Seawater isotopic measurements ($\delta^{18}O$ and δD) reveal significant freshwater influxes into the Arctic seas

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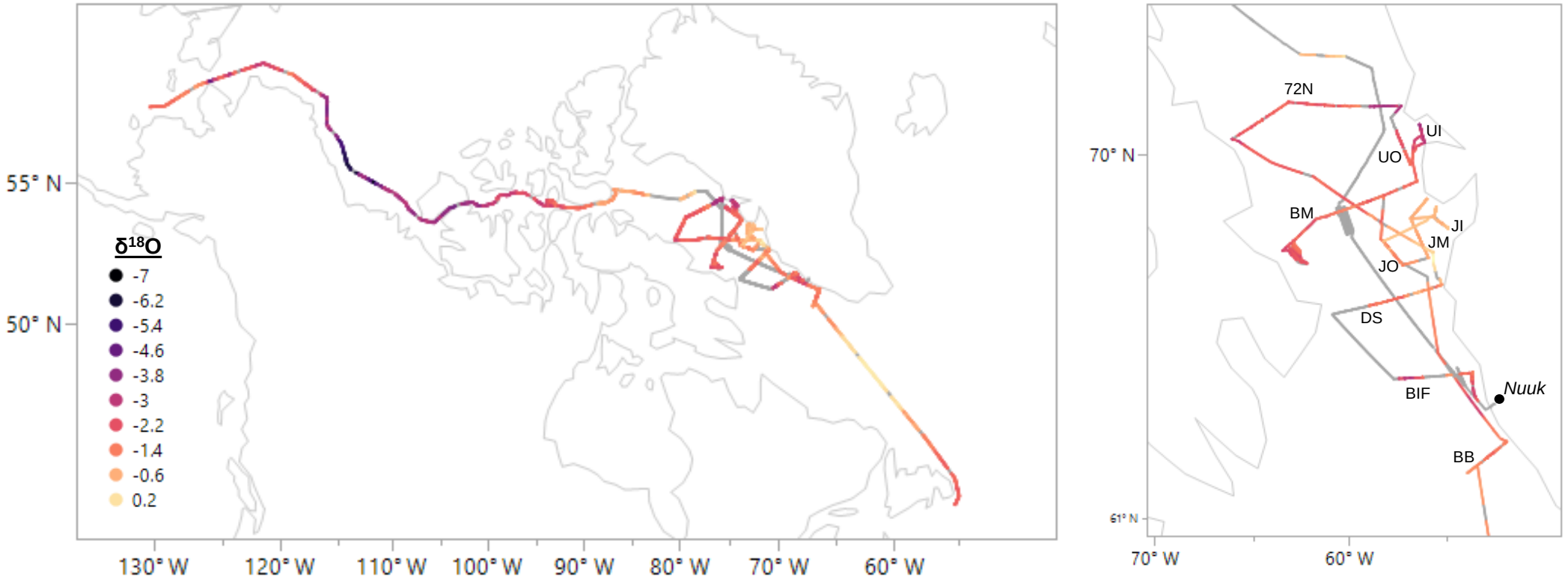
Objectives

1) Identify freshwater inputs along cruise track
2) Explore mixing relationships between different freshwater sources and older ocean waters
    a) Disentangle freshwater sources and mixing relationships
    b) Examine potential advantages of $\delta^{18}O$-*d-excess* observations over traditional salinity only or $\delta^{18}O$-salinity relationships to delineate water masses
3) Examine impact of freshwater and different mixing relationships on biologic productivity

Photo: Ben Kopec

1) Identify freshwater inputs along cruise track

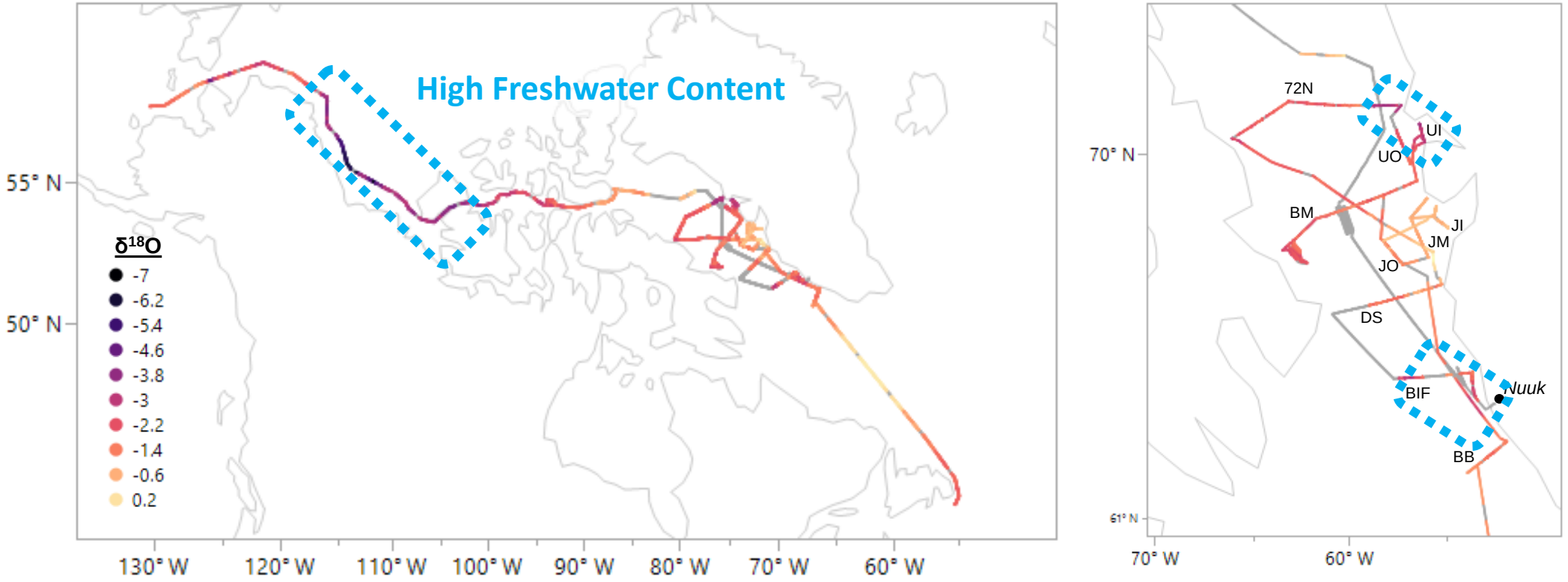
USCGC Healy cruise track colored by $\delta^{18}O$ (gray = no isotopic data)



Transect labels: **BB** = Before Bifurcation, **BIF** = Bifurcation, **DS** = Davis Strait, **JI**/**M**/**O** = Jakobshavn Inner/Middle/Outer, **BM** = Baffin Middle, **UI**/**O** = Uummannaq Innter/Outer, **72N** = 72° North

1) Identify freshwater inputs along cruise track

We observe significant freshwater content in two primary regions: 1) the Beaufort Sea and Amundsen Gulf and 2) along west coast of Greenland – Uummannaq Fjord and Labrador Sea near Nuuk



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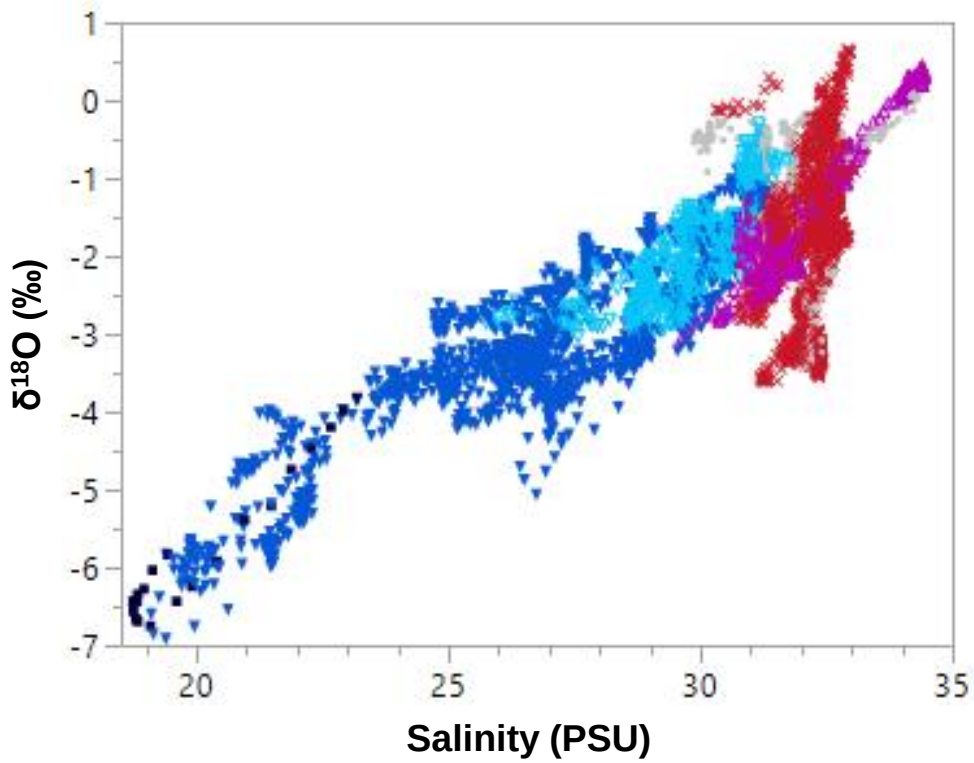
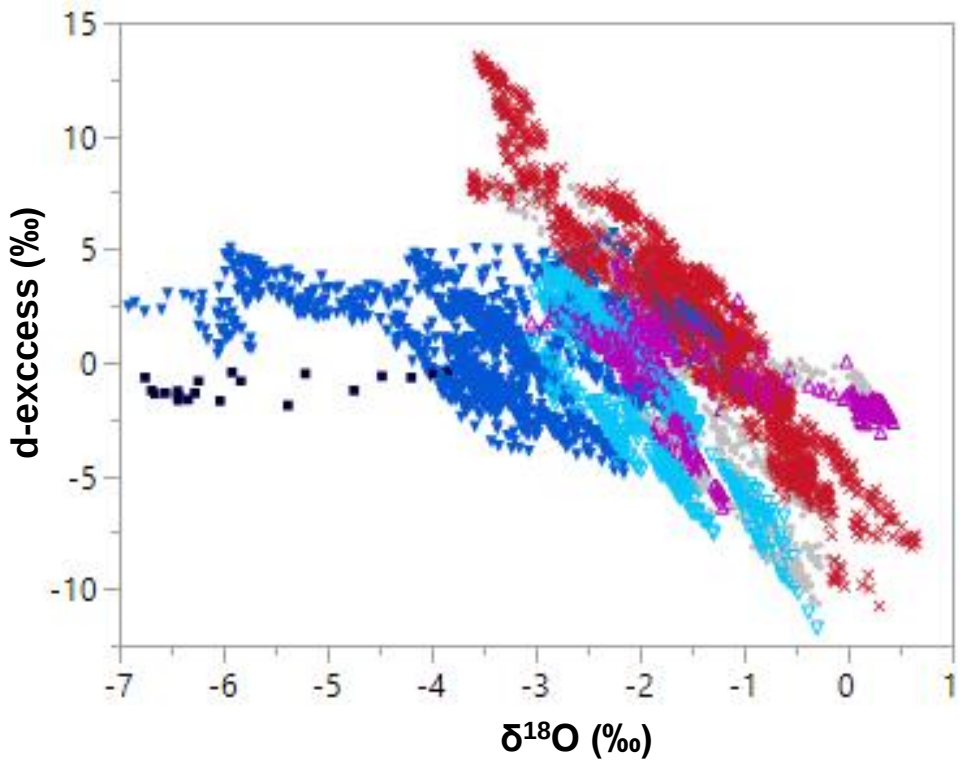
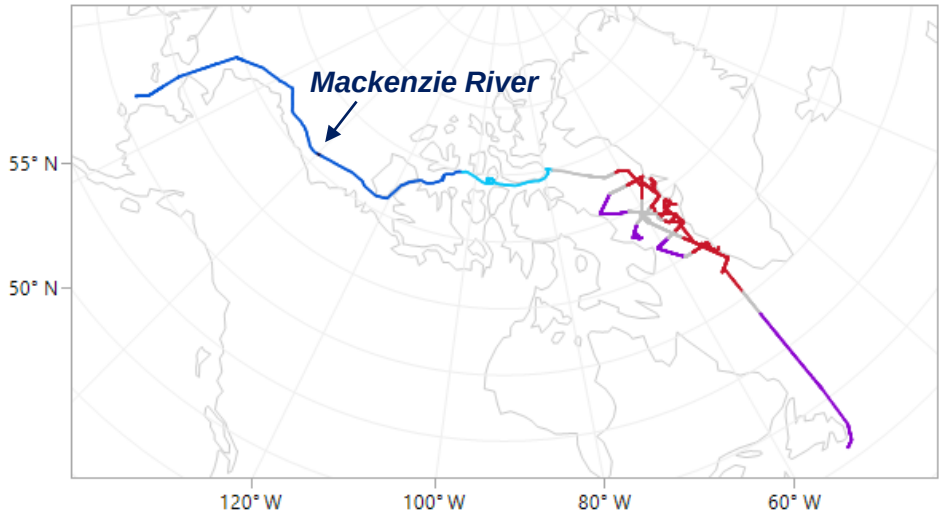
2) Explore mixing relationships between different freshwater sources and older ocean waters







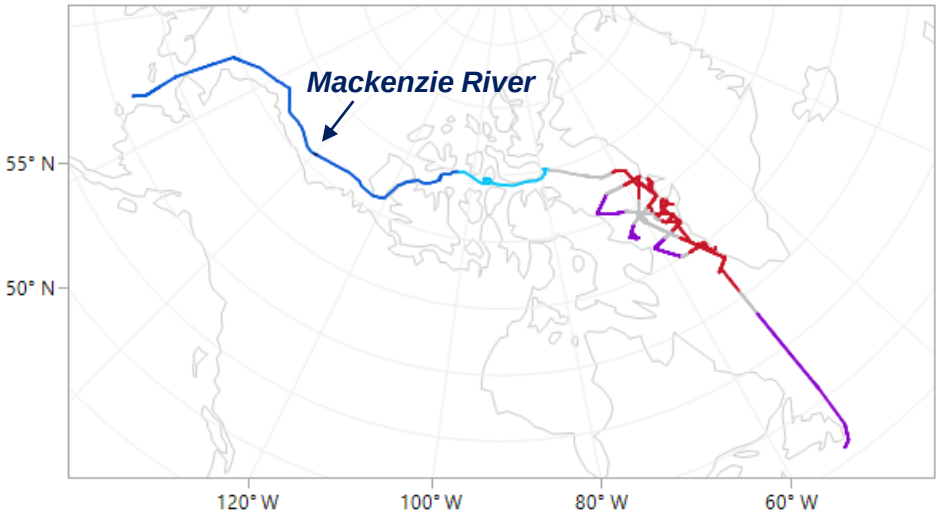
Mixing Relationships

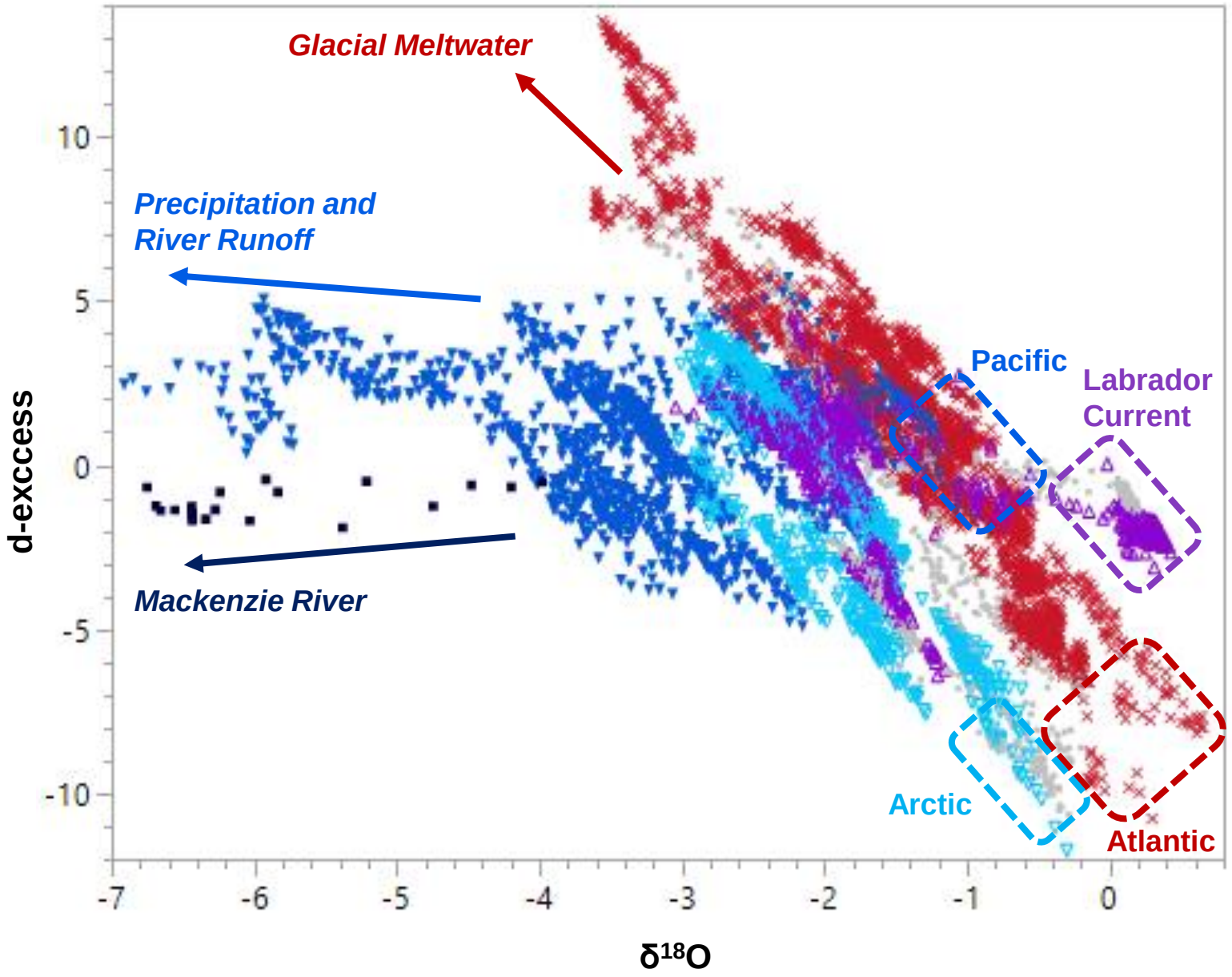
Ocean ‘end members’:

1) Atlantic - Arctic input
2) Pacific – Arctic input
3) Arctic
4) Labrador Current – Arctic output

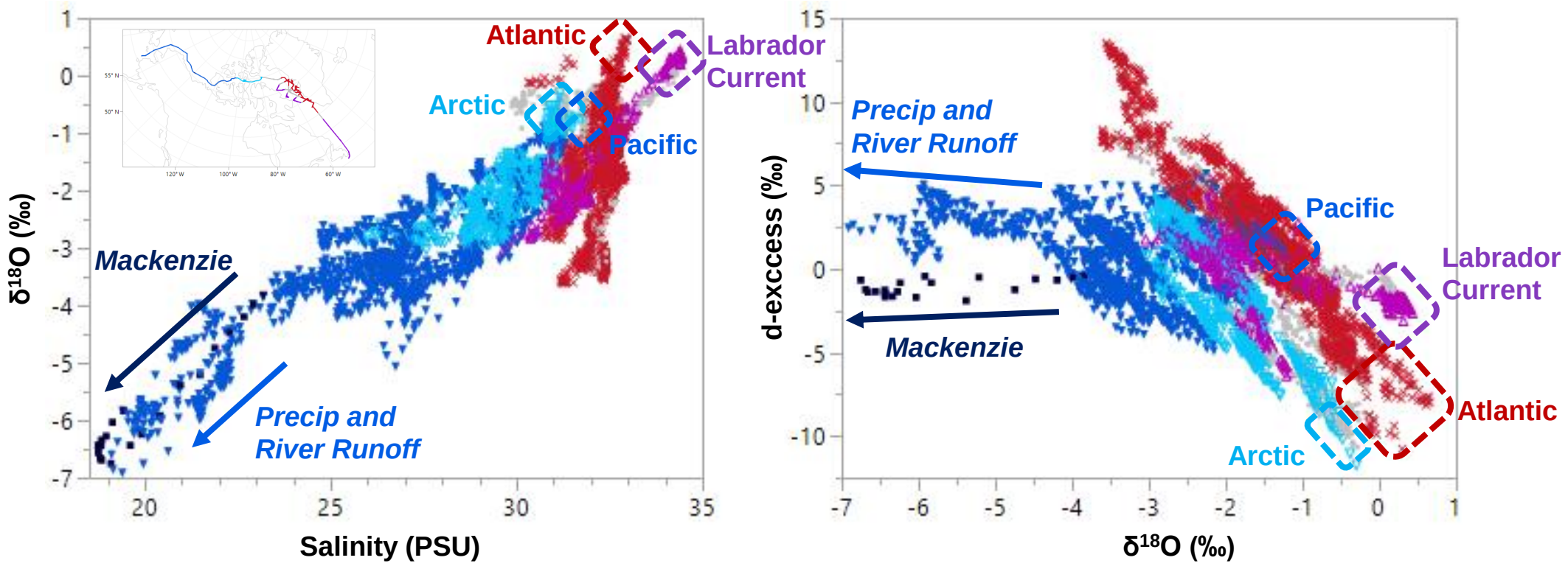
Freshwater inputs:

1) (Sub)Glacial meltwater - Greenland
2) Precipitation and river runoff
    a) North Slope AK and Canadian Archipelago
    b) Mackenzie River





How does the traditional salinity-$\delta^{18}O$ relationship compare to $\delta^{18}O$-*d-excess* relationship for delineating water masses and identifying mixing patterns?



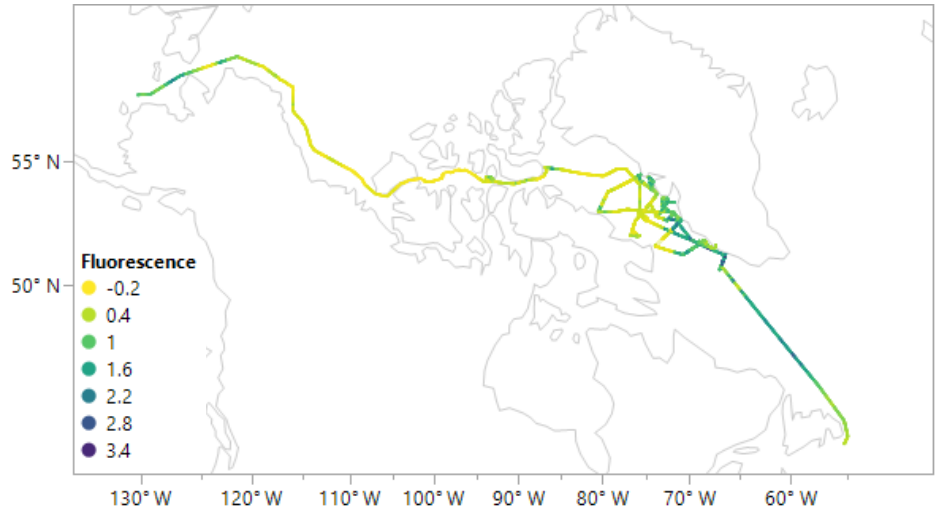
The $\delta^{18}O$-*d-excess* plot (using two isotope ratios) is more effective to delineate water masses and mixing relationships

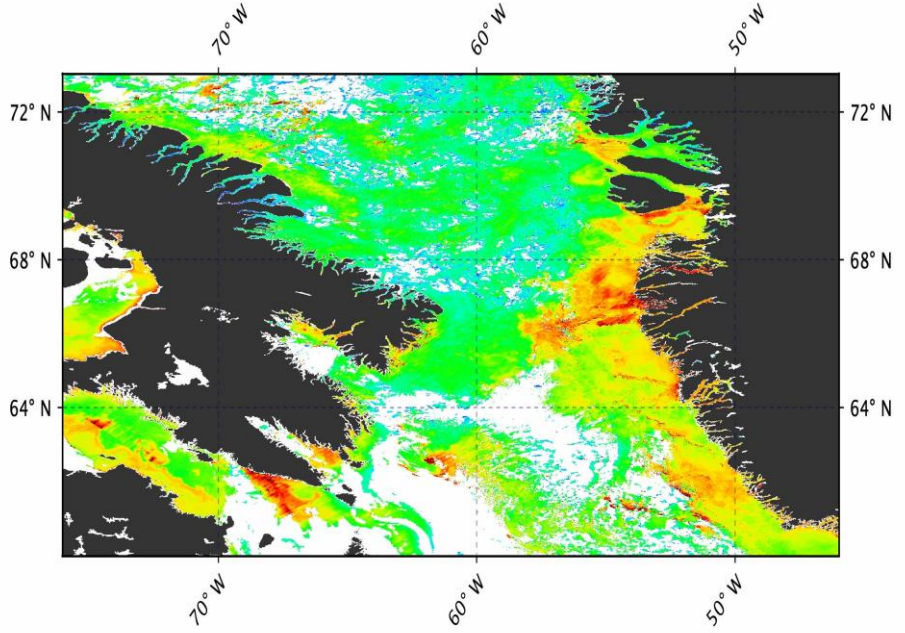
Two key examples of benefits of using two isotope ratios:

1) Separating the old ocean water sources and how they mix with different freshwater inputs is clearer when using *d-excess*
2) The Mackenzie River input has a distinct mixing relationship compared to other similar sources (Yukon River or precipitation) when using *d-excess*; **if using salinity, all of these freshwater end members look the same**

3) Examine impact of freshwater and different mixing relationships on biologic productivity

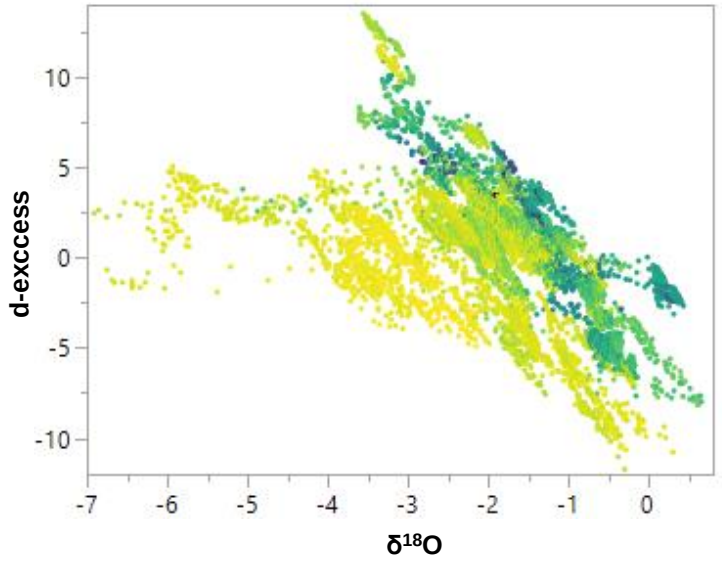
Points colored by Fluorescence

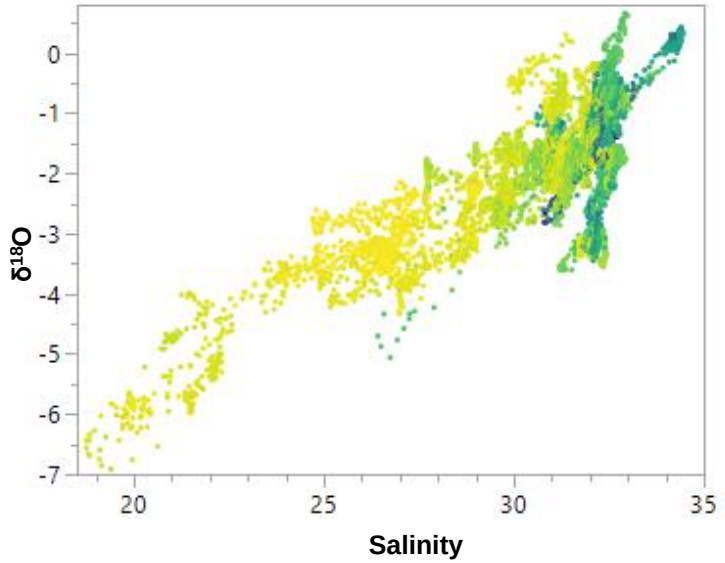




Chlorophyll
15-20 Sep 2021
MODIS Aqua

(high chlorophyll-a
Low chlorophyll-a)





Greenland coast: freshwater influx correlated with increased productivity

Beaufort Sea: freshwater not associated with increased productivity; lowest fluorescence values of cruise

What roles does freshwater play in influencing productivity? Why are these two regions different?

Freshwater and productivity

Two mechanisms driven by freshwater inputs drive divergent biologic responses:

1) Because of low density, freshwater caps the ocean surface and causes stratification (Farmer et al. 2021). This nutrient-poor water limits productivity.
2) Greenland meltwater discharge from the base of marine-terminating glaciers will rise to the surface after exiting the ice, and mixes the water column as it moves upward. This causes nutrient rich deeper waters to mix upward and increases the productivity (Hopwood et al. 2018).

Our observations are consistent with these two concepts:

1) The large freshwater influxes into the Beaufort Sea that are associated with low productivity (fluorescence) follow the *Farmer et al.* mechanism: **Surface freshwater influxes** (precip/river runoff) → **low productivity**
2) Large freshwater influxes of Greenland meltwater that are associated with high productivity follow the *Hopwood et al.* mechanism: **Marine terminating glacier basal meltwater → high productivity**

Farmer et al. 2021

OPEN

Arctic Ocean stratification set by sea level and freshwater inputs since the last ice age

Jesse R. Farmer[1,2], Daniel M. Sigman[1], Julie Granger[3], Ona M. Underwood[1], François Fripiat[2,4], Thomas M. Cronin[5], Alfredo Martínez-García[2] and Gerald H. Haug[2,6]

Hopwood et al. 2018

ARTICLE

DOI: 10.1038/s41467-018-05488-8 OPEN

Non-linear response of summertime marine productivity to increased meltwater discharge around Greenland

M.J. Hopwood[1], D. Carroll[2], T.J. Browning[1], L. Meire[3,4], J. Mortensen[4], S. Krisch[1] & E.P. Achterberg[1]

Conclusions

1. We have identified significant freshwater influxes into the Arctic seas with seawater $\delta^{18}O$ data – primary freshwater influence is in the Beaufort Sea and along West Greenland coastline

2. We observe clear mixing relationships between various freshwater sources and older ocean waters
   a) We can delineate different ocean water masses using $\delta^{18}O$-*d-excess* relationships – waters of Atlantic, Pacific, or Arctic Ocean origin as well as the Labrador Current
   b) Freshwater end members can also be delineated - e.g. glacial meltwater vs precipitation/surface runoff and the Mackenzie River compared to other nearby sources (Yukon River)
   c) Compared to traditional salinity only or $\delta^{18}O$-salinity relationships, examining $\delta^{18}O$-*d-excess* relationships provide significant additional information to delineate water masses and mixing

3. Freshwater influxes have diverging biologic impacts – Beaufort Sea has low productivity due to stratification effects that limit nutrients at the surface, while eastern Baffin Bay/Labrador Sea has high productivity in response to freshwater due to mixing effects of glacial meltwater

Photo: Ben Kopec