GO-MARIE 2023 –

Land Retreated Glacial Fjords Study: Southwest Greenland, Case study sites: Sermilik & Akuliaq Fjord

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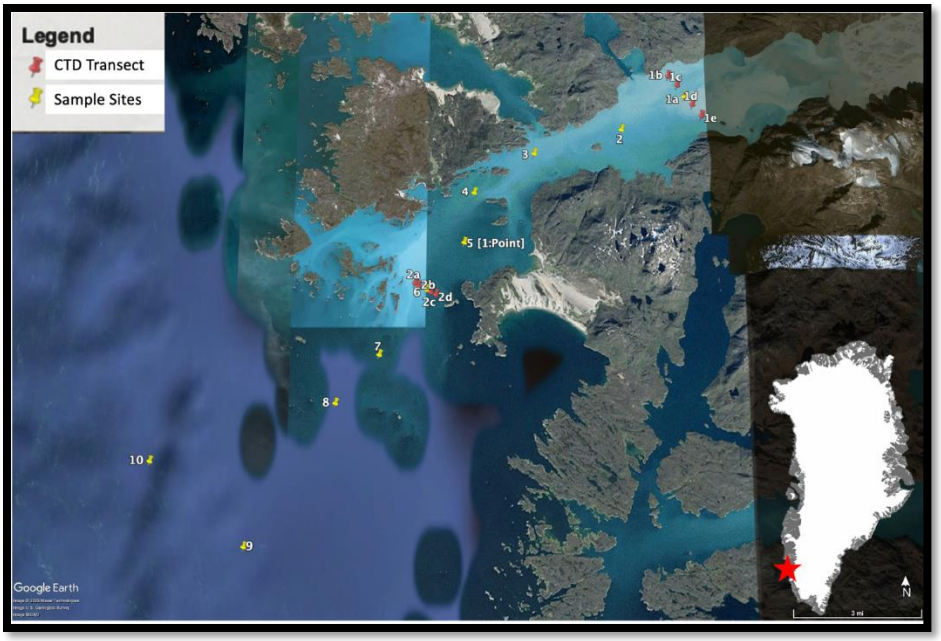
During the GO-MARIE 2023 campaign, operations were led by Ocean Research Project (ORP) Inc. 501c3, under the supervision of Field Operations Scientist, Nicole Trenholm and Captain Matthew Rutherford aboard the SRV Marie Tharp within southwest Greenland coastal fjords. Two case study sites were identified for this campaign, Sermilik and Akuliaq Fjord which both contain land retreated glacial fjords of various magnitude.

Increased sediment in glacial meltwater increases the turbidity and can limit photosynthesis from limiting light penetration impacting water quality. Ocean and glacial meltwater runoff geochemistry availability also limit the capacity for primary production as well. The interpretation of satellite remote sensing of suspended sediment concentration has shown that Sermeq Glacier thus Sermilik Fjord releases an average of 1500- 3000 mg TSS /L between 1999-2014[(1.)]. Increased sediment corresponds with increased nutrient runoff and in the adjacent and season algal bloom magnitude inevitably is impacted whereas, the potential for harmful algal bloom production is ill understood.

Our intent is to determine the distribution and character of suspended material both particulate and dissolved from the sea surface to the seabed and from the glacial meltwater source to the sea particularly in glacial fjords of a land retreated glacier stage.

Primary Land Retreated Glacial Fjord Study Location: Sermilik Fjord, southwest Greenland
Latitude: between 63.510600° N & 63.342900° N
Longitude: between -51.481233° W & -51.044233°W
Sermilik Fjord Sampling Date Range: June 19-21, 2023
Number of Stations: 18 with 5 at Transect 1 and 2, where station 1 & 6 overlap with the transects.



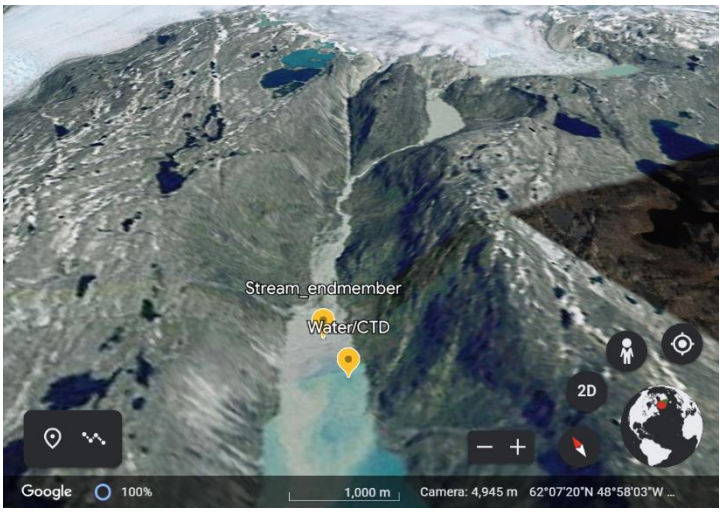
Sermilik Fjord Map:
Figure 1: Sampling sites along Sermilik Fjord, Greenland. Yellow pins represent stations where physical samples and CTDs were collected and red pins represent CTD-only transects. Red star on Greenland Map designates Sermilik Fjord.

Our primary research site is downstream of Sermeq Glacier and it is a land terminating and retreating glacier in Sermilik Fjord that contributes 25% of Greenland's sediment discharge due to glacial melt(1). Investigating this fjord waters will offer us important insights into understanding the geochemical character of the incredible volume of glacial meltwater discharging into the ocean while indicating the nutrient controls on the biological response between the meltwater source and the ocean. The Sermeq Glacier moraine is characterized by braided proglacial streams, a tidal delta and a land-sea interface that is around 3 km wide. The Sermilik Fjord width varies between 2-4 km and is about 30 km long. The area of the fjord is approximately 80 km^2.

Our secondary project site is 190 km south of Sermilik Fjord where at the end of Kuannersooq Fjord one of three branches is also a land retreated glacial fjord however called Akuliaq Fjord. The meltwater source in Akuliaq Fjord also arrives from a braided proglacial stream and tidal delta. However, the glacier is gone and the glacial meltwater comes from two paths, directly from a proglacial stream leading to the Greenland ice sheet and via another pathway, streamfed by a glacial lake, whereas the lake is then fed via meltwater from the ice sheet. Akuliaq Fjord is much smaller then Sermilik Fjord, its width varies from 1-1.5 km, and is about 6.3 km long with an area about

6.89 km^2. Akuliaq Fjord has a lesser glacial meltwater and sediment discharge than Sermilik Fjord and is much further away from the ocean water.

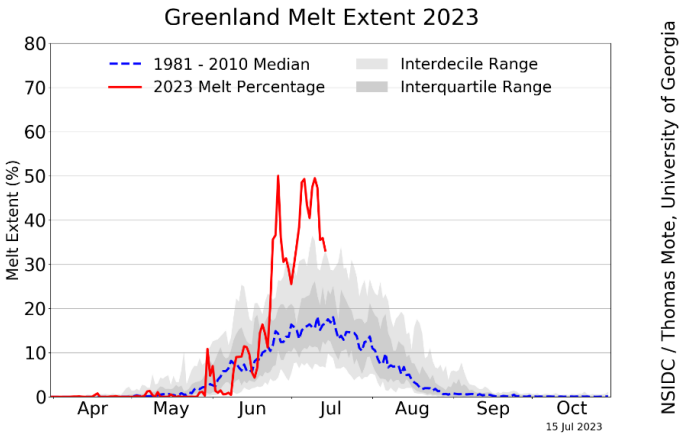
Secondary Land Retreated Glacier Study Location: Akuliaq Fjord, Greenland is at
62.27138889 N,
-49.10027778 W
Akuliaq Fjord Sampling Date Range: July 03, 2023
Number of Stations: 2, one water column station (2 discrete depth samples) and one endmember (proglacial stream sample).
Akuliaq Fjord Map:



Questions:

1. What are the available nutrients in circulation in a land retreated glacial fjord in the summer season?
2. How does the nutrient concentrations and their form transition throughout the water column, to the seabed and along the fjord due to physical to biogeochemical interactions?
3. How much sediment is transported from the source to the sea?
4. How much organic carbon is buried in a land retreated glacial fjord and how does the marine vs terrestrial organic carbon content vary from source to sea?

Objectives: Samples were collected during the beginning of the peak melt season for 2023.



1. Q1. Identify the concentrations of dissolved macronutrients (N, P, Si, and C) and micronutrients (including but not limited to Fe, U, Zn) representative of both case study sites.
2. Q2. Observe how the hydrography and seabed proximity between the meltwater source and the sea controls the geochemical dynamics.
3. Q3. Identify the variation in suspended sediment concentration with depth and across the fjord.

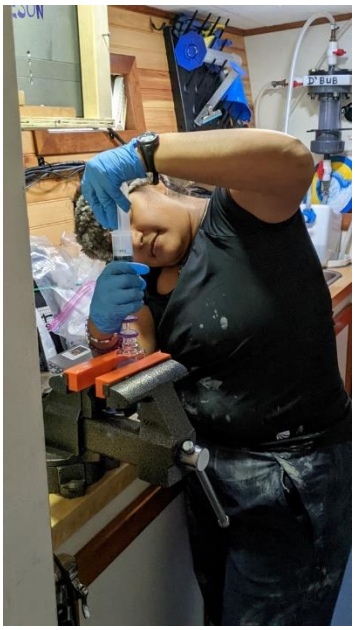
4. Q4. Interpret the organic carbon concentration and terrestrial or marine origin of the suspended sediment and seabed surface, specifically the C:N ratio & $^{13}\delta C$ for indicators of the biological state.

Methods:

We referred to a satellite image from 6/16/23 USGS NASA LandSat 8-9 to observe the sediment plume before sampling.

A. M1-4. *Shipboard Observations:* All data collection was acquired from the Ocean Research Project's SRV Marie Tharp, a 22 m steel schooner with water column sensor profiling, water column & seabed physical sampling, a flow-through continuous water sampling system and filtration wetlab capacity.
B. M1-4. *Hydrographic profiles:* Were conducted at two transects where multiple hydrographic profiles were acquired in an across-fjord orientation in the beginning and end of Sermilik Fjord and one transect at the beginning Akuliaq Fjord. The Sermilik Fjord transects overlapped with station 1 and 6 while there was only one full water column water sample station in Akuliaq Fjord acquired. Two RBR Concerto CTD instruments were lowered on the same cage to just above the seafloor. *S/N* 060671 was calibrated in June 2023 and had a turbidity sensor (NTU). The other Concerto is S/N 204223 and was calibrated in spring 2022 and it has a chl a sensor. They both have traditional physical ocean measurements and an auxiliary dissolved oxygen concentration sensor. Since one CTD had an older calibration date both CTDs were compared for salinity and temperature at the same depth with a linear regression and they agreed to an R^2 number of 0.97. We deployed both CTDs at each 18 stations total.
C. M2. & M.4 *Ponar Grab sampler*: Seabed sediment grab samples were collected at all main 10 stations in Sermilik Fjord and one station at Akuliaq Fjord. Sediment is stored in a fridge onboard during the cruise.
D. M2. *Water quality: pH probe:* We collected pH at each Sermilik Fjord station and depth. We used the DeltaTrak Model 240081 pocket pH meter. This was calibrated before analyses on 6/19/23.
E. M1-4. *Niskin Bottle*: Manual 5L- Niskin bottle with trigger weight. Collected water samples at the surface and a deeper depth. We determined this deeper depth based on the CTD results. After one of the Niskin bottles broke, we used the ship's continuous flow-through system to collect water from 1 m deep. At station 1 Tia collected a 1 m sample and a surface sample.
F. *Singlebeam*: Ray Marine/ AIRMAR Frequency (50-200 pw) EchoSounder. Collected depth measurements which supported water coloumn profiling and sampling activity.
G. *Shipboard Lab Filtration:*
    a. 120 mL of water at surface and each discrete depth at each station was filtered using a 0.45 and 0.2 µm stack filter. The filter water is for dissolved macro and micronutrient analyses. Filters and water samples were stored at 4 °C. There are 21 water samples.

b. 0.7 GF/F were filtered until clogged for total suspended sediment, organic content concentration and C-isotope analyses. The recorded amount mL of water filter was documented. The filters are stored at 4 °C.



Research Initial Findings/Notes:

- Find out from RBR which temperature to use for hydrographic studies.
- At Sermilik Fjord, we noticed a color difference in the water at different stations. Water at station closer to the mouth of the fjord were more of a navy blue and appeared to be clearer. Water closer to the glacier terminus tended to be more aqua, likely from mica and sediment.
- At Sermilik Fjord, we noticed that the bottom water was more turbid. This aligned with filtering deeper depth samples.
- At Sermilik Fjord, we attempted a gravity core at the mouth of the fjord but will likely be more successful in the fjord closer midway to the glacial terminus considering the coarse grain sediment observed at the fjord interface with the sea, also due to rocks and vegetation.
- At Sermilik Fjord, we did not get 2 grab samples (st9 and 10) because seabed was mostly vegetation.
- The turbidity sensor takes measurements every 3 seconds so shallow water profiling speeds needed to be adjusted.

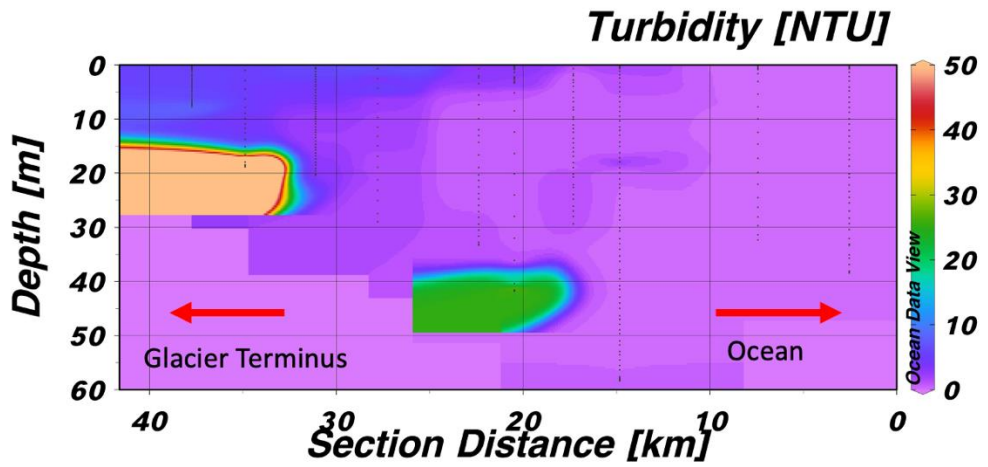


Figure 2: Turbidity concentrations (NTU) alongtrack Sermilik Fjord. 40 km represents station 2 (closest to glacier terminus) and increased distance 30 km represents marine samples.

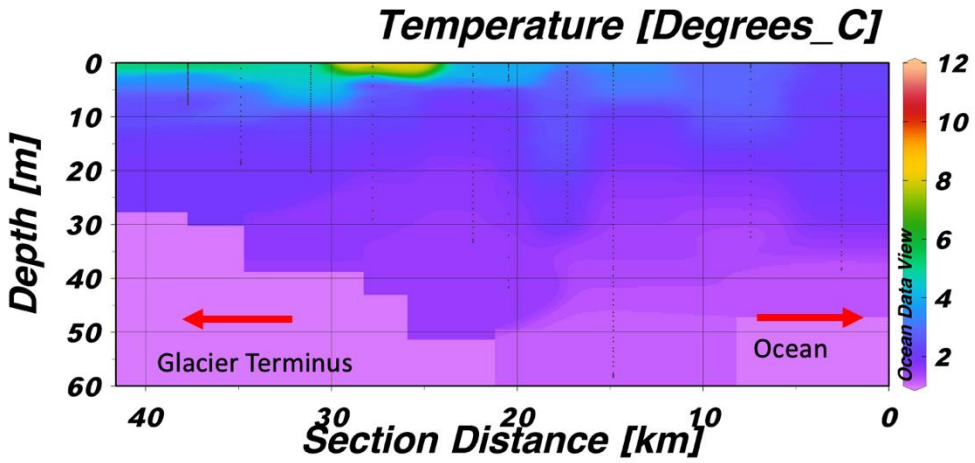


Figure 3: Temperature (°C) alongtrack Sermilik Fjord. 40km represents station 2 (closest to glacier terminus) and increased distance 30 km represents marine samples.

General Timeline:

Summer 2023:

- XRF and grain size on sediment (Tia)
- Look into RACMO for discharge into Sermilik fjord

Fall 2023:

- Water Column nutrient analysis (Tia) ~$2,000
- Sediment P extractions (Tia)
- Water Column TSS (Nicole)

- Water Column and seabed sediment 13C and C/N (Nicole) ~ ($330)
- Meet with Carli, Tia, Nicole, and Andrea when Nicole returns in ~ October

References

1. Doi.10.1038/NGEO3046
   Overeen et al., 2017