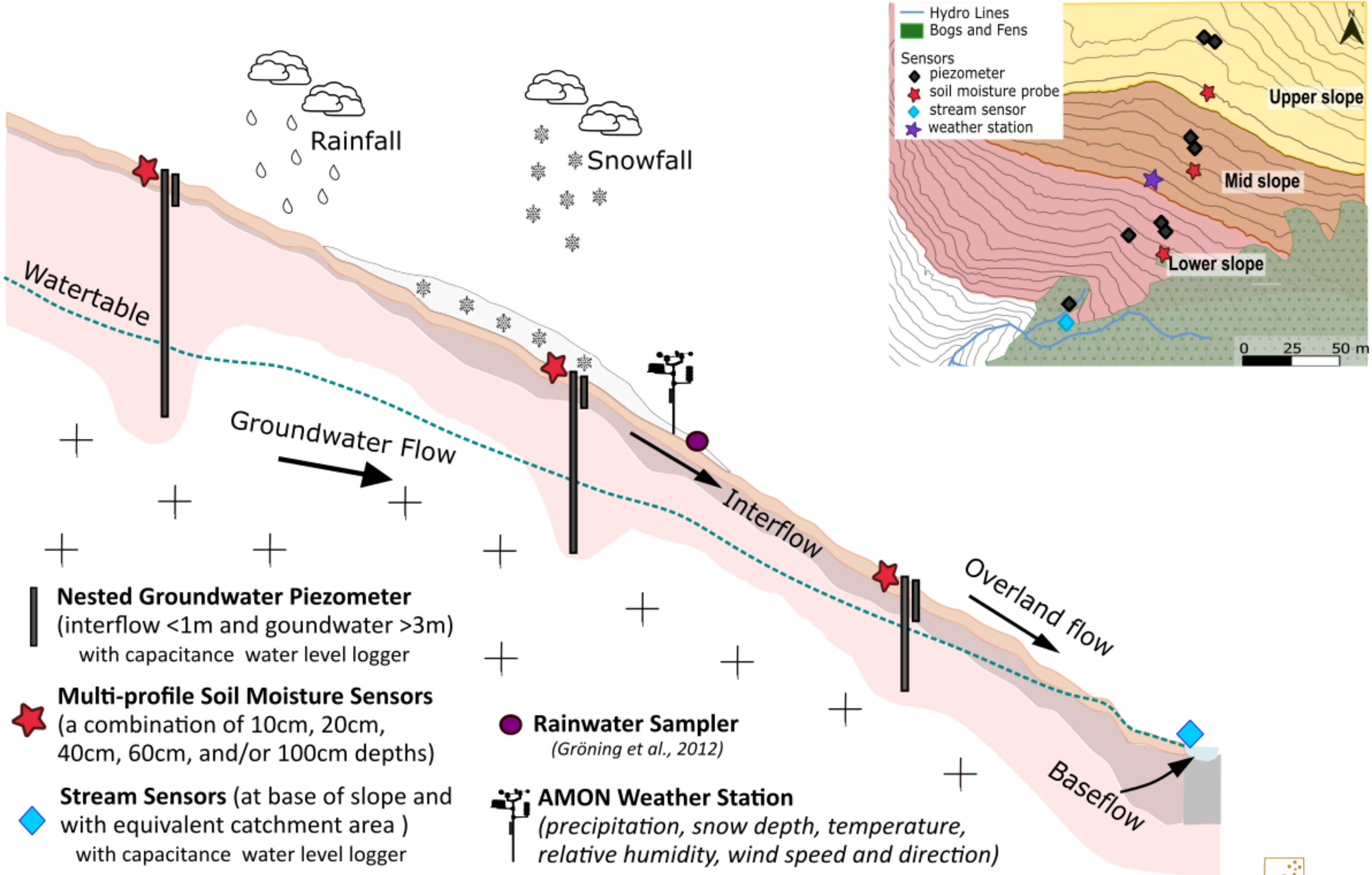
(1) How does water move through the hillslope hydrological system?

(2) What are the residence times for water in the hillslope?

(3) How are alpine hillslope hydrological response patterns likely to change as a result of predicted climate change?

Precipitation to stream flow generation, how is the water getting there and what are the residence times?

Hydrological Monitoring Array



Gröning, M., Lutz, H., Roller Lutz, Z., Kralik, M., Gourcy, L., Pöltenstein, L., 2012. A simple rain collector preventing water re evaporation dedicated for $\delta^{18}O$ and $\delta^{2}H$ analysis of cumulative precipitation samples. Journal of hydrology 448, 195–200.

Current Data Set

- ❑ 3-years of data (across 3 sites)
  - Weather Station (precipitation, snow-depth, temperature, humidity, wind speed and direction)
  - Hydrological array

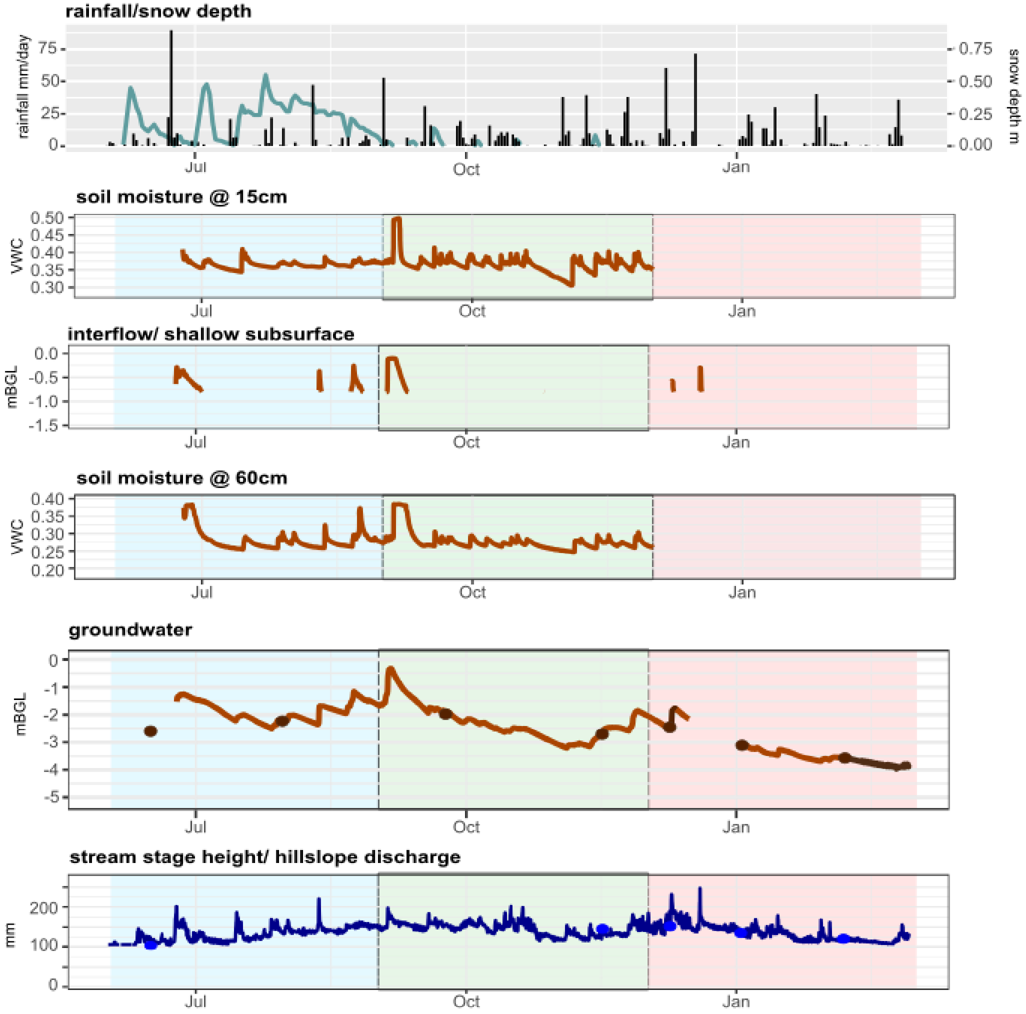
    (soil moisture, groundwater level, stream height)
  - Physicochemical measurements (EC, pH, Temp)

    (groundwater and stream water)
- ❑ 600 Water Samples

  (rainwater, snowpack, groundwater, surface water)
  - Stable Isotopes ($\delta^{18}O$ and $\delta^{2}H$)
  - Hydrogeochemistry (Major cations and anions)

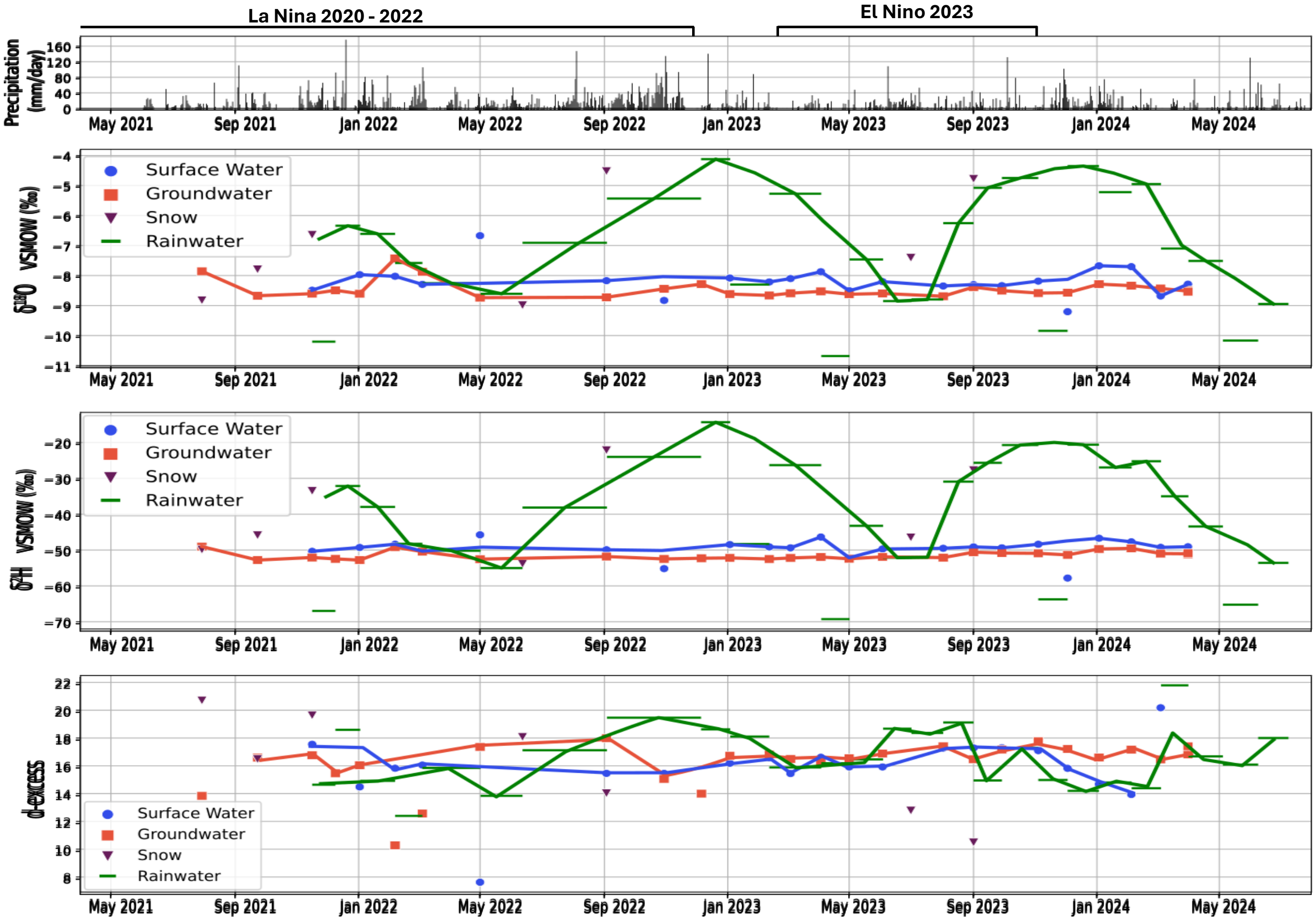
Hydrological Array

- Significant number of rain on snow events
- Soil moisture is highly responsive to precipitation
- Intense precipitation events required for lateral interflow in soils
- Groundwater recharge occurs predominantly during winter months



Stable Isotope Temporal Analysis

δ¹⁸O, δ²H, d-excess

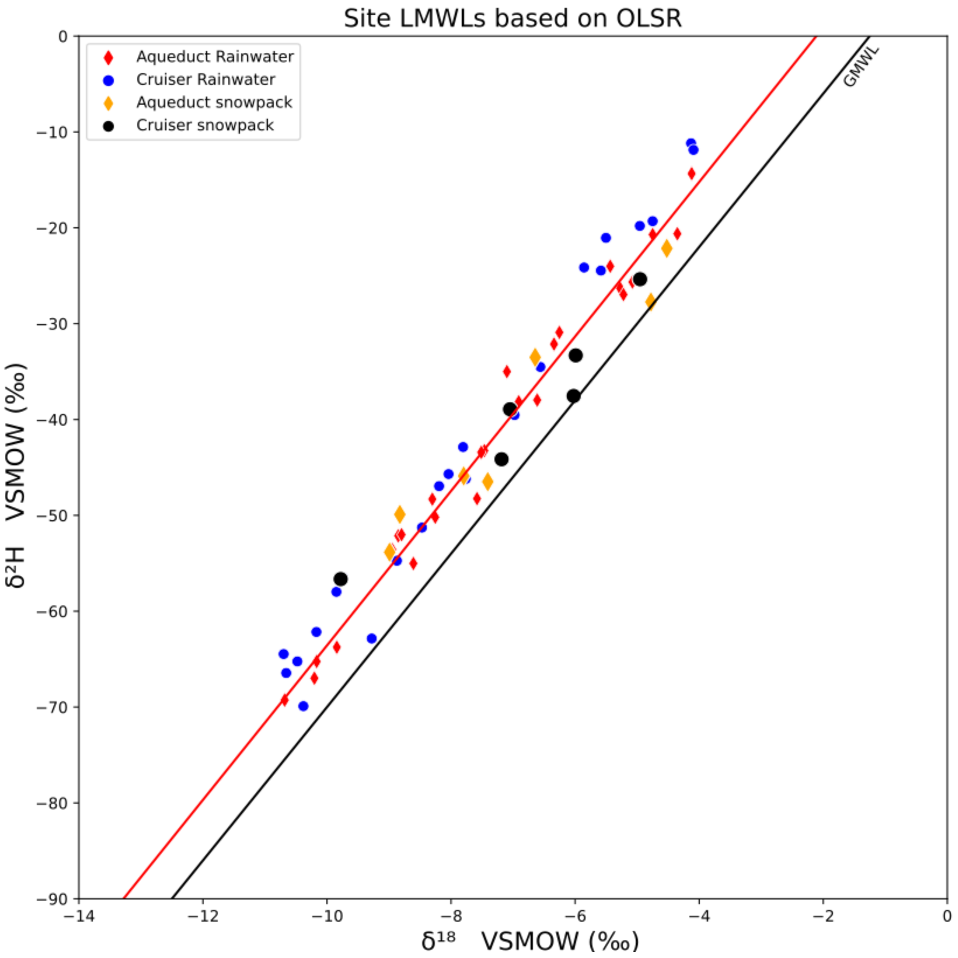


Stable Isotopes

Rainfall $\delta^{18}O$ vs $\delta^{2}H$ Plot

Precipitation Weighted Average

	$\delta^{18}O$	$\delta^{2}H$	d-excess
Aqueduct Site Data	**-7.26**	**-41.41**	**16.66**
South-east NSW Highlands Isoscape [1]	**-7.34**	**-37.92**	**20.88**
Continental Isoscape [2]	**-7.56**	**-40.19**	**19.97**

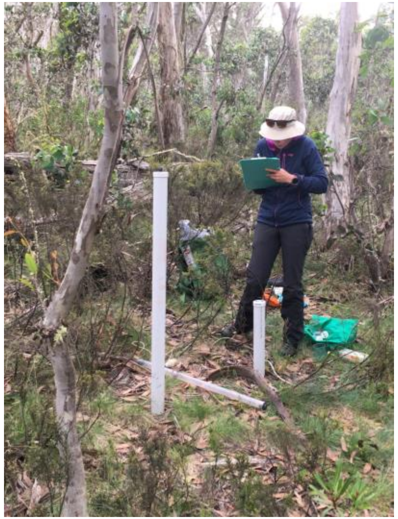


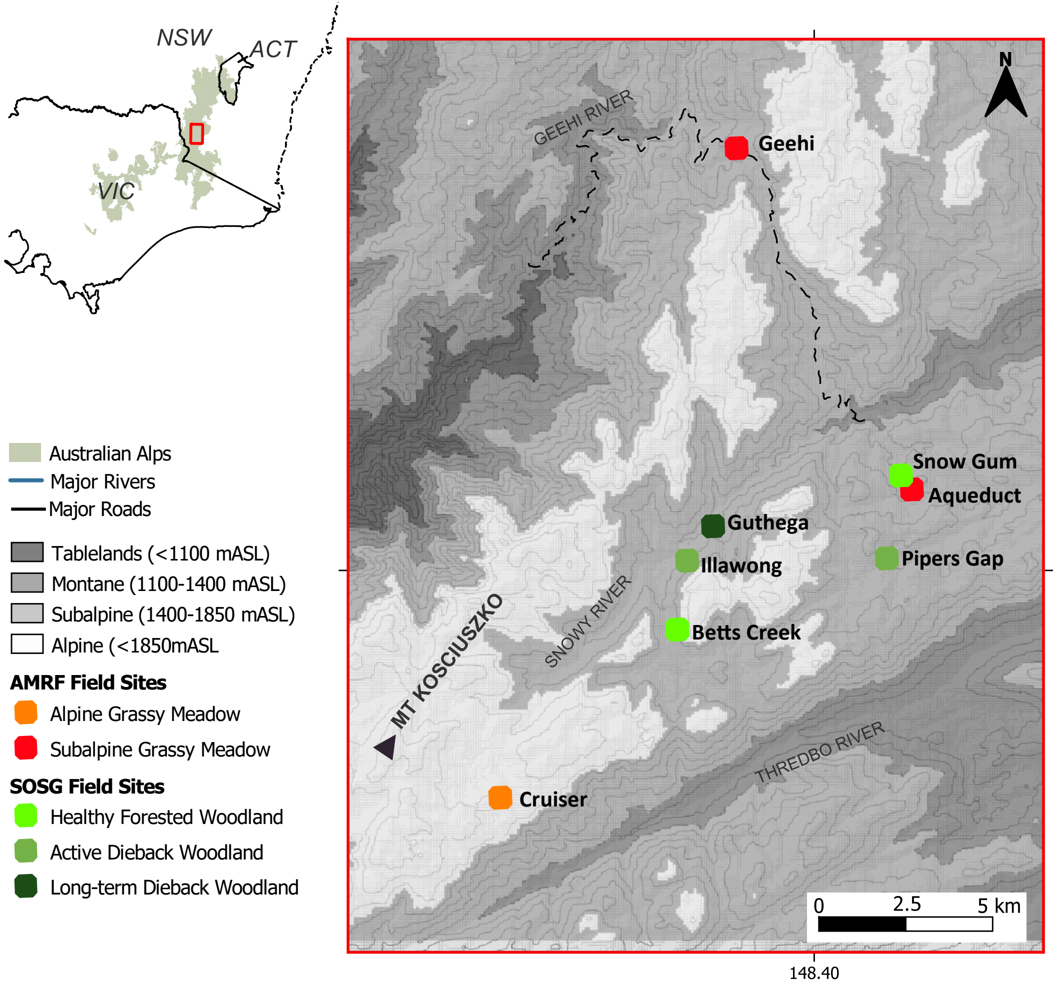
[1] Gray, S.S., in progress. Interactions between meteoric, surface, and ground water in the Upper Murrumbidgee Catchment (doctoral thesis). Australian National University.

[2] Hollins, S.E., Hughes, C.E., Crawford, J., Cendón, D.I., Meredith, K.T., 2018. Rainfall isotope variations over the Australian continent – Implications for hydrology and isoscape applications. Science of The Total Environment 645, 630–645. https://doi.org/10.1016/j.scitotenv.2018.07.082

Next Steps for Fieldwork

1. Continue to collect data from hydrological monitoring array and water samples
   (till December 2025)
2. Event Based Sampling Round/s
   Hourly water sampling preceding, during and following precipitation events
3. Intensive winter 'snow' sampling round (2025)
   Snowfall, snowpack and snowmelt samples and measurements collected fortnightly
4. Set-up hydrological monitoring array and water sampling rounds at new Snow Gum eucalypt forests



Is there a difference in hydrological response between forested (eucalypt) and grassy meadow hillslopes in the Australian Alps?

SOSnowgum

Hydrological Monitoring Array Analysis

1. Hillslope Water budget

$$\Delta S = (R_{in} - R_{out}) + (Q_{in} - Q_{out}) + (P_{rain} + P_{snow}) - (E_{dir} + ET_{veg})$$

2. Hillslope hydrogeologic conceptual model/s

   Seasonal flow pathways and elevation effect on hydrological response patterns

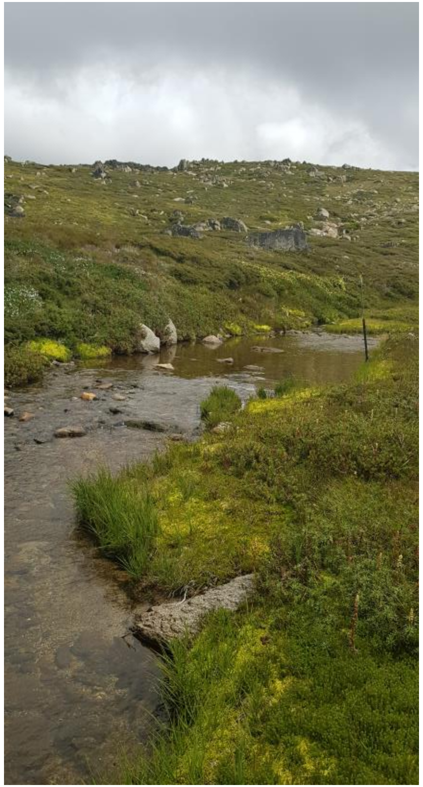
3. Event analysis of discrete precipitation patterns

   Affect of precipitation intensity, duration, form and frequency of events

4. Vegetation influence on soil moisture, groundwater recharge and drawdown

Isotope Hydrogeochemistry Analysis

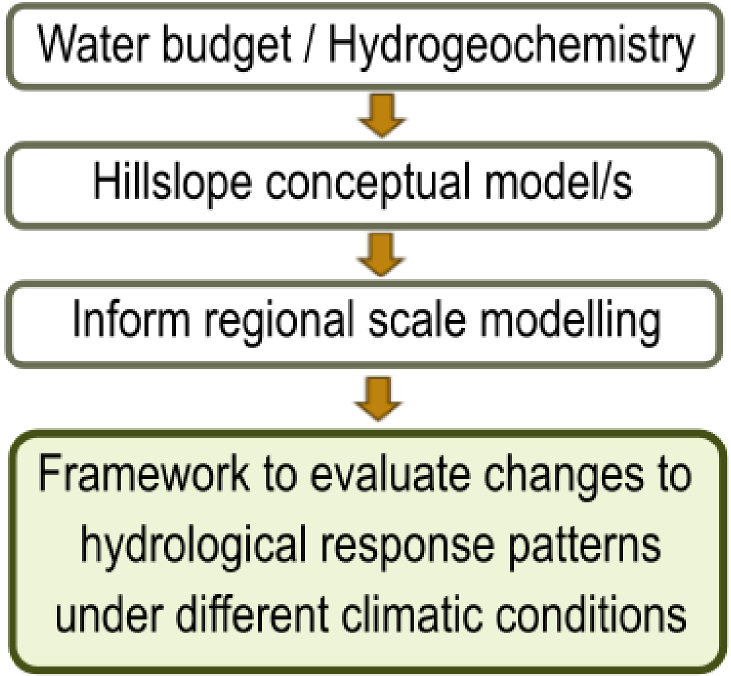
1. Event Based Sampling
   i. Hydrograph Separation
2. Chemistry Analysis
   i. Mass Balance (Cl^-)
   ii. Multi-Variate Statistical Analysis (MSA)
      Principal Component Analysis (PCA)
      Hierarchical Cluster Analysis
   iii. Hydrograph Separation
   iv. Mean Transit Time Analysis
      (residence times, e.g. $\delta^{18}O/\delta^{2}H$ ratios, ^{3}H, and ^{222}Rn)



Research Aspirations

‘To understand hydrological processes occurring at the hillslope scale and the environmental and/or climatic drivers influencing hydrological response patterns.’

- ❑ Natasha Harvey’s PhD Project (ANU)[1]
  “Reimagining the representation of snow hydrology in catchment models within an age of emerging technologies for sensing, data science and machine learning”
- ❑ NSW and Australian Regional Climate Modelling (NARCliM 2.0)[2]



[1] Harvey, N., Razavi, S., & Bilish, S. (2024). Review of hydrological modelling in the Australian Alps: from rainfall-runoff to physically based models. *Australasian Journal of Water Resources*, 1–17. DOI: 10.1080/13241583.2024.2343453
[2] NSW Department of Climate Change, Energy, the Environment and Water. (2024). NARCliM2.0 Climate Projections. Data. NSW. https://data.nsw.gov.au/data/dataset/narclim-climate-projections-n2-0

THANK YOU

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tern
Ecosystem Research Infrastructure

NCRIS
National Research Infrastructure for Australia

AINSE
The Australian Institute of Nuclear Science and Engineering

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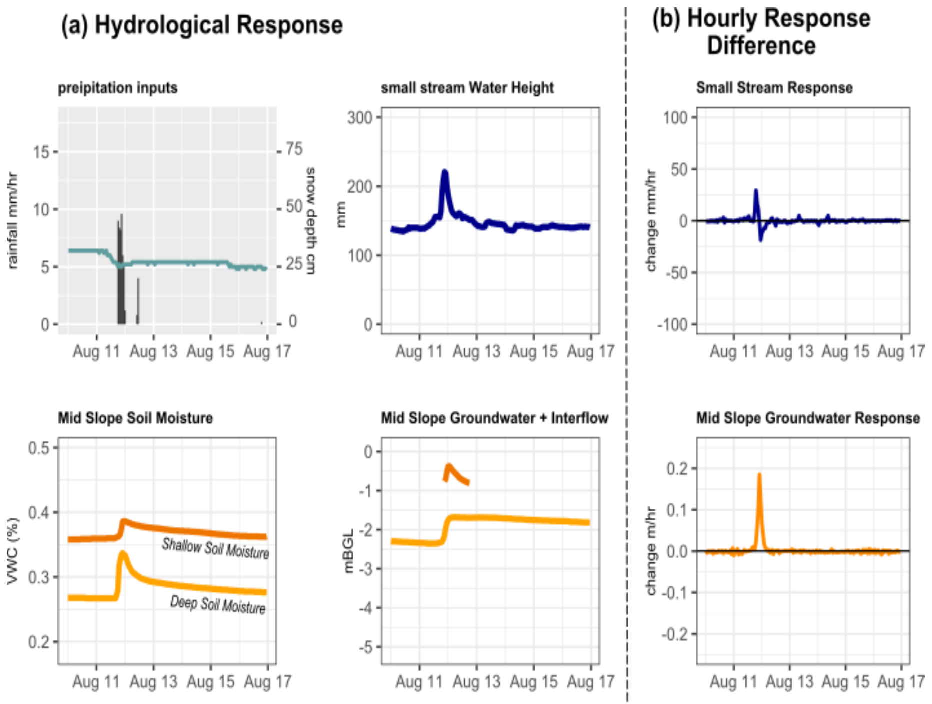
Australian Mountain Research Facility

Hydrological Array - Event-based Response

Winter 2021

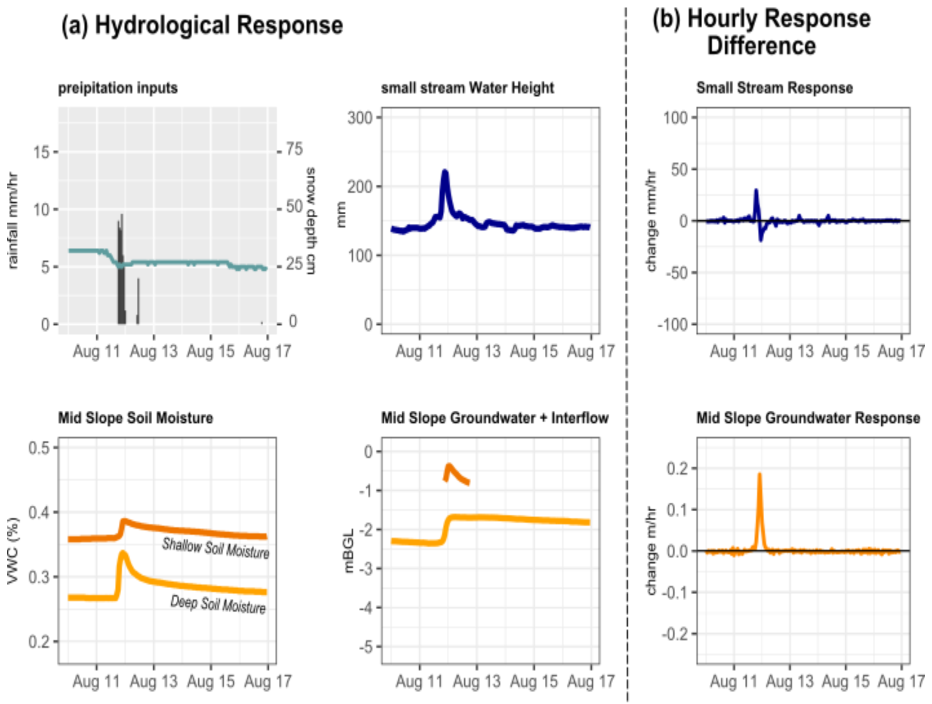


High rates of groundwater recharge during rain-on-snow events

- ❑ *56mm precipitation over 1.5 days (average 1.5mm/hr)*
- ❑ Soil Moisture experiences a minimal response, near field capacity due to snowmelt contributions
- ❑ "Highly localised" interflow occurred in soils lasting 22 hrs.
- ❑ Groundwater levels increased by 0.6 m
- ❑ Stream response lag time of ~2 hrs peak response 10 hrs preceding event began.

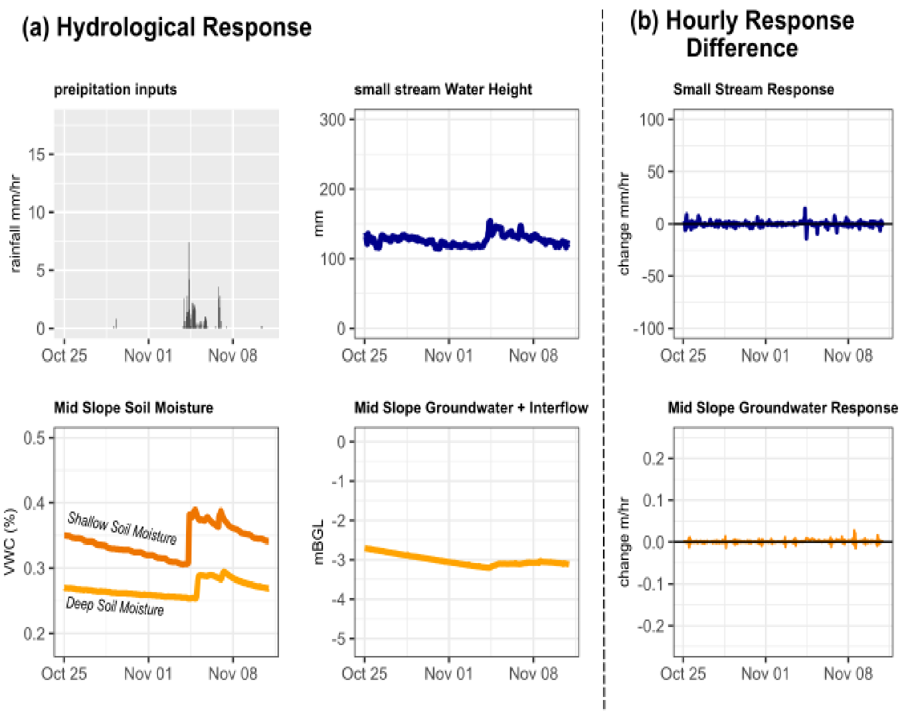
Hydrological Array - Event-based Response

Winter 2021



56mm precipitation over 1.5 days (average 1.5mm/hr)

Spring 2021



50.0mm precipitation over 2 days (average 1.0mm/hr)