Journal of Geophysical Research: Oceans

Supporting Information for

A refinement of the processes controlling dissolved copper and nickel biogeochemistry: Insights from the pan-Arctic

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Contents of this file

Introduction

This supporting information file includes eight supplemental figures with additional data and interpretation that may be useful to the reader in following our interpretations. A supplemental table is included with literature values of Cu and Ni concentrations in Arctic rivers to compare to this study. All data used to make these supplemental figures is within the scope of the published datasets reference in our data availability statement.

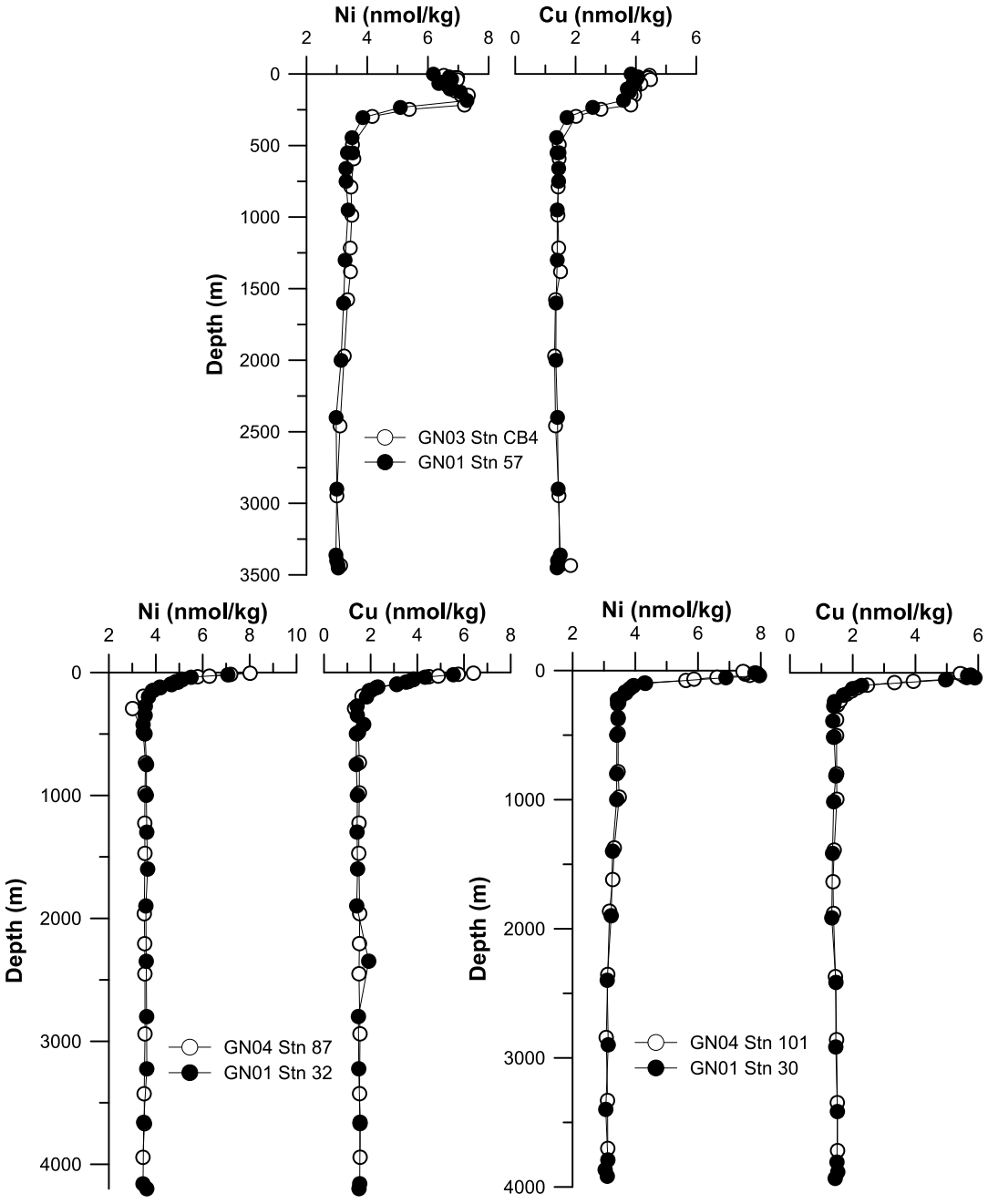

Figure S1. Results of the intercalibration between GN01 and GN02/GN03 (top) and GN01 and GN04. Agreement was strong for both elements at multiple intercalibration stations (mapped in Figure 1).

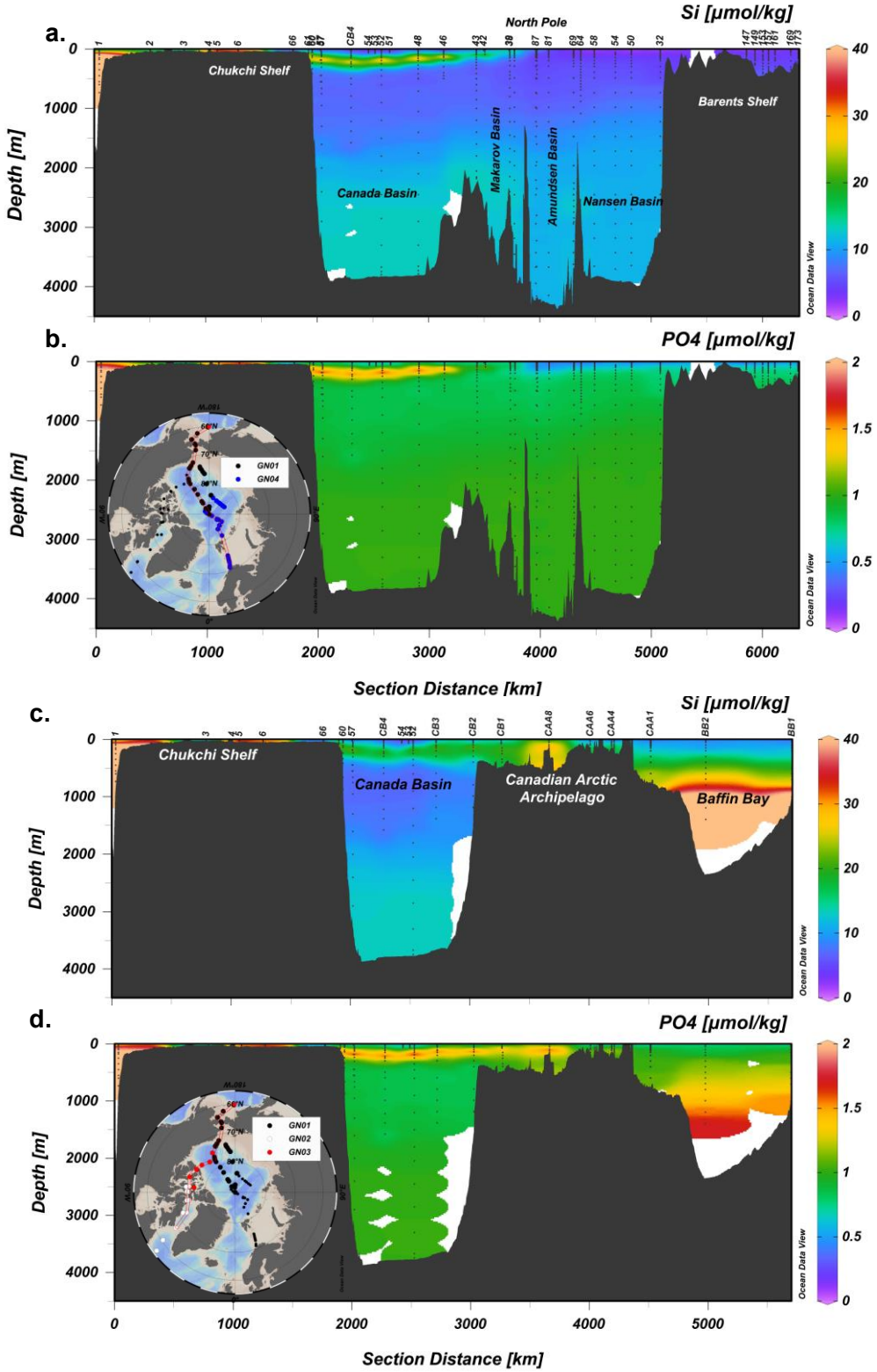

Figure S2. Sections replicating Figures 2 and 3 for silicate (Si) and phosphate (PO_4) across GN01 and GN04 (a,b) and GN01, GN02, GN03 (c,d). Station labels and inset section map included.

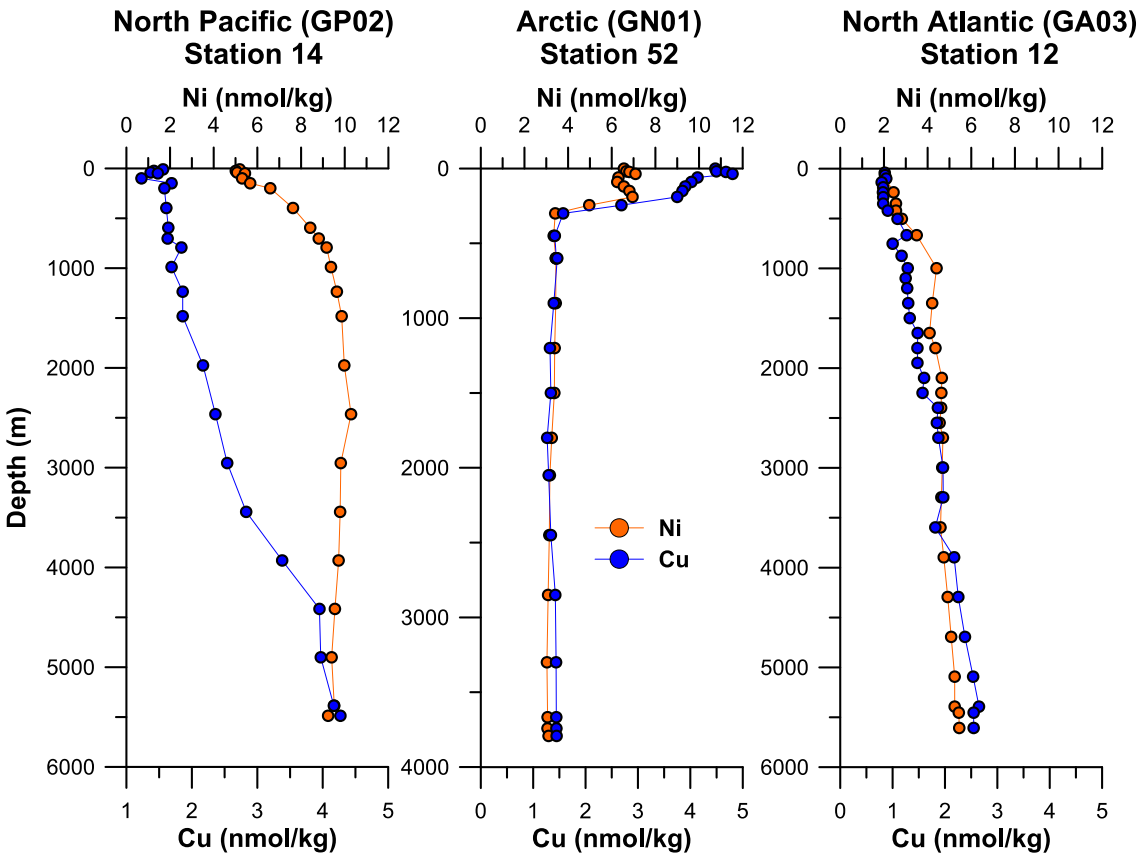

Figure S3. Global comparison of the profile shapes of Cu (blue) and Ni (orange) in the Arctic (GEOTRACES GN01, Station 52) to other major ocean basins. Atlantic and Pacific data taken from the subarctic North Pacific (GEOTRACES GP02, Station 14, 47°N, 170°W) and the subtropical Western North Atlantic (GEOTRACES GA03, Station 12, 29.7°N, 56.8°W), from Schlitzer et al. (2018).

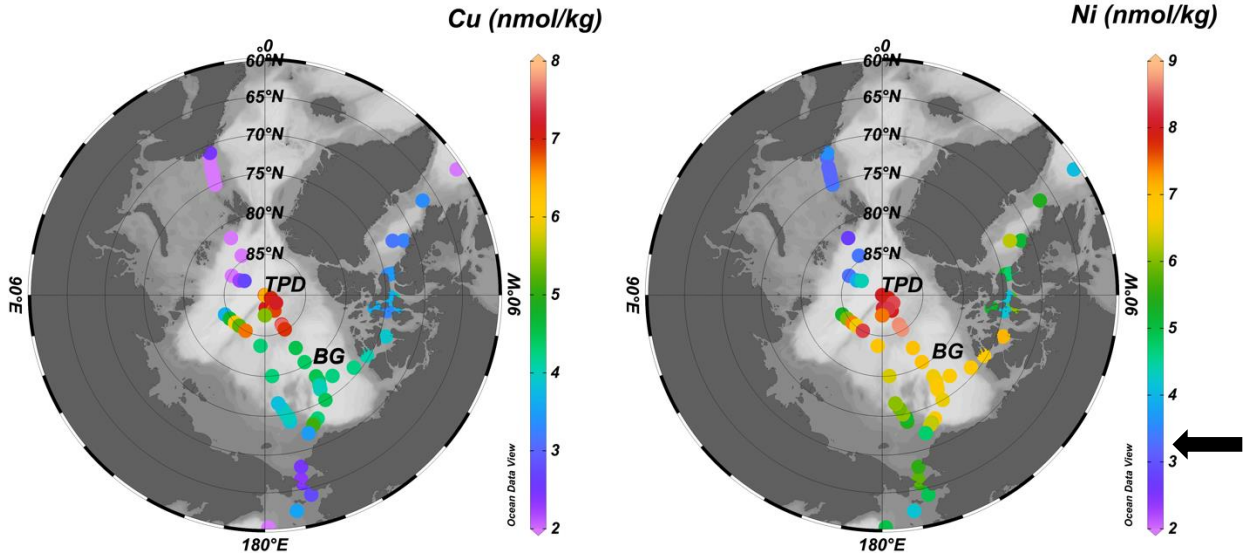

Figure S4. Isosurface plots of Cu (left) and Ni (right) in the upper 20 m of the Arctic. Color corresponds to concentration as shown in the color bars. The TPD (transpolar drift) and BG (Beaufort Gyre) are approximately labeled to show were concentrations for both Cu and Ni are slightly elevated. Global surface concentrations are 0.80 ± 0.64 and 3.18 ± 1.53 nmol/kg for Cu and Ni, respectively [Schlitzer et al., 2018]. This average is marked by a black arrow in the color bar for Ni (right) but is below-scale for Cu.

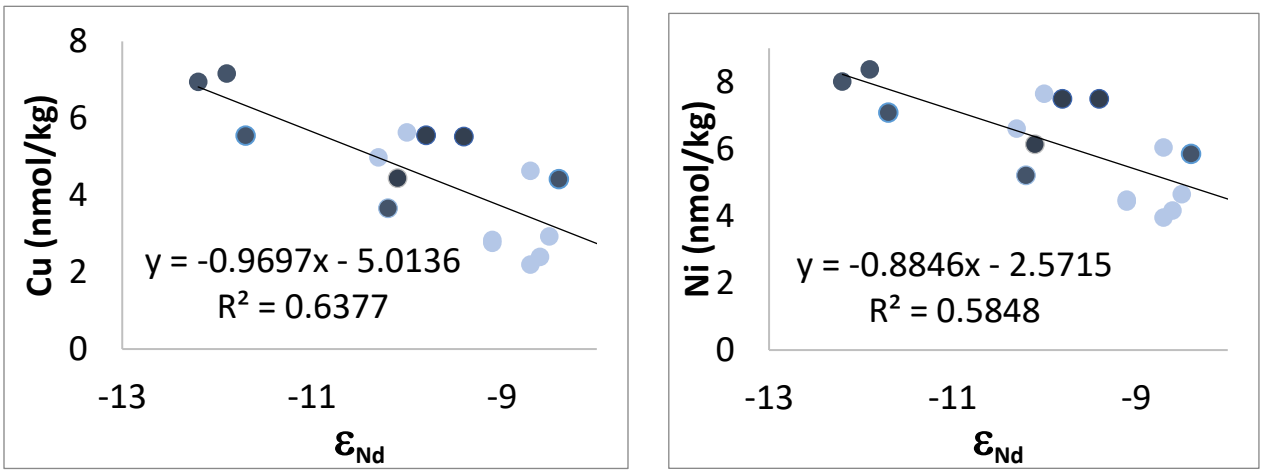

Figure S5. Cu (left) and Ni (right) vs. εNd along GN04 TPD-influenced stations 81, 96, 101, 117, 125, where εNd measurements were taken in the upper 100 m. Surface values (dark blue, 0-30m) are generally unradiogenic, while deeper values (light blue, 50-100m) are more radiogenic. The less radiogenic surface values are thought to be Lena River water overlying more radiogenic Yenisei/Ob water [Paffrath et al., 2021]. The linear relationships suggest that Lena River may carry higher Cu and Ni concentrations compared to the Yenisei/Ob Rivers.

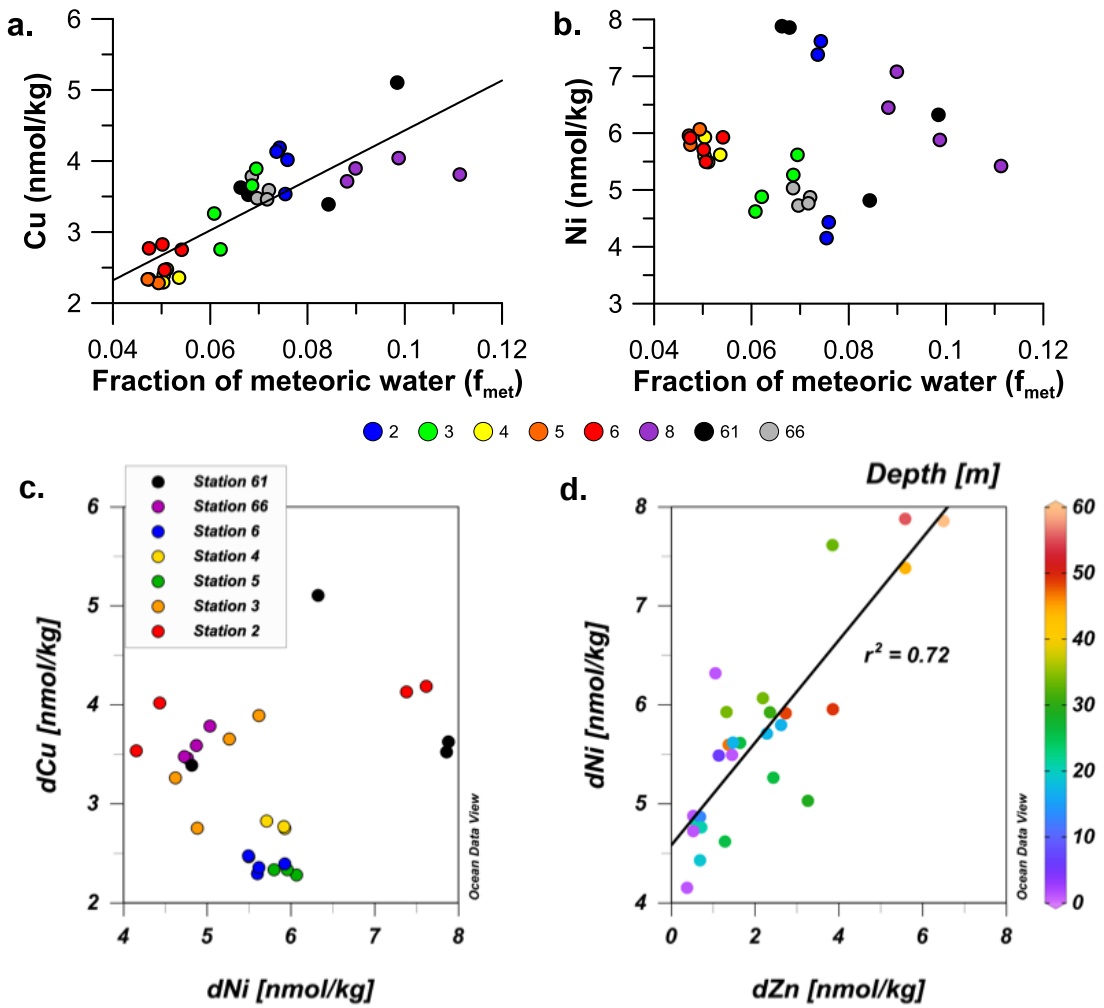

Figure S6. Plots showing fraction of meteoric water (fmet) vs a) Cu and b) Ni and c) Ni vs Cu, d) Zn vs Ni along the Chukchi Shelf and Bering Strait. GN01 station numbers are in color and referred to in the legends, except for d) where the color refers to depth in the water column to highlight benthic relationship between Ni and Zn.

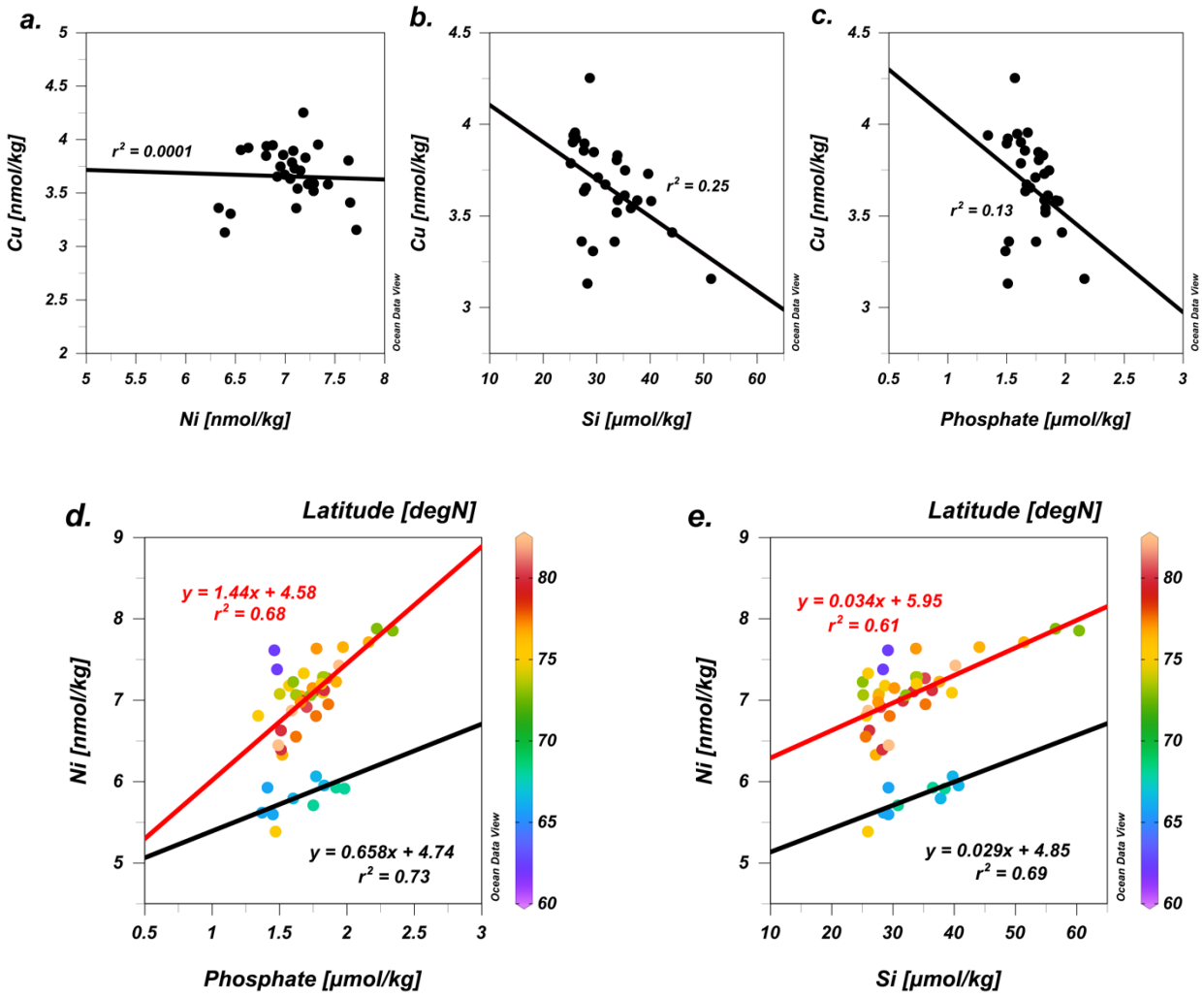

Figure S7. Correlations within the UHL between Cu vs. a) Ni, b) Si, c) P and within the UHL (higher latitudes, red/orange color) and the Chukchi Shelf (lower latitudes, blue/green color) for Ni vs d) P and e) Si. In d and e, correlations are shown because relationships are significant within the UHL (red) and the Chukchi Shelf (black). In panels a-c, no relationships were found between Cu and other elements in the UHL. Stations used for UHL: GN01 stations 8-19, 46-60, GN03 stations CB2-CB4.

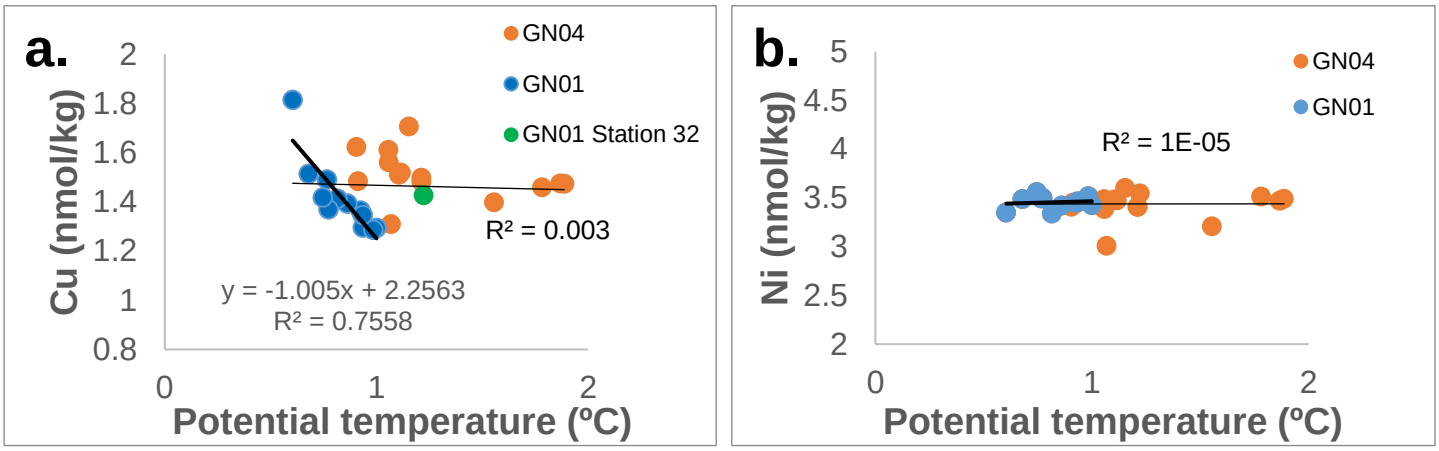

Figure S8. Relationships between a) Cu and b) Ni and the maximum potential temperature in the AL. Temperatures are generally higher in the AL along GN04, in line with a younger source of Atlantic water. In both cases, there is no significant linear relationship between the metals and temperature across both cruises, therefore there is no scavenging or regeneration within this layer as water transits from the Barents Shelf to the Chukchi Shelf. However, Cu shows a relationship within the GN01 cruise (excluding Station 32), indicative of mixing within the Western Arctic.

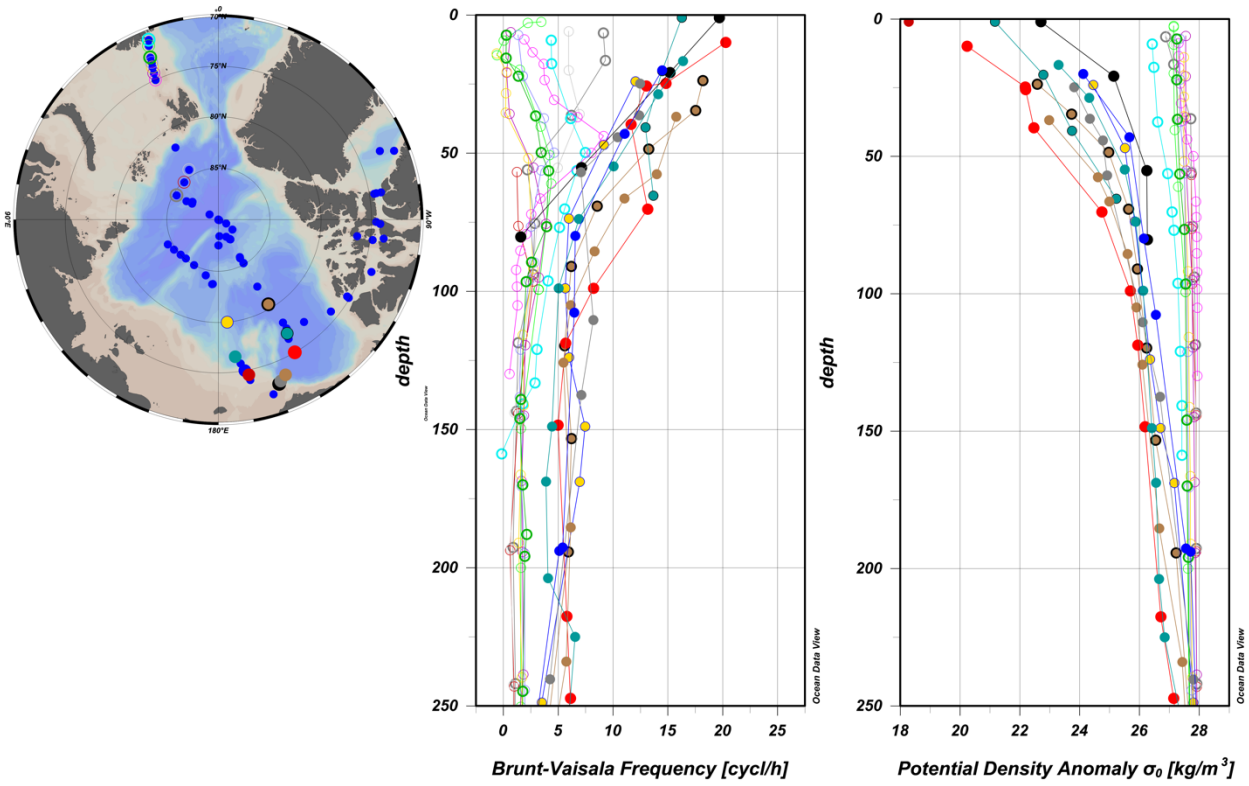

Figure S9. The Brunt-Väisälä Frequency (N, lefthand panel) and potential density anomaly (righthand panel) for stations along the Chukchi Shelf and Canada Basin (closed circles) and the Barents Shelf and Nansen Basin (open circles). The inset map shows location for each profile shown in the panels. The profiles show lower potential density and higher N values above 100 m in the Western Arctic, indicative of higher stratification along the Chukchi Shelf and central Canada Basin.

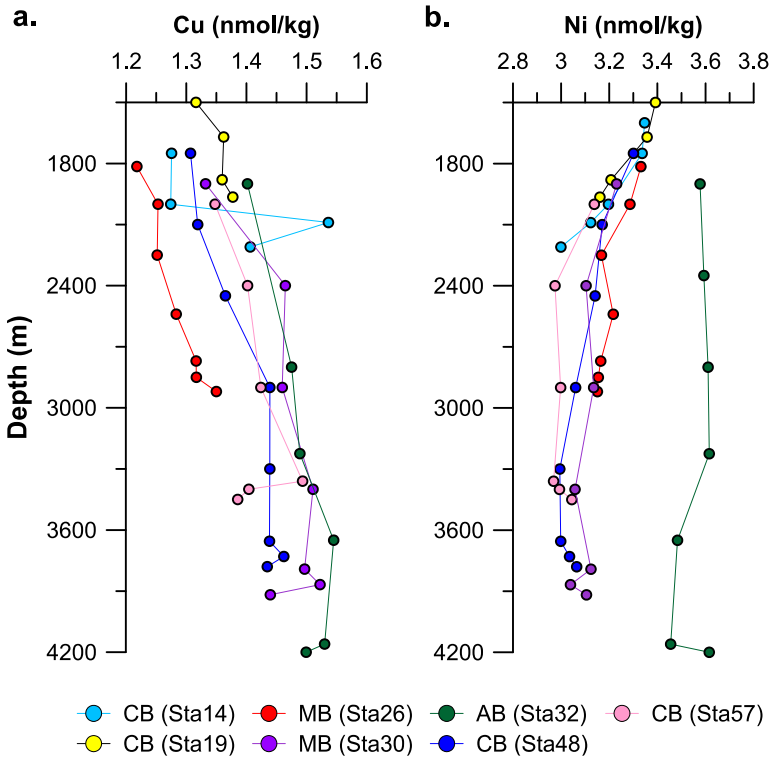

Figure S10. Deep water concentration profiles of a) Cu and b) Ni at GN01 Stations 14, 19, 26, 30, 32, 48, and 57 where BNLs were present below 1500 m. CB = Canada Basin, MB = Makarov Basin, AB = Amundsen Basin.

	River and estuary measurements		**Projected freshwater endmember**		
River	Cu (nmol/kg)	Ni (nmol/kg)	Cu (nmol/kg)	Ni (nmol/kg)	Study
Mackenzie	12 – 24	18 – 24	27	25	Kipp et al. (2020)
Ob	3.8 – 9.2	-	-	-	Guay et al. (2010)
Ob	28.4 – 37	20.5 – 23			Dai and Martin (1995)
Ob	28.4 – 37	20.4 – 23.1			Moran and Woods (1997)
Yenisey	6.1 – 14.2	-	-	-	Guay et al. (2010)
Yenisey	21 – 29	8.6 –9.2			Dai and Martin (1995)
Lena	11.2 – 38	8 – 18	-	-	Holemann et al. (2005)
Lena	12.1 – 15.3	4.2 – 5.8	19.5	11.7	Guieu et al. (1996)
Eurasian Arctic river compilation	22	17	30	31	Holmes et al. (2019) river and estuary; Charette et al. (2020) endmembers
Eurasian Arctic river compilation	-	-	22	23	This study*

Table S1. Compilation of recent Cu and Ni concentrations from major Arctic rivers expected to influence this study. Composite measurements from Eurasian rivers refer to Siberian origin rivers such as the Yenisei/Ob, and minor rivers that contribute to the TPD. When studies did not have direct river measurements (this study; Charette et al., 2020; Kipp et al., 2020) but there was a strong, positive relationship with meteoric water (fmet) a projected freshwater endmember was extrapolated at 100% meteoric water using the slope of the line. Variations in concentrations occurred over the estuary and mouth of the river deltas, although concentrations remained relatively constant over season and location. *More stations and different depths than in Charette et al. (2020).