Joint Ocean Ice Study / Beaufort Gyre Exploration Project
2022 Cruise Report

Photo by James Kuo

Report on the oceanographic research conducted aboard the *CCGS Louis S. St-Laurent,* September 15th to October 13th, 2022*
IOS Cruise ID 2022-045

* Sail dates, w/in this science had 25 days.

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Contents

1 OVERVIEW

The Joint Ocean Ice Study (JOIS) in 2022 is an important contribution from Fisheries and Oceans Canada to international Arctic climate research programs and is jointly supported by Fisheries and Oceans Canada and the National Science Foundation.
It is a collaboration between researchers from Fisheries and Oceans Canada (lead: Bill Williams lead) and, in the USA, from Woods Hole Oceanographic Institution (lead: Isabela Le Bras) and Yale University (Mary-Louise Timmermans). The scientists from WHOI and Yale University lead the Beaufort Gyre Exploration Project (**https://www2.whoi.edu/site/beaufortgyre/**) which maintains the Beaufort Gyre Observing System (BGOS) as part of the National Science Foundation's Arctic Observing Network (AON).

The 2022 program includes collaborations with researchers from the following nations and institutions:

USA:
- Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.
- Yale University, New Haven, Connecticut.
- Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.
- University of Montana, Missoula, Montana.
- Oregon State University, Corvallis, Oregon.

Japan:
- Japan Agency for Marine-Earth Science and Technology (JAMSTEC), as part of the Pan-Arctic Climate Investigation (PACI).
- Tokyo University of Marine Science and Technology (TUMSAT), Tokyo.
- Kitami Institute of Technology, Kitami, Hokkaido.

Switzerland:
- ETH Zurich, Zurich.

Canada:
- Fisheries and Oceans Canada, Institute of Ocean Sciences (DFO-IOS), Sidney, British Columbia
- Fisheries and Oceans Canada, Bedford Institute of Oceanography (DFO-BIO), Dartmouth, Nova Scotia
- Université de Sherbrooke, Sherbrooke, Québec
- Université Laval, Québec City, Québec.
- Concordia University, Montreal, Québec
- University of Victoria, Victoria, British Columbia

Research questions seek to understand the impacts of global change on the physical and geochemical environment of the Canada Basin of the Arctic Ocean and the corresponding biological response. We thus collect data to link decadal and inter-annual variation in the Arctic atmosphere and ocean to basin-scale changes in the Beaufort Gyre Region, including the freshwater content of the Beaufort Gyre, freshwater sources, ice properties and distribution, water mass properties and distribution, ocean circulation, ocean acidification and biota distribution.

Table 1. Project websites

Project	Website Address
Beaufort Exploration Project	https://www2.whoi.edu/site/beaufortgyre/
Beaufort Gyre Observing System dispatches	https://www2.whoi.edu/site/beaufortgyre/expeditions/2022-expedition/2022-dispatches/
Ice-Tethered Profiler buoys	https://www2.whoi.edu/site/itp/
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
Arctic Ocean Flux Buoy	www.oc.nps.edu/~stanton/fluxbuoy/

2 CRUISE SUMMARY

The JOIS/BGOS science program onboard the *CCGS Louis S. St-Laurent* began September 15th , departing from Cambridge Bay, NU and finished October 13th , 2022, back in Kugluktuk with 25 days dedicated to science. The research was conducted in the Canada Basin from the Beaufort Slope in the south to close to 80°N in the north by a research team of 26 people from 9 institutions from 4 countries, including 6 students (undergraduate and graduate students). Full depth CTD/Rosette casts with water samples were conducted. These casts measured biological, geochemical and physical properties of the seawater. Underway expendable temperature and salinity probes (XCTDs) were deployed between the CTD/Rosette casts to increase the spatial resolution of CTD measurements. Moorings and ice-buoys were serviced and deployed in the central and northern Beaufort Gyre to collect year-round time-series data. Underway ice observations and on-ice surveys were conducted. Zooplankton net tows, phytoplankton and bacteria measurements were collected to examine distributions of the lower trophic levels. Underway measurements were made of the surface water. Daily dispatches were posted to the web. The location of science stations, the primary sampling at each station, and the total number of each type of station, are shown in Figure 1 below.

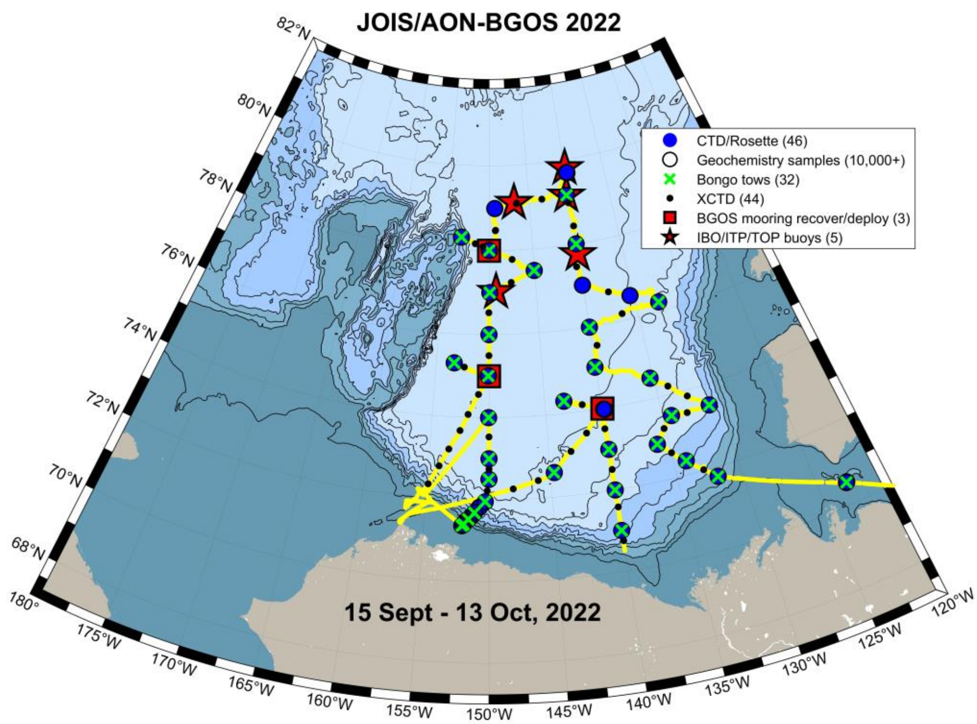


Figure 1. The JOIS/BGOS-2022 cruise track showing the location of science stations.

Following the JOIS program, opportunistic sampling was conducted from the CCGS Sir Wilfrid Laurier, deploying 11 XCTDs across the south-west Beaufort Sea. Although not part of this program, the XCTDs were conducted in support of the Beaufort Sea observations and are listed in the appendix.

2.1 Program Components

Measurements:

- At CTD/Rosette Stations:
    - 46 CTD/Rosette Casts at 41 Stations (DFO) with 1028 Niskin bottle water samples collected for hydrography, geochemistry and pelagic biology (bacteria, microbial diversity and phytoplankton) analysis (DFO, Sherbrooke U, TUMSAT, WHOI, Yale, U Laval, Concordia, JAMSTEC, UVic, ETH Zurich).
    - Water samples taken:
        - At all full depth stations: Salinity, dissolved O_2 gas, Nutrients (NO_3+NO_2, PO_4, SiO_4), ^{18}O isotope in H_2O, Bacteria, Alkalinity, Dissolved Inorganic Carbon (DIC), Fluorescent Dissolved Organic Matter (FDOM), Chlorophyll-a
        - At selected stations: microbial diversity, radio-nuclides (^{129}I, ^{236}U, ^{14}C, ^{39}Ar), Barium, Dissolved Organic Matter (DOM), Lignin-phenols (from underway system only), Transparent Extracellular Polysaccharides (TEP), lithogenic material (Nd, Hf)
    - Zooplankton Vertical Net ("Bongo") Casts at 32 CTD/Rosette stations with one cast to 100m. The two nets per cast have a mesh size of 150 µm. (DFO).
- 46 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1100m depth. (DFO, JAMSTEC, WHOI)
- Mooring operations at 3 sites (WHOI, UMontana, USherbrooke)
    - 3 Mooring Recoveries and Re-deployments in the deep basin (BGOS-A,B,D; WHOI)
- Buoy operations at 5 sites (WHOI, Yale, CRREL,U Montana, NPS)
    - Ice Based Observatory (IBO) 1 Ice Station with:
      1 Ice-Tethered Profiler (ITP 130, WHOI)
    - IBO 2 Ice Station with:
      1 Ice-Tethered Profiler w/ SAMI-CO2 (ITP 136, WHOI, UMontana)
      1 Tethered Ocean Profiler (TOP005, WHOI)
      1 Arctic Ocean Flux Buoy (AOFB 47, NPS)

1 Seasonal Ice Mass Balance Buoy (SIMB-2021#7, CRREL)

- IBO3 Ice-Station with:
  1 Ice-Tethered Profiler w/ SAMI-CO2 (ITP 137, WHOI, UMontana)
  1 Tethered Ocean Profiler (TOP006, WHOI)
  1 Seasonal Ice Mass Balance Buoy (SIMB-2021#6, CRREL)
- IBO4 Ship-based deployment in open water with:
  1 Ice-Tethered Profiler (ITP 131, WHOI)
- IBO5 Ship-based deployment in open water with:
  1 Tethered Ocean Profiler (TOP007, WHOI)

- Ice Observations (KIT/OSU)
  - Visual ice observations were made hourly from the bridge during daylight hours while in ice.
  - Automated photographs were taken from 3 cameras: forward looking, mounted above bridge with 1 minute interval, port side looking down on the overturning ice with a measuring stick in view at 10 second interval, forward looking mounted inside bridge window at 1 minute interval

    In addition, a self-contained unit with multiple cameras (upward, forward and downward looking) and GPS was trailed. It was mounted above the bridge on the port side to somewhat overlap images with the other cameras.
  - Underway ice thickness measurements from and electromagnetic inductive sensor (EM31-ICE).
  - On-ice measurements at the ice-stations including:
    - Drill-hole ice thickness transects
    - Snow structure observations
    - Ice-cores for temperature, salinity and structure profiles
    - Ice-cores for TEP (UVic)

- Underway collection of meteorological, depth, and navigation data, and near-surface seawater measurements of salinity, temperature, chlorophyll-a fluorescence, FDOM fluorescence and pCO2 (DFO-IOS, USherbrooke, UMontana).

Water samples (100) were collected from the underway seawater loop for salinity, nutrients, chlorophyll, DIC and alkalinity (DFO), and FDOM (USherbrooke).

- Daily dispatches to the web (WHOI/Yale)

2.2 Comments on Operation

Due to the ice conditions associated with the timing of the cruise, we chose to travel anti - clockwise around the Beaufort Gyre, allowing us to work in the heavier ice area of the southeast Beaufort before freeze-up began in earnest, to reach the northern area where the ice-buoys were deployed before losing too much daylight, and to allow some freeze-up to begin in the western Beaufort which can help dampen waves in high winds.

The three on-ice stations were performed by parking the ship within an ice floe, lowering the gangway for people to walk out to the ice. The ship's crane transferred gear to and from the ice. This method worked well. Multiple science teams could start working quickly once the ladder was down and gave easy access to the ship for workers on the ice. Due to the weak ice at the first ice-station, the number of workers and the extent of the science operations on the ice were restricted to an ITP deployment. New this year, one of TOP buoys was deployed in open water over the side of the ship. The success of this method and data will be important for future years, as open water deployments may become a necessary standard.

See the figures below for details of the ice cover during the expedition. Figures are from the Canadian Ice Service showing Western Region Ice Concentration and Stage (source: https://iceweb1.cis.ec.gc.ca/Archive/page1.xhtml) and the National Snow and Ice Data Center showing Arctic-wide sea-ice extent (source: https://nsidc.org/data/seaice_index/archives)

There was an ice specialist from the Canadian Ice Service on board. Her daily briefings prepared for the ship regarding weather, sea-state and ice-conditions. Knowing current conditions and forecasts helped us decide how to budget program time, the order of operations, find the appropriate ice for the buoy placement. We were fortunate with good weather and did not have to cancel or postpone any stations or mooring operations due to weather, although winds were high enough at times to cancel the zooplankton casts.

The three mooring recoveries this year were for systems that had been in place for 1 year. The transponders and acoustic releases worked as planned which made the operations, particularly the ice-covered operation run as smoothly as possible. The recoveries and redeployments went well.

International participants from Japan and Europe were able to join us this year as COVID related travel restrictions have eased. This meant a return to the ice-observation work normally done and additional geochemistry sampling was possible.

An initial trip to Utqiagvik, AK was made to offload a scientist whose home in Florida was severly damaged by Hurricane Ian. The timing fit well with science stations being performed close to Utqiagvik.

A couple of days later, an emergency medivac occurred via USCG helicopter and required a return to Utqiagvik, AK to reboard our health officer. Science operations were suspended for a day.

The ship's helicopter was not in service for the first two thirds of the program due to Transport Canada's grounding of the helicopters while an investigation into an earlier crash of the same type of helicopter was being performed. This impacted the start of the program by roughly 12 hours where the crew change was switched to a more sheltered location (from Kugluktuk to Cambridge Bay) for barge operation.

All of the various science programs aboard the ship, that together build this inter-disciplinary expedition, were conducted successfully. Individual reports on each program are provided below.

Completion of planned activities:

Our primary goals, save the CTD/Rosette stations along the southern end of the 140W line, were met during this successful program due to efficient use of time by science and the ship, and the unflagging support from the officers and crew.

We missed a total of 9 CTD/Rosette stations. Some of these simply reduced spatial coverage, and others left areas uncovered. The first was adjusted in order to have daytime operations for moorings and buoys (CB12.5 replaced CB12 and CB13). The rest were missed due to lack of time from a neccary medivac to Utqiagvik, AK (CB6, CB22, MK6, MK4, MK3, MK2, MK1, CB28aa).

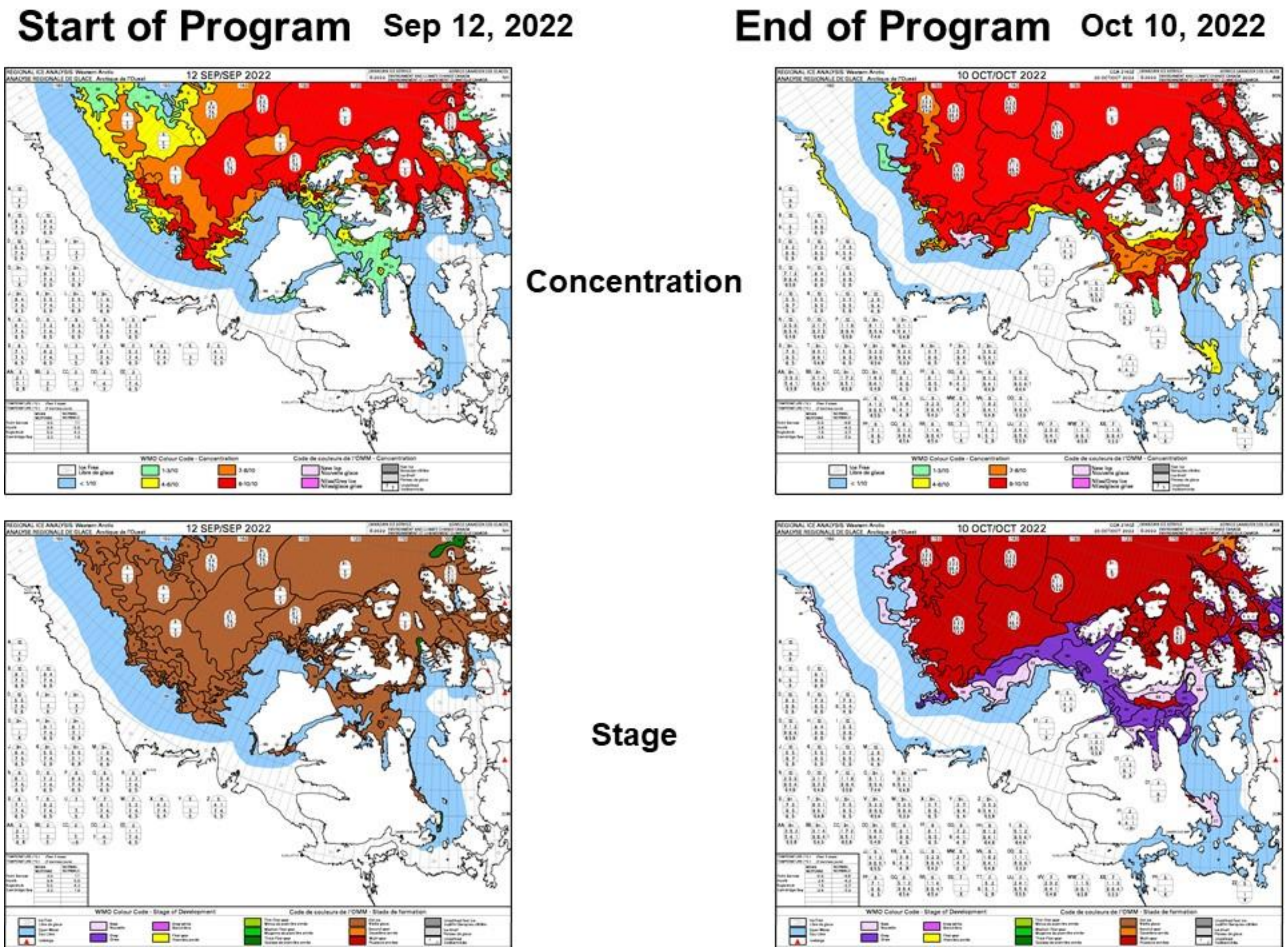


Figure 2. Ice conditions at the start and end of the program.

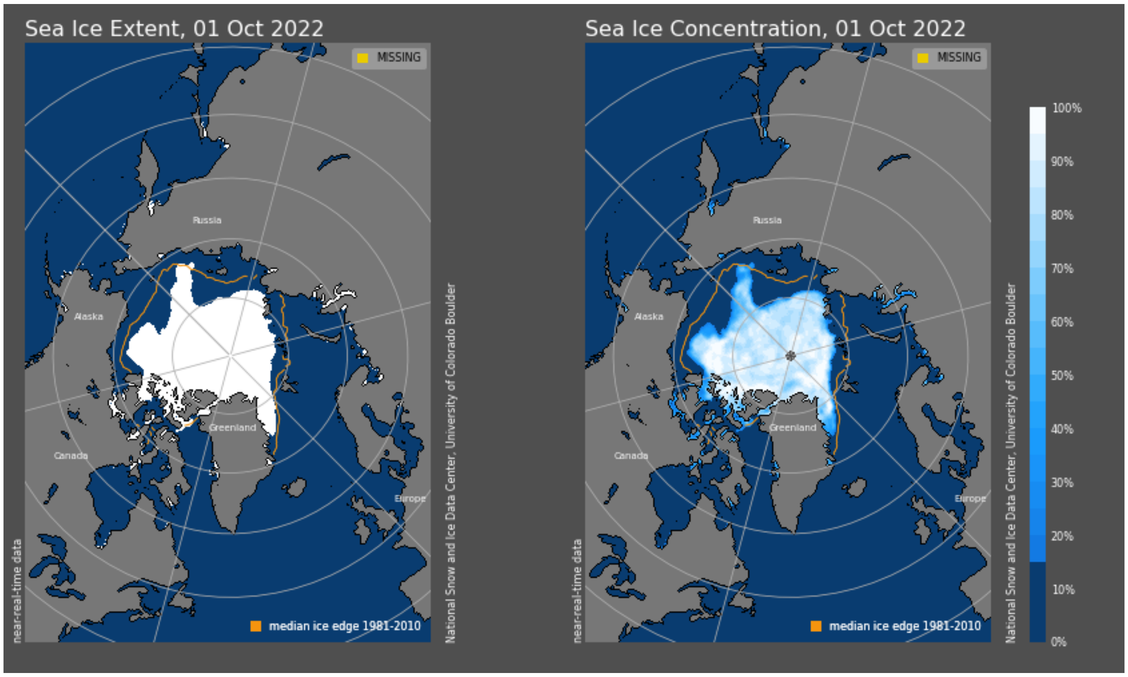
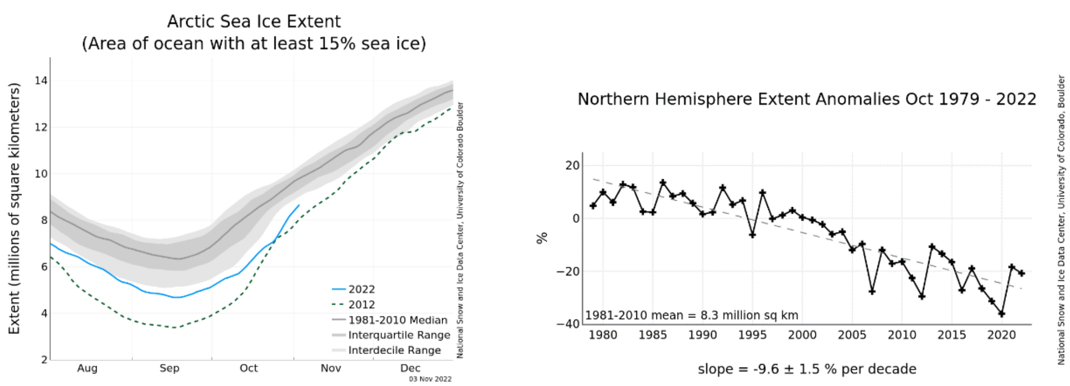


Figure 3. Sea Ice Extent and Concentration from the midpoint of this year's cruise. Images from the National Snow and Ice Data Center:

[Index of /pub/DATASETS/NOAA/G02135/north/daily/images/2022 (nsidc.org)]



Figures 4. Sea Ice Extent and Extent Anomaly from National Snow & Ice Data Center (source: http://nsidc.org/arcticseaicenews/)

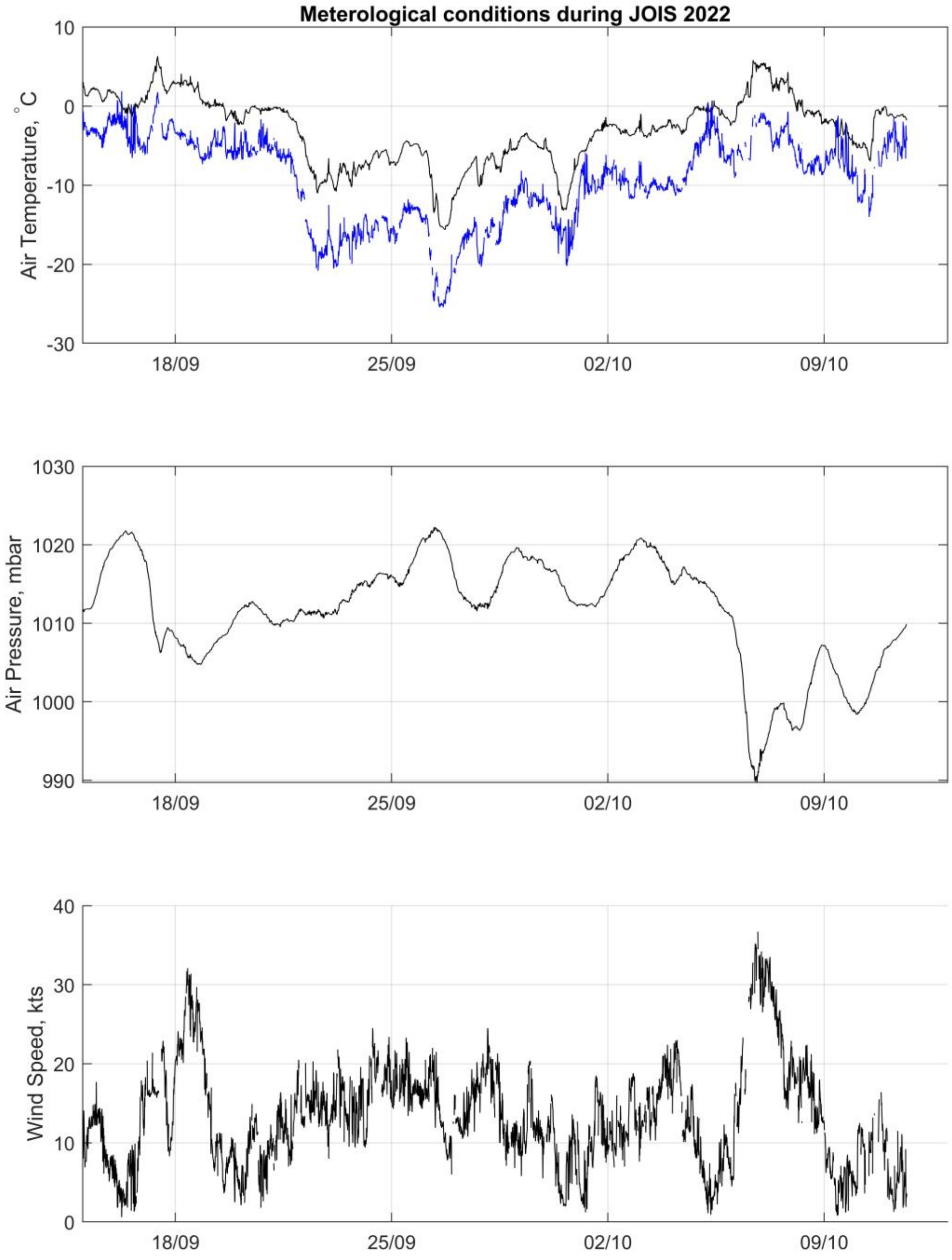


Figure 5. Temperature (black), wind chill temperature (blue), air pressure and wind speed for the duration of the expedition from the ship's AVOS weather station above the bridge of the CCGS Louis S. St-Laurent.

3 ACKNOWLEDGMENTS

The science team would like to thank Captains Jim Chmiel and Wayne Duffett and the crews of the *CCGS Louis S. St-Laurent* and the Canadian Coast Guard for their support. Pre-cruise work to address our wish-list from last year was completed. At sea, we were very grateful for everyone's performance and assistance with the program. The ice specialist from the Canadian Ice Service gave daily briefings that were much appreciated. The health officer's work this year with COVID protocols and testing, along with a number of cases requiring his attention showed how key it was to have a health officer onboard. The helicopter pilot and engineer, when allowed to fly again towards the end of the program were very helpful and highlighted the time-savings the helicopter provides. A special thank you to the bosun Rico and the engineering department for attending to the CTD winch which required extra attention this year.

Importantly, we'd like to acknowledge Fisheries and Oceans Canada, the National Science Foundation (USA), National Institute for Polar Research (Japan) and the Japan Agency for Marine Earth Science and Technology for their continued support of this program.

This was the program's 20th consecutive year and the exciting and valuable results are a direct result of working with such experienced, well trained and professional crews.

Figure 6. Ship and science personnel. Photo by Gary Morgan

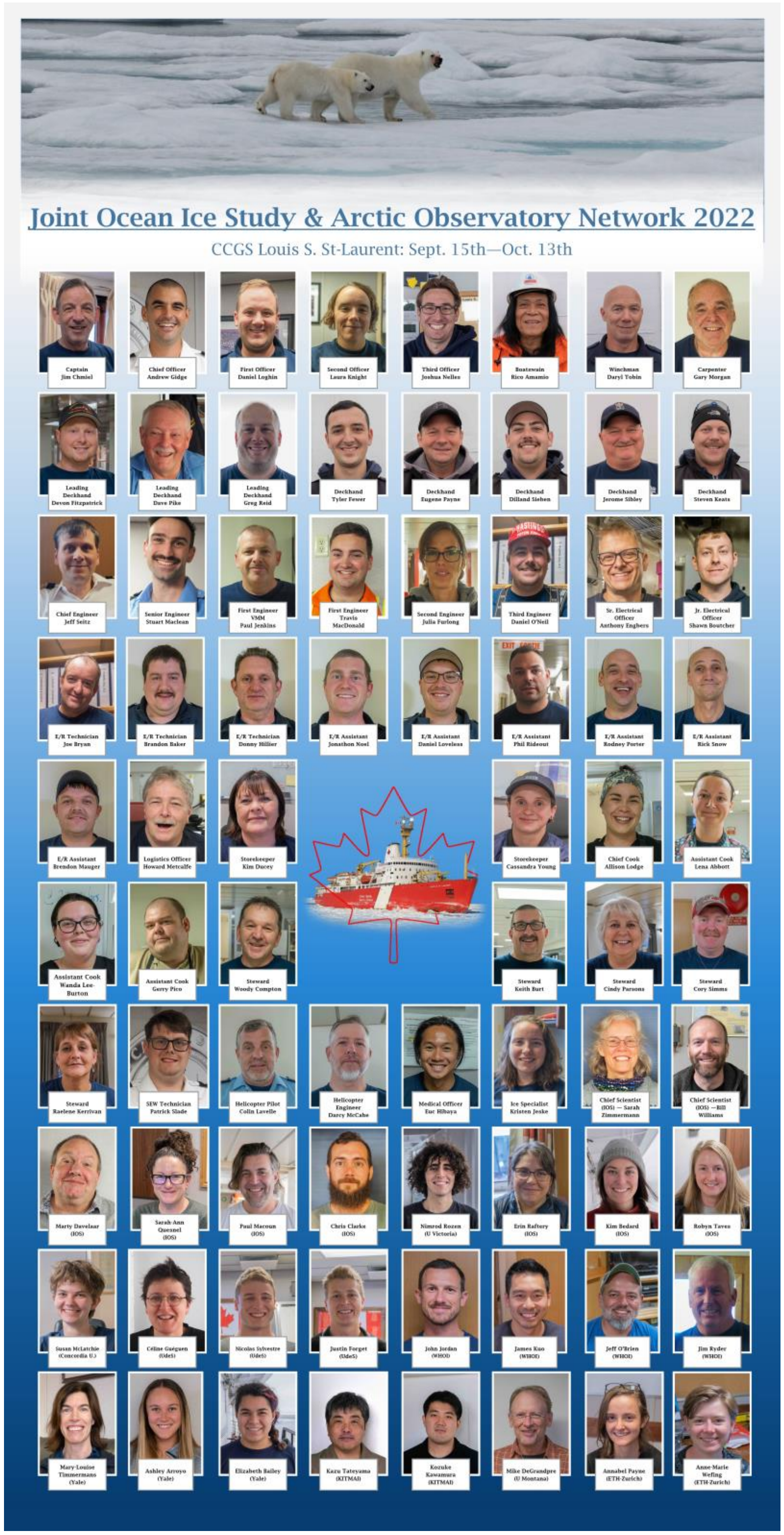


Figure 7. All crew and science on board. Poster made by Elizabeth Bailey

4 PROGRAM COMPONENT DESCRIPTIONS

Descriptions of the programs are given below with event locations listed in the appendix. Please contact program principle investigators for complete reports.

4.1 Rosette/CTD Casts

PI: Bill Williams (DFO-IOS)
Chris Clarke, Paul Macoun, Sarah Zimmermann (DFO-IOS)

4.1.1 Overview

A Seabird 9/11+ CTD system was used with SBE9+ s/n 756 CTD the entire cruise. The CTD was mounted on an ice-strengthened rosette frame configured with a 24-position SBE-32 pylon with 10L Niskin bottles fitted with internal stainless steel springs. The rosette has been modified to accommodate extra instrumentation by adding an extension on the bottom of the frame.

The data were collected real-time using the SBE 11+ deck unit and computer running Seasave V 7.26.7.107 acquisition software. The CTD was set up with two temperature sensors, two conductivity sensors, dissolved oxygen sensor, and chlorophyll fluorometer, all with pumped flow. Also on the CTD was a transmissometer, CDOM fluorometer, cosine PAR and altimeter. In addition, an Alec RINKO III dissolved oxygen sensor was used for comparison and sensor testing purposes for most casts.

This year, WHOI added an experimental "D2" CTD sensor/logger and its battery pack to the rosette frame. The temperature and salinity sensor was mounted as close as possible to the sensors of the SBE9+ in order to be able to reasonably compare data.

A surface PAR sensor connected to the CTD deck unit was integrated into the CTD data for all casts. In addition, a serial communicating surface PAR sensor providing continuous 1hz data was mounted beside the other SPAR unit. Continuous PAR data was collected for the whole cruise. These 1-minute averaged data are reported with the underway suite of sensors.

A typical station started with a CTD cast down to 10 m off the seafloor. While in the water, at most stations where weather allowed, a zooplankton vertical net hauls (bongo nets) to 100m would occur from the foredeck. At 8 stations, water was collected from 2 niskins on the foredeck winch wire (along with a SBE19+ CTD) for hafnium/neodymium analysis. At 5 stations, a shallow CTD cast for microbial diversity sampling ("RNA/DNA") was performed and was followed by a full geochemistry cast. Casts were also done at mooring and ITP/TOPP/flux buoy deployment and recovery sites. During JOIS 2022, there were a total of 46 CTD/Rosette casts

Figure 3. Rosette operation on deck with Hawboldt winch and Brooks Ocean Instrumented Sheave display box mounted on the right.

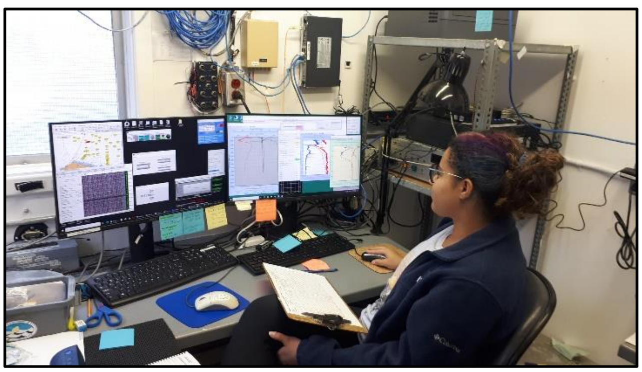


Figure 4. CTD operator and acquisition display in the CTD lab.

Figure 5. Recovered rosette being brought in for sampling.

Figure 6. CTD electronics and D2 logger inside the ring of Niskin bottles.

4.1.2 During a typical deployment

On deck, the transmissometer, CDOM sensor, and Rinko III sensor windows were sprayed with deionised water and wiped with a Kimwipe prior to each deployment. The CTD/Rosette was lowered to 10m and the pumps turned on. This soak cools the sensors to ambient sea water temperature and removes bubbles from the sensors. After 3 minutes, the package was brought up to just below the surface to begin a clean cast, and lowered at 30m/min to 300m, then at 60m/min to within 10m of the bottom. Routinely, the winch was switched from low to high gear and vice versa at 900m to make operations smoother. Niskin bottles were closed during the upcast, normally without a stop. For surface bottles, and where multiple bottles were closed at the same depth, the rosette was "yo-yo'd" to mechanically flush the bottle, meaning it was stopped for 30sec, raised 1m, lowered 2m, raised 1m, and stopped again for 30 seconds before bottle closure. The bottles closed using this method are indicated in the rosette log and water sample data spreadsheet ("chemistry spreadsheet"). The instrumented sheave (Brook Ocean Technology) provided a read out to the winch operator, CTD operator, main lab and bridge, allowing all to monitor cable out, wire angle, tension and CTD depth during the cast. After the cast the rosette was brought back on deck and rolled using a pallet jack into the heated rosette sampling room.

4.1.3 Performance notes

CTD

We used SBE9plus s/n 724 with s/n 756 as backup. The temperature, conductivity and dissolved oxygen sensors will have pre and post cruise calibrations to compare and decide on best options for data processing. Salinity, Oxygen and Chlorophyll water samples will be used for further sensor calibration.

Assembly – Sensors
The CDOM sensor, cosine PAR, altimeter, and transmissometer were mounted in roughly the same positions as 2021.

Pylon/ Water Sampler
Generally the system performed well, but there were a few cases where the trigger mechanism did not fire due to "stickiness". Due to our new wire on the Hawboldt winch being over lubricated, the trigger mechanism was routinely swapped when cable lubricant dripped into the mechanism. Each time, the trigger was removed and thoroughly cleaned with soapy hot water and isopropanol to remove the sticky lubricant residue. It was observed that the retaining screws had came loose on trigger #21 on s/n 498 on Oct 7, which may have contributed to some misfires on Niskin 21. This was rectified immediately after discovery.

Water sampling around 24 bottle rosette

Niskin Bottles
All o-rings were changed prior to the 2022 cruise on the 24 Niskins on the rosette. Silicon rubber o rings are used on the spigots to reduce sticking in cold conditions. The lanyards were also checked and replaced. There were very few integrity problems (leaky spigots, endcap seating) with the 24 Niskins during JOIS this year, and most of them were related

to forgotten vent closures. Bottle closure issues were related to lanyard hang-ups or trigger issues

Per usual, due to the instrumentation on the rosette, we had to cock some of the Niskins bottom end caps to the side rather than straight back. We had a number of issues with bottle flushing and/or misfires this year. These seemed most pronounced in Niskins 15-21, which could be attributed to the rosette tilt as Niskins close sequentially and create drag (but this issue was not solved).

Seasave and CTD data

Seasave worked reasonably well throughout. There are still issues when zooming in/out and replotting the display plots with the profile becoming corrupted (graphics only, not the actual data). This was observed in the past and thought to be a low memory issue particularly with the new CTD computer. More memory has been added prior to the 2022 cruise, however the same problem persisted.

SBE11 Deck Unit

We swapped the SBE11 deck unit s/n 649 to s/n 680 prior to cast #5 as there was a problem with communication with the CTD. After troubleshooting s/n 649 on the bench for some time, it was eventually discovered that the switch next to the power button was switched to "TAPE" rather than "FISH". Therefore, deck unit s/n 649 is working just fine, but s/n 680 was used for the rest of the cruise without issue.

GPS feed

The GPS feed and GPSgate worked well this year. No observed dropouts on the CTD computer.

Instrumented Sheave (BOT)

The Instrumented Measurement System (IMS) and the Brooke Ocean Technology (BOT) block bridge display feed worked well throughout the cruise. We used the IMS display on the Knudsen computer this year (not the CTD Acquisition computer), as there were issues in 2021 using the IMS on the CTD computer. Potential issues with cabling observed in 2021 was not observed in 2022, as cabling was tested in spring of 2022 and the serial (DB9) communication y-cable was re-terminated with new connector ends.

Transmissometer

WetLabs CSTAR transmissometer 1047 was swapped to s/n 1052 prior to Cast 19 because of small offsets (high and low) between casts. However, the problem persisted even with the second transmissometer. Cabling or method of mounting could be examined next.

Altimeter

We used a new altimeter this year for most of the cruise, Valeport VA500 s/n 80262. There were some issues with settings on the Valeport at first, but these were rectified by cast 10 (see below). The Valeport VA500 works very well, kicking in at full range (99m) every cast without spiking.

Issues of note:
Cast 1-3: used Valeport s/n 80262. Incorrect settings on the Valeport sensor (analogue V range set at 0-5V @ 10m range). Attempted to fix by changing Seasave scale factor from 15 to 150 but does not work as needed.
Cast 4: used Benthos PSA916 s/n 40853. Worked as expected, kicking in around 40m with spiking. Scale factor @ 15 however data were spiky.
Cast 5: used Valeport s/n 80262. Valeport sensor settings corrected (analogue V range set at 0-5V @ 100m range), but scale factor was not corrected back from 150 to 15, so the readout was not as expected.
Cast 6-9: used Benthos PSA916 s/n 40853. Worked as expected, kicking in around 60m-40m with spiking. Scale factor @ 15
Cast 10+: used Valeport s/n 80262 for rest of cruise. Valeport sensor settings correct (analogue V range set at 0-5V @ 100m range), and scale factor corrected back from 150 to 15. Went back and re-ran previous casts with corrected scale factors in order to resolve issues.

The altimeter was mounted in the same position as 2021, on a piece of aluminium pipe hose-clamped to the main frame. Recommend making this mounting area permanent for future cruises.

FDOM fluorometer
We attempted to use s/n 4305 for casts 1-3, but the data were not good. The sensor had been in for repair at WETLabs following its previous use in 2020 where it did not work, however no problem could be found. S/n 4305 needs to be retired from use on the rosette moving forward. It could be considered for use on the TSG if the problem is only pressure related.
The WetLabs FLCDRTD (s/n 6677) fluorometer worked well for the rest of the cruise (Cast 4 to 46).
It would be good to purchase a new spare CDOM sensor for 2023.

Rinko III dissolved oxygen sensor
As first tested on the JOIS 2020 cruise, an Alec Rinko III dissolved oxygen sensor was mounted on the rosette next to the SBE43 oxygen sensor for all CTD casts. The RINKO was configured on a splitter Y cable with the Satlantic cosine PAR sensor. Raw voltage measurements were recorded in the Seasave data file using the User Poly option. The Rinko has a fast 2 s response time but is thought to drift between casts. It is hoped that the drift found in this sensor can be corrected for, and the Rinko can be used to provide accurate dissolved oxygen profile data when an oxygen analyst cannot be present on board cruises (C3O, CBS-MEA, CROW etc). Analysis of the data collected will be used

to prepare a method for independent oxygen measurements. A 2-point calibration was performed on each sensor twice during the cruise.
The Rinko III s/n 009 was used from Casts 1 to 21, and s/n 369 used from Casts 22 to 46.

CTD wire issues and re-termination
The CTD wire is brand new for JOIS 2022 and terminated prior to JOIS 2022 at IOS.

The new wire was heavily over lubricated. It was observed that at least a few litres worth of excess lubricant has come off the wire over the course of the cruise (via the BOT block, levelwind rollers, and manual removal). Lubricant has gotten on nearly every surface of the CTD/Rosette area, and most of our equipment. The BOT block, CTD, rosette, Niskins, ice chummy and all sensors will all need to be inspected and cleaned prior to 2023. Ship side, the deck, A-frame, winch, doors, door handles, railings, and Rosette shack floor all could use a clean with degreaser prior to 2023.

Otherwise, the CTDwire, seacable and communication worked well for the JOIS 2022 cruise and no re-terminations were needed.

Winch

The CTD winch, the Hawboldt model SRO 75, with 75hp, has been a part of JOIS since 2005. This year, 7000 m of new 0.322” 3 conductor UNOLS wire was installed prior to the cruise, in Dec 2021.

The winch operated well this year, after some issues near the beginning of the cruise. It was discovered quickly that the hydraulic brake on the winch was not engaging properly, so we were forced to overuse the manual brake adjustment to operate the winch. This resulted in a lot of brake pad wear and smoking for 2 casts. The issue was resolved by the engineering department, who discovered that the hydraulic hoses had not been correctly installed, preventing the hydraulic brake ram from being able to engage by flushing fluid in and out (effectively creating a hydraulic lock up). The hoses and winch have now been marked more clearly to prevent future issues during installation.

Some issues were observed with spooling of the wire on the forward side of the winch drum. It is possible that the fairlead levelwind is not quite adjusted correctly, or that excessive lubricant build up and/or freezing of the levelwind rollers may have had an effect on occasion. This happened approximately 3-4 times over the course of the trip with no real indication of an obvious reason.

There was a single case in which the winch began surging/pulsing in high gear @ ~ 3200m wire out. Senior engineer was consulted but there was no obvious reason/cause. Issue resolved by slowly engaging the valve on the control stick. It is possible the valve is slightly faulty, but this only occurred (or was observed) once.

After the initial issues with the brake hydraulics were addressed, regular wear on the brake pad was observed, and only slight tweaking the hand wheel adjustment was needed on occasion. Should the brake appear to not come off completely or not seat properly in the future it can be adjusted with the hand wheel. This has been done in the past and it should be noted that there is a small sweet spot for ideal operation.

See appendix for CTD sensor configuration and calibration information.

4.2 Chemistry Sampling

The table below lists the sampled properties. Please see the Rosette Sample Log for the full list of each sample drawn.

Table 2. Water Sample Summary from CTD/Rosette – JOIS program

Parameter	Canada Basin Casts	Depths (m) or properties	n (duplicates)	Analyzed	Investigator
Dissolved Oxygen	All casts (geochemistry)	Full depth	844 (100)	Onboard	Bill Williams (IOS)
DIC	All casts (geochemistry)	Typically to S=34.7 (5 to 400m)	637 (145)	Onboard and Onshore	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)
	Along 140W and Mooring sites: CB18, CB17, CB15, CB16, ICE2-22, NE1, CB9, CB4, CB2, Stn-A, CB21, CB27, CB29, CB28b	Full depth			
Alkalinity	Most surface bottles, full casts for CB4, CB9, CB15 (to400m), CB21, CB29		About 145	Onshore	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)
FDOM	All casts (geochemistry)	5, Chl Max,S=33.1, S=34.4, AtlW Tmax, 1000, 2000, 2500, Bot-100 Add 31.8 at DOM stations	416	Onboard	Celine Gueguen (U Sherbrooke)
	All 140W stations (ICE2-22, NE1, CB16, CB15, CB17, CB18, CB21, ~~CB29, MK6~~, CB28b, ~~MK4, MK3, MK2, MK1,~~ ~~CB28aa~~) along with Barium	5 to S=33.1, S=34.4, Tmax, 1000, 2000, 2500, Bot-100			
Chl-*a*	All casts (geochemistry)	5-200 (select)	290 (150)	Shore lab	Bill Williams (IOS)
Bacteria	All casts (geochemistry)	5, 20, Chlmax, S=32.3, S= 33.1, 34.4, Tmax, 1000, Bottom	352	Shore lab	Connie Lovejoy (Ulaval) David Walsh (Concordia)
Nutrients	All casts (geochemistry)	Full depth	848 (105)	Onboard	Bill Williams (IOS)
Salinity	All	Full depth	1024 (91)	Onboard	Bill Williams (IOS)
$\delta^{18}O$	All casts (geochemistry)	5-400 (typically to S=34.7 or 34.8)	633 (55)	Shore lab	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)

	Along 140W and Mooring sites: CB18, CB17, CB15, CB16, CB9, CB4, Stn-A, CB21, CB27, CB29, CB28b	Full depth		Not all collected samples will be analyzed .	
Barium	All 140W stations (ICE2-22, NE1,CB16, CB15, CB17, CB18, CB21, ~~CB29, MK6~~, CB28b, ~~MK4, MK3, MK2, MK1,~~ CB28aa) along with FDOM	5 to S=33.1 (5 to ~200m)	151 (3)	Shore lab	Celine Gueguen (USherbrooke)
DOM	CB19, CB9, CB12, CB13, CB15, PP7, PP6	5,ChlMax, S=31.8, S=33.1	44	Shore lab	Celine Gueguen (USherbrooke)
Lignin/Phenol	CB5, CB4, ~~CB6,~~ CB19, CB21, ~~CB22,~~ CB23a, CB31b, CB1	Surface from TSG system (Seawater Loop)	7	Shore Lab	Celine Gueguen (USherbrooke)
Microbial Diversity (DNA/RNA)	AG5, CB4, CB9, CB21, NE1 (Ice station), (dedicated casts)	5, 20, Chlmax, S=32.3, S= 33.1, Atl Tmax, 1000, Bot-100	74 samples	Shore lab	Connie Lovejoy (ULaval), David Walsh (Concordia)
	StnA ,CB31b, CB50, CB40, CB17, PP7, CB15, CB16, CB11, CB10, CB8, CB7, CB3, CB2, BL8, CB27, CB28b	5, ChlMax,then “spare” water from above depths			
^{129}I and ^{236}U	North – South stations along 140W and 150W as well as CB10, CB5, StnA, CB51, AG5	Full depth (13 select depths)	260	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)
^{14}C	CB4, CB9, CB21	All depths (from ^{39}Ar Niskin when available)	75	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)
^{39}Ar	CB4, CB9, CB21	5, Tmax, 1000,1500,2000,3000,3500, bottom	27	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)
Nd and Hf	AG5, CB16, CB9, CB4, CB2, BL1, BL3, CB21 (Water from Rosette and Over-the-side Niskins)	5m, SPW (TMax)	12	Shore Lab	Nuria Casacuberta (ETH Zurich
TEP	Approximately 2/3rd of the stations (31 of 46)	Surface	31	Shore lab	Diana Varela (UVic)

4.2.1 Dissolved Oxygen

Erinn Raftery (DFO-IOS)
P.I.: Bill Williams (DFO-IOS)

Overview

Dissolved oxygen concentrations were measured on board the *CCGS Louis S. St-Laurent* (LSSL) from September 15 to October 13 during the JOIS mission in the Canada Basin. A total of 855 unique samples were collected from 46 stations, some of which over 2 rosette casts, along a cruise track starting in Cambridge Bay, NU and ending in Kugluktuk, NU. All samples were analyzed on the SIO Winkler oxygen titration kits. Oxygen concentrations ranged from 5.404 to 9.082 ml/L with ~12% of samples analyzed in duplicate. Including duplicates, 961 samples were collected and analyzed. The pooled standard deviation (s_p) for duplicate samples was 0.004 ml/L after the removal of 1 outlier based on Chauvenet's criterion. The mean deep water (>3000 m) DO value in the Canada Basin was 6.510 ± 0.015 mL/L.

Pre-cruise preparation

4.2.1.1.1 Reagents and Standards

All reagents and standards were prepared in soap and acid-washed glassware and plastic ware and were prepared using chemicals of the highest purity available at the time of purchase. Reagents and Thio were made in 2000 ml and 4000 mL glassware and the KIO_3 standards were prepared in 2000 mL Class A volumetric flasks. All chemical batches were prepared in 2018, 2019, 2020, 2021, and 2022. Most were left on board the ship from the previous cruise.

4.2.1.1.2 Equipment Calibrations

Bottle Top Dispensers: Bottle top dispensers were purchased new in April 2019. Gravimetric checks were performed before the 2022 field They generally performed well though, both the NaI-NaOH dispenser and the MnCl2 dispenser had to be swapped to the spare dispenser about halfway through the cruise. Both dispensers were replaced with spares due to bubbles erratically appearing during sample fixing, despite the dispensers having plenty of reagent left and having been primed. The primary dispensers were cleaned with hot water and DMQ, but not put back into circulation.

Oxygen Sample Flasks: A new flask file for 2022 was obtained from Kenny Scozzafava prior to the cruise and loaded into the appropriate LVO2 directory.

2 flasks (817 – Arctic Yellow; 847 – #6 Arctic Green) did not have volume calibrations in the 2022 file; during analysis, bottle volumes from other flasks were used, and after analysis during data processing the volume calibrations from 2020 calibration were used for these flasks and were recalculated with the correct flask number/volume. These flasks were removed from circulation.

While no flasks were broken on this survey, it was discovered that two flasks (1123 - #9 HoneyBee and 835 - #6 Arctic Green) had cracks in their glass. The damage to flask 1123 was extensive; the crack went from the top to the bottom of the flask. The damage to flask 835 was limited to the top of the flask. Both flask 1123 and 835 were removed from circulation during sampling.

10 mL Exchange Units: Calibrations were performed in January 2020 to determine the exact volume delivered at 20°C using the broad dosing tip. Both 10 mL exchange units were calibrated with the primary and spare Dosimat base for dispensing KIO_3. For each calibration, ten 10 mL aliquots of deionized water were dispensed into a clean 100 mL glass beaker and each weight was recorded. The mean weight of the 10 aliquots was used along with the temperature of the water to determine the exact volume dispensed at 20°C using the SIO program “glasscal.exe”. The appropriate volume for the exchange unit and Dosimat combo in use was entered into the operating parameters at the beginning of the cruise.

Sampling

Samples were collected in nominal 125 mL calibrated ground glass stoppered iodine flasks. Seawater temperatures at the time of sampling were measured with a digital probe thermometer (Fisher Scientific) potted into one arm of a Y-connector with sampling tubing attached to the other two arms (one to the Niskin bottle spigot and one into flask). No issues were encountered with the primary thermometer used, and the same thermometer was used for the entirety of the 2022 JOIS program. The samples were immediately fixed with 1.0 mL of $MnCl_2$ and 1.0 mL of NaI/NaOH, stoppered, and shaken to preserve the dissolved oxygen in precipitate form. Samples were re-shaken immediately after all biogeochemical samples were collected (approximately 20 minutes), water-sealed and allowed to settle again to ensure that if any expansion occurred, no precipitate would be lost from the sample. The bottles were then moved to the temperature-controlled (21.5-25°C) oxygen lab. All samples were analyzed onboard within 48 hours of collection.

Analysis at sea

All samples were analyzed by Erinn Raftery (DFO-IOS) on the Scripps Institution of Oceanography (SIO) Winkler-based UV titration kit B. Refer to previous years’ reports for system details.

Figure 7. Dissolved Oxygen Analysis

4.2.1.1.3 Blank and Standard Preparation

Blanks and standards were run just prior to sample runs every day to every other day. A dedicated Dosimat was used to accurately dispense either 1.00 mL of KIO_3 for blanks or 10.00 mL of KIO_3 for standards. Blanks and standards were always prepared in ultrapure deionized water and were run in sets of 4 with the criteria that 3 out of 4 titers had to agree to within 0.0003 mL. Generally, this was easy to achieve with the standards; only occasionally did an additional set of standards need to be run. This was less difficult to achieve with blanks; extra blanks were run frequently. Variability caused by the flask moving around in the bath during ice-breaking was responsible for some variability; variability in reagent dispensing was likely the primary cause of poor blank replication where the 2^{nd} titers were generally more consistent. Blanks were run with every standard set if even if no reagent changes had occurred in the interim. The temperature of both the standard and the thiosulfate were recorded by the program and used to correct the delivered mass of both reagents to 20°C in order to calculate the Thio titrant normality.

4.2.1.1.4 Analytical Procedure

Prior to analysis each day, the UV light source and stir plate were turned on and allowed to warm up and stabilize for a minimum of 30 minutes. The water bath, which holds the sample flasks, was drained, cleaned and refilled with fresh deionized water to ensure good light transmission. Both the Thio and KIO_3 bottles were gently swirled prior to priming the Dosimat line. The Dosimat lines leading from the Thio and KIO_3 bottles were checked thoroughly for bubbles and were purged as needed. The bottle top dispensers connected to the three reagent bottles and the Dosimat burettes were primed prior to dosing. Stirring was optimized to ensure rapid mixing without drawing bubbles into the light path.

Following the standardization procedure described above, the sample run was started. Sample flasks were inspected for bubbles and the water seal was removed from atop the stopper. A 1.0 mL aliquot of sulfuric acid and a stir bar were added to the flask, which was then placed inside the water bath. The Thio burette dose tip was inserted into the flask and the titration initiated until endpoint was reached. The two options at the end of every sample run were either "FINISH SAMPLE", which displays the dissolved oxygen (DO) value and resets the Thio burette, or "OVER-TITRATE" (OT), which allows one to salvage a bad titration curve (or an over-shot endpoint) by adding 1.0 mL of KIO_3 standard and re-titrating the sample. The amount of Thio needed to titrate 1.0 mL of KIO_3 is then subtracted by the software from the final titer. After every sample, the DO value was noted on the rosette log sheet. All endpoints were inspected for accuracy and either over-titrated, or had corrected titers determined after the fact by the "O2CHECK" function of the LVO2 software. These updated titers were then entered into the "Recalculations" tab of the dissolved oxygen spreadsheet so that new DO values could be calculated using the relevant flask volume and standardization parameters.

4.2.1.1.5 Thio normality

Two batches of Thio (#2001, #2202) and three batches of KIO_3 standard (#2206, #1901, #2003) were used during the cruise and the stability of the Thio for both batches was good with a maximum daily change of 0.00028 N, below the 0.0005N threshold.

4.2.1.1.6 Precision and Accuracy

Of the 855 unique samples collected during the course of this survey, 102 (12%) were collected in duplicate. Of the replicated samples, the first replicate was always chosen as the Final DO value except when a problem was noted with it during analysis (i.e. sample redrawn due to bubble addition during fixing). Replicate samples with a known problem (A or B replicate with flag 4 or 5) were not included in the precision study. In total, 7 pairs were excluded due to a known problem. The precision of the dissolved oxygen replicate measurements was very good, with a pooled standard deviation (s_p) of 0.005 mL/L from 95 replicates. After the removal of 1 outlier determined by the Chauvenet's criterion, the pooled standard deviation (s_p) improved to 0.004 mL/L for 94 replicate samples. Triplicate samples were ignored for the purposes of calculating s_p as fewer are being collected each year. It is recommended that the s_p formula on the Precision tab of the data spreadsheet be simplified to the calculation for duplicate samples only. The range of dissolved oxygen values was 5.404 to 9.082 ml/L.

Accuracy is much harder to assess than precision but the stability of the deep water (>3000m) DO content in the Canada Basin can act as a proxy reference standard.

Although this value has been decreasing over the course of the JOIS program, starting in 2003, and can't be assumed to be completely constant, it has generally been stable over the past decade with an average of 6.53 ml/L (Figure 1). The 2022 value of The 2022 value of 6.510 +/- 0.015 falls significantly below this average. However, preliminary nutrient data and a good pooled standard deviation (s_p) in the dataset as a whole provide confidence that the measurements are accurate. Further data interpretation with the geochemical dataset as a whole is needed to infer causal mechanisms.

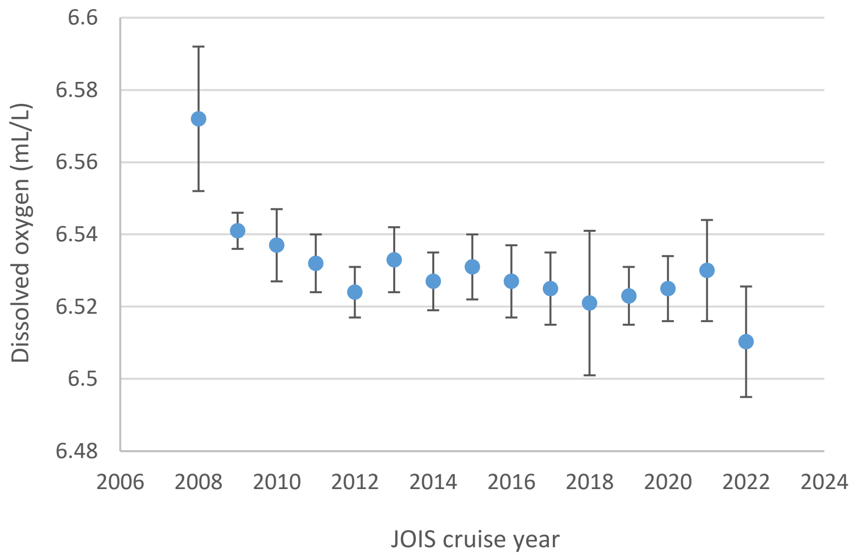


Figure 8: Mean annual dissolved oxygen concentration (mL/L) for the Canada Basin reference stations at all depths below 3000m. Error bars represent standard deviations of the deep reference water for each year.

4.2.1.1.7 Issues during sampling and analysis

__Post entry of drawn temperature__: No temperatures were required to be entered post-analysis. Two samples did not have recorded draw temperatures; in this case, they were set to the average of the sample bottles above and below them.

__Abort analysis__: Abort analysis needed to be used a few times over the course of the cruise.

- Sample 9011: titrated >2mL when kimwipe piece fell in bath and floated in front of detector; sample lost.

- Sample 1000: did not have dispensing tip in flask; aborted, wiped clean, and put in flask. Sample was not lost.

Sampling: There were, on very few occasions, problems with bubbles being introduced to the samples via the bottle-top dispensers despite dispensers always being primed prior to sampling. Samples with bubbles were always redrawn into a clean, unused flask and noted in the comments and given flag 2.

While the occasional flask was discovered without a water seal, one cast (cast 23, station CB12.5) was entirely missing the water seal. The samples without water seals were generally in good shape (no bubbles), but a few had developed bubbles. Samples from this cast without bubbles were flagged with QF 3 (probably good), and those with bubbles were flagged with QF 4 (probably bad).

Bottle top dispensers were purchased new in April 2019. Gravimetric checks were performed before the 2022 field They generally performed well though, both the NaI-NaOH dispenser and the MnCl2 dispenser had to be swapped to the spare dispenser about halfway through the cruise. Both dispensers were replaced with spares due to bubbles erratically appearing during sample fixing, despite the dispensers having plenty of reagent left and having been primed. The primary dispensers were cleaned with hot water and DMQ, but not put back into circulation.

Lab Space Issues:

The "heat shield" heater (between inner and outer doors of container lab) was not working for ~48 hours when initially labwork was started. The engineering team was able to fix the heater, and it worked well as a guard against extreme temperature swings.

When the water to the lab was initially hooked up, only hot water was hooked up; it was dissolved that using both the hot and cold taps caused the sink to leak slowly. The engineering team was able to fix the slow leak on the sink drain to stop water pooling on the floor of the container lab within 12 hours of it being discovered.

On a few occasion the lab temperature got too cool for the salts to sufficiently warm to temperature for analysis, despite the heater bexchange uniteing set to ~24C. Keeping the fan running on low helped abate this problem significantly.

Exhchange Unit #10: During initial set-up, problems were had with the primary thio exhchange unit. When the burette unit was priming, it kept sucking fluid from the dispensing tube into the reservoir. Adjusting and removing the water bong and tubing didn't correct this. The tubing connections were threaded correctly. In the end, it was easier to swap to the spare 1mL exchange unit (#12) than it was to fiddle with the tubing.

On-going noisiness and cut of curves during titrations:

Over the course of the cruise, an initially intermittent problem developed during the titration curve: the curve wouldn't actually draw when the voltage was at 1.6V. Rather, the curves would start 'drawing' around 2.1V, leading to the curve looking short/cut off. While the endpoints appear to be valid (volumes correct) and could initially be managed

with over-titrating the samples, it got to a point where ~1/2 the samples in a case needed to be over-titrated.
Initially, I (ER) was wondering if it was an issue with the power supply or an electrical issue or detector problem. I was able to email Kenny (KS) for suggestions. On 29 Sep I tried the following:

- Replacing power supply to UV (needed to adjust gain down with new supply)
- Moving power supply to different outlet and entirely wiring the supply out of a separate cut-out in the kit so that the cables have no chance of touching
- Replaced the thio dispensing tip
- Checked all electrical connections
- Replaced all electrical cables

After checking all of the above, setting the titrations to the 'Low O2' setting seemed to improve the problem initially.

However, on 2 Oct, the weird behaviour returned – this time, the computer would not recognize that the A/D was plugged in, and would not allow for it to be setup again (Configure → A/D Port) despite the computer making sounds affirmative that something had been plugged in. I tried restarting the system several times to no avail. I was worried that maybe the detector wasn't working, so I tried using the spare detector – this did not work. Then, I tried the spare laptop (Grey Whale) – which would talk to the detector, but the problem with the strange-looking curves (now stepped) persisted. Next, the UV lamp was replaced (rotated to maximize gain when installed, gain adjusted to 2.5V, and changed operating parameters → edit UV Pars → changed first column fourth row to +0.005 above the new 0 for lamp when DI flask is placed in the bath. Finally, all of the 1mL exchange unit tubing was changed. A few junk samples were run, and it seemed to be working that night. The next day, there were a few bumpy curves, but the problem seemed to resolve, and the operating parameters were kept at a lower dosing speed as it seemed to be more consistently cooperative with a lower dosing speed. The reduced dosing speed was kept for the remainder of the cruise (~cast 25 onwards).

Figure 9. Oxygen sampling from the rosette. Photo by Fred Marin (2019).

4.2.2 Dissolved Inorganic Carbon and Alkalinity

Marty Davelaar, Robyn Taves (DFO, IOS)
P.I.: Bill Williams (DFO-IOS)
P.I.: Michiyo Yamamoto-Kawai (TUMSAT)

Samples for DIC were collected at all stations (geochemistry) in the upper waters down to a salinity value of 34.7, approximately 300 to 400m deep. Samples were collected from full depth at select stations: StnA, mooring stations and intermittent along 140W. Analysis took place on board this year.
Due to problems with the Alkalinity system, Alkalinity was not run at sea (3 failed pH sensors). These samples: all surface bottles and full depth at the mooring casts (CB4, CB9, CB15, CB21) have been brought back to IOS for analysis. A subset of these will also be run for DIC repeats.

Sampling

Samples for DIC and Alkalinity analysis were collected into 250 mL glass bottles. The bottle was filled smoothly from the bottom (tubing touching the bottom of the bottle) and the bottle overflowed by two times its volume. One percent of the stoppered sample volume was removed to leave a headspace (about 1 % of the bottle volume - i.e., 2.5 mL for a 250 mL bottle) by inserting a nylon plug into the bottle. Samples being analysed within 2 days for DIC, were closed with a Teflon stopper. Samples being returned to IOS for analysis had 100uL of mercuric chloride added to the bottle to stop biological activity, were closed with a greased stopper, which was secured with multiple wraps of electrical tape. Samples were stored at 4°C until analysis. Where both measurements come from the same bottle, DIC, then alkalinity are measured.

Analysis for DIC

DIC samples were analyzed at sea shortly after sampling using a VINDTA 3D - analysis system to determine the concentration of dissolved inorganic carbon (or total carbon dioxide). The VINDTA (Versatile Instrument for the Determination of Titration Alkalinity) is a sea-going, computer-controlled automated dynamic headspace analysis, constructed in Kiel Germany by Ludger Mintrop of Marianda Instruments. The VINDTA uses a Windows based PC and LabView software along with a coulometric detector (UIC Coulometrics, model 5017). The VINDTA dispenses and acidifies a known volume of seawater, strips the resultant CO2 from solution, dries it and delivers it to the coulometric detector. Dickson CRM was used to standardize the system.

At the start of each day, seawater was run through the system to condition the cell. Next a system blank was started. If the blank was below 0.90 ug Carbon or approximately 360 counts in a ten minute period a Dickson CRM sample was analyzed to confirm the system was working properly. For each analysis (standard or sample) a peristaltic pump was used to pull the sample out of the bottle and into the water-jacketed calibrated pipette. The water from the pipette was then forced into a scrubber compartment with UHP nitrogen to which approximately 0.5 mL of 8.5 % ortho-phosphoric acid had been added. UHP nitrogen is then pushed through a bottom mounted frit, the nitrogen pushes the CO2 which has been stripped from the sample by the acid through a Peltier cooler and an Orbo-53 tube which are used to keep water vapor and impurities from entering the cell where the CO2 is titrated The coulometer was operated in the counts mode. The software then uses the counts total along with the pipette's temperature, the salinity of the water and other constants to calculate the umol/kg value of each sample. At the start of each sample or standard, the system is rinsed twice with the sample being analyzed and a system clear check is performed to ensure there is no CO2 in the system. The final concentrations are calibrated with the daily measured Dickson CRM where:

corrected value = raw value * certified CRM value / Daily CRM measured value

DIC values are reported in units of µmol/kg.

Analysis for Alkalinity

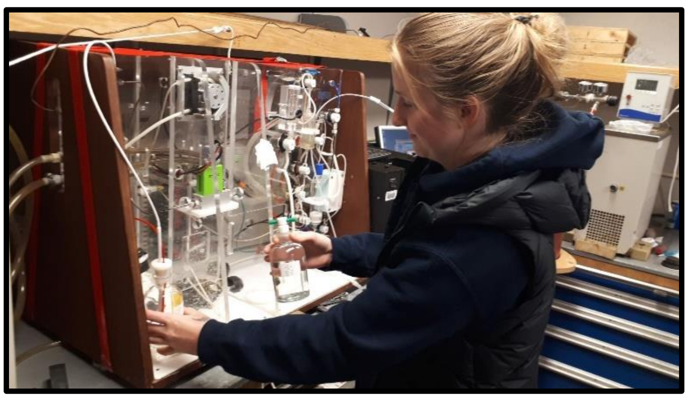
The total alkalinity will be analyzed on shore.
It will be determined by potentiometric titration using 0.1N HCl/0.6N NaCl, and using a software program written by Paul Covert, PMEL, University of Washington which is based on Andrew Dickson's, SCRIPPS system. The method is also standardized using Dickson CRM seawater

Precision, Standards, and Blanks

Table 3. Water sample precision and accuracy

Chemistry Sample	Precision (s_p)	Units	Number of Replicates (*n*)	Outliers removed	Minimum Range	Maximum Range	Accuracy (%recovery)
DIC	2.07	µmol/kg	35	1	1779.20	2236.10	100.011

The accuracy of DIC analysis was assured by daily analysis of Dickson CRM sea water (batch 170, S=33.573 psu, concentration 1982.42 µmol/kg; DOE 1994; Dickson 2001; Dickson et al. 2003) supplied by Andrew Dickson (Scripps Institute of Oceanography, San Diego, USA). The accuracy (%recovery), calculated by dividing the measured CRM value by the expected CRM value, slightly varied from 99.86 to 100.22%. The precision is given by the pooled standard deviation (s_p) of sample duplicates and was calculated to be 2.07 µmol/kg, with 1 outlier removed because of problems with the analysis.



Problems and Solutions

Problems with the Shuttle brand computer arose when the computer monitor would only work when the computer was in “safe mode”. A total of four samples were analyzed in “safe mode” before a different computer was set up to analyze samples as normal

Samples 727 to 742: The peristaltic inflow tubing was leaking so pipette may not have been filled. These samples were flagged as questionable.

References

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DOE. 1994. In: Dickson, A.G. and Goyet, C. (Eds.). Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water, Version 2. ORNL/CDIAC-74.

4.2.3 Fluorescent Dissolved Organic Matter Sampling

Céline Guéguen(USherbrooke)
Nicolas Sylvestre (USherbrooke)
Justin Forget (USherbrooke)
P.I.: Céline Guéguen (USherbrooke)

Summary

Samples for Fluorescent Dissolved Organic Matter (FDOM), Dissolved Organic Matter (DOM) and Lignin-Phenol analysis were collected for Céline Guéguen (USherbrooke), following the protocol given below. A total of 419 FDOM samples were collected at 39 stations (45 casts) and 67 from the underway seawater loop system. In addition there were 40 DOM samples and 6 Lignin-Phenol samples. All samples were collected between September 15th and October 11 th, 2022 on board the CCGS Louis S. St-Laurent during the Joint Ocean Ice Study-Beaufort Gyre Observational System 2022.

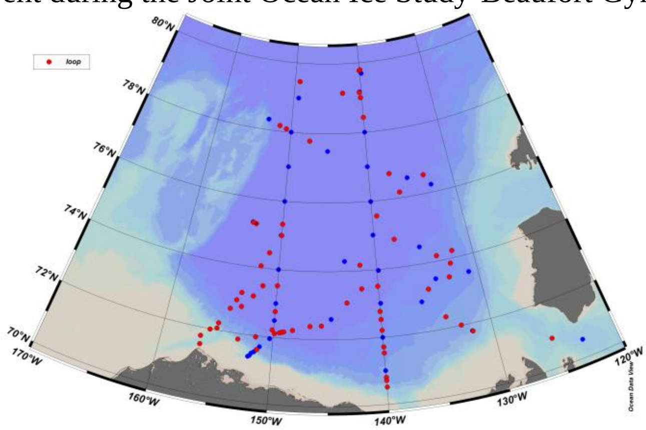


Figure 1: Map of the Canada Basin representing the sampling sites of the CTD stations (blue) and the loop samples (red).

Rosette Casts Samples

4.2.3.1.1 Samples > 200m

The bottom spigot of Niskin was opened to allow stream of seawater to flush the 40 mL amber glass vial used for FDOM sampling. The vials and caps were rinsed 3X with sample water before collecting the actual sample.

1L water samples were collected for DOM analysis at 4 depths (Surface 5m, Chlmax, 31.8 and 33.1) at PP6, PP7, CB15, ICE2-22, NE-1, CB10, CB9, CB12.5, CB2 and CB3, for a total of 40 samples. The samples were acidified and solid phase extracted immediately after collection.

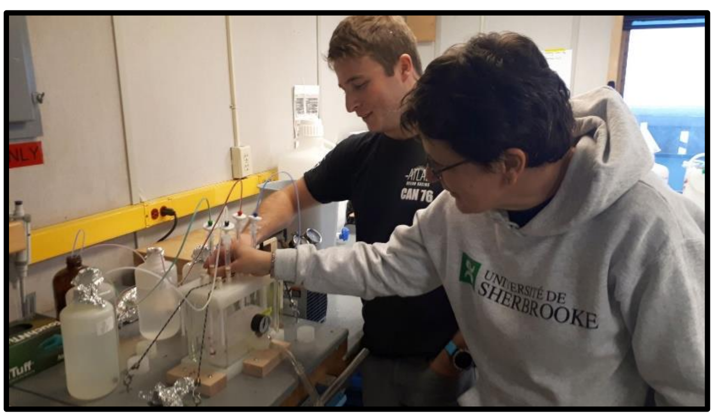
4.2.3.1.2 Samples <200m

Samples from depth shallower than 200 m were filtered in line through a pre-combusted GF/F, 47 mm, held in a Swinnex filter holder after the amber glass vials and caps were rinsed three times with the filtered seawater. Approximately 5 mL of seawater was forced through the filter before rinsing and sample collection.

4.2.3.1.3 Incubations samples

At CB40, approx. 5 L were filtered from niskin 19 (32.3 PSU, 122 m) and filtered with a pre-combusted GF/D filter and stored in fridge for use as the inoculum.

Forty-five (45) pre-combusted 1L amber glass bottles were marked at 650 mL and filled with filtered (double layer of GF/F pre-combusted filters) water from the following depths (15 bottles per depth) : 2000 and 2500 m (combined), 1000 m, and 33.1 (205 m). Nutrients (NO3 and PO4) were amended in all bottles to reach a final concentration of 15.3 uM (NO3) and 1.05 (PO4). For each set of 15 bottles, 5 were kept as a control and 65 mL of the inoculum was added to the remaining 10 bottles. Bottles were kept in the fridge in the dark, gently shaken daily, and sampled following a pre-determined schedule.



Underway Samples

Six (6) 20L water samples were collected from the underway system for lignin phenol analysis before arriving at CB1, CB31b, ICE2-22, NE-1, CB4 and CB5. The samples were acidified and solid phase extracted immediately after collection.

67 FDOM samples were collected from the underway system while the ship was steaming, at a frequency of approximately 2-3X per day, generally at XCTD sites. Seawater from the TSG outlet was used to flush the 40 mL amber glass vial used for FDOM sampling. Vials and caps were rinsed 3X with sample before collecting the actual sample. Upon collection of each sample from the underway system, FDOM sensor reading (volts and counts), latitude, longitude, UTC time, sample ID etc. was noted. Samples for nutrients, salinity and chlorophyll were collected once a day to post-calibrate the sensor.

The USherbrooke real-time FDOM sensor was tested and compared to the old one.

Storage

After collection, FDOM samples were analysed onboard within 12h of collection.

The DOM and Lignin-Phenols extracts were stored in the -80°C freezer and transferred to the University of Sherbrooke for analysis.

A selection of FDOM samples were kept in the fridge (-4°C) and will be transferred to the University of Sherbrooke for absorbance analysis.

4.2.4 Barium

Celine Gueguen (USherbrooke)
Nicolas Sylvestre (USherbrooke)
Justin Forget (USherbrooke)
P.I.: Celine Gueguen

Background

Barium is naturally released from rocks during the weathering process and is dissolved in river water. The naturally occurring concentration of barium in North America is higher than in Eurasia resulting in different concentrations in rivers from the two continents. When studying the source of fresh water in the Arctic Ocean, the oxygen isotope ratio can identify river water from sea-ice melt, and barium can further distinguish which continent the river water is from (Guay and Falkner, 1998; Guay and Falkner, 1997).

Sampling

147 barium samples were collected along the BL and 140W lines, typically from 0 to 200 m depth. Barium samples were drawn from the Niskin into small (~20 mL) pre-rinsed plastic vials. Once at room temperature the caps were retightened for storage until analysis back onshore.

Analysis

Barium concentrations will be determined at the University of Sherbrooke on an 7800 Agilent inductively coupled quadrupole mass spectrometer using isotope dilution. Briefly, 250 µL aliquots of sample were spiked with an equal volume of a 135Ba-enriched solution (Oak Ridge National Laboratories) and diluted with 10 mL of 1% HNO3.

References

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Guay, C.K. anf K.K. Falkner (1998). A survey of dissolved barium in the estuaries of major Arctic rivers and adjacent seas. *Cont. Shelf Res*., 18(8): 859-882 (doi:10.1016/S0278-4343(98)00023-5)

Guay, C.K. and K.K. Falkner (1997). Barium as a tracer for Arctic halocline and river waters. Deep-Sea Res. II, 44(8)1543-1570 (doi: 10.1016/S0967-0645(97)00066-0)

4.2.5 Chlorophyll-a

Sampled by CTD Watch
P.I.: Bill Williams (DFO-IOS)

Onboard Sampling and Filtering

Chlorophyll-*a* was sampled from the upper 200m, with roughly 50% in duplicate at all geochemisty stations. In addition, 9 loop samples were taken in replicate (18 total). Samples were drawn from each of the selected Niskins into pre-calibrated 530mL brown Nalgene bottles (calibrated at IOS in 2021 and 2022). Each bottle and cap was rinsed three times with the sample water. The bottle and cap were both filled and the cap quickly put on resulting in the fullest bottle possible.

The sample water was filtered immediately under low pressure onto ~0.7 µm pore size GF/F 25mm filters. If the samples could not be filtered immediately, they were kept cool and in the dark until filtered, and the time elapsed until filtered noted. Filters were folded in half in another GF/F filter (90mm) being used as a blotter, wrapped in aluminum foil and stored at -80°C for later analysis onshore at IOS.

Each sample was expected to take 10-15 minutes to filter. If it was not completed within 30 minutes, the remaining sample water was removed from the tower and the volume was measured to determine how much of the sample water was filtered.

Chlorophyll-a samples were filtered by Kim Bedard, Elizabeth Bailey, Celine Gueguen, Nimrod Rozen, and Ashley Arroyo.

Blanks were prepared at the end of the cruise. Three sample bottles were filled with artificial seawater, two with pre-filtered seawater, and two with deionized water. Filtration of the “sample”, and handling of the filter was performed as usual.

Analysis on shore

Frozen samples will be brought back to IOS for analysis. Samples will be extracted in glass scintillation vials with 10 mL of 90% Acetone/10% double deionised water for 24 hours in the dark, in the -20°C freezer. One hour before sample reading, they will be removed from the freezer and placed in the dark to equilibrate to room temperature. Samples will be analyzed on a Turner 10AU fluorometer, SN:5152FRXX, calibrated with commercially pure chlorophyll a standard (Sigma). Fluorescence readings taken before and after acidification will be used to calculate chlorophyll and phaeopigment concentrations (Holm-Hansen et al 1965).

Holm-Hansen, O., Lorenzen, C.J., Holmes, R.W., and Strickland J.D.H. 1965. Fluorometric Determination of Chlorophyll. J.du Cons. Intl. Pour l’Epl. De la Mer. 30:3-15.

4.2.6 Bacteria sample collection

Céline Guéguen (USherbrooke),
Nicolas Sylvestre (USherbrooke),
Justin Forget (USherbrooke)
P.I. : Connie Lovejoy (ULaval)

Sampling

Bacteria samples were collected at every station at select depths on all geochemistry casts. Flow cytometry (FCM) samples for bacteria, pico- and nanoeukaryotes were collected for Connie Lovejoy (ULaval), who took over for Bill Li (BIO), following the protocol given below. Samples were collected and processed alternately by Justin Forget (USherbrooke) and Nicolas Sylvestre (USherbrooke).

The sample depths where changed this year. Up to 2021 samples were collected at all depths. In 2021 this was changed to just the depths of the microdiversity interest: 5, 20, Chlmax, S=32.3, S= 33.1, 34.4, Tmax, 1000, Bottom. In 2022 this was changed to add S = 34.4 which represents the lower halocline and where FDOM is also sampled.

The same protocol (see below) used since 2013 was followed this year.

Methods

Sampling:

1. Take one sample from each Niskin bottle. Rinse scintillation vial three times with sample water before collecting actual sample into the vial. Please make note of approximate time elapsed between sampling and adding paraformaldehyde fixative (below).
2. Pipet 1.8 mL of raw seawater sample (now held in scintillation vial) into a 2 mL capacity cryogenic vial. This is done using 1 squirt of pipet set for 1.8 mL. Between samples, 'clean' pipet by drawing and tossing 2 squirts of the new sample, then use next squirt for the cryogenic vial. Use a new tip for each station.

Fixation:

1. Paraformaldehyde (PFA, 10%) stock solutions (10mL) are provided in manufacturer glass ampoules which must be kept at room temperature until use. The ampoules are best opened using the plastic breaking tool supplied. Transfer ampoule contents into a scintillation vial to facilitate pipetting. PFA solution, once opened, should be kept cold (4C) in a refrigerator, but NOT frozen in the freezer.
2. Under the fume hood, pipet 0.2 mL of 10% paraformaldehyde (PFA) into the vial using the eppendorf repeating pipet (repipet). Do this by immersing the tip of the fully-depressed repipet pipet into the PFA, draw up plunger to fill the barrel, and then dispense two times back into the PFA container to help remove bubbles and drips from the pipet tip. Next slowly pipet the set 0.2 mL into several of the vials, being careful not to let the tip touch the seawater, nor to make a big splash when the PFA is injected. When there is less than 0.2 mL of PFA left in the repipet, empty and refill the repipet. The repipet can be left with its tip on but cover with aluminium foil to prevent contamination.
3. Note on the repeating pipet settings: The new eppendorf pipet is set on #1 to deliver 0.2mL and uses the blue labeled pipet tips. The old black repeater is set on #2 to deliver 0.2mL and uses the other tips.
4. Cap each vial using the threaded-screw cover.

5. Vortex mix the vial, and let it stand at room temperature for not less than 10 minutes.
6. Place the vial into storage box directly into the -80ºC freezer and leave onboard ship for offloading in St-John's NL.
7. Log samples taken in logsheet recording cast number, niskin number and approximate time between sampling and adding fixative.

Issues

Not enough cryoboxes were brought on the ship to store the samples. Once the third box was full, the next samples were put into an identified plastic bag, identified as *Box 4* and *Box 5*.

Wishes for next year

- More cryogenic vials are needed to sample every depth at every station. Ideally all from the same company, with the orange caps and flat bottom.
- A new rack that locks the vials in place.
- 5000 µL pipet and tips Thermo Scientific Finnpipette are awesome.
- Syringe and needle (10 mL) to transfer paraformaldehyde from ampoule to scintillation vial, instead of the 5 mL one.
- **Dedicated cryoboxes are to be added to the bacteria box.**
- **More protective plastic ampoule openers are really needed for next year. Only a few left, definitely not enough to go through JOIS 2023 without running out of them.**

4.2.7 **Oxygen Isotope Ratio ($\delta^{18}O$)**

Sampled by CTD Watch
P.I.: Bill Williams (DFO-IOS)

Oxygen isotopes, ^{16}O and ^{18}O, are two common, naturally occurring oxygen isotopes. Through the meteoric water cycle of evaporation and precipitation, the lighter weight ^{16}O is selected preferentially during evaporation, resulting in a larger fraction of ^{16}O in meteoric water (rain, snow) than in the source water (i.e. seawater). Sea-ice formation and melt on the other hand, does not changes the source water's $^{18}O/^{16}O$ ratio (noted as $\delta^{18}O$) by much. River water is fed from meteoric sources and thus the $\delta^{18}O$ is a valuable tool used in the Arctic Ocean to distinguish between fresh water from river (meteoric) sources and from sea-ice melt.

Samples for $\delta^{18}O$ were collected at all geochemistry stations, typically from 5 to 550 m depth. At the select stations, full depth profiles were collected. Samples were collected into 25 ml glass vials after 3 rinses with sample water. Once at room temperature, the caps were retightened and the vials inverted for storage. Samples will be analyzed at Oregon State University, at the College of Oceanic and Atmospheric Sciences (COAS) Stable Isotope Lab, by Jennifer McKay. Samples will be analysed using a DeltaPlusXL Isotope Ratio Mass Spectrometer connected to a H_2O-CO_2 equilibration unit.

Samples were collected into a new type of vial this year due to availability constraints . The vial and cap were chosen for good long-term seal from evaporation: 25 mL glass bottles with 24-400 Phenolic PTFE/14BRubber caps.

4.2.8 Nutrients

Sarah-Ann Quesnel (DFO-IOS)
P.I.: Bill Williams (DFO-IOS)

Sampling

Seawater samples for nutrient determination were collected at all geochemistry stations at all depths into new 15 mL polystyrene tubes after the tube and cap had been rinsed three times with the sample water. A total of 824 samples were collected, of which 101 in duplicates. At each station, 2 sets of samples and their duplicates were collected; one set of sample was analyzed onboard within 12 hours of collection, while the other set was frozen at -20 °C for later analysis, if needed.

Additional samples were analyzed: 45 samples for Nicholas Sylvestre' (USherbrooke) incubation experiments and 36 (including replicates) for ice station and over the side Niskin work for Nimrod Rozen and Mike DeGrandpre. No samples were collected from the seawater loop system this year.

A total of 129 samples were re-run onboard, after QA/QC processing to ensure the feature observed was real or not. Frozen replicate samples were thawed at ~45-50°C for 30 min, and let cool to room temperature before being analyzed.

Standards, reference material samples and reagents

Primary stock standards of nitrate (nitrate + nitrite, NO_3, phosphate (PO_4) and silicate (SiO_4) were prepared onboard from pre-weighted dry salts and were calibrated against Kanso certified reference materials lot CO (NO_3 = 16.30 µM, SiO_4 = 35.58 µM, PO_4 = 1.206 µM). The primary stock standards were prepared in Milli-Q water, using high purity grade dry chemicals (Fluka puriss. grade for sodium hexafluorosilicate, and Fluka ultra p.a. for potassium nitrate and potassium phosphate monobasic), and grade "A" volumetric flasks, according to Barwell-Clarke and Whitney (1996).

A set of 5 working standards, were prepared daily from the primary standard solutions, using freshly prepared 3.4% sodium chloride/0.02% sodium bicarbonate solution and calibrated electronic pipette. Concentrations of the standards were selected to bracket the expected nutrient levels in the samples (NO_3: 0.00 to 24.23 µM, SiO_4 : 0.00 to 47.43 µM and PO_4: 0.000 to 2.361µM).

For quality assurance and quality control purposes, Kanso certified reference material (CRM), lot CO and CR, deep water reference (DWR), medium check (2nd lowest working standard) and drift cup (D) samples were analyzed at the beginning, in between stations and at the end of a day's run.

The KANSO CRM values were:

KANSO	nitrate + nitrite	silicate	phosphate
Lot CO	16.30 µmol/L	35.58 µmol/L	1.206 µmol/L
Lot CR	6.59 µmol/L	14.35 µmol/L	0.410 µmol/L

Onboard DWR samples were collected from station CB-18, cast#10, at 3591m depth (sample #196). Water was collected into a carboy after 3 rinses, mixed well and sub-sampled into new polystyrene tubes, frozen at -20°C, and thawed as required in ~45-50°C water.

Reagents were prepared onboard, as required, using ACS grade, or better, dry chemicals (pre-weighted at IOS in May 2022), and water from onboard Milli-Q Direct 8 water purification system that produced 18.2 mΩ-cm resistance Type I reagent grade water. The system was supplied with the ship's distilled water. Two new pre-filters were installed before the Milli-Q Direct 8 system.

Sample analysis

Unfiltered nutrients (nitrate, silicate and phosphate) samples were analyzed within 12 hours of collection by Sarah-Ann Quesnel onboard using a three channel Seal Analytical nutrient Auto-Analyser 3 (AA3), following the methods described by the manufacturer.

A 34 g/L solution of sodium chloride, 0.2 g/L sodium bicarbonate (Sigma, BioXtra grade) was prepared, as needed, and was used to rinse the system between samples, to prepare the working standards and as the blank samples. The platen tubing did not require to be changed during our voyage. The cadmium column for nitrate analysis was changed as required to maintain the reduction efficiency greater than 96%, which occurred on a couple of occasions when air passed through the column.

At the beginning of each day, the AA3 was allowed to equilibrate for at least 60 minutes, with reagents and wash solutions hooked- up to the platen tubing. Nitrate, phosphate and silicate were analyzed simultaneously with the AA3. A typical sample run would consist of a drift cup, carryover cup, 5 point standard curve, a set of reference material, a set of cadmium column recovery samples, blanks, followed by a station's samples and it's replicate. If multiple stations were analyzed in the same day, a set of reference material (medium check, Kanso, DWR, and drift cup) would separate each station. A set of reference material were analyzed at the end of a day's run, along with a second set of cadmium column recovery check samples. After each run, wash solutions were run through the system for cleaning the system for roughly 15 minutes. Data were logged digitally using the AACE software provided with the AA3 system, which calculated all standards, reference materials and sample concentrations, correcting for drift, carryover and baseline. When the nitrate level in surface samples was the same or slightly lower than the sodium chloride solution it was reported as zero.

Precision, Accuracy and L.o.D.

The precision was calculated as the pooled standard deviation (s_p), with outliers rejected by the Chauvenet statistic, and the values for the different sets of samples are given in Table 2 below.

Table 4. Water Sample Precision, L.o.D. and accuracy summary.

Chemistry Sample	**Units**	**Minimum Range**	**Maximum Range**	**L.o.D**	**Precision (s_p)**	**Number of Replicates (*n*)**	**Outliers removed**	**Accuracy (% recovery)**
Nitrate (fresh)	mmol/m^3	0.00	17.05	0.07	0.05	98	4	96.3-99.8
Silicate (fresh)	mmol/m^3	1.81	38.69	0.05	0.02	100	5	96.6-98.3
Phosphate (fresh)	mmol/m^3	0.323	1.911	0.007	0.003	99	2	99.9-102.2

The accuracy of nutrient analysis was assured by daily analysis of Kanso CRM for Nutrients in Seawater (RMNS) (batch CL, NO3: 16.30 µmol/L, SiO4: 35.58 µmol/L; PO4: 1.206 µmol/L, salinity: 34.376 PSU).

Corrections were applied to the samples as follows:

$$[\text{sample}]_{corr} = [\text{sample}]_{uncorr} \times \frac{[\text{Kanso CRM}]_{exp}}{[\text{Kanso CRM}]_{daily\ avge}}$$

Where, $[\text{sample}]_{corr}$ = corrected sample nutrient concentration
$[\text{sample}]_{uncorr}$ = measured, uncorrected sample nutrient concentration
$[\text{Kanso CRM}]_{exp}$ = expected Kanso certified material nutrient concentration
$[\text{Kanso CRM}]_{daily\ avge}$ = daily average measured Kanso certified material nutrient concentration.

The % recovery of the Kanso RMNS analytes ranged from 96.3-99.8% (n = 67) for NO_3, 99.9-102.2% for PO_4 (n = 67) and 96.6-98.36% for SiO_4 (n = 67).

The limit of detection (mean of 10 samples consisting of NaCl/NaHCO3 solution plus 3 times its standard deviation) were 0.07 μmol/L for NO_3, 0.05 μmol/L for SiO_4 and 0.007 μmol/L for PO_4.

Problems and Solutions

4.2.8.1.1 General Issues

No general issues occurred this year.

Figure 10. Nutrients analysis on the AA3. Photo by Fred Marin, 2019, but similar set up for 2022.

4.2.9 **Salinity**

Analyst: Robyn Taves (DFO-IOS)
P.I.: Bill Williams and Sarah Zimmerman (DFO-IOS)

Sampling

Salinity samples were collected from nearly all bottles on all rosette casts to be used for calibrating the CTD salinity and to verify Niskin sample was from intended location. Salinity samples were collected in 200 mL glass bottles sealed with disposable nylon inserts and screw caps. Approximately 10% of samples were collected in duplicate and stored in a separate case to be analyzed independently. Water samples were collected from Niskin bottles immediately following a rosette cast, after dissolved gas and other sensitive samples were collected. Salinity bottles and inserts were rinsed 3 times with sample water before filling. Samples were transferred to the temperature controlled lab for storage until they were analyzed onboard.

Analysis at Sea

All samples were analyzed onboard during the program. Samples were analyzed after a minimum 24 hour temperature acclimation period but within 1 week of collection, on the Guildline Salinometer Model 8400B (S/N: 69086). The procedure followed is outlined in the standard IOS protocol for salinity analysis. Room and sample temperature was maintained consistently between 21°C and 24°C as much as possible.

An order placement system was established within the room whereby salinity cases were cycled in order to establish a constant sample temperature. This system ensured two things: 1) the analyst knew which case to begin with and the location of each subsequent case, and 2) each case was held at a stable temperature for an extended period of time before analysis. Bottles were inverted and mixed prior to analysis.

IAPSO Standard Seawater (OSIL batch P165, expiry 15 April, 2024, K_{15} Value = 0.99986, Salinity = 34.994 PSU) was measured before the beginning of every other day of analysis to standardize the instrument and identify drift or if the standby number changed by more than 2 units

If the standard's conductivity ratio obtained was within ±0.0001 of the standard K_{15} value on the bottle, the value was accepted. If the value was greater, the cell was flushed and another reading was taken. If the ratio fell outside this range, the standardize dial was used to bring the conductivity reading back into specification.

Deep water reference samples (DWR, see below) were normally run after P165 calibration, at the beginning of each sample case (24 samples), at the end of the day, or more often if deemed necessary to assess instrument stability.

Data are reported in practical salinity units (PSU; Lewis & Perkin 1978).
Three sets of deep water reference (DWR) samples were collected throughout the cruise:

- DWR-CB18: CB18, Cast 10, Niskin 2, Sample 197, 3000m (34.959/34.957)
- DWR-CB16: CB16, Cast 15, Niskin 2, Sample 317, 2545m (34.956/34.953)
- DWR-StnA: StnA, Cast 40, Niskin 1, Sample 861, 3330m (34.959/34.956)

To collect the reference samples, the remaining volume of each Niskin was collected into an 10L plastic carboy and mixed thoroughly before sub-sampling into individual 200 mL salinity bottles for storage and analysis as outlined above. See below for DWR salinity values.

Precision and Accuracy

Table 5. Salinity Precision for niskin samples collected on 2022-045
The L.o.D. represents the Limit of Detection, the s_p represent the pooled standard deviation of duplicates for precision.

Chemistry Sample	**Units**	**Minimum Range**	**Maximum Range**	**L.o.D**	**Precision (s_p)**	**Number of Replicates (*n*)**	**Outliers removed**
Salinity (all samples, all depths)	psu	27.0715	34..9602	N/A	0.0048	92	3

Table 6. Salinity Precision for TSG samples collected on 2022-045

Chemistry Sample	**Units**	**Minimum Range**	**Maximum Range**	**L.o.D**	**Precision (s_p)**	**Number of Replicates (*n*)**	**Outliers removed**
Salinity (all samples, all depths)	psu	23.8386	25.8836	N/A	0.0028	4	1

The precision of the analyses was determined as the pooled standard deviation (s_p) of duplicate samples.

The precision value for samples collected from a single niskin is larger than expected (0.005 psu) based on the expected variability of the autosalinometerr (0.002 psu).

Table 7. Salinity Deepwater reference values for precision
The %RSD represents the percent relative Standard Deviation (SD) to the mean, and indicates the day to day variability (precision).

Sample	**Mean (psu)**	**% RSD**	**Expected Arctic Ocean Deep Water salinity (±**	**n**

			SD)	
DWR-CB18	34.9522	0.0017	Only DWR-StnA is actually from Deep Bottom Water Expected value: 34.597 +/- XX	24
DWR-CB16	34.9541	0.0019		23
DWR-StnA	34.9570	0.0019		15

Issues with Salinometer

Function dial is sensitive to touch or wiggle: The function dial, if touched or wiggled due to icebreaking was changing the standby number. On Sep 23rd the function knob was taken apart and the problem found to be the knurled collet had backed off which had loosened the contact ring underneath to pin3. Retightening the function dial components corrected the jumpy standby number.

Persistent bubbles on cell 3 and 4, less so on cell 2 and water/salt deposit in small tubing connecting to the cells:

These are persistent problems from the last couple of years. Even with repeated cleaning of DI, TritonX, isopropyl alcohol, the bubbles, although they may reduce, kept coming back. The small tubing connecting to the coils are for air only, but were regularly showing water or evidence salt water has been present (dried salt). Regular cleaning and clearing reduced bubbles on the cells but the bubbles would return, and evidence of water in the tubing would recur. At sea, more silicone was added to the tubing connections over the existing seals but this did not fully correct the problem. Its thought that there are still leaks in the silicone seals and as described in 2021: the integrity of the closed system is suspect. Detailed repair was too risky at sea (fear of catastrophic mishap and the time it would take to correct and then cure the silicone)

Some steps tried:

Sep 23rd: cleaned all salt from tubing, ziptied any remaining connections to prevent leaks.

Sep 29th see more salt in problem tube. Water seen in tiny tube leading to C3, blown out and reconnected but checking shortly after there is water in the tiny tube to C3 again.

Sep 30th: re-siliconed the connections of the tiny tubes leading to C3 and C4. Used small gauge needle to clear cell tubing with air and RMQ

Oct 1st: bubbles back on C4

Oct 3rd: clean tiny and large tubing, bubbles still on C4

Oct 5th: bubbles back on C4

Electronic connections between Autosal and computer:

Oct 5th: computer software logged bad reading (high STD) but the autosal was showing a good reading. Unclear if this is a computer or cabling issue? The power cable was changed, the ribbon cable was repositioned. Last year there had been problems with the software/computer interface as well. This may not have been the same problem but still good to check.

Software error message:

As in 2021, it was observed that after approximately 80-120 samples, the error message “error in Module “SaveSampleDataToFile”; 70, Permission denied” would appear after any user input. The workaround was to make a new file every time the autosal was recalibrated so one run file will have at most 120 samples or so. This same error was observed on a different autosal/computer configuration at IOS so it appears not to be specific to a single computer.

Salinometer disconnection from software:

As in 2021, there were occurrences of the Autosal disconnecting from the software. This only happened a few times and reconnected without a problem. This has also occurred with a different autocal/computer configuration at IOS.

Recommendations

- Check all tubing within the salinometer for integrity. Leaks have been a problem for 2 (or 3 years).
- Bubble issue on conductivity cell electrodes C3 and C4. This has been a problem for 2 (or 3 years). This may require factory fixing and calibration of cells if fix is not possible in house.

4.2.10 Iodine-129 & Uranium-236

Samples collected by CTD watch.
Responsible on board: Annabel Payne, Anne-Marie Wefing (ETH Zurich)

P.I.: Nuria Casacuberta Arola (ETH Zurich)

Background/summary

Measurements of ^{129}I and ^{236}U provide information about the spread and transit times of Atlantic-origin water labeled by discharges from European nuclear reprocessing plants. High concentrations of both isotopes are expected in the mid-depth Atlantic layer, comprising Fram Strait and Barents Sea Branch Water. Pacific-origin water (residing on top of the Atlantic layer) and old Atlantic water (deep and bottom waters) have very low concentrations of ^{129}I and ^{236}U.

Sampling

Combined samples for ^{129}I and ^{236}U were collected into 3L cubitainers after rinsing 3x with seawater from the Niskin.
87 samples were pre-processed on board: An aliquot of about 200ml was filled for ^{129}I into a 250ml bottle. The remaining water was acidified, spiked with ^{233}U, and iron solution was added. Uranium was co-precipitated with iron hydroxides by increasing the pH to 8.5 using Ammonia. The supernatant was decanted and the precipitates were transferred into 250ml bottles. ^{129}I aliquots and ^{236}U precipitates were sealed with parafilm.
Cubitainers with samples that were not pre-concentrated on board were sealed with parafilm and packed into cardboard boxes.

All samples were packed into pallets and shipped to ETH Zurich, Switzerland, for analysis.
In total, 263 samples were collected for the analysis of ^{129}I and ^{236}U.

4.2.11 Argon-39 & Carbon-14

Samples collected by Anne-Marie Wefing (ETH Zurich)

P.I.: Nuria Casacuberta Arola (ETH Zurich)

Background/summary

Measurements of ^{39}Ar and (natural) ^{14}C provide information about the ventilation times of deep and bottom waters in the Canada Basin. Both isotopes are formed in the atmosphere by interaction with cosmic rays and introduced into surface seawater by air-sea gas exchange. Once water is not in contact with the atmosphere any more, the concentrations of both isotopes decrease due to their radioactive decay with half-lives of 269 yrs (^{39}Ar) and 5730 yrs (^{14}C), respectively. This allows calculating the time since the water sample was last in contact with the atmosphere, referred to as the ventilation time.

Sampling

Argon-39: About 10L of seawater are required for the measurement of ^{39}Ar. To avoid any contamination from ambient air, samples were collected into evacuated steel flasks. Some water was run through the tubing for rinsing and flushing out any air prior to filling the flask by switching a valve. A full Niskin bottle was dedicated to the ^{39}Ar sample AND the flask was filled to about 8 kg (checked with a mechanical scale). Samples will be shipped directly to Heidelberg University, Germany, for analysis.

Carbon-14: Samples for ^{14}C were collected into 120ml glass bottles, avoiding any air bubbles in the tubing, and letting water overflow 3x. Bottles were closed with a rubber stopper and crimped tight with aluminium caps. About 15uL of mercury chloride was added with a syringe after sampling to avoid any biological activity affecting the carbon isotopic signature. Samples were packed into pallets and shipped to ETH Zurich, Switzerland, for analysis.
^{14}C samples were taken from the waste water stream of the ^{39}Ar sample for those depths where ^{39}Ar samples were collected. At the remaining depths of the stations, ^{14}C was sampled directly from the Niskin to get a better resolved, full-depth profile for this isotope.

^{14}C and ^{39}Ar samples were collected at the same three stations: CB9, CB4, and CB21. In total, 27 samples were collected for ^{39}Ar and 75 samples were collected for ^{14}C.

4.2.12 Lithogenic Neodymium & Hafnium

Samples collected from Foredeck Niskins.
Responsible on board: Annabel Payne, Anne-Marie Wefing (ETH Zurich)

P.I.: Nuria Casacuberta Arola (ETH Zurich)

Background/summary

Neodymium isotopes are considered conservative tracers of seawater, with an intermediate residence time of 600 – 1000 years. Delivered to the oceans dominantly by riverine input, the isotopic signature of the ocean basin is strongly controlled by the surrounding continental geology. Neodymium is not subject to fractionation during silicate weathering, and so is a robust indicator of the source lithology. Hafnium isotopes show a strong positive correlation with neodymium (Bayon et al. 2006), but in contrast are strongly fractionated by weathering processes, with the radiogenic isotope being preferentially released during chemical weathering from apatite and sphene leading to more radiogenic signatures for a given neodymium value in seawater (known as the seawater array). The non-radiogenic isotope in particular is concentrated in zircons, which are highly resistant to weathering and are only broken down during extreme processes such as glacial erosion. This releases the isotope and allows it to be transported after glacial retreat, shifting the isotopic signature of the transporting water to less radiogenic value (the zircon array).

Sampling

17 combined samples for Nd and Hf were filtered to obtain the truly dissolved fraction (Acropack filter 0.2um mesh) either directly from the foredeck niskins, or were collected and then filtered using a peristaltic pump into acid cleaned (HCl) 10L or 20L cubitainers, with 1 L collected in separate nalgene bottles for isotopic concentration checks. After filtering all samples were acidified to pH 2 with ultrapure HNO3, sealed with parafilm and packed into cartons. All samples were packed into pallets and shipped to ETH Zurich, Switzerland, for analysis.

Each sample was made of 2 10L Niskins either collected from the Rosette or from Niskins attached to the hydro-wire on the foredeck. Salinities were taken from each sample to confirm trip depth.

Station	**Depth**	**Method**
AG5:	30m	Rosette
CB16:	sPW(45m)	Niskin on wire
CB9:	sPW(45m)	Niskin on wire
CB4:	sPW(47m)	Niskin on wire
BL1:	5m, 40m	Rosette
BL3:	5m, sPW	Rosette
CB2:	5m	Niskin on wire
CB21:	5m, sPW(57)	Niskin on wire
CB27:	5m, sPW(54)	Niskin on wire
CB29:	5m, sPW(54)	Niskin on wire
CB28b:	5m, sPW(58)	Niskin on wire

4.2.13 Biogeography, taxonomic diversity and metabolic functions of microbial communities in the Western Arctic Ocean

On board: Susan McLatchie (Concordia University)

P.I.: David Walsh (Concordia University)

Introduction

Rising temperatures and atmospheric CO_2 are altering the ocean's chemistry and circulation, causing intense stress on the foundations of marine food webs such as microbes. The Arctic Ocean is experiencing fast environmental change brought about by a changing climate, leading to a decline in its ice cover. Our efforts to assess microbial diversity have shown that Arctic communities are altered by environmental change. This project aims to determine if the taxonomic changes in microbial assemblages observed in the Arctic are accompanied by genomic and metabolic changes which may potentially impact ecosystem functioning.

Methodology

This year we started the JOIS cruise from the South of the Beaufort Sea, in a counter clockwise direction in the Canada Basin. Water column samples were collected at a total of 22 stations (Figure 1) to cover a range of previously studied stations (between 2012-2021). Starting with AG5 and the 21 following stations (CB31b, CB50, CB40, CB17, PP7, CB15, CB16, NE1, CB11, CB10, CB9, CB8, CB7, CB4, BL8, CB21, CB2, CB3, CB27, and CB28b). Samples were collected at eight depths per station: surface water (5m), 20m, SCM (subsurface chlorophyll maximum), the Pacific Summer Water (salinity of 32.3PSU), Pacific Winter Water (salinity of 33.1PSU), temperature maximum, Atlantic water (1000m), as well as either 100m or 10m from the bottom at AG5, CB31b, CB50, CB40, NE1, CB9, CB4, CB3 and CB21. Samples were collected a 4 depths per station: surface water (5m), 20m, SCM (subsurface chlorophyll maximum), the Pacific Summer Water (salinity of 32.3PSU) at CB17, PP7, CB15, CB16, CB11, CB10, CB9, CB7, BL8, CB2, CB27, CB28b).

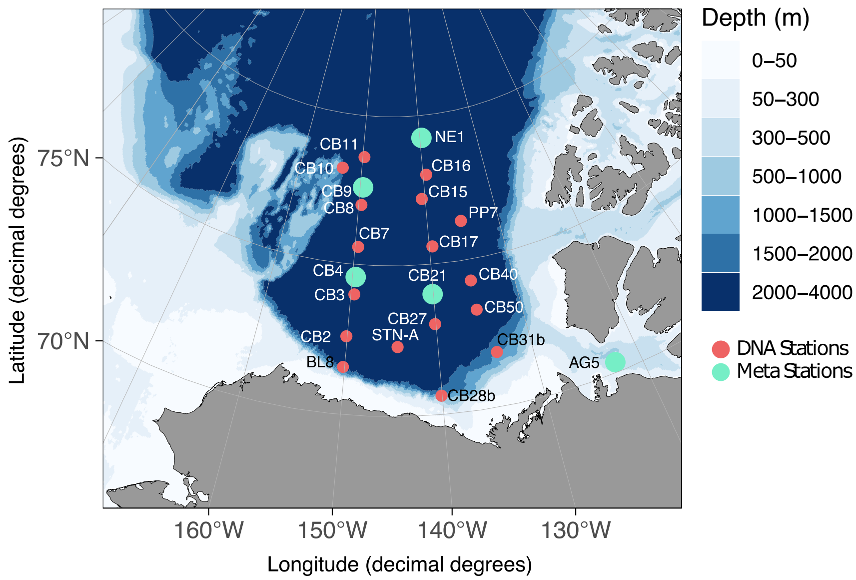


Figure 1: Stations designated as "DNA stations" had designated Niskin bottles for two water masses (surface and SCM layers) and shared bottles for the other sampled water masses with the routine IOS geochemistry casts. We collected and filtered 7L of water for each water mass at DNA stations dedicated for later DNA extraction (27 DNA stations total). For five selected stations (Meta stations), a designated DNA cast featuring two Niskin bottles per water layer was conducted. At these sites, for each water layer 6-14L of sea water were filtered for each water mass twice. One filtration per water mass was dedicated for DNA and protein extraction, whereas the other filtration was dedicated to RNA extractions for the CBOmics collaborative study between the Lovejoy, Walsh, and Guéguen groups.

Seawater filtration

For DNA stations, we collected samples from the large (>3µm) and small (0.22 - 3µm) fraction of organisms by filtering 7L of seawater at room temperature onto a 3.0µm polycarbonate filter followed by a 0.22µm Sterivex filter. Filters were immersed in RNAlater solution (Ambio) and left for at least 15 minutes at room temperature before being stored at -80°C. DNA/RNA (Meta Stations) samples were treated and stored as described previously, except that approximately 14L and 6-14L of seawater were filtered for each water mass, for DNA/protein and RNA extractions, respectively.

Single Cell Genomics

For each station and depth, 1.8 mL of sample were gently mixed with Glycerol-TE buffer before freezing at -80˚C for single cell genomic sequencing.

Additional projects

Isolation of Western Arctic Ocean SAR11 bacteria

The SAR11 clade of bacteria comprises one of the most abundant and successful clades in the ocean and is characterized by small genomes, but high metabolic flexibility. Previous work has shown that the western Arctic Ocean environment harbours distinct SAR11 bacterial genotypes, but the potential metabolic specializations underlying such an apparent endemism are still unknown. To resolve this, we have collected frozen seawater samples, as well as filtered seawater for SAR11 isolation from cryopreserved samples from two of the Meta stations (NE1 and CB21). 1.5mL of seawater was gently mixed with 375µl of a 50% V/V glycerol/filter sterilized seawater solution and cooled by one degree per hour to freezing before being stored at -80˚C.

Viral diversity within the Canada Basin

Viruses influence marine microbes and therefore microbe-mediated biogeochemical cycling. To access virus diversity, ecology, and ecosystem functioning, virus metagenome sampling was carried out. 20L of 0.22 µm filtrate from the surface (5m) and subsurface chlorophyll maximum at two Meta stations (NE1 and CB21) was incubated with $FeCl_3$ to precipitate organic material. The precipitate was then collected on a 1 µm polycarbonate filter and stored at 4˚C.

Enrichment cultures of acetone degrading bacteria

Acetone is a volatile organic compound which influences the oxidative capacity of the atmosphere. The direction of acetone flux in the ocean varies across latitudes with the strongest sink at high latitudes. Microbial cycling of acetone is hypothesized to be a major sink of acetone in high latitude oceans. Previous work has shown that a large fraction of the microbial community of the surface waters in the Canada Basin has the capacity to degrade acetone. The rates and mechanisms of acetone consumption by bacteria from high latitudes remains unknown. To address this, enrichment culture of acetone degrading bacteria were set up by amending 15 mL of seawater from the surface and 20m at one Meta station (CB21) with acetone at a range of final concentrations of acetone including concentrations similar to that of seawater and concentrations used to culture model acetone degrading bacteria.

4.2.14 Transparent Exopolymer Particles in surface waters

Nimrod Rozen (UVic)
P.I. Diana Varela (UVic)

Parameters Measured

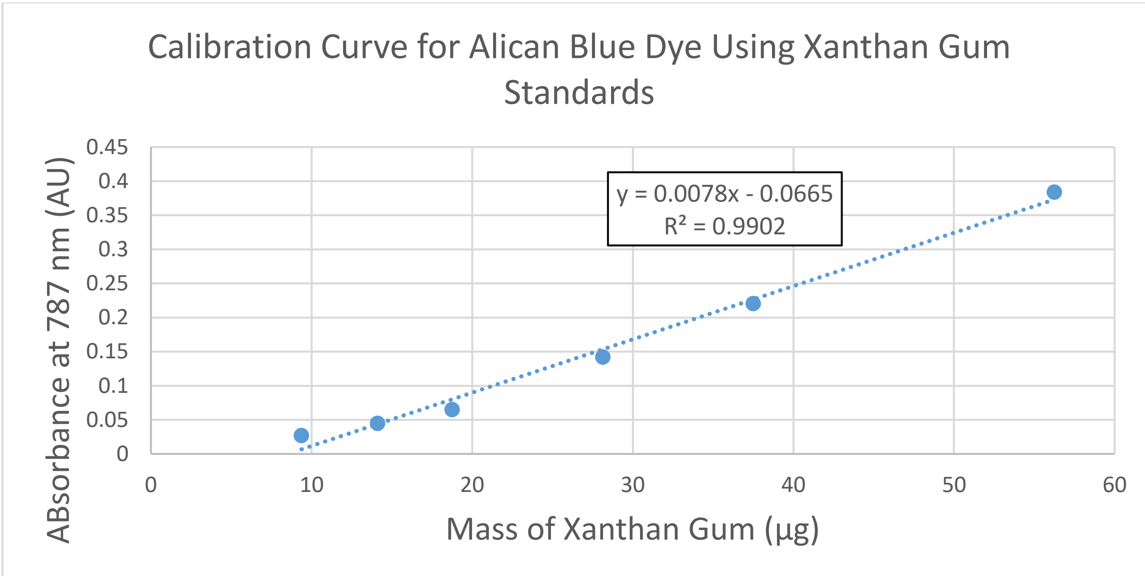
- Transparent Exopolymer Particles (TEP)
- Particulate Organic Carbon (POC)
- Chlorophyl-a (chla)
- Nutrients (Nuts),
- Phytoplankton Identification (Phyto ID)

Sampling Rationale:

Transparent exopolymer particles (TEP) are a class of marine polysaccharides composed of the excretions from phytoplankton. These carbon rich carbohydrates play two important roles in the carbon cycle of the ocean. First, TEP, which is neutrally or positively buoyant, partially forms a sea-surface microlayer at the top of the water column when unbound by other particles. Secondly, TEP acts as an effective 'marine glue' that binds large particulates of marine snow together, allowing large concentrations of carbon to be transported to depth. The distribution of TEP in the upper water column, as well as its relationship to distributions of particulate organic carbon (POC) and chlorophyll (chl) are investigated in this study in an effort to gain a deeper understanding of the abundance and dynamics of TEP in Canadian Basin surface waters. Findings from this cruise will be applied to the project being run by University of Victoria PhD Candidate Michael Livingston (primarily focused on the north-east Pacific), in an effort to expand the geographical scope of his research.

Pre-Cruise:

TEP was measured in the methods described by *Bittar et al. (2018)*. An alcian blue (AC) dye was made pre-departure by dissolving 50 mg of AC powder ($C_{56}H_{68}Cl_4CuN_{16}S_4$) in 100 mL of deionized water, and then acidifying to a pH of ~2.5 with a 6 mL addition of acetic acid (CH_3COOH). This dye was then calibrated using a series of external standards generated with Xanthan Gum (XG, monomeric form - $C_{35}H_{49}O_{29}$) with concentrations ranging from 9.375 µg/mL to 56.25 µg/mL. These standards were stained with AC dye, filtered through 0.4 µm polycarbonate filters, and then extracted using 6 mL of 80% v/v sulfuric acid (H_2SO_4). The sulfuric acid extractions were then read in a UV-VIS spectrophotometer at a wavelength of 787 nm, and the absorbances were corrected using a series of method blanks (filtered DI water contains no XG). The standard curve for this calibration is displayed below:



1. Bittar, T.B., U. Passow, L. Hamaraty, K.D. Bidle, and E.L. Harvey. 2018. An updated method for the calibration of transparent exopolymer particle measurements. *Limnology and Oceanography: Methods.* 16. Pp. 621-628. doi: 10.1002/lom3.10268

The calibration factor of the dye was noted to be 1/0.0078 = 128.21 µg XG/AU. This calibration factor will be used to calculate the mass of TEP on the filter papers of the samples collected on the cruise once processing is complete in the lab.

Rosette Sampling:

Samples of TEP were collected in a 2L polycarbonate (PC) plastic Nalgene sampling bottle, which was partially filled, and split between TEP and POC sampling. The bottles were given three rinses from the niskins from which they were being sampled (almost always the surface bottle). In the aft-lab, graduated cylinders were rinsed three times using the sampled water, and then filled to 300-500 mL. This volume of water was filtered through a 0.4 µm polycarbonate filter on a filtration manifold attached to an Erlenmeyer flask with a spout connecting to a vacuum pump set to a pressure of less than -5 Hg in magnitude. The sides of the manifold were cleaned using DI water, and then the sample was given a 500µL addition of the AC dye using an Eppendorf adjustable pipette. Any unbound stain was then filtered through with a final rinse of DI, and the filter was folded and placed inside a 30 mL High-Density Polyethylene (HDPE) bottle, which was subsequently sealed, labelled, and placed in the -80^{o}C freezer on the 500-level deck of the ship. The concentrations of TEP will be determined at the University of Victoria after the cruise.
Concurrently, Particulate Organic Carbon (POC) samples (also from the same 2L polycarbonate bottle), were filtered through a pre-combusted glass fibre filter (GFF). Similarly, to TEP, small amounts of sample water were used to rinse a graduated cylinder

three times, afterwards 800-1000 mL of sample water were measured out and then filtered through the GFF using the IOS chlorophyll filtration manifold. The graduated cylinder and filtering manifold were then rinsed with filtered sea water, and the filter was folded in half, placed in an aluminium foil envelope, labeled, and placed in the -80^{o}C freezer on the 500-level deck. The concentrations of POC will be determined at the University of Victoria after the cruise.

Lastly, chlorophyll samples were collected in a manner similar to that of POC, with the exception of two notable differences. Firstly, dark plastic sampling bottles were used to collect the water, so that sampled water would be shielded from light between sampling and filtration. And secondly, regular (i.e., non-combusted) GFFs were used for the filtration. Chlorophyll filtration volumes were almost always 500 mL, unless water budgeting of a cast did not allow for this volume of water. The chlorophyll filters will be analyzed at the University of Victoria after the cruise.

Ice sampling (at stations Ice-2 and Ice-3):

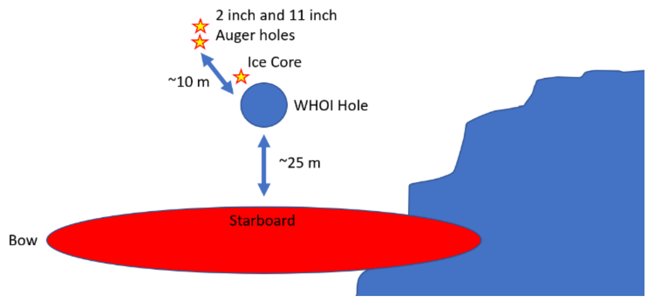
At stations Ice-2 and Ice-3, the TEP concentrations (and affiliated properties) were measured at 4 ‘depths’. These samples came from 10-m below the ice surface, 5-m below the ice surface, directly under the ice bottom, and as an ice core.

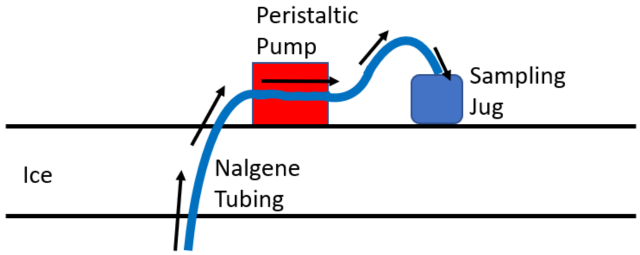
The 5m and 10m samples were collected by attaching a 1.7L niskin onto a rope and lowering it down below the ice the appropriate length of rope before sending a messenger down to trigger the bottles to close. Niskins were deployed through an 11-inch auger hole which was cut using auger flights borrowed from the Woods Hole Oceanographic Institution team aboard the ship. Each depth was sampled multiple times so that a sufficient volume of water would be collected for replicate TEP, POC, and chlorophyll samples (these analyses were conducted in the same manner as described in the ‘rosette sampling’ section). In addition, nutrient samples (analyzed by Sarah-Ann Quesnel), dissolved oxygen samples (analyzed by Erinn Raftery), and salinity samples (analyzed by Robyn Taves/Christopher Clarke) were taken from these casts. The 5m cast also involved a 125 mL sample for phytoplankton identification (6 drops of Lugol’s Iodine were added to each bottle using a dispensable pipette). Lastly, a seabird SBE19plus CTD was lowered through the same auger hole to collect pressure, temperature, and conductivity data from the sampling environment.

Ice cores were cut by the Woods Hole Oceanographic Institution ice-work team near the sites of their Ice-tethered Profiler (ITP) deployments so that go-pro cameras could be lowered through the ice to film the process. Given that the WHOI team did not need the ice collected in the coring process, these cores were placed in nylon garbage bags and brought inside, where they were subsequently measured, and then slowly melted inside of a Yeti cooler. After the ice cores had fully melted, they were filtered through a 53 micron mesh (to remove any contaminants such as large plastic strips from the garbage bag), and subsampled into TEP, chlorophyll, POC, nutrients, and salinity samples.

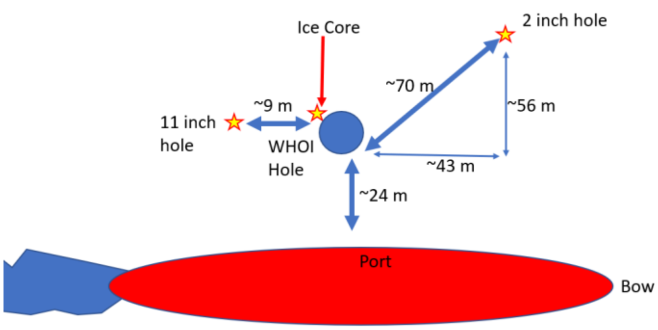
Lastly, the under-ice sampling procedures at Ice-2 and Ice-3 differed slightly. A masterflex peristaltic pump with Nalgene tubing was lowered through a 2-inch auger hole to draw water up from directly underneath the ice at Ice-2. This water was subsampled into salinity, nutrients, TEP, chlorophyll, POC, and phyto ID samples. A similar procedure was attempted at Ice-3, but because the air-temperature was much colder than at the previous station, water began freezing inside the tubing on the way to the sample bottles. So, an alternative sampling procedure was developed last-minute in which a vacuum pump was used to draw water into a large (~12L) glass carboy. Water did not freeze in the tubing, as the thick rubber tubing of the vacuum pump provided the water more insulation than the thin-walled Nalgene tubing used with the peristaltic pump. This water was subsampled in the same manner as station Ice-2.

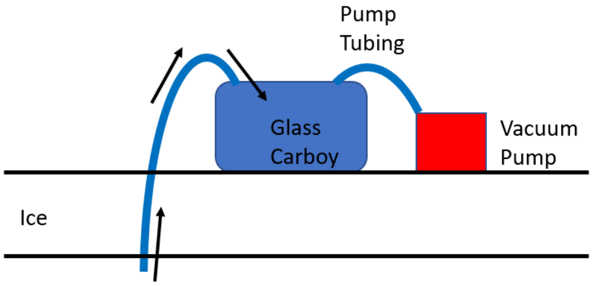
Ice-2 / Peristaltic Pump Set-up:





Ice-3 / Vacuum Pump Set-up:





Data Log for TEP/Chl/POC:
See Appendix for list of samples collected

4.3 On-the-wire Niskin with SBE19+

To supplement the volume of water collected by the rosette or where the rosette was not appropriate (on the ice station), several samples were collected by hanging solo Niskins onto a line with an internally logging SBE19+ CTD. The Niskins were closed with a weighted messenger dropped along the line.

4.3.1 Niskin Sampling off the Forward Deck

Kim Bedard and Chris Clarke *(DFO-IOS), with help from Annabel Payne, Anne-Marie Wefing (ETH Zurich),* Nicolas Sylvestre , *Justin Forget (Universite de Sherbrooke), Nimrod Rozen (University of Victoria)*

Sampling

Additional samples for Lithogenic Neodymium and Hafnium were collected using the foredeck zooplankton winch. Samples were collected using the Swann 310 hydraulic winch and 3/16" wire through the forward starboard A-frame. Two niskin bottles were set up on the winch wire above a SBE19plus CTD. The deeper bottle was 1.6m above the CTD and the upper was 4.6m above. The winch counter was zeroed when the deeper niskin was just below the surface. The CTD was lowered to 10m and a three minute surface soak was completed before the CTD was brought back to the surface, and the cast begun. The CTD was first lowered below the desired closure depth (often 60m) then back up to close the niskin bottles at the Pacific Summer Water temperature maximum which was confirmed by the rosette operator. A messenger was used to trip the upper bottle at the desired depth and a subsequent messenger attached to the upper bottle would then trigger the lower bottle. UTC was used to log all times and dates in the sample log unless otherwise specified.

A table of the casts and sample number for the foredeck Niskins is in the appendix.

4.3.2 **SBE19+ use and Processing**

Kim Bedard, Chris Clarke (DFO-IOS)

A Seabird 19+ CTD was used when lithogenic samples were collected off the foredeck winch as well as for water samples taken at the ice stations. The CTD was plumbed with a pump and set in profiling mode. For the foredeck work see the section above: *Niskin Sampling off the Forward Deck.* For ice stations, the CTD was lowered into the hole by hand.

The standard Seabird recommended data processing routines for the SBE19+ were run on the CTD data (data convert, filter, align, cell thermal mass, derive) and then bin averaged to 1db. The nearest 1db averaged data was then pulled into the sample spreadsheet for each sample collected.

4.4 Moorings and Buoys

On board: Jeff O'Brien, Jim Ryder, James Kuo, John Jordan (WHOI); Mike DeGrandpre (U. Montana); Mary-Louise Timmermans (Yale)

Other PIs: Isabela Le Bras, Andrey Proshutinsky, Rick Krishfield, John Toole (WHOI)

4.4.1 Summary

2022 operations from the CCGS Louis S. St-Laurent as part of the Beaufort Gyre Observing System (BGOS) included the recovery of three bottom-tethered moorings (deployed in 2021) and the deployment of three moorings at the same locations. Three ice-based observatories were installed, one Ice-Tethered Profiler (ITP) was deployed in open water, and a Tethered Ocean Profiler (TOP) was deployed in open water. A summary of moorings and buoys recovered and deployed are listed in Tables 1 and 2.

Table 1: BGOS mooring recoveries and deployments from CCGS Louis S. St-Laurent 2022. *Both the mooring anchor and the acoustic pinger near the top of the mooring were ranged on in the pre-recovery survey (see columns 2 and 3).*

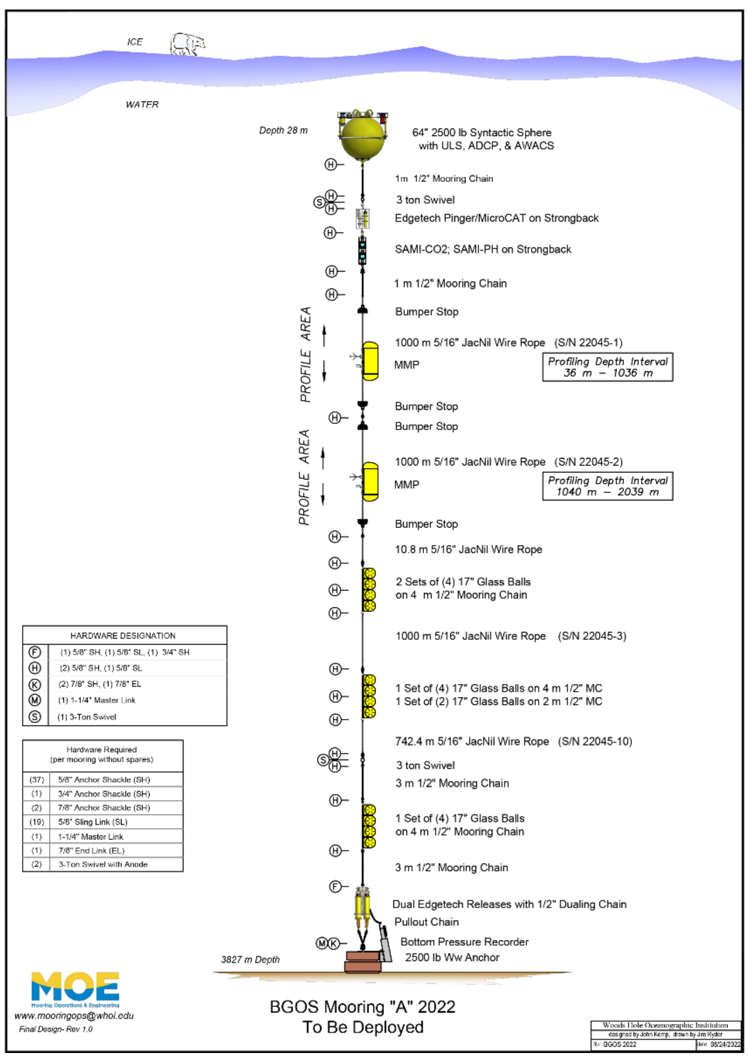
Mooring	Surveyed location (pinger*)	2022 Recovery	2022 Deployment	2022 Location (drop posn.)	Deploy bottom depth (m)
A	75 00.032 N 150 00.000 W *11 m from anchor	2 Oct. 2:29 UTC Anchor at 34m from 2021 drop location	3 Oct. 3:06 UTC	74 59.397 N 149 57.618 W	3823
B	77 58.843 N 150 04.503 W *51 m from anchor	28 Sept. 19:25 UTC Anchor at 450m from 2021 drop location	29 Sept. 23:16 UTC	78 01.101 N 150 02.559 W	3828
D	73 59.343 N 140 02.396 W *6 m from anchor	9 Oct. 01:01 UTC Anchor at 495m from 2021 drop location	10 Oct. 00:42 UTC	74 00.017 N 140 02.840 W	3527

Table 2: BGOS ice and open-water deployments from CCGS Louis S. St-Laurent 2022. *Single-buoy deployments are listed as "IBOs" to denote Ice-Based Observatory; this simplifies record keeping, although it is understood that an IBO more commonly describes the case where more than one system is deployed on the same floe.*

IBO	Buoy system	Date (2022)	Location	Ice thickness (m)
1	ITP 130	Sept. 24 19:09 UTC	77 45.5732 N 140 01.1866 W	0.55
2	ITP 136, TOP005, AOFB 47, SIMB 2021#7	Sept. 25 23:50 UTC	79 10.1412 N 140 16.9807 W	1.1 – 1.9
3	ITP 137, TOP006, SIMB 2021#6	Sept. 26 20:29 UTC	79 48.6967 N 139 57.4278 W	1.0 – 1.1
4 (open water)	ITP 131	Sept. 28 02:00 UTC	79 07.474 N 146 53.583 W	–
5 (open water)	TOP007	Sept. 30 23:47 UTC	77 01.510 N 149 15.080 W	–

4.4.2 Moorings

Bottom-tethered moorings have been maintained in at least three (up to four) locations under the BGOS program since 2003. The moorings and their nominal locations and deployment durations are as follows: Mooring A (75N, 150W; 2003-2022), Mooring B (78N, 150W; 2003-2022), Mooring C (77N, 140W; 2003-2008), and Mooring D (74N, 140W; 2005-2022). The moorings acquire time series at fixed locations of ice draft of sea ice overlying the mooring, heat, freshwater, ocean currents, and sea-level variations, plus other properties. The top float is



positioned at least 30 - 40 m below the sea surface (see e.g., the schematic diagram [right] for Mooring A, deployed in 2022).

Instruments on each of the moorings are as follows: an Upward Looking Sonar (ULS) (i.e., Ice Profiling Sonar, IPS) sampling ice draft; an Acoustic Doppler Current Profiler (ADCP) sampling upper ocean currents; McLane Moored Profilers (MMPs, two on each mooring recovered and deployed in 2022) making profiles through the water column sampling ocean currents, temperature and salinity; a fixed-depth MicroCAT sampling temperature, salinity and pressure; a Bottom Pressure Recorder (BPR) sampling pressure fluctuations at the seafloor; and SAMI-CO2 and SAMI-pH instruments (University of Montana). In addition, moorings A and D include Acoustic Wave and Current Profilers (AWACs, University of Washington).

The vertically profiling MMPs sample conductivity-temperature-depth (CTD) and velocities in the water column from around 50-m depth to about 2050-m depth, making two profiles every two days.

Before each recovery, the mooring's location was determined precisely using Art Newhall's (WHOI) Acoustic Survey Software (available in MATLAB) to range first on the releases at the bottom of each mooring, and then on the ELCAT acoustic pinger located just below each surface float. Mooring recovery and anchor-first deployment operations are summarized by WHOI Technical Report 2005-05 (Kemp et al., 2005).

Data return from the recovered moored instruments was excellent overall. The Upward Looking Sonars and Bottom Pressure Recorders returned full records and the deep McLane Moored Profilers (MMPs) all returned a full set of profiles over the approximately year-long deployments. Two of the shallow MMPs (moorings A and D) returned a full year of data, while the shallow MMP on mooring B had flooded, and no data were recovered. Two ADCPs returned a full year of velocity data in the upper water column, while a third only returned a couple of months of data for a reason that is still to be diagnosed.

4.4.3 **Buoys**

An important part of the BGOS program is the deployment of automated buoys, designed to drift with a host ice floe and return information about the upper water column, sea ice, snow and the atmosphere year-round and transmit data via satellite. Four types of automated buoys were deployed during the 2022 expedition:

1. Woods Hole Oceanographic Institution Ice-Tethered Profilers (ITPs), sampling temperature, salinity, and pressure from ~5m to 760m depth (https://www2.whoi.edu/site/itp/)
2. 2. Woods Hole Oceanographic Institution Tethered Ocean Profilers (TOP), sampling temperature, salinity, and pressure from the ice-ocean interface to 200 m depth (https://www2.whoi.edu/site/itp/)
3. 3. US Army CRREL Seasonal Ice Mass Balance Buoy (SIMB), sampling ice and snow thickness, temperature, and atmospheric pressure (https://www.cryosphereinnovation.com/)
4. 4. Naval Postgraduate School Arctic Ocean Flux Buoy (AOFB), sampling turbulent ocean fluxes near the ice-ocean interface and meteorological data (https://www.oc.nps.edu/~stanton/fluxbuoy/)

A total of four ITPs were deployed during the 2022 expedition, ITP numbers 130, 136, 137 and 131 (in order of deployment date). All the ITPs are returning 4 one-way profiles between 5 m and 760 m depth each day, sampling ocean temperature and salinity (conductivity). Two of the systems (ITPs 136 and 137) are configured to additionally sample dissolved oxygen, and each of these has a fixed-depth (5 m) SAMI PCO2 with ODO and PAR sensor to sample upper ocean chemistry (CO2, pH) and chlorophyll fluorescence. Three TOPs were deployed, 2 SIMBs and 1 AOFB (**see Table 2**). ITP and TOP data are made available in near real time from the project website (see link above). As of this writing (Oct 10, 2022), all ITPs and TOPs are returning good profiles, except no SAMI data are being returned from ITP 137.

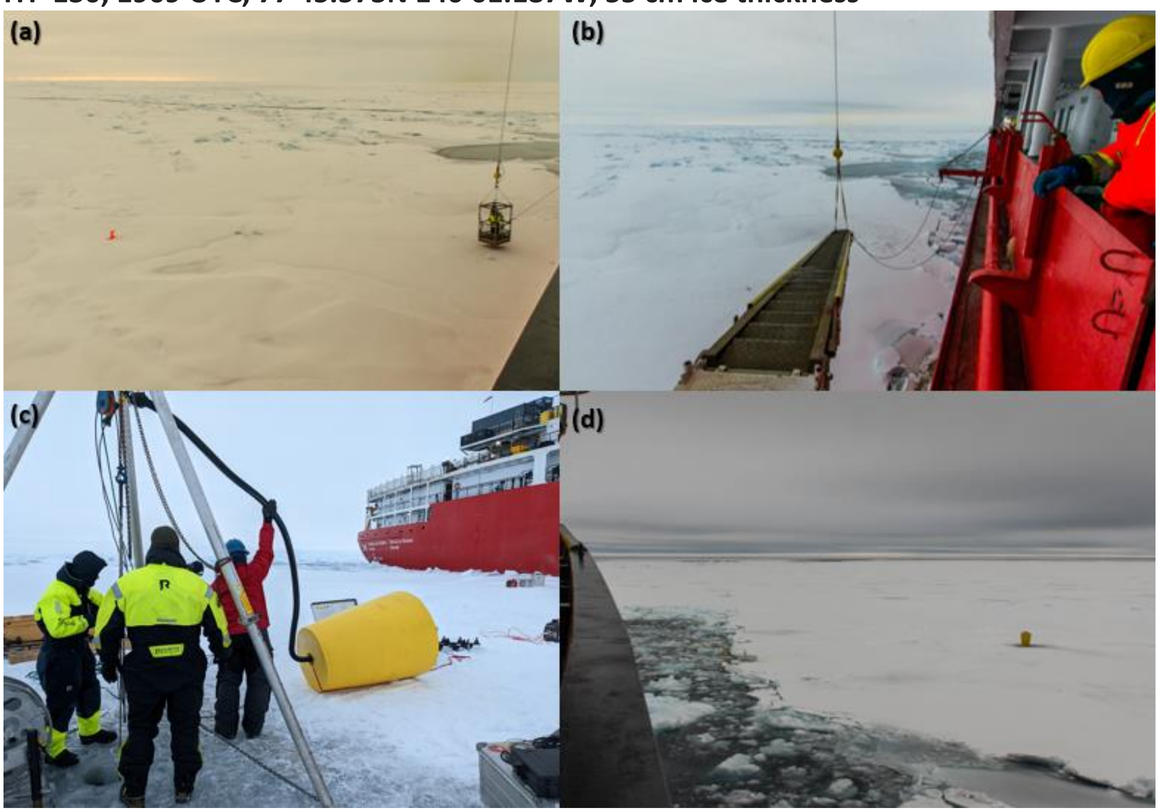
Ice-Based Observatory deployments:

 # 1, September 24, 2022, *near 77.5N, 140W; air temperature: -10°C, winds: 10-15 knots*
Personnel: Jeff O'Brien, Jim Ryder, James Kuo, John Jordan (WHOI); Mary-Louise Timmermans (Yale); Mike DeGrandpre (U. Montana) plus IOS ice team and LSSL crew

An appropriate floe was located from the ship's bridge that was deemed sufficiently flat and robust for deployment of a single ITP (ITP 130). The floe was covered in a few inches of snow and refrozen melt ponds (visible as light grey under the snow). The CCGS Louis S. St-Laurent eased into the floe around 1430 UTC, with the working area off the ship's starboard side. Shortly after Jeff O'Brien and Jim Ryder were positioned on the floe using the man basket off the starboard side. They drilled 3 or 4 holes in a relatively flat spot around 30 m from the starboard side of the ship. The floe was about 0.85 m thick plus or minus 30 cm (i.e., laterally variable). The floe was deemed to be about 1 m thick by the side of the ship where the gear would be placed. The ice survey was completed at 1600, having taken 15 minutes, and the ice team of two returned on board to begin staging gear. All the gear was slung over the starboard side from the helicopter deck with the main crane; the gangway was put down on the starboard side for personnel. The installation was complete at 1820 UTC.

Once the gear, people and gangway were all back on deck (1930), the captain and mate were able to back the ship out gently the way we had come in without disturbing ITP 130's ice floe.

ITP 130, 1909 UTC, 77 45.573N 140 01.187W, 55 cm ice thickness



IBO #1 deployment: (a) Man-basket over the side for the ice survey; (b) Gangway lowered off the LSSL port side in preparation for ITP 130 deployment. (c) Deploying ITP 130 surface package. (d) ITP 130 off the starboard bow of the LSSL as the ship backed away gently after the ITP was installed.

 # 2, September 25, 2022, near 79N, 140W; air temperature: -4^{o}C, winds: 25 knots

Personnel: Jeff O'Brien, Jim Ryder, James Kuo, John Jordan (WHOI); Mary-Louise Timmermans (Yale); Mike DeGrandpre (U. Montana) plus IOS ice team and LSSL crew

Four buoys were deployed on a single floe: ITP 136, TOP005, AOFB 47 and SIMB 2021 #7.

At 1445 UTC the LSSL settled into a large floe O(1km) across, free of large ridges. There was some smooth topography (the floe was not completely flat) and melt ponds visible as grey patches under the snow covering. The floe was deemed to be strong given that it took the LSSL three attempts on three engines to settle into it. There was some cracking visible in the melt ponds, but a clear starboard side free of ice rubble for landing gear and the gangway. Winds were blowing toward the starboard side of the ship.

At 1545 Jeff O'Brien and Jim Ryder were lowered over the starboard side in the man basket to survey. They found the ice to be about 1.1 to 1.9 m thick along a 100 m line running perpendicular from the ship's starboard side. TOP005 was to be installed closest to the ship (about 25 m away from the hull), with ITP 130 situated for deployment at the far end of the line, and AOFB 47 and SIMB 2021 #7 between. The survey was completed, and the ice team was back on deck at 1640.

After the ice survey, some time was taken for the crew to position all the gear onto the ice using the starboard crane (the starboard gangway was also deployed). The large black AOFB box and components amounted to 2.5 sling loads with the crane. At 1754 UTC, all the AOFB gear was on the ice and a 14" hole was drilled for the system. An additional small hole was drilled about 10 m from the AOFB hole for under-ice Go-Pro video (using a 20-ft selfie-stick). The AOFB was assembled and installed before any of the other systems on this IBO, with this stage complete at 2013 UTC. The manual describes an altimeter which we were not able to locate; it appears this system does not have one. Before proceeding to communicate with the AOFB and initiate deployment, ITP 136 was installed next.

At 2200 UTC, ITP 136 was installed and deployed. ITP 136 had a dissolved oxygen sensor on the profiling unit. Mike DeGrandpre (U. Montana) installed a SAMI system at a fixed depth (about 5 m) on the ITP wire. A small hole was drilled by Kazu Tateyama (Kitami Institute of Technology) about 3 m from the ITP 136 hole, and a Go-Pro camera was put on a 20-foot selfie stick to acquire video of the ITP profiler under ice.

Deployment of TOP005 was complete at 2350 UTC.

Concurrently with the other deployments on this floe, a team from IOS (Kim Bedard, Chris Clarke and Paul Macoun) deployed the SIMB 2021 #7.

A summary of precise positions at 2350 UTC and ice thicknesses for each of the systems on this IBO is as follows, and the respective buoy configuration is shown in the schematic below:

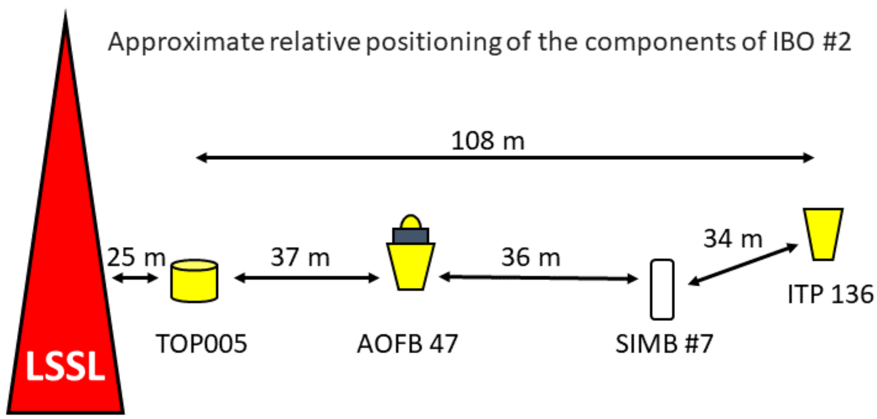
ITP 136, 1.2 m thick ice, 79 10.1807N, 140 16.7515W

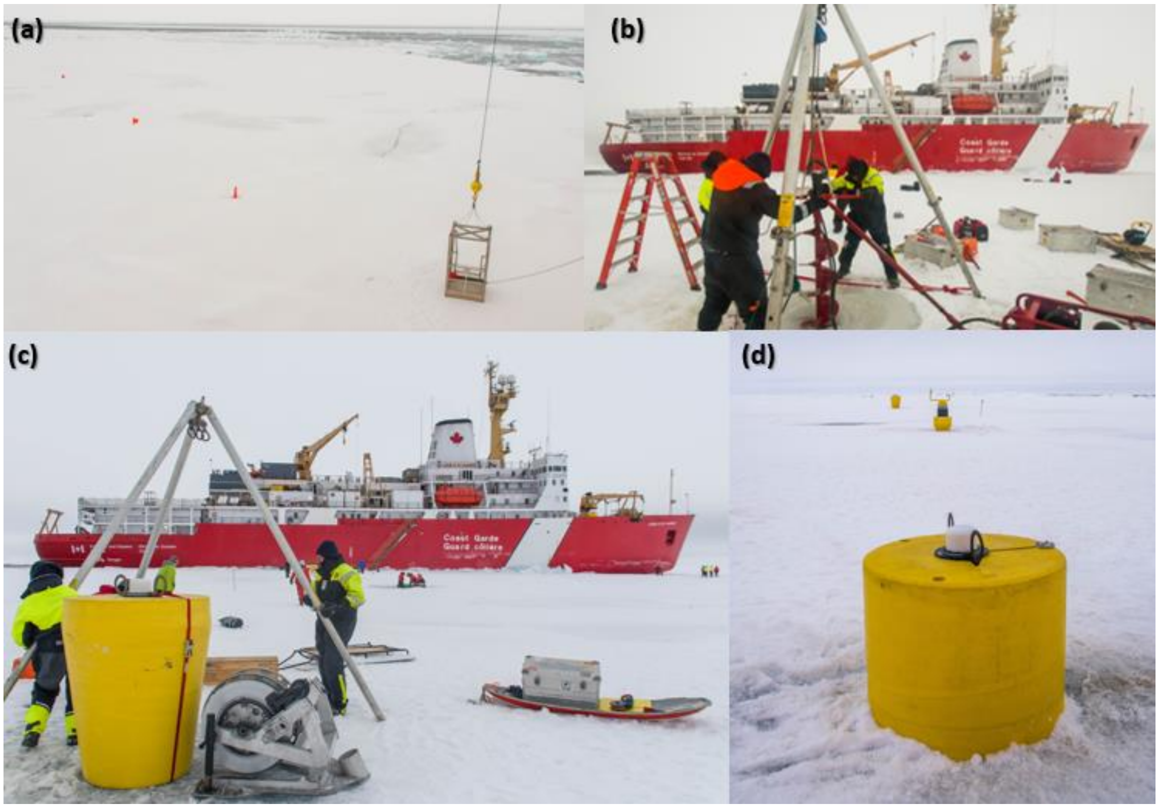
SIMB Dartmouth 2021 #7, 1.1 m thick ice, 2 cm freeboard, 7.5 cm snow thickness, 79 10.1699N, 140 16.8335W

AOFB 47, 1.9 m thick ice, 79 10.1548N, 140 16.9006W

TOP 5, 1.7 m thick ice, 79 10.1412N 140 16.9807W

OO30 UTC all personnel and gear were back on deck and the LSSL gently reversed out of the floe.





IBO #2 deployment: (a) Survey flags in test drill holes indicating approximate buoy placement; the man basket is on the ice for the ice survey; (b) Drilling the hole for the AOFB deployment; (c) Surface package of the installed ITP; (d) The installed IBO, with TOP in the foreground, ITP in the far field and AOFB in the middle (the IMB is the white pole to the right of the AOFB).

 # 3, September 26, 2022, near 79.5N, 140W; air temperature: -15^{o}C, winds: 15-20 knots

Personnel: Jeff O'Brien, Jim Ryder, James Kuo, John Jordan (WHOI); Mary-Louise Timmermans (Yale); Mike DeGrandpre (U. Montana) plus IOS ice team and LSSL crew

Three buoys were deployed on a single floe off the port side of the ship: ITP 137, TOP006 and SIMB 2021 #6.

The LSSL came into concentrated sea ice overnight with few visible leads and extensive ridging. The flat ice between the ridges was estimated to be only about 1 m thick. Before finding a floe in the early morning, transiting through the ridges was taking the LSSL multiple tries with all 5 engines on.

At 1345 UTC we found a suitable flat area off the port side, about 250 m across between the ship and the next ridge. There was significant snow cover, with drifts about 40 cm in places.

At 1430 Jeff O'Brien and Jim Ryder went over the side in the man basket and tracked a 100-m line to deploy TOP006 (closest to ship), SIMB 2021 #6 in the middle and ITP 137 furthest from the ship. At 1500 UTC, the survey was complete and the ice was found to be 1 m to 1.3 m thick. Most of the gear was slung by crane and the port gangway was out at 1650 UTC.

ITP 137 was deployed first. Near the start of this deployment a long crack in the ice formed (~10 cm wide) about 4 m away from the ITP hole, running parallel to the ship (about 100 m from the ship). The floe did not appear to separate, with the crack evidently confined to the upper part of the floe. Re-freezing was rapid throughout the day; the survey flags froze solid in their holes.

ITP 137 deployment was complete at 1830 UTC, followed by TOP006 deployment, complete at 2020 UTC. SIMB 2021 #6 was deployed at the same time as the ITP and TOP by the team from IOS (Kim Bedard, Chris Clarke and Paul Macoun).

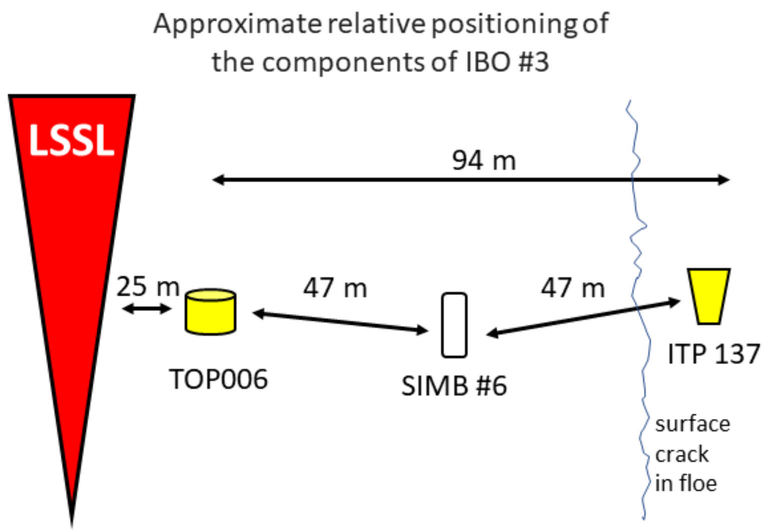
GoPro video was acquired through nearby drill holes of the ITP/SAMI and TOP.
After completion of the work at 2130, it took some time for the bridge to back the LSSL away from the IBO floe as the ice was so concentrated. We left the region on the track we made coming in.

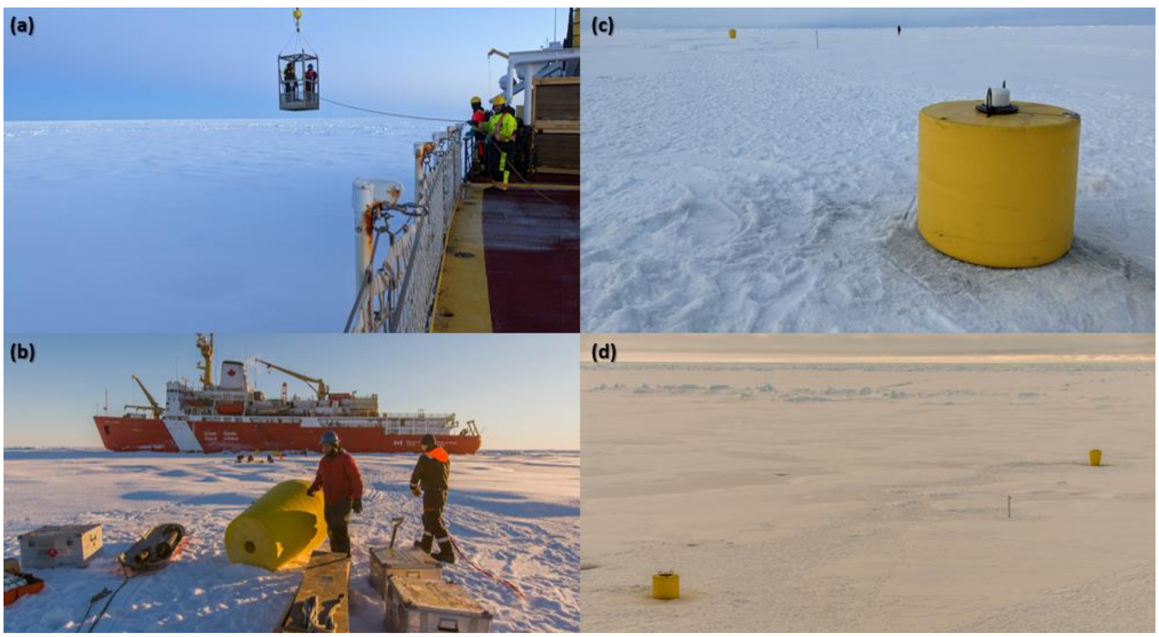
A summary of precise positions at 2030 UTC and ice thicknesses for each of the systems on this IBO is as follows, and the respective buoy configuration is shown in the schematic below:

ITP 137 (with DO sensor & SAMI at fixed depth), 1.0 m thick ice, 79 48.7023N, 139 57.7118W

SIMB Dartmouth 2021 #6, 99 cm thick ice, 3 cm freeboard, 12 cm snow thickness, 79 48.7038N, 139 57.5674W

TOP006, 1.1 m thick ice, 79 48.6967N, 139 57.4278W



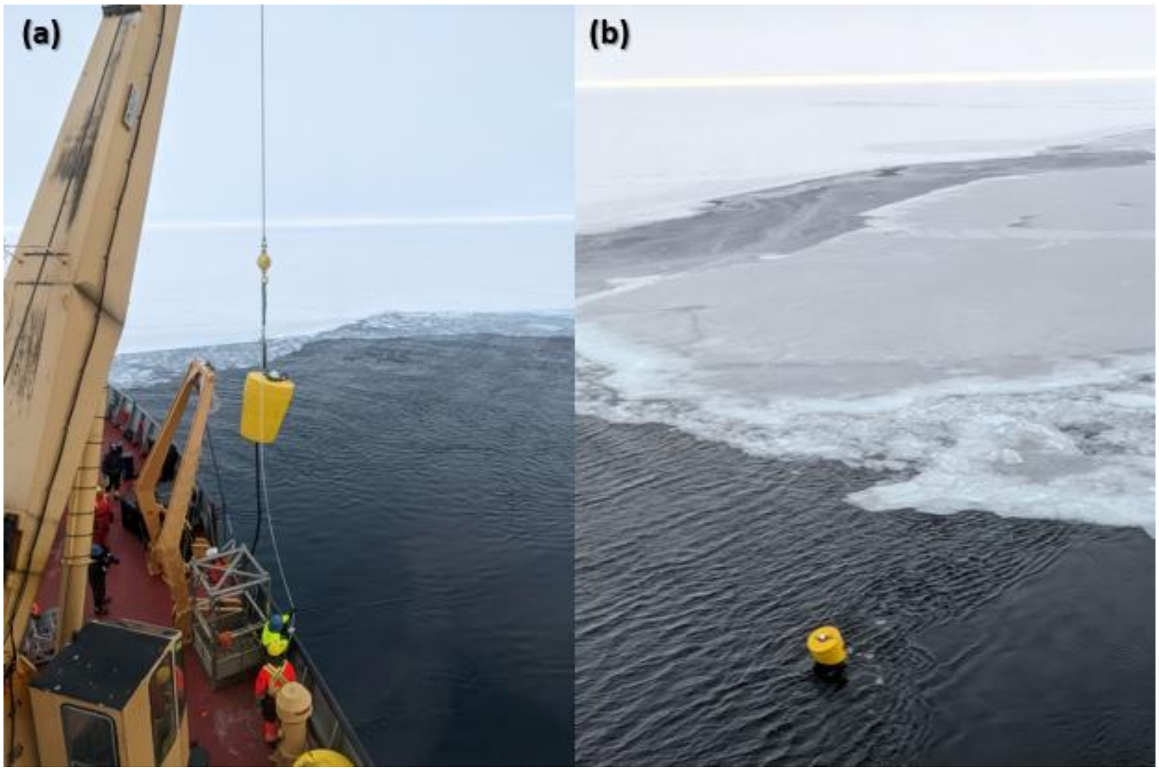


IBO # 3 deployment: (a) Man-basket over the port side to begin the ice survey; (b) Setting up to deploy the ITP; (c) IBO installed, with TOP in the foreground; (c) IBO installed with TOP in bottom left, IMB in middle and ITP on the right.

 # 4, September 27, 2022, near 79.0N, 147W; air temperature: -7^{o}C, winds: 26 knots

ITP 131 open water deployment off the CCGS LSSL (Jeff O'Brien, Jim Ryder, John Jordan, James Kuo and the LSSL deck crew).

At 1320 UTC, the WHOI team began preparing the gear on the deck for the open-water ITP deployment. All was ready when the LSSL stopped at 1350 UTC in a small pool of open water surrounded by mostly new ice, up to 10 cm in thickness. Its precise location on being released at 1506 UTC was 79 07.296N, 146 50.518W. As the LSSL left the site (1510 UTC), the ITP drifted toward new ice and the surface float listed to one side.



IBO # 4 deployment: (a) ITP surface float suspended over the side of the LSSL during the open water deployment; (b) ITP deployed after release from the ship.

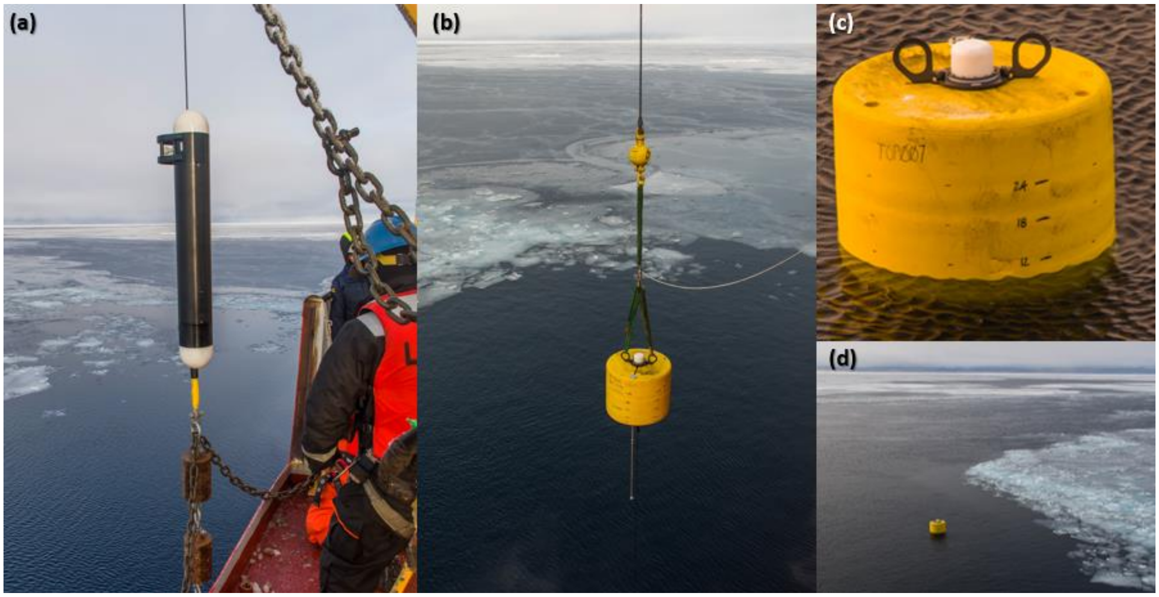
 # 5, September 30, 2022, *near 79.0N, 147W; air temperature: -10 ^{o}C, winds: 10 knots*

TOP007 open water deployment off the CCGS LSSL (Jeff O'Brien, Jim Ryder, John Jordan, James Kuo and the LSSL deck crew); this was the first TOP to be deployed in open water.

At 2230 UTC, the team prepared the gear on deck, and the ship stopped in a pool of open water surrounded by grey/nylus ice. The anchor for the 200 m deployment was over the side at 2301, and at 2308 UTC, the profiler was in the water.

TOP007 was released from the ship at 2347 UTC, at 77 01.51N, 149 15.08W.

The surface float was marked in increments to examine the draft of the surface float in open water (see photos). Based on visual inspection, the float was deemed to sit about 27 cm into the water.



IBO # 5 deployment: (a) TOP profiling unit and weights suspended over the side of the LSSL during the open water deployment; (b) TOP surface float with grounding pole suspended over the side; (c,d) TOP surface float after release from the ship.

4.4.4 **Outreach**

Dispatches documenting the expedition were written by Ashley Arroyo and Elizabeth Bailey (both from Yale U.) and posted in near real time on the WHOI website.

Table 8. Project websites

Project	**Website Address**
Beaufort Gyre Observing System	www2.whoi.edu/site/beaufortgyre/
Beaufort Gyre Observing System dispatches	www2.whoi.edu/site/beaufortgyre/expeditions/
Ice-Tethered Profiler buoys	www2.whoi.edu/site/itp/
Ice Mass Balance buoys	imb-crrel-dartmouth.org/simb3/
Arctic Ocean Flux Buoy	www.oc.nps.edu/~stanton/fluxbuoy/

4.5 Sea surface pCO_2, pH, and dissolved O_2

P.I.: Mike DeGrandpre and Cory Beatty (University of Montana, michael.degrandpre@umontana.edu)

4.5.1 Overview: U.S. National Science Foundation Project: An Arctic Ocean sea surface observing network for the partial pressure of carbon dioxide (pCO_2), acidity (pH), and dissolved oxygen (DO)

This project is a collaboration between the University of Montana, Woods Hole Oceanographic Institution (Jeff O'Brien, Isabela Le Bras and John Toole) and Yale University (Mary-Louise Timmermans). The primary objective is to provide the Arctic research community with high temporal resolution time-series of sea surface partial pressure of CO_2 (pCO_2), pH, temperature, dissolved oxygen (DO) and photosynthetically active radiation (PAR). Sensors for pCO_2 and DO are deployed on WHOI ice-tethered profilers (ITP). Placed on the ITP cable just under the ice, the sensors send their data via satellite using the WHOI ITP interface. On each of the 3 BGOS moorings, a SAMI-CO_2/SAMI-pH pair equipped with DO, PAR and temperature sensors are deployed at a depth of approximately 42 meters. In 2021, a fluorescence sensor was also deployed on Mooring D, in collaboration with Céline Guéguen (University of Sherbrooke).

Figure 11. SAMI CO_2 being deployed on an ITP (left) and CO_2 and pH sensors after recovery on Mooring B (right).

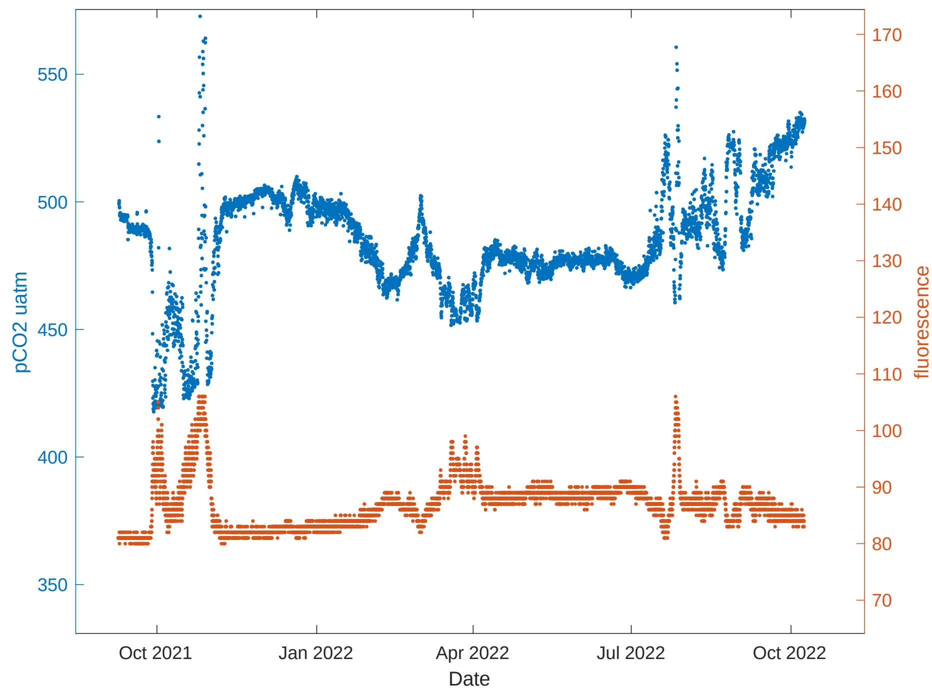


Figure 2. The *p*CO_2 (blue) and organic matter fluorescence (red, courtesy of Céline Guéguen) > 1 year time-series collected at ~42 m depth on Mooring D (Oct 2021 to Oct 2022). The strong correlation is evident.

4.5.2 **Cruise Objectives**

1. Deploy SAMI-CO_2 sensors with DO and PAR on 2 of the WHOI ITPs (ITP136 & ITP137).
2. Conduct underway *p*CO_2 measurements to provide data quality assurance for the ITP-based sensors and to map the spatial distribution of *p*CO_2 in the Beaufort Sea and surrounding margins.
3. Recover SAMI-CO_2/SAMI-pH pairs with DO and PAR on each of the three BGOS moorings (A, B and D).

4. Deploy SAMI-CO_2/SAMI-pH pairs with DO and PAR on each of the three BGOS moorings (A, B and D).
5. Assist with other shipboard research activities and interact with ocean scientists from other institutions.

4.5.3 **Cruise Accomplishments**

- We deployed SAMI-CO_2 sensors equipped with dissolved O_2 and PAR sensors on 2 of the ITPs (ITP136 & ITP137).
- We collected underway pCO_2 data using an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors) continuously over the 27 day cruise. The instrument was connected to the Louis seawater line manifold located in the main lab.
- We also deployed SAMI-CO_2/SAMI-pH pairs on the BGOS-A, BGOS-B and BGOS-D moorings.

The sensor time-series collected for moorings deployed in 2021 and the new ITPS are summarized in the Table below. The recovered mooring D pCO_2 and fluorescence time-series are shown in Figure 2.

Table 9. DeGrandpre group sensor data collection summary

BGOS-A Mooring					
	CO2	**pH**	**O2**	**PAR**	
Instrument ID	C38u	XXX	4175: 1765 (4-pin b/h)	XXX	
	XXX	P47u	XXX	9387	
Days of data	263	398	398	398	
BGOS-B Mooring					
	CO2	**pH**	**O2**	**PAR**	
Instrument ID	C48u	XXX	4175: 717 (4-pin b/h)	XXX	
	XXX	P68u	XXX	9385	
Days of data	392	0	392	392	
BGOS-D Mooring					
	CO2	**pH**	**O2**	**PAR**	**Fluorometer**
Instrument ID	C37u	XXX	4175: 1699 (5-pin b/h)	XXX	FNTQ
	XXX	P5u	XXX	9386	
Days of data	394	20	394	394	394
ITP-136					
	CO2	**IMM ID**	**O2**	**PAR**	
Instrument ID	C221	700-9548	4531A: 1517	UWQ-10479	
Days of data (so far)	14	14	14	14	
ITP-137					
	CO2	**IMM ID**	**O2**	**PAR**	
Instrument ID	C222	700-9551	4531A: 1518	UWQ-10480	
Days of data (so far)	no data		no data	no data	

4.6 XCTD Profiles

Onboard lead: Paul Macoun

PIs: Bill Williams (DFO-IOS), Motoyo Itoh (JAMSTEC), Andrey Proshutinsky, Isabel Le Bras, Rick Krishfield (WHOI), Mary-Louise Timmermans (Yale),

Overview

Profiles of temperature and salinity were measured using expendable probes capable of being deployed while the ship was underway. Profiles were collected at 52 locations along the ship's track between the CTD stations.

Procedure

Expendable CTD probes (Tsurumi-Seiki Co., Ltd) were deployed from a hand-held launcher LM-3A (Lockheed-Martin_Sippican, Inc) from the ship's stern. The data were communicated from the probe back to the launcher by a fine wire which breaks when the probe reaches its maximum depth. The launcher was connected to the Lockheed-

Martin-Sippican MK-21 Ethernet deck unit and data were logged using the WinMK-21 software installed on the IOS laptop “Arrow”.

The MK21 firmware and software were updated this year (2022) to ensure compatibility with the new XCTD-1N probe.

Connection between the laptop and the deck unit was via an Ethernet switch. The switch was also connected to the science network. The ship’s GPS stream was provided by science server over the network via GPSGate. Water depth from the sounder was displayed on the laptop in a terminal window. Data were automatically backed up by the WinMK-21 software to the local drive on the laptop. At the end of the cast the operator filled in the log sheet and manually transferred the new files to the science server.

Operation Notes

Three types of probes were used:

Probe Type	Number Used	Filename convention	Max Depth (m)	Max Ship Speed (Kts)
XCTD-1	23	“C3_”	1100	12
XCTD-1N	19	“C3_”	1100	12
XCTD-2	9	“C4_”	1850	3.5

According to the manufacturer’s nominal specifications, the range and accuracy of parameters measured by the XCTD are as follows;

Parameter	Range	Accuracy
Conductivity	0 ~ 60 [mS/cm]	+/- 0.03 [mS/cm]
Temperature	-2 ~ 35 [deg-C]	+/- 0.02 [deg-C]
Depth	0 ~ 1000 [m]	5 [m] or 2 [%] (whichever is larger)

Of the 23 XCTD-1 probes, 19 successfully reached maximum depth (1,000 m). The 4 probes that did not complete the cast achieved depths of 115 m, 163 m, 260 m and 361 m before the data connection to the probe was lost. In most cases the wires were prematurely severed by ice in the wake of the ship.

Of the 19 XCTD-1N probes, 16 successfully reached maximum depth (1,000 m). Two of the probes that did not complete the cast achieved depths of 610 m and 800 m. No specific reason was determined for the loss of data before maximum depth was achieved. In one separate case the 1N probe produced reasonable data up until a depth of 658 m after which it continued to report data that was clearly incorrect.

Of the 9 XCTD-2 probes, 7 successfully reached maximum depth (1,850 m). One probe that did not complete the cast achieved a depth of 358 m. One probe failed to initialize when it was loaded into the launcher.

Two casts were compromised when the operator inadvertently selected the wrong type of probe (XBT). The deployments still yielded data but it was not decipherable/usable (XCTD casts 16 & 17).

Start time in file header

The XCTD file’s launch information uses start time from the computer clock, not NMEA. The computer clock was checked against NMEA time at the start of the cruise and was within 1 minute.

See Appendix for table of stations.

4.7 Vertical Net Tows

Kim Bedard (DFO-IOS), Annabel Payne, Anne-Marie Wefing (ETH Zurich), Justin Forget (Universite de Sherbrooke), Nimrod Rozen (University of Victoria)

P.I.: John Nelson (DFO-IOS)

4.7.1 Sampling

Zooplankton sampling and preservation were conducted on board by Kim Bedard, Anne-Marie Wefing, and Justin Forget of the day watch as well as Nimrod Rozen and Annabel Payne of the night watch. A standard bongo net system was used with a fitted 150µm net on both sides as well as a calibrated TSK flowmeter installed to measure the amount of water flowing through the nets. In addition, an RBR Virtuoso pressure recorder was mounted on the gimble rod to record the actual depth of each net cast.

A total of 32 bongo vertical net hauls were completed at 32 stations (see list in appendix).

The sampling strategy was to perform net hauls whenever time and weather permitted, provided they did not interfere with the rosette operation or require additional ship time. At each station where net hauls were performed a single 100m bongo vertical net haul was completed. A total of two samples were collected at each station, one from each side of the bongo net.

Bongos were deployed on the foredeck using a Swann 310 hydraulic winch and 3/16” wire through the forward starboard A-frame. Rinsing of the nets was accomplished by attaching an electrically heated hose to the salt-water tap on the port side near the outer door near the lounge. Water was left running during the cast to prevent the hose from freezing. The hose was removed after every station, emptied of water, coiled, and carried to the port foredeck sciences container to keep it warm.

The bongo was fitted with two 150µm mesh nets. One side of the bongo was labeled E with TSK serial number 7085 and the other side was labeled F with TSK serial number 7303. For consistency samples collected from the net marked E was preserved in 95% ethanol and samples collected from the net marked F were preserved using formalin with final sample concentration 3.7%. The formalin samples will be examined for species identification and the ethanol samples for DNA sequence analysis coordinated by John Nelson.

UTC was used to log all times and dates in zooplankton log unless otherwise specified.

Figure 12. Bongo nets being deployed from the foredeck, photo Gary Morgan, JOIS 2021

Net Mesh Size	TSK Flow Meter	Sample Preservation
150um	sn7085	95% Ethanol for DNA sequence analysis
150um	sn7303	3.7% Formalin for for species identification

A new storage box for the bongo system was used this year replacing the large wood box that tended to leave splinters of wood in the nets. The new large plastic box worked well however it will be brought back to IOS after the program to modify the gate to ease the launching and recovery of the nets.

4.7.2 Issues and solutions

Some stations with loose flowing ice were challenging for the bridge to maintain an ice free pond for both the bongo and rosette at the same time. For several stations, the nets were held at the bottom of the cast for extra time while the bubblers pushed back ice then the haul was resumed right after the bubblers turned off. This is preferable way to manage fast ice. Unfortunately, at CB3, Net 17, the bubblers had to be turned on again during the up cast at 34m and the net could not be brought up in one motion due to large ice blocking the surface and the ship drifting into unbroken ice.

Zooplankton operations take place on the starboard side and the saltwater supply for rinsing is drawn further aft on the port side. It would be helpful to have a saltwater source on the starboard side to reduce the length of hose needed to reach the A-frame. In 2022, the heating element of the 100' hose was not working during the cruise so the water was left running over the side of the ship when not in use to prevent freeze up.

A brass hose nozzle was used on the foredeck; this was a great choice as it is much more durable than plastic nozzles.

It was noticed that after several stations on the night watch, the nets were not rinsed down thoroughly and there was part of the sample remaining in the net prior to the next cast. This was rinsed prior to continuing as not to contaminate the next sample, but should be noted that some samples may not be complete from this watch. This is known to be true for CB23a, CB51, CB17, CB12.5, StnA, and CB19 and has been recorded in the logs.

4.8 Underway Surface Sea-water Measurements

Sarah Zimmermann (DFO-IOS), Celine Gueguen, Nicolas Sylvestre, and Justin Forget (USherbrooke)
P.I.s: Bill Williams, Celine Gueguen (USherbrooke), Mike DeGrandpre (UMontana)

The ship's seawater loop system draws seawater from below the ship's hull at 9 m using a 3" Moyno Progressive Cavity pump. After measuring the intake seawater temperature, seawater travels through ~50m of stainless steel piping to a manifold in a wetlab off the main science lab. The wetlab is configured with an integrated Seabird SBE21 thermosalinograph, Seapoint Chl-a fluorometer and Wetlabs FDOM fluorometer.

Recording independently, a second Wetlabs FDOM fluorometer, and a pCO2 system were connected to the wetlab manifold.

Measurements were made for:

a. Surface temperature (inlet and lab), salinity, and fluorescence for Chlorophyll-a and FDOM.
b. Water samples were drawn for
    - Salinity, Dissolved Inorganic Carbon, Alkalinity, and Chlorophyll (IOS/DFO)
    - Fluorescent Dissolved Organic Matter (*Celine Gueguen, USherbrooke*)
c. Measurements of partial pressure of carbon dioxide ($p\mathrm{CO_2}$) using a SunBurst SUPER instrument (*Mike DeGrandpre, UMontana). See section on Sea surface pCO2, pH and dissolved O2.*

Details of the set-up, operation, instruments' make, model, serial numbers, calibration, and performance are given in the appendix.

4.9 Underway data logging using SCS

Sarah Zimmermann, Paul Macoun (DFO-IOS)
P.I.s: Bill Williams

The ship uses the Shipboard Computer System (SCS) written by the National Oceanographic and Atmospheric Administration (NOAA), to collect and archive underway measurements. This system takes data arriving via the ship's network (LAN) in variable formats and time intervals and stores it in a uniform ASCII format that includes a time stamp.

The Shipboard Computer System (SCS) was used to log

1. GPS from the ship's Furuno GPS, using NMEA strings $GPGGA and $GPRMC. These are the same GPS sentences, available on the science VLAN, being used by CTD, XCTD, TSG and mapping programs.

2. AVOS weather observations of air temperature, humidity, wind speed and direction, and barometric pressure ($AVRTE)

3. Sounder depth and the applied ship's draft and sound speed

4. Surface Photosynthetically Active Radiation (PAR)

5. Thermosalinograph (TSG), and the inlet sea surface temperature from the SBE38 that is also given in the TSG data stream.
6. Heading from the ship's Gyro ($HEHDT)
7. Data from the FDOM fluorometer in the seawater loop (FDOM)
8. Derived true wind speed calculated in SCS

Note the AVOS, TSG (and SBE38), PAR and FDOM data are also logged through their own software programs which may be more complete than the SCS record.
In particular, the TSG files will have updated calibration and processing through the SeaBird software. On the otherhand, computer feeds (ex. navigation feed to TSG computer) can mean the TSG file is incomplete and the SCS data server as a great backup.

Also note, the timestamp that precedes all the SCS strings is very useful for combining records, however keep in mind this timestamp comes from a computer clock that can drift. Please correct to the GPS time from the GGA or RMC record for the correct time.

The SCS system on a shipboard computer called the "NOAA server" collects *RAW files. The files are periodically restarted and contain up to a weeks' worth of data.

More information on *.RAW files, string definitions, equipment and instruments, and issues are given in the Appendix.

4.10 Ice Observations – Bridge Watch

Kazu Tateyama and Kosuke Kawamura (KIT)
P.I.: Kazu Tateyama (KIT), Jennifer Hutchings (OSU)

As in previous years, the ice observations recorded during the cruise will provide detailed information for the interpretation of satellite imagery of the ice pack.

4.10.1 Observations from the Bridge: Methodology

While the ship was in the ice pack, ice conditions and supporting weather information were recorded every hour within 1nm about the ship when visibility allowed along the ships track. The combined 12-hour Ice and XCTD watch were carried out by the two ice observers, Kazu Tateyama and Kosuke Kawamura, to cover the full 24 hours.

Ice observations were made using the ASSIST protocol. ASSIST is based upon ASPECT (Worby & Alison 1999) bridge observation protocol, with additional information to characterize Arctic sea ice. Additional observables included melt pond characteristics, sediment on ice and an additional ice type – second year ice.

Observations were started on 18th September and ended on 10th October. The thick old ice such as multi-year ice and second-year ice around 100 cm were observed largely as shown in Fig.1.

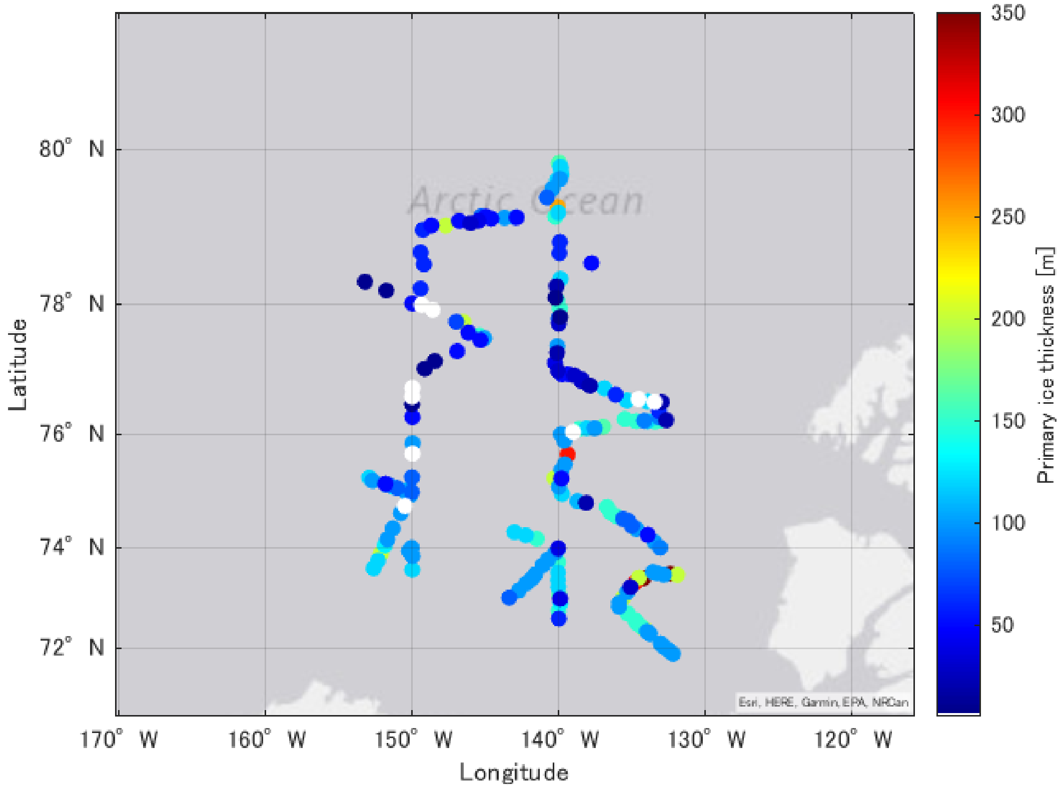


Figure 1. Ice thickness distribution for primary ice

4.10.2 Web and GoPro Cameras

Network camera (Netcam) imagery has been collected since 2007. This year, three cameras, were installed above or on the bridge with views of the sea-ice.

One netcam was mounted above the bridge on the port-side rail looking down to where the ice rolls on edge after contact with the ship to measure ice thickness. A 2m long pole with 10cm marked increments was mounted on the 400 deck rail was in the field of view of the images to aid in sea-ice thickness measurements. This camera recorded images every 10 seconds.

The other netcam was mounted above the bridge on the forward rail, looking forward to measure ice concentration. There had been a problem with powering this camera resulting in no images in 2019 or 2020. As in 2021, the problem was solved by using an extension cord to supply the camera's power instead of a powered network cable. This camera recorded images every 1 minute.
A gigabit router/switch was used to connect the ship's network port (running at 100mb) to the netcams (running at 10mb). The switch was able to automatically connect the two and no resetting of the ship's port was needed as in past years. The network port is in the ice observers room on the bridge.

As started in 2019, a self-recording GoPro camera was installed pointing forward looking over the bow from inside the bridge. New this year, the port-side forward facing window was replaced with a full length window. A new mount for the Go-Pro was attached to the window sill. These images duplicate those collected by the forward looking web camera and was also set to record images every 1 minute.

The netcam imagery was saved in real-time onto the Science server. The GoPro camera memory card was downloaded as needed (~5days). The quality of the GoPro image is superior to the netcams.

Issues
The netcams needed regular tending to record meaningful imagery. For setup, the time needed resetting after startup, the focal settings needing fine tuning to find best focus, zoom and light level, the mounting was important to have the correct field of view. During operation the housing box's window would ice up (snow and rain) blocking the focus and view.

The GoPro was fairly trouble free once running properly. It also needed time to be checked as the file date is the only link to the time of the photo. Being inside looking through the protected bridge window, the view was typically free of ice/rain/snow issues.   Problems arose with on/off buttons accidently getting pressed due to how the strapping held the camera in place. These issues would not be notices until it came time to download the data potentially losing days of data. The file and folder names cycle after downloading so each download was written to a unique folder.

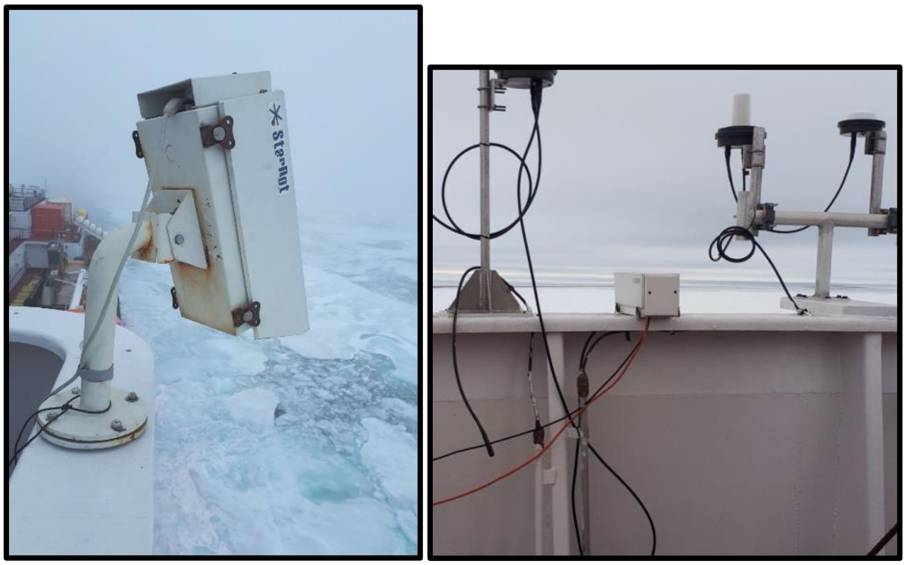


Figure 13. The downward and forward looking netcams above the bridge.

New location of forward looking GoPro camera on the port side of the bridge.

4.10.3 Experimental Self-contained Camera

Kazu Tateyama (KIT) continued trials of a new self-contained camera system. A single housing contains three camaras: forward looking, port-side downward looking, and upward all-sky looking cameras. The same housing hold a GPS receiver, data logger and battery. The housing connects to a solar panel to power the system Operationally we found there was a problem with icing where it was mounted above the bridge, similar to the netcameras.

Self-contained camera system with solar panel mounted above the bridge on forward, port corner.

4.11 Ice Observations – Ice Thickness from suspended EM sensor

Kazu Tateyama and Kosuke Kawamura (KIT)
P.I.: Kazu Tateyama (KIT), Jennifer Hutchings (OSU)

After a two year absence due to COVID related travel restriction, ice thickness measurements from an Electro-Magnetic induction device (EM sensor) were made again.

4.11.1 **Methodology**

An Electro-Magnetic induction device EM31/ICE (EM) and a laser altimeter LD90-3100HS were used for indirect sea-ice thickness measurement continuously, installed at foredeck's crane on the portside. EM and laser instruments were covered by a yellow-orange coloured waterproof fibre reinforced plastic case and hung at 4.5m height above sea surface and with at least 7m separation from the side of the ship to avoid getting hit by the ice and the effect from ship's hull as shown Fig.2.

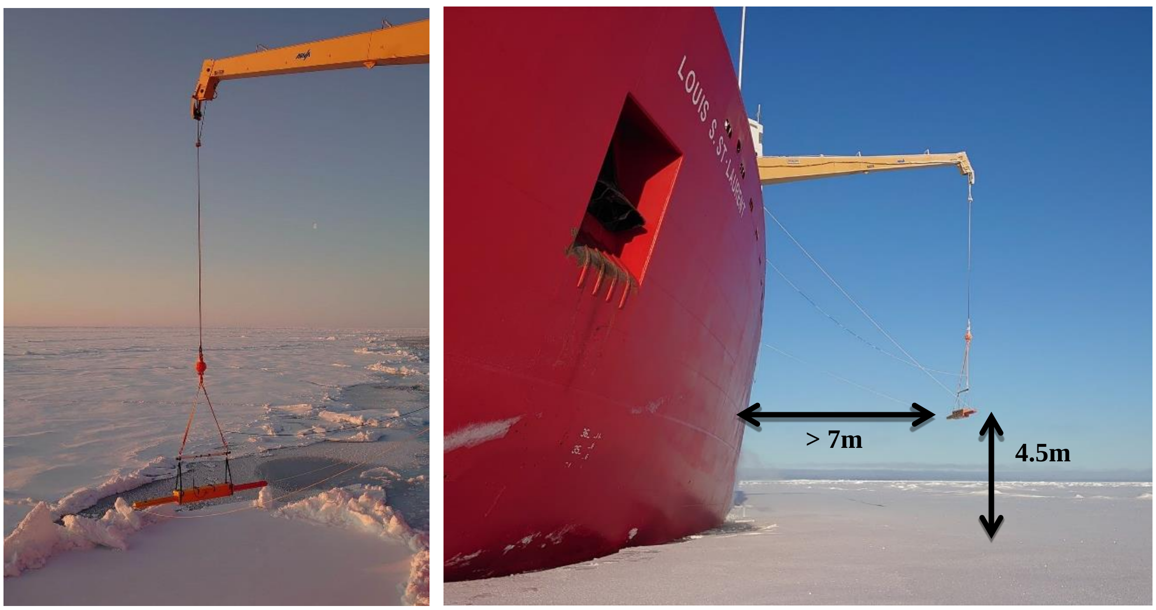


Figure 2. Photos of EM sensor

The EM provides apparent conductivities σ_a (mS/m) in which can be converted to a distance between the instruments and sea water at sea-ice bottom Z_E (m) by using following empirical equation.

$$Z_E = a - \ln{(\sigma_a - b)}/c \qquad (1)$$

where *a*, *b*, and *c* is coefficients which derived from regression analysis of calibration data. The laser distance meter provides a distance between the instruments and snow/sea-ice surface Z_L (m). Thus, the total thickness of snow and sea-ice Z_{S+I} can be derived by subtracting Z_L from Z_E.

$$Z_{S+I} = Z_E - Z_L \qquad (2)$$

The laser distance meter could not observe correct distance on the open water, because mirror reflection occurs at sea-surface. Therefore, sea-ice concentration can be derived from ratio of error and correct distance.

The Z_{S+I} was recorded every 0.1 second by a data logger and averaged into 1 second data during cruise in order to survey interannual thickness change. EM total thickness also used to validate estimated sea-thickness from the satelliteborne passive microwave radiometer AMSR2 (Krishfiled et al., 2014; Tateyama et al. 2018).

4.11.2 Total thickness profiles

Please contact Kazu Tateyama for more information.

4.12 Ice Observations – On ice stations

Kazu Tateyama and Kosuke Kawamura (KIT) ,Nicolas Sylvestre and Justin Forget (Sherbrooke), Sarah Zimmermann, Erin Raftery and Kim Bedard (IOS), Susan McLatcie (ConcordiaU), Ashley Arroyo and Elizabeth Balley (YaleU) , Annabel Payne and Anne-Marie Wefing (ETH Zurich)

P.I.: Jennifer Hutchings (OSU), Kazu Tateyama (KIT)

Ice observations were made at two of the three on-ice stations where the WHOI ITP buoys were deployed to characterize the sea-ice floe, by measuring ice thickness, temperature, salinity and density profiles of ice-cores, and snow properties.

Ice and snow measurements were conducted by following the standard JOIS protocol at each ice station:

1. Establishing 100m-long or 200m-long transect line by using tape measure and flags
2. Collecting snow depth, ice thickness and freeboard data along transects at every 10m by using an electrical-powered ice auger with a generator.
3. Collecting ice cores at 0m, 50m, 100m
4. Measuring snow pit at 0m, 50m, 100m

Due to on board storage problems of the ice equipment this year (the ship suffered a leak causing a full renovation of the storage room), it was belatedly discovered that many items had been contaminated with oily water which resulted in rust, mildew and some unrepairable losses. A special thanks to the ship's engineers and deck department for helping to clean many of the rusted items and bringing the auger and generator back to life.

4.12.1 **Overviews of ice stations**

<u>Ice Station 2</u>
Drilling: Erin Raftery, Kosuke Kawamura, Susan McLatcie
Coring: Nicolas Sylvestre, Ashley Arroyo, Justin Forget, Annabel Payne
Snow pit: Kazu Tateyama

Ice was accessed from gangway of starboard side. Two 100m-long transects were set as shown in Fig.3. Ice cores were collected at three sites (0, 50, 100m) along the transect #1 line. Averaged thickness of transect #1 and #2 were 1.20m and 1.56m, respectively.

<u>Ice Station 3</u>
Drilling: Anne-Marie Wefing, Erin Raftery, Kosuke Kawamura, Susan McLatcie
Elizabeth Balley, Kazu Tateyama, Paul Macoun
Coring: Ashley Arroyo, Justin Forget, Sarah Zimmermann, Annabel Payne, Nicolas Sylvestre, Susan McLatcie, Kim Bedard
Snow pit: Kazu Tateyama

Ice was accessed from gangway of port side. 200m- and 100m- long transects were set as shown in Fig.3. Ice cores were collected at three sites (0, 100, 200m) along the transect #1 line and one site along transect #2 below the EM sensor. Averaged thickness of transec#1 and #2 were 1.04m and 1.01m, respectively.

Station 2 **Station 3**

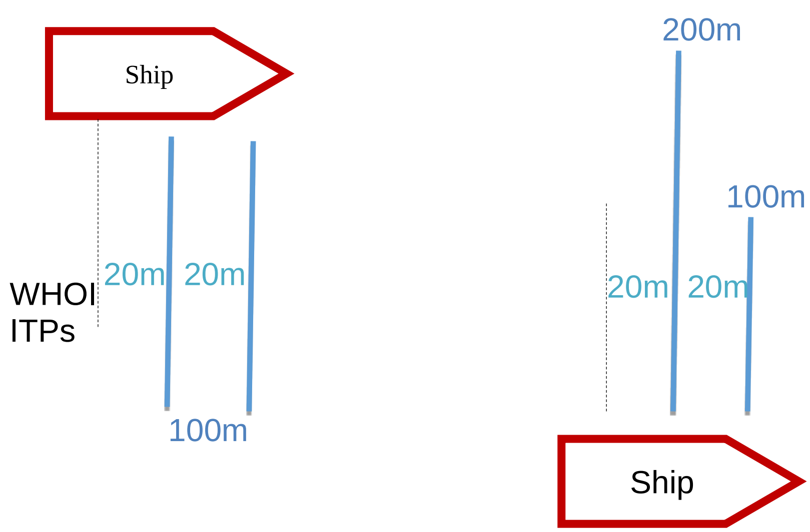
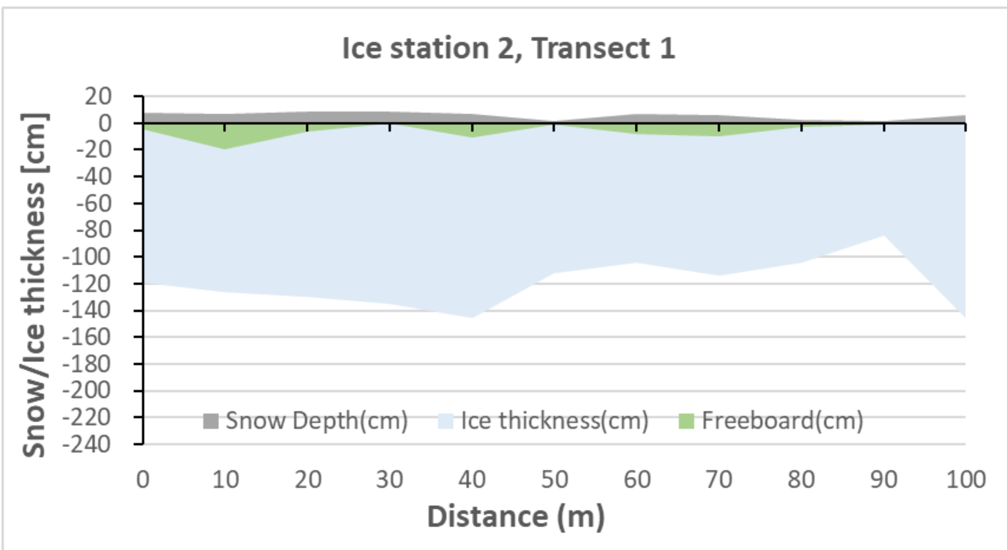


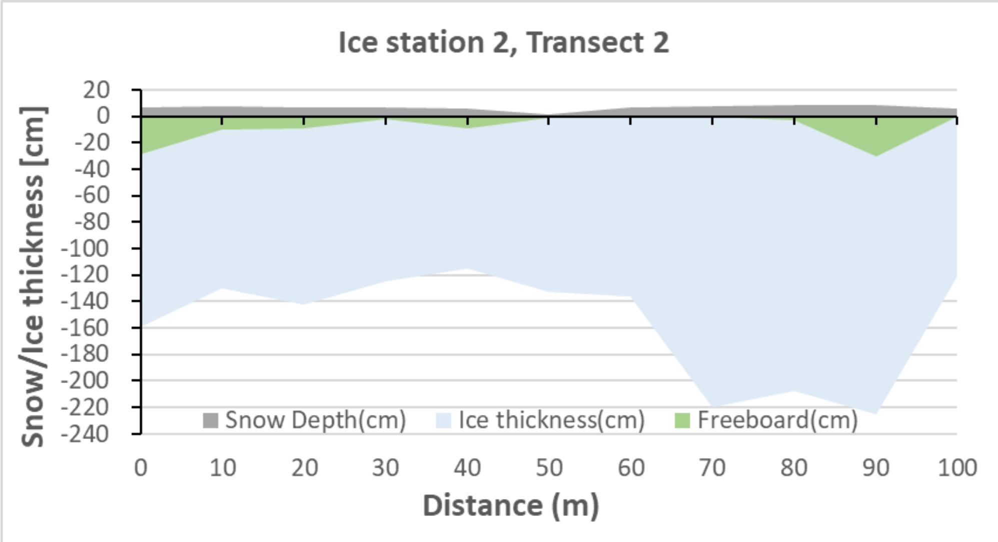
Figure 3. Drawing of transects on each ice stations.
Station 2 and 3 consist of 2 parallel transects.

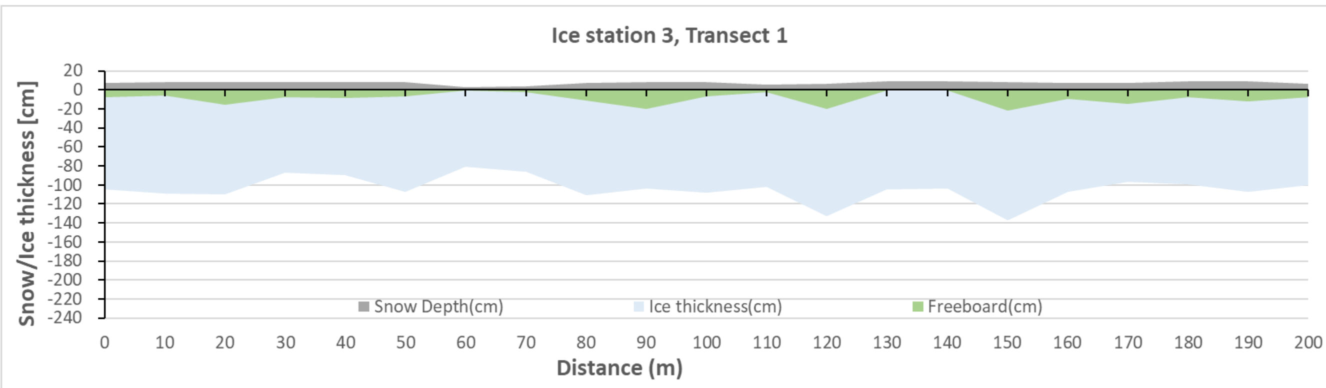
4.12.2 Ice thickness transects

At ice station 2 and 3 we measured two 100m transects for snow depth, ice thickness and ice freeboard every 10m along the transect. A 2” ice auger and electric drill were used to make a hole in the sea-ice. Ice thickness and freeboard were measured with using a tape measure with a weighted end (“dongle”). Snow depth was measured with a plastic ruler.

Transect #1 is the mid-ship transect and transect #2 is towards the bow. The start of the transect (0m) is closest to the ship.







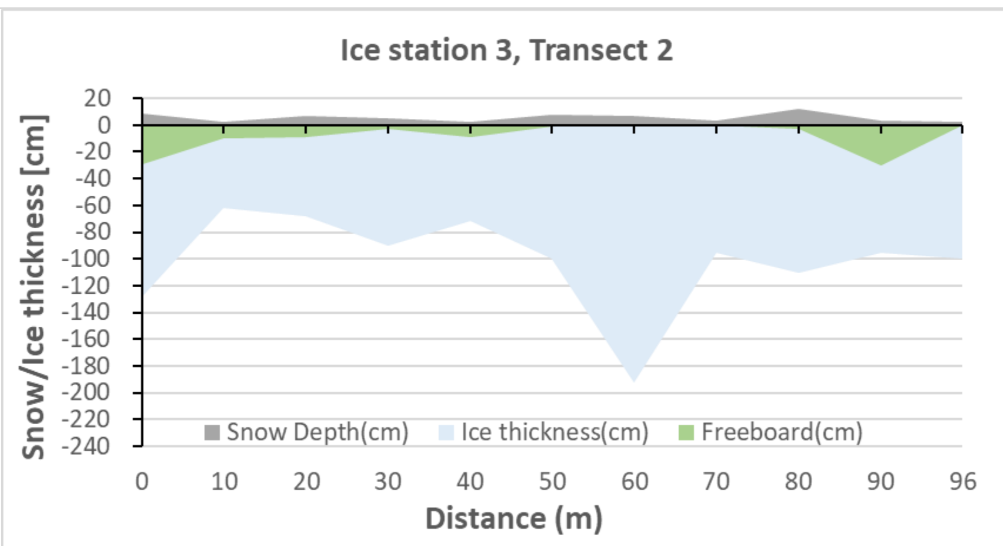


Figure 4. Snow depth, ice thickness and freeboard measurements at ice station 2 and 3.

4.12.3 **Ice Cores**

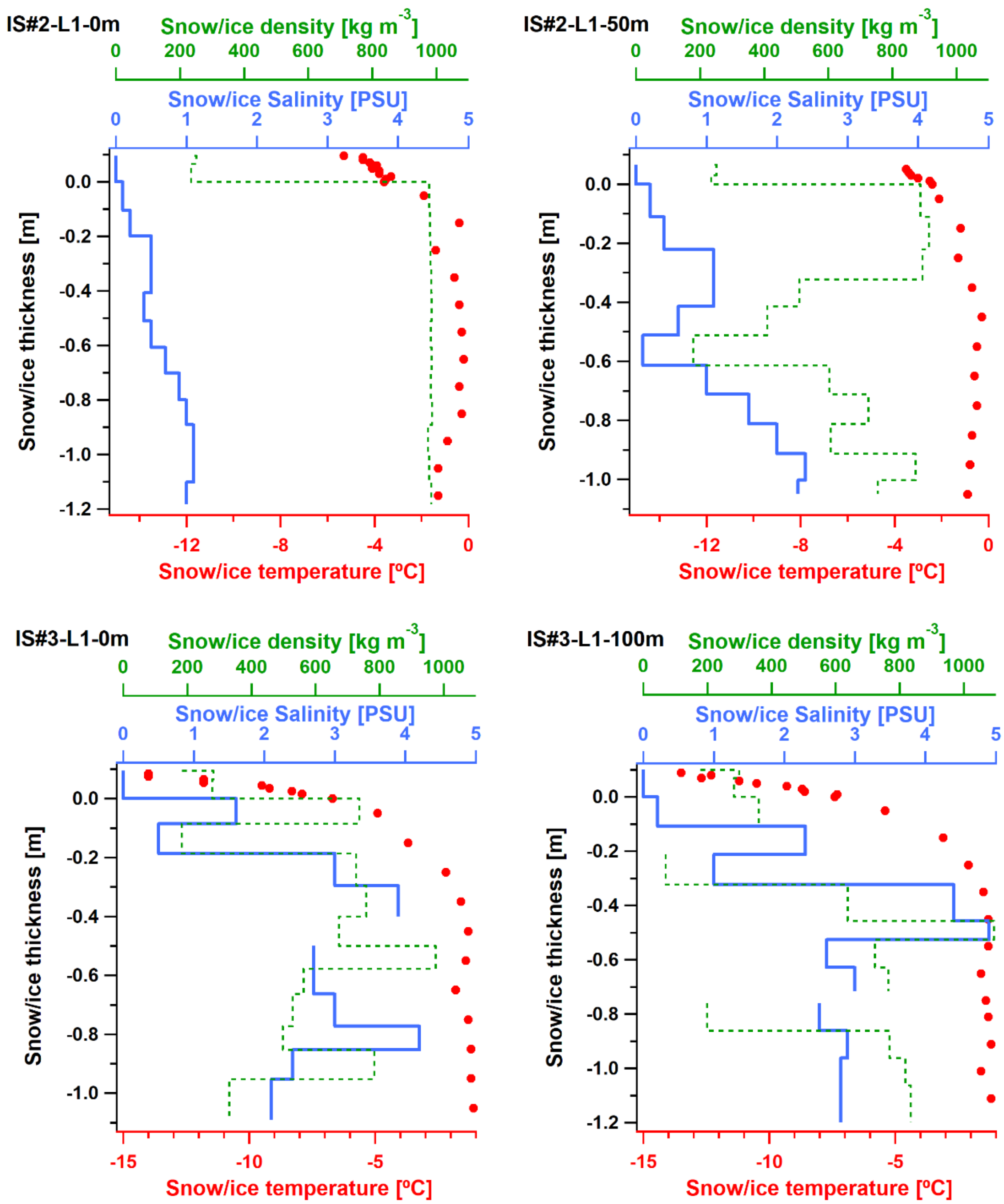
Table 1 shows the summary of collected ice core samples

Station	**Transect # and distance**	**Property**
Ice Station 2	Transect 1, 0m	Temperature, Salinity, Density
Ice Station 2	Transect 1, 50m	Temperature, Salinity, Density
Ice Station 2	Transect 1, 100m	Temperature only
Ice Station 2	Next to ITP (20m from Transect 1)	TEP chemistry (see Chemistry Sampling section)
Ice Station 3	Transect 1, 0m	Temperature, Salinity, Density
Ice Station 3	Transect 1, 100m	Temperature, Salinity, Density
Ice Station 3	Transect 1, 200m	Temperature only
Ice Station 3	Transect 2, 0m	Temperature, Salinity, Density
Ice Station 3	Next to ITP (20m from Transect 1)	TEP chemistry (see Chemistry Sampling section)

Temperature, Salinity and Density Profiles

Temperature, salinity and density profiles were measured at each core site. Figure 5 shows temperature, salinity and density profiles of snow and ice. Figure 6 shows the snow structure and photograph of observed snow crystal types.

Cores were collected using a 1m long ~4” diameter corer using a gas powered auger head. Immediately after collecting the core, the temperature was measured at 10cm intervals starting at 5cm. The core was then sectioned into 10cm chunks, measured for volume, bagged and melted back on board for salinity measurements. Salinity was measured using a hand held salinity probe.



IS#2-L1-0m
IS#2-L1-50m
IS#3-L1-0m
IS#3-L1-100m
Snow/ice density [kg m-3]
Snow/ice Salinity [PSU]
Snow/ice thickness [m]
Snow/ice temperature [ºC]

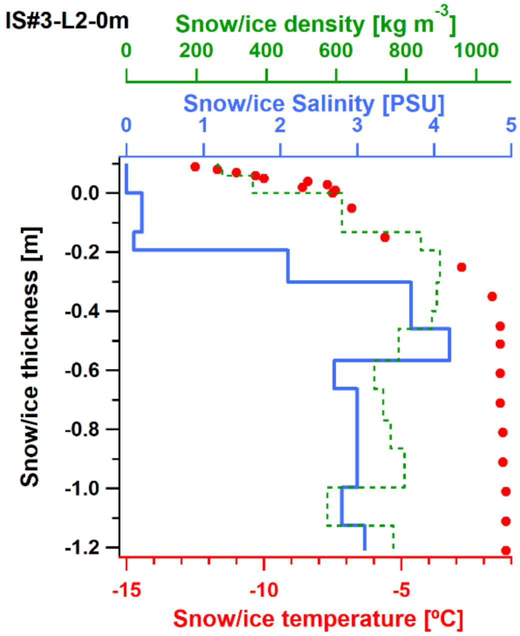
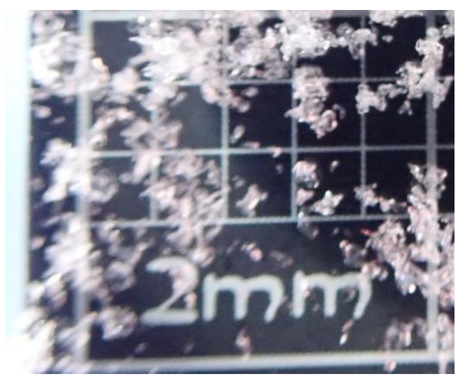


Figure 5. Temperature, salinity and density profiles of ice core samples from Ice station 2 and 3.

cm	
9.5	
	Rounding surface hoar (0.1-0.3mm)
8.0	
	Ice layer
7.5	
	Rounding depth hoar (2.0mm)
6.5	
	Rounding depth hoar (2.0-4.0mm)
3.0	
	Large striated crystals (2.0-6.0mm)
0.0	

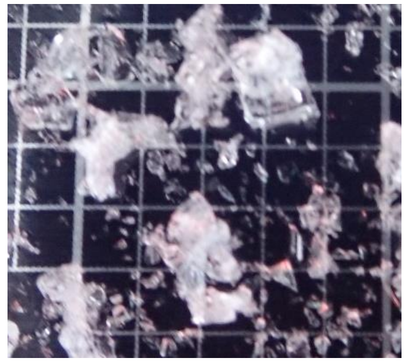
Ice station 2-#1-0m



Rounding surface hoar

cm	
9.5	
	Rounding surface hoar (0.1-0.3mm)
8.0	
	Ice layer
7.5	
	Rounding depth hoar (2.0mm)
6.5	
	Rounding depth hoar (2.0-4.0mm)
3.0	
	Large striated crystals (2.0-6.0mm)
0.0	

Ice station 2-#1-50m



Rounding depth hoar

cm	
9.5	
	Rime (0.5-1.0mm) Surface hoar crystals (2.0-4.0mm)
9.0	
	Hollow cups (2.0-4.0mm)
5.0	
	Hollow prisms (3.0-6.0mm)
0.0	

Ice station 3-#1-0m

Hollow prisms

cm	
10.5	
	Dendrites, Surface hoar crystals (2.0mm), Rime (0.5-1.0mm)
10.0	
	Rounding faceted particles (0.5-1.0mm)
8.0	
	Hollow prisms (1.5-2.5mm)
5.0	
	Hollow cups (2.0-4.0mm)
3.0	
	Large rounded particles (4.0-6.0mm)
0.0	

Ice station 3-#1-100m

Large rounded particles

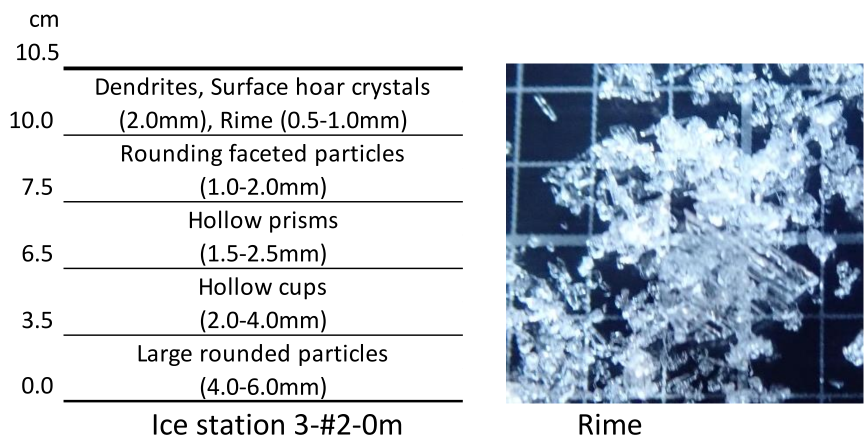


Figure 6. Results of snow structure observations and photograph of each snow crystal.

4.12.4 **Data**

For more information and data, please contact Kazu Tateyama referencing

2022-45-JOIS/Data/

- /JOIS2022_Icestation_Transect_Core/
  JOIS2022_Ice_Stations_Summery.xlsx
  JOIS2022_Icestation_Transect.xlsx
  /Ice_station#2/ and /Ice_station#3/
  /Ice Core Photos/
  /Snow pit photos/

- /Ice_Watch/
  JOIS2022_ice_watch.xlsx
  /Ice_Watch_Photos/

- /Shipborne_EM/
  Not ready

4.12.5 **References**

Hutchings, JK, Heil, P, Lecomte, O, Stevens, R, Steer, A and Lieser, JL. (2015). Comparing methods of measuring sea-ice density in the East Antarctic. *Ann. Glaciol.*, 56(69): 77-82 (*doi.org/10.3189/2015AoG69A814).*

Krishfield, RA, Proshutinsky, A, Tateyama, K, Williams, WJ, Carmack, EC, McLaughlin, FA and Timmermans, M-L. (2014). Deterioration of perennial sea ice in the Beaufort Gyre from 2003 to 2012 and its impact on the oceanic freshwater cycle. *J. of Geophys. Res.: Oceans*. 119(2): 1271-1305.

Tateyama, K, Inoue, J, Hoshino, S, Sasaki, S and Tanaka, Y. (2018). Development of a new algorithm to estimate Arctic sea-ice thickness based on Advanced Microwave Scanning Radiometer 2 data. *Okhotsk Sea and Polar Oceans Research*, 2:13-18.

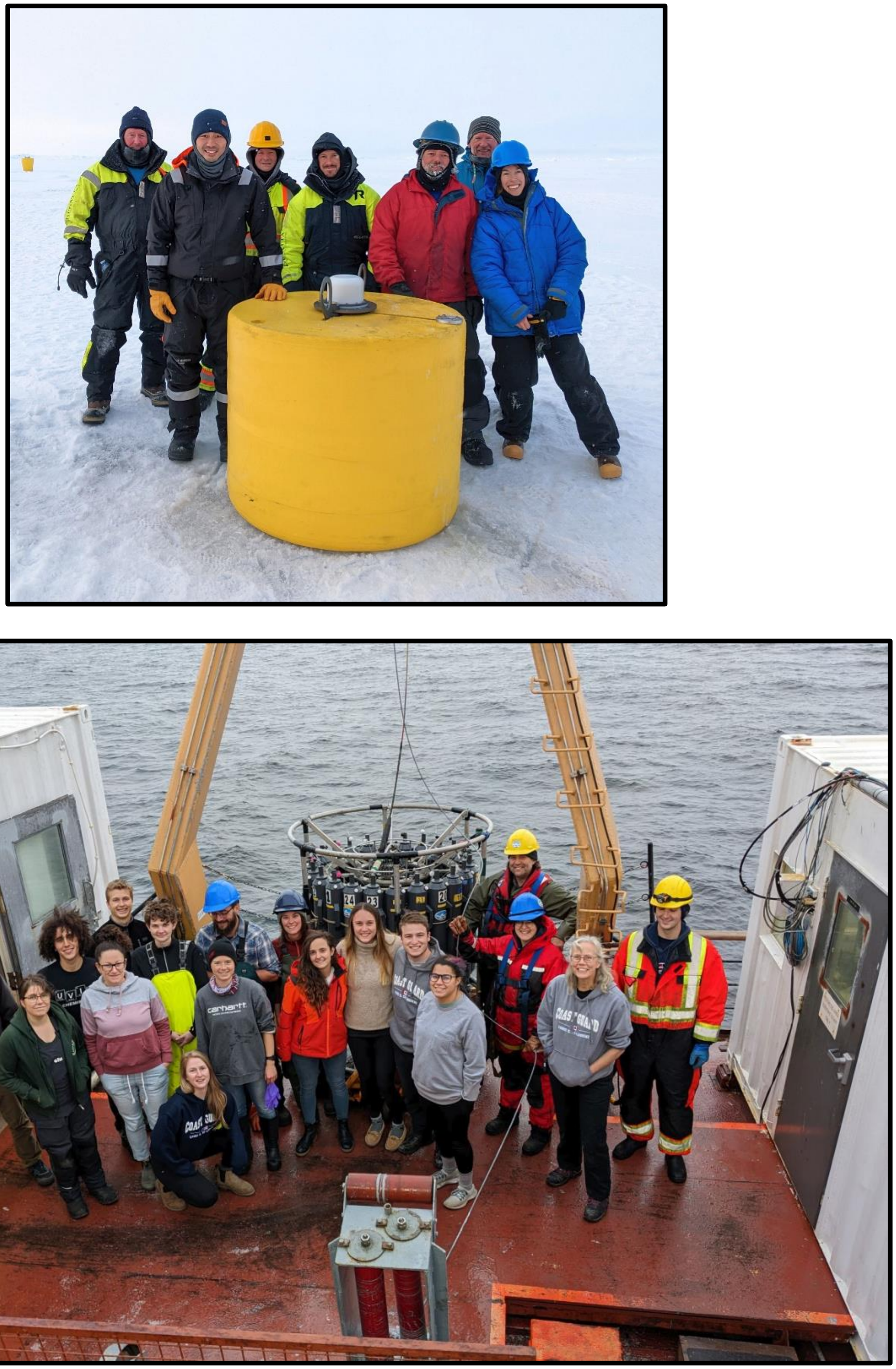


Figure 14. Science complete! Photos by Mary-Louise Timmermans

5. APPENDIX

1.1 SCIENCE PARTICIPANTS

Table 10. Onboard Science Participants for 2022-045

Number	Personnel	Institution	Role
1	Bill Williams	DFO-IOS	Chief Scientist
2	Sarah Zimmerman	DFO-IOS	Data Analyst
3	Sarah-Ann Quesnel	DFO-IOS	Nutrient Analyst
4	Marty Davelaar	DFO-IOS	DIC/Alkalinity Analyst
5	Erinn Raftery	DFO-IOS	Oxygen Analyst
6	Chris Clarke	DFO-IOS	Watchleader, Chief Technician
7	Paul Macoun	DFO-IOS	Watchleader
8	Robyn Taves	DFO-IOS	DIC/Alk/Salinity Analyst
9	Kim Bedard	DFO-IOS	Watchstander
10	Nimrod Rozen	UVIC	TEP Analyst, Watchstander
11	Susan McLatchie	Concordia	Microbial Diversity (RNA/DNA)
12	Anne-Marie Wefing	ETH Zurich	Radio Isotope, Watchstander
13	Annabel Payne	ETH Zurich	Radio Isotope, Watchstander
14	Kazu Tateyama	KITAMI	Sea-Ice Observation
15	Kozuke Kawamura	KITAMI	Sea-Ice Observation
16	Mike DeGrandpre	U Montana	Carbonate System Studies
17	Celine Gueguen	U Sherbrooke	FDOM Studies, Watchstander
18	Justin Forget	U Sherbrooke	FDOM Studies, Watchstander
19	Nicolas Sylvestre	U Sherbrooke	FDOM Studies, Watchstander
20	Mary-Louise Timmermans	Yale	Moorings and Buoys
21	Ashley Arroyo	Yale	Bloggers, Watchstanders
22	Elizabeth Bailey	Yale	Bloggers, Watchstanders
23	Jeff O'Brien	WHOI	Moorings and Buoys
24	Jim Ryder	WHOI	Moorings and Buoys
25	John Jordan	WHOI	Moorings and Buoys
26	James Kuo	WHOI	Moorings and Buoys

Table 11. Principal Investigators Onshore for 2022-045

Name	**Affiliation**	**Program**
Isabela LeBras	WHOI	Mooring and Buoy co-lead
Andrey Proshutinsky	WHOI	Moorings and ITP program lead / CTD/Rosette / XCTD

Richard Krishfield	WHOI	Moorings and ITP / CTD/Rosette / XCTD
John Toole	WHOI	ITP Buoys
Motoyo Itoh	JAMSTEC	CTD/Rosette / XCTD
Shigeto Nishino	JAMSTEC	CTD/Rosette
Takashi Kikuchi	JAMSTEC	CTD/Rosette
Don Perovich	CRREL	Ice Mass-Balance Buoy
Michiyo Yamamoto-Kawai	TUMSAT	CTD / Rosette / Alkalinity
Connie Lovejoy	U Laval	CTD/Rosette / Microbial Diversity
David Walsh	Concordia U	CTD/Rosette / Microbial Diversity
John Nelson	DFO-IOS	Zooplankton
John Smith	DFO-BIO	CTD / Rosette / ^{129}I / ^{236}U
Nuria Casacuberta Arola	ETH Zurich	CTD / Rosette / ^{129}I / ^{236}U/ ^{39}Ar/ ^{14}C; Nd, Hf
Jennifer Hutchings	OSU	Ice Observations

Table 12. Affiliation Abbreviations.

Abbreviation	Definition
APL	Applied Physics Laboratory, University of Washington, Seattle, Washington, USA
BIO	Bedford Institute of Oceanography, DFO, Dartmouth, NS, Canada
ConcordiaU	Concordia University, Montreal, Qc, Canada
CRREL	Cold Regions Research Laboratory, New Hampshire, USA
DFO	Department of Fisheries and Oceans, Canada
IOS	Institute of Ocean Sciences, DFO, Sidney, BC, Canada
JAMSTEC	Japan Agency for Marine-Earth Science Technology, Japan
KIT	Kitami Institute of Technology, Kitami, Hokkaido Prefecture, Japan
OSU	Oregon State University, Corvallis, Oregan, USA
USherbrooke	University of Sherbrooke, Quebec, Canada
TUMSAT	Tokyo University of Marine Science and Technology, Tokyo, Japan
NPS	Naval Postgraduate School, Monterey, California, USA
ULaval	University of Laval, Quebec City, Quebec, Canada
UMontana	University of Montana, Missoula, Montana, USA
UVic	University of Victoria, Victoria, British Columbia, Canada
WHOI	Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
YaleU	Yale University, New Haven, Connecticut, USA
ETH Zurich	ETH Zurich, Switzerland

5.2 PROJECT WEBSITES

Project	Website Address
Beaufort Gyre Observing System	https://www2.whoi.edu/site/beaufortgyre/overview/scientific-motivation/
Beaufort Gyre Observing System dispatches	https://www2.whoi.edu/site/beaufortgyre/expeditions/2022-expedition/2022-dispatches/
Ice-Tethered Profiler buoys	https://www2.whoi.edu/site/itp/
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
Arctic Ocean Flux Buoy	www.oc.nps.edu/~stanton/fluxbuoy/

5.3 LOCATION OF SCIENCE STATIONS

The scientific crew boarded the *CCGS Louis S. St-Laurent* icebreaker in Cambridge Bay, NU, on 15 September, 2022 and departed at Kugluktuk, NU on 13 October 2022. Locations of CTD/Rosette, XCTD, zooplankton vertical net, as well as the mooring and buoy recovery and deployments are listed in the tables below.

5.3.1 CTD/Rosette

Table 13. CTD/Rosette cast locations for 2022-045

Cast #	Station	CAST START DATE and Time (UTC)	Latitude (°N)	Longitute (°W)	Water Depth (m)	Cast Depth (m)	Sample Numbers	Ice Coverage (tenths) (Rough Estimate by CTD Operator)	Comments
1	AG5-DNA	9/18/2022 2:45	70.5495	122.9050	645	636	1-24	0	Spikes in salinity (mostly). Altimeter needs checking - likely wrong scale factor in con file. A new Valeport altimeter replacing **B**enthos data sonic;
2	AG5	9/18/2022 5:11	70.5395	122.9452	630	592	25-48	0	
3	CB1	9/18/2022 19:52	71.7748	131.8860	1125	1123	49-72	0	Altimeter range is too small. The range is 0-9m. Altimeter read 7m at bottom. Stopped at 930m and switched gears. Ship roll easy to see in the CTD data.
4	CB31b	9/19/2022 4:02	72.3453	133.9958	2061	2054	73-96	6	Oxygen spikes for the last 300 m @ depth on down/up casts. Otherwise seems normal.; yoyo on bottle 19-20, 23-24
5	CB23a	9/19/2022 16:38	72.8993	135.9672	2733	2737	97-120	9	At 120 m ice snagged wire briefly. Stopped Rosette. Winch jammed at 400 m. Brake issue, likely due to new pads. Winch operator needed to adjust the brake throughout the downcast.; yoyo on bottle 24. bottle 16: wire grease on bottle.
6	CB50	9/20/2022 0:59	73.4990	134.2538	2891	2876	121-144	1	yoyo on bottle 19-20, 23- 24. bottle 4 did not fire (sticky trigger)
7	CB51	9/20/2022 11:29	73.4997	130.9033		2485	145-168		yoyo on bottle 23-24
8	CB40	9/21/2022 3:07	74.5000	135.3113	3258	102	169-171	3	Mini DNA cast. yoyo on bottle 3
9	CB40	9/21/2022 3:46	74.5025	135.3093	3256	3250	172-195	4	yoyo on bottle 5, 15, 24. bottle 24: spigot had a slow drip.
10	CB18	9/21/2022 16:12	75.0168	140.0768	3630	3625	196-219	8	yoyo on bottle 24
11	CB17	9/22/2022 2:03	75.9883	140.0072	3693	3685	220-243	7	yoyo on bottle 23. bottle 19 did not close: cap got stuck on wire.
12	PP6	9/22/2022 23:31	76.2273	132.7022	3079	3071	244-267	10	yoyo on bottle 24
13	PP7	9/23/2022 12:17	76.5443	135.3708	3600	3556	268-291	10	CTD sat on deck for ~ 5 minutes, no nets at PP7 (very cold);
14	CB15	9/24/2022 2:02	77.0063	140.0402	3727	3717	292-315	10	yoyo on bottle 19-20, 23-24
15	CB16	9/24/2022 23:19	78.0010	140.0163	3750	3743	316-339	7	yoyo on bottle 19-20, 23-24
16	Ice2-22	9/26/2022 2:29	79.1725	140.2597	3770	3762	340-363	6	yoyo on bottle 24, Ice Station 2
17	NE1DNA	9/27/2022 2:23	79.7013	139.8178	3759	1007	364-387	10	yoyo on bottle 1-3, 6-24; Near Ice Station 3

18	NE1	9/27/2022 4:21	79.6915	139.7523	3758	3751	388-411	10	yoyo on bottle 1-4, 23-24; Near Ice Station 3
19	CB11	9/28/2022 5:29	78.9975	149.2898	3819	3806	412-435	9	yoyo on bottle 19-20, 23-24. bottle 10: grease on Niskin vent. Offset between downcast and upcast on beam transmission.
20	CB10	9/29/2022 7:19	78.3062	153.2122	2500	2404	436-459	9	yoyo on bottle 19-20, 23-24
21	CB9 (Short)	9/29/2022 13:35	78.0047	149.9460		320	460-483	8	yoyo on bottle 5-7, 10-12, 14-24
22	CB9 (Deep)	9/30/2022 0:43	78.0108	149.9892	3825	3813	484-507	9	yoyo on bottle 1-4, 7-16, 20-23
23	CB12.5	9/30/2022 12:51	77.4910	145.0260	3800	3789	508-531	10	yoyo on bottle 24
24	CB8	10/1/2022 1:40	77.0043	149.9142	3822	3815	532-555	10	Past 3000m, the high gear on the winch was creating erratic behavior. The winch was switched to low gear w/ a max speed of 54 m/min for the rest of the downcast. High gear was working normally from 3000m to 900m on the way up. After switching to low gear at 900m, the max speed possible was 58 m/min.; yoyo on bottle 19-20, 23-24
25	CB7	10/1/2022 11:07	75.9990	150.0060	3627	3818	556-579	10	yoyo on bottle 19-20, 23-24
26	CB4 (Deep)	10/2/2022 3:42	75.0052	150.0805	3825	3817	580-603	7	yoyo on bottle 1-4, 7-16, 19-22
27	CB5	10/2/2022 13:18	75.2995	153.3045	3841	3832		10	yoyo on bottle 24
28	CB4 (Shallow)	10/3/2022 4:43	75.0095	150.0518	3823	603	628-651	8	yoyo on bottle 5-7, 10-12, 14-24
29	BL1	10/4/2022 9:58	71.3607	152.0813	82	76	652-664	0	yoyo on bottle 4-6, 10-13
30	BL2	10/4/2022 11:34	71.3945	151.9447	160	162	665-676	0	yoyo on bottle 11-12
31	BL3	10/4/2022 12:57	71.4655	151.8243	490	506	677-697	0	no bongos; yoyo on bottle 13-15, 18-21
32	BL4	10/4/2022 15:18	71.5207	151.5898	1152	1153	698-719	0	yoyo on bottle 21-22
33	BL5	10/4/2022 19:51	71.5962	151.3602	1500	1598	744-764		No bongos. Bonus samples due to extra time because of helicopter ops. Sample numbers were added after cast 34's labels were made so these (Cast 33) sample numbers are out of order. Also, sample # 764 was kept even though no samples were taken from this tripped Niskin.
34	BL6	10/4/2022 23:49	71.6820	151.1342	2008	2085	720-743	0	yoyo on bottle 23-24. trip bottle order: 1-6, 7, 9, 10-16, 8, 17-24
35	BL7	10/5/2022 2:33	71.8172	150.7568	2600	2560			No bongos. No bottles.
36	BL8	10/5/2022 5:23	71.9542	150.3002	3000	2963	765-788	0	The x10 gain cable was added to CTD Chl fluorometer for BL8.; yoyo on bottle 19-20, 23-24. bottle 21, 22 special trip order
37	CB2a	10/5/2022 10:21	72.5003	150.0053	3730	3711	789-812	0	bottle 22: vent open. bottle 21 out of depth order, special trip. yoyo on bottle 24
38	CB2	10/5/2022 15:23	73.0007	150.0015	3750	3738	813-836	0	Knudsen funky; yoyo on bottle 19-20, 23-24
39	CB3	10/5/2022 23:29	73.9983	150.0382	3830	3815	837-860	8	At 1600m on upcast we were required to come back on deck as soon as possible. We came up btw 90-70 m/min. stopped at 60m for chummy recovery and then tripped 2x DNA/geochem bottles before starting up. Stopped at 5m for permission to recover etc. and tripped 2x DNA/geochem bottles before recovery. CTD cast seasave accidently stopped at 5m after bottle closures.; bottle 3 did not fire. yoyo on bottle 19-20, 23-24

40	STNA	10/7/2022 17:14	72.5997	144.6827	3443	3422	861-884	0	yoyo on bottle 19-20, 23-24
41	CB21 (Deep)	10/8/2022 7:24	73.9847	139.9057	3520	3486	885-908	9	No nets due to wind. Very mobile ice. After last yoyo came up at 60 m/min.; yoyo on bottle 1-4, 6-17, 19-22. lots of swell during cast.
42	CB21 (SH)	10/8/2022 11:13	73.9712	139.8077	3508	602	909-932	9	Ice was less mobile, cast went as planned; yoyo on bottle 5-7, 10-12, 14-24
43	CB19	10/9/2022 8:11	74.2947	143.2810	3700	3686	933-956	9	Special tripping order. yoyo on bottle 1, 5, 24
44	CB27	10/10/2022 8:18	73.0093	139.9148	3220	3203	957-980	9	Polar bear tracks on the ice ; bottle 23 did not fire; yoyo on bottles 19&20 and 23&24
45	CB29	10/10/2022 15:58	72.0007	140.0003	2698	2670	981-1004	0	
46	CB28b	10/10/2022 22:11	71.0103	139.9893	2100	2077	1005-1028	0	yoyo on bottle 18&19 and 23&24

5.3.2 **XCTD**

Table 14. XCTD cast deployment locations for 2022-045.

File name starting with C3 means XCTD-1 or XCTD-1N probes were used. File name starting with C4 means XCTD-2 probes were used. S/N = serial number of the probe launched
Files C3_00009, C3_00019 and C3_00020.edf are not in the at-sea distribution of preliminary data but will be added if they can be recovered when xctd computer returns from sea.

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	Probe Serial Number	Probe Type	Cast Depth (m)	Comment (Initials of Operator)
C3_00002.edf	9/19/2022 0:15	72.0258	132.8333	20111241	XCTD-01	1000	First XCTD cast with new software. All worked well.
C3_00003.edf	9/19/2022 12:46	72.6208	134.9908	20111240	XCTD-01	1000	Success! Stopped for cast, 10/10 ice cover.
C4_00005.edf	9/19/2022 22:05	73.2360	135.1263	15115716	XCTD-02	1850	Old probe, expired October 2017, worked OK
C4_00006.edf	9/20/2022 6:14	73.4710	132.8959	15115717	XCTD-02	1850	Old probe, expired October 2017, worked OK
C3_00007.edf	9/20/2022 17:24	73.8593	132.5007	20121374	XCTD-01	1000	NR, KT - Ship at 1.1 knots
C4_00008.edf	9/20/2022 23:08	74.2119	133.9272	15115713	XCTD-02	1850	KK,PM
Missing C3_00009.edf	9/21/2022 11:33	74.8263	137.7127	20111242	XCTD-01	1000	Ship at 10 kts [missing: check laptop in return shipment]

C3_00011.edf	9/21/2022 23:05	75.5296	139.5507	20111239	XCTD-01	1000	This time use X-CTD1 at 3kts.When the ship is 3kts, do we use X-CTD1 or 2 ?
C3_00012.edf	9/22/2022 11:09	76.1657	136.5506	20111238	XCTD-01	1000	NR, KT
C3_00013.edf	9/23/2022 18:19	76.7407	137.4731	20111236	XCTD-01	974	KT,KK
C3_00014.edf	9/24/2022 9:58	77.4623	140.3501	20111233	XCTD-01	1000	NR, AA, KT
C3_00015.edf	9/25/2022 6:52	78.4305	139.9824	20111237	XCTD-01	1000	
First Try C4_00016.edf	9/25/2022 11:16			15115724	XCTD-02		Bad cast, no data
C4_00018.edf	9/25/2022 11:19	78.9888	140.1701	15115724	XCTD-02	1371	Same probe as C4_00016, but this time it worked ok
Missing C4_00019.edf	9/26/2022 11:13	79.7926	140.0182	15115720	XCTD-02	358	NS, KT, ship at full stop ,failed [missing: check laptop in return shipment]
Missing C3_00020.edf	9/26/2022 11:24	79.7922	140.0175	20111235	XCTD-01	1000	NS, KT, ship at full stop, success [missing: check laptop in return shipment]
C3_00021.edf	9/27/2022 17:06	79.1549	143.3819	20121387	XCTD-01	260	AA/KT, probe failed at 260 m
C3_00022.edf	9/27/2022 17:14	79.1544	143.3791	20111234	XCTD-01	1000	AA/KT, success
C3_00023.edf	9/27/2022 23:47	79.1103	146.5522	20121396	XCTD-01	361	KK,PM,ship at full stop ,failed (stopped recording at 361m)
C3_00024.edf	9/27/2022 23:56	79.0961	146.6020	20121393	XCTD-01	163	KK,PM,ship at full stop ,failed 2nd (stopped recording at 163m)
C3_00025.edf	9/28/2022 11:37	78.4840	149.2212	20121390	XCTD-01	128	Failed, profiles stopped recording at 128m; KT/AA
C3_00026.edf	9/28/2022 11:41	78.4735	149.2542	20121391	XCTD-01	1000	KT,AA
C3_00027.edf	9/29/2022 4:45	78.1640	151.5908	20121394	XCTD-01	1000	KT,PM
C4_00028.edf	9/29/2022 12:02	78.0950	150.7039	15115719	XCTD-02	1850	KK, NS, success, ship at full stop
C3_00029.edf	9/30/2022 7:19	77.7834	147.4068	20121388	XCTD-01	1000	KT,PM, success, ship stopped
C3_00030.edf	9/30/2022 19:52	77.2375	147.6027	20121389	XCTD-01	995	KK,KT, siccess, ship stopped
C3_00031.edf	10/1/2022 7:38	76.5243	150.0182	20121392	XCTD-01	1000	KT,PM, successful deployment, ship @ 3 knots
C4_00032.edf	10/1/2022 15:57	75.4946	150.0073	15115722	XCTD-02	1850	KK,AA
C3_00033.edf	10/2/2022 10:45	75.2074	152.3251	20121395	XCTD-01	1000	NS, KK, success to 1000 m, no daily logbook w/ us. Sounder depth : 3841, boatspeed 3 kts
C3_00034.edf	10/3/2022 8:55	74.5573	150.9569	20121398	XCTD-01	1000	KK, KT, success, ship at full stop
C3_00035.edf	10/3/2022 11:57	74.0696	151.8464	20121397	XCTD-01	1000	NS, KK, success to 1000 m, ship @ 3 kts
First Try C3_00036.edf				21107551	XCTD-01		The computer did not recognize XCTD when placed in launcher. The probe was removed and launch sequence retried (using the same probe) with success (C3_00038.edf).

C3_00038.edf	10/3/2022 14:35	73.6726	152.5035	21107551	XCTD-01	1000	KK, NR, success to 1000m at 3 knots
C3_00039.edf	10/3/2022 17:23	73.2128	153.3815	21107548	XCTD-01	1000	KK/AA, success to 1000m
C3_00040.edf	10/3/2022 19:27	72.7910	154.1093	21107552	XCTD-01	1000	KK,KT, success, ship stopped
C3_00041.edf	10/3/2022 21:51	72.3360	154.8938	21107544	XCTD-01	1000	KT,PM, success
C3_00042.edf	10/5/2022 8:47	72.2202	150.1461	21107541	XCTD-01	1000	KK,KT, success, ship stopped
C3_00043.edf	10/5/2022 13:55	72.7469	150.0011	21107542	XCTD-01	1000	KK/AA, success to 1000m, ship @ 5 kts
C3_00044.edf	10/5/2022 20:41	73.5319	150.0057	21107545	XCTD-01	1000	KT/PM, success, ship at 3 knots
C3_00045.edf	10/7/2022 11:40	72.2586	148.0607	21107550	XCTD-01	1000	NS,KK, success, ship slow
C3_00046.edf	10/7/2022 14:24	72.4344	146.0230	21107549	XCTD-01	1000	AA/KK, success; Bottom depth unknown.
C4_00047.edf	10/7/2022 22:46	73.0722	143.1454	15115723	XCTD-02	1850	KT,PM, success, ship at 3 knots
C3_00049.edf	10/8/2022 2:53	73.4702	141.6541	21107543	XCTD-01	821	KT,PM, success, ship at 3 knots
C3_00050.edf	10/9/2022 13:12	74.1663	141.7132	21107546	XCTD-01	615	AA/KK, failed, stopped recording at ~610m
C3_00051.edf	10/9/2022 13:23	74.1661	141.7078	21107547	XCTD-01	1000	AA/KK, success
C3_00052.edf	10/10/2022 4:27	73.5091	140.0603	21107505	XCTD-01	1000	KT,PM, success, ship at 3 knots
C3_00053.edf	10/10/2022 13:22	72.5052	139.9860	21107508	XCTD-01	1000	NR,KK, succes at ship speed ~6 knots
C3_00054.edf	10/10/2022 19:36	71.5804	139.9774	21107511	XCTD-01	1000	NS, KK, success at ship speed slower than 10 kts
C3_00055.edf	10/11/2022 1:14	70.7454	139.9702	21107514	XCTD-01	1000	KT,PM, success, ship at 12 knots
C3_00056.edf	10/11/2022 2:11	70.5096	139.9847	21107515	XCTD-01	658	KT,PM, success, ship at 12 knots, probe issue @ 660 m, bad data after that
C3_00057.edf	10/11/2022 5:18	70.7197	137.9171	21107512	XCTD-01	1000	KT,PM, success, ship at 12 knots

Table 15. XCTD cast deployment locations for CCGS Sir Wilfrid Laurier in support of the JOIS/BGOS program (Cruise ID 2022-053 DFO-IOS).

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	Probe Serial Number	Probe Type	Cast Depth (m)	Comment (Initials of Operator)
C3_00001.edf	10/8/2022 14:04	70.6235	141.2309	21107495	XCTD-01N	925.94	
C3_00002.edf	10/8/2022 17:49	71.1106	142.6223	21107496	XCTD-01N	1000.03	
C3_00003.edf	10/8/2022 21:24	71.5246	144.1901	21107497	XCTD-01N	1000.03	
C3_00004.edf	10/9/2022 0:40	71.8815	145.7465	21107498	XCTD-01N	1000.03	
C3_00005.edf	10/9/2022 4:00	72.2342	147.3457	21107499	XCTD-01N	1000.03	
C3_00006.edf	10/9/2022 7:31	72.5943	149.0939	21107500	XCTD-01N	1000.03	
C3_00007.edf	10/9/2022 10:55	72.9430	150.8810	21107501	XCTD-01N	1000.03	
C3_00008.edf	10/9/2022 14:13	73.2514	152.6401	21107502	XCTD-01N	1000.03	
C3_00009.edf	10/9/2022 17:39	73.5546	154.6228	21107503	XCTD-01N	1000.03	
C3_00010.edf	10/9/2022 21:45	73.8812	156.9338	21107504	XCTD-01N	1000.03	
C3_00011.edf	10/10/2022 1:36	74.1925	159.2825	21107494	XCTD-01N	43.905	

5.3.3 Zooplankton – Vertical Bongo Net Hauls

Table 16. Zooplankton vertical bongo net hauls.

Summary of samples taken at each station. At each station 2 samples were collected using The same net mesh size 150µm. One net's samples were preserved in 95% ethanol, the other in buffered formalin.

Station	Net #	CTD #	Date (UTC)	Time (UTC)	Lat Deg N	Lon Deg W	Bottom Depth	Wire angle	RBR Depth Recorded	Mesh	Notes
AG5	1	2	18/9/22	4:10	70.5433	122.9317	645	0	93	150	
CB1	2	3	18/9/22	20:14	71.7733	131.9017	1134	30	104	150	~25 kt winds. TSK likely changed with wind
CB31b	3	4	19/9/22	4:30	72.3470	133.9917	~2071 (estimate)	0	94	150	Bubblers on prior to bringing up due to ice
CB23a	4	5	19/9/22	17:06	72.9017	135.9683	2751	5	92	150	ETOH: residual smple found in filter before doing next station (filter not rinsed fully).
CB50	5	6	20/9/22	1:16	73.5000	134.2500	2891	0	99	150	
CB51	6	7	20/9/22	11:56	73.4983	130.9067	2504	0	94	150	ETOH: part of sample still in filter (dried) at start of next cast.
CB40	7	9	21/9/22	3:58	74.5017	135.3100	3259	0	93	150	There was a lot of zoop stuck in bottom of net at end of cast. Very stuck and had to use hose - potentially dried zoop from previous cast added to sample (Formaldehyde sample).
CB18	8	10	21/9/22	16:33	75.0167	140.0750	3625	5	92	150	
CB17	9	11	22/09/22	2:34	75.9900	140.0083	3700	0 down, 20 up	95	150	Form net had residual zoop in net at end of cast. Corrected date to 22/09/2022 (UTC)
PP6	10	12	22/09/2022	23:43	76.2267	132.7067	3081	~15	95	150	Bubblers on prior to net n the water
CB16	11	15	25/09/2022	0:10	77.9967	140.0183	3750	~15	99	150	15kn wind, -7, ETOH cod end clip released from weight during recovery. Formaldehyde net's flow end originally read at 10301. Believed to be 10400 at start of next cast.

											Corrected.
ICE2-22	12	16	26/09/2022	2:52	79.1700	140.2617	3771	~10	96	150	
CB10	13	20	29/09/2022	7:57	78.3100	153.2083	2450	15-20	100	150	The ship's bubblers were on at bottom and prior. Sample in FORM very sticky and hard to rinse.
CB9(De)	14	22	30/09/2022	0:55	78.0117	149.9853	3820	5-10	96	150	wire out = 102
CB12.5	15	23	30/09/2022	13:19	77.4917	145.0300	3798	5	95	150	ETOH net, dried zoop found on filter after sample
CB8	16	24	1/10/22	2:00	77.0033	149.9133	3820	0	95	150	Bubbler on prior to cast. Water not draining through EtOH cod end (possibly clogged?). Rinsed net into bucket with hose (unfiltered)
CB7	17	25	1/10/22	11:47	75.9962	149.9937	3825	10	89	150	Bubbler on prior to cast. FORM: Different flow number recorded.
CB4(de)	18	26	2/10/22	4:20	75.0017	150.0750	3784	5	95	150	
CB5	19	27	2/10/22	13:44	75.2996	153.2984	3848	0	94	150	bubblers on at bottom
BL1	20	29	4/10/22	10:14	71.3617	152.0817	82	30	63	150	wire out = 70. lots of large euphausids (probably)
BL2	21	30	4/10/22	11:50	71.3933	151.9450	169	30	94	150	wire out = 115
BL4	22	32	4/10/22	15:32	71.5217	151.5883	1148	5	96	150	FORM: end reading in paper log was 1735. chose to take start reading of next cast.
BL6	23	34	5/10/22	0:02	71.6817	151.1350	2094	35	111	150	wire out = 125
BL8	24	36	5/10/22	5:53	71.9550	150.3050	2796	15-20	98	150	wire out = 105. bioluminescent
CB2a	25	37	5/10/22	11:00	72.5017	150.0267	3513	20	90	150	wire out = 105. a lot more in ETOH than in FORM net.
CB2	26	38	5/10/22	16:09	73.0000	150.0033	3819	5	93	150	
CB3	27	39	5/10/22	23:40	73.9983	150.0400	3821	0	95	150	bubblers on at bottom and again at 34m on the way up.

StnA	28	40	7/10/22	17:28	73.6017	144.6783	3443	20	105	150	wire out = 110. Dried zoop found in form net after sample.
CB19	29	43	9/10/22	8:47	74.2920	143.2853	3721	0	94	150	almost nothing in form Net - maybe torn net? Update: checked for tear in net on next shift - no hole. Likely the Net was not rinsed thoroughly.
CB27	30	44	10/10/22	2:04	73.0017	139.8833	3219	15-20	100	150	
CB29	31	45	10/10/22	16:58	71.9998	139.9850	2693	0	94	150	
CB28b	32	46	10/10/22	23:03	71.0083	139.9833	2080	15+	98	150	ETOH: didn't check TSKs at start. Large wire angle on recovery - strong current?

5.3.4 Foredeck Niskin Samples

Cruise	Event No.	Cast No.	Station Name	Cast Start Time [UTC]	LAT DEG	LAT MIN	LON DEG	LON MIN	Water Depth [m]	Cast Depth [m]	CTD @ bottle stop	Correction (distance from CTD)	CTD Pressure @ niskin bottles	Sample No. [All others match to this sample number]
2022-45	Nisk1	901	CB15-test1	Sep 23 2022 03:18	77	0.2	140	3.5	3725	NA	NA	NA	NA	-
2022-45	Nisk1	901	CB15-test1	Sep 23 2022 03:18	77	0.2	140	3.5	3725	NA	NA	NA	NA	-
2022-45	Nisk2	914	CB15-test2	Sep 23 2022 03:38:53	77	0.2	140	3.5	3725	NA	NA	1.6	NA	-
2022-45	Nisk2	914	CB15-test2	Sep 23 2022 03:38:53	77	0.2	140	3.5	3725	NA	NA	4.6	NA	-
2022-45	Nisk3	N003	CB16	Sep 23 2022 23:42:34	77	59.9	141	1	3750	60	48	1.6	46.4	**N3A**
2022-45	Nisk3	N003	CB16	Sep 23 2022 23:42:34	77	59.9	141	1	3750	60	48	4.6	43.4	**N3B**
2022-45	Nisk4	N004	CB9(SH)	Sep 29 2022 13:52:05	78	0.4	149	56	3789	48	48	1.6	46.4	**N4A**
2022-45	Nisk4	N004	CB9(SH)	Sep 29 2022 13:52:05	78	0.4	149	56	3789	48	48	4.6	43.4	**N4B**
2022-45	Nisk5	N005	CB4(SH)	Oct 2 2022 04:55:29	75	0.5	150	2.9	3823	60	50	1.6	48.4	**N5A**
2022-45	Nisk5	N005	CB4(SH)	Oct 2 2022 04:55:29	75	0.5	150	2.9	3823	60	50	4.6	45.4	**N5B**
2022-45	Nisk6	N006	CB2	Oct 4 2022 17:51:11	72	59.9	150	1.3	3970	22	8	1.6	6.4	**N6A**
2022-45	Nisk6	N006	CB2	Oct 4 2022 17:51:11	72	59.9	150	1.3	3970	22	8	4.6	3.4	**N6B**
2022-45	Nisk8	N008	CB21	Oct 8 2022 12:24:27	73	58	139	47.3	3502	67	60	1.6	58.4	**N8A**
2022-45	Nisk8	N008	CB21	Oct 8 2022 12:24:27	73	58	139	47.3	3502	67	60	4.6	55.4	**N8B**
2022-45	Nisk9	N009	CB21	Oct 8 2022 13:14	73	57.9	139	47.2	3502	12	7.5	1.6	5.9	**N9A**
2022-45	Nisk9	N009	CB21	Oct 8 2022 13:14	73	57.9	139	47.2	3502	12	7.5	4.6	2.9	**N9B**
2022-45	Nisk10	N010	CB27	Oct 10 2022 9:03	73	0.5	139	53.9	3228	17.5	8.5	1.6	6.9	**N10A**
2022-45	Nisk10	N010	CB27	Oct 10 2022 9:03	73	0.5	139	53.9	3228	17.5	8.5	4.6	3.9	**N10B**
2022-45	Nisk11	N011	CB27	Oct 10 2022 9:36	73	0.3	139	53.6	3216	67	57.5	1.6	55.9	**N11A**
2022-45	Nisk11	N011	CB27	Oct 10 2022 9:36	73	0.3	139	53.6	3216	67	57.5	4.6	52.9	**N11B**
2022-45	Nisk12	N012	CB29	Oct 10 2022 16:18	72	0	139	59.8	2700	17	7	1.6	5.4	**N12A**
2022-45	Nisk12	N012	CB29	Oct 10 2022 16:18	72	0	139	59.8	2700	17	7	4.6	2.4	**N12B**

5.3.1 TEP Sample Locations

Station:	Cast #:	Date (UTC):	Time (UTC):	Lat (deg, min)		Lon (Deg, min)		Lat (dd)	Lon (dd)	Bottom Depth (m)	Chl max depth (m)	Sample Depth (m)	Sample #:	IOS #:	Draw Temp (oxy)	Replicate:	Vol TEP (ml)	Vol chl (mL)	Vol POC (mL)	Notes:
AG 5	2	18-9-22	05:37:00	70	32.241	-122	56.831	70.53735	-122.9471833	620	22	5	1	48	3.8	1	250	500	1000	TEP Pump guage not working, suction was likely too high
																2	420	-	500	
CB 1	3	18-9-22	20:29:00	71	46.483	-131	53.36	71.77472	-131.8893333	1134	60	5	2	72	-1.4	1	350	400	700	
CB 31b	4	19-9-22	04:53:00	72	20.737	-133	59.714	72.34562	-133.9952333	2060	60	5	3	96	-1.4	1	400	550	1120	
CB 23a	5	19-9-22	17:53:00	72	53.987	-135	58.037	72.89978	-135.9672833	2736	60	5	4	120	-1.2	1	438	500	1000	
CB 50	6	20-9-22		73	29.956	-134	15.184	73.49927	-134.2530667	2891	61	5	5	144	-1.2	1	450	500	955	
CB 51	7	20-9-22	12:30:00	73	29.971	-130	54.184	73.49952	-130.9030667	2484	50	5	6	168	-1.2	1	500	500	1000	Nutrients were tken from same depth but different bottle (bottle 23 = sample 167)
																2	400	500	1000	
																3	400	500	-	
CB 40	9	21-9-22	03:18:00	74	30.162	-135	18.541	74.5027	-135.3090167	3258	57	5	7	195	-1.5	1	500	500	1000	
CB 17	11	22-9-22	03:20:00	75	59.311	-140	0.47	75.98852	-140.0078333	3700	49	5	8	243	-1.6	1	250	500	305	very limited water availability
PP6	12	23-9-22	23:49:00	76	13.646	-132	42.204	76.22743	-132.7034	3124	60	5	9		-1.9	1	400	500	860	
PP7	13	23-9-22	13:37:00	76	32.669	-135	22.288	76.54448	-135.3714667	3556	63	5	10	291	-1.7	1	400	500	600	
																2	400	500	600	
																3	-	-	600	
												40	11	288	-0.1	1	400	500	600	
																2	400	500	600	
												63	12	286-287	-0.7	1	400	500	600	
																2	400	500	600	
CB 15	14	24-9-22	03:14:00	77	0.371	-140	2.479	77.00618	-140.0413167	3725	60	5	13	314-315	-1.6	1	400	500	800	samples kept in fridge for ~1 hour pre filtration
CB 16	15	25-9-22	00:36:00	78	0.042	-140	0.99	78.0007	-140.0165	3750	46	5	14	339	-1.7	1	500	500	850	
Ice 2	902-910	25-9-22	-	79	10.4	-140	15.6	79.17333	-140.26	3771	-	5	I.S. 1	9001-9002	-1.7	1	450	500	1000	samples partially froze while on ice, so some time between sampling and filtration to thaw (in dark fridge)
			-									10	I.S. 2	9003-9004	-1.6	1	450	500	1000	
Ice 2	701	25-9-22	-	79	10.4	-140	15.6	79.17333	-140.26	3771	-	0.972 (under ice)	I.S. 3	7001	-	1	450	500	1000	
			-												-	2	450	500	1000	
			-												-	3	450	500	1000	
Ice 2	801	25-9-22	-	79	10.4	-140	15.6	79.17333	-140.26	3771	-	core	I.S.4	8001	-	1	100	450	460	core filtered very slowly (maybe due to plastics from garbage bag)
Ice 2-22	16	26-9-22	03:46:00	79	10.35	-140	15.606	79.1725	-140.2601	3770	36	5	15	363	-1.4	1	400	500	800	
Ice 3	912-922	26-9-22	-	79	42.1	-139	44.9	79.70167	-139.7483333	3759	-	5	I.S. 5	9013-9016		1	400	500	1000	Ashley filtered chlorophylls
																2	400	500	1000	
																3	400	500	1000	
												10	I.S. 6	9017-9020		1	400	500	900	
																2	400	500	550	
																3	400	500	-	
Ice 3	702	26-9-22	-	79	42.1	-139	44.9	79.70167	-139.7483333	3759	-	1.10 (under ice)	I.S. 7	7002	-	1	400	500	800	Under ice, 110 cm
																2	400	500	800	
																3	400	500	800	
Ice 3	802	26-9-22	-	79	42.1	-139	44.9	79.70167	-139.7483333	3759	-	core	I.S. 8	8002	-	1	500	500	1000	Top 2/3 of ice core (filtered oct 1st)
																2	500	-	-	
														8003	-	1	350	500	460	bottom 1/3 of ice core (filtered oct 3rd)
CB11	19	28-9-22	06:46:00	78	59.845	-149	17.266	78.99742	-149.2877667	3819	47	5	16	434-435	-1.7	1	400	500	910	
CB10	20	29-9-22	08:18:00	78	18.398	-153	12.598	78.30663	-153.2099667	2344	42	5	17	458-459	-1.7	1	400	500	870	
CB12.5	23	30-9-22	14:11:00	77	29.461	-145	1.577	77.49102	-145.0262833	3794	53	5	18	531	-1.9	1	400	500	1000	
																2	-	500	-	
CB8	24	1-10-22	02:05:00	77	0.228	-149	54.791	77.0038	-149.9131833	3822	60	5	19	554-555	-1.7	1	450	500	1000	
CB7	25	1-10-22		75	59.966	-149	59.623	75.99943	57.48266667	3825	53	5	20	578-579	-1.6	1	450	500	1000	slighlty leaky manifold for TEP
																2	450	500	1000	
																3		500	1000	
																4		500	1000	
BL1	29	4-10-22	10:18:00	71	21.644	-152	4.882	71.36073	-152.0813667	82		5	21	664	-0.2	1	460	500	500	oxy temp taken from sample 661
																2	220	500	1000	
																3	-	500	1000	
BL2	30	4-10-22	11:48:00	71	23.675	-151	56.674	71.39458	-151.9445667	171		5	22	676	-0.6	1	300	500	700	oxy temp taken from sample 675
																2	300	500	700	
BL3	31	4-10-22	13:19:00	71	27.928	-151	49.447	71.46547	-151.8241167	496	46	5	23	697	-0.6	1	300*	500	750	oxy temp taken from sample 693, accidentally added ~50 mL from POC(2) to TEP(1)
																2	310	500	750*	
																3	-	500	650	
BL4	32	4-10-22	15:51:00	71	31.24	-151	35.4	71.52067	-151.59	1153	33	5	24	719	-0.9	1	350	500	1000	oxy temp taken from sample 718, TEP(2) left under suction accidentally extra 2-3 min
																2	350	500	1000	
																3	-	500	-	
BL6	34	5-10-22	00:07:00	71	40.975	-151	8.144	71.68292	-151.1357333	2100	28	5	25	742	-0.6	1	350	500	800	oxy temp taken from sample 742, filtration ~4 hours post sampling
																2	350	500	800	
BL8	36	5-10-22	06:26:00	71	57.284	-150	18.094	71.95473	-150.3015667	2950	34	5	26	787-788	0.4	1	385	500	1000	
CB2a	37	5-10-22	11:36:00	72	30.034	-150	0.494	72.50057	-150.0082333	3725	17	5	27	812	0.4	1	450	500	1000	
																2	-	500	-	
CB2	38	5-10-22	16:36:00	73	0.042	-150	0.086	73.0007	-150.0014333	3745	10	5	28	835-836	0.5	1	400	500	1000	
																2	-	265	-	
STN-A	40	7-10-22	18:22:00	72	35.986	-144	40.912	72.59977	-144.6818667			5	29	883-884	0.7	1	400	500	1000	
																2	-	500	-	
CB19	43	9-10-22	09:28:00	74	17.665	-143	16.894	74.29442	-143.2815667	3697	68	5	30	956	-1.1	1	350	500	1000	
																2	350	500	-	
CB29	45	10-10-22	16:55:00	72	0.037	-140	0.002	72.00062	-140.0000333	2698	54	5	31	1004	0.1	1	350	500	1000	TEP(1) may have lost ~1-2 mL
																2	350	500	-	
																3	350	-	-	
CB28b	46	10-10-22	22:12:00	71	0.614	-139	59.334	71.01023	-139.9889	2080	50	5	32	1027-1028	0.8	1	400	500	1000	

5.3.2 Mooing Operations

Table 17. BGOS mooring recoveries and deployments from CCGS Louis S. St-Laurent 2022. ***Both the mooring anchor and the acoustic pinger near the top of the mooring were ranged on in the pre-recovery survey (see columns 2 and 3).***

Mooring	Surveyed location (pinger*)	2022 Recovery	2022 Deployment	2022 Location (drop posn.)	Deploy bottom depth (m)
A	75 00.032 N 150 00.000 W *11 m from anchor	2 Oct. 2:29 UTC Anchor at 34m from 2021 drop location	3 Oct. 3:06 UTC	74 59.397 N 149 57.618 W	3823
B	77 58.843 N 150 04.503 W *51 m from anchor	28 Sept. 19:25 UTC Anchor at 450m from 2021 drop location	29 Sept. 23:16 UTC	78 01.101 N 150 02.559 W	3828
D	73 59.343 N 140 02.396 W *6 m from anchor	9 Oct. 01:01 UTC Anchor at 495m from 2021 drop location	10 Oct. 00:42 UTC	74 00.017 N 140 02.840 W	3527

5.3.3 BGOS ice and open-water deployments from CCGS Louis S. St-Laurent 2022.

Single-buoy deployments are listed as "IBOs" to denote Ice-Based Observatory; this simplifies record keeping, although it is understood that an IBO more commonly describes the case where more than one system is deployed on the same floe.

IBO: Ice-Based Observatory; ITP: Ice-tethered Profiler; TOP: Tethered Ocean Profiler; SIMB: Seasonal Ice Mass Balance Buoy; AOFB: Arctic Ocean Flux Buoy, SAMI: pCO2 system

IBO	Buoy system	Date (2022)	Location	Ice thickness (m)
1	ITP 130	Sept. 24 19:09 UTC	77 45.5732 N 140 01.1866 W	0.55
2	ITP 136 w/SAMI, ODO, PAR,and Flr, TOP005, AOFB 47, SIMB 2021#7	Sept. 25 23:50 UTC	79 10.1412 N 140 16.9807 W	1.1 – 1.9
3	ITP 137 w/SAMI,ODO, PAR, and Flr, TOP006,	Sept. 26 20:29 UTC	79 48.6967 N 139 57.4278 W	1.0 – 1.1

	SIMB 2021#6			
4 (open water)	ITP 131	Sept. 28 02:00 UTC	79 07.474 N 146 53.583 W	–
5 (open water)	TOP007	Sept. 30 23:47 UTC	77 01.510 N 149 15.080 W	–

Buoy recovery summary

None in 2022

Table 18. DeGrandpre group sensor data collection summary The sensor time-series collected for moorings deployed in 2021 and the new ITPS are summarized below.

In addition we collected underway pCO_2 data using an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors) continuously over the 27 day cruise. The instrument was connected to the Louis seawater line manifold located in the main lab.

BGOS-A Mooring					
	CO2	**pH**	**O2**	**PAR**	
Instrument ID	C38u	XXX	4175: 1765 (4-pin b/h)	XXX	
	XXX	P47u	XXX	9387	
Days of data	263	398	398	398	
BGOS-B Mooring					
	CO2	**pH**	**O2**	**PAR**	
Instrument ID	C48u	XXX	4175: 717 (4-pin b/h)	XXX	
	XXX	P68u	XXX	9385	
Days of data	392	0	392	392	
BGOS-D Mooring					
	CO2	**pH**	**O2**	**PAR**	**Fluorometer**
Instrument ID	C37u	XXX	4175: 1699 (5-pin b/h)	XXX	FNTQ
	XXX	P5u	XXX	9386	
Days of data	394	20	394	394	394
ITP-136					
	CO2	**IMM ID**	**O2**	**PAR**	
Instrument ID	C221	700-9548	4531A: 1517	UWQ-10479	
Days of data (so far)	14	14	14	14	
ITP-137					
	CO2	**IMM ID**	**O2**	**PAR**	
Instrument ID	C222	700-9551	4531A: 1518	UWQ-10480	
Days of data (so far)	no data		no data	no data	

5.4 Record of Ship's Time Changes

To centre our work day with the available daylight, the ship's clocks were changed during the program.

Sep 15, start of cruise ship local is UTC-4, EDT
Sep 18 at 0200 local changed to UTC-6, EDT to MDT (-2hrs change)
Sep 19 at 0200 local, changed to UTC-7, MDT to PDT (-1hr change)

Sep 28 at 0200 local, changed to UTC-8, PDT to AKDT (-1hr change)

And then back again, after science was complete
Oct 11? 0100 or so ahead to 0200, changed to UTC-7, AKDT to PDT (+1hr change)
Oct 12? 0100 or so ahead to 0200, changed to UTC-6, PDT to MDT to match Kugluktuk (+1hr change)

5.5 CTD/Rosette Sensor Configuration

V0 = chlorophyll fluorometer
V1= transmissometer
V2 = dissolved oxygen
V3 = altimeter
V4 = CDOM fluorometer
V5 = free
V6 = Cosine PAR
V7 = Rinko III (UserPolynomial)

ROS 4: Datasonic Benthos Altimeter SN40853 and matching Y-cable replaced Valeport Altimeter sn80262 with scalefactor 150
Switched from WETLabs ECO CDOM #4305 to #6677
ROS 5: Valeport Altimeter sn80262 with scalefactor 15 put back on with analogue range to 0 to 5V and SoundSpeed to 1477.
ROS 6: Datasonic Benthos Altimeter SN1161 and matching Y-cable replaced Valeport Altimeter sn80262
ROS 10: Valeport Altimeter put back on
ROS 19: WETLabs Transmissometer CST-DR 1047 replaced with 1052
ROS 36 to 38: Seapoint Chl Fluorometer gain cable swapped from 30x to 10x (0 to 5v gives 0 to 15ug/l)
ROS 22: Rinko III # 9 replaced with #369

CTD

CTD#	Make	Model	Serial#	Used with Rosette?	Casts Used
Primary	SeaBird	911+	724	Yes	All Casts
Secondary	SeaBird	911+	756		Not used, backup.

	Calibration and Accuracy Information CTD #724 PRIMARY						
Sensor		Accuracy	Pre-Cruise		Post Cruise		Comment
Name	S/N		Date	Location	Date	Location	
Pressure Sensor	0724 (# 90559)	Nominal 1.2 m	02 Jan 2020	SeaBird Lab			

Temperature, SBE3plus	4322	Nominal ± 0.001 °C	03 Nov 2020	SeaBird Lab				
Conductivity, SBE4C	2809	Nominal 0.003 mS/cm	30 Oct 2020	SeaBird Lab				
Pump, SBE5T	053610							
Secondary Temp., SBE3plus	4239	Nominal ± 0.001 °C	03 Nov 2020	SeaBird Lab				
Secondary Cond., SBE4C	2810	Nominal 0.003 mS/cm	30 Oct 2020	SeaBird Lab				
Secondary Pump, SBE5T	053615							

Calibration and Accuracy Information, External Sensors							
Sensor		**Accuracy**	**Pre-Cruise**		**Post Cruise**		**Comment**
Name	**S/N**		**Date**	**Location**	**Date**	**Location**	
SBE 43 Dissolved Oxygen sensor	1117		29 Jan 2022	SeaBird Lab			CTD Voltage Channel 2 On Primary pump;
Altimeter Valeport VA500SBE1	80262		08 Feb 2022	Manufacturer			CTD Voltage Channel 3 Cast 1,2,3: Scale factor 150, Range limit 10m Cast 5, 10 to 46 Scale factor 15, Range limit 100m
Altimeter Datasonics Benthos	PSA-916D, 40853		12 Feb 2007	Benthos			CTD Voltage Channel 3 Cast 4
Altimeter Datasonics Benthos	PSA-916D, 1161		31 Mar 2005	Benthos			CTD Voltage Channel 3 Cast 6,7,8,9

Seapoint Fluorometer (Chl-a)	SCF 3741, 30x gain 10x gain		22 Feb 2016	Seapoint 2pt health check at IOS (17 Feb 2022)			CTD Voltage Channel 0 On Secondary Pump; 10x gain cable and setting for Casts 36, 37, 38 all others used 30x gain cable and settings
Wetlabs Transmissometer	C-Star CST-1047DR		09 Jul 2022	IOS (In-house light/dark test)			CTD Voltage Channel 1 Casts 1 to 18
Wetlabs Transmissometer	C-Star CST-1052DR		10 Jul 2022	IOS (In-house light/dark test)			CTD Voltage Channel 1 Casts 19 to 46
WETLabs ECO CDOM	4305		27 Jan 2022	WETLabs			CTD Voltage Channel 4 Casts 1 to 3
WETLabs ECO CDOM	6677		4 Mar 2021	WETLabs			CTD Voltage Channel 4 Castsw 4 to 46
Satlantic Cosine Log PAR	517		25 Jun 2014	Satlantic			CTD Voltage Channel 6
Biospherical Surface PAR QSR2200	20498		4 Apr 2016	Biospherical			
Biospherical PAR QSR2150 (Continuous)	50228		21 Jun 2016	Biospherical			
Alec Rinko III dissolved oxygen sensor	9, Film A	Data collected in uncalibrated volts		Ship board 2-pt calibration			CTD Voltage Channel 7 Casts 1 to 21
Alec Rinko III dissolved oxygen sensor	369, Film B	Data collected in uncalibrated volts		Ship board 2-pt calibration			CTD Voltage Channel 7 Casts 22 to 46

Deck Units

Type	***make***	***model***	***serial***	***comment***
Deck Unit	Seabird	11plus	649	Casts 1 to 4. Swapped after Cast 4, but realized afterwards problem

				was simply the "Fish/Tape" switch had changed from Fish to Tape. All OK.
Deck Unit	Seabird	11plus	680	Casts 5 to 46

Rosette Pylons

Type	*make*	*model*	*serial*	*comment*
Water Sampler Carousel	Seabird	32	1231	Pylon used for all casts; trigger swapped throughout
Water Sampler Carousel	Seabird	32	498	Pylon as backup; trigger swapped in throughout

TSG Seabird SBE21 sn 3297

Calibration and Accuracy Information, TSG							
Sensor		**Accuracy**	**Pre-Cruise**		**Post Cruise**		**Comment**
Name	**S/N**		**Date**	**Location**	**Date**	**Location**	
Seabird TSG SBE21	3297		10-Dec-2020	SeaBird Lab	In progress	SeaBird Lab	Post cruise calibration at Seabird currently underway
Seabird Temperatrue SBE-38 (Intake temperature)	0319		30 Dec 2020	SeaBird Lab	In progress	SeaBird Lab	Post cruise calibration at Seabird currently underway
Seapoint Chlorophyll Fluorometer	SCF3651 30x gain		Jun 2014	Seapoint 2pt health check at IOS (17 Feb 2022)			30x gain cable (0 to 5V = 0 to 5mg/mL)
Wetlabs ECO CDOM Fluorometer	WSCD-1281		17 Jun 2015	Wetlabs			

Seabird specifications on sensors:
SBE 3plus temperature sensor
Range -5.0 to +35 °C
Resolution 0.0003 °C at 24 samples per second
Initial Accuracy2 ± 0.001 °C
Response Time3 [sec.] 0.065 ± 0.010 (1.0 m/s water velocity)
Self-heating Error < 0.5 sec. to within 0.001 °C

SBE4c conductivity sensor
Measurement Range 0.0 to 7.0 Siemens/meter (S/m)
Settling Time 0.7 seconds to within 0.0001 S/m
Initial Accuracy 0.0003 S/m
Stability 0.0003 S/m/month
Time Response 0.060 seconds (pumped)

Digiquartz pressure sensor
Measurement Range Pressure 0 to 6800m (10,000 psi)
Accuracy 0.018% of full scale
Resolution (at 24 Hz) Pressure 0.001% of full scale
Time Response Pressure 0.015 second

5.6 Seawater Loop Measurements

Details on set-up, operation, instruments and performance are below.

5.6.1 Seawater Loop

The ship's seawater loop system draws seawater from below the ship's hull at 9 m using a 3" Moyno Progressive Cavity pump Model #2L6SSQ3SAA, driven by a geared motor. The current pump was installed August, 2016. The pump rated flow rate is 10 GPM. It supplies seawater to the TSG lab, a small lab just off the main lab where a manifold distributes the seawater to instruments and sampling locations. This system allows measurements to be made of the sea surface water without having to stop the ship for sampling. The water is as unaltered as possible coming directly from outside of the hull through stainless steel piping without recirculation in a sea-chest.

Figure 15. Seawater loop system w/ Chl-a and FDOM sensors attached to left wall, the second FDOM sensor in wood cradle and pCO2 system on bench in center. The seawater loop provides uncontaminated seawater from 9m depth to the science lab for underway measurements

Figure 16. TSG manifold and water supply manifold (2019, pretty similar for 2022).

Figure 17. The Moyno pump installed in the engine room (2021, similar for 2022).

Figure 18. Seawater passes through a filter before going to the pump (in background). When the ship is in sea-ice the flow is switched from one filter to the other to allow the necessary frequent clearing out of slush from the filter. This picture is from a previous year but is the same strainer configuration for 2022.

Control of the pump from the lab is via a panel with on/off switch and a Honeywell controller. The Honeywell allows setting a target pressure, feedback parameters and limits on pump output.

Figure 19. Honeywell controller for the pump, located in the TSG lab.

On one of the seawater manifold arms is a Kate's mechanical flow rate controller followed by a vortex debubbler, installed inline to remove bubbles in the supply to the SBE-21 thermosalinograph (TSG).

The SBE38 Inlet Temperature is connected to the TSG remotely. It is installed in-line, approximately 4m from pump at intake in the engine room. This is the measurement to use for sea-surface temperature (as opposed to the seawater temperature measured by the SBE21 in the TSG lab).

Figure 20. SBE38 temperature sensor in the engine room (2022)

The fluorometer and CDOM sensors were plumbed off a second manifold output with no debubbling.

The data were collected through SeaBird's Seasave acquisition program v Seasave V 7.26.7.107 onto a laptop using a serial to usb adapter cable. GPS was provided to the SBE-21 data stream using the NMEA from PC option rather than the interface box. A 5 second sample rate was recorded.

The computer used the ship's science LAN to pass ship's GPS for integration into sensor files, to pass the SBE38 (inlet temperature) data from the engine room to the TSG instrument, and to pass the TSG and SBE38 data to the ship's data collection system (SCS). The software program GPSgate was used to facilitate the conversion between USB, TCP/IP, and virtual and real communication ports.

On a third arm of the manifold, an automated system for measurements of pCO2 from the seawater and atmosphere was used. This year's measurements were made with a an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors) owned and operated by Mike DeGrandpre (UMontana). Data were recorded through the cruise with discreet

DIC, Alkalinity water samples drawn for comparison. For more information please see his report.

5.6.2 Issues, Settings, Instruments

TSG Flow Rate
Flow rate varied often due to sea-ice clogging the strainer at the ship's sea-water inlet, or pump malfunction. Quite often the flow stopped altogether due to clogging and the pump would be turned out until conditions improved (less ice). The TSG data acquisition was typically left running however the periods of bad data will need to be identified and removed.

Sea Water Pump and TSG data
Notes are recorded primarily in the TSG Log Book and will be copied to the file:
2022 TSG Log with CNV and Sample data.xlsx

Highlights below:

Sep 17th	01:53, not far from Cambridge Bay, NU. tsg_2022-09-17-0153 first good file.
Oct 10th	Oct 8th 14:00 to Oct 9th 16:55 UTC the GPS position is frozen and will need correction. The GPS information come from the science server. When the server rebooted, the TSG laptop need the GPSgate program cycled to unfreeze the incoming GPS data. In the processing these bad values will need replacing from the SCS logged GPS data.
Oct 12th	15:20 The TSG and Seasave turned off as the ship approached Kugluktuk.

Manifold is configured with four outlet arms:

- One going to TSG
- One going to pCO2 system
- One going to Fluorometer SN3651 w/ 30x gain and then to CDOM fluorometer SN1281.
- One going to new FDOM sensor

See processing report for file names and processing steps applied to TSG data:
2022 LSSL Converting TSG data v2022-10-12.docx

Settings
TSG SBE21 SN 3297 calibrated 10 Dec 2020

SBE38 SN319 Temperature calibrated 30 Dec 2020
Seapoint Flr #3651 with 30x gain calibrated Jun 2014
WETLabs Flr #1281 for CDOM, calibrated 9 Jun 2011
Computer: laptop Pteropod D2020-02

NMEA Com # w/ “Time Added” box checked
SBE38 via internet using Com # USB to serial to null modem to cable to TSG unit with virtual Com # for testing.
Pump set to 18.3 PV

New for 2022:
Chl-a and FDOM sensors were plumbed so they can be calibrated at sea using Sprite or rhodomene dye. Celine oversaw a couple rhodamine reference checks. nsors.

New communication cable to TSG was used (pilfered from SBE19+ supply).

Flow rate was measured manually
Using the Honeywell controller, pressure set point was 18.3 PSI.

Measured flow rates to the sensors were approximately:

TSG	6 L/min at start of cruise 12 L/min 21 Sep 17:44 UTC (increased flow by opening Kates valve from 9.7 to 11GPM) but varied through cruise
Fluorometer pair	4 L/min
FDOM single	5.45 L/min

Water samples
Discrete water samples for salinity, DIC, Alkalinity, Chlorophyll and FDOM were collected from the fluorometer line. Samples were assigned a consecutive “Loop” number which was unique by time, i.e. if 4 different properties were measured at the same time they received the same Loop number.

5.7 Logging of Underway measurements with SCS

P.I.s: Bill Williams

This section gives the SCS string definitions and lists the issues encountered this year.

These are the measurements taken at frequent regular intervals continuously throughout the cruise logged by NOAA’s “Shipboard Computer System” (SCS) software running on the science server. These measurements are:

1. GPS from the ship's Furuno GPS, using NMEA strings $GPGGA and $GPRMC. These are the same GPS sentences, available on the science VLAN, being used by CTD, XCTD, TSG and mapping programs.
2. AVOS weather observations of air temperature, humidity, wind speed and direction, and barometric pressure ($AVRTE)
3. Sounder depth and the applied ship's draft and sound speed
4. Surface Photosynthetically Active Radiation (PAR)
5. Thermosalinograph (TSG), and the inlet sea surface temperature from the SBE38 that is also given in the TSG data stream.
6. Heading from the ship's Gyro ($HEHDT)
7. Data from the FDOM fluorometer in the seawater loop (FDOM)
8. Derived true wind speed calculated in SCS

5.7.1 Issues with the underway system and data

Unlike in previous years, acquisition was stopped and restarted manually instead of the automatic daily files.

Time stamp on SCS files
Computer time corrected 7 Oct 2022 from 20:55 to 20:45 so SCS data feed's timestamp will

1. Be ahead by 10 minutes from UTC time up until 7 Oct 20:45
2. Repeat itself after being set back 10 minutes (ex. 20:45 to 20:55 will occur twice).

All systems
No data 2022-10-08 14:00 to 17:30 UTC. The server turned off by itself stopping SCS data acquisition. Patrick the E-tech restarted the server at 14:30 UTC to get the GPS distribution feed restarted as it was needed by the WHOI group for mooring ops). SCS acquisition was restarted at 17:30 UTC. The independent system (TSG, FDOM, PAR and AVOS) continued collecting data during this downtime however TSG is missing the correct position (GPS) information.

GGA-GPS

OK from start of cruise

RMC-GPS
OK from start of cruise

AVOS –
Feed established 09/27/2022,21:41 UTC.
Etherlite box in AVOS computer room had reset itself to wrong IP address. When this was reassigned to correct address the data came through fine.
The AVOS system did not have the ship's Gyro data connected but instead used its fluxgate compass when calculating corrected windspeed and direction. Preferred True wind speed and direction are instead calculated by SCS and stored both in .Raw files and in the database, however this year there was no Gyro until Feed established 10/01/2022,21:02 UTC

Sounder –
OK from start of cruise. Data bad between stations.
It was determined that the 12kHz data are poor when the ship has its Skipper sounder turned on – although its at a higher frequency there is interference.
During transits and operations in areas where the presence of bowhead whales was possible, the sounder intensity was turned down, or the sounder turned off between stations.

Ascii PAR
This system took a few days to get set up properly in the CTD shack. Once the Biospherical serial to USB connector was found and installed all worked well. The data file logged to PAR computer (not SCS) will be more complete. PAR data started 9/22/2022 12:53:10 AM UTC, however SCS feed not established until 09/27/2022, 22:08 UTC.

SBE38
OK from start of cruise

TSG
No GPS information from **2022-10-08 14:00 to 2022-10-09 16:55 UTC** due to server reboot and not noticing GPSGate on TSG computer needed to be stopped and restarted.
OK from start of cruise, however these data are preliminary, need to confirm config file being used and further processing and calibration performed in the Seabird TSG files as opposed to these file.

CDOM
Feed established 09/28/2022,03:17 UTC.

Gyro

Feed established 10/01/2022,21:02 UTC

True Wind
OK once Gyro data feed connected 10/01/2022,21:02 UTC

5.7.2 SCS Data Strings Defined

This system takes data arriving via the ship's science network (a VLAN) in variable formats and time intervals and stores it in a uniform ASCII format that includes a time stamp.

Note the AVOS, TSG, FDOM and PAR data are also logged through their own acquisition software.

The SCS system, running on a shipboard computer called the "NOAA server" or "science server" collects *.Raw files. The files are restarted periodically so they do not get too large. Each sentence logged in a .Raw file is also parsed for data fields of interest, and the values extracted, labelled and stored in the SCS database. The compress utility can be used on these extracted data to create files from a single data file for one sentence for the entire cruise.

The list of *.Raw files and fields within the data string are given below for 2020 but are similar for 2022:

Position, Time, Date, Speed and Course over ground - $GPRMC

File: RMC_*.Raw
Time interval 1 second

Description of *.Raw file string , example file: RMC_20200910-214857.Raw
09/10/2020,21:48:58.578,$GPRMC,214427.00,A,7238.52537,N,07151.97735,W,15.051,310.9,100920,999.9,E,D*10
09/10/2020,21:48:59.999,$GPRMC,214428.00,A,7238.52807,N,07151.98798,W,15.050,310.2,100920,999.9,E,D*13

Sentence fields:

a. Date MM/DD/YYY (timestamp from SCS)
b. Time HH:MM:SS.SSS (timestamp from SCS)
c. "$GPRMC"
d. Time HHMMSS.SS
e. Status A= Active, V=Navigation receiver warning
f. Latitude DDMM.MMMM
g. Latitude N or S
h. Longitude DDDMM.MMM
i. Longitude E or W
j. Speed over ground in knots
k. Course over ground in degrees (True)
l. Date DDMMYY
m. Magnetic variation in degrees (999.9 = not valid)
n. Variation E or W
o. Mode indicator: A=Autonomous, D=Differential
p. No comma before this field – checksum starting with *

Extracted and stored in the Database:

1. RMC-Time UTC
2. RMC-Latitude
3. RMC-Longitude
4. RMC-SOG
5. RMC-COG
6. RMC-Date

Position - $GPGGA

File: GGA_*.Raw
Time interval 10 second

Description of *.Raw file string , example file: GGA_20200909-160350.Raw

09/09/2020,16:03:52.027,$GPGGA,155920.0,6642.04389,N,06103.44820,W,2,08,1.0,16.8,M,18.5,M,7.0,0138*50
09/09/2020,16:04:02.996,$GPGGA,155931.0,6642.08959,N,06103.44817,W,2,08,1.0,16.9,M,18.5,M,6.0,0138*5F

Sentence fields:

1) Date MM/DD/YYY (timestamp from SCS)
2) Time HH:MM:SS.SSS (timestamp from SCS)
3) "$GPGGA"
4) Time HHMMSS.S
5) Latitude DDMM.MMM
6) Latitude N or S
7) Longitude DDDMM.MMM
8) Longitude E or W
9) Fix type: 0=invalid position, 1=autonomous GPS,2=DGPS
10) Number of satellites used
11) Horizontal dilution of precision
12) Height of the geoid
13) M (units of height)
14) Age of correction data for DGPS in seconds
15) Correction station ID number
16) No comma before this field – checksum starting with *

Extracted and stored in the Database:

1. GGA-Quality (#9 above)
2. GGA-Satellite Count
3. GGA-Age of data

Depth – "Sounder"

Depth is measured using the 3.5, 12 or 30kHz transducers using a new for 2018 Knudsen CHIRP 3260 Echosounder, labeled "Science". The CHS/NRCAN-purchased CHIRP 3260 was not used. The depth value has been increased by the ship's draft for each transducer. The depth is calculated using a specified sound speed. Both the draft and nominal sound speed variables are set by the user in the Knudsen software. Nominal sound speed is the average of the water column sound speed. To improve accuracy post-cruise, a new sound speed based on the CTD data could be applied. The currently applied draft and sound speed are given in the data string.

Time interval depends on ping rate, but in practice is between 5 and 7 seconds.
The sounder worked well on station once the system was properly connected although in the southern section of the 150W and 140W the sounder did not work well even though the depth was similar.

It was determined if the ship's "fishfinder" is on, there is interference with the 12kHz system.

Sounder data are more problematic than other types collected by SCS. 0.0 values are reported when the sounder does not detect bottom. It will report values that to the eye judging the visual echogram are clearly incorrect; any values less than 35m or values that either double or halve those nearby should likely be discarded. In areas with steep bathymetry the sounder will often report incorrect values from side reflections of deeper or shallower water – these artefacts can be difficult to filter out.

File: Knudsen-Sounder_*.Raw

Description of *.Raw file string
Knudsen-Sounder_20200921-001000.Raw
09/21/2020,00:11:32.929,Sounder,21092020,001435,,,,12.0kHz,3750.71,9.00,,,,1479
09/21/2020,00:11:43.929,Sounder,21092020,001448,,,,12.0kHz,3750.84,9.00,,,,1479

Sentence fields:

1) Date MM/DD/YYY (timestamp from SCS)
2) Time HH:MM:SS.SSS (timestamp from SCS)
3) "Sounder"
4) Date UTC: DDMMYYYY
5) Time UTC: hhmmss
6) Sounder frequency (3.5kHz)
7) Depth (3.5kHz)
8) Applied draft (3.5kHz)
9) Sounder frequency (12kHz)
10) Depth (12kHz)
11) Applied draft (12kHz)
12) Sounder frequency (30kHz)
13) Depth (30kHz)
14) Applied draft (30kHz)
15) Soundspeed m/s

Extracted and stored in the Database:

1. Knudsen-Sounder-3.5kHzDepth
2. Knudsen-Sounder-3.5kHzTD
3. Knudsen-Sounder-12kHzDepth
4. Knudsen-Sounder-12kHzTD
5. Knudsen-Sounder-30kHzDepth
6. Knudsen-Sounder-30kHzTD
7. Knudsen-Sounder-NominalSoundSpeed

Meteorological data from AVOS (Automatic Voluntary Observing Ships System) - $AVRTE

The AVOS system is mounted above the bridge and is operated and serviced annually by Environment Canada. The temperature/relative humidity sensor and The RM Young mechanical anemometer are mounted on the starboard side, about 4m above the bridge-top (approx. 25m above sea-level).
Note that the ship's gyro feed is not connected to AVOS so the compass being used for relative to apparent calculation is the AVOS fluxgate compass and should thus be avoided if possible. SCS does a relative to true wind calculation, using the gyro heading and SOG and this is described below.

Barometer – not sure where this is mounted.
Time interval is 10 sec

File: AVOS-serial-AVRTE_*.Raw
Description of *.Raw file string
AVOS-serial-AVRTE_20200915-001000.Raw
09/15/2020,00:10:10.605,$AVRTE,200915,001014,00840,CGBN,24.9,322,181,,,,1018.60,,-1.9,60,,,,5.0,,,141.7,13.3*45
09/15/2020,00:10:21.199,$AVRTE,200915,001024,00840,CGBN,24.4,321,181,,,,1018.84,,-2.0,60,,,,24.7,,,140.8,13.4*75

Sentence fields:
1. Date MM/DD/YYY (timestamp from SCS)
2. Time HH:MM:SS.SSS (timestamp from SCS)
3. "$AVRTE"
4. Date UTC: YYMMDD
5. Time UTC: hhmmss
6. Region?
7. Ship's Call Sign
8. Relative wind speed, knots
9. Apparent wind direction, degrees true north
10. Relative wind direction, degrees where ship's bow is "North"
11. Space for 2nd wind sensor, not installed
12. Space for 2nd wind sensor, not installed
13. Space for 2nd wind sensor, not installed
14. Barometric pressure, Mbar (same as mmhg)
15. Space for 2nd barometer, not installed
16. Air temperature, degrees C
17. Relative Humidity, %
18. Space for 2nd temperature sensor
19. Space for 2nd humidity sensor
20. Space for Sea Surface Temperature, degrees C (this is NOT the same as the sea water loop TSG intake reading – different source)
21. Wind gusts, knots
22. Blank space for 2nd wind sensor gust
23. Heading ($HEHDT) direction, "Compass 1", degrees (not active)
24. AVOS fluxgate compass direction, "Compass 2", degrees
25. AVOS battery voltage
26. No comma before this field – checksum starting with *

Extracted and stored in the Database:
1. AVOS-serial-AVRTE-date
2. AVOS-serial-AVRTE-time
3. AVOS-serial-AVRTE-wind speed
4. AVOS-serial-AVRTE-apparent wind
5. AVOS-serial-AVRTE-relative wind

6. AVOS-serial-AVRTE-barometric pressure
7. AVOS-serial-AVRTE-air temperature
8. AVOS-serial-AVRTE-relative humidity

Seawater Loop (TSG)
Sea surface properties from sea water loop. Intake is ~9m below waterline. Please separate TSG report section for description of TSG sensors.
Time interval is 5 seconds.

File: TSG-serial-*.Raw

Description of *.Raw file string
TSG-serial-_20200911-193215.Raw
09/11/2020,19:32:33.321, 1.58 1.36 30.741 27.035 0.380 0.37973 0.07204 255.811262
09/11/2020,19:32:38.321, 1.57 1.36 30.736 27.027 0.369 0.36874 0.07082 255.811319

Sentence fields:
1. Date MM/DD/YYY (timestamp from SCS)
2. Time HH:MM:SS.SSS (timestamp from SCS)
3. Sea Surface Temperature in lab, Deg C
4. Sea Surface Temperature at intake, Deg C
5. Sea Surface Salinity, PSU
6. Sea Surface Conductivity in lab, mS/cm
7. Sea Surface Fluorescence (Chlorophyll-a), ug/L
8. Sea Surface Fluorescence (Chlorophyll-a) voltage, V
9. Sea Surface Wetlabs ECO CDOM Fluorometer voltage, V
10. Julian Day

Extracted and stored in the Database:
1. TSG-serial--T1
2. TSG-serial--T2
3. TSG-serial—Salinity
4. TSG-serial—Conductivity
5. TSG-serial—ChlFuorescence
6. TSG-serial--V0
7. TSG-serial--V1
8. TSG-serial--JulianDay

Seawater Intake Temperature (SBE38)
Sea surface temperature from sea water loop. Note this is the same temperature that appears in the TSG record. Intake is ~9m below waterline. Please see separate report for description of TSG sensors.

File: SBE-38-serialport-*.Raw
Time interval is about 1 second.

Description of *.Raw file string
SBE-38-serialport-_20201005-001000.Raw
10/05/2020,00:10:03.877, 3.3221
10/05/2020,00:10:14.343, 3.3265

Sentence fields:
1. Date MM/DD/YYY (timestamp from SCS)
2. Time HH:MM:SS.SSS (timestamp from SCS)
3. Sea Surface Temperature at intake, Deg C

Extracted and stored in the Database:
1. TSG-serial--T1

Surface PAR
The continuous logging Biospherical Scalar PAR Sensor QSR2150A (S/N 50228, calibration date 21 June 2016), was mounted above the CTD operation area and next to the CTD surface reference PAR located mid-ship, starboard side, on railing two decks above the CTD (boat) deck with an unobstructed view over approximately 220deg. The blocked area is due mostly to the ship's crane and smoke stack which are approximately 50 feet inboard, aft and forward of the sensor. The sensor logged data files independently and also reported data to the NOAA Server for logging through the SCS system (given here).

Logging and transfer of the PAR data froze numerous times during the cruise; it was restarted whenever noticed.

File: ASCII-PAR-serialport-*.Raw
Time interval is 10 second.

Description of *.RAW file string
ASCII-PAR-serialport-_20200912-001000.Raw
09/12/2020,00:11:41.768,D|35.813,1.54,7.451
09/12/2020,00:11:52.143,D|35.439,1.54,7.43

Sentence fields:
1. Date MM/DD/YYY (timestamp from SCS)
2. Time HH:MM:SS.SSS (timestamp from SCS)
3. "D|" - not sure what this is, ignored
4. Surface PAR, uE/m2/sec (same as in CTD data)
5. Unknown
6. unknown

Extracted and stored in the Database:
1. ASCII-PAR-serialport-PAR