

Mission Arctic Summary

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Introduction

This document provides a brief, informal summary of daily activities during the Mission Arctic Science Expedition to western Greenland in June-July 2017. The expedition was organized by Nicolas Peissel and the sailing vessel Exiles was crewed by Dr. Pippa Pett, Will Turner, Peter Lundgren, and J.L. Crosbie. The efforts of many others, including Gareth Carr, were essential in converting and outfitting the boat for her voyage to the Arctic. Exiles departed St. John's Newfoundland, bound for southern Greenland, in late June 2017.

Scientific activities were coordinated by Dr. Daniel F. Carlson, who was supported by the Arctic Research Centre at Aarhus University in Denmark and the Greenland Institute of Natural Resources in Nuuk, Greenland. Dr. Carlson met Exiles in Paamiut, in southern Greenland, and disembarked in Upernavik, in northwest Greenland. The primary scientific objectives were hydrographic (CTD) surveys of fjords in contact with the Greenland Ice Sheet, the retrieval of bottom-mounted instrumentation, testing/development of drone photogrammetry of icebergs, and drone aerial surveys of intertidal environments.

Dr. Carlson equipped the crew with a Sontek CastAway CTD so that they could continue measurements after his departure. After Dr. Carlson disembarked in Upernavik in late July, Exiles continued north, through Melville Bay and into Nares Strait, where they proceeded as far north as possible, reaching >80N, before the ice impeded their progress. Exiles then turned southwest, following the coast of Ellesmere Island to Craig Harbor and Grise Fjord. With daylight dwindling and winter fast approaching, Exiles continued southward along the western boundary of Baffin Bay, with stops in Pond Inlet and Clyde Harbor on Baffin Island. Exiles returned to Newfoundland in late September or early October 2017, completing a circuit of Baffin Bay and collecting an impressive 98 CTD profiles along the way.

CTD Profiles

The primary CTD used during the scientific expedition in July 2017 was a RBR Concerto CTD that measured conductivity, temperature, and pressure. These data were used to compute salinity, density, potential temperature, and potential density. The RBR CTD was mounted in a custom stainless steel frame that was constructed by Gareth Carr. Will Turner installed an electric pot puller on the stern that was used for deep profiles. The CTD frame was attached to a Dyneema tether.



Dr. Carlson prepares for a CTD profile. The CTD was mounted in a stainless steel frame, which was tied to a Dyneema tether. An electric pot puller was used to raise the CTD on deep casts.

Aerial Drone Surveys

A DJI Phantom 3 Standard quadcopter 'drone' was used to carry out aerial photography surveys of coastal areas and icebergs. The Phantom 3 was equipped with a 12 megapixel camera that was stabilized by a 3-axis gimbal. The DJI Go App was used to configure the drone, monitor flight data, and change camera settings. Two types of aerial photography surveys were carried out during Mission Arctic: 1) Photographs with a high degree of overlap were acquired for post-processing in Structure from Motion photogrammetry software to generate three-dimensional point clouds and high-resolution digital elevation models (DEMs) and orthomosaics; 2) Time lapse imagery of drifting icebergs was acquired whereby the drone hovered at a fixed location (within a few meters) with the camera pointed downward to examine high-frequency ice motion.

Three photogrammetry mapping missions were flown during Mission Arctic. The first was conducted over a small island in Kobbefjord on 5 July 2017 where 218 overlapping images were acquired. The images were processed using Agisoft PhotoScan and the resulting DEM and orthomosaic was used by Pons et al (In preparation) to quantify coastal macroalgae. Another 251 images were acquired in a small bay in Godthåbsfjord on 11 July 2017 and these images

were also used to quantify coastal macroalgae by Pons et al. (In preparation). The final photogrammetry survey was flown around a grounded iceberg on the north side of Qeqertarsuaq Island (72.51N, 53.44W) on 27 July 2017. At the time of the survey flight, the use of photogrammetry to model iceberg geometry was still contested, as photographs of low-contrast and highly reflective objects generally produce poor results when using photogrammetry techniques. The iceberg survey was conducted at approximately 04:00 local time, when the sun angle was low. The skies were overcast, which further limited the amount of sunlight. Exposure bracketing was used to deliberately underexpose the drone images to ensure that the roughness features on the icebergs were adequately resolved. During the first survey flight, a large growler calved from the iceberg, which caused the iceberg to oscillate. As a result, this photo survey was terminated and a second survey was conducted after the iceberg stopped oscillating. 127 photographs were acquired by the drone and were processed in Agisoft PhotoScan to produce a high resolution 3D model of the iceberg.

Scientific Datasets

All scientific datasets produced during Mission Arctic are available on Zenodo.

- CTD data doi: 10.5281/zenodo.4508549
- Drone aerial images in Kobbefjord https://zenodo.org/record/3731024#.XrqlvKszZp_
- Drone aerial images in Godthåbsfjord <https://zenodo.org/record/3823840#.XruojqsZp8>
- Drone aerial images of a grounded iceberg near Qeqertarsuaq Island
 - <https://zenodo.org/record/4014709#.X5rG41NKjUo>
 - <https://skfb.ly/6SBrT>

Outreach Blogs

- [Mission Arctic Blogs](#)
- [Dyneema](#)
- [Lenovo - Carlson](#)
- [Lenovo - Mission Arctic](#)
- [Lenovo - Carr](#)
- [Lenovo - Peissel](#)
- [ResearchGate](#)
- [Popular Science](#)

Daily Activity Summary

Date: 24 June 2017

Location: St. John's, Newfoundland

Summary:

Exiles, sailed by Nicolas Peissel (NP), Dr. Pippa Pett (PP), Peter Lundgren (PL), and Will Turner (WT) departed from Newfoundland and sailed north to Paamiut. The crew had to deal with icebergs and the remnants of Tropical Storm Cindy.

Date: 28 June 2017

Location: Paamiut, Greenland

Summary:

Dan Carlson (DC) arrived in Paamiut, settled into the only hotel in town, and explored the surroundings.



A stone cairn with a wooden post marks the top of a rocky outcrop near Paamiut, Greenland.

Date: 30 June 2017

Location: Paamiut, Greenland

Summary:

Exiles arrived in the afternoon under sail after experiencing engine problems. Thankfully, DC had time to scout out the town and found a mechanic who would be able to look at the engine the following day. DC, PL, and WT attended a benefit concert by Enok Poulsen (Greenland's Elvis) to raise money for the survivors of the tsunami in Nuugaatsiaq.



Date: 1 July 2017

Location: Paamiut, Greenland

Summary:

The mechanic arrived in the morning to find a clogged fuel filter. DC tested his CTDs. The RBR CTD was mounted in the custom stainless steel frame that was constructed by Gareth Carr. PL refilled the water tanks.



The RBR CTD mounted inside the custom stainless steel frame.



NP and the mechanic inspect the engine

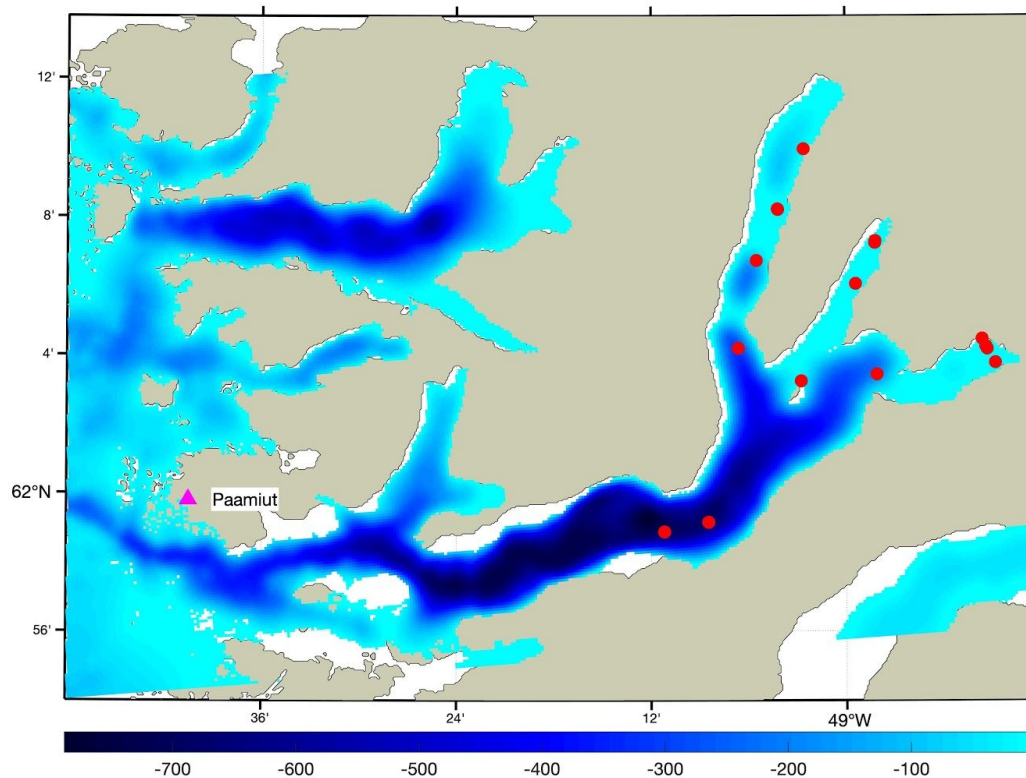
Date: 2 July 2017

Location: Fvanefjord, near Paamiut (62.06N, 49.04W)

Summary:

Sailed into the fjord, which forks into 3 small arms (see map, below). Exiles visited the northern arm first, which has a tidewater glacier that discharges many small icebergs, bergy bits, and

growlers. We took the dinghy as close as the ice would allow to acquire a CTD profile. Next we proceeded to the central arm, which is land-terminating. We collected 1 profile with the RBR and 2 with the CastAway. We sailed to the southern arm near midnight. There were several shallow (< 50 m) sills leading up to the glacier. The south side of the glacier is marine terminating and the north side has retreated on to land. After anchoring for the night, Nicolas, Pippa, and DC went ashore. N+P hiked up to a waterfall while DC flew the Phantom 3 drone (P3). All CTD profiles were done by hand as WT was installing the pot puller.



A map of Fvanefjord with the locations of CTD profiles indicated by red circles. The town of Paamiut is labeled with a pink triangle. Bathymetry contours are plotted from BedMachine v3 (Morlighem et al., 2017).



Exiles anchorage near a retreating glacier (62.04N, 48.86W)

Date: 3 July 2017

Location: Fvanefjord and Sailing north to Nuuk

Summary:

In the morning, NP, PP, and DC took the dinghy to a rock on the southern end of the fjord, facing the terminus of the glacier. While the glacier was technically marine terminating, the water directly in front of the glacier was quite shallow, as indicated by the small icebergs and bergy bits that grounded when they calved at low tide. Many had to wait until they melted for the tide to be able to carry them away. DC flew the P3. After pulling anchor, Exiles sailed out of Fvanefjord, with several of the crew stopping to explore a small island (62.05N, 49.05W) near the location where the fjord branches. The crew found stone graves with human remains on the island, which they were careful not to disturb. After sailing out of the fjord, Exiles turned north and followed the coast to the entrance of Godthåbsfjord.



A drone image of NP, PP, and DC on a small rock near the terminus of the marine terminating glacier in the southern branch of Fvane fjord (62.07N, 48.84W)

Date: 4 July 2017

Location: Kobbefjord, near Nuuk

Summary:

Around 22:00 Exiles anchored in a shallow bay near a small island in Kobbefjord, near Nuuk (64.14N, 51.59W).



Snow-covered mountains in Kobbefjord (64.14N, 51.59W)

Date: 5 July 2017

Location: Kobbefjord, near Nuuk

Summary:

Exiles spent the day at anchor. The crew went ashore on the island and DC flew the P3. DC acquired several hundred images of the island to create a three-dimensional point cloud and a high-resolution orthomosaic using photogrammetry software (Agisoft PhotoScan/MetaShape). We pulled anchor that evening and, in the process, the stern anchor line became entangled in the propeller. WT heroically freed the propeller by diving underwater to cut the line free. Once free, Exiles sailed for the harbor in Nuuk.



Drone image of the island in Kobbefjord

Date: 6-7 July 2017

Location: Nuuk

Summary:

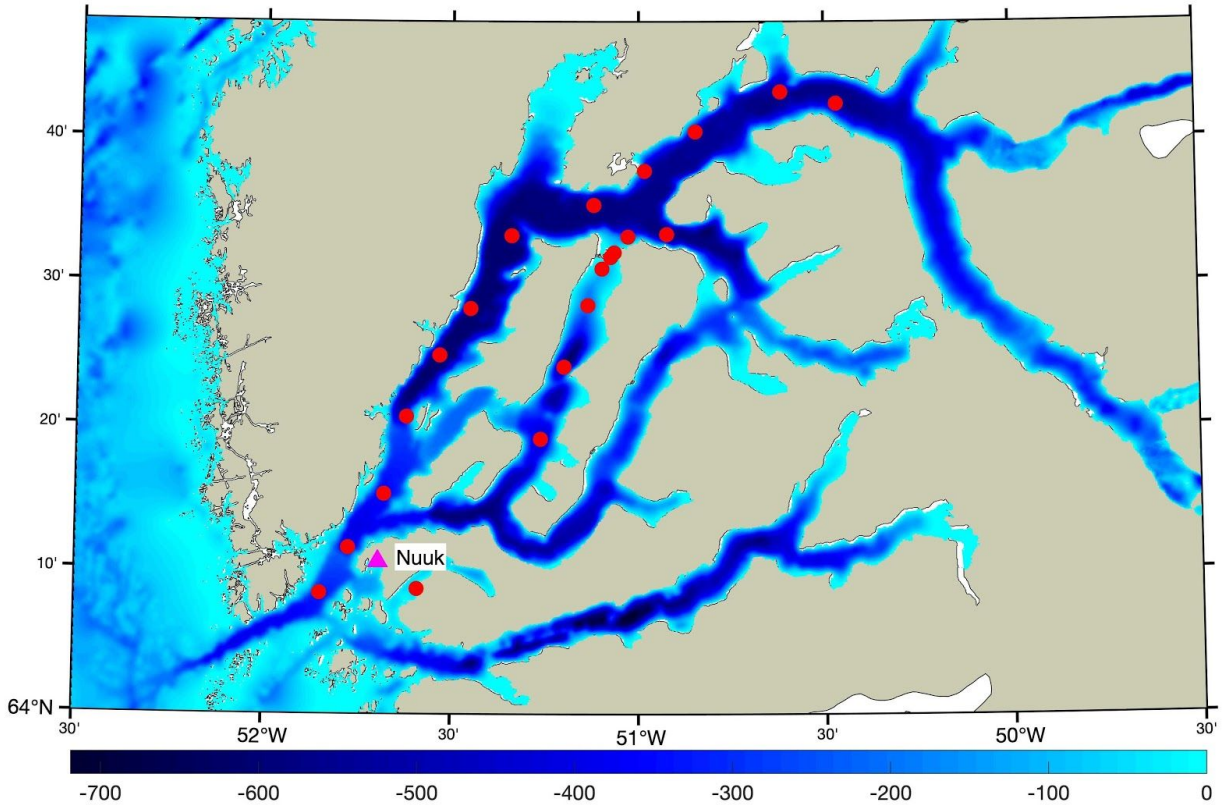
Exiles spent two days in Nuuk. DC went to the Greenland Institute of Natural Resources to submit a revised manuscript and to pick up the acoustic release that the team would use to retrieve bottom-mounted CTDs later in the expedition. J.L. Crosbie joined the crew and supports were welded to the solar panel frame on the stern to provide additional seating.

Date: 8 July 2017

Location: Godthåbsfjord

Summary:

Exiles sailed into Godthåbsfjord and DC commenced a CTD transect in the main arm of the fjord (map below). Exiles stopped to top off her water tanks at a waterfall in the fjord.



A map of Godthåbsfjord with CTD profile locations indicated by red circles. The pink triangle indicates the location of Greenland's capital, Nuuk.

Date: 9 July 2017

Location: Godthåbsfjord

Summary:

Exiles continued making her way into the fjord, which was full of icebergs. DC continued the CTD transect.



Sunset in Godthåbsfjord



The crew watches icebergs drifting in the fjord

Date: 10 July 2017

Location: Godthåbsfjord

Summary:

Exiles turned back towards Nuuk, taking the central arm of the fjord and continued the CTD transect.



Sailing back towards Nuuk.

Date: 11 July 2017

Location: Godthåbsfjord

Summary:

Exiles returned to Nuuk. DC dropped off equipment at the Nature Institute. JL's missing luggage arrived.

Date: 12 July 2017

Location: Fyllas Banke (64.37N, 52.74W)

Summary:

Exiles departed from Nuuk, with a stop at the mouth of Godthåbsfjord for some whale watching. Afterwards, the crew set a course for a bottom mounted CTD that was located on the shelf in about 400 m of water. After reaching the location of the CTD, DC made several unsuccessful attempts to communicate with the acoustic release on the bottom and then entered the release code. The crew waited anxiously, scanning the horizon for any sign of the CTD and its flotation. After a nerve-wracking 5 minutes, the yellow and orange flotation was spotted on the surface. The CTD, acoustic release, and flotation were brought safely onboard and Exiles.



A humpback whale at the mouth of Godthåbsfjord



The happy crew posing with the recovered gear

Date: 13 July 2017

Location: Hamburger Sund, north of Maniitsoq (65.63N, 52.82W)

Summary:

The crew explored Hamburger Sund, found a protected anchorage, and hiked inland. DC flew the P3.



A humpback whale in Hamburger Sund.



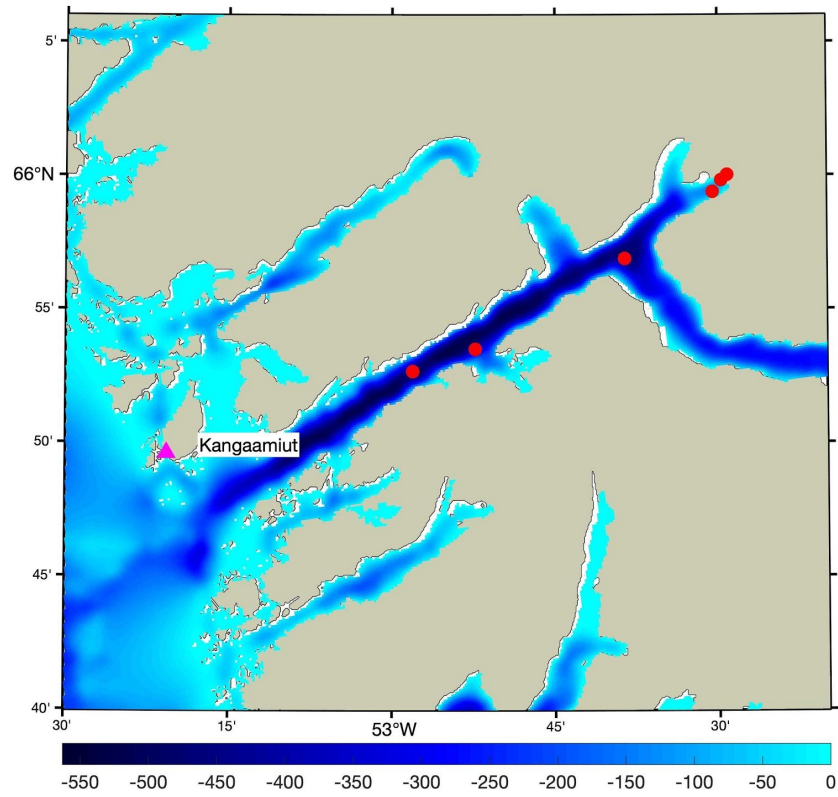
A drone image of a small bay in Hamburger Sund (65.66N, 53.12W).

Date: 14 July 2017

Location: Eternity Fjord, east of Kangaamiut (66N, 52.49W)

Summary:

Exiles sailed into Eternity Fjord in the morning. DC conducted a CTD transect and Exiles anchored near the terminus of a tidewater glacier. DC acquired some CTD profiles near the terminus that night.



A map of Eternity Fjord with CTD profile locations indicated by red circles. The pink triangle indicates the location of Kangaamiut.



Exiles at anchor near a glacier in Eternity Fjord. Only a small portion of the glacier terminus on the northern side of the fjord remains in contact with the fjord. The southern part of the glacier has retreated onto land.

Date: 15 July 2017

Location: Kangaamiut, Greenland

Summary:

Exiles left the glacier in Eternity Fjord and sailed for Kangaamiut, at the mouth of fjord. Exiles spent the night at the dock there.

Date: 16 July 2017

Location: Sailing to Sisimiut, Greenland

Summary:

After departing Kangaamiut, Exiles sailed north towards Sisimiut. WT, JL, and PL were dropped ashore and they hiked the rest of the way to Sisimiut. DC, NP, and PP continued with Exiles to Sisimiut.

Date: 17 July 2017

Location: Sisimiut, Greenland

Summary:

After departing Kangaamiut, Exiles sailed north towards Sisimiut. WT, JL, and PL were dropped ashore and they hiked the rest of the way to Sisimiut. DC, NP, and PP continued with Exiles to Sisimiut. Exiles arrived in Sisimiut around mid-day and those onboard explored the city.



The old town in Sisimiut, Greenland.

Date: 18-19 July 2017

Location: Sisimiut, Greenland

Summary:

WT, JL, and PL rejoined Exiles, but with a storm brewing out at sea, they decided to wait it out in the harbor.

Date: 20 July 2017

Location: En route to Ilulissat, Greenland

Summary:

Exiles departed Sisimiut the night of the 19th, on the heels of the storm. The swells were 3-4 m and the winds blew a steady 20-30 kts. Flying only a foresail, Exiles made a steady 6 kts under trailing winds and following seas. Near the entrance to Disko Bay, Exiles passed a large, grounded iceberg, and retrieved another bottom-mounted CTD. The winds and seas made it difficult, but luckily the flotation reached the surface only a few meters from Exiles and the instruments were recovered safely.



Exiles approached a large grounded iceberg near the entrance to Disko Bay.

Date: 21 July 2017

Location: Ilulissat, Greenland

Summary:

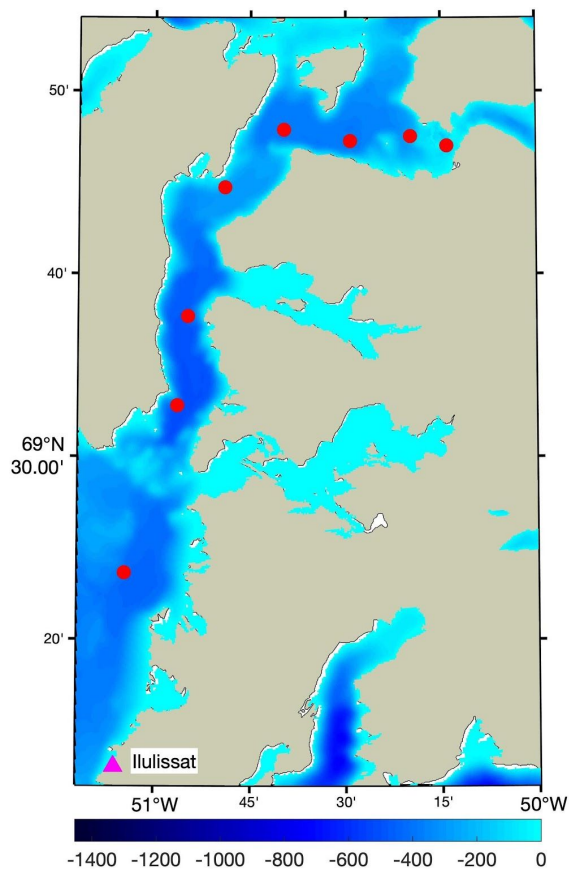
Exiles reached Ilulissat and tied up in the harbor. The crew spent the day exploring the town and the ice fjord and getting caught up with emails etc.

Date: 22 July 2017

Location: Ata Sund and Eqip Sermia, Greenland

Summary:

Exiles departed Ilulissat and sailed into Atasund, towards Eqip Sermia (the glacier at the head of the fjord). DC conducted a CTD transect and another bottom-mounted CTD was recovered. Exiles reached the terminus of Eqip Sermia around midnight and the CTD transect continued into the early hours of the 23rd.



A map of Ata Sund with CTD profile locations indicated by red circles. The pink triangle indicates the location of Ilulissat.



PP and WT recover the flotation attached to the CTD and acoustic release in Ata Sund.

Date: 23 July 2017

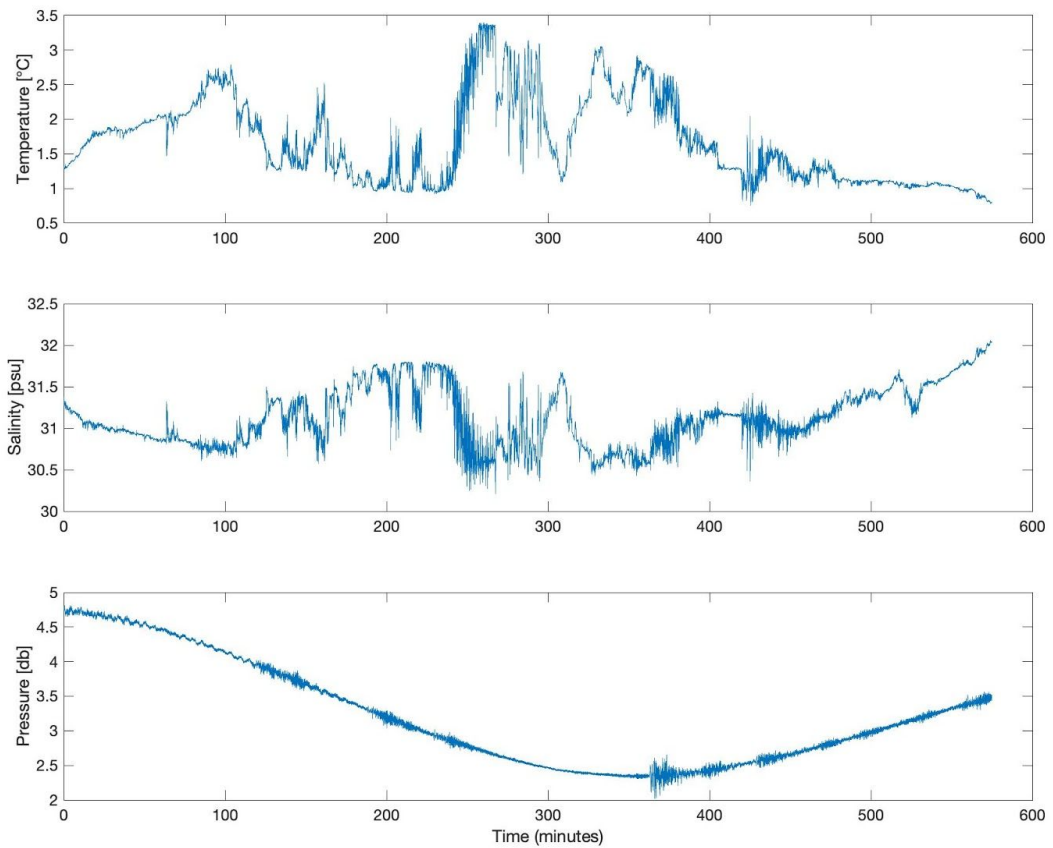
Location: Ata Sund and Eqip Sermia, Greenland

Summary:

The CTD transect continued until 04:00 local time. Exiles found an anchorage in shallow, relatively protected waters south of Ice Camp Eqi. After a short respite, NP, PP, WT, and JL went ashore. They hiked up to the glacier and spent the night. DC took the dinghy and the CastAway to collect some CTD profiles near the glacier. Afterwards, DC mounted the RBR CTD to a lobster trap and set it on the bottom near Exiles to record overnight. DC and PL went ashore that night and DC flew the P3.



The RBR CTD was mounted to a lobster trap and deployed overnight near the terminus of Eqip Sermia. The pressure sensor recorded waves that were generated by calving events.



Temperature (top), salinity (middle) and pressure (bottom) recorded by the RBR CTD that was mounted on the lobster trap. The squiggles in the pressure data correspond to waves generated by icebergs that calved from the terminus of the glacier.

Date: 24 July 2017

Location: Eqip Sermia and Vaigat

Summary:

Onboard Exiles, DC and PL awoke to strong (30 kts +) winds. NP radioed from Ice Camp Eqi and requested a pickup. DC attempted to retrieve them with the dinghy but after leaving the protected bay the waves were too large for the dinghy. PL and DC hauled the anchor and sailed towards the glacier and Ice Camp Eqi. DC launched the dinghy and retrieved the shore party. After retrieving the crew, Exiles sailed up to the terminus of the glacier. The water depth near the terminus was quite shallow (~30 m). DC collected a CTD profile with the CastAway. Afterwards, Exiles had a chat with the Royal Danish Navy and then sailed out of Ata Sund and turned northwest into the Vaigat Strait.



Exiles sails up to the terminus of the Eqip Sermia glacier (69.8N, 50.33W)

Date: 25 July 2017

Location: En route to mooring in Laks Fjord

Summary:

Exiles sailed northwest through the Vaigat Strait on her way north, passing some impressive icebergs.



Exiles sails past a large iceberg in the Vaigat Strait

Date: 26 July 2017

Location: Qeqertarsuaq Island (72.51N, 53.44W)

Summary:

Exiles sailed to the entrance of Laksfjord to retrieve a mooring and then anchored in a shallow bay on the north side of Qeqertarsuaq Island. Early in the morning, DC flew the P3 to acquire imagery that was used to construct a detailed 3D model of the iceberg using photogrammetry structure from motion software.



One of many drone images that were acquired of the iceberg pictured here. These images were used to construct a detailed 3D model of the iceberg using Agisoft PhotoScan.

Date: 27 July 2017

Location: Laksfjord

Summary:

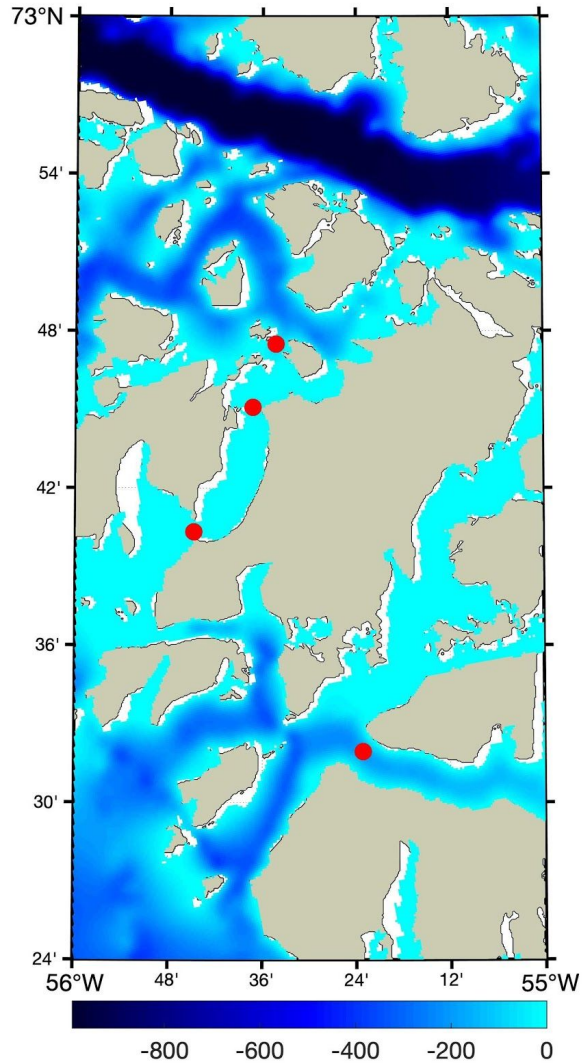
Exiles stopped at a small village and DC and WT took the dinghy to investigate an interesting dark patch on the bottom near a grounded bergy bit. DC attached a GoPro to the CTD frame and lowered it to the bottom, revealing many urchins. DC and WT sailed around the bergy bit, acquiring some interesting images in the process. Exiles then completed a CTD transect in Laksfjord on the way to Upernavik Isfjord. WT had a swim.



Many urchins on the bottom in a shallow bay in northwest Greenland (72.51N, 55.16W)



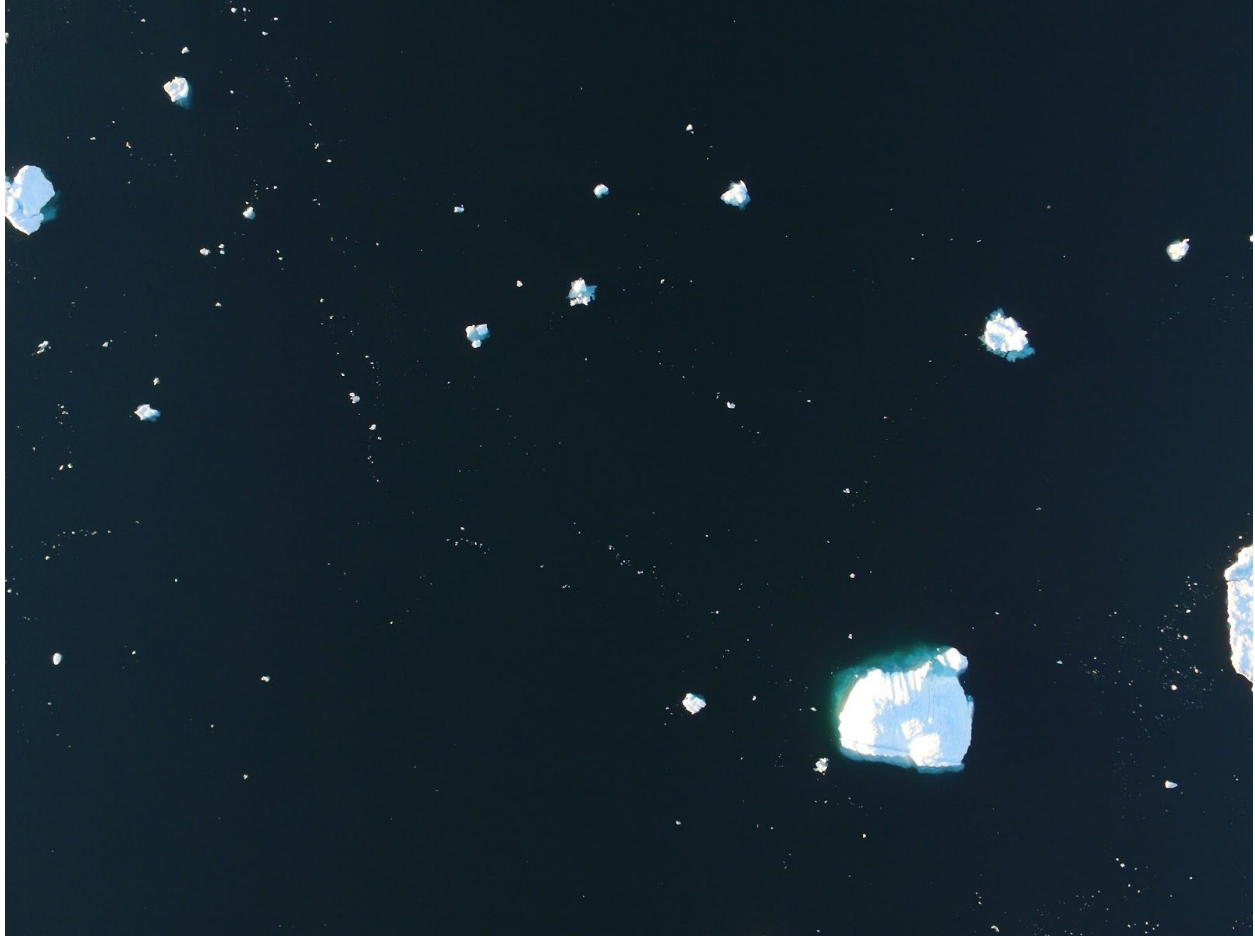
An underwater GoPro image of a backlit bergy bit keel (72.51N, 55.16W)



A map of CTD profile locations indicated by red circle near Upernavik.

Date: 28 July 2017
Location: Upernavik Isfjord
Summary:

Exiles reached the Upernavik Isfjord early in the morning on the 28th. DC flew the P3 to take some outreach video of Exiles sailing past the massive icebergs. On the second flight, DC took a time lapse of drifting icebergs. After the drone flights, Exiles navigated as close as possible to the glacier terminus and started a CTD transect. Exiles anchored in a small bay that night.



One image in a drone time lapse of drifting icebergs and bergy bits in Upernavik Isfjord (72.89N, 55.45W)

Date: 29 July 2017

Location: Upernavik Isfjord and Upernavik

Summary:

DC went ashore and hiked to the top of a ridge to fly the P3 out over the fjord. DC conducted two flights, acquiring time lapse imagery of drifting, disintegrating, and capsizing icebergs. DC rejoined Exiles and they sailed out of the fjord to the village of Upernavik.



One image in a drone time lapse of drifting icebergs and bergy bits in Upernavik Isfjord (72.89N, 55.53W)

Freshwater content

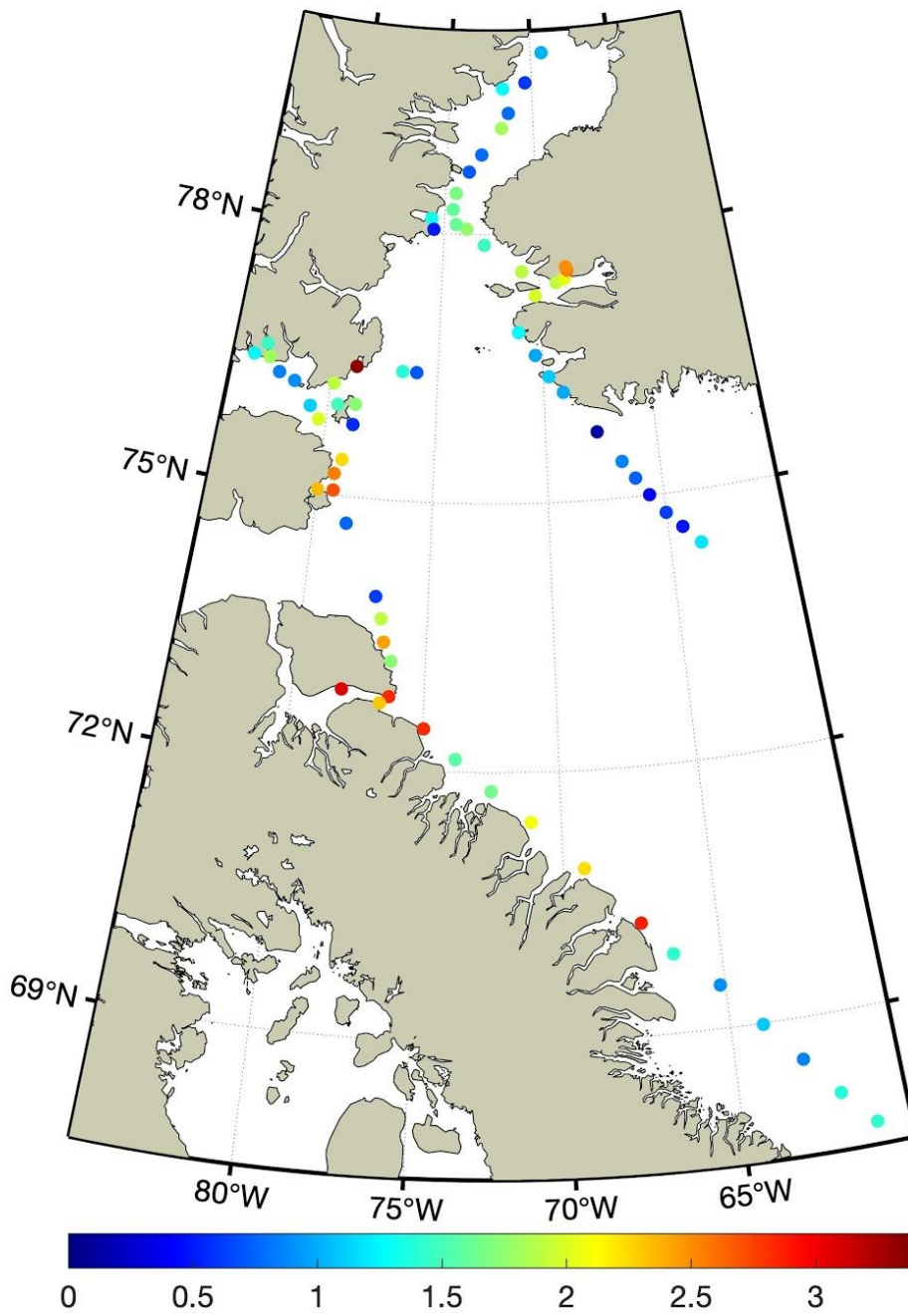


Figure 1. The freshwater content of the upper 40 m (units of m).

T-S Diagram

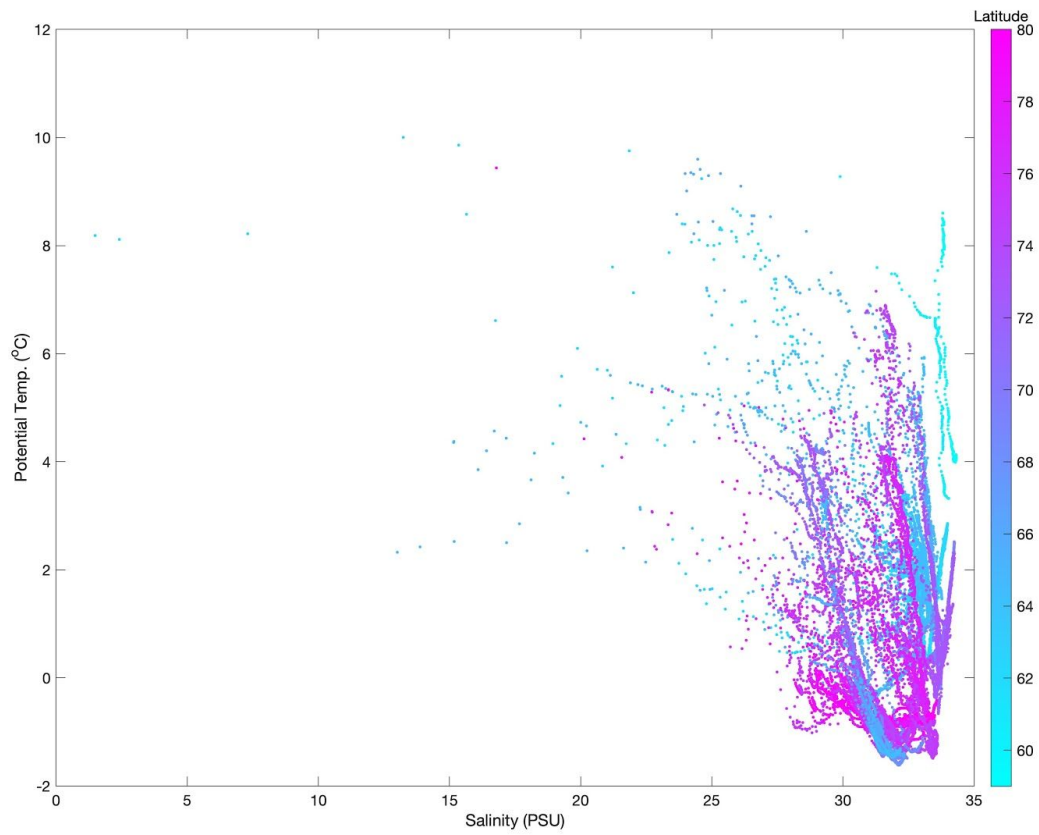


Figure 2. The temperature-salinity diagram of all measurements reveals latitudinal changes in water masses observed during the expedition. Each dot is color-coded according to latitude.

CTD Transects

Fvanefjord (Paamiut) North

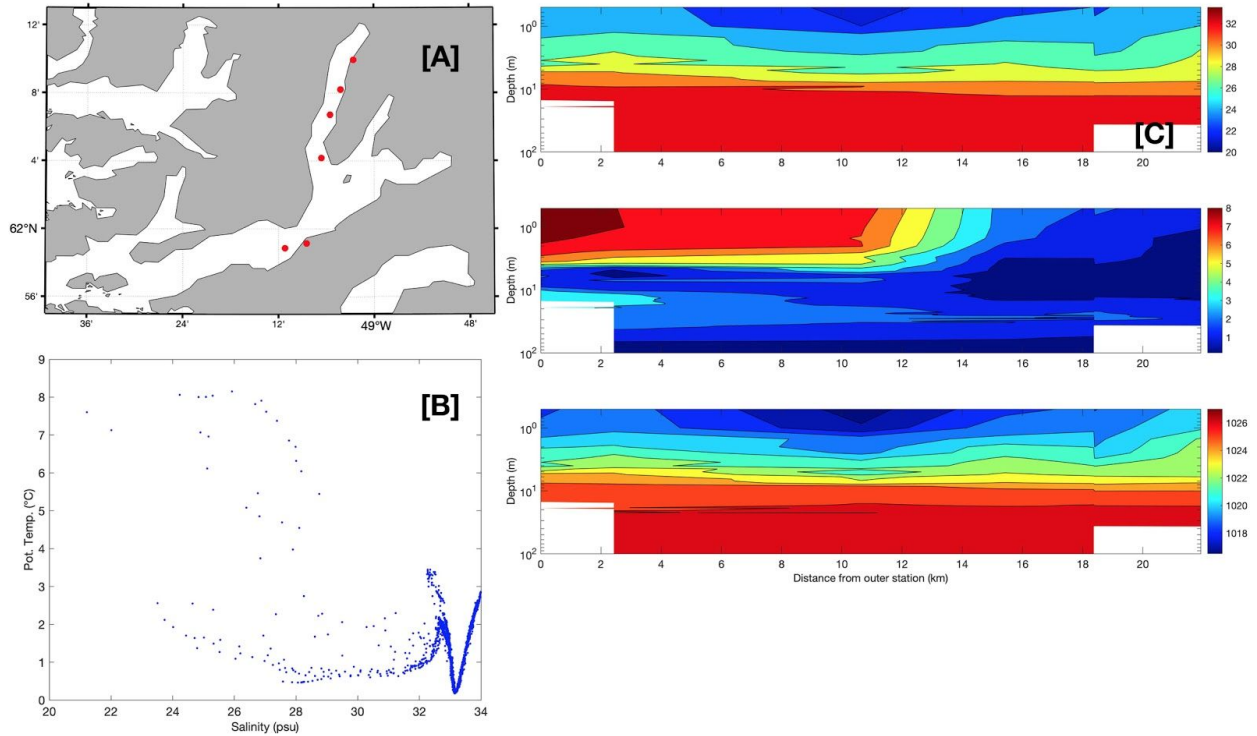


Figure 3. [A] CTD profile locations in the northern arm of Fvanefjord (near Paamiut) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the northern arm of the fjord. [C] Contour plot of salinity (top), potential temperature (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

Fvanefjord (Paamiut) Center

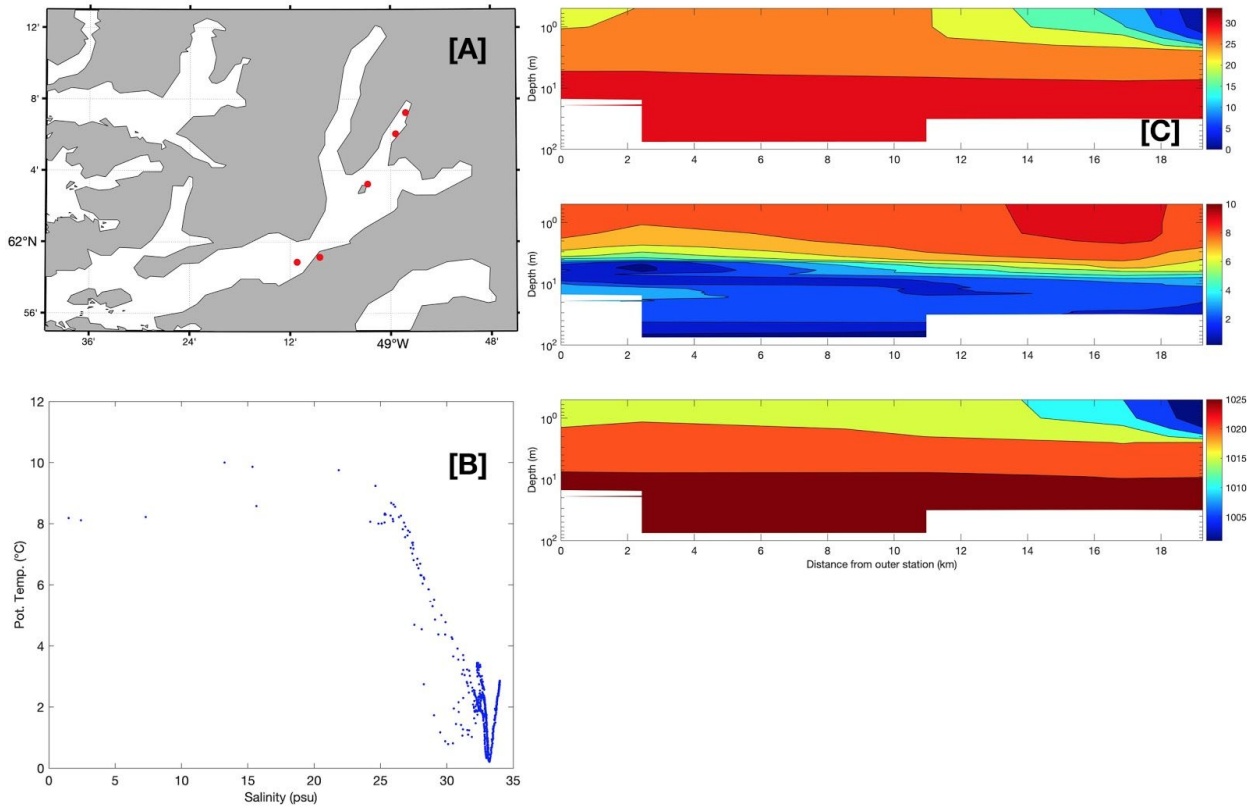


Figure 4. [A] CTD profile locations in the central arm of Fvanefjord (near Paamiut) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the central arm of the fjord. [C] Contour plot of salinity (top), potential temperature (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

Fvanefjord (Paamiut) South

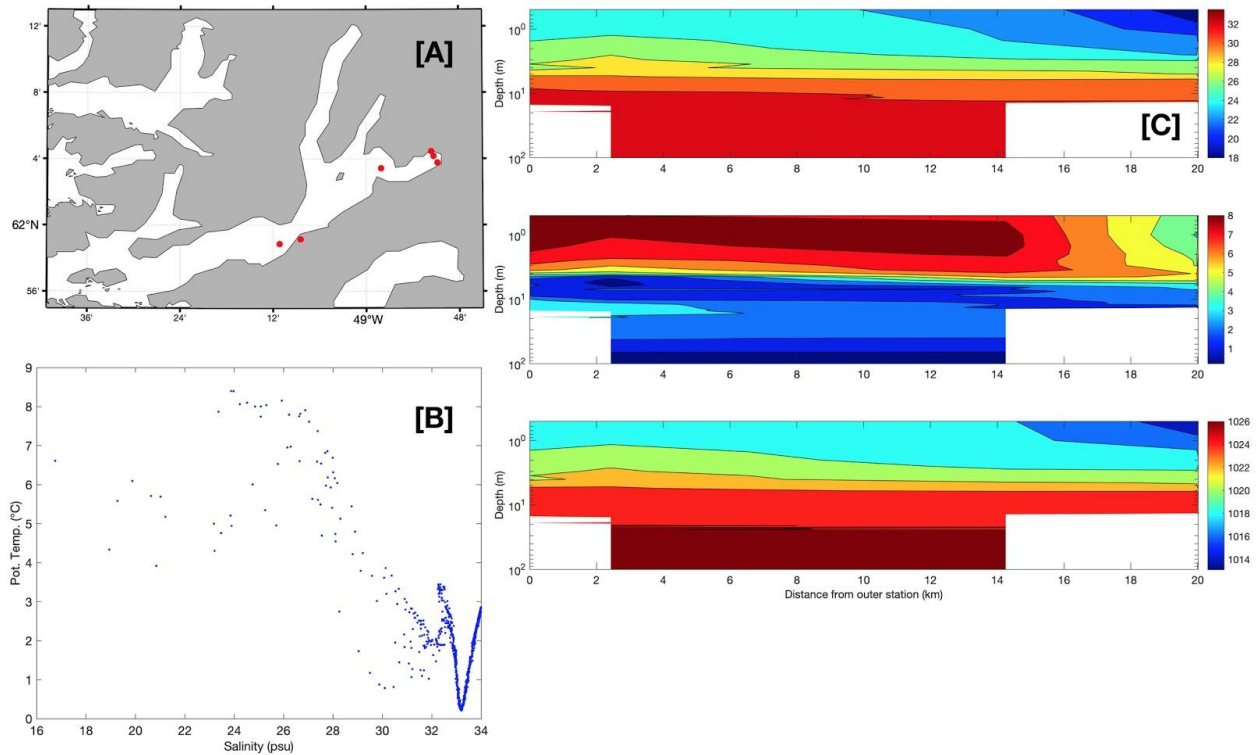


Figure 5. [A] CTD profile locations in the southern arm of Fvanefjord (near Paamiut) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the southern arm of the fjord. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

Nuup Kangerlua (Godthabsfjord) North

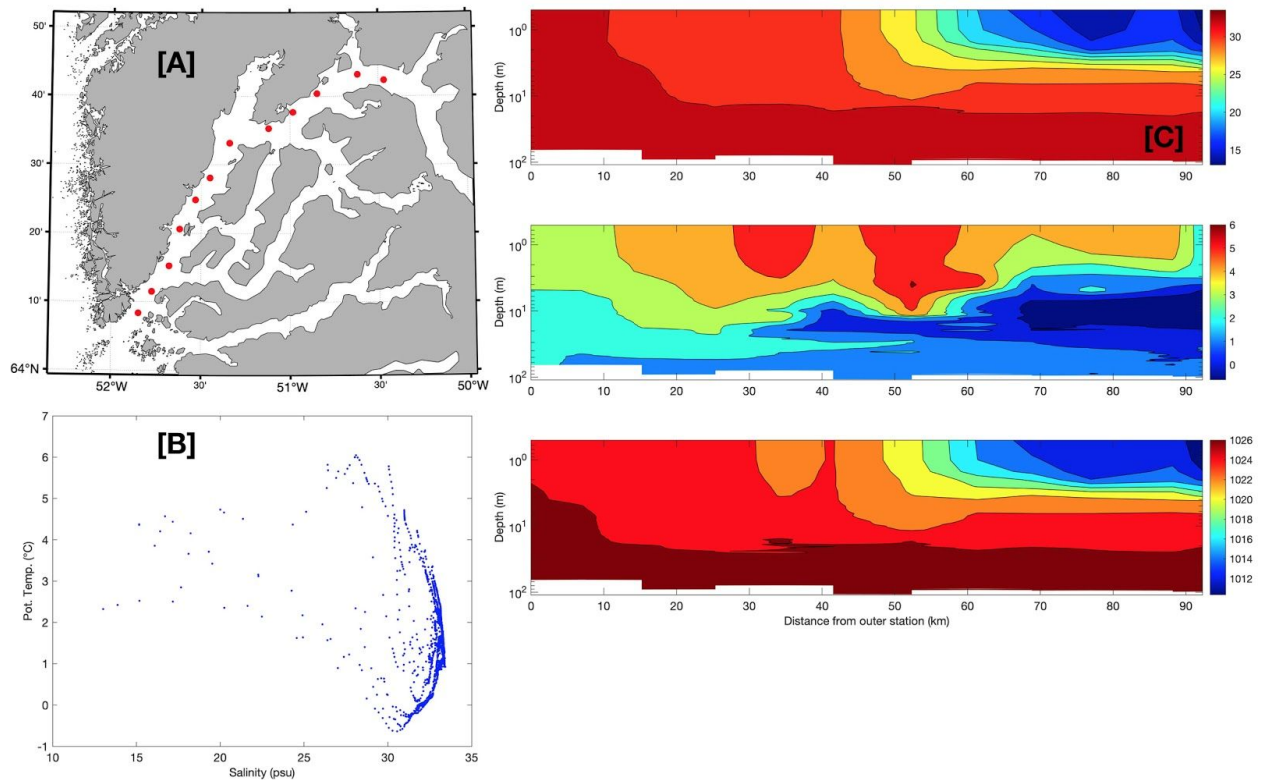


Figure 6. [A] CTD profile locations in the northern arm of Nuup Kangerlua (near Nuuk) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the northern arm of the fjord. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

Nuup Kangerlua (Godthabsfjord) Center

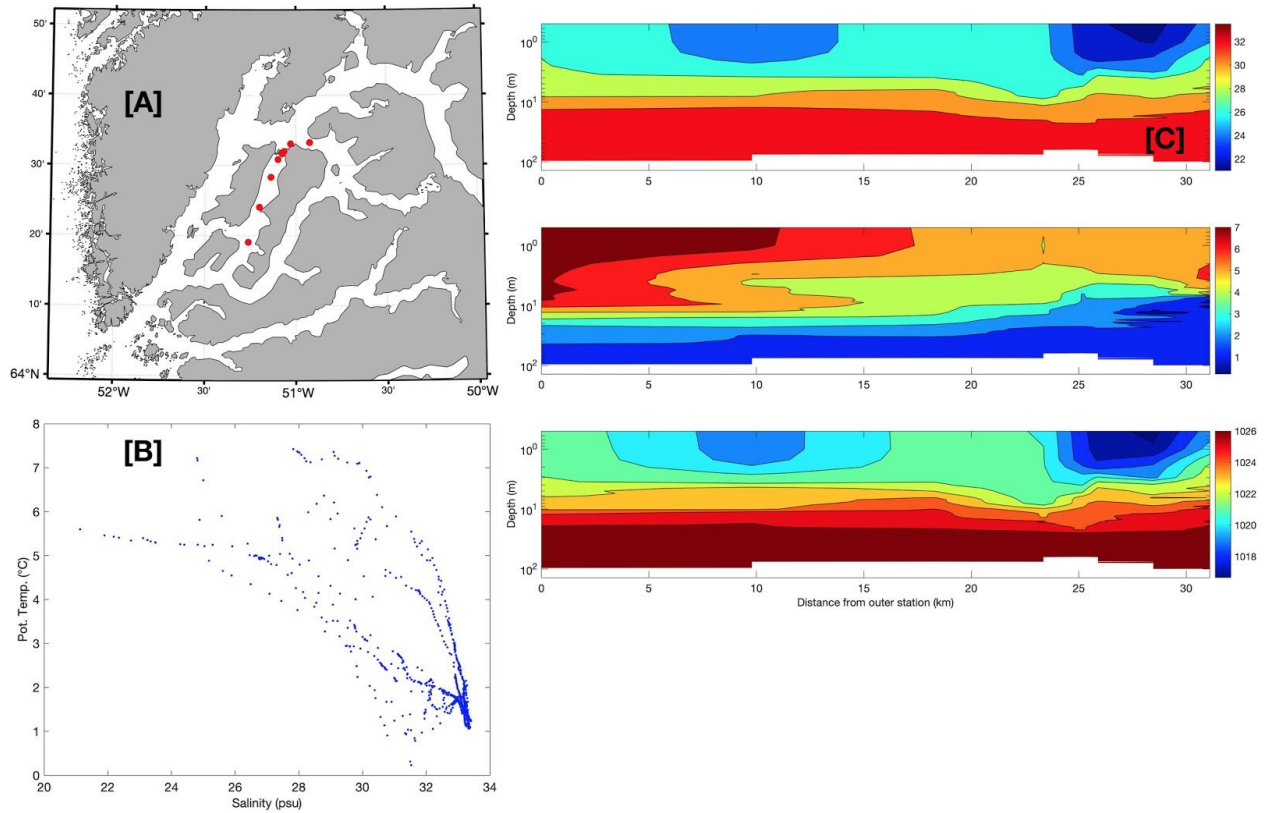


Figure 7. [A] CTD profile locations in the central arm of Nuup Kangerlua (near Nuuk) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the central arm of the fjord. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

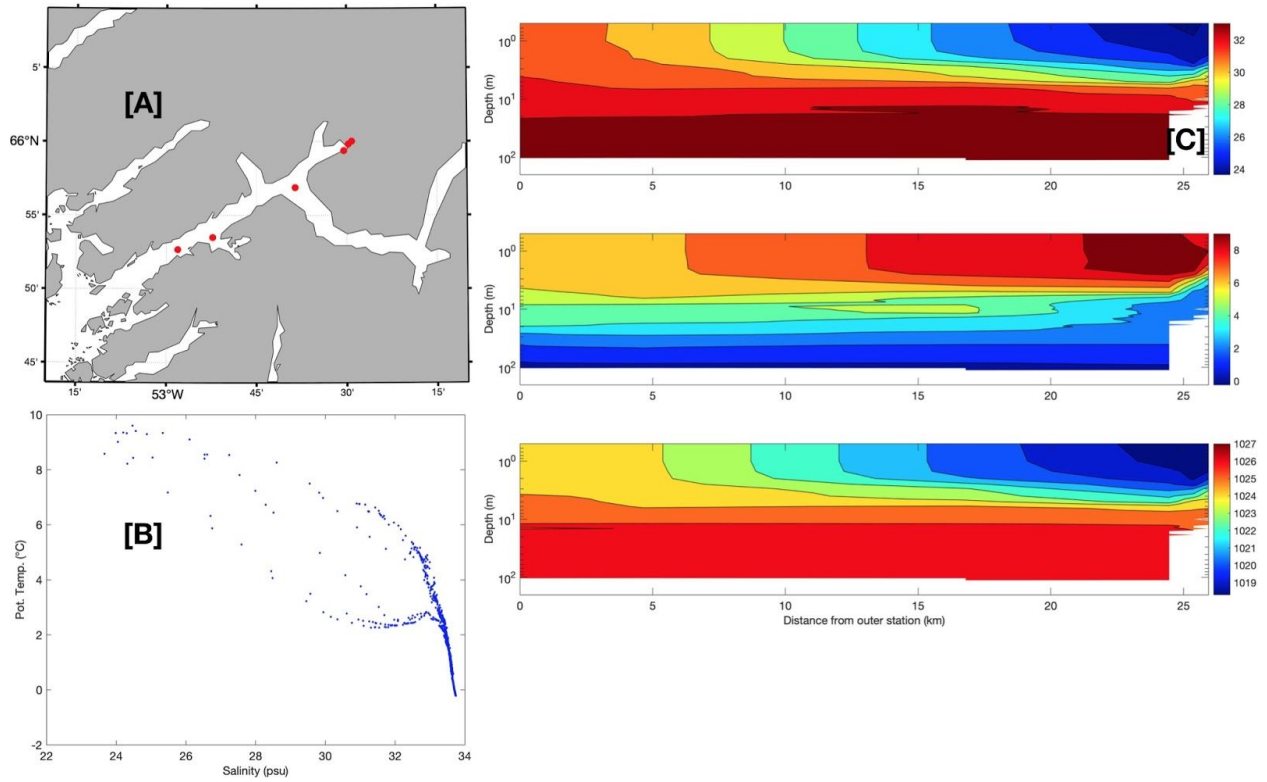


Figure 8. [A] CTD profile locations in Eternity Fjord (near Kangaamiut) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the fjord. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

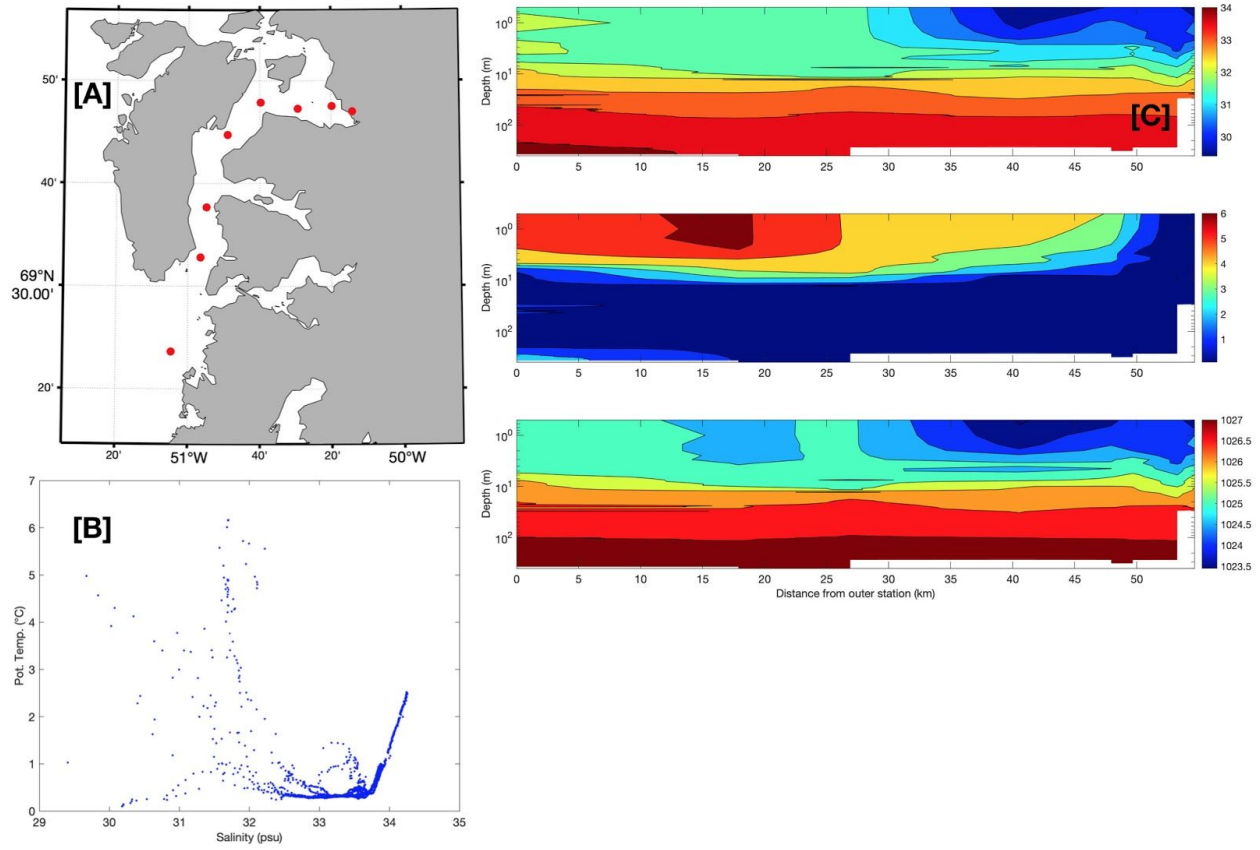


Figure 9. [A] CTD profile locations in Ata Sund (near Ilulissat) are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements in the fjord. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

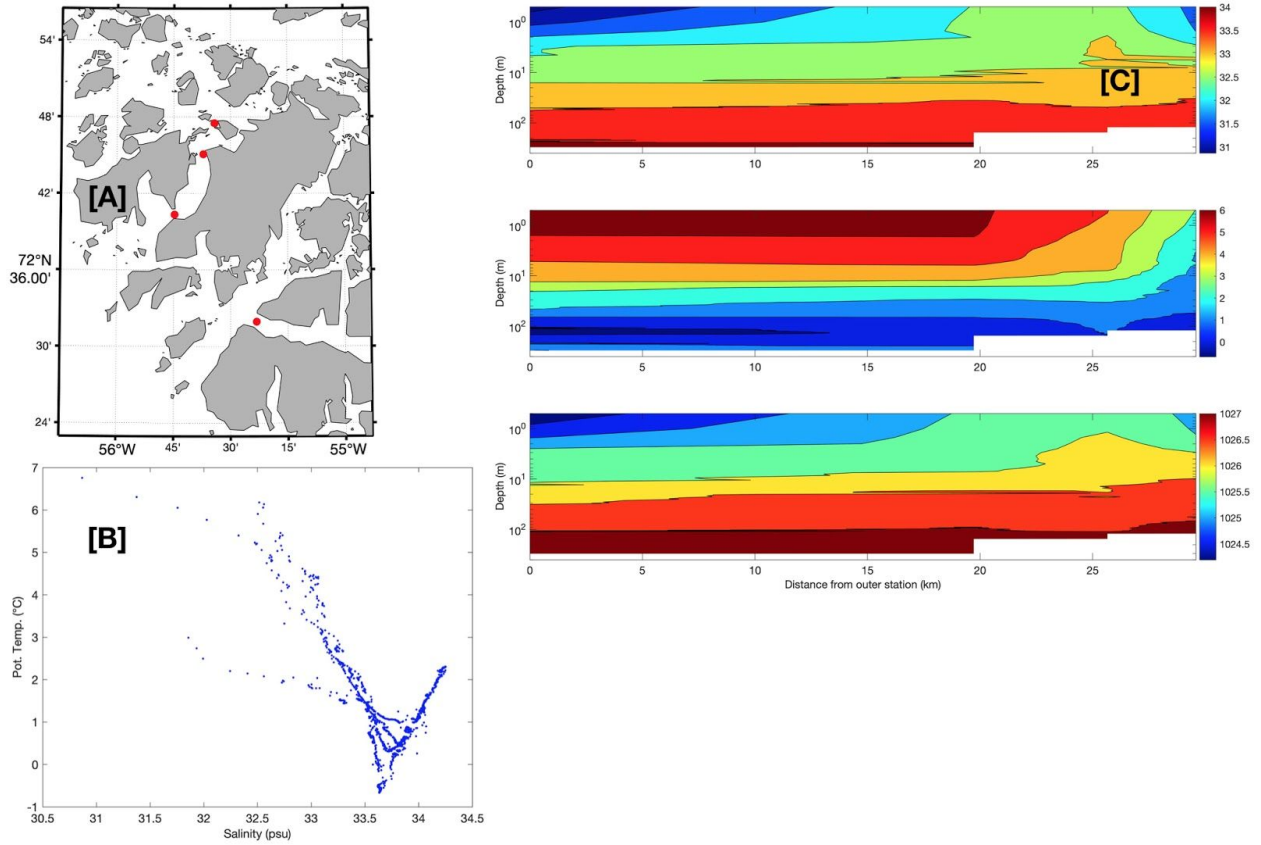


Figure 10. [A] CTD profile locations south of Upernavik Ice Fjord are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.

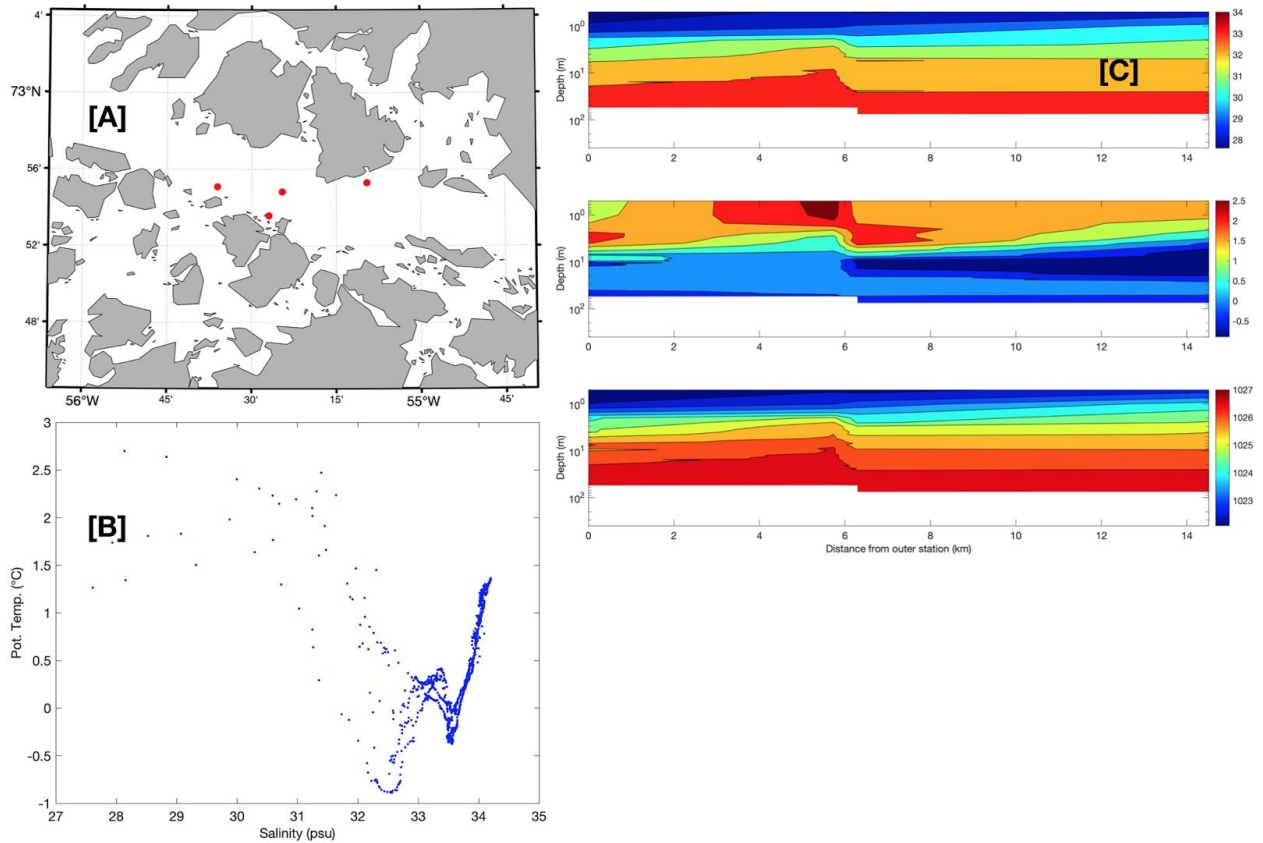


Figure 11. [A] CTD profile locations in Upernavik Ice Fjord are indicated by red circles. [B] T-S diagram of all temperature and salinity measurements. [C] Contour plot of potential temperature (top), salinity (middle), and potential density (bottom). Note that depth is plotted on a log scale to emphasize near-surface gradients.