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GLOBAL WATER FUTURES
OBSERVATORIES



UC-HAL
Hydrologic Analysis Lab

From Sea to Sky, Across the Continental Divide

*High Frequency Isotope and Hydrologic
Monitoring for Improved Runoff
Prediction in the Canadian Rockies*

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2026 INARCH WORKSHOP

SEPTEMBER 8-10, 2026





Objectives

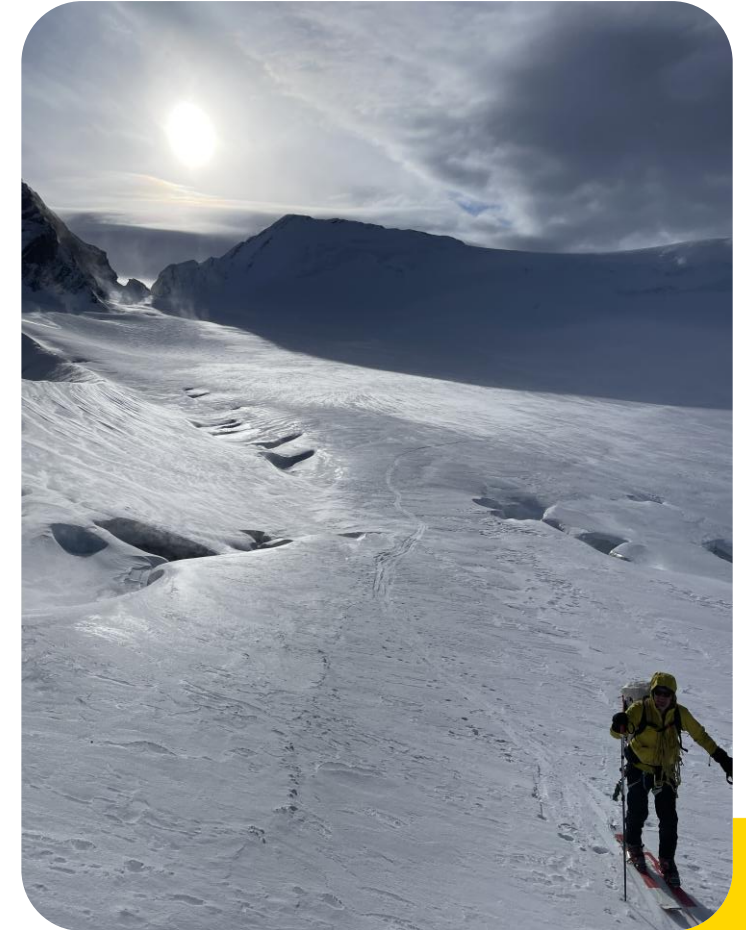
Improve our understanding and prediction of mountain headwater runoff generation and change.

1. **Monitor** hydrological change
2. Improve **simulated** process representation
3. Increase **data** resolution in models

→ Add a compliment of **stable isotopes of water** (^{18}O , ^2H) to current Fortress Mountain hydrometeorological monitoring

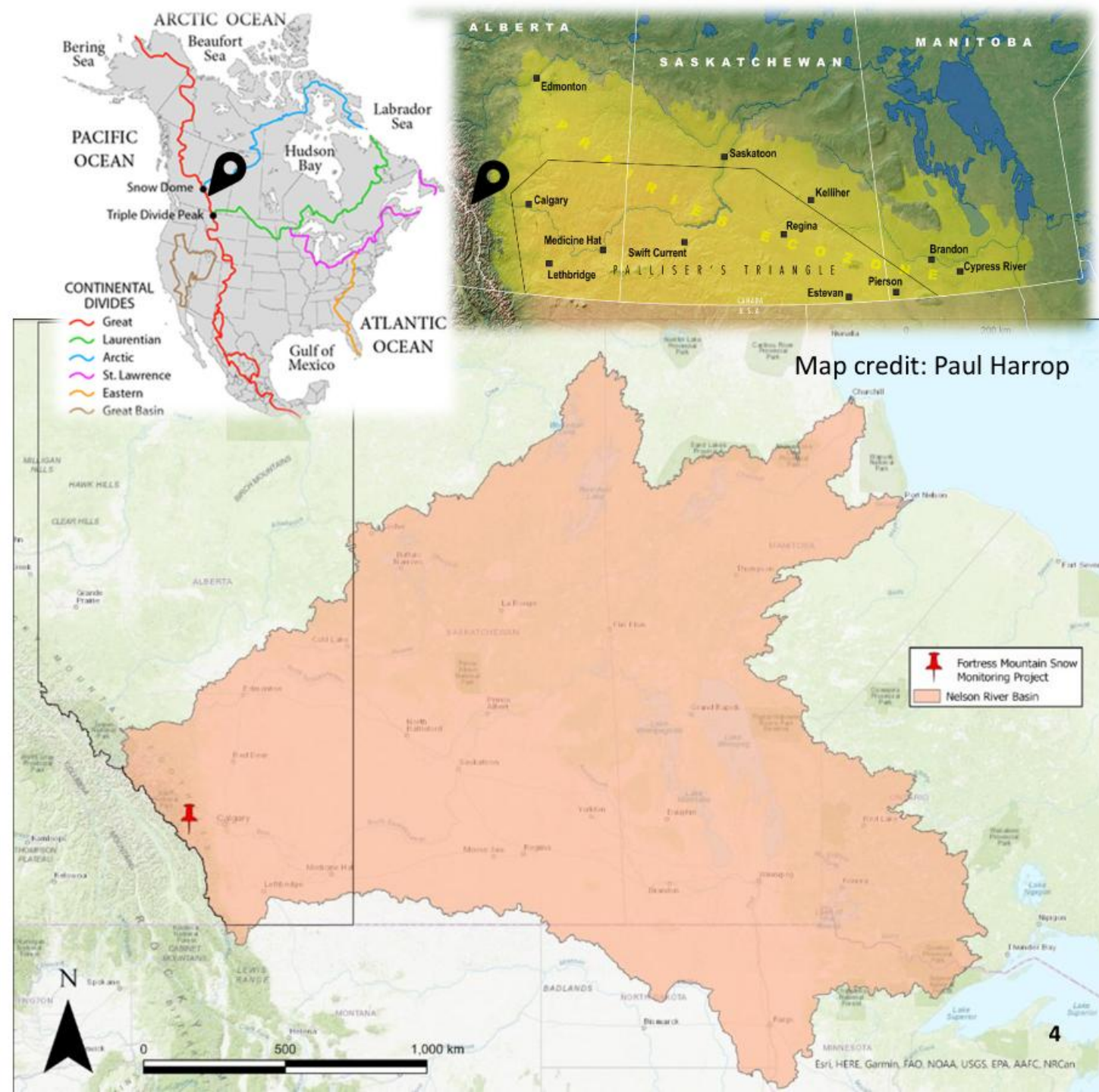
→ Isotopes as **tracers** → offer insight into underlying **processes** and **reasons** for changing streamflow

1. Origin of water (isotope signatures tell a story - "water's fingerprints")
2. Baseflow separation and evaporative signals
3. Early climate change detection

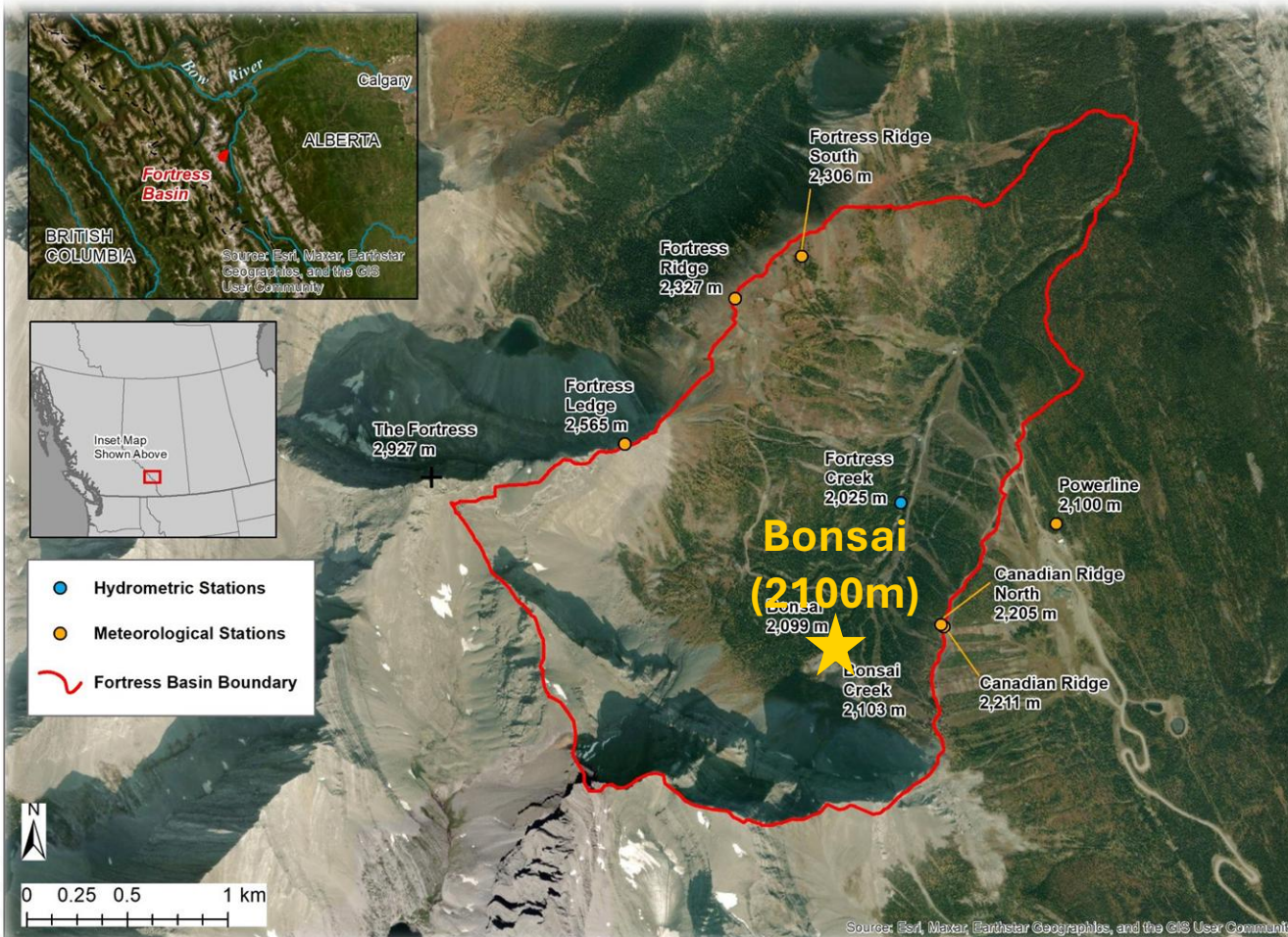


Fortress - From Sea to Sky

- From Sea-to-sky, across the continental divide
- Canadian Rockies Hydrological Observatories (CRHO) program
 - Canadian Rocky Mountain Front Ranges (Eastern Slopes)
 - WMO Global Cryosphere Water Programme basin
- Headwaters of the Hudson Bay (Arctic) drainage system
 - Nelson River (1.1M km²)
 - Transboundary significance
 - Driest portion of Canada



Fortress Mountain Research Basin



- High altitude basin (1786–2832 masl)
- Mean Annual Air Temp. 0.04°C @2100m
- Total Mean Annual Precip. 1052mm @2100m
- Basin Area: 5.92 km²



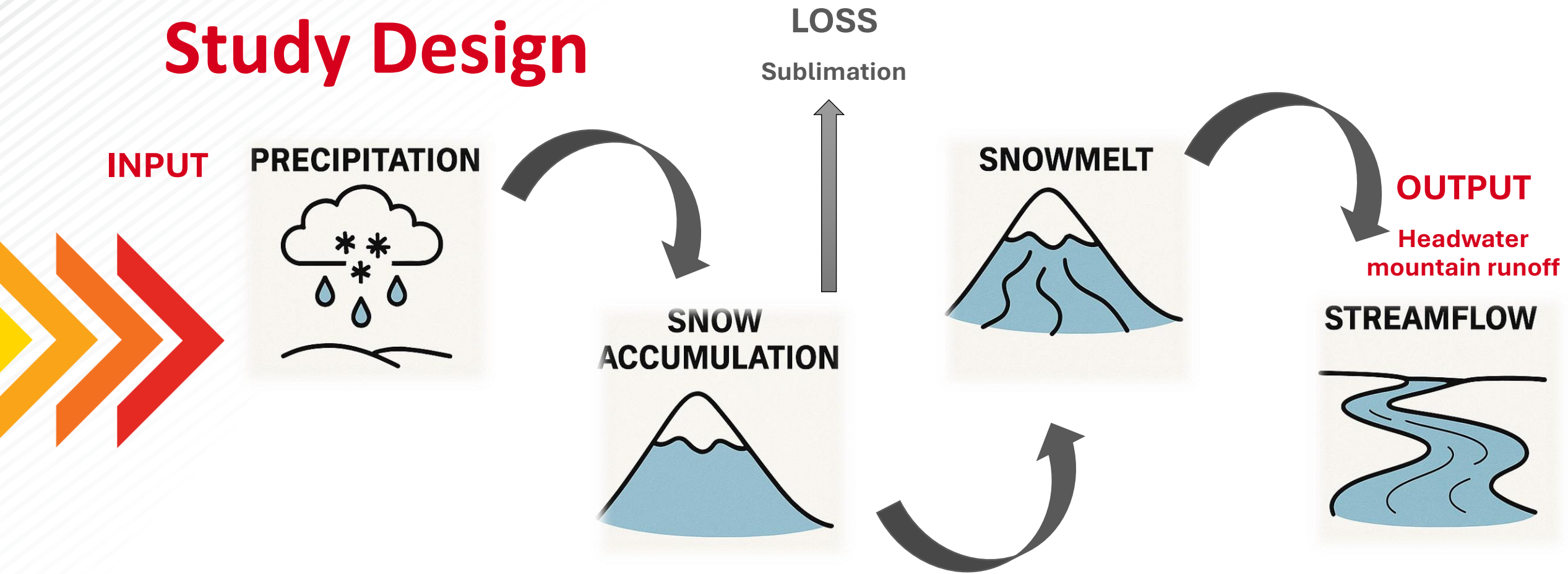
Map Credit: <https://gwfo.ca/sites/fortress.php>

Ozade Îmne



- *Fortress Basin (Kananaskis Country) is Treaty 7 territory in Canada, located within Ozade Îmne, which is named for its “V-shaped valley” and “neck of land between two lakes” by the **Îyârhe Nakoda**, or mountain people.*
- *Bonsai = Hathamaga Valley ("huckleberry")*

Study Design

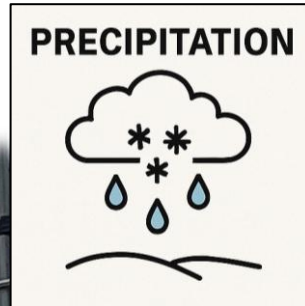


- Collect stable isotopes of water from
 - Four components of the water cycle (three phases)
 - Four types of sampling (instruments/methods)

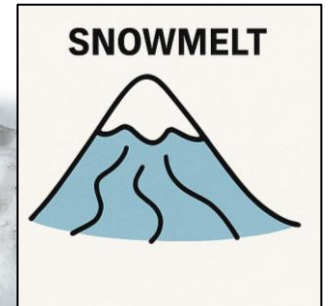
Precipitation Sampling (Rain)



**RS-1C Rainfall Sampler
(Palmex)**



Extended Funnel Sampler



Precipitation Sampling (Rain/Snow)

PRECIPITATION



TB3 Heated Tipping Bucket Rain Gauge (Hydrological Services)

Snowpack Sampling



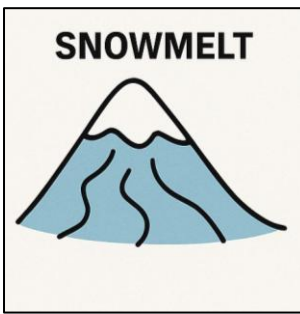
**Snow core sample
Mt. Rose / Federal
Snow Sampler**

Snow Pit Sampling

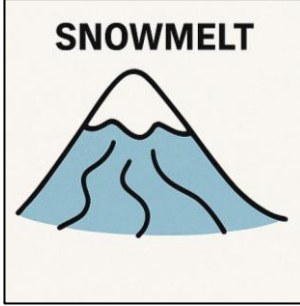


**Snow pit
samples,
Interval based**

Snowmelt Sampling - Lysimeter-1



Snowmelt Lysimeter-1: The Reality

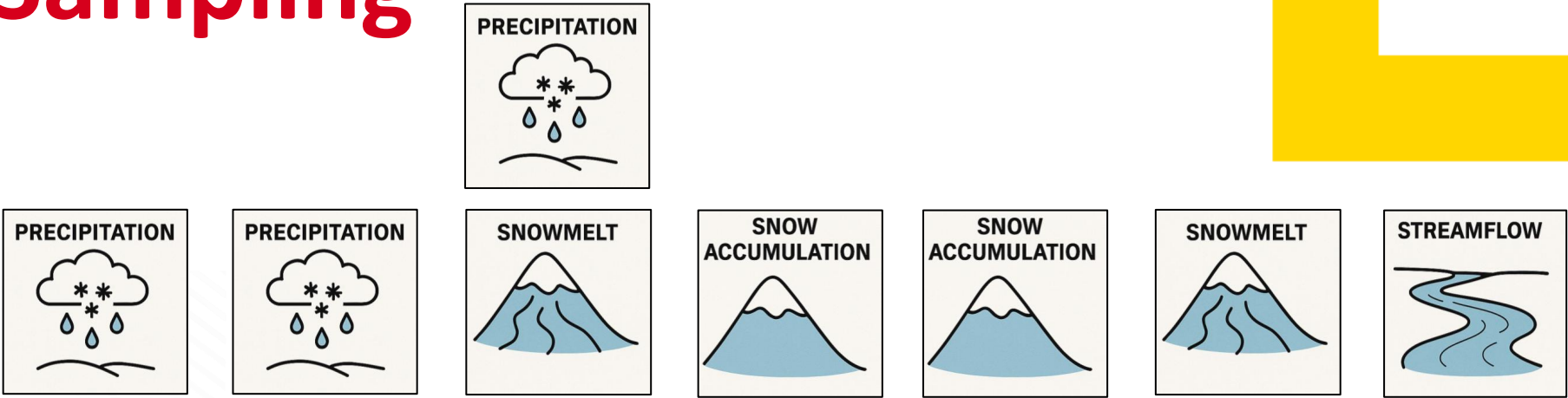




Streamflow Sampling



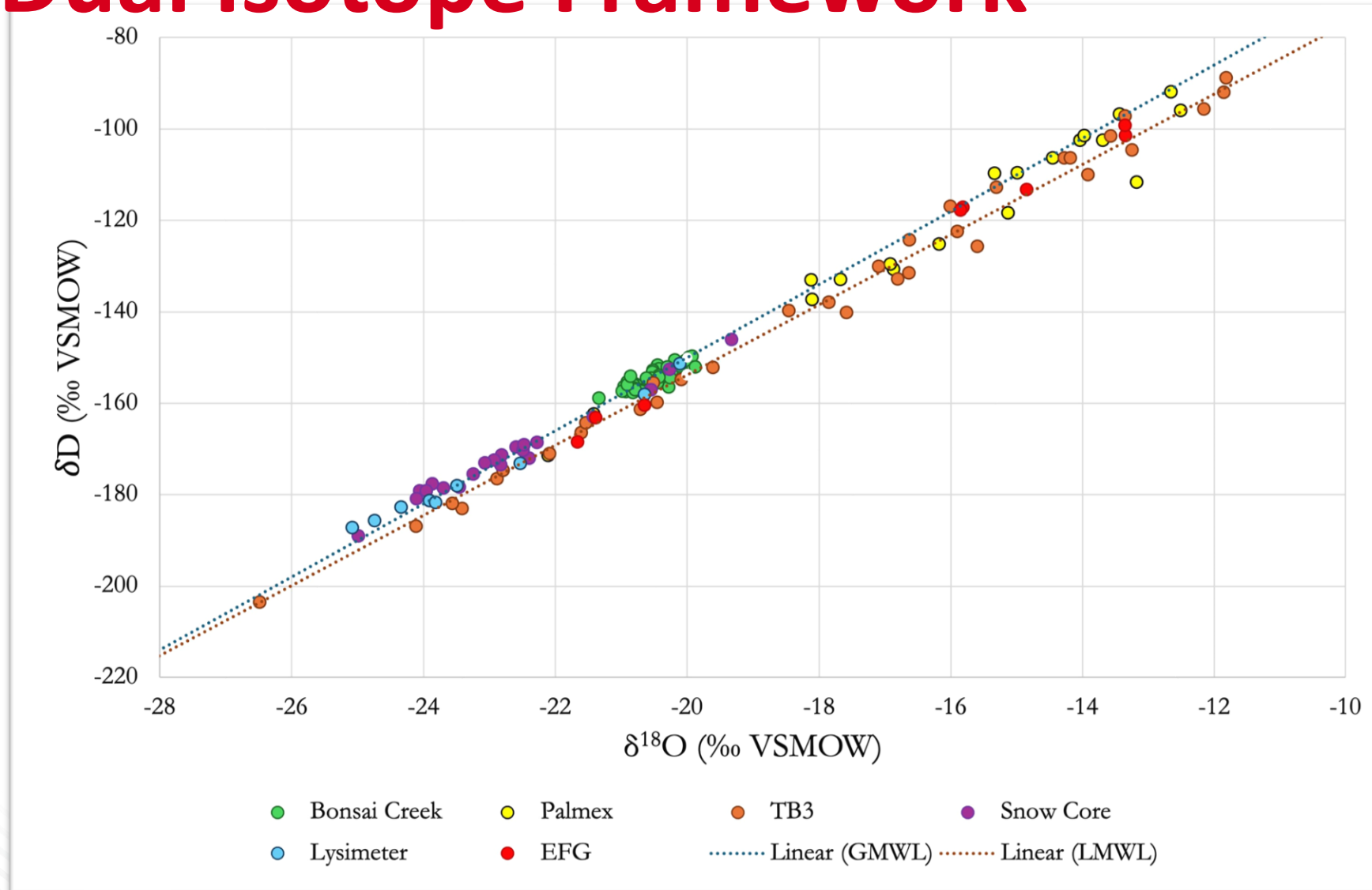
Methods: Instrumentation & Isotope Sampling



	TB3	Palmex	EFG	Snow Core	Pit Wedge	Lysimeter	Creek
# of samples 2023	14	5	2	6	--	3	14
# of samples 2024	18	11	3	12	--	6	20
# of samples 2025	21	6	4	11	56	5	14

From 10 snow pits (10 sampled days),
January – May 2025 (weekly during melt)

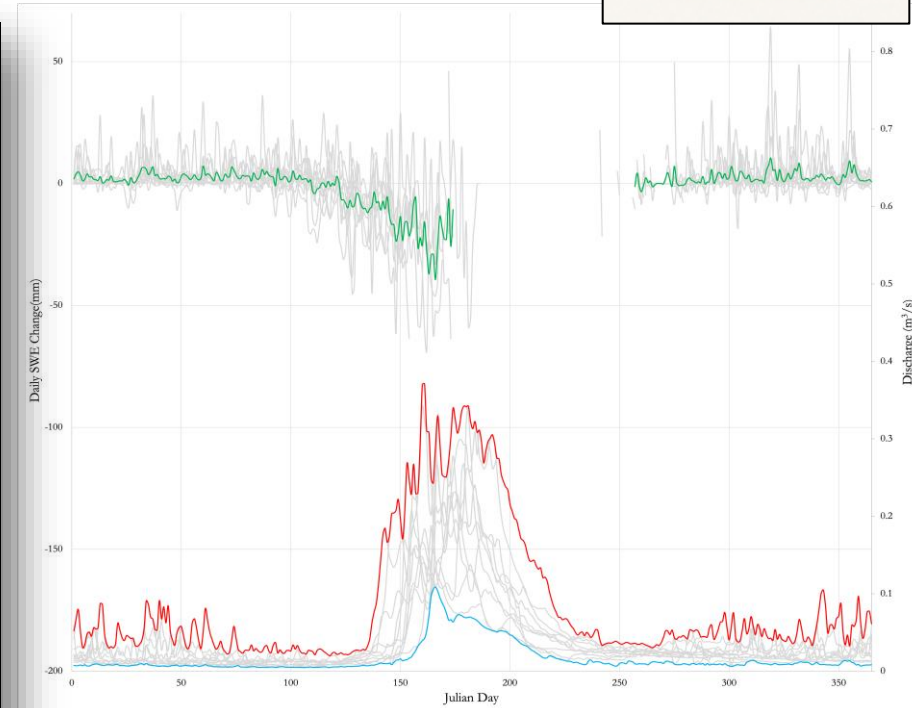
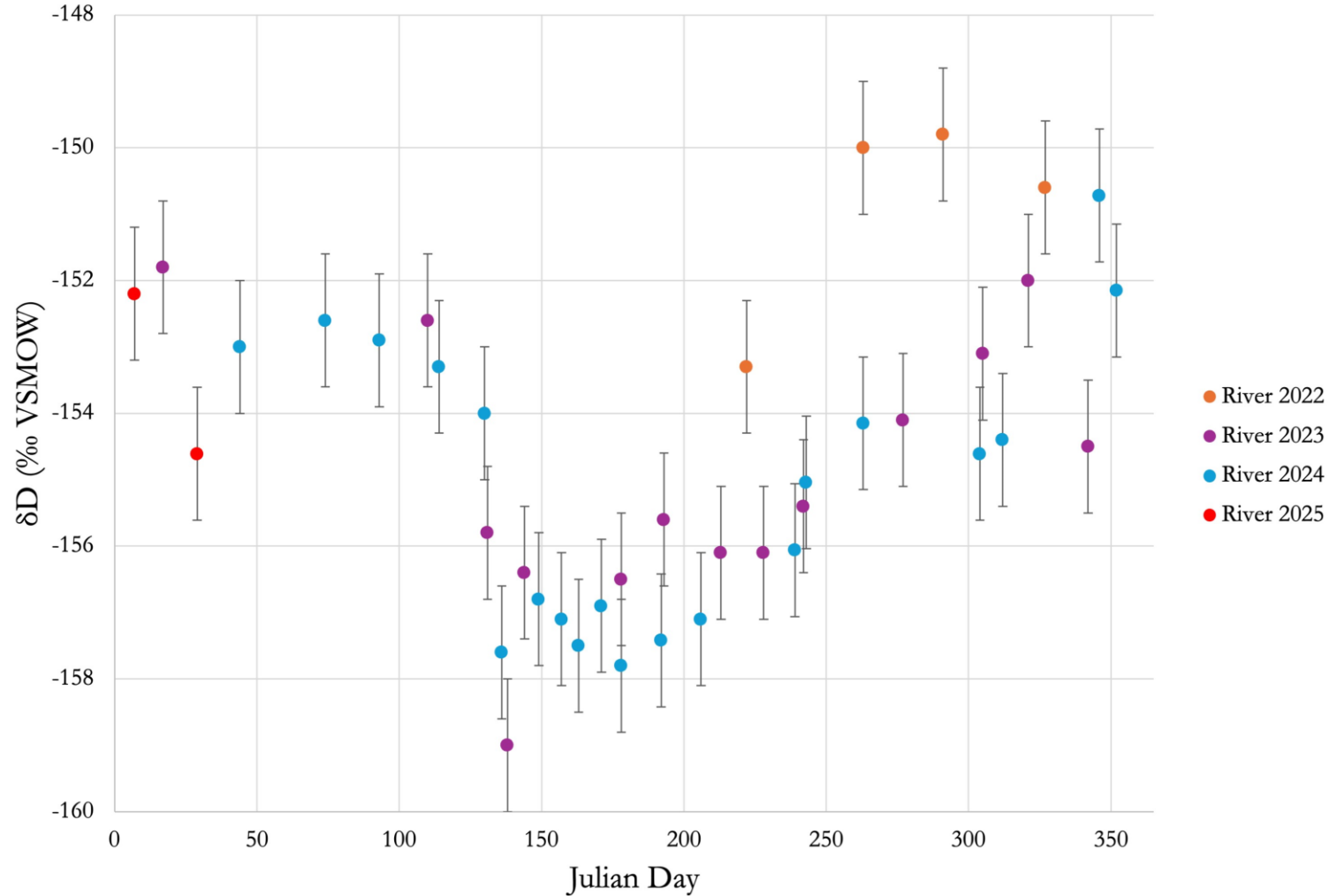
Dual Isotope Framework



- Separation of Rain v. Snow
- Comparable variability among measurement types
- Lysimeter captures enriched tail of snowmelt

Streamflow

STREAMFLOW

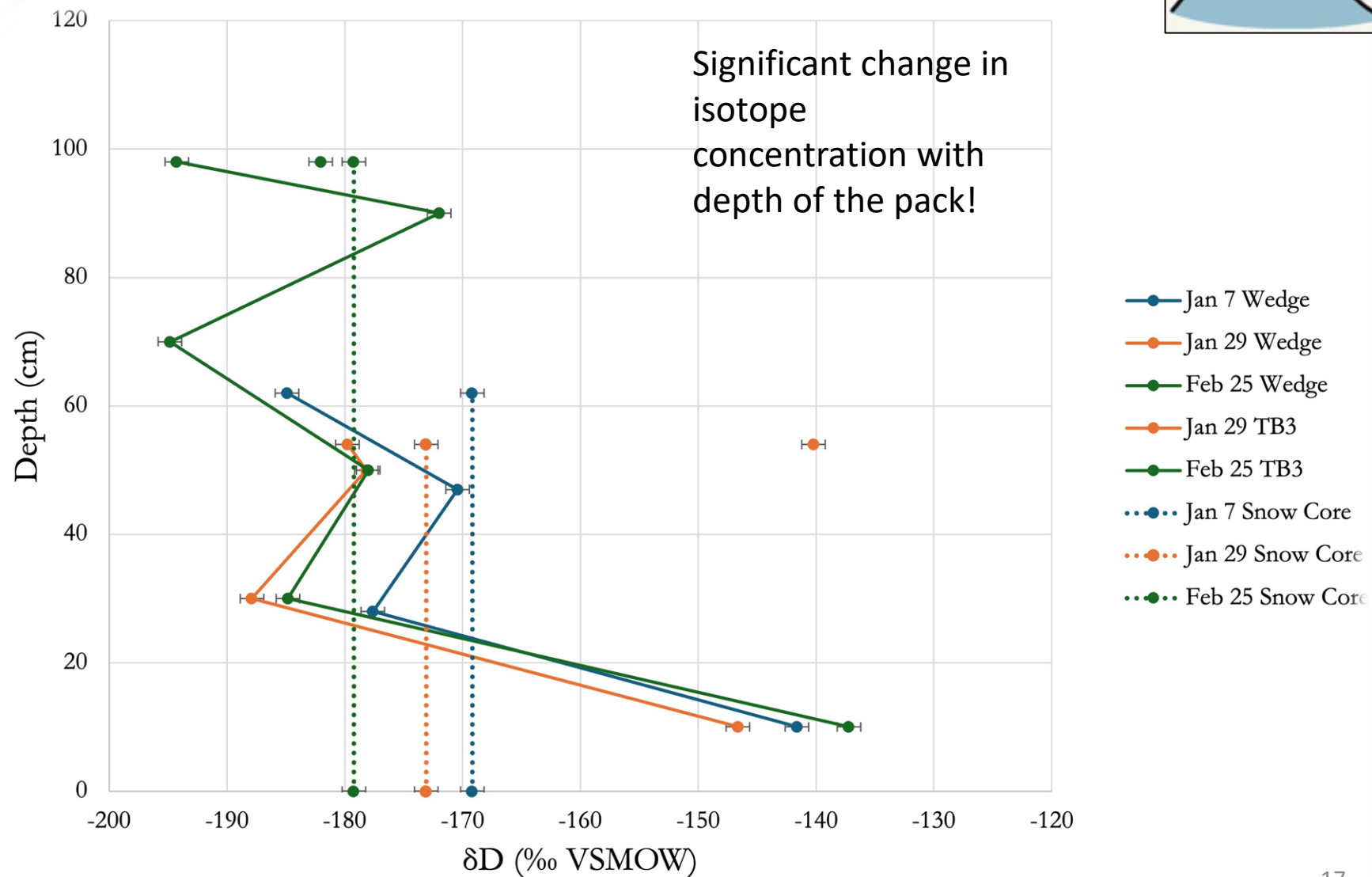


Strong isotope depletion correlates to peak streamflow

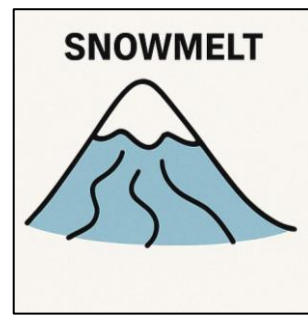


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Snowpack Accumulation Profile

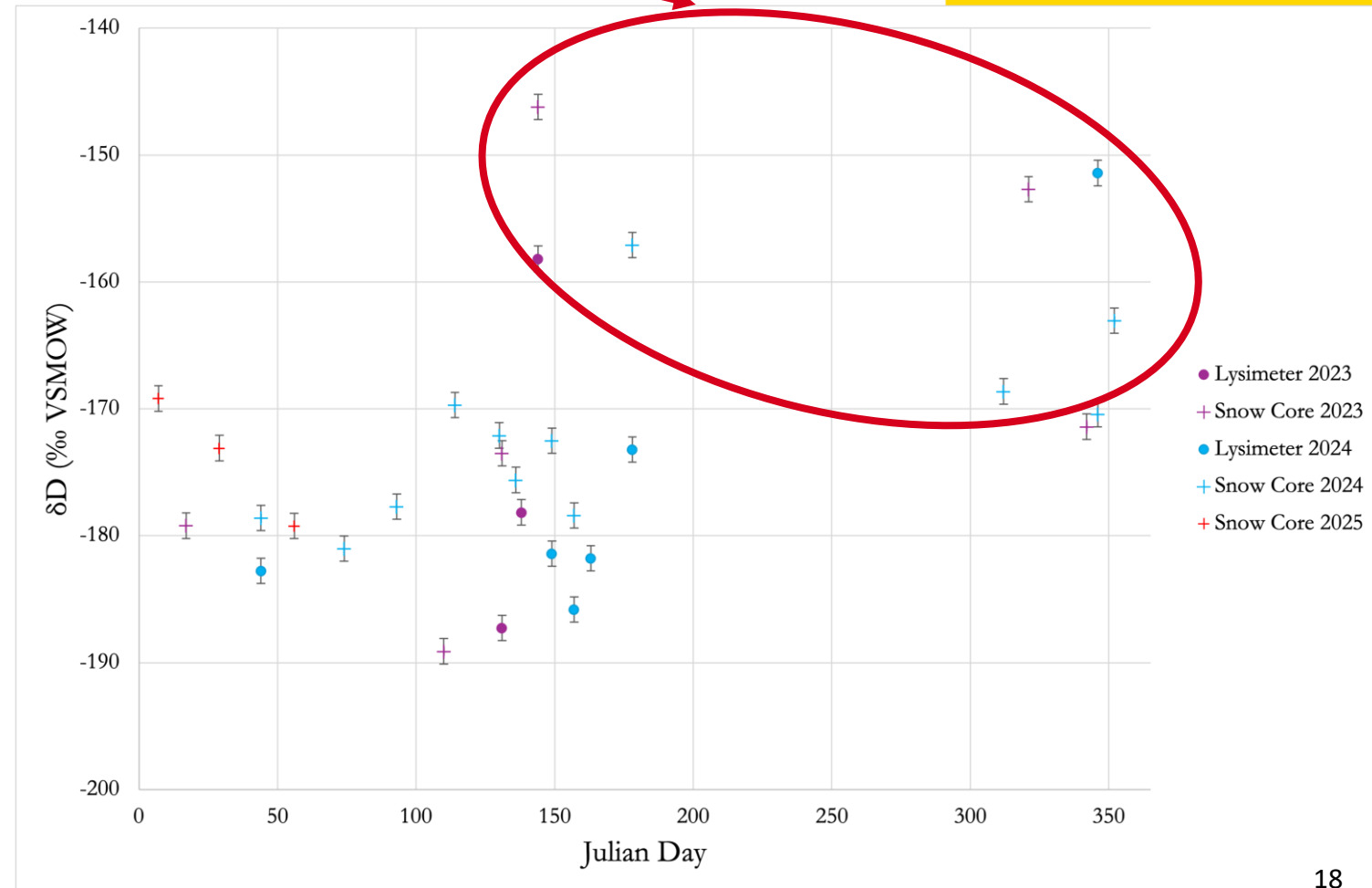


Snowmelt



- Lysimeter is the primary snowmelt measurement device
 - Isotopically lighter than snow cores
 - Melt starts with light isotopes
 - Heavy isotope late freshet 'flush'

Captures end of freshet enriched "flush" of isotopes from snowpack



University of Oulu, Finland Collaboration

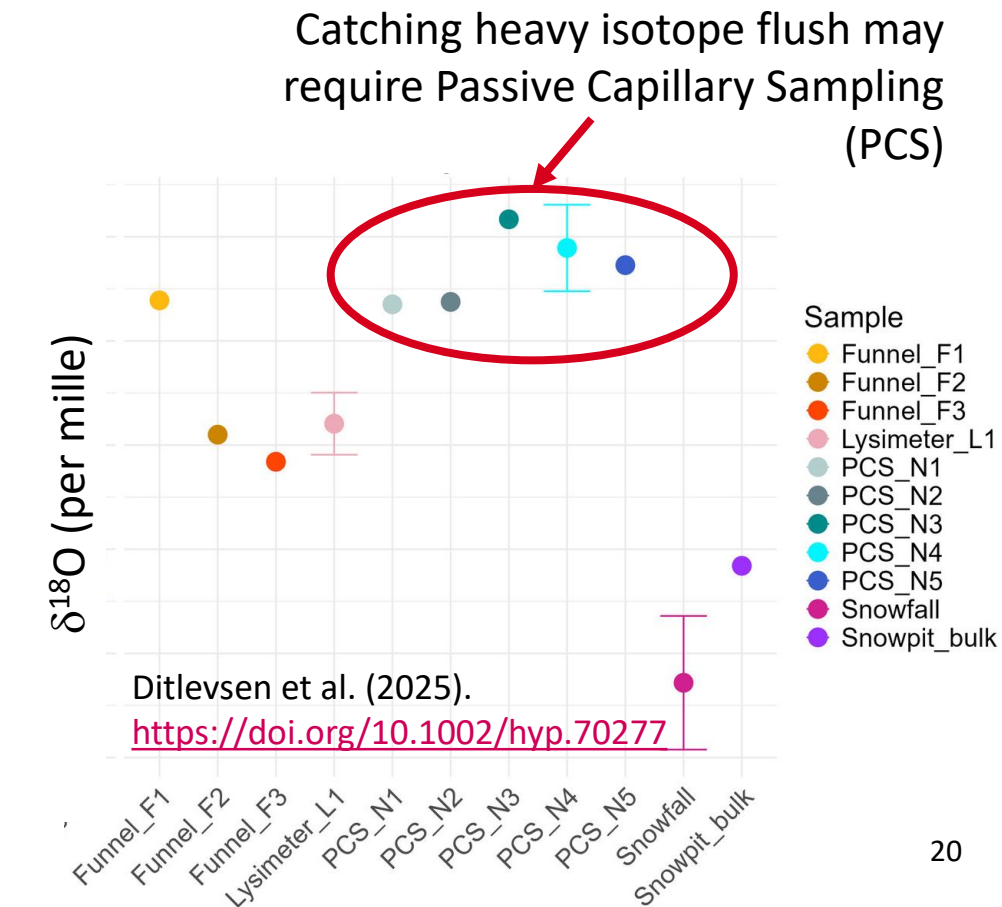
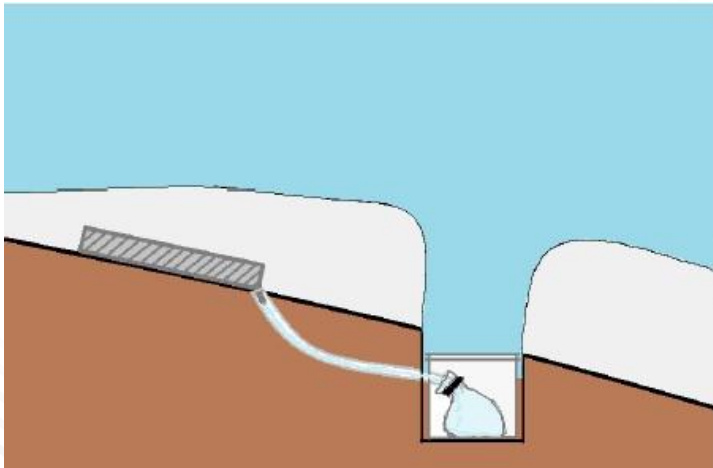


- WE3 Unit (Pertti Ala-Aho, Snow Hydrology) 2025-2029
 - PhD student C. Ditlevsen
- Joint monitoring of isotopes in Arctic snowpack
 - *Finland*: Oulanka, Pallas, Oulu
 - *Sweden*: Abisko, Krycklan
 - *Canada*: Fortress mountain, (maybe Kluane)
- **Goal**: observe and detect changing Arctic precipitation source and cryospheric conditions across the pan-Arctic
 - Horizon EU Cryoscope project



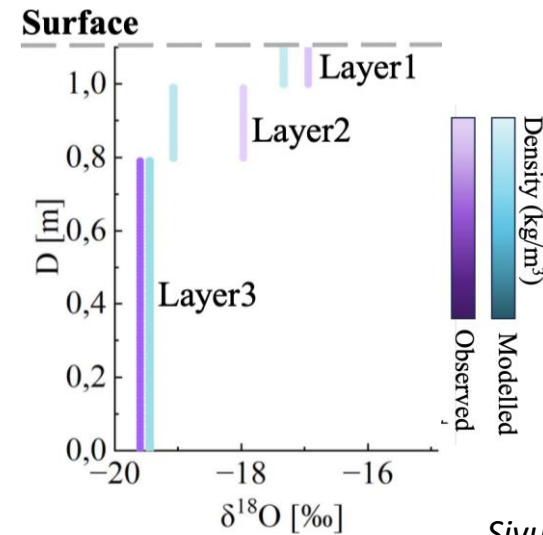
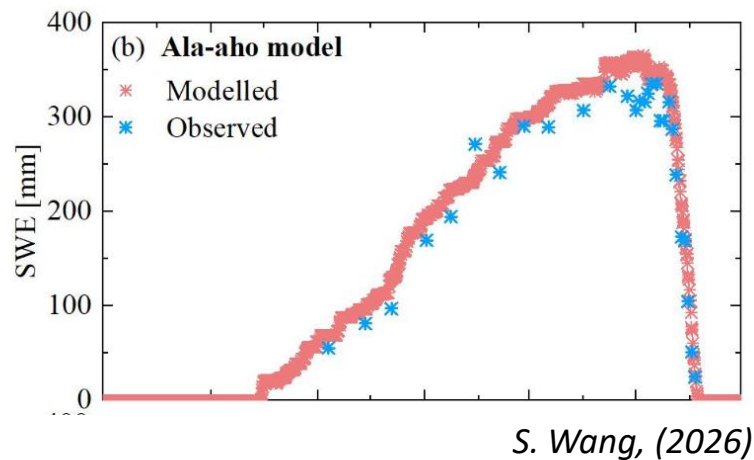
Monitoring Redesign for 2026-27

- New Lysimeter-2 design based on Oulu method
 - Collection tray at ground level
 - Sampling box (disturbance) farther from collection tray
 - Simplified (one outlet)

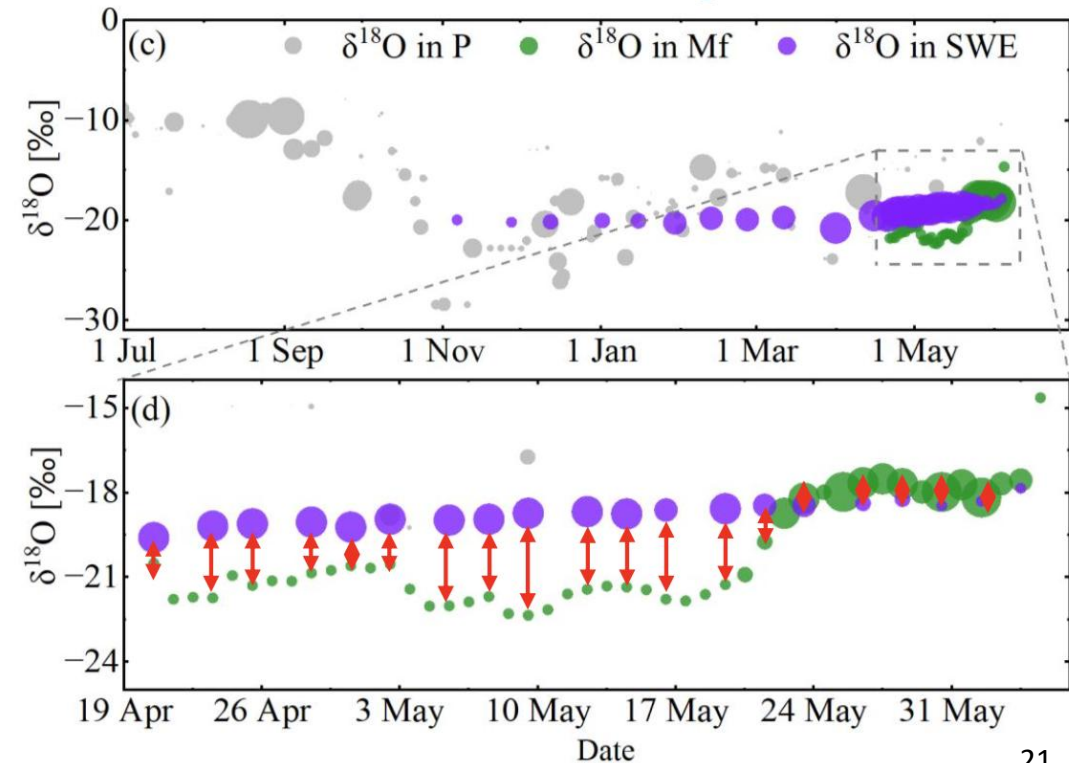


Snowmelt Modelling

- Observed heavy isotope late-freshet tail not captured by snowmelt (isotope-enabled) models
 - Depth-dependent error in isotopic fractionation
- Leads to an overestimation of SWE at peak snowmelt by hydrological models



Siyuan Wang, PhD Research (2026)



Key Takeaways

- Practical lessons from setting up water isotope sampling in small catchments
- Precipitation under-catch issues
 - Precipitation ***should not*** be heavier than snowpack
- Snowmelt monitoring challenges require focus on
 - Depth-dependent snowpack sampling
 - Capturing heavy isotope tail of snowmelt (lysimeters v. PCS)
- Nordic-Canadian collaboration on cryospheric monitoring (2025-2029)
 - Modelling that leverages high resolution global data

Acknowledgements

- Funders: CFI and NSERC CRC Program
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- Fortress Mountain Holdings Ltd.
- Randy Fagan, Zoe Walker, Anthony Kroll, Paul Harrop, Gaby Tejada
- Hannah Koslowsky, Kieran Lehan, Kevin Sevalrud, Noah Bacal
- Everyone in the Stadnyk-Pietroniro-Pomeroy labs who answered the call:

“Hey, want to help in the field/lab today? It’ll be fun...”



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