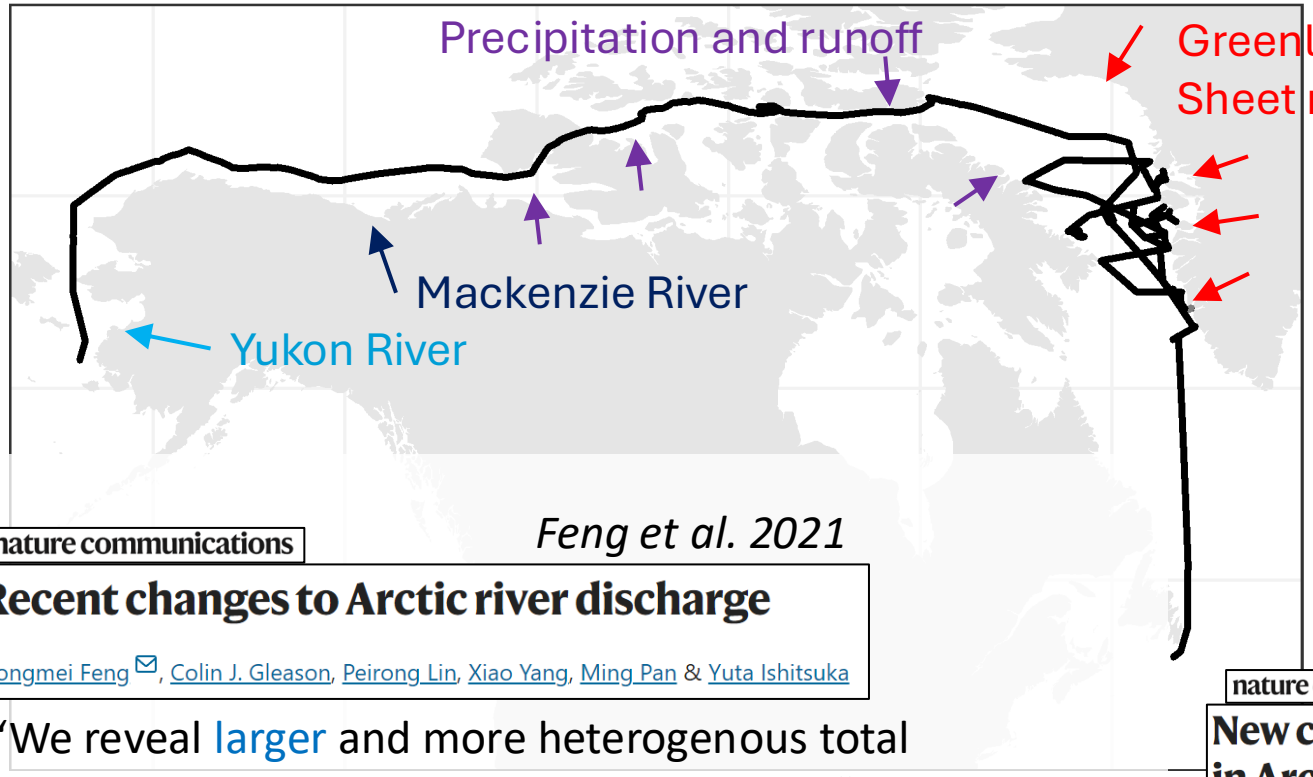
High resolution freshwater partitioning with continuous seawater isotopic ($\delta^{18}O$, $\delta^{2}H$) tracing

Ben Kopec (bkopec@mtu.edu) – Michigan Technological University

Eric Klein, Jeffrey Welker, *many others*

What are the primary freshwater sources? Can we distinguish between these sources?



Feng et al. 2021

nature communications

Recent changes to Arctic river discharge

Dongmei Feng, Colin J. Gleason, Peirong Lin, Xiao Yang, Ming Pan & Yuta Ishitsuka

"We reveal larger and more heterogenous total water export and water export acceleration"

Trusel et al. 2018

nature

Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming

Luke D. Trusel, Sarah B. Das, Matthew B. Osman, Matthew J. Evans, Ben E. Smith, Xavier Fettweis, Joseph R. McConnell, Brice P. Y. Noël & Michiel R. van den Broeke

"continued atmospheric warming will lead to rapid increases in Greenland Ice Sheet runoff"

McCrystall et al. 2021

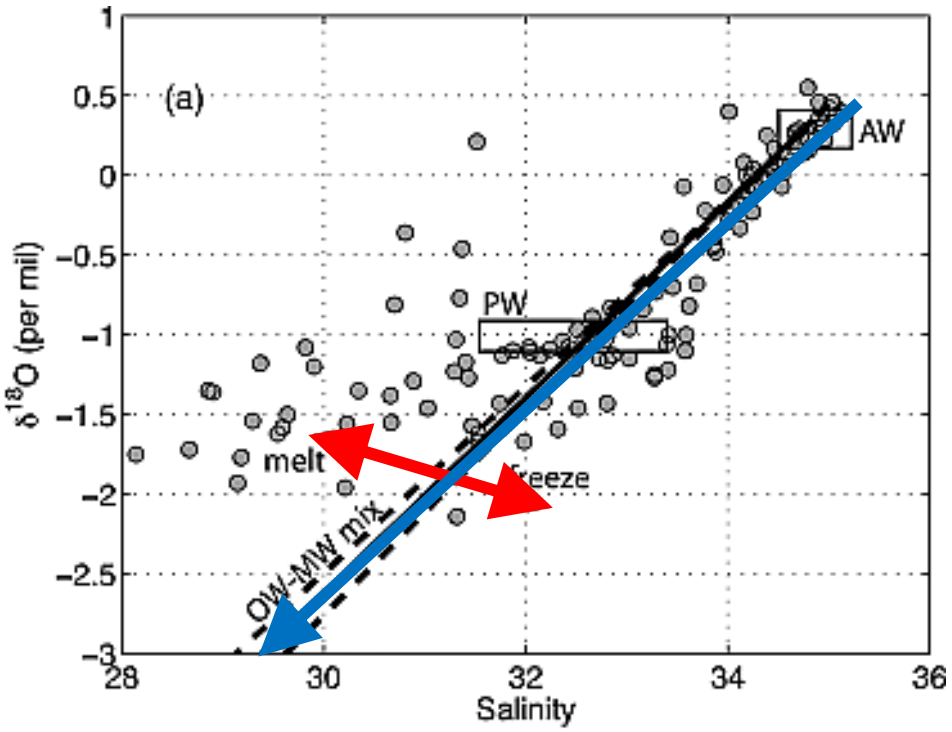
nature communications

New climate models reveal faster and larger increases in Arctic precipitation than previously projected

Michelle R. McCrystall, Julienne Stroeve, Mark Serreze, Bruce C. Forbes & James A. Screen

"larger and faster increases in precipitation and an earlier transition to a rainfall-dominated Arctic"

Oxygen isotopes ($\delta^{18}O$) as a tracer of freshwaters – delineate between meteoric water and sea ice influence



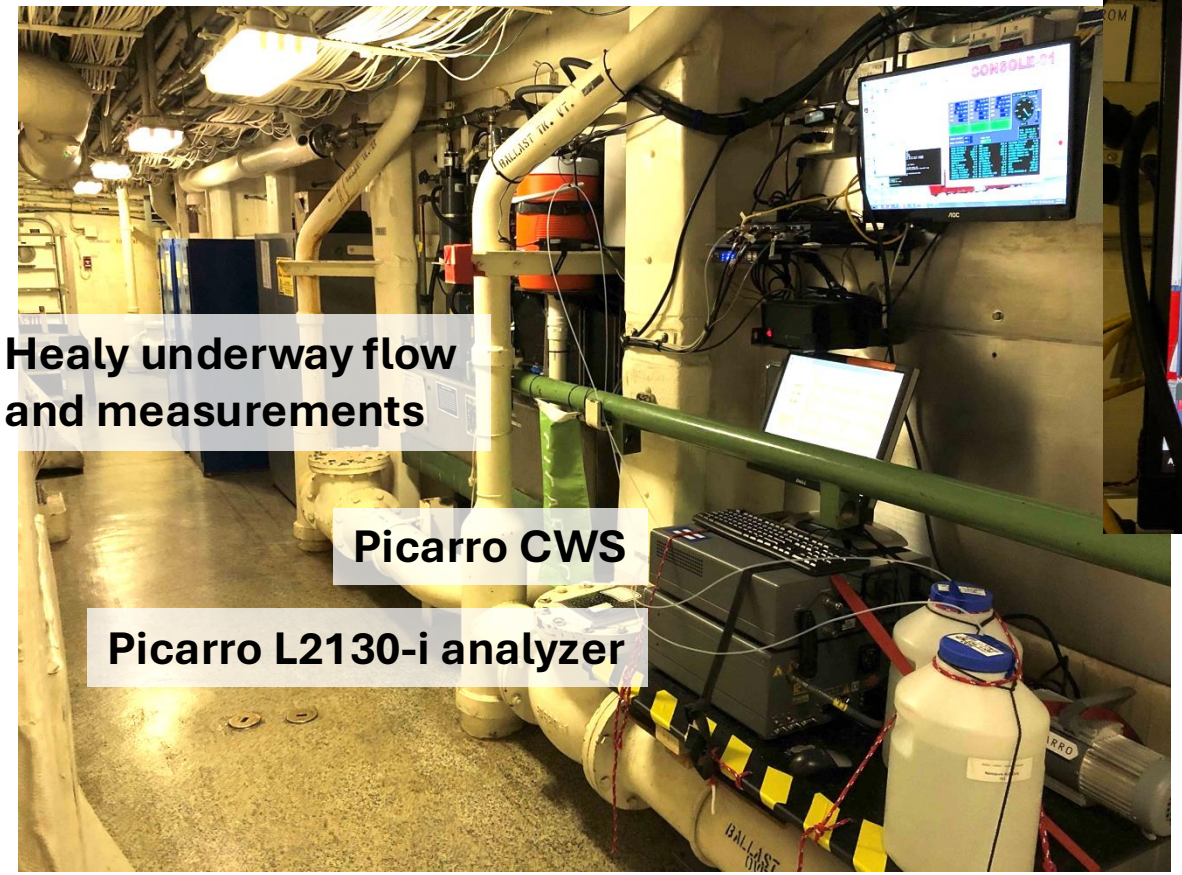
Sutherland et al., 2009 *JGR-O*

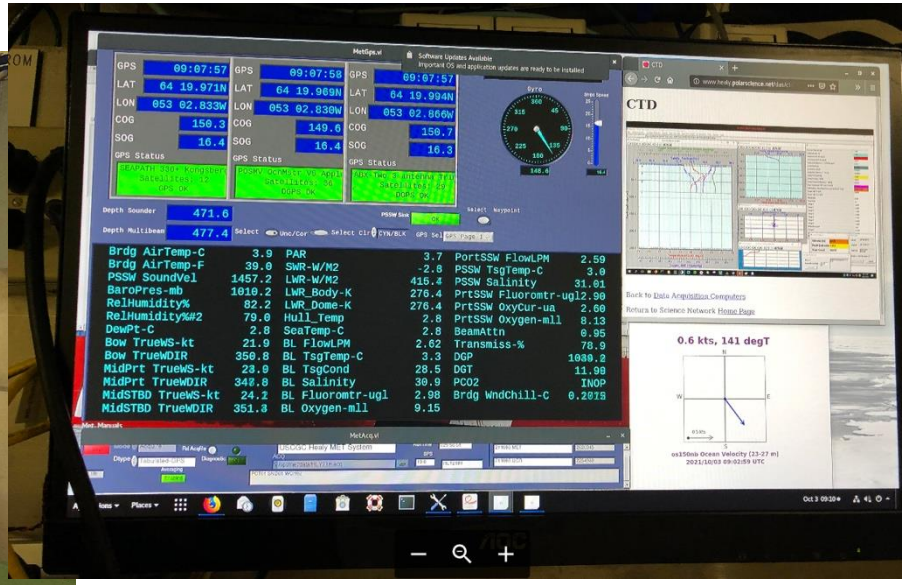
$\delta^{18}O$ – salinity relationships are different for sea ice influences (melt or freeze up) or mixing with fresh meteoric waters

- $\delta^{18}O$ can thus be used to disentangle these two types of freshwater influences

*Limited by how many discrete samples you can collect and analyze/process in the lab

Methods: Continuous flow through underway seawater isotopes ($\delta^{18}O$, $\delta^{2}H$, **d-excess**)





Depth = 8 m

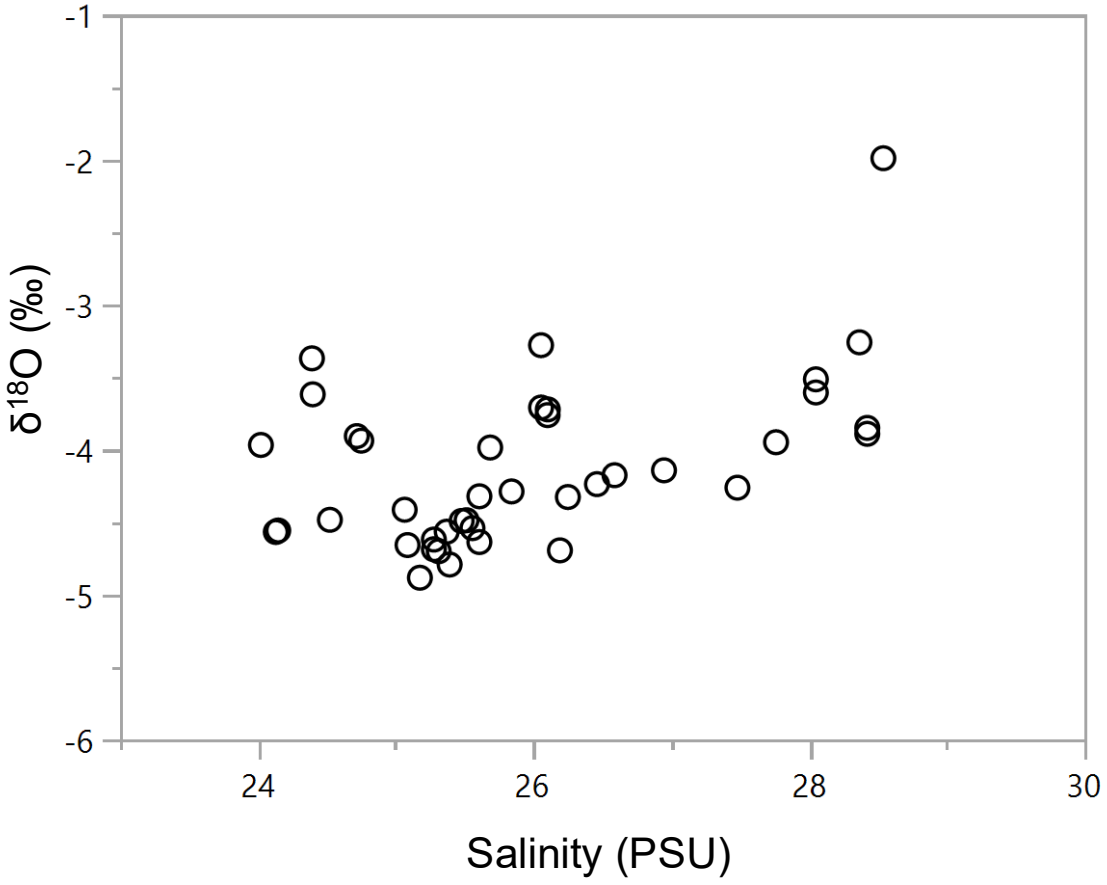
Isotopic analysis at 1 hz resolution (average to 5 mins)

Water isotope measurements paired with other physical oceanographic (salinity, temperature, etc) and meteorological observations

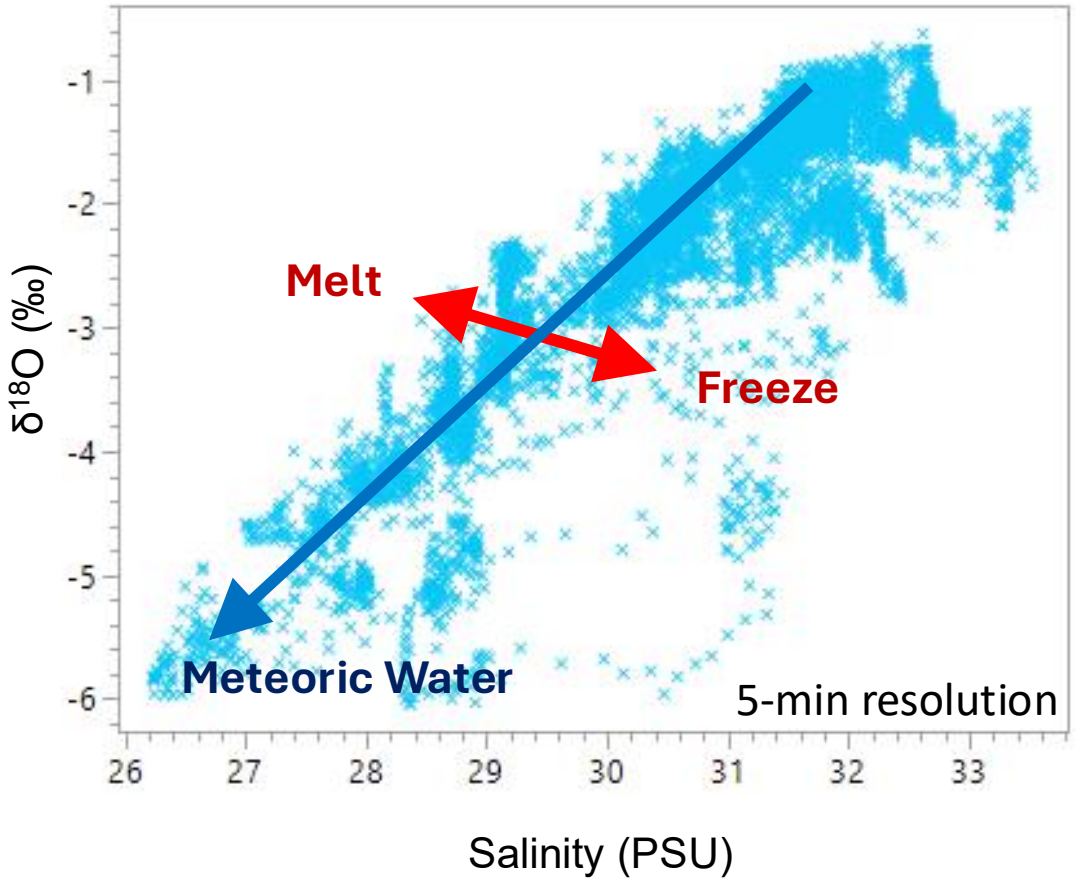
From discrete to continuous measurements

We can now examine freshwater dynamics at unprecedented spatial and temporal scales

SASSIE salinity-$\delta^{18}O$ relationships

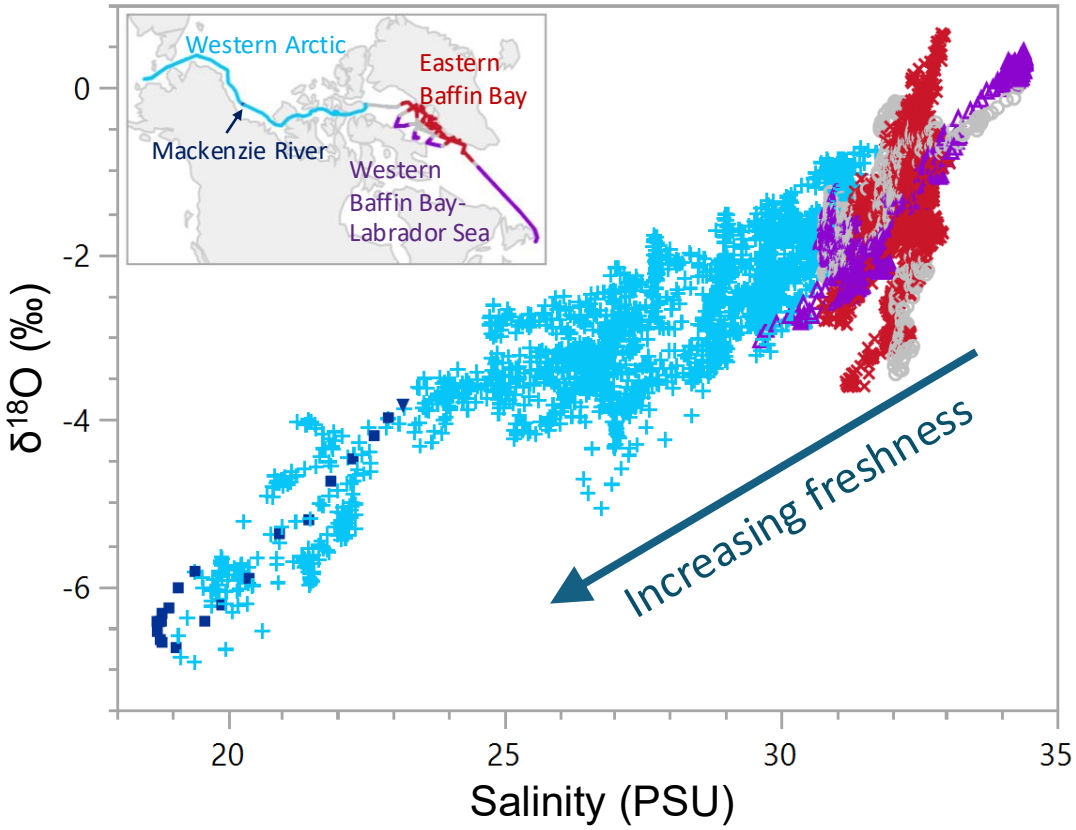


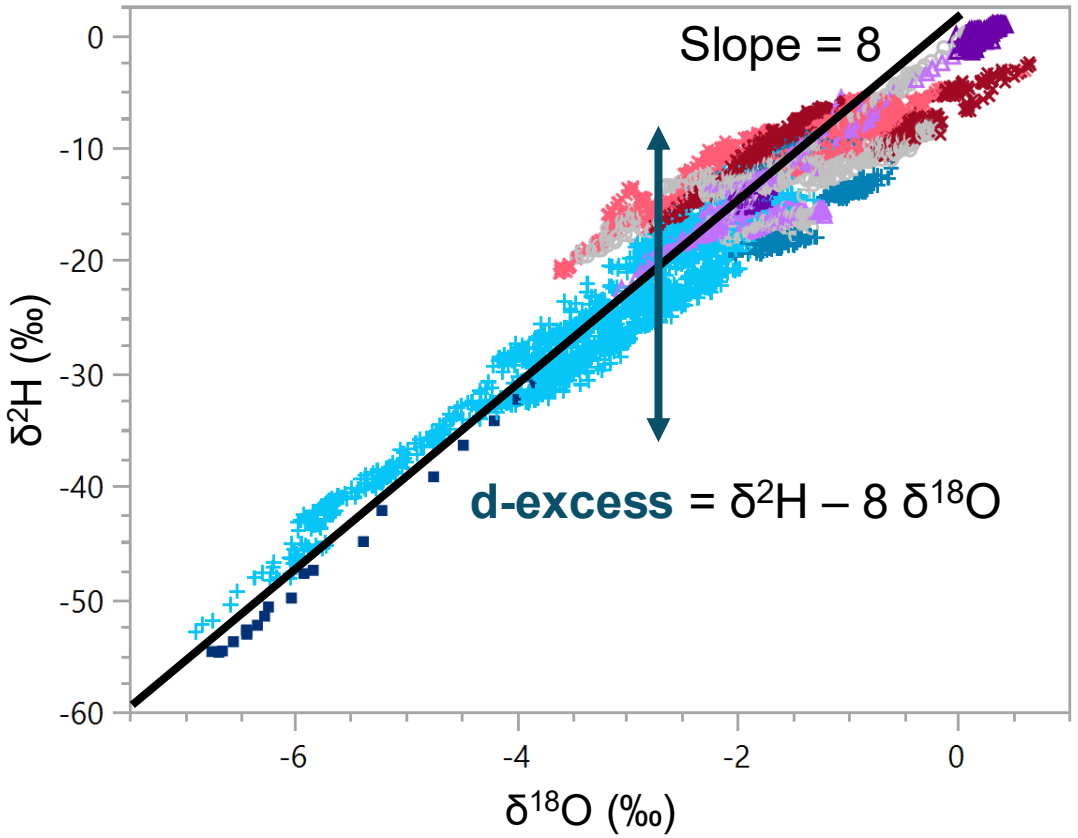
Kopec-Sikuliaq salinity-$\delta^{18}O$ relationships



*Both datasets from similar length cruises in the Beaufort Sea ice 2022

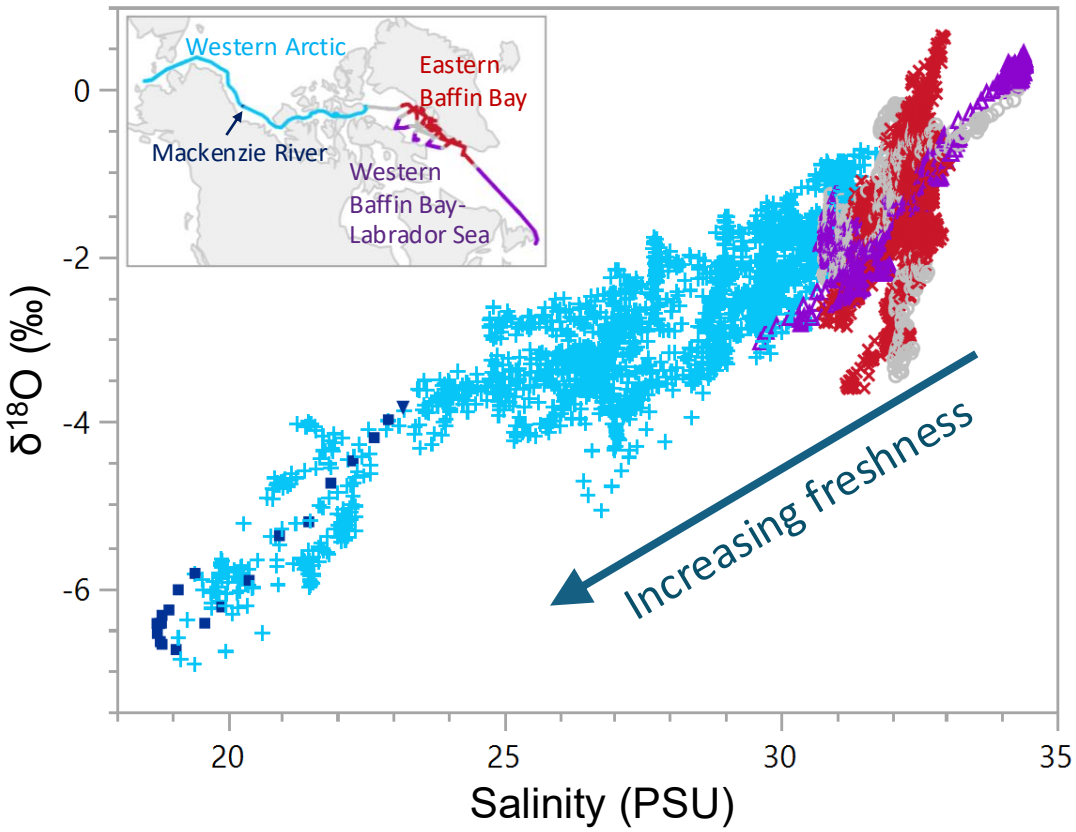
New approach to **tracing freshwater sources**: coupling both primary water isotope ratios - **$\delta^{18}O$, $\delta^{2}H$** - and their secondary term - **deuterium excess (d-excess)**

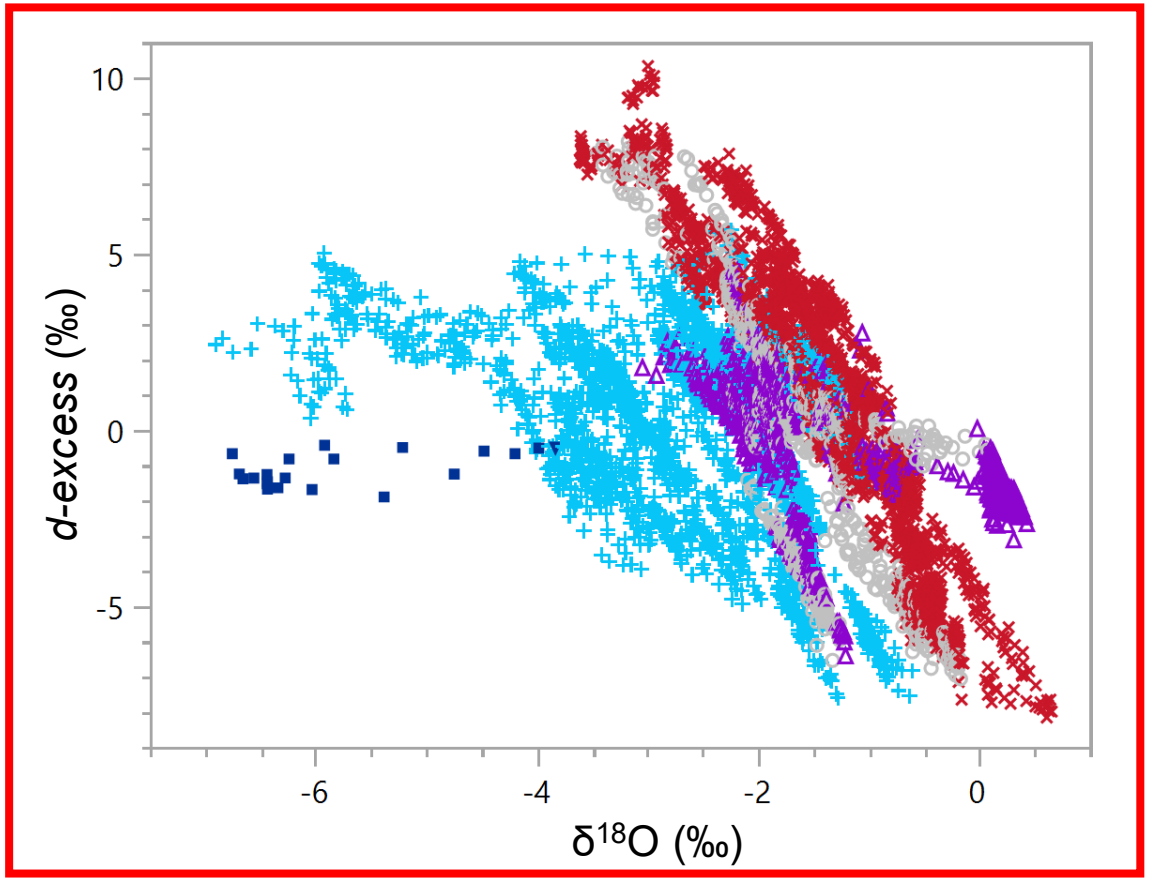




Kopec et al. 2024, *JGR-O*

New approach to **tracing freshwater sources**: coupling both primary water isotope ratios - **$\delta^{18}O$, $\delta^{2}H$** - and their secondary term - **deuterium excess**



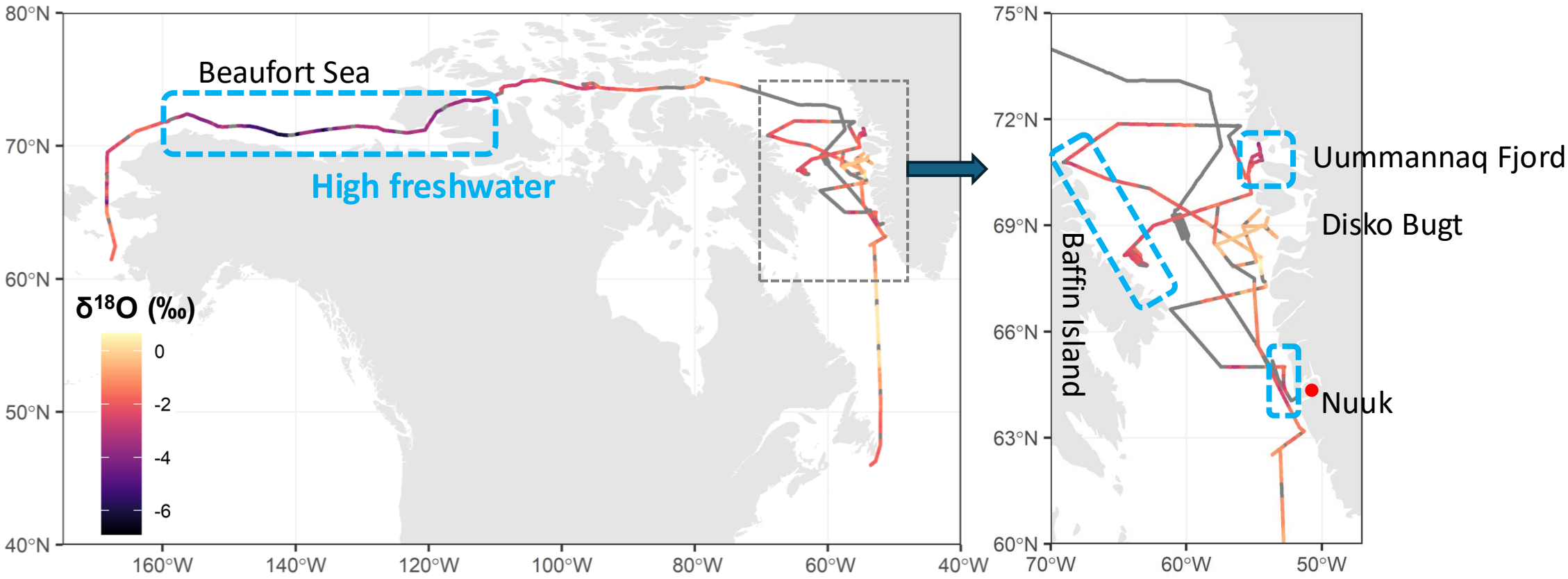


Objectives: explore $\delta^{18}O$-d-excess relationships to:

1) **Quantify freshwater contributions and their mixing relationships**
2) **Partition distinct meteoric water inputs**

Kopec et al. 2024, *JGR-O*

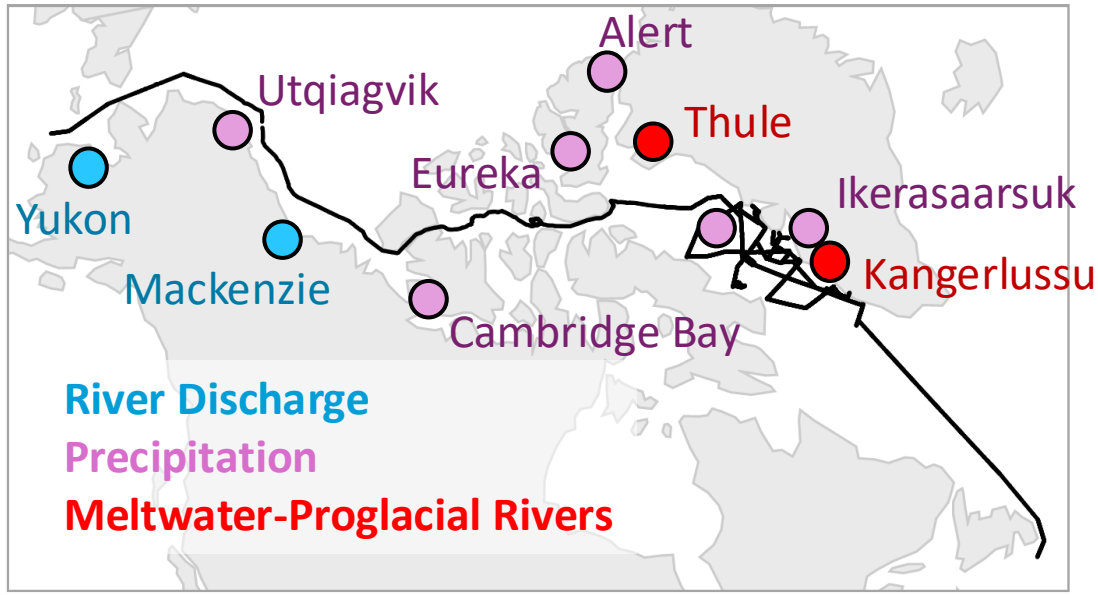
Regions of heightened freshwater identified by $\delta^{18}O$ measurements



More negative oxygen isotope ratio (**$\delta^{18}O$**) values show regions of **higher freshwater proportions**

Kopec et al. 2024, *JGR-O*

Arctic freshwater end members



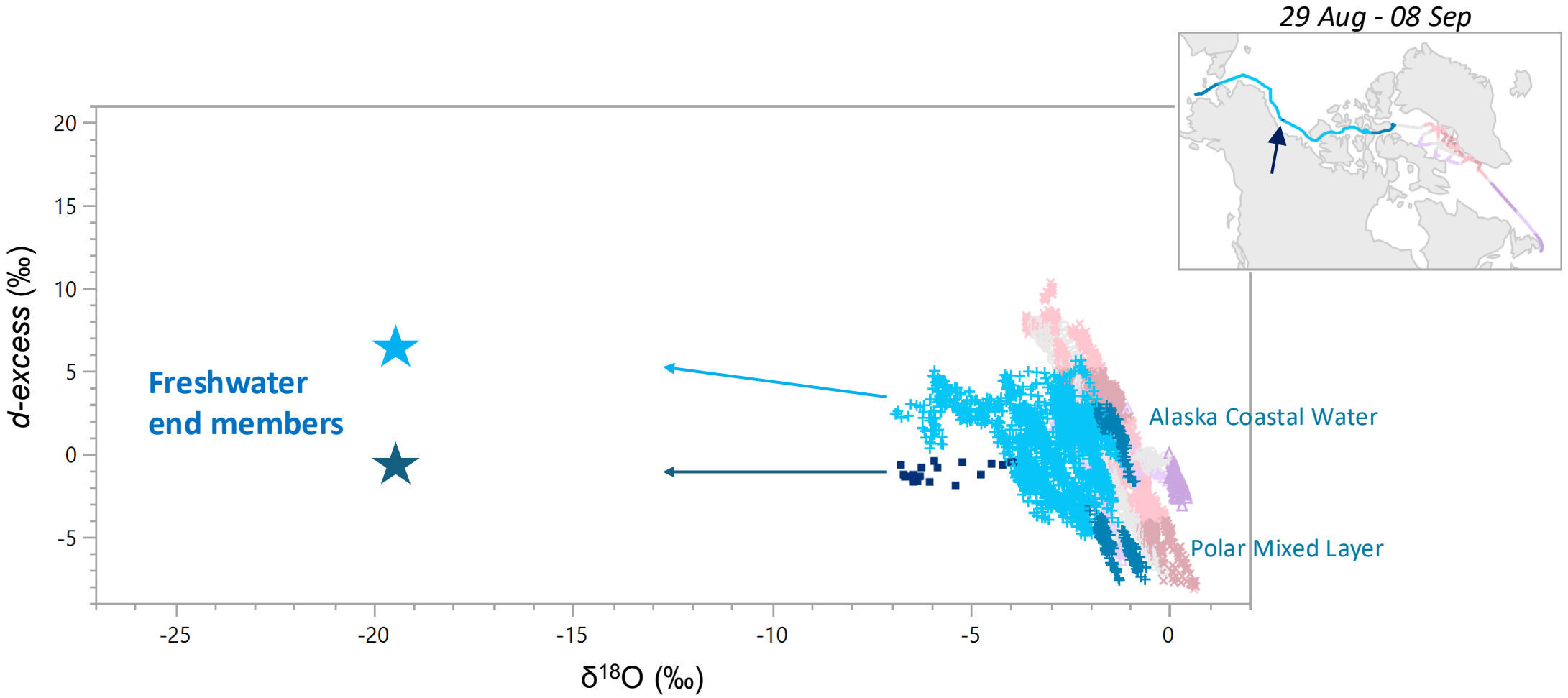
Requirements for freshwater delineation:

1. Some waters with relatively high freshwater content (> 10%)
2. Unique isotopic composition for freshwater end members

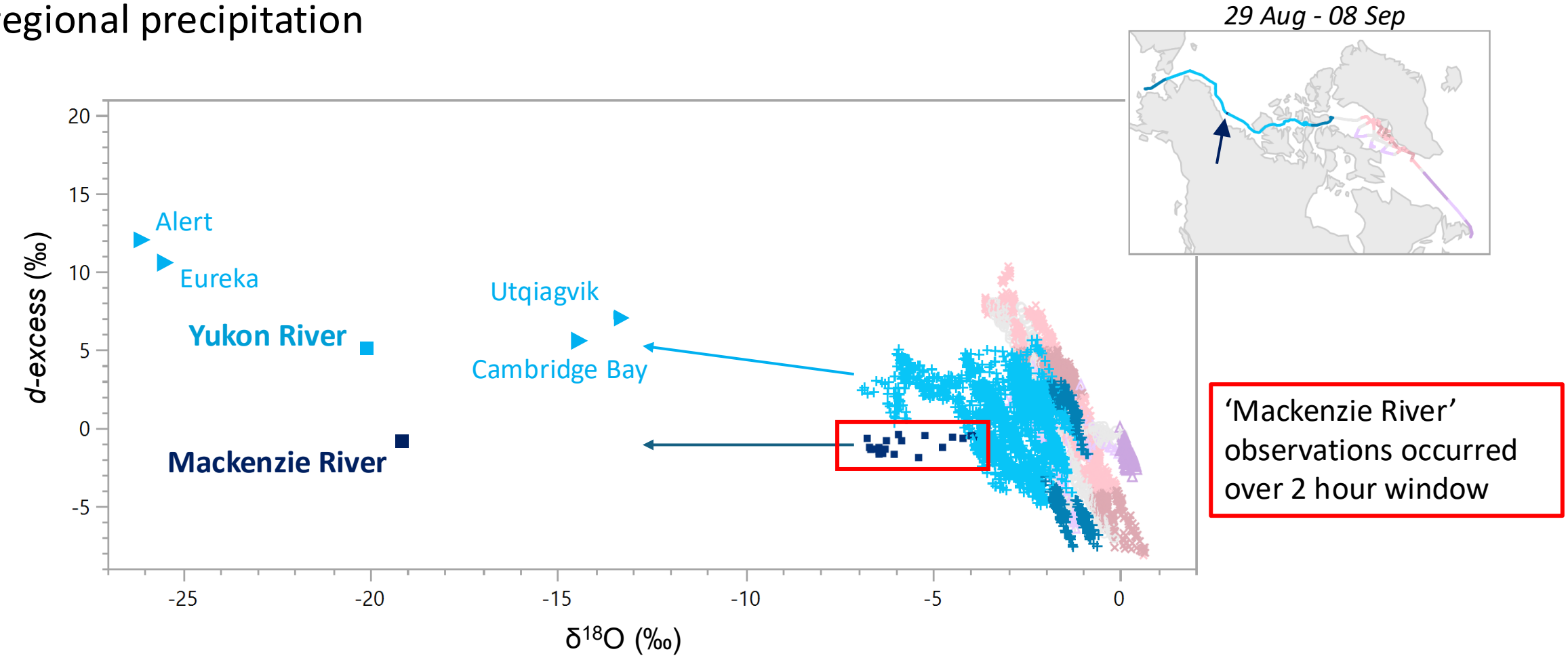
Freshwater end members:

- River discharge: Arctic Great Rivers Observatory – Mackenzie and Yukon Rivers
- Precipitation: Multi-year observations at Utqiagvik, Alert, Cambridge Bay, Eureka, and Ikerasaarsuk; 3 snowfall events sampled on Healy
- Glacial meltwater: Proglacial rivers sampled in Thule and Kangerlussuaq

Western Arctic: What are the primary freshwater sources?



Western Arctic: Freshwater driven primarily by major river discharge and regional precipitation

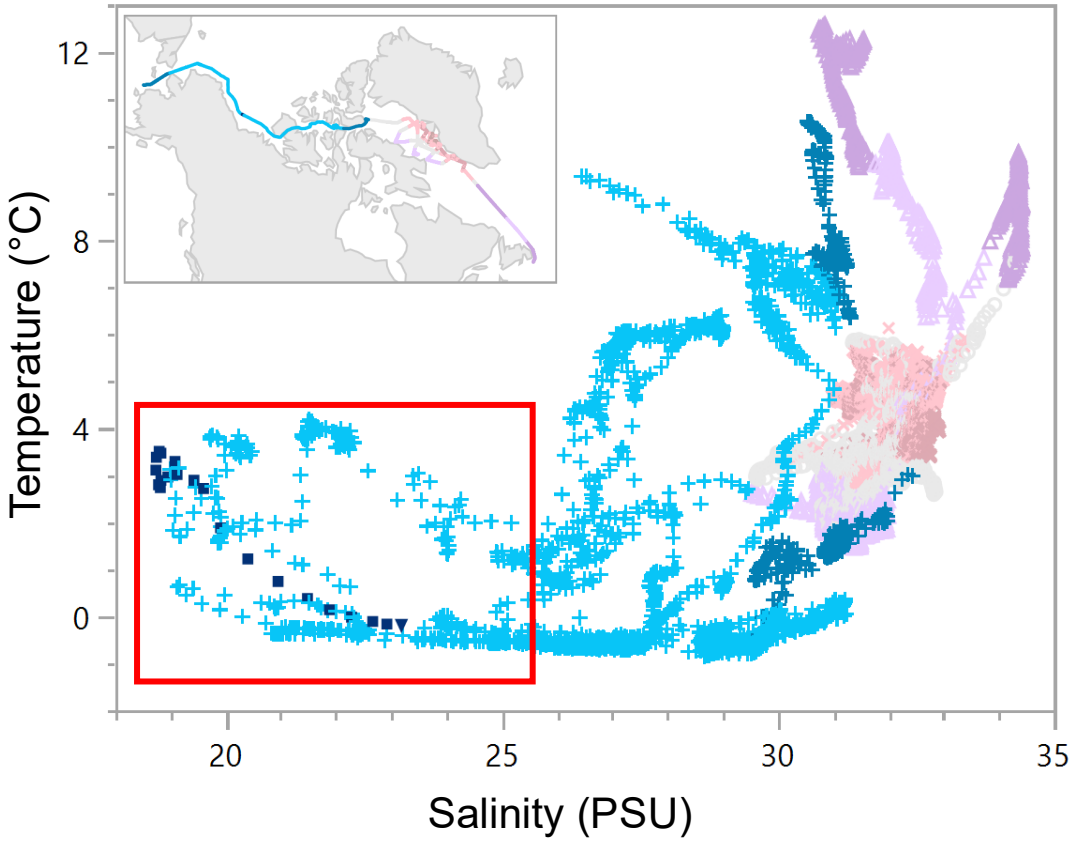


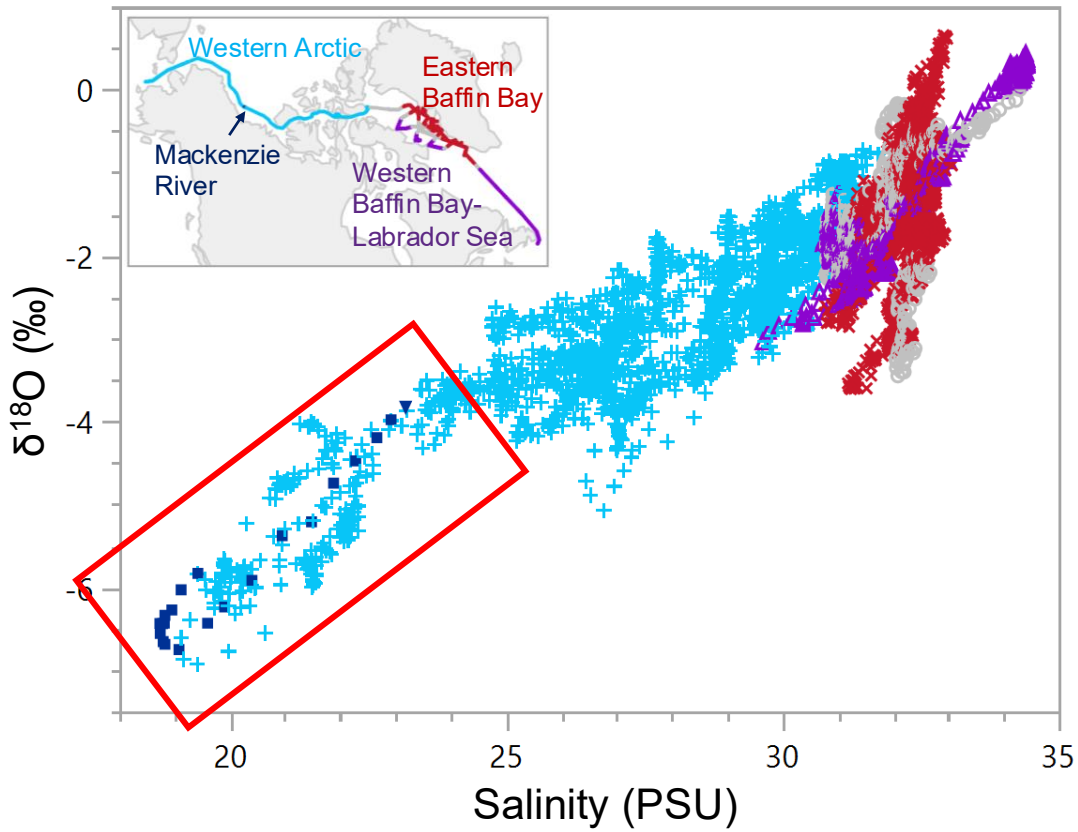
Freshwater end members:

■ Rivers: Yukon, Mackenzie Rivers - Arctic Great Rivers Observatory (Holmes et al. 2022 *Arctic Data Center*)

► Precipitation: Alert, Cambridge Bay, Eureka (Kopec et al., 2016 *PNAS*); Utqiagvik (Putman et al., 2017 *ACP*)

Western Arctic: Freshwater source delineation not possible in T-S or S-$\delta^{18}O$ space

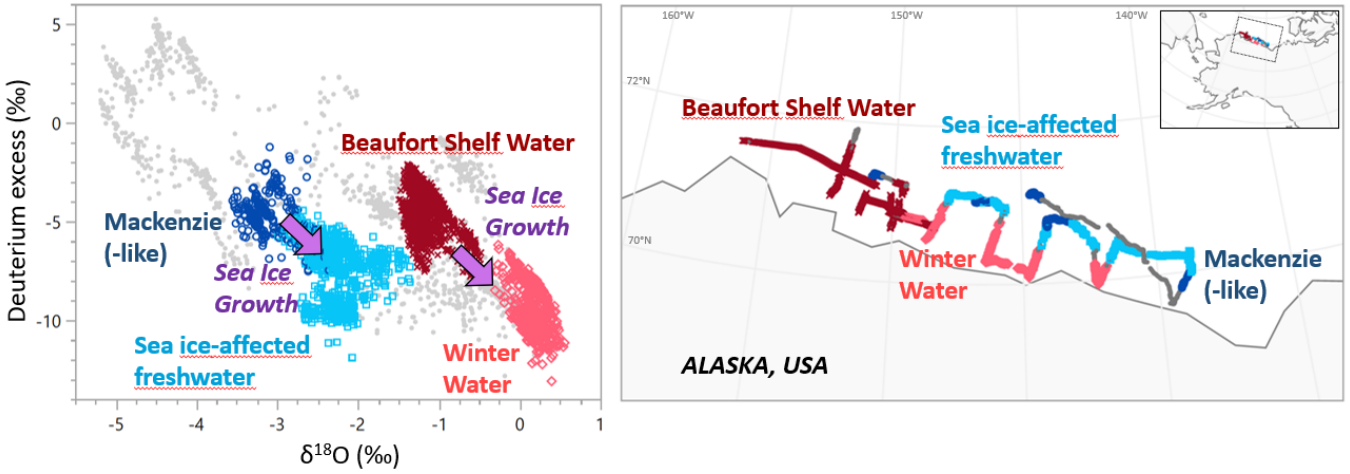




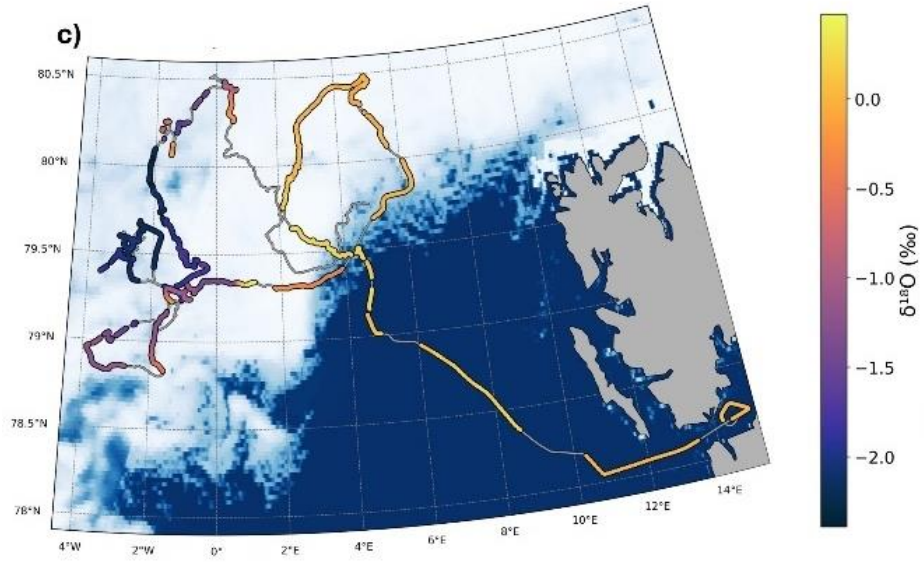
Kopec et al. 2024, *JGR-O*

Other cruises with continuous isotopes

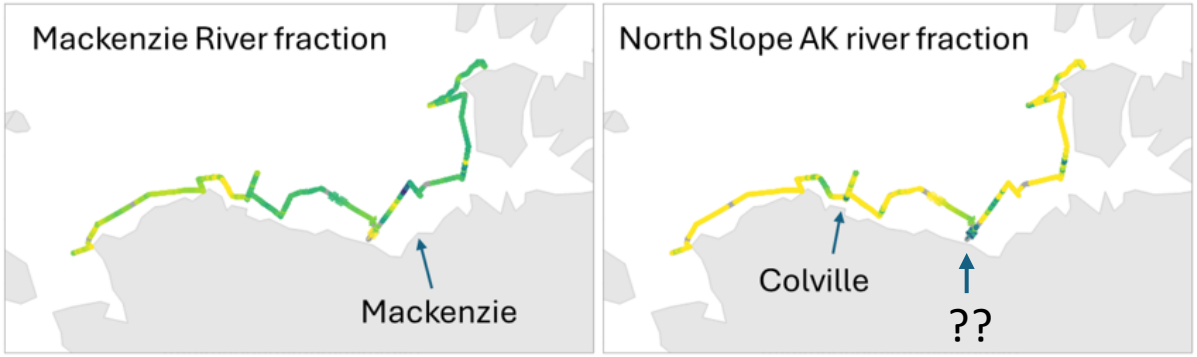
R/V Sikuliaq: 01 Nov – 03 Dec 2022



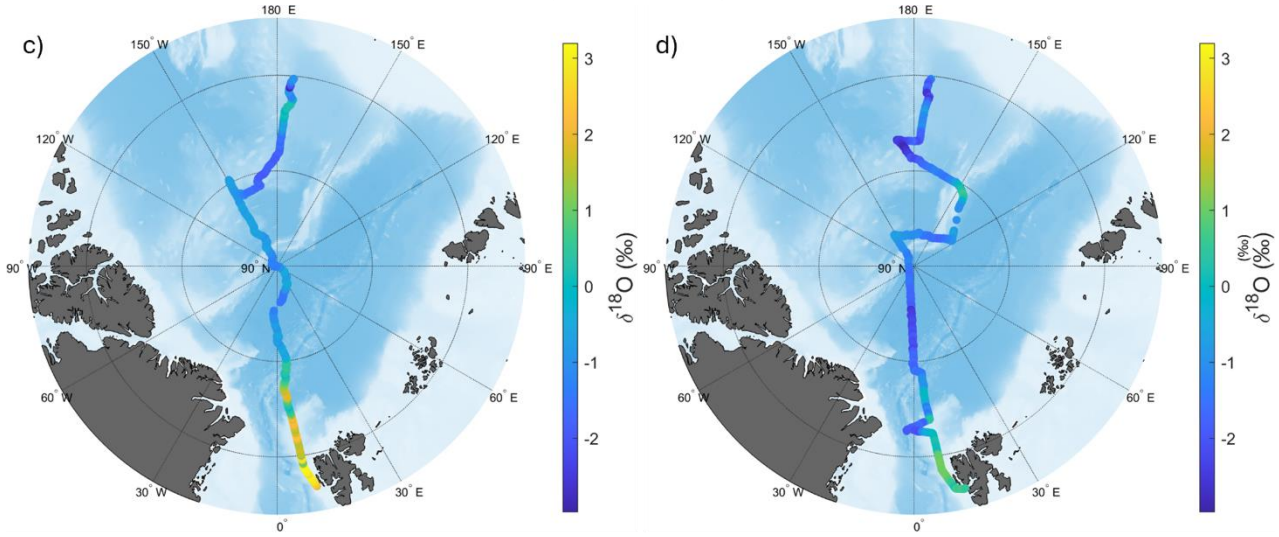
I/B Oden - ARTofMELT: 8 May – 14 June 2023



USCGC Healy: 03 Jul – 31 Jul 2024

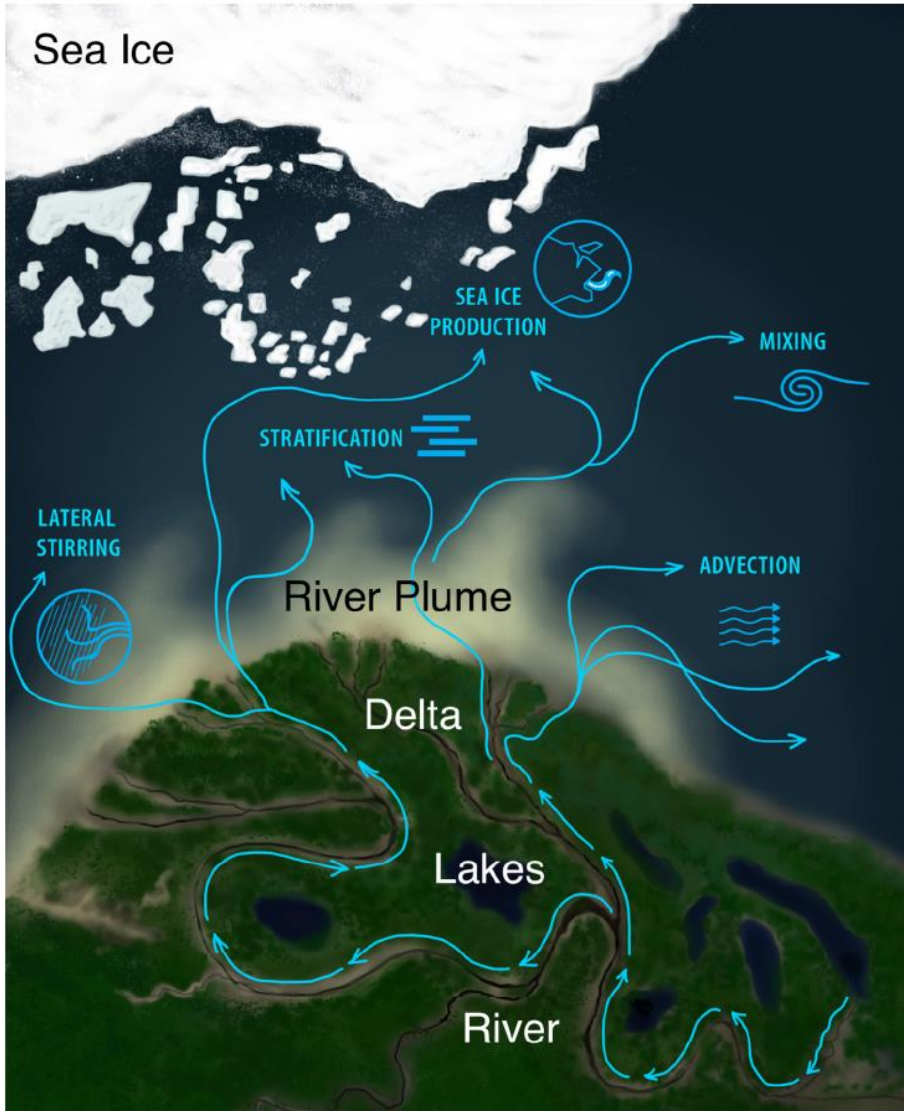


I/B Oden: 10 Aug – 18 Sep 2025



NASA - Exploring the FRESH Arctic: Fate of River Export and Surface Hydrology

How does freshwater move through the land-delta-ocean system and ultimately control the pathways that dictate the fate of freshwater in the Beaufort Sea?



Objectives:

- Measure continuous seawater isotopes to quantify freshwater contributions and mixing relationships from the delta to the open ocean at high spatiotemporal resolution

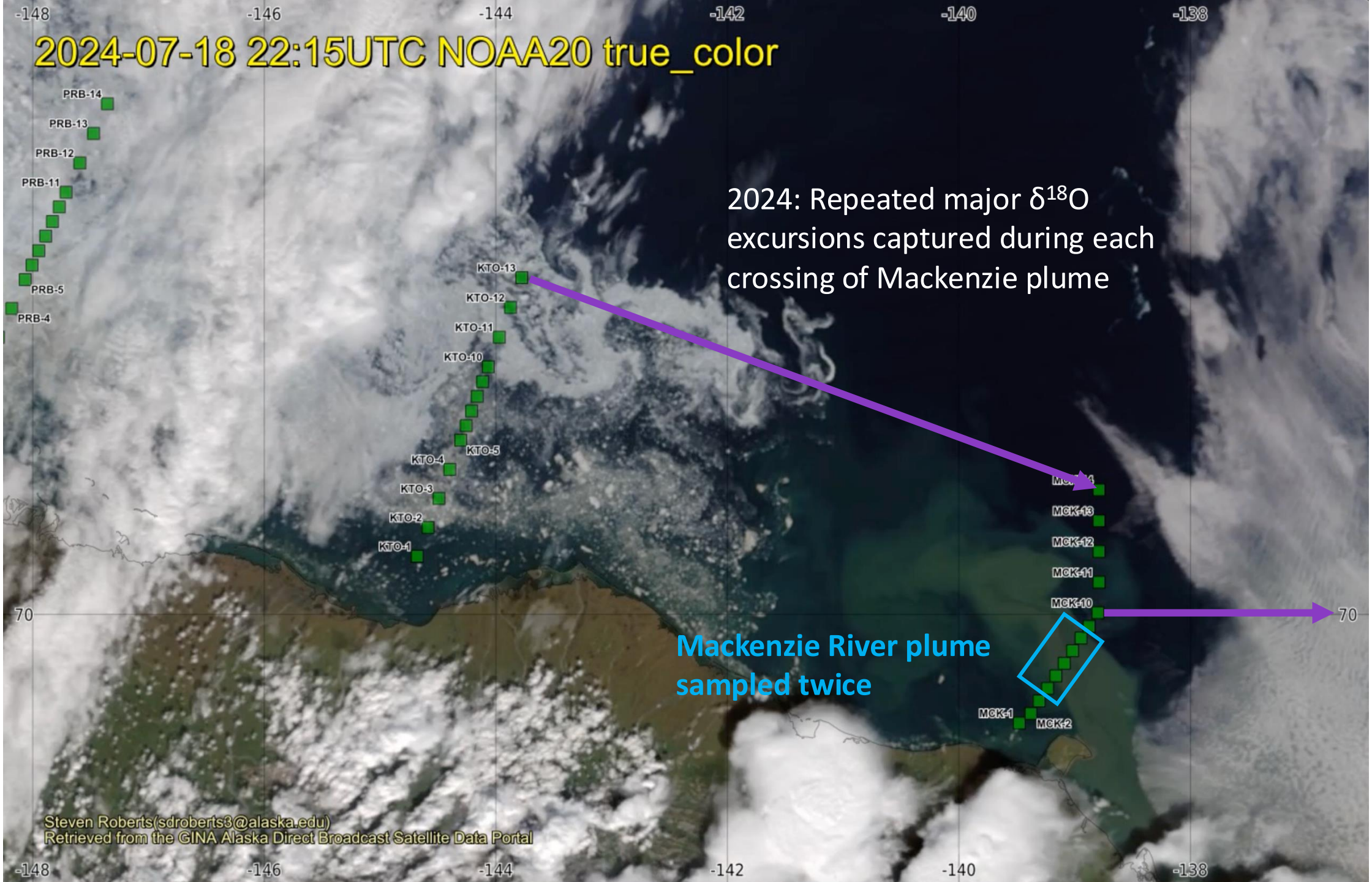
- Water isotopic tracing in river / delta waters to determine contributions from snowmelt, new precipitation, lake and wetland exchange
    - How much new water is from precipitation sourced from the Beaufort Sea as related to sea ice coverage?

Conclusions

$\delta^{18}O$-*d-excess* relationships provide an important complementary tool for water mass and freshwater delineation

New continuous flow-through isotopic measurements provide high resolution to measure meteoric water contributions and examine the influence of sea ice at unprecedented spatial and temporal scales

At high enough freshwater proportions and/or distinct enough isotopic end member values, we can delineate between and quantify specific meteoric inputs (e.g., Mackenzie vs Yukon Rivers)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KTO-12
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KTO-10
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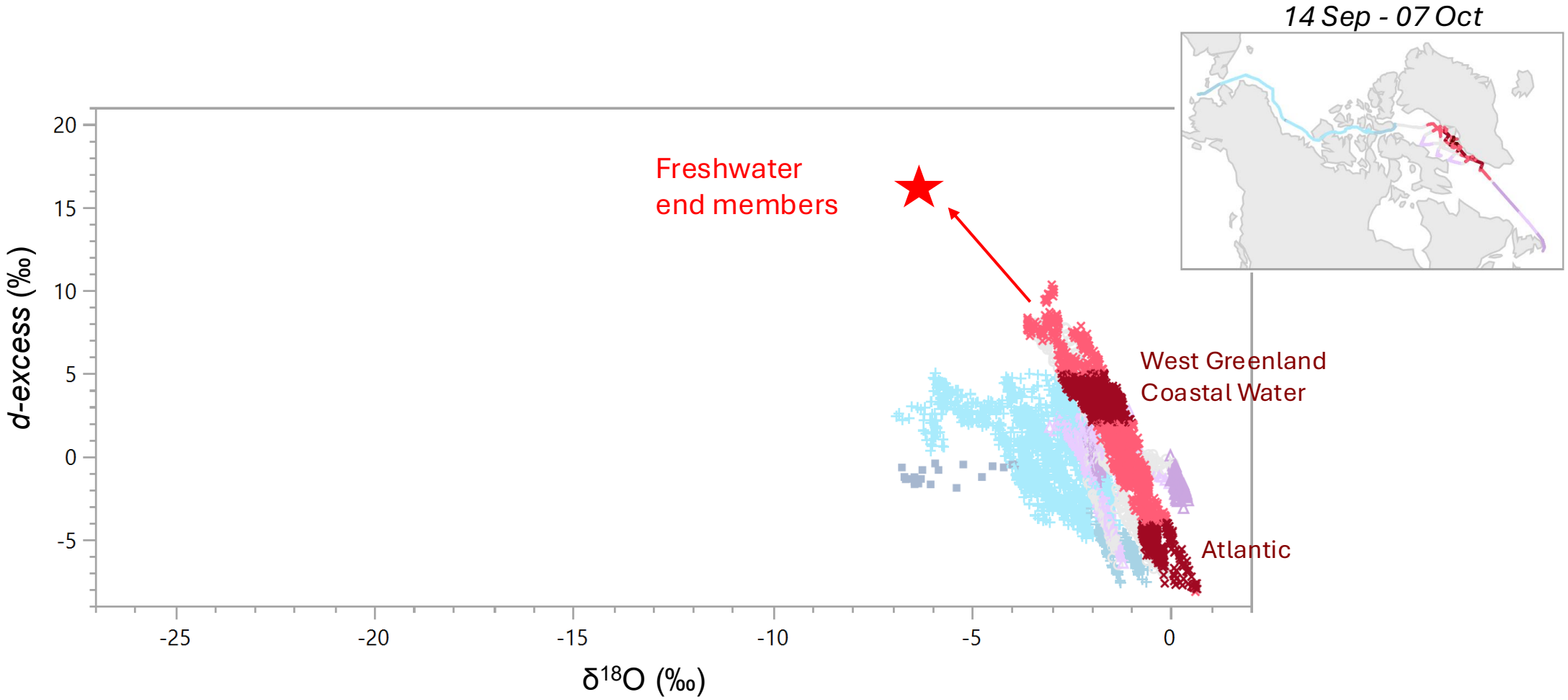
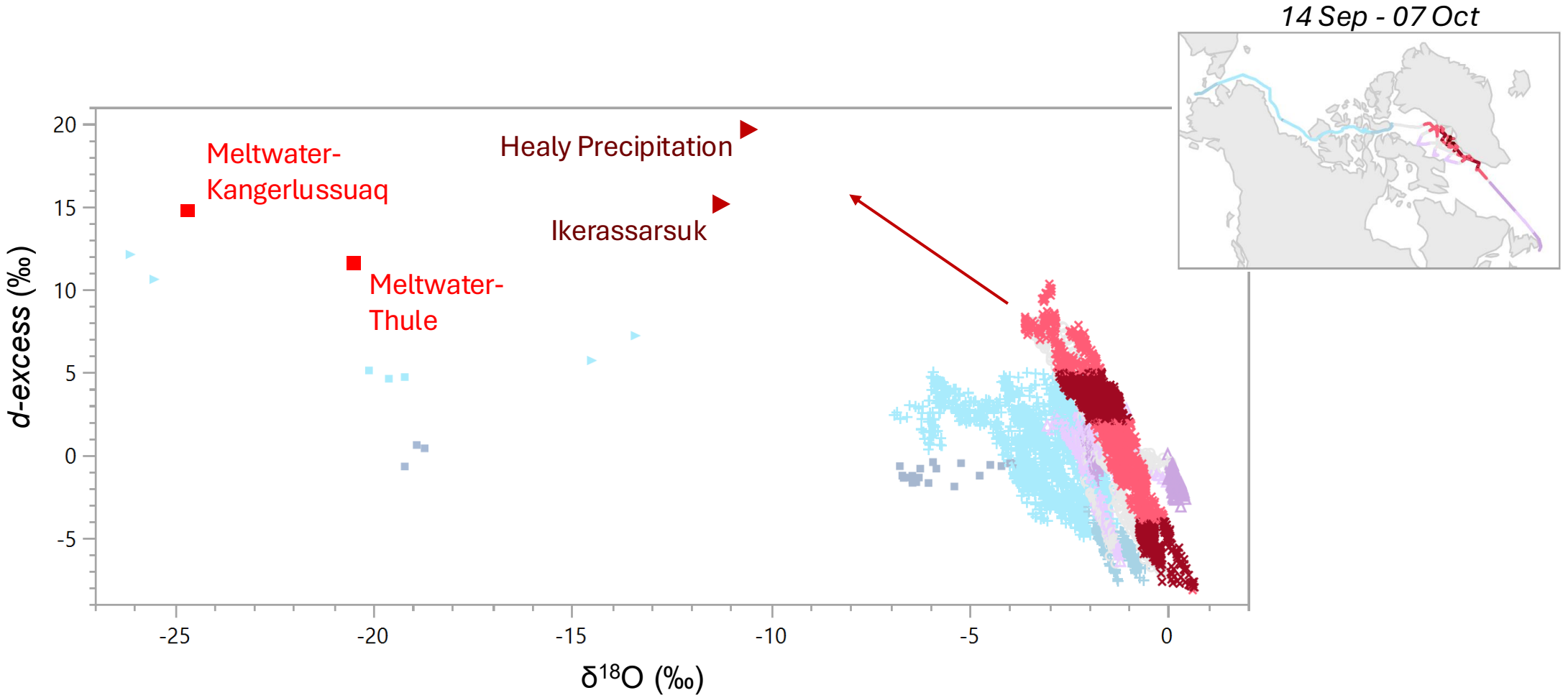
KTO-4
KTO-3
KTO-2
KTO-1
MCK-13
MCK-12
MCK-11
MCK-10
MCK-1
MCK-2
70
2024: Repeated major δ18O excursions captured during each crossing of Mackenzie plume
Mackenzie River plume sampled twice
Steven Roberts(sdroberts3@alaska.edu)
Retrieved from the GINA Alaska Direct Broadcast Satellite Data Portal

Eastern Baffin Bay: What are the primary freshwater sources?



Eastern Baffin Bay: Freshwater driven primarily by local precipitation

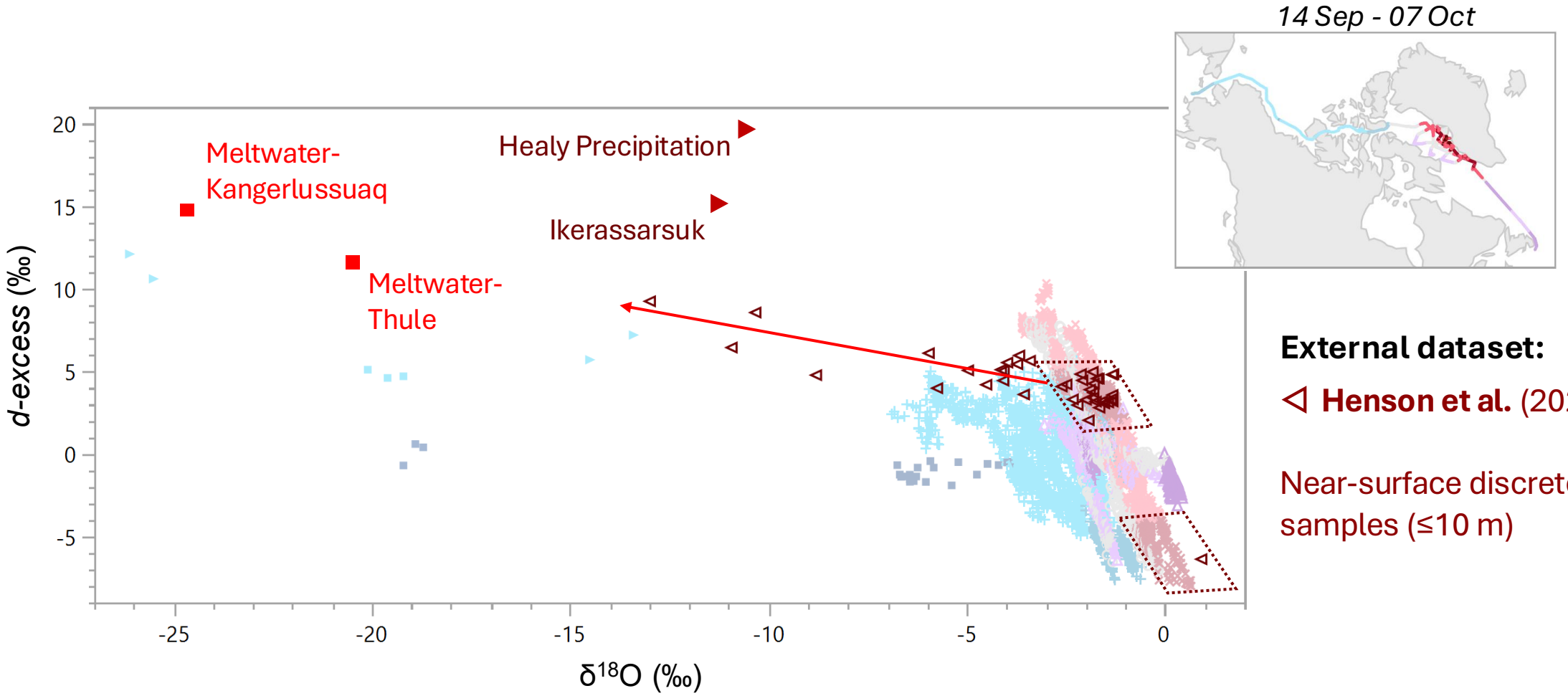


Freshwater end members:

■ Meltwater, Proglacial Rivers: Kangerlussaq (Kopec et al. 2018 *L&O*); Thule (Csank et al., 2019 *JGR-B*)

► Precipitation: Healy snow samples; Ikerasaarsuk (Xiahong Feng, *personal communication*)

Eastern Baffin Bay: Other studies show large freshwater fluxes from meltwater in summer



Coastal West Greenland samples collected by Henson et al. (2022 *Zenodo*, 2023 *Sci. Tot. Env.*) in August 2016 show evidence of significant glacial meltwater incorporation (up to 50%) whereas the measurements in our study in late September/early October show small amounts of glacial meltwater