Joint Ocean Ice Study (JOIS)
Beaufort Gyre Observing Program (BGOS)
2023 Cruise Report

Photo by Malte Dehler, CCG

Report on the oceanographic research conducted aboard the *Canadian Coast Guard Ship Louis S. St-Laurent*

September 14th to October 12th, 2023*
IOS Cruise ID 2023-013

* Sail dates, within this time frame science had 25 days.

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1 Overview

The Joint Ocean Ice Study (JOIS) in 2023 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) 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 lead the Beaufort Gyre Exploration Project, which maintains the Arctic Observing Network's Beaufort Gyre Observing System (AON-BGOS), funded by the National Science Foundation (NSF).

The 2023 program includes collaborations with researchers from the following nations and institutions:

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

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 Concordia, Montreal, Québec
Université Laval, Québec City, Québec.

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/2023-expedition/2023-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/
ARGO buoys	https://www.ocean-ops.org/board?t=argo

2 Cruise Summary

The JOIS/BGOS science program onboard the *CCGS Louis S. St-Laurent* began September 14th , departing from Cambridge Bay, NU and finished October 12th , 2023, back in Cambridge Bay 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 in 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.

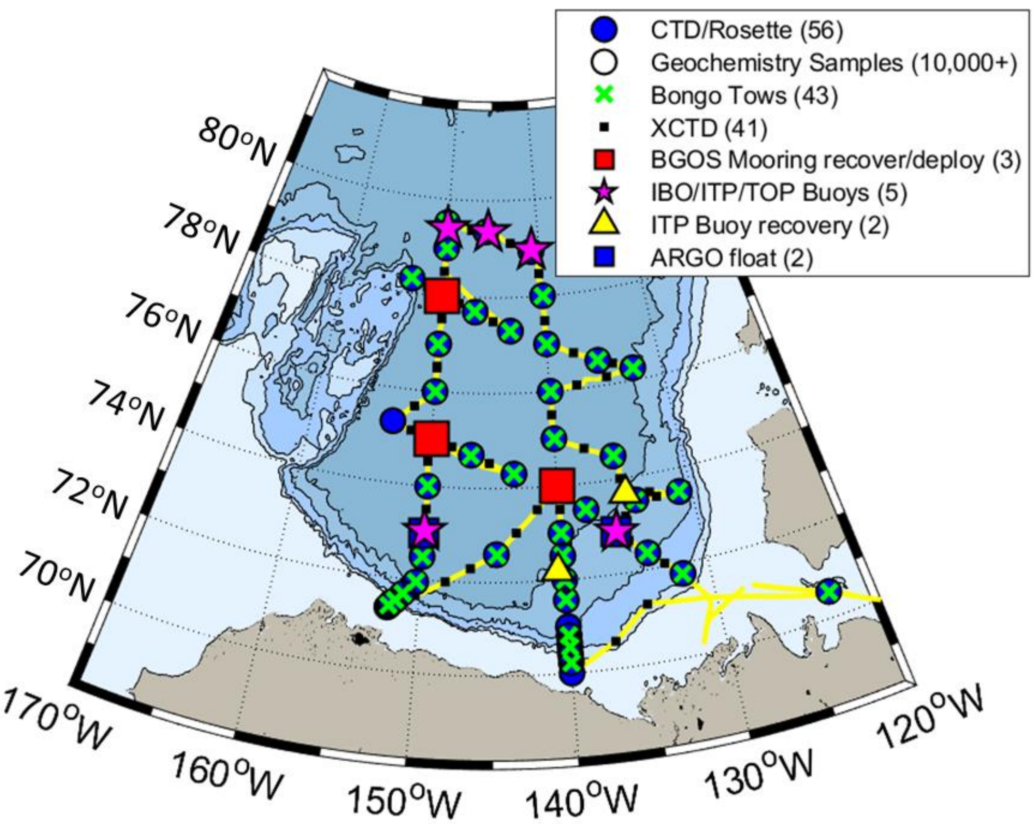


Figure 1. The JOIS/BGOS-2023 cruise track showing the location of science stations.

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. There was a problem with the launch system so that most of the 11 casts are either not full depth or have multiple gaps during the profile.

2.1 Program Components

Measurements:

- At CTD/Rosette Stations:
  - 56 CTD/Rosette Casts at 50 Stations (DFO) with 1242 Niskin bottle water samples collected for hydrography, geochemistry and pelagic biology (bacteria, microbial diversity and phytoplankton) analysis (DFO, U. Sherbrooke, TUMSAT, WHOI, Yale, U. Laval, U. Concordia, JAMSTEC, ETH Zurich, U. Delaware).

  - 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, ^{13}C isotope in DIC

    - At selected stations: microbial diversity, radio-nuclides (^{129}I, ^{236}U, ^{14}C), Barium, Dissolved Organic Matter (DOM), Lignin-phenols (from underway system only),

  - 44 Zooplankton Vertical Net (“Bongo”) Casts at 44 CTD/Rosette stations. One 100 m cast per station using two nets with mesh size of 150 µm. (DFO).

- 41 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1000 m depth. (DFO, JAMSTEC, WHOI)

- Mooring operations at 3 sites (WHOI, U. Montana, U. Sherbrooke)
  - 3 Mooring Recoveries and Re-deployments in the deep basin (BGOS-A,B,D; WHOI)

- Buoy operations at 7 sites (WHOI, Yale, CRREL,U Montana, NPS)

  - Open Water Deployment 1
    Ice-Tethered Profiler (ITP 141, WHOI)

  - Ice Based Observatory (IBO) 1 Ice Station with:

Ice-Tethered Profiler (ITP 138, WHOI)
Tethered Ocean Profiler (TOP011, WHOI)
1 Arctic Ocean Flux Buoy (AOFB 55, NPS)
1 Seasonal Ice Mass Balance Buoy (SIMB-2023#6, CRREL)

- IBO 2 Ice Station with:
  Tethered Ocean Profiler (TOP008, WHOI)

- IBO3 Ice-Station with:
  Ice-Tethered Profiler w/ SAMI-CO2 (ITP 139, WHOI, U. Montana)
  Tethered Ocean Profiler (TOP009, WHOI)
  Seasonal Ice Mass Balance Buoy (SIMB-2023#7, CRREL)

- Open Water Deployment 2
  Tethered Ocean Profiler (TOP010, WHOI)

- Open Water Recoveries of instruments no longer profiling.
  Ice-Tethered Profiler (ITP 130, WHOI)

- Open Water Recoveries of instruments no longer profiling.
  Tethered Ocean Profiler (TOP004, 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 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 trialled. 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

- Underway collection of meteorological, bottom depth, and navigation data, and near-surface seawater measurements of salinity, temperature, chlorophyll-a fluorescence, FDOM fluorescence, pCO2, and Oxygen/Argon (DFO-IOS, U. Sherbrooke, U. Montana, U. Delaware).

  Water samples (85) were collected from the underway seawater loop for salinity, nutrients, chlorophyll, DIC, alkalinity and oxygen (DFO), and FDOM (U. Sherbrooke).

- Daily dispatches to the web (WHOI/Yale)

2.2 Comments on Operations

Due to the ice conditions associated with the timing of the cruise, we chose to travel anti - clockwise around the Beaufort Gyre. This is the preferred direction in late September, 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. This year however, with the lack of sea-ice, the direction was chosen as it puts the buoy and mooring operations earlier in the program and gives some maneuverability with dates if the sea-state affects the schedule.

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 gangway was down and gave easy access to the ship for workers on the ice. Due to the weak ice at the second ice-station, the number of workers and the extent of the science operations on the ice were restricted to a single TOP deployment. This year two of the five buoy deployments were in open water. The success of this method and data returned will be important for future years, as open water deployments may become a necessary standard.

The Arctic summer sea-ice minimum was the 7th lowest on record. This is an Arctic-wide average, however, and in the Beaufort Sea the extent of the sea-ice minimum was very similar to 2012, the lowest on record. 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. She prepared daily briefings 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, and successfully find suitable ice for the buoy placements.

Due to predicted strong winds, we did alter our schedule for the open water mooring operations by 1) postponing operations by a day at mooring A and 2) skipping two CTD/Rosette stations and increasing our transit speed to start mooring D a day early. At most stations we were able to perform concurrent zooplankton casts and only had to cancel once due to strong winds.

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 run as smoothly as possible. The recoveries and redeployments went well however the mooring-A operation was difficult with the amount of swell we experienced.

An short side trip was made towards Tuktoyaktuk to helicopter off a crew member. Transit speeds were increased for this detour which only amounted to a few hours of delay.

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, 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 shortened station time of one CTD/Rosette cast (CB2a) and replaced two others with XCTD casts (BL5, BL7) to allow us to fit a mooring operation into a good weather-window.

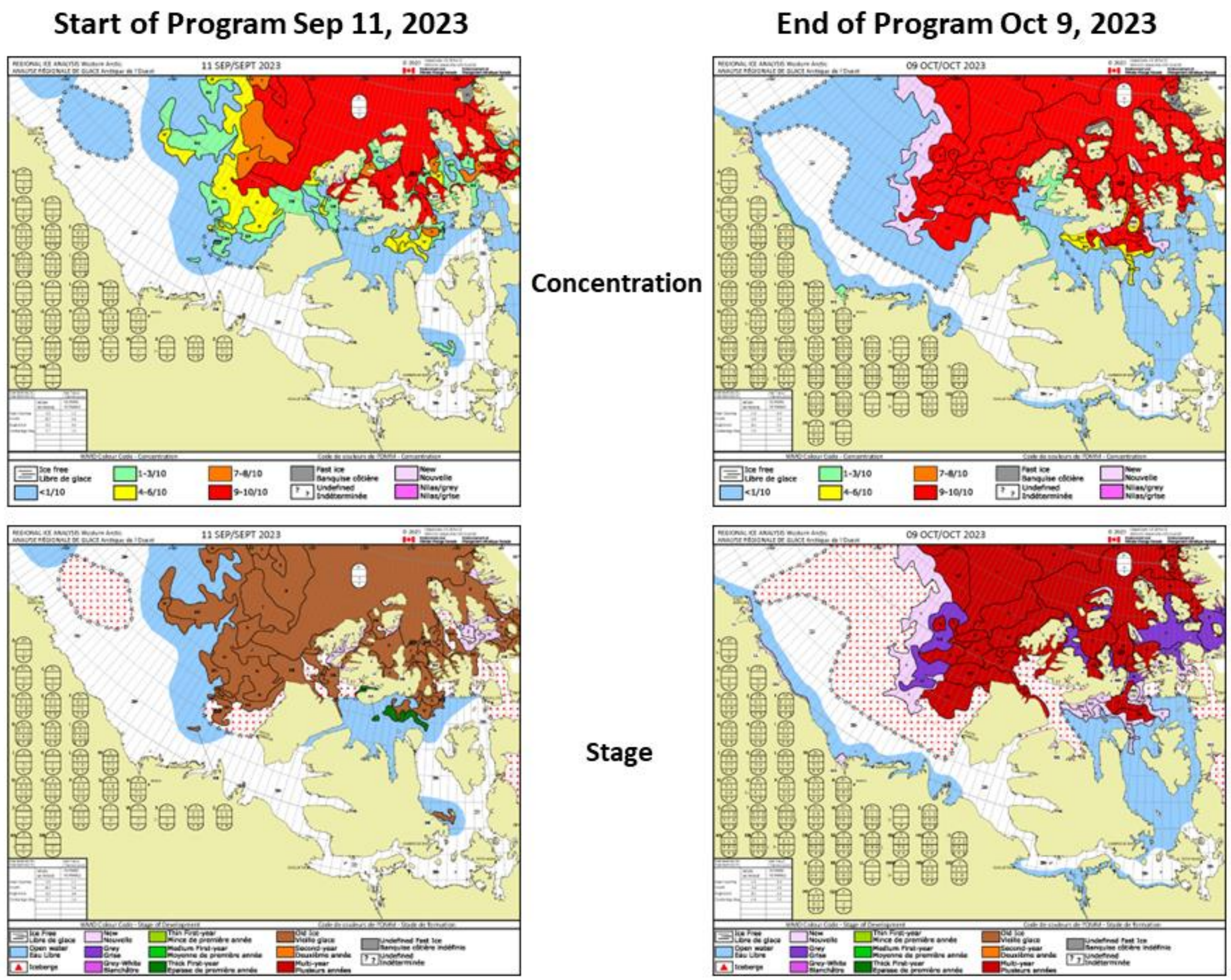


Figure 2. Ice conditions at the start and end of the program (source: https://iceweb1.cis.ec.gc.ca/Archive/page1.xhtml).

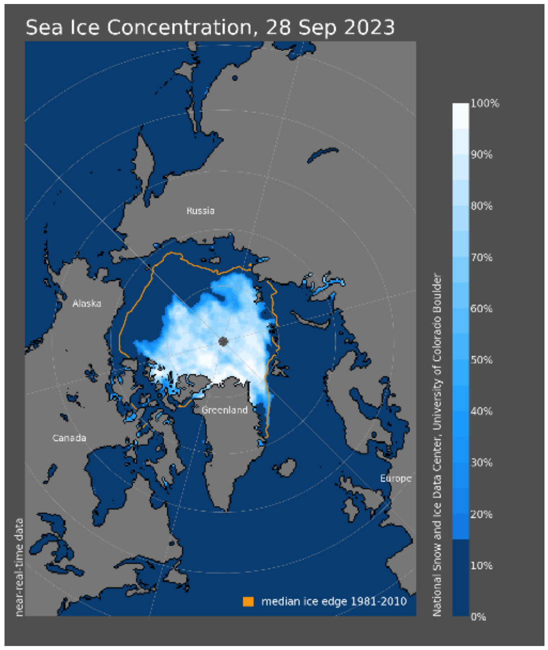
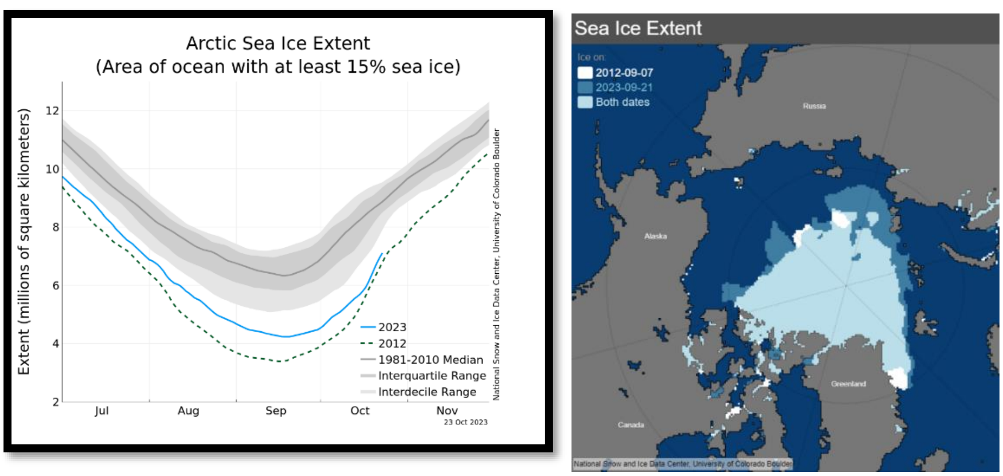


Figure 3. Sea Ice Concentration from the midpoint of this year's cruise. Image from the National Snow and Ice Data Center:

Index of /pub/DATASETS/NOAA/G02135/north/daily/images/2023/09_Sep (nsidc.org)



Figures 4. Sea Ice Extent for all years and a comparison of 2012 (lowest on record) and 2023, from National Snow & Ice Data Center (source: http://nsidc.org/arcticseaicenews/)

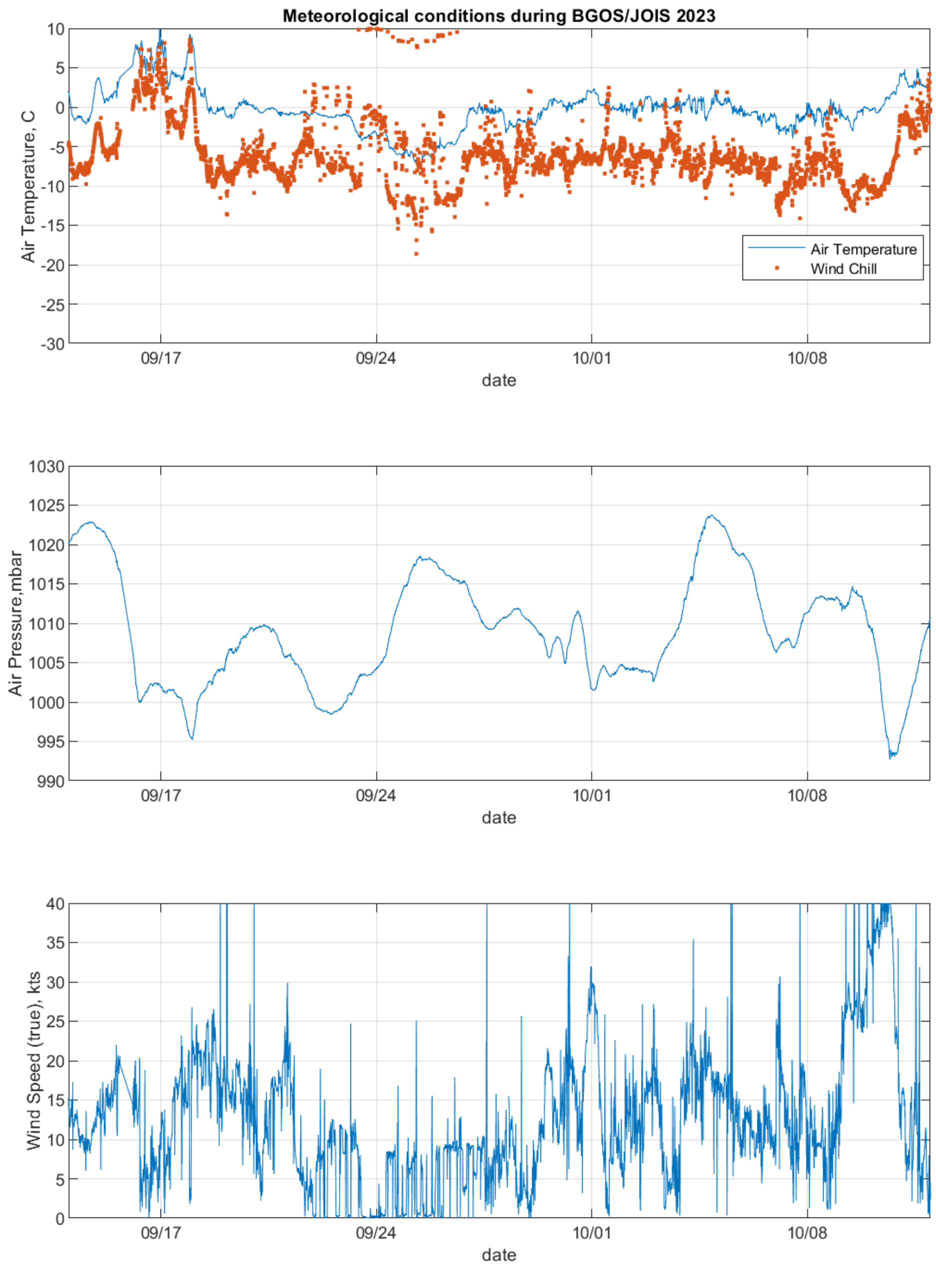


Figure 5. Temperature (blue) and wind chill temperature (red) in top plot, air pressure (middle plot) and wind speed (bottom plot) during the expedition from the ship's AVOS weather station above the bridge of the CCGS Louis S. St-Laurent. Note windspeed is incorrect for 21 Sep 22:19 to 28 Sep 00:00 (frozen sensor).

3 Acknowledgements

The science team would like to thank Captains Wayne Duffett and Byron Briggs, the crews of the *CCGS Louis S. St-Laurent* and the Canadian Coast Guard for their support. We appreciate the pre-cruise updates to the ship made related to our wish-list from last year.

At sea, we were very grateful for everyone's hard work and dedication to the delivery of the program. The specialists from the Canadian Ice Service gave daily briefings that were very helpful to operational decision making. It was very reassuring to have a health officer onboard. The helicopter pilot and engineer provided great time-savings assistance with transit loading/offloading, as well as excellent support when there was a medical-related flight to Inuvik in the first few days of the trip.

We'd also 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 JOIS Program's 21st consecutive year in the Beaufort Sea, and the exciting and valuable scientific results now in hand are a direct result of the experienced, well trained and professional crews of the *CCGS Louis S. St-Laurent*.

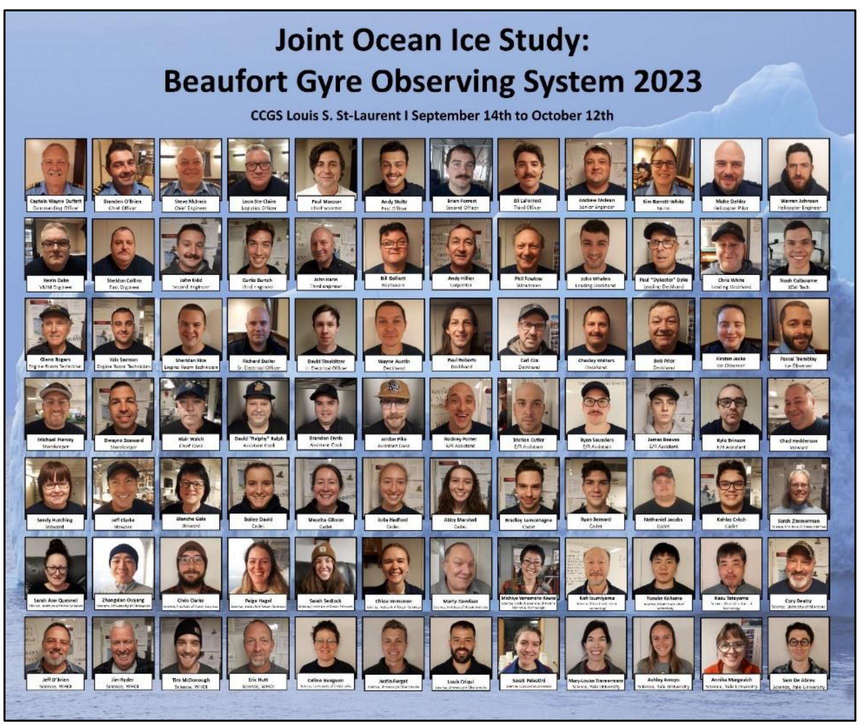


Figure 6. All crew and science on board. Poster made by Sam De Abreu.

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 1493 CTD the entire cruise. The CTD was mounted on an ice-strengthened rosette frame configured with a 24-position SBE-32 pylon s/n 1231 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 s/n 1281 and computer running Seasave version 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 s/n 0285 dissolved oxygen sensor was used for comparison and sensor testing purposes for all casts.

Similar to last year, WHOI added an experimental “D2” CTD sensor and logger 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 the CTD rosette was in the water, at most stations where weather allowed, a zooplankton vertical net haul (bongo nets) to 100m would occur from the foredeck. 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 2023, there were a total of 56 CTD/Rosette casts.

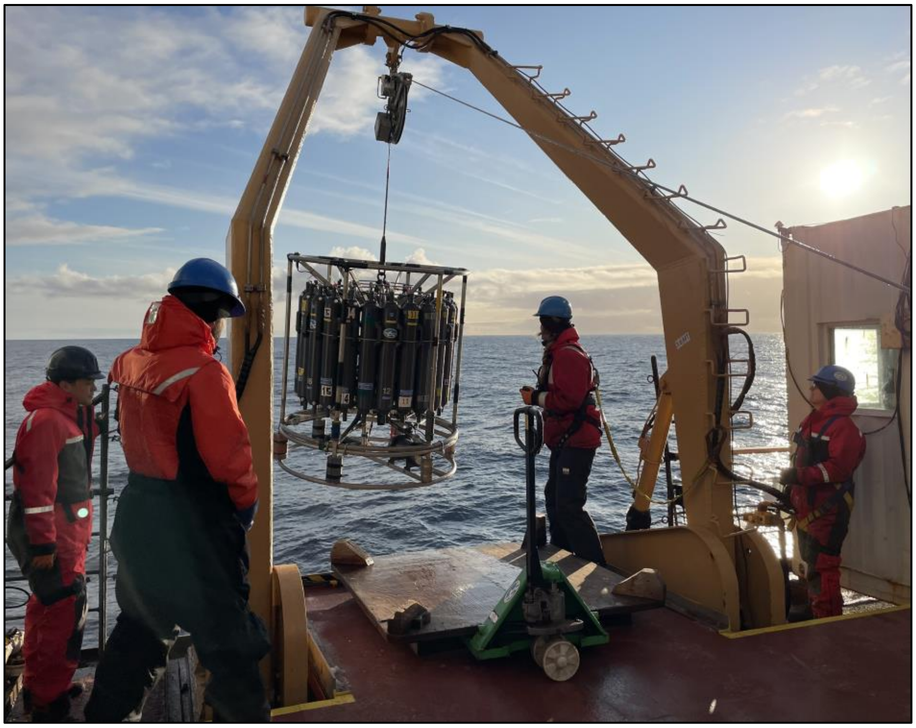


Figure 7. Typical rosette deployment

Figure 8. Rosette operation on deck with Hawboldt winch and Brooks Ocean Instrumented Sheave display box mounted on the right. (photo 2022 but similar for 2023).

Figure 9. CTD operator and acquisition display in the CTD lab.

4.1.2 Typical deployment

On deck, the transmissometer and CDOM 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 (Brooke 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.

For 2023, “yo-yo” Niskin closures were added for three standard depths in high gradient areas where bottle flushing issues typically occur. In addition to the surface (5m), the yo-yo’d depths were the chlorophyll maximum, where salinity is 33.1PSU, and where salinity is 34.4 PSU.

4.1.3 Performance notes

CTD

We used the SBE9plus s/n 1493 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 s/n 6677, cosine PAR s/n 517, altimeter s/n 80262, and transmissometer s/n 1052 were mounted in roughly the same positions as 2022. These all performed well throughout the cruise.

Pylon/ Water Sampler

We used the SBE32 Pylon s/n 1231 for the entirety of the 2023 cruise. Generally the system performed well, but there were a quite a few cases where the trigger mechanism did not fire due to “stickiness”. Due to our wire on the Hawboldt winch being over lubricated, the trigger mechanism s/n 1231 was routinely swapped with s/n 498 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.
During one of these swaps, the trigger mechanism s/n 1231 was accidentally dropped and multiple triggers were damaged. After this point, we just used a single trigger mechanism s/n 498, but took it off between most casts to inspect for wire lubricant, clean, and soak in hot soapy water.

Figure 10. Water sampling around 24 bottle rosette

Niskin Bottles

All o-rings were changed prior to the 2022 cruise on the 24 Niskin bottles on the rosette, and were checked and replaced as needed during the 2023 cruise. Silicon rubber o rings are used on the spigots to reduce sticking in cold conditions. The lanyards were also checked, modified and replaced as needed during the 2023 cruise. There were a few integrity problems (leaky spigots, endcap seating) with the 24 Niskins during JOIS this year. We tracked any pattern issues, and replaced o-rings, spigots, and vent screws as needed. Some bottle closure issues were related to suspected lanyard hang-ups or sticky trigger issues (due to wire lubricant in the trigger).

Per usual, due to the instrumentation on the rosette, we had to cock some of the Niskins bottom end caps slightly to the side rather than straight back. As mentioned above, we are now stopping for four yo-yo bottle trips per cast to counter the bottle flushing problems seen in the high gradient areas. The cause may be attributed to the rosette tilt as Niskins close sequentially and create drag (but this issue was not solved). On this ship, the yo-yo stop is much more effective at matching bottle to CTD value than the common 30second wait.

Four Niskins were replaced throughout the cruise in 2023. Niskin 13 was found to be cracked on cast 1, and replaced prior to cast 2. Niskins 2 and 9 had signs of (FDOM) contamination from wire lubricant, and were replaced prior to cast 28. Niskin 10 was damaged/cracked on rosette recovery of cast 29, and was replaced prior to cast 30.

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 had been added prior to the 2022 cruise, however the same problem persisted. We suspect this is a limitation of the Seasave program itself, but again are unsure.

SBE11 Deck Unit

We used the SBE11 deck unit s/n 1281 for the duration 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. We had one instance on cast 49 where the winch display lost communication, but we suspect it was a loose connection. There were no further issues after reseating and checking connections.
We had a retaining screw (attaching the bearing hub to the plastic sheave block) loosen unexpectedly during the cast 13 upcast, which was tightened immediately upon recovery of the Rosette. We replaced the outboard plastic guide roller that had seized/frozen and were worn through at the same time. We replaced the outboard plastic guide roller again prior to cast 27. Recommend to use Loctite on retaining screws prior to the 2024 cruise.

Transmissometer

WetLabs CSTAR transmissometer s/n 1052 performed without issue this year.

Altimeter

We used the Valeport VA500 s/n 80262 for the duration of the 2023 cruise. The Valeport VA500 was new in 2022 and works very well compared to our older Benthos altimeters, kicking in at full range (99m) every cast without spiking. The altimeter was mounted in the same position as 2021/2022, on a piece of aluminium pipe hose-clamped to the main frame. Recommend making this mounting area permanent for future cruises.

FDOM fluorometer

The WetLabs FLCDRTD (s/n 6677) fluorometer worked well for the entirety of the cruise.

Rinko III dissolved oxygen sensor

An Alec Rinko III s/n 0285 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 the sensor twice during the cruise, between casts.

CTD Rosette frame

We had some consistent issues with balancing the frame with lead weights this year, which could have contributed to some issues with our wire “spinning up” excessively during casts/recoveries. Recommend rebalancing frame as best as possible onshore prior to 2024. The CTD Rosette frame lower aluminium ring addition was damaged upon recovery during cast 47, resulting in a broken bottom support and a couple welds. This will need to be repaired prior to 2024.

CTD wire issues and re-termination

The CTD wire was new for JOIS 2022. Wire was cut back 10 m and re-terminated prior to JOIS 2023 during ship loading in July 2023.

The wire was heavily over lubricated in 2022, and we were still having issues with excess lubricant in 2023. It was observed that this excess lubricant was still coming off the wire over the course of the cruise, mostly via the BOT block and level wind rollers. Wire lubricant caused issues with the trigger mechanism, leading to Niskins not firing, as well as some contamination issues in two Niskin bottles. Recommend the BOT block, CTD, rosette, Niskins, ice chummy and all sensors to be inspected and cleaned prior to 2024.

We had a consistent issues with the wire “spinning up” during casts, and consequently on recovery. We did our best to mitigate this by letting the Rosette un-spin while hanging upon recovery when possible, which helped but did not solve the issue. While we did not see any issues with communications during the entirety of the 2023 cruise, this did lead to the wire slightly bird-caging near the termination almost immediately, and starting a proud strand that ran up the wire over the course of the cruise. In order to prevent further damage to the wire, prior to cast 22, ~225m of wire was removed after chasing the proud wire back to an acceptable point to re-terminate, and was observed to have no proud wires or evidence of bird-caging. The first ~25m of wire removed was observably bird-caged, and the rest was a single proud wire. Within 1 or 2 casts, the wire had begun to bird-cage near the termination again, and a proud wire could be observed on the first wrap (~300m) of the winch drum. It was decided to leave the wire termination as is, as it had essentially returned to the same state as it was prior to re-terminating.

We are not entirely sure why the wire is spinning up and damaging itself. It is possible that the rosette was poorly balanced, causing under/over spinning. It is possible that there is built up tension in the wire due to the way it has been spooled onto the winch drum. It is possible that there is a flaw in the wire construction. This is an issue that has been observed in previous years as well, so it is something to keep an eye on in the future.

The wire was very slightly kinked at ~10m upon a rough recovery on cast 29. No issues observed, so we continued without re-termination. The wire was kinked again at ~0.5m above the termination upon a rough recovery on cast 47. Communications were tested while bending and checking the kink, and no issues were found, so we continued without re-termination. The wire will need to be re-terminated prior to 2024, recommend removing >10m, above the second slight kink.

Otherwise the sea cable and communications worked well for the JOIS 2023 cruise, without issue.

CTD Winch

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

Some issues were observed with spooling of the wire on the forward side of the winch drum, where the wire will cross over itself and lay incorrectly when changing direction against the cheek of the drum. This is a persistent issue from previous years. It is possible that the fairlead levelwind rollers are not quite adjusted correctly. This happened twice over the course of the trip, but can otherwise be mitigated by paying close attention and/or slowing down slightly when spooling the forward cheek of the drum.

There was an occasional issue in which the winch began surging/pulsing in high gear @ ~ 3200m – 3500m wire out. Senior engineer was consulted but there was no obvious issues identified. Issue is resolved by stopping the winch and slowly engaging the valve on the control stick. If the control stick is moved too quickly (i.e. valve opened too quickly), the winch will surge again. It is possible the valve is faulty, but it is also possible that it is just the limitation of the winch's acceleration with so much wire/weight out. It is suspected that the issue presents itself if the winch operator unintentionally moves the control stick too quickly/erratically at >3000m.

Maintenance suggestions for next year

1. Calibrate T,C&O sensors on SBE 9plus s/n 1493
2. Inspect Niskin o-rings and lanyards for replacement of worn items
3. Inspect BOT block cabling; clean off wire lubricant and Loctite retaining screws
4. Make new mounting location for altimeter permanent
5. Check weights and balance Rosette Frame; repair lower ring
6. Remove ~15 m of wire and re-terminate sea cable

See appendix for CTD sensor configuration and calibration information.

4.2 Chemistry Sampling

Table 2 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	1077 (122)	Onboard	Bill Williams (IOS)
DIC	All casts (geochemistry)	Typically to S=34.7 (5 to 400m)	695 (61)	Onboard	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)
	Along 140W (not all) and Mooring sites: CB21, CB18, CB17, CB15CB9, CB4, CB3, Stn-A, AG5	Full depth			
Alkalinity	Same as DIC, analyzed from same bottle.	Same as DIC	695 (61)	Onboard	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)
FDOM	All casts (geochemistry)	5, Chl Max,S=33.1, S=34.4, AtlW Tmax, 1000, 2000, DeepTmin, Bot-100	529	Onboard	Celine Gueguen (U Sherbrooke)
	All 140W stations (CB16N, CB16, CB15, CB17, CB18, CB21, CB27, MK7, CB29, MK6, CB28b, MK4, MK3, MK2, MK1, CB28aa), BL8, BL6, BL4, BL3, BL2, BL1	5 to S=33.1			
Chl-*a*	All casts (geochemistry)	5-200 (select)	294 (292)	Shore lab	Bill Williams (IOS)
Bacteria	All casts (geochemistry)	5, 20, Chlmax, S=32.3, S= 33.1, 34.4, Tmax, 1000, Bottom	428	Shore lab	Celine Gueguen (U Sherbrooke David Walsh (Concordia)
Nutrients	All casts (geochemistry)	Full depth	1077 (130)	Onboard	Bill Williams (IOS)
Salinity	All	Full depth	1229 (107)	Onboard	Bill Williams (IOS)
$\delta^{18}O$	All casts (geochemistry)	5-400 (typically to S=34.7 or 34.8)	765 (60)	Shore lab	Bill Williams (IOS), Michiyo Yamamoto-

	Along 140W and Mooring sites: CB18, CB17, CB15, CB16, CB9, CB4, CB3, Stn-A, CB21, CB27, CB29	Full depth		Not all collected samples will be analyzed.	Kawai(TUMSAT)
Barium	All 140W stations (CB16N, CB16, CB15, CB17, CB18, CB21, CB27, MK7, CB29, MK6, CB28b, MK4, MK3, MK2, MK1, CB28aa), BL8, BL6, BL4, BL3, BL2, BL1	5 to S=33.1	204	Shore lab	Celine Gueguen (USherbrooke)
DOM	Along 140W: I2-23, CB11.5, CB18, CB17,CB15, CB16, CB16N, CB21, CB27	5, S=33.1	20	Shore lab	Celine Gueguen (USherbrooke)
Lignin/Phenol	CB19, CB31b, CB22 (and under the ice at each ice station)	Surface from TSG system (Seawater Loop)	6	Shore Lab	Celine Gueguen (USherbrooke)
Microbial Diversity (DNA/RNA)	AG5, CB4, CB9, CB21, CB16N (Farthest North)	5, 20, Chlmax, S=32.3, S= 33.1, Atl Tmax, 1000, Bot-100	142	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	CB10, CB5, BL4, StnA	Full depth (15 select depths)	56	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)
^{14}C	CB4, CB9	All depths	40	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)
DIC^{13}C	Most casts	Full depth	857 (40)	Shore lab	
	CB2a, CB6, CB10, CB12, CB13, CB17, CB19, CB31b, CB40, CB50, CB51, PP7, I2-23	5m to S=34.7 (5 to 400m)			
	StnA, CB22, MK7	Not sampled			

4.2.1 Dissolved Oxygen

Chloe Immonen (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 14 to October 12 during the JOIS mission in the Canada Basin. A total of 1077 unique samples were collected from 56 stations, some of which over 2 rosette casts, along a cruise track starting and ending in Cambridge Bay, NU. All samples were analyzed on the SIO Winkler oxygen titration kits. Oxygen concentrations ranged from 5.338 to 9.78 mL/L with ~10% of samples analyzed in duplicate. Including duplicates, 1199 samples were collected from rosette casts and analyzed. The pooled standard deviation (s_p) for duplicate samples was 0.007 ml/L after the removal of 1 outlier based on Chauvenet's criterion. The mean deep water (>3200 m) DO value in the Canada Basin was 6.514 ± 0.009 mL/L.
In addition to rosette sampling, dissolved oxygen samples were taken from the ship's underway loop system. Samples were taken in duplicate at 17 locations. Oxygen concentrations ranged from 7.529 to 9.92mL/L.
One oxygen sample was taken from a hole in the ice made for the TOP deployment at ice station IBO1. The concentration of that sample is 9.316mL/L.

Pre-cruise preparation

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 2019, 2022, and 2023. Most were shipped from IOS this year but the ones from 2019 were left on board the ship from the previous cruise. All remaining chemicals will be shipped back to IOS at the end of the season for proper inventory and determining which chemicals can be used in future years.

Equipment Calibrations

Bottle Top Dispensers: Bottle top dispensers were purchased new in April 2019. Gravimetric checks were performed before the 2023 field season. They generally performed well, aside from the first day as the straws were installed upside down. This error resulted in very bubbly dispensing of fixing reagents during the first cast. This was promptly solved and the bottle top dispensers worked well after this and did not need to be changed through the cruise.

Oxygen Sample Flasks: A new flask file for 2023 was obtained from Kenny Scozzafava prior to the cruise and loaded into the appropriate LVO2 directory.
Lids from two flasks (862 and 866 from #7 Arctic White) broke during sampling so they were replaced with 887 and 889, respectively, in the same spots in the case. These flasks were removed from circulation and a new box file was created to account for the change in order.
All flasks used during the standardization procedure became chipped at the lip. These chips do not affect the standardization process or quality of the results.

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 2023 JOIS program. The secondary thermometer electrical wire got severed in initial transport to the ship so could not have been used. 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 Chloe Immonen (DFO-IOS) on the Scripps Institution of Oceanography (SIO) Winkler-based UV titration kit B. Refer to previous years' reports for system details.

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 2nd 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.

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 between each case of samples 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.

Thio normality

Two batches of Thio (#2201, #2202) and four batches of KIO_3 standard (#2207, #2301, #2203, #2307) were used during the cruise and the stability of the Thio for both batches was good with a maximum daily change of 0.00021 N, below the 0.0005N threshold.

Precision and Accuracy

Of the 1077 unique samples (from the rosette) collected during the course of this survey, 120 (10%) 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, 3 pairs were excluded due to a known problem. The precision of the dissolved oxygen replicate measurements was not great, with a pooled standard deviation (s_p) of 0.034 mL/L from 120 replicates. After the removal of 1 outlier determined by the Chauvenet's criterion, the pooled standard deviation (s_p) improved to 0.007 mL/L for 119 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 5.338 to 9.780 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 2023 was 6.514 ± 0.009 mL/L falls 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.

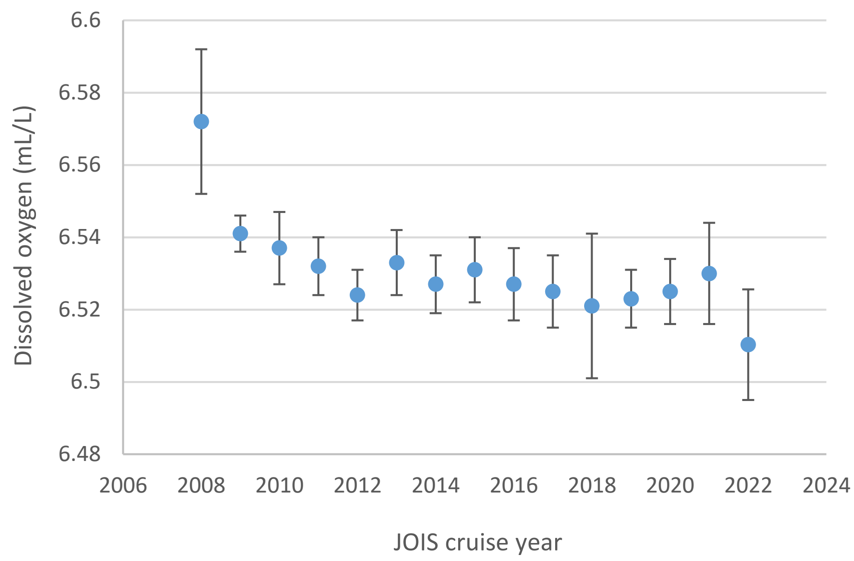


Figure 13: Mean annual dissolved oxygen concentration (mL/L) for the Canada Basin reference stations at all depths below 3000m. Error bars are one standard deviation for each year. I was unable to add the current year's data to this figure but the mean deep water (>3200 m) DO value in the Canada Basin in 2023 was 6.514 ± 0.009 mL/L.

Issues

Post entry of drawn temperature: One sample did not have a recorded draw temperature; in this case, the sample was titrated with a draw temperature of 0°C when the actual draw temperature is -1.3°C.

- Ice station sample 9917

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

- Sample 55: probably extra thio added, resulting in lower reported [O2]. Started titrating in air, aborted but only after a few drops of thio got in sample. OT 0.5252. Concentration reported as 5.186mL/L but I don't trust that. QF 5.
- Sample 659: could not run sample due to kimwipe chunk in sample ABORT
- Sample 786: titrated in air, reran, ABORT, deleted aborted value
- Sample 817: could not run (dumped DI into sample pre-analysis) ABORT, deleted first value

Sampling: While the occasional flask was discovered without a water seal, one cast (cast 18, station CB11.5) 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). For analysis of this cast, double the acid was added to most of the samples since the precipitate was taking a particularly long time to dissolve.
Some loop samples (loop 16) and the ice station sample (IBO1) did not have a water seal. These samples were flagged.

Stepped titration curves: During analysis of samples during casts 17 (I2-23/IBO2-2023), 18 (CB11.5), 19 (CB11), 20 (CB13), 21 (CB12), 25 (CB9), 32 (CB4 geochem) and loop samples (loop 10) and the ice station sample (IBO1), numerous samples per cast experienced dancing bubbles during titration. These introduced bubbles created stepped titration curves and necessitated over-titrations. The source of the bubbles was not conclusive, but it was thought that there could have been a leak somewhere in the thio burette lines, even though the lines were thoroughly inspected for bubbles before the start of each sample run. Samples were always inspected for bubbles before the beginning of the titration and stir bars were stopped and restarted if a bubble was seen. The bubbles seemed to be worse when samples had been sitting in the lab for a few days prior to analysis (for example, after ice days when no analysis was done). This seemed to cause the precipitate to take longer to dissolve and more time to pass with the burette tip in the sample before titration could begin. It seemed to improve/be less likely for bubble introduction if the analyst waited to place the burette tip in the sample until after the precipitate was fully dissolved. The stir bar speed needed to be adjusted to below the pre-marked rate as the higher rate seemed responsible for more bubble introduction.

Lab Space Issues: Within the first two days of the cruise, the engineering and SEW Tech teams were able to hook up hot water and access to the loudspeaker system to the lab. No further lab space issues to report.

4.2.2 Dissolved Inorganic Carbon and Alkalinity

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

Overview

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.

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. All samples were analyzed on the ship using VINDTA 84 and a coulometer 5017O. DIC, then alkalinity were measured from the same sample. A total 703 samples were collected from Niskin bottles, 2 were lost. Of these, 62 samples were taken in duplicate. In addition, 20 samples from the TSG system and 2 samples from ice stations were analyzed.

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.

DIC values are not corrected for based on CRM values. DIC values are reported in units of μmol/kg.

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	1.25	µmol/kg	59	2	1716.63	2256.09	99.99

The accuracy of DIC analysis was assured by daily analysis of Dickson CRM sea water (batch #203, concentration of S=33.464, DIC = 2029.92 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, varied from 99.88 to 100.16%. The precision is given by the pooled standard deviation (s_p) of sample duplicates and was 1.25 µmol/kg, with n=59 pairs after removing 2 outliers based on the Chauvenet criteria.

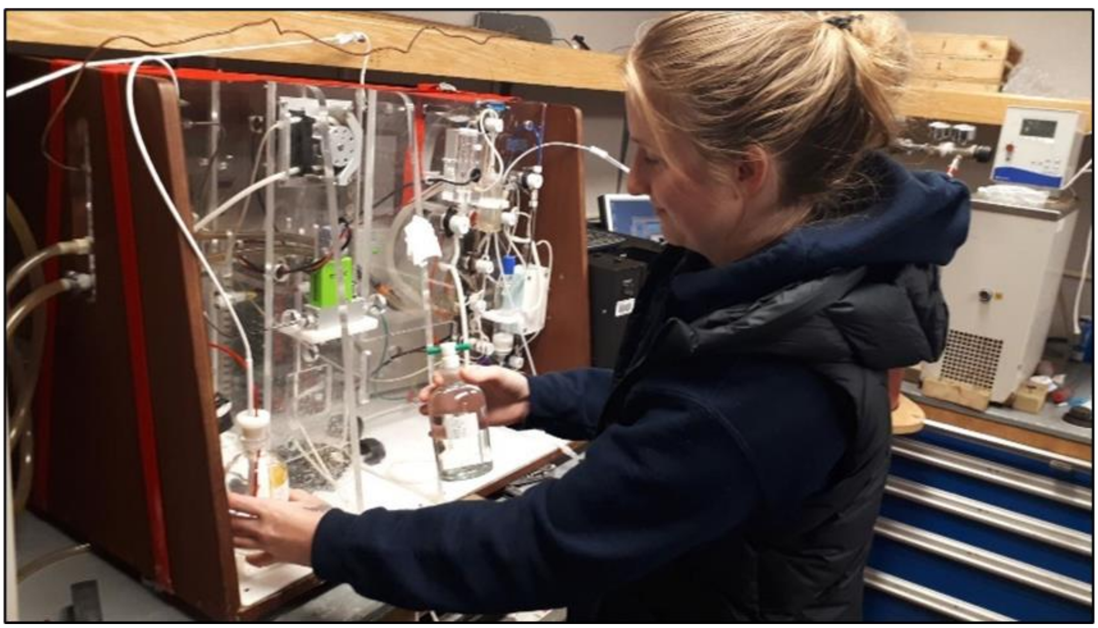


Figure 12. DIC analysis apparatus.

Analysis for Alkalinity

Samples were analyzed for DIC first, and then seawater left in the bottle was analyzed for alkalinity on board. Samples were put in water bath (20 °C) at least 20 minutes before being analyzed. The total alkalinity was determined by potentiometric titration using 0.1N HCl using an open cell system named ATT-05 based on DOE (1994). Alkalinity values are reported in units of µmol/kg.

At the start of each batch, seawater was run through the system to condition the instruments. Once the system appeared to be working well, certified reference material (CRM) was run to confirm proper operation. The concentration of acid was chosen to give the assigned alkalinity values for CRM. 90mL of seawater was transferred from the sample bottle to a glass beaker by using a glass syringe equipped with a stopper to take a same volume of sample water every time. An initial amount (ranged from 1.7 to 2.0 mL) of the HCl was added to the seawater and then 0.07 ml aliquots of acid were added to the seawater until a pH of below 3.6 was obtained. The sample was then stirred for 600 seconds to degas CO_2, the reading of pH (EMF) and addition of 0.07 mL of acid were repeated until a final pH of below 2.995 was reached.

A plot of total alkalinity measurements vs. CTD-salinity or CTD-depth was made simultaneously during analysis, and samples that seemed unusual in the plot were re-analyzed. Drift throughout the day was monitored by checking the values of replicate analysis of seawater and/or CRM.

Issues

After October 2nd, more data were found to be questionable in the salinity-alkalinity plot and more samples had to be reanalyzed. Suspecting that the electrode had gone bad, it was replaced. Not much improvement was seen for two days, so the electrode was returned to the original one. Since then, data looked better and stable.

However, CRM value had become ~2 to 6 µmol/kg lower than the assigned value. Re-analysis of samples measured the day before did not show such a change. Comparison of deep waters analyzed before and after the electrode replacements did not show corresponding decrease as well. Therefore, no corrections were applied for this matter.

Stations

10/2-4 (batch 18-20) unstable, more reanalysis made: CB6, CB4, CB2, CB2a
10/4-5 (batch 21-22) electrode changed to “Metrohm”: CB2a, BL8, BL6, BL4, BL3, BL2, BL1
10/6 (batch 23-27) electrode changed to the original “Red rod”, low CRM: BL2, BL1, StnA, CB22, CB27, CB29, MK6, CB28b, MK4, MK3, MK2, MK1, CB28aa

Precision, Standards, and Blanks

Table 4. Water Sample Precision

Chemistry Sample	Precision (s_p)	Units	Number of Replicates (*n*)	Minimum Range	Maximum Range
Alkalinity	1.76	µmol/kg	62	1758	2307

The accuracy of the alkalinity analysis was assured by daily analysis of certified reference material (batch #203, concentration of S=33.464, alkalinity=2214.54 µmol/kg; DOE 1994; Dickson 2001; Dickson et al. 2003) supplied by Andrew Dickson (Scripps Institute of Oceanography, San Diego, USA). Precision is given by the pooled standard deviation (s_p) of sample duplicates and was 1.76µmol/kg, where n = 62 pairs.

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4.2.3 Stable isotope of dissolved inorganic carbon ($\boldsymbol{\delta}^{13}$C-DIC)

Zhangxian Ouyang (University of Delaware)
P.I.: Wei-Jun Cai (University of Delaware)

Overview

To better understand how acidified-PWW transporting from the Chukchi/Beaufort shelves to the adjacent Canada Basin accelerates the subsurface ocean acidification associated with anthropogenic carbon storage, we collected data of stable isotopes (δ^{13}C-DIC) in addition to the routine survey of biogeochemistry (DIC, total alkalinity (TA), dissolved oxygen (DO), and nutrients) during the BGOS/JIOS Cruise from Sept 12 to Oct 12, 2023. Such new observations will serve as a useful tool to identify and distinguish the contributions of dissolved inorganic carbon (DIC) to PWW from air-sea gas exchange and organic matter remineralization. It will also provide more direct evidence that the remineralization of organic matter in the bottom water of the Chukchi/Beaufort Seas mainly contributes high DIC to PWW in the Canada Basin, and hence strengthened ocean acidification. In addition, we will also gain more insight from the stable isotopic samples collected during this cruise on seasonal variation of oceanic carbonate chemistry, especially for the late growing season. Finally, observations of δ^{13}C-DIC in 2023 will provide a baseline study for monitoring the long-term trends of anthropogenic carbon storage in the western Arctic Ocean.

Sampling

The water samples of (δ13C-DIC) were collected on board the *CCGS Louis S. St-Laurent* (LSSL) from September 15 to October 8, 2023, during the BGOS/JOIS mission in the Canada Basin. A total of 861 samples were collected from 47 stations.

The sampling procedure is following DOE, (1994). All samples were collected from Niskin bottles into 125 mL and 250 mL borosilicate glass bottles and preserved with 50 µL and 100 µL $HgCl_2$, respectively. Briefly, the sampling tube was connected to the spigot of the Niskin bottle and, by holding the tube above the spigot, was rinsed by flowing approximately one tube volume of sea water through the tube. Any trapped air bubbles were removed by tapping or squeezing the tube. The bottle was filled smoothly from the bottom (tubing touching the bottom of the bottle) and the bottle overflowed by two times its volume. The tubing was withdrawn to the neck and the spigot valve closed or the flow in the tubing squeezed off before the tubing was removed from the bottle. 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. Seal the bottle gas-tight by applying grease around the ground glass stopper, then inserting the stopper completely, and twisting the stopper to squeeze the air out of the grease to make a good seal. Finally, use a rubber band and a clamp to positively reinforce closure, then invert the bottle several times to disperse the mercuric chloride solution thoroughly. All samples were stored in a cool, dark, location.

Analysis

All samples will be shipped back to University of Delaware after the cruise. δ^{13}C-DIC will be analyzed using a Picarro-based δ^{13}C-DIC analyzer (Su et al., 2019; Deng et al. 2022).

Precision and Accuracy

Of the 861 unique samples collected during the course of this survey, 40 (5%) were collected in duplicate. The precision of analysis will be evaluated by the results of the replicated samples. Based on previous practices both in the lab and on the sea, the analytical precision is better than ±0.05‰. We will ensure the accuracy of the analysis by calibrating against 2-3 $NaHCO_3$ internal standard solutions and comparing with selected samples analyzed at the UC Davis Stable Isotope Facility. DIC Certified Reference Materials (CRMs) will also be used for quality control purposes.

References

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.

Su, J., Cai, W.J., Hussain, N., Brodeur, J., Chen, B. and Huang, K., 2019. Simultaneous determination of dissolved inorganic carbon (DIC) concentration and stable isotope (δ^{13}C-DIC) by Cavity Ring-Down Spectroscopy: Application to study carbonate dynamics in the Chesapeake Bay. *Marine Chemistry*, *215*, p.103689.

Deng, X., Li, Q., Su, J., Liu, C.Y., Atekwana, E. and Cai, W.J., 2022. Performance evaluations and applications of a δ^{13}C-DIC analyzer in seawater and estuarine waters. *Science of The Total Environment*, *833*, p.155013.

4.2.4 Fluorescent Dissolved Organic Matter Sampling

Justin Forget (USherbrooke)
Louis Criqui (USherbrooke)
P.I.: Céline Guéguen(USherbrooke)

Overview

Fluorescent Dissolved Organic Matter (FDOM) samples were collected for Céline Guéguen (USherbrooke), following the protocol given below. A total of 531 FDOM samples were collected at 45 stations and 46 from the underway seawater loop system. In addition there were 20 DOM samples from the rosette and 6 Lignin-Phenol samples from the underway system. Samples were collected between September 14th and October 08th, 2023 on board the CCGS Louis S. St-Laurent during the Joint Ocean Ice Study-Beaufort Gyre Observational System 2022.

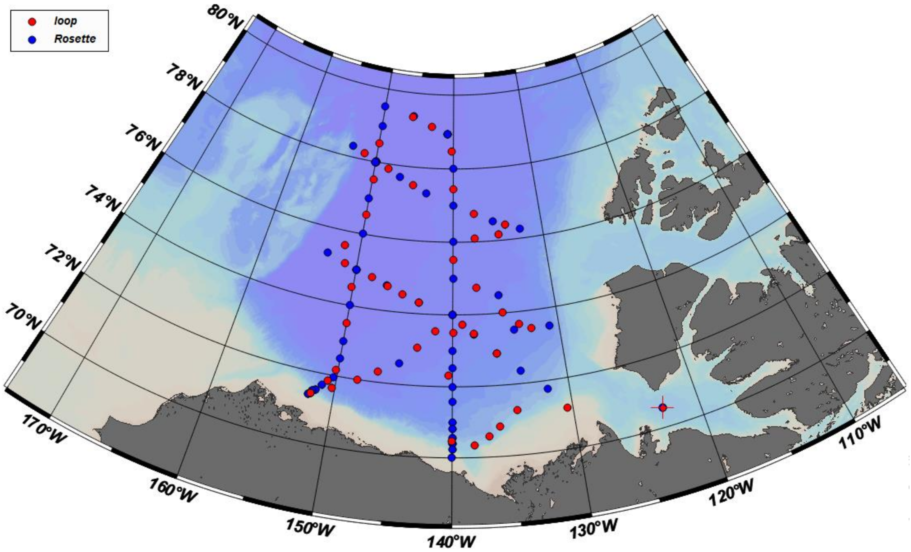


Figure 13: Map of the Canada Basin representing the sampling sites of the CTD stations (blue) and the loop samples (red).

Rosette Casts Samples

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 2 depths (Surface 5m and 33.1) at CB8, CB17, CB15, CB16, CB16N, I2-2023, CB11.5, CB21, and CB27, for a total of 18 samples. The samples were acidified and solid phase extracted immediately after collection.

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.

Underway Samples and Under Ice Samples

Three (3) 20L water samples were collected from the underway system for lignin phenol analysis before arriving at CB19, CB31b, and CB22. Three additional samples were collected under the ice at each of three ice stations. The samples were acidified and solid phase extracted immediately after collection.

Forty six (46) FDOM samples were collected from the underway system while the ship was steaming, 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.

Analysis and 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.

4.2.5 Barium

Justin Forget (USherbrooke)
Louis Criqui (USherbrooke)
P.I.: Celine Gueguen (USherbrooke)

Overview

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

204 barium samples were collected along the BL and 140W lines, typically from 0 to 200 m depth. Barium samples were drawn from the Niskin and filtered at 0.3um 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 ^{135}Ba-enriched solution (Oak Ridge National Laboratories) and diluted with 10 mL of 1% HNO_3.

References

Falkner, K.K., R.W. MacDonald, E.C. Carmack, and T. Weingartner (1994) The potential of barium as a tracer of Arctic water masses, *in* The Polar Oceans and Their Role in Shaping the Global Environment: The Nansen Centennial Volume, AGU Geophys. Monograph Series, edited by O.M. Johannessen, R.D. Muench, and J.E. Overland, pp. 63-76, AGU Books, Washington, DC (doi: 10.1029/GM085p0063)

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)

4.2.6 Chlorophyll-a

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

Onboard Sampling and Filtering

Chlorophyll-*a* was sampled from the upper 200m at all geochemistry stations (294 samples, all in replicate). In addition, 18 loop samples were taken in replicate. 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. Each sample took about 10 to 15 minutes to filter. Filters were folded in half in another half section of filter (90mm) being used as a blotter, wrapped in aluminum foil and stored at -80°C for later analysis onshore at IOS. Samples were divided into two bags, one for the primary "A" samples, and one for the replicate "B" samples.

Chlorophyll-a samples were filtered by Ashley Arroyo, Annika Margevich, Sam De Abreu, Zhangxian Ouyang, and Sarah Zimmermann.

Blanks were prepared for each box of filters, substituting artificial seawater (500mL) from a graduated cylinder for the sample bottles of seawater. Handling and processing of the filter was performed as for a sample.

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 deionized 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 analysed 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).

References

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.

4.2.7 Bacteria sample collection

Justin Forget (USherbrooke),
Louis Criqui (USherbrooke)
P.I. : Céline Guéguen (USherbrooke)

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 taken for Celine Gueguen (USherbrooke), David Walsh (UConcordia) and in past years for Connie Lovejoy (ULaval) and Bill Li (DFO-BIO). Onboard, samples were collected and processed alternately by Justin Forget (USherbrooke) and Louis Criqui (USherbrooke).

The sample depths were 5, 20, Chl max, S=32.3, S= 33.1, S=34.4, T max, 1000, Bottom.

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 labelled 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

None

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

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

Overview

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.

Sampling

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, secured with parafilm, and the vials inverted for storage. Samples will be analyzed with a 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: 24 mL glass bottles with 20-400 Phenolic PTFE/14BRubber caps (VWR # 14230-830).

4.2.9 Nutrients

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

Sampling

Unfiltered 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 1074 samples were collected, of which 244 were 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: 17 samples from the seawater loop system were collected in duplicate, and analyzed within 12 hours of collection. Additional loop samples from Dolphin and Union Strait were brought back to IOS for analysis as they were collected after the analysis equipment was packed.

A total of 38 samples were re-run onboard, after QA/QC processing to ensure the feature observed was real or not, and 88 samples from the BL line were re-run to make the data more robust for the unusual features. 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 (see table below for certified values). The primary stock standards were prepared in Milli-Q water, using pre-weighted 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 24.06 µM, SiO_4 : 0.00 to 48.47 µM and PO_4: 0.000 to 2.416µM).

For quality assurance and quality control purposes, Kanso certified reference material (CRM), lot CO and CR, deep water reference (DWR), medium check (2^{nd} 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.

Table 5. KANSO CRM values

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#9, at 3592m depth (sample #189). 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 April2023), 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 6. Water Sample Precision, L.o.D. and accuracy summary.

Chemistry Sample	Units	Min Range	Max 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	0.04	225	9	98.4-100.3
Silicate (fresh)	$mmol/m^3$	2.34	43.27	0.04	0.03	220	14	97.3-99.2
Phosphate (fresh)	$mmol/m^3$	0.372	2.022	0.015	0.005	223	10	97.9-100.2

The accuracy of nutrient analysis was assured by daily analysis of Kanso CRM for nutrients in Seawater (RMNS) (batch CO, 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.

A total of 85 each Kanso certified reference material Lot CO and CR were analyzed to ensure accuracy.

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

On the last day of analysis, phosphate showed a significant upward drift, more than usual. However, the AACE software corrected the data appropriately as seen in low %CV of the check samples (<1% CV).

Figure 44. Nutrients analysis on the AA3. Photo by Fred Marin, 2019, but similar set up for 2023.

4.2.10 Salinity

Analyst: Chris Clarke, Paige Hagel, Chloe Immonen, Sarah Sedlock (DFO-IOS)
P.I.: Bill Williams (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 samples were from the intended depth. 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. Salinity bottles and inserts were rinsed 3 times with sample water from the Niskin 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 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. The majority of standard water used was batch P165, however, the last calibration was performed using P166.

OSIL batch P165, expiry 15 April, 2024, K_{15} Value = 0.99986, Salinity = 34.994 PSU
OSIL batch P166, expiry 6 April, 2025, K_{15} Value = 0.99987, Salinity = 34.995 PSU

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 a 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:

1. DWR-CB50: CB50, Cast 6, Niskin 1, Sample 117, 2921m (CTD S1,S2: 34.9545,34.954)
2. DWR-CB11.5: CB11.5, Cast 18, Niskin 1 & 2, Sample 405 & 406, 3790m (CTD S1,S2: 34.955634.9554) WS S1 and S2: 34.9547 34.9533
3. DWR-CB6: CB6, Cast 30, Niskin 1 & 2, Sample 693 & 694, 3750m 3790m (CTD S1,S2: 34.9557, 34.9552)

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 7. Salinity Precision for Niskin samples collected on 2023-013. The L.o.D. represents the Limit of Detection, the s_p represents the pooled standard deviation of duplicates for precision.

Chemistry Sample	Units	Min Range	Max Range	L.o.D	Precision (s_p)	Number of Replicates (*n*)	Outliers removed
Salinity (all samples, all depths)	psu	24.2808	34.9586	N/A	0.0077	103	2

Table 8. Salinity Precision for TSG samples collected on 2023-013

Chemistry Sample	Units	Min Range	Max Range	L.o.D	Precision (s_p)	Number of Replicates (*n*)	Outliers removed
Salinity (all samples, all depths)	psu	24.2590	29.3443	N/A	Use Rosette value		

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 (0.008 psu) based on the expected variability of the auto-salinometer (0.002 psu).

Table 9. Salinity deepwater reference values. The Standard Deviation (STD) indicates the variability throughout the expedition.

<table>
<tr><th>Sample</th><th>Mean (psu)</th><th>STD</th><th>Expected Arctic Ocean Deep Water salinity</th><th>n</th></tr>
<tr><td>DWR-CB50 (#117)</td><td>34.9439</td><td>0.0022</td><td>CTD = 34.954</td><td>21</td></tr>
<tr><td>DWR-CB11.5 (#405, #406)</td><td>34.9540</td><td>0.0012</td><td rowspan="3">34.956 STD +/-0.001</td><td>41</td></tr>
<tr><td>DWR-CB6 Bot2 (#693)</td><td>34.9549</td><td>0.0011</td><td>34</td></tr>
<tr><td>DWR-CB6 Bot1 (#694)</td><td>34.9548</td><td>0.0006</td><td>22</td></tr>
</table>

Issues

Auto-salinometer had been serviced by the manufacturer before this trip.

Flow rate was slow. Sep. 21st adjusted the bung and added silicone seal to tubing to seal connections and improve flowrate.

Fluctuating and spikes in standby number. Stabilized during the trip. Reason unknown.

Bubbles on cells. Removed with regular cleaning but would come back.

Software error message:

As in 2021 and 2022, 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.

4.2.11 Iodine-129 & Uranium-236

Samples collected by CTD watch.
P.I.: Nuria Casacuberta Arola, Annabel Payne (ETH Zurich)

Overview

Measurements of ^{129}I and ^{236}U provide information about the spread and transit times of Atlantic-origin water labelled 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. Cubitainer caps were secured with parafilm and packed into cardboard boxes. All samples were packed into a pallet container and shipped to ETH Zurich, Switzerland, for analysis.
In total, 56 samples were collected at 4 stations were collected for the analysis of ^{129}I and ^{236}U.

4.2.12 Carbon-14

Samples collected by Sarah Zimmermann, (DFO-IOS)
P.I.: Nuria Casacuberta Arola, Annabel Payne (ETH Zurich)

Overview

Measurements of ^{14}C provide information about the ventilation times of deep and bottom waters in the Canada Basin. This isotope is 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 concentration decreases due to its radioactive decay with half-lives of 5730 yrs (^{14}C). This allows calculating the time since the water sample was last in contact with the atmosphere, referred to as the ventilation time.

Sampling

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.. After 30min of warming, sample bottles with bulging stoppers due to expanding seawater were decanted with a syringe through the rubber stopper. About 100uL of saturated mercuric chloride was added with a syringe after sampling to avoid any biological activity affecting the carbon isotopic signature. The box of samples were packed into a pallet container with the ^{129}I and ^{236}U cubitainers, and shipped to ETH Zurich, Switzerland, for analysis.

^{14}C was collected at two stations, CB4 and CB9 for a total of 40 samples.

Issues

Some of the bottles had small bubbles around the sides of the rubber stopper. These seemed to show up when the $HgCl_2$ was added and the excess water from pressure buildup was released. Perhaps during initial capping, air was trapped and then it was drawn further down the side of the stopper when the pressure was released.

Figure 15: Small bubbles accumulated around stopper.

After further warming (1 day), the caps were again bulging indicating more water needed to be released. However, before this was done, the case of C14 samples was accidently stored near a heater. It was moved after it was realized how warm the side of the box was getting. After cooling back to ~18C, while removing the excess water from the samples (about 0.1mL from most), it was noted the four bottles that had been closest to heater had been compromised (samples 752, 755, 757 and 762). These four had no extra pressure and it appears at least two of them had a large bubble under the cap indicative of leaking. The fifth sample 749 on the same side of the box just had a small amount of excess water so may also have leaked.

Sample number:

749	Less than 0.1mL of excess water on the second release
752	No excess water, salt on outside of bottle neck
755	No excess water, large bubble under cap
757	No excess water
762	No excess water, large bubble under cap

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

Sara Palestini (Concordia University)
P.I.: David Walsh (Concordia University)

Overview

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 starting at AG5. The JOIS cruise track followed a general path North following transect 140 W and proceeded west then south down transect 150 W. Beaufort Sea.

Water column samples were collected at a total of 22 stations (Figure 1) to cover a range of previously studied stations (between 2012-2022). The cruise proceeded in the order: AG5, CB31b, CB50, CB40, CB17, PP7, CB15, CB16, CB16N, CB11, CB9, CB10, CB8, CB7, CB4, CB3, CB2, BL8, StaA, CB21, 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, CB17, PP7, CB15, CB16, CB16N, CB11, CB9, CB8, CB4, CB21. Samples were collected a 7 depths (all previously mentioned except PSU 33.1) at CB10. Samples were collected at 2 depths, surface water (5m), and SCM (subsurface chlorophyll maximum) at CB7, CB3, CB2, BL8, StaA, CB27, and CB28b.

Stations AG5, CB4, CB9, CB16N, and CB21 were designated as Meta stations, where a greater volume of water was collected for DNA/RNA extractions. At all other stations water was collected according to what could be salvaged save surface water (5m), and SCM (subsurface chlorophyll maximum) from which 7L of water was taken every time.

Seawater filtration

Water was filtered first through a 3µm filter and then through a 0.22 µm filter. The first filter collected organisms greater than 3µm and that which filtered through was collected by the 0.22 µm filter. When all water had been filtered through the apparatus they were contained and preserved with RNAlater® solution and then stored at -80°C.

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.

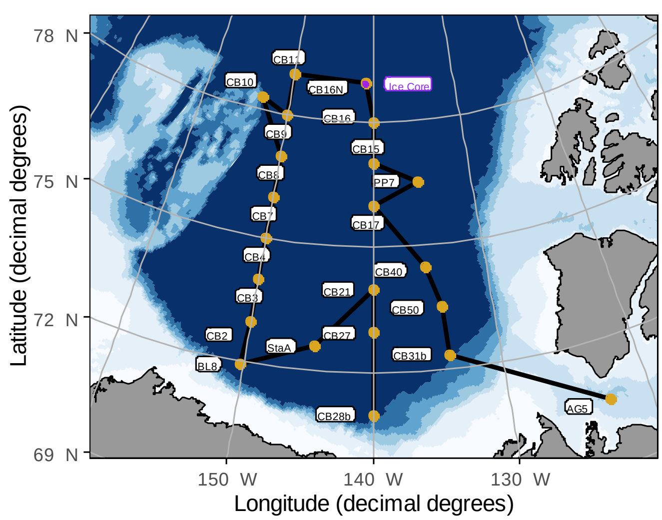


Figure 16. Map depicting stations where water samples for filtration were taken (gold). The station where the Ice Core was taken is in purple (in vicinity of CB16N). The cruise track is shown as a black line beginning at AG5 and ending at CB28B.

Additional Activities

Isolation Culture

At our most Northern and Southern Meta Stations (CB21, CB16N) 1.5mL of seawater was collected from surface water (5m), 20m, SCM (subsurface chlorophyll maximum), Pacific Winter Water (salinity of 33.1PSU) and the temperature maximum. Following this, 375µl of a 50% V/V glycerol/filter sterilized seawater solution was added to each vial and gently mixed; they were then stored in a cooling container at -80˚C.

Ice Core Collection and Filtering

This year an ice core was collected from an ice floe at (78.927049N, - 140.8723W). Before the day of collection two bags were prepared to receive portions of the ice core by rinsing with 0.1 M HCl and rinsing again with three times the volume of MilliQ water. The ice core was retrieved using a corer (Kovacs 4" plastic barrel). The ice core was 100 cm long and was sectioned into equal 50 cm segments one representing the top of the core and one the bottom which touched the sea. The ice was melted over the course of 12 hrs and amounted to 2L of top water and 2L of bottom water. It was then filtered following the methods discussed for filtering seawater above and preserved as per the same protocol.

4.3 Moorings and Buoys

On board: Jeff O'Brien, Jim Ryder, Eric Hutt and Tim McDonough (WHOI), Cory Beatty (U. Montana), and Mary-Louise Timmermans (Yale)

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

4.3.1 Summary

2023 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 2022) 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. One ITP was recovered, and one TOP was recovered. Dispatches (coordinated by Ashley Arroyo, Yale) were sent daily and posted on the BGOS website. A summary of moorings and buoys recovered and deployed are listed in Tables 1 and 2, and descriptions of each activity are given below.

Table 10: BGOS mooring recoveries and deployments from CCGS Louis S. St-Laurent 2023. The mooring anchor was ranged on in the pre-recovery survey, but it was deemed not necessary to range on the acoustic pinger near the top of the mooring because all mooring recovery and deployments were in completely open water.

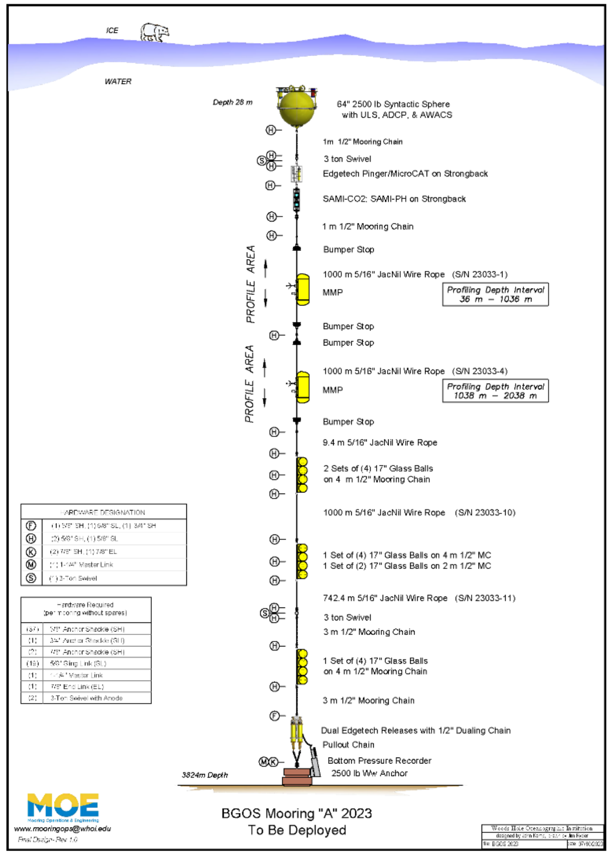
Mooring	Surveyed location (anchor*)	2023 Recovery	2023 Deployment	2023 Location (drop position)	Deploy bottom depth (m)
A	74 59.381 N 149 57.853 W *112 m from 2022 drop location	30 Sept. 16:29 UTC	2 Oct. 22:40 UTC	74 59.956 N 149 59.629 W	3825
B	78 00.894 N 150 03.101 W *435 m from drop	27 Sept. 15:49 UTC	28 Sept. 21:47 UTC	78 00.001 N 150 00.010 W	3822
D	74 00.103 N 140 03.191 W *240 m from drop	5 Oct. 15:48 UTC	6 Oct. 22:52 UTC	73 59.993 N 140 02.897 W	3527

Table 11: BGOS ice and open-water deployments/recoveries from CCGS Louis S. St-Laurent 2023. IBO = Ice Based Observatory; OW = Open Water deployment

Event	Buoy system	Date (2023)	Location	Ice thickness (m)
#1 OW 1	ITP 141	Sept. 18 21:06 UTC	72 54.313 N 135 59.115 W	N/A
#2 Recovery 1	ITP 130	Sept. 19 17:23 local	73 42.000 N 134 00.000 W	N/A (open water)
#3 IBO 1	ITP 138 TOP 011 AOFB 55, SIMB 2023 #6	Sept. 23 23:40 UTC	78 57.9826 N 140 48.4792 W	0.42 – 0.80
#4 IBO 2	TOP 008	Sept. 24 19:07 UTC	79 21.609 N 145 27.916 W	0.35
#5 IBO 3	ITP 139 TOP 009, SIMB 2023 #7	Sept. 25 20:26 UTC	79 24.120 N 149 58.310 W	0.50 – 1.2
# 6 OW 2	TOP 010	Oct. 3 20:43 UTC	73 02.930 N 148 57.647 W	N/A
#7 Recovery 2	TOP 004	Oct. 7 20:44 UTC	72 12.100 N 140 25.020 W	N/A (open water)

4.3.2 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; 2003-2023), Mooring B (78N, 150W; 2003-2023), Mooring C (77N, 140W; 2003-2008), and Mooring D (74N, 140W; 2005-2023). 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 about 30 m below the sea surface (see e.g., the schematic diagram [right] for Mooring A, deployed in 2023).



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 2023) 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). Mooring D includes a fluorometer on the same housing as the SAMI instruments (Celine Gueguen, University of Sherbrooke).

The vertically profiling MMPs sample conductivity-temperature-depth (CTD) and velocities in the water column from around 40-m depth to about 2050-m depth, making 2 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 on the releases at the bottom of each mooring. In 2023, all mooring operations were done in 0%

ice cover and it was never deemed necessary to additionally range on the ELCAT acoustic pinger located just below each surface float. Recoveries in 2023 were all in 1-to-2-meter swell and the LSSL's rigid hull inflatable was used each time to hook the surface float (this method was preferred by the crew over the man basket for the sea states). 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. All units returned high quality data. The only record that was incomplete was from the MicroCAT on mooring A; data were returned through January 19, 2023, after which time the batteries expired. There were likely defective batteries in the new batch that was loaded at deployment. We are going to bring a battery load testing device in the future, and test each individual new cell before loading into the instruments. All other sensors on the moorings returned full records. Information on the SAMIs can be found in a separate data report.

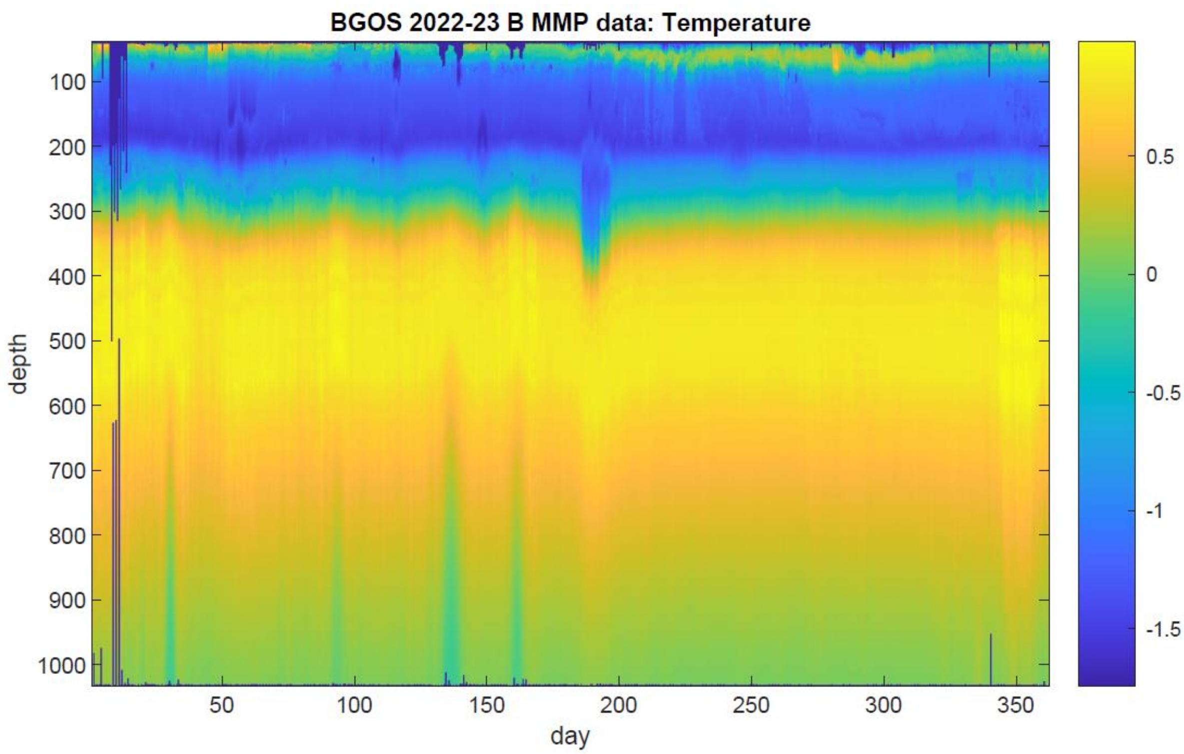


Figure 17. Data from the shallow MMP on BGOS Mooring B 2022-2023. Time-depth (m) section of temperature (ºC) over the course of the year-long deployment showing the rich variety of eddies and warm water layers.

4.3.3 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 2023 expedition:

1. Woods Hole Oceanographic Institution Ice-Tethered Profilers (ITPs), primarily sampling temperature, salinity, and pressure from ~5m to 760m depth (https://www2.whoi.edu/site/itp/)

2. WHOI Tethered Ocean Profilers (TOP), sampling temperature, salinity, & pressure from the ice-ocean interface to 200m depth (https://www2.whoi.edu/site/itp/)

3. US Army CRREL Seasonal Ice Mass Balance Buoy (SIMB), sampling ice and snow thickness, temperature, and atmospheric pressure (https://www.cryosphereinnovation.com/)

4. Naval Postgraduate School Arctic Ocean Flux Buoy (AOFB), sampling turbulent ocean fluxes near the ice-ocean interface and met data (https://www.oc.nps.edu/~stanton/fluxbuoy/)

A total of three ITPs were deployed during the 2023 expedition, ITP numbers 141, 138, and 139 (in order of deployment date). ITP 141 is returning 4 one-way profiles per day, sampling ocean temperature and salinity (conductivity). Two of the systems (ITPs 138 and 139) are returning 2 one-way profiles per day and are configured to additionally sample dissolved oxygen; each of these has a fixed-depth (5 m) SAMI pCO_2 with ODO and PAR sensor to sample upper ocean chemistry (CO_2, pH) and chlorophyll fluorescence. Four TOPs were deployed: TOP008 & TOP009 (each with Solumetrics CTD sensors), TOP010 (RBR sensor) and TOP011 (D2 sensor). Two SIMBs (Dartmouth 2023 #6 & #7) and 1 AOFB (55) (**see Table 11**). ITP and TOP data are made available in real time at www2.whoi.edu/site/itp. As of this writing (October 10, 2023), all buoys deployed in sea ice are returning good profiles. One of the systems (ITP 141) deployed in open water is returning good profiles, while the profiling unit of TOP010 is presently not communicating with the surface package. One ITP (ITP 130) and one TOP (TOP004) were recovered.

Buoy deployment/recoveries:

#1, OW 1, September 18, 2023, ~ 73.0N, 136W; air temp.: 2ºC, winds: 20 knots easterly; 0% ice

ITP 141 open water deployment off the CCGS LSSL. *[Times are given as local unless otherwise stated, where UTC = local + 7 hours.]*

At 12:30 pm, the WHOI team began preparing the gear on the deck for the open-water ITP deployment. All the gear was out of the forward hold and deployment operations started at 12:46pm. The profiling unit was in the water at 1:18 pm, and wire payout was complete by 1:26 pm. Communication with the surface package took another 10 minutes and the surface float was released from the ship at 2:06 pm (21:06 UTC). Release location was 72 54.313 N, 135 59.115 W. As of October 10, 2023, the ITP is returning good quality profiles.

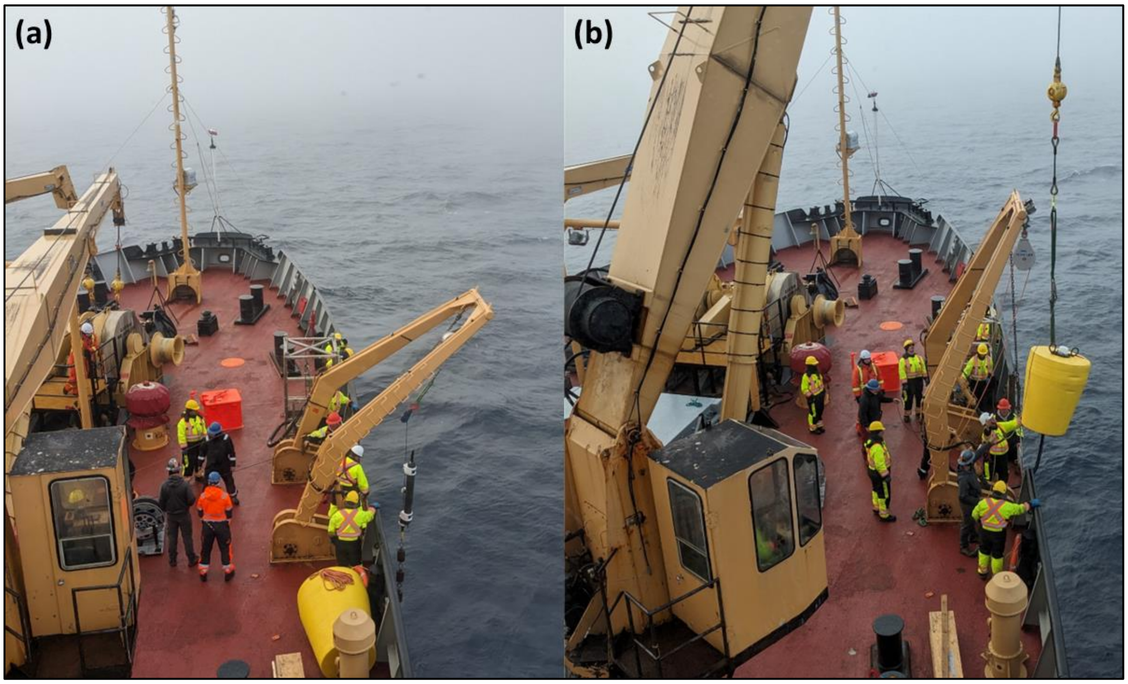


Figure 18. ITP 141 deployment: (a) ITP141 profiling unit and weights suspended over the side of the LSSL near the beginning of the deployment; (b) surface float suspended just before release of the system from the ship.

#2, September 19, 2023, ~ 73.7 N, 134 W; air temp.: 0°C, winds: 2 knots; 0% ice; fog

ITP 130 Recovery

This ITP was deployed from the LSSL during the 2022 expedition and profiled for nearly a year before the profiling unit battery expired. It was still returning GPS positions, drifting approximately along route, providing an opportunity for recovery. With hourly GPS locations, the buoy was located quickly [at 74 40.52N, 134 54.73W], drifting in open water in the fog. The surface float was sitting upright in the water, indicating that the profiling unit and weight were still attached.
At 5:20 pm, the basket was sent over the side and the surface package was hooked. The surface float was no longer secured to the package (a ratchet strap connection had failed).

To prevent the surface float from damaging the profiling unit when it was brought to the surface, the LSSL's rigid-hull inflatable boat was put over the side, so that the surface float could be secured with a strap and picked up separately with the ship's crane. All components of the system were on deck by 7:23 pm, with the profiling unit in good condition, ready for refurbishment and redeployment on a future expedition.

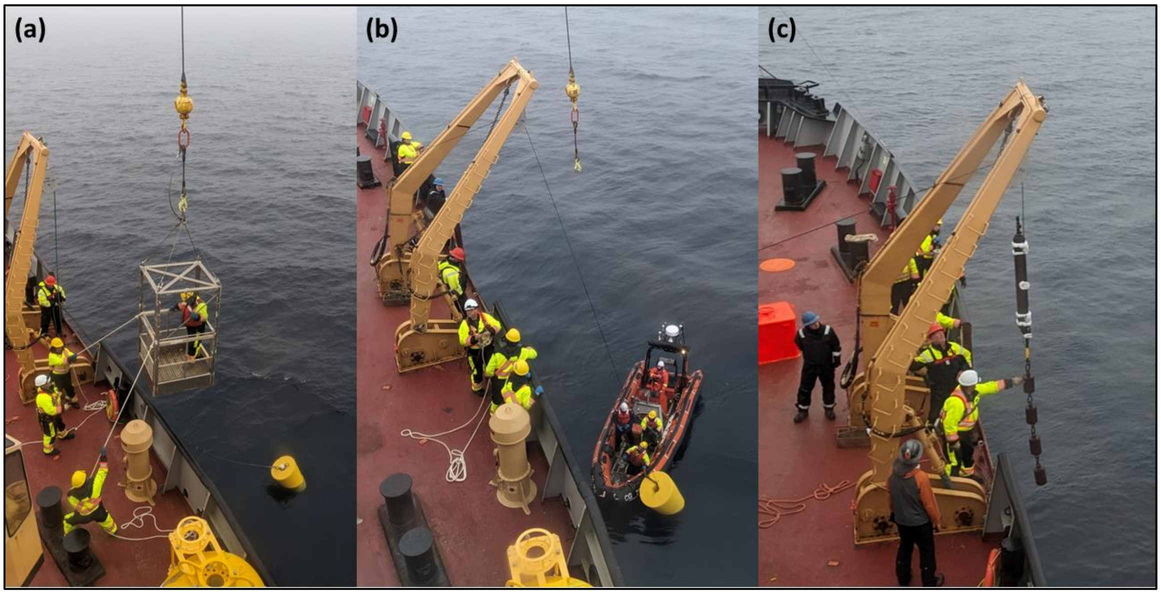


Figure 19. ITP 130 recovery: (a) Preparing to hook the surface package from the man-basket; (b) securing the surface float from the LSSL small boat; (c) bringing the profiling unit and weights on board to complete the recovery.

#3, IBO 1, September 23, 2023, near 79N, 141W; air temperature: -3ºC, winds: 15 knots, o'cast

Four buoys were deployed on a single floe: ITP 138, TOP011, AOFB 55 and SIMB 2023 #6.

The LSSL arrived at a large pan of ice (several km across) around 3:45 am (selected via satellite – MODIS and RADARSAT) at 3:45 am. We circumnavigated the pan to find a suitable spot to park and work off the port side. The working area of the floe was O(1km), free of large ridges, but melt ponds visible as grey patches under the snow covering. The port side was free of ice rubble for landing gear and the gangway.

At 6:30 am Jeff O'Brien and Cory Beatty were lowered over the port side in the man basket to survey. They found the ice to be about 0.5 to 1.9 m thick along a 100 m line running perpendicular from the ship's port side. TOP011 was to be installed closest to the ship (about 25 m away from the hull), with ITP 138 situated for deployment at the far end of the line, and AOFB 55 and SIMB 2023 #6 between. The survey was completed, and the ice team was back on deck at 7:30 am. The variable thickness of the pan suggested regions of rafted floes with melt pockets and regions of single-layer ice (with the latter being optimal for deployment, so some effort was made to locate sites with thinner ice).

After the ice survey, the port gangway was deployed and the port crane was used to sling gear over. The large black AOFB box and components amounted to 2.5 sling loads with the crane. At 11:30 am, all the AOFB gear was on the ice and a 14" hole was drilled for the system. The AOFB was mostly assembled first, then the ITP, the SIMB and the TOP. A substantial amount of slush built up over the day (surface air temperatures remained just below freezing) with a lot of seawater on the ice. During the TOP deployment, about 20 cm of seawater covered the hole which made for less-than-ideal working conditions.
ITP 138 had a dissolved oxygen sensor on the profiling unit and a SAMI system at a fixed depth (about 5 m) on the ITP wire. Chris Clarke (IOS) took a Niskin bottle near-surface water sample for calibration. A Go-Pro camera was put on a 20-foot selfie stick to acquire under-ice video. This revealed a water pocket between two solid pieces of ice about 5 m away from where the AOFB was deployed; this is where initial drill tests indicated 1.8 m thickness and 0.5 m thickness separated laterally by about 10 m. Deployment of the last buoy (TOP011) was complete at 6 pm.

A summary of precise positions at 3:45 pm (22:45 UTC) and ice thicknesses for each of the systems on this IBO is as follows, and the relative buoy positions are shown in the schematic below:

ITP 138, 80 cm thick ice, 78 58.120N, 140 47.657W

SIMB 2023 #6, 42 cm thick ice, 0 cm freeboard, 4 cm snow thickness, 78 58.137N, 140 47.570W

AOFB 55, 0.5 m thick ice, 78 58.132N, 140 47.660W

TOP011, 0.6 m thick ice, 78 58.132N 140 47.581W

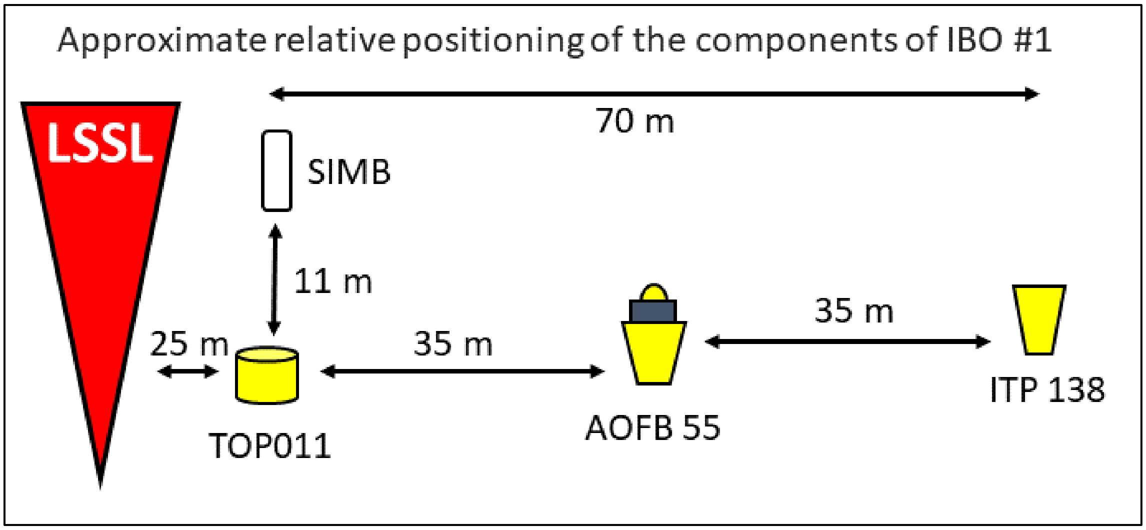


Figure 20. Relative positions of ice buoys at IBO1.

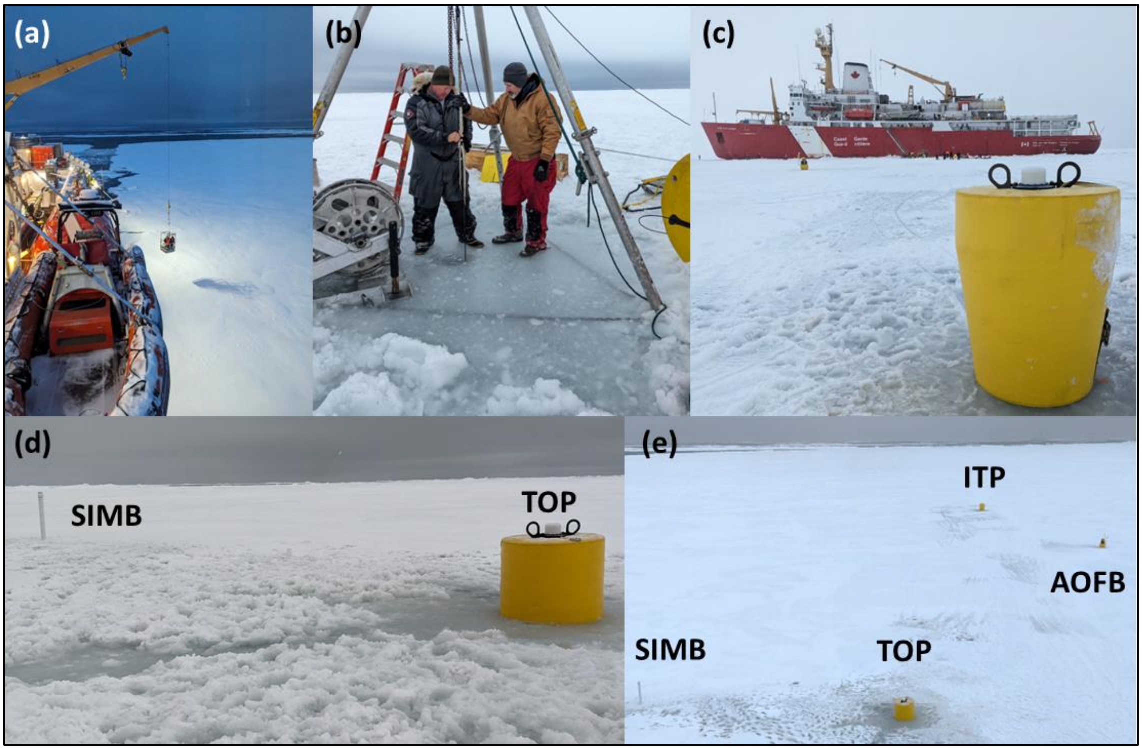


Figure 21. IBO 1 deployment: (a) The man basket going over the port side for the ice survey; (b) After drilling the hole for the TOP deployment; (c) Surface package of the installed ITP; (d) Two components of the installed IBO - the TOP on the right and the SIMB on the left; (e) Components of the IBO as labelled.

#4, IBO 2, September 24, 2023, near 79 N, 145 W; air temperature: -6°C, winds: 22 knots

A possible floe was identified on RADARSAT the previous day and targeted for the ice station. The floe was an approximately coherent large pan, circular in shape. It took two attempts with Captain Duffett on the bridge to nestle the LSSL into the floe on the starboard side with, but a crack prevented the use of the gangway. Gear was craned off and personnel were put on the ice with the man basket. Jeff O'Brien and Cory Beatty first performed a survey, settling on a point about 30 m away from the starboard side, and ship side of a large crack. Ice thickness was 35 cm. Deployment of a single buoy on this floe (TOP008) began at 10 am local and the installation was complete at 12:30 pm. The ice did not crack when we backed out.

TOP008, 1930 UTC, 79 21.609N 145 27.916W, 35 cm ice thickness

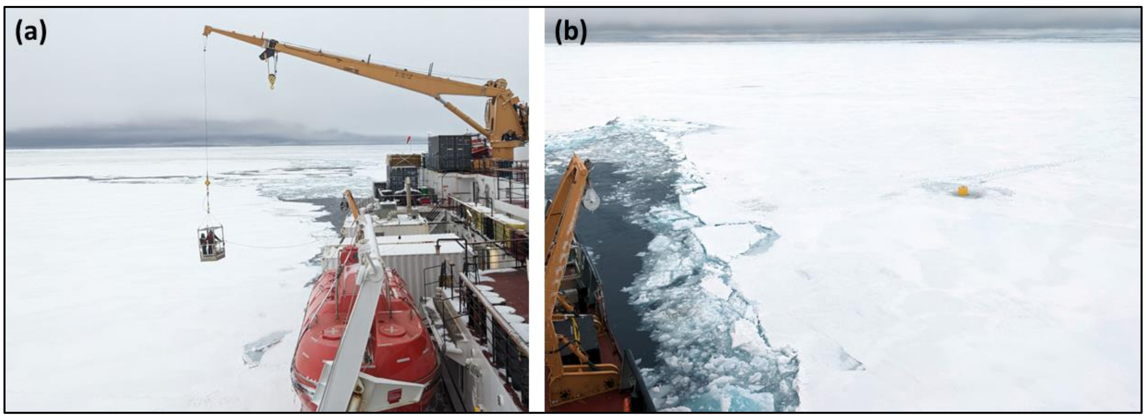


Figure 22. IBO 2 deployment: (a) Man-basket over the side for the buoy team; (b) TOP008 off the starboard bow of the LSSL as the ship backed away after the TOP was installed.

#5, IBO 3, Sept. 25, 2023, near 79N, 150W; air temperature: -6°C, winds: 12 knots, light snow

Three buoys were deployed on a single floe off the starboard side of the ship: ITP 139, TOP009 and SIMB 2023 #7.

A large floe, at least several kilometres across, was identified by RADARSAT the previous day and a way point was set for the ship. At about 4:30 am we were circling the floe to try to nestle in with minimal cracking. After several attempts, and some significant cracking, we were suitably parked at 6:30 am with the best part of the floe for working off the starboard side. There was sufficient room for the gangway between ice rubble at the side of the ship.

At 8:30 am Jeff O'Brien and Cory Beatty went over the side in the man basket and drill tested several sites. Ice thickness was variable and there was significant ridging plus re-frozen melt ponds. Snow cover drifts were about 40-60 cm in places. Ice thickness ranged from 30 cm to 1.2 m.

Sling load operations began at 9:30 am, with all buoys in place by 1:30 pm, and sling loads back onto the ship were complete at 2 pm. Buoys were positioned as depicted in the schematic below. GoPro video was acquired through nearby drill holes of the ITP/SAMI, TOP and SIMB.

A summary of precise positions at 1:26 pm local and ice thicknesses for each of the systems on this IBO is as follows, and the relative buoy positioning is shown in the schematic below:

ITP 139 (with DO sensor & SAMI at fixed depth), 1.2 m thick ice, 79 24.120N, 139 58.310W

SIMB Dartmouth 2023 #7, 67 cm ice, 1.5 cm freeboard, 5 cm snow, 79 24.087N, 149 58.554W

TOP009, 0.5 m thick ice, 79 24.082N, 149 58.628W

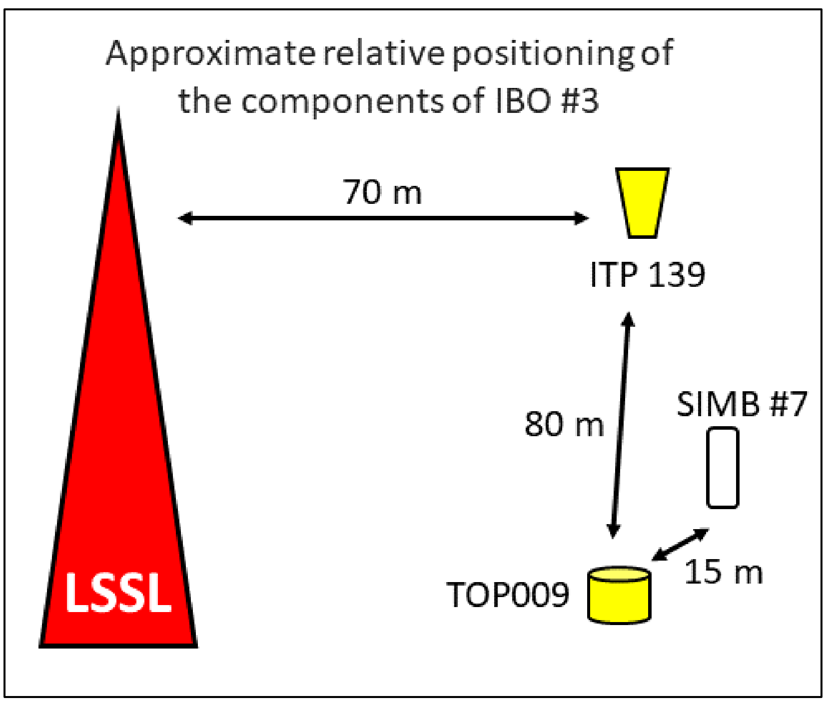


Figure 23. Relative positions of ice buoys at IBO3.

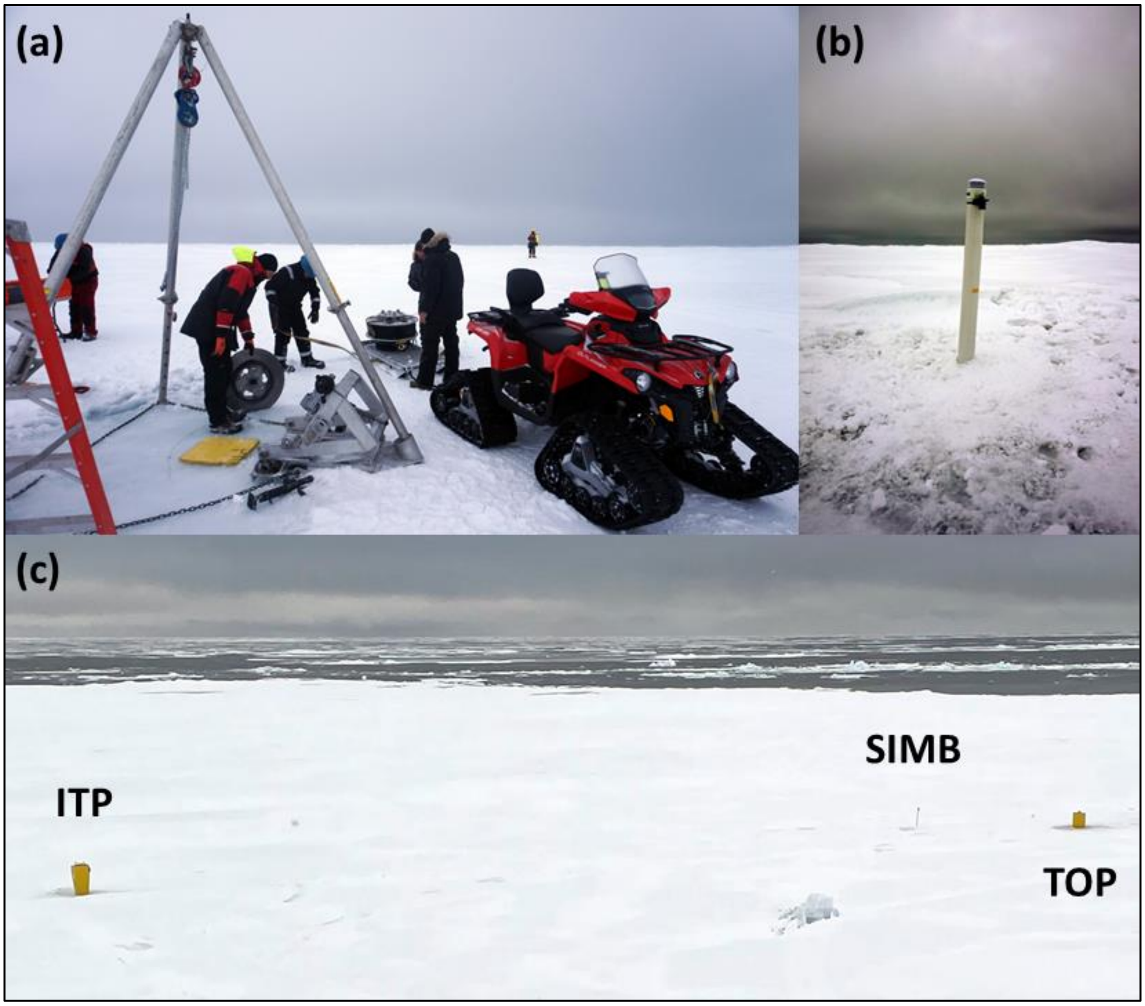


Figure 24. IBO 3 deployment: (a) Setting up to deploy the TOP (the LSSL's all-terrain vehicle proved to be invaluable for hauling gear from the ship to the buoy deployment sites); (b) The SIMB installed; (c) IBO installed.

#6, OW 2, October 3, 2023, ~73N, 150W; air temp.: 1 ºC, winds: 8 kn, o'cast, snow squalls, 0% ice

TOP010 open water deployment; this was the second TOP to be deployed in open water (TOP007 in 2022 was the first).

At 12:25 pm, the team prepared the gear on deck, and the anchor for the 200 m deployment was over the side at 12:47 pm. At the end of the deployment, no communications were done (unlike for in-ice deployments) given the risk of holding the system (including the grounding pole) in the water adjacent to the ship during a communications sequence and lifting it out again to remove the connection.

TOP010 was released from the ship at 1:43 pm, at 73 02.93N, 149 57.65W. The surface float maintained an upright position in about 1 m swell.

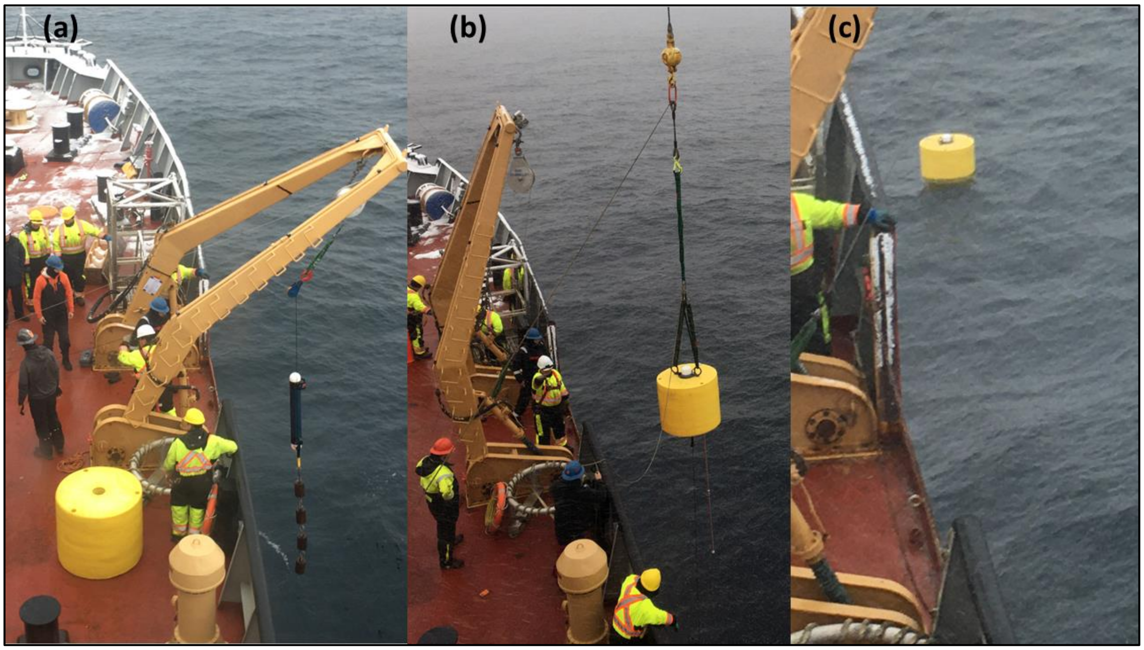


Figure 25. TOP010 deployment: (a) TOP profiling unit and weights suspended over the side of the LSSL during the open water deployment; (b) TOP surface float with grounding pole suspended over the side; (c) TOP surface float after release from the ship.

#7, Recovery 2, October 7, 2023, near 72N, 140W; air temp.: -1 ºC, winds: 15-20 kt, 0% ice

The profiling unit of TOP004 expired its battery and had stopped sending profiles after January 10, 2023, after acquiring ~5900 temperature profiles. The system was deployed on the same ice floe as ITP 122, but the buoys had separated and TOP004 was drifting such that the LSSL only had to make a 4-mile deviation from the 140W line to locate it for recovery. The TOP was configured to report GPS positions every hour, so locating the buoy was easy, and it was spotted floating at 12:32 pm. Swell was 1-2 m and the rigid-hull inflatable boat was deployed to hook the top ring on the surface package. Recovery was complete by 1:44 pm local time.

All components were still on the system and can be refurbished for redeployment. The grounding pole had sheared off at about 30 cm below the base of the buoy. Scratch marks and scrapes out of the surface float indicated that a polar bear had visited. The white end cap at the top of the profile unit was significantly dented, and it is unclear whether this was a result of ice or repeated contact with the grounding pole.
TOP004 recovery position: 72 12.100 N, 140 25.020 W

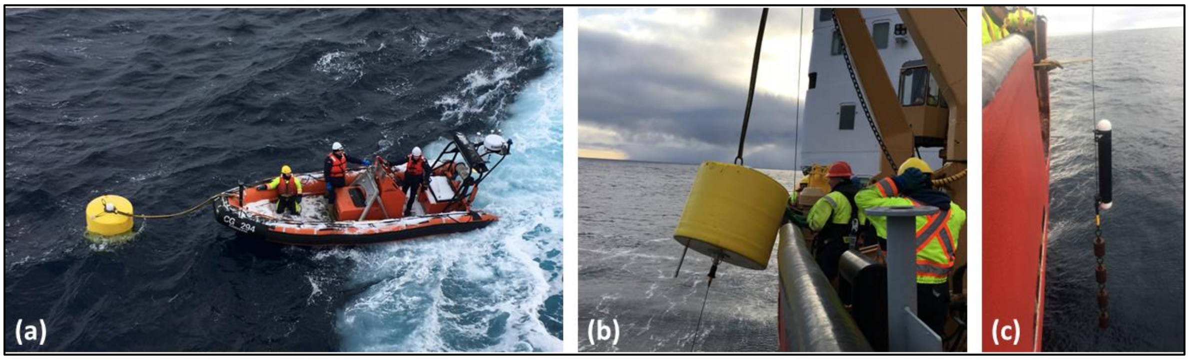


Figure 26. TOP004 recovery: (a) TOP surface package is hooked by the inflatable boat; (b) TOP surface float with grounding pole (left) is brought on board; (c) TOP profiling unit and anchor weights are recovered.

4.3.4 Outreach

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

Table 12. BGOS Project Websites

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

4.4 Sea surface pCO_2, pH, and dissolved O_2

Cory Beatty (University of Montana)
P.I.: Mike DeGrandpre (University of Montana)

4.4.1 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 2023, a fluorescence sensor was also deployed on Mooring D, in collaboration with Céline Guéguen (University of Sherbrooke).

4.4.2 Objectives

1. Deploy SAMI-CO_2 sensors with DO and PAR on 2 of the WHOI ITPs (ITP138 & ITP139).
2. Conduct underway pCO_2 measurements to provide data quality assurance for the ITP-based sensors and to map the spatial distribution of pCO_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). Mooring D also equipped with Fluorometer (collaboration with Céline Guéguen (University of Sherbrooke).
5. Assist with other shipboard research activities and interact with ocean scientists from other institutions.

Figure 27. SAMI CO_2 being deployed on an ITP (left) and CO_2 and pH sensors after recovery on Mooring B (right).

4.4.3 Accomplishments

- We deployed SAMI-CO_2 sensors equipped with dissolved O_2 and PAR sensors on 2 of the ITPs (ITP138 & ITP139).
- 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 ship's surface 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 2022 and the new ITPS are summarized in the Table below.

Table 13. 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 (6-pin b/h)
Days of Data	85	251	94	367
BGOS-B Mooring				
	CO2	**pH**	**O2**	**PAR**
Instrument ID	C48u	XXX	4175: 717 (4-pin b/h)	XXX
	XXX	P68u	XXX	9385 (6-pin b/h)
Days of Data	67	339	67	339
BGOS-D Mooring				
	CO2	**pH**	**O2**	**PAR**
Instrument ID	C37u	XXX	4175: 1699 (5-pin b/h)	XXX
	XXX	P5u	XXX	9386 (4-pin b/h)
Days of Data	361	251	361	251
ITP-138				
	CO2	**IMM ID**	**Aanderaa ID**	**PAR**
Instrument ID	C252	700-9548	4531A: 1517	UWQ-11435
Days of Data	20	20	20	20
ITP-139				
	CO2	**IMM ID**	**Aanderaa ID**	**PAR**
Instrument ID	C253	700-9551	4531A: 1518	UWQ-10480
Days of Data	17	17	17	17

4.5 XCTD Profiles

Onboard: Kazu Tateyama, Yusuke Kohama (KIT) and Koh Izumiyama (HU)
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 41 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 in 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 written 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.

Operational Notes

The Lockheed Martin XCTD-1N probe was used exclusively in 2023.

Table 14. XCTD probe operational parameters.

Probe Type	Number Used	Filename Convention	Max Depth (m)	Max Ship Speed (Kts)
XCTD-1N	44	"C3_"	1100	12

According to the manufacturer's nominal specifications, the range and accuracy of parameters measured by the XCTD probe are summarized below in Table 15.

Table 15. XCTD probe specifications.

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 44 XCTD-1N probes, 40 successfully reached maximum depth or bottom depth (1,000 m). Only one probe did not complete the cast, achieving a depth of 641 m. No specific reason was determined for the loss of data before maximum depth was achieved. Of the 3 probes that failed, the cause was determined to be a combination of human error and trouble with the PC (e.g. sudden power failure and hard disk read error). In the case of human error, the operator selected the wrong type of probe (XBT) in the probe selection field. The chance of repeating this error was mitigated by changing the software settings to skip the selection screen and select the XCTD-1N probe-type as default. The hard disk read errors on the laptop may have been caused by ship vibration or other unknown factors. For stable operation, it is desirable to use a SSD that is resistant to vibration. 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. A probe failure is likely the reason for this anomaly.

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. It was set to update to the science time-server.

File Edits including Location

File with original filename C3_00030-2 was second file with name C3_00030. It was renamed to C3_00230. The text line inside file was changed from "Raw Data Filename: C3_00030" to "Raw Data Filename: C3_00230"

Files C3_00016.edf, C3_00017.edf and C3_00230.edf were all missing location information. This was added from the TSG record matching on time. However it might be preferable to use the bridge logged latitude and longitude. So this still needs to be edited.

See Appendix for table of stations.

4.6 Zooplankton Vertical Net Tows

Chris Clark (DFO-IOS), Sarah Sedlock (DFO-IOS), Paige Hagel (DFO-IOS), Justin Forget (Sherbrooke University), Sam De Abreu (Yale), Louis Criqui (Sherbrooke University), Zhangxian Ouyang (University of Delaware).
P.I.: John Nelson (DFO-IOS)

4.6.1 Sampling

Zooplankton sampling and preservation were conducted on board by Paige Hagel, Louis Criqui and Zhangxian Ouyang of the day watch in addition to Chris Clark, Justin Forget, Sarah Sedlock and Sam De Abreu 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 45 bongo vertical net hauls were completed at 45 stations (see list in Appendix).

Figure 28. Bongo nets being deployed from the foredeck in 2023.

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 labelled E with TSK serial number 7085 and the other side was labelled 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.

Table 16. Bongo net parameters.

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

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

A new storage box for the bongo system supplied in 2022 was used again this year. The new large plastic box works reasonably well for storage of the nets however it is awkward to move around under the A-frame. A more compact solution is being considered. In addition, the "knee" for supporting the nets within the box needs to be reworked to provide better support.

Issues

Some stations with strong currents were challenging for the bridge to maintain an angle away from the ship 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 corrected the angle, so the nets were not under the ship and the haul was resumed after the bubblers were turned off.

The winch-counter on the zooplankton winch electrically failed after progressive difficultly in turning the counter on. The senior engineer replace the power supply with a ship's spare. With this quick fix we did not bother swapping in our spare winch counter. At the end of the cruise the power supply was returned to the ship.

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 freezing up. In 2023 the hose was challenging to coil up after each cast because the heat trace which no longer works hardened the plastic. It is advisable to replace the 100-foot hose with an unheated softer rubber hose to rectify this issue.

4.7 Underway Surface Sea-water Measurements

Sarah Zimmermann and Paul Macoun(DFO-IOS)
Céline Guéguen, Justin Forget and Louis Criqui (USherbrooke)
Cory Beatty (UMontana), Zhangxian Ouyang (University of Delaware)
P.I.s: Bill Williams, Celine Gueguen (USherbrooke), Mike DeGrandpre (UMontana), Wei-Jun Cai (University of Delaware)

4.7.1 Overview

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 lab off the main science lab. The lab is configured with an integrated Seabird SBE21 thermosalinograph (TSG), Seapoint Chl-a fluorometer and Wetlabs FDOM fluorometer. Recording independently, a second Wetlabs FDOM fluorometer, a Sunburst SUPER pCO2 system and an O2/Argon 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, Chlorophyll, Oxygen, and a limited number of Nutrients (IOS/DFO)
    - Fluorescent Dissolved Organic Matter (*Celine Gueguen, USherbrooke*)

c. Partial pressure of carbon dioxide (pCO_2) using a SunBurst SUPER instrument (*Mike DeGrandpre, UMontana). See section on Sea surface pCO2, pH and dissolved O2.*
d. New in 2023: The ratio of oxygen and argon concentrations (*Zhangxian Ouyang and Wei-Jun Cai, University of Delaware).* See following section on *Underway measurement of O2/Ar ratio*

New in 2023, the manifold valves were replaced with stainless steel needle valves to allow more precise flow adjustment and with flow meters with a logged display in L/min. This system allowed real-time adjustment and monitoring of flow rate. The logged information can be used to remove poor data when ice and slush slowed or blocked the flow. Please see appendix for more information on this system.

Note that in 2023 there were problems with the TSG:

- Flow was not fully diverted to run past the intake temperature sensor until the problem was discovered and fixed Sep 22 09:00 UTC. Data will be looked at before and after this fix and a correction to the earlier data may be needed.

- Salinity from the SBE21 TSG was inconsistent and may not be useable. The salinity was jumping to values that were too fresh (by ~1PSU), then back to a realistic value. On Sep 25th 02:14UTC a SBE19+ CTD was set up in the lab using a 'Y" from the TSG seawater input with flow from the underway system. This CTD will supply the correct salinity.

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

4.7.2 Underway measurement of O_2/Ar ratio

Zhangxian Ouyang (University of Delaware)
P.I.: Wei-Jun Cai (University of Delaware)

Overview

The Arctic Ocean is currently experiencing rapid environmental and ecological changes in response to climate change. In recent decades, sea ice extent has drastically declined, resulting in earlier seasonal ice retreat and thinning in the Canada Basin. This change has profound and potentially effects on surface net community production (NCP), as sea-ice state is a crucial factor to regulate light availability, water column stability and nutrient availability. In addition, sea ice provides habitat for numerous autotrophs in polar regions. Thus, sea ice can greatly affect the timing, location, and intensity of Arctic NCP. In 2023, the Arctic summer ice sea extent reached the second lowest in the record, especially in the Canada Basin. It is of great interest to examine how massive sea ice retreat in the Canada Basin and Beaufort Sea affects NCP in a late growing season.

Sampling and Data Processing

The ratio of oxygen and argon concentrations (O_2/Ar) was continuously measured underway on board the *CCGS Louis S. St-Laurent* (LSSL) from September 14 to October 10, 2023, during the BGOS/JOIS mission in the Canada Basin using an equilibrator inlet mass spectrometry (EIMS; Cassar et al., 2009). Underway water (~9 m below waterline) was pumped through the loop system at a flow rate of 2-3 L min^{-1}, through one filter to remove particulates, then to a gas-permeable membrane contactor cartridge (MicroModule 0.75×1). The equilibrated gas in the headspace was sent to a quadrupole mass spectrometer (Pfeiffer Prisma model QMG 220) for measurement. The O_2/Ar ratio was recorded every 2 s, then averaged into 2 min intervals. This measurement was calibrated with ambient air every 3 hours. The precision of the EIMS system is better than ±0.3% (Cassar et al., 2009). We removed any measurements that reflected interference from ice rubble when the ship was breaking ice, but we retained measurements collected when the ship was on station or tethered to ice (with less interference from ice rubble).

To quantify oxygen status as influenced by both physical and biological processes in the mixed layer, oxygen saturation percentage (O_2%) was measured every 30 s underway using an Aanderaa optode (model 4531A). The optode was calibrated before each cruise with 0% and 100% O_2-saturated water according to manufacturer's instructions. Discrete DO samples collected from both the loop pipeline and CTD Niskin bottles (surface samples) were used to check and validate the optode measurements. Note that O_2% results are only used to demonstrate the total O_2 state in the mixed layer, not for NCP calculation.

NCP Calculation

Measurements of the ratio of oxygen and argon concentrations relative to their saturated state allow for the effects of physical forcing to be removed from the effects of biological and physical forcings combined. Here, the biological oxygen saturation, $\Delta(O_2/Ar)$, is defined as,

$$\Delta(O_2/\mathrm{Ar}) = \frac{(O_2/\mathrm{Ar})_{meas}}{(O_2/\mathrm{Ar})_{sat}} - 1$$

where $(O_2/Ar)_{meas}$ is the ratio of dissolved gases measured in the water and $(O_2/Ar)_{sat}$ is the ratio in the ambient air.

Then NCP within the surface mixed layer can be estimate:

$$NCP\ (mmol\ O_2\ m^{-2}\ d^{-1}) = \Delta\ (O_2/Ar) \cdot kO_2 \cdot [O_2]_{sat}$$

where kO_2 is the gas transfer velocity of oxygen; $[O_2]_{sat}$ is the saturated concentration of O_2, calculated from sea surface temperature and salinity (Garcia and Gordon, 1992). $[O2]_{sat}$ is also corrected for atmospheric pressure by multiplying the ratio of sea level pressure to standard pressure.

In addition, we will apply an exponentially-weighted scheme to estimate NCP from $\Delta(O_2/Ar)$, which more accurately reflects an average state of NCP over the past few weeks by taking the impacts of both wind and sea ice histories into account (Teeter et al., 2018; Ouyang et al., 2021).

References

Garcia, H., & Gordon, L. (1992). Oxygen solubility in seawater: Better fitting equations. *Limnology and Oceanography, 37*(6), 1307-1312. doi:10.4319/lo.1992.37.6.1307

Cassar, N., Barnett, B., Bender, M., Kaiser, J., Hamme, R., & Tilbrook, B. (2009). Continuous high-frequency dissolved o2/ar measurements by equilibrator inlet mass spectrometry. *Analytical Chemistry, 81*(5), 1855-64. doi:10.1021/ac802300u

Teeter, L., Hamme, R., Ianson, D., & Bianucci, L. (2018). Accurate estimation of net community production from O_2/Ar measurements. *Global Biogeochemical Cycles*, *32*(8), 1163-1181. doi:10.1029/2017GB005874

Ouyang, Z., Qi, D., Zhong, W., Chen, L., Gao, Z., Lin, H., Sun, H., Li, T. and Cai, W.J., 2021. Summertime evolution of net community production and CO_2 flux in the western Arctic Ocean. *Global Biogeochemical Cycles*, p.e2020GB006651.

4.8 Underway data logging using SCS

Paul Macoun, Sarah Zimmermann (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. This timestamp comes from a computer clock that can drift. However, new for 2023 a time-server was used to keep the science server and other data computers (CTD, TSG, XCTD) up to date. If in doubt, check against 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 performance issues are given in the Appendix.

4.9 Ice Observations – Bridge Watch

Kazu Tateyama, Yusuke Kohama (KIT) and Koh Izumiyama (HU)
P.I.: Kazu Tateyama (KIT), Jennifer Hutchings (OSU)

As in previous years, the ice observations recorded during the Louis S. St-Laurent 2023-013 cruise will provide detailed information for the interpretation of satellite imagery of the ice pack. Figure 1 shows the cruise track and averaged sea ice concentration during the cruise (15 Sep. – 6 Oct.) observed by GCOM-W AMSR2.

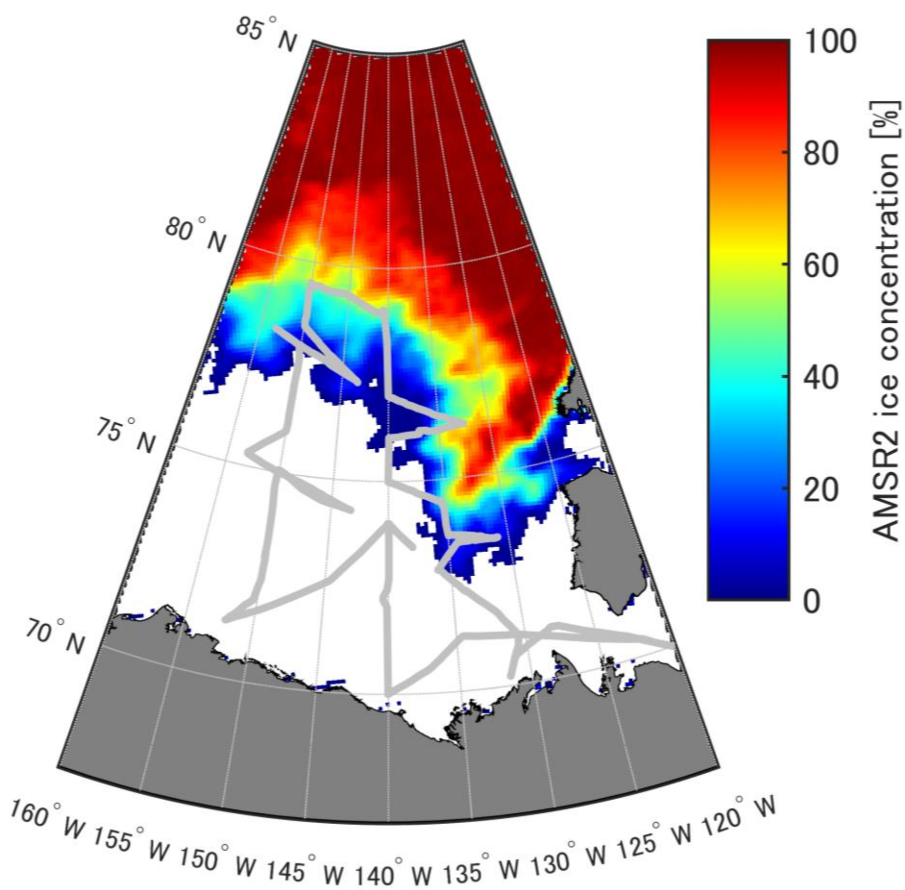


Figure 29. Averaged AMSR2 sea ice concentration and ship track during the cruise.

4.9.1 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 8-hour Ice and XCTD watch were carried out by the three ice observers, 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.

Observation has started on 19th September and ended on 30th September. 151 hourly data were recorded. The thick old ice such as multi-year more than 250cm and second-year ice around 80-150 cm were observed as primary (thickest) ice.

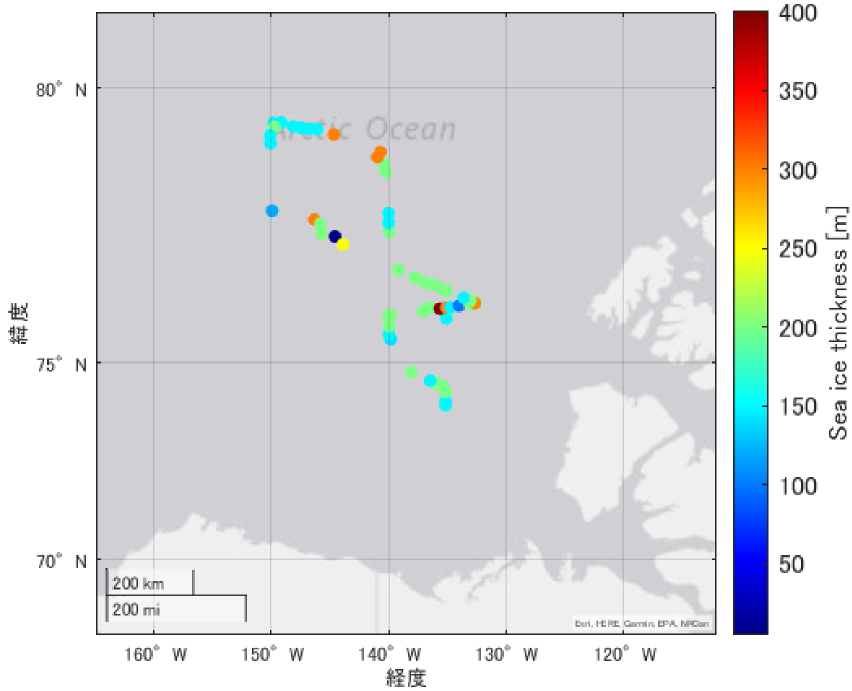


Figure 30. Ice thickness distribution for primary ice.

4.9.2 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. The “measuring stick” was not installed this year. It is a 2m long pole with 10cm marked increments typically mounted on the 400 deck rail in the field of view of the images to aid in sea-ice thickness measurements. This camera recorded images every 10 seconds. The image quality was quite poor from this camera and a replacement should be considered.

The other netcam was mounted above the bridge on the forward rail, looking forward to measure ice concentration. An extension cord was used to supply the camera’s power instead of a powered network cable which has too long of a run to carry the needed power. 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. Being inside, looking through the protected bridge window, the view was typically free of ice/rain/snow issues. These images duplicate those collected by the forward looking web camera and was also set to record images every 1 minute using 7M size and Regular width.

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 typically superior to the netcams.

Measurement of the port netcam started on September 16, the forward looking netcam was started September 24. These cameras were uninstalled and completed ice observation on October 7. The GoPro camera took images from Sep 18th to Oct 10th.

Issues

- Both netcam’s time and date were not set at the start of the program. This resulted in incorrect photo filenames since they include the camera’s date and time. See below for a relationship between filename and UTC date and time.

- The downward looking netcam images were very poor and are likely not useable.
- The GoPro had several patches of missing data: The mount bracket let loose a few times and the camera was found fallen on the windowsill. The power connection was periodically interrupted due to accidental bumping of the on/off switch due to ship vibration but also to some unknown camera issue.
  See the GoPro Log for details: *2023-013 GoPro on Bridge Log v2023-12-14.docx*
- The GoPro file and folder names cycle after downloading so each download was written to a unique folder.

Camera filenames compared to correct time.

1. Forward Looking WebCam in folder "CamBow"

Web Camera	File Date (UTC-7hr)	UTC time
Bow_20000112_192517	2023-09-27 08:51	2023-09-27 15:51

This is based on mooring B recovery captured in images and timing logged by mooring team. Mooring was released at 15:49 UTC and the mooring top float is first seen shortly thereafter at 15:51 UTC.

2. Portside Downward Looking WebCam in folder "CamPort"

The web camera looking down on the water, does not have the measuring stick set up this year so there is no 'ice ruler' . Focus for this camera is poor so unlikely these photos can be used in anycase. The time and date were not configured on the web camera.

To correct the time and date use the relationship:

Web Camera	File Date (UTC-7hr)	UTC time
Port_20230108_194525	2023-09-27 08:51	2023-09-27 15:51

There is no visual reference to match camera time to file time, however since the camera is writing to the same computer as the forward camera, the relationship between forward camera's file time and UTC time can be used to determine the portside camera filename offset.

3. GoPro

GoPro had Time and Date set to UTC however somehow the file dates are not as expected.

The picture's MODIFIED date is Pacific time (UTC-7hr) and the FILE date is UTC.

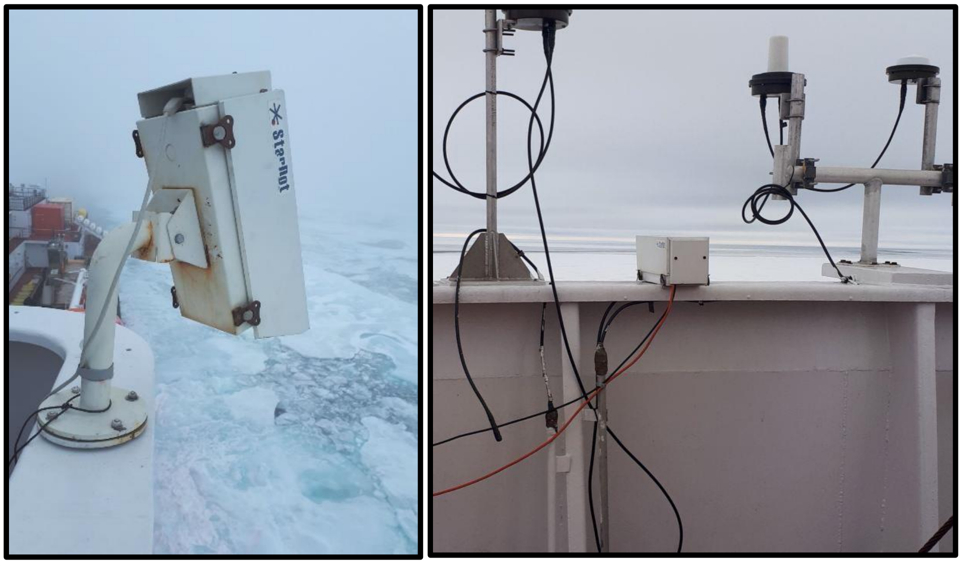


Figure 31. The downward and forward looking netcams above the bridge. Photos from 2022 but similar for 2023.

Figure 32. Location of forward looking GoPro camera on the port side of the bridge. Photo from 2021 but similar to 2023.

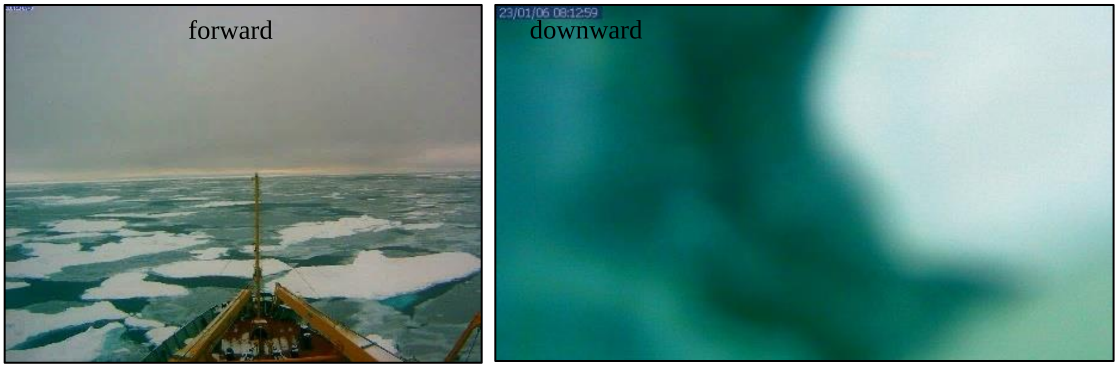


Figure 33. Examples of WebCams.

4.9.3 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 holds a GPS receiver, data logger and battery. The camera was powered through an extension cable from the ship.

Figure 34. Self-contained camera system with solar panel mounted above the bridge on forward, port corner. Photos from 2022 but similar to 2023 but without the solar panel.

4.9.4 Ship Performance

New for this year, LSSL's performance data, including ship speed, propeller shaft revolution, and propulsion motor power, were collected from the bridge. LSSL is an icebreaker equipped with triple propellers that are independently driven by an electric motor powered by diesel engines. Data for revolution speed of and motor power to each of three shafts were collected.

All these data above were manually read from different displays located on bridge as follows. – ship speed (GPS speed) was read from a radar screen, revolution speeds of three shafts from a power control table, and power output of three motors from a multi-information display. Fig. 3 is a photo of the multi-information display showing power flow from engines to motors via generators. According to the display, the maximum power that each motor can deliver is 6.714 MW.

Values displayed, particularly motor power, can fluctuate over the course of data reading. Although a representative value that deemed to be a mean was recorded, it should be noted that such data is subjected to unavoidable uncertainty. It is also noted that this is not a dedicated test where a ship is supposed to sail straight at a constant power given, but an underway measurement performed during ship navigation between science stations. LSSL may be operated so as to avoid difficult ice.

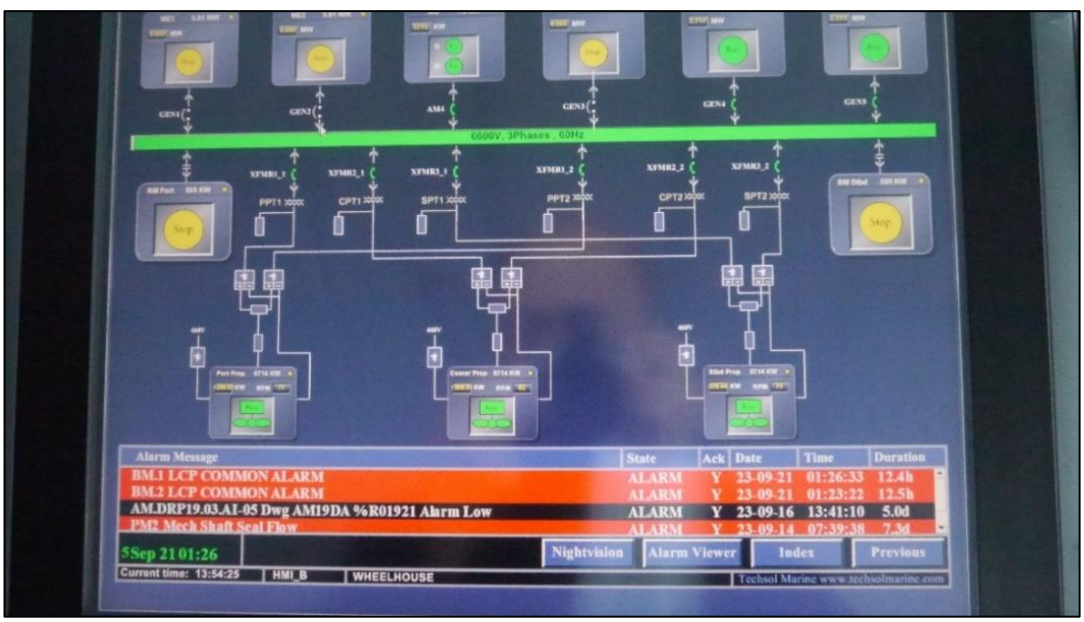


Figure 35. Multi-Information Display showing Power Flow

Results

Performance data collection was made in open water as well as in ice-covered conditions.

Fig. 36 shows total (sum of three motors) propulsion power measured in open water condition as a function of ship speed. The highest speed of 17.6 kt was recorded on September 17th in the beginning of the cruise when LSSL was steaming to pick up a nurse. This speed was achieved with propulsion power of approximately 10 MW that is only a half of the maximum power. Given that this speed is almost the same as the ship's maximum speed of 18 kt, the data clearly shows LSSL's propulsion system was designed with a plentiful focus on icebreaking.

Scatter in data plot in Fig. 36 attributes in part to the above-mentioned uncertainty in data reading. In addition, wind may also contribute to the data scatter. The highest power was recorded at the second highest speed of 16.5 kt. This data was collected when LSSL was steaming in a strong headwind of relative speed of 45 kt. The same ship speed was achieved with approximately half power when the sea was very calm.

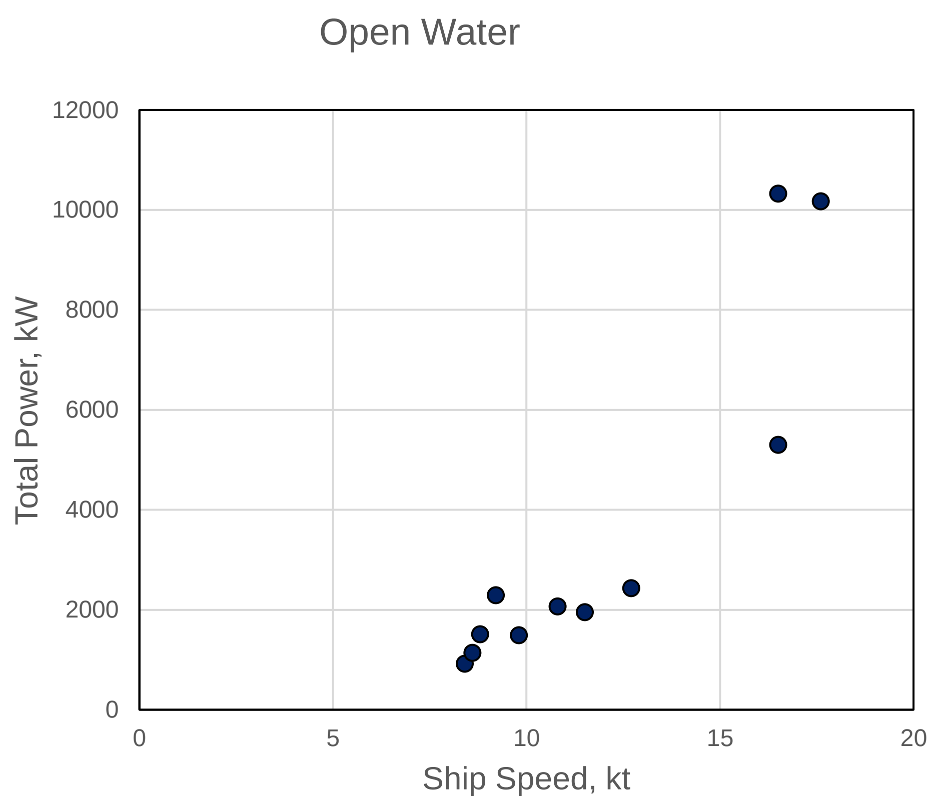


Figure 36. Total Propulsion Power vs Ship Speed in Open Water.

Fig. 37 presents data collected in ice. Again, total propulsion power is plotted against ship speed. Number suffixed to each data maker shows ice concentration in tenth. Open water data for ship speed up to 12 kt are also shown for comparison.

As is obvious, higher power is required in ice than water to achieve a same speed. The power difference between ice and water increases with ice concentration. Power in 2/10 concentration ice is equivalent to that in open water. This reflects the fact that LSSL was operated so that contact with ice is minimized as described above. 'MP' in the figure stands for melt pond.

For this data while ice concentration was 9/10, ice surface was overwhelmed by numerous melt pond (Fig. 6). Power recorded in this ice was equivalent to that in 7/10 concentration ice.

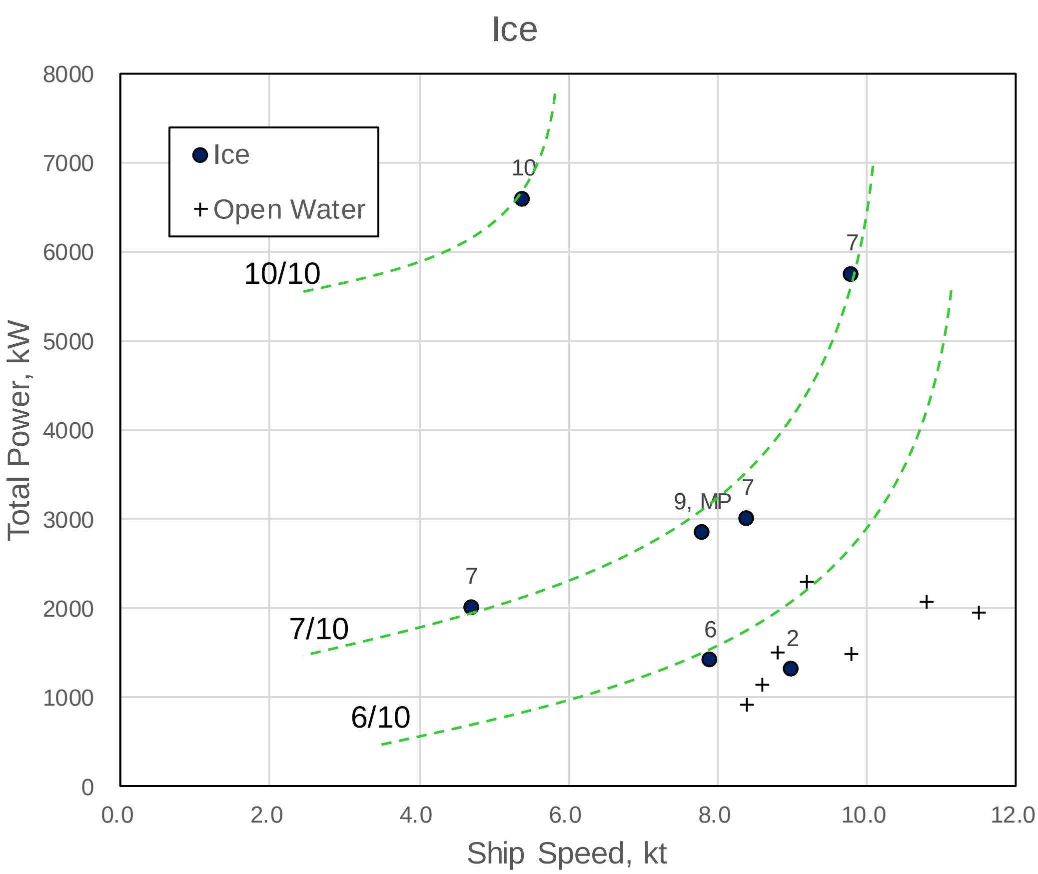


Figure 37. Total Propulsion Power vs Ship Speed in Ice.

Figure 38. Example of icebreaking navigation.

The ship data collection was made with an intention to draw a general picture of the relationship for LSSL's performance (speed and power) and ice parameters (concentration, types, ridging, etc.), and to look for potentiality of using the ship as a 'sensor' for the degree of ice severity. Unfortunately, however, ice conditions encountered during the course of the cruise (also in the Western Arctic in general) were very mild. Chances to have ship data in middle to high ice concentration conditions were much less than expected.

Attempt was made to interpret ship performance from limited data points obtained. Green dashed curves in Fig. 5 present power-speed relationship estimated for different ice concentration. A curve for ice concentration 7/10 was drawn and then it was applied to 10/10 and 6/10 concentrations. It should be noted that ice thickness, which will be calculated later from EM sensor data, is not taken into consideration in Fig. 5.

4.10 Ice Observations

Kazu Tateyama, Yusuke Kohama (KIT) and Koh Izumiyama (HU)
P.I.: Kazu Tateyama (KIT), Jennifer Hutchings (OSU)

4.10.1 Ice Observations - Ice Thickness from suspended EM sensor

An Electro-Magnetic induction device EM31/ICE (SEM) 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 color waterproof fiber reinforced plastic case and should be hanged at 4.5 m height above sea surface and in more than 7 m separation from ship due to avoid hitting ice and the effect from ship hull.

A new boom for SEM was introduced from this cruise as shown Fig. 39. The new boom was stable enough under strong winds and was easier to handle. Advantages such as easier calibration of the SEM were obtained. In addition, the SEM data loggers were connected to the ship's network using LAN cables. It is now possible to monitor raw data in real time and download hourly recorded data via FTP. However, converting the raw data to sea ice thickness in real time remains an issue for the future.

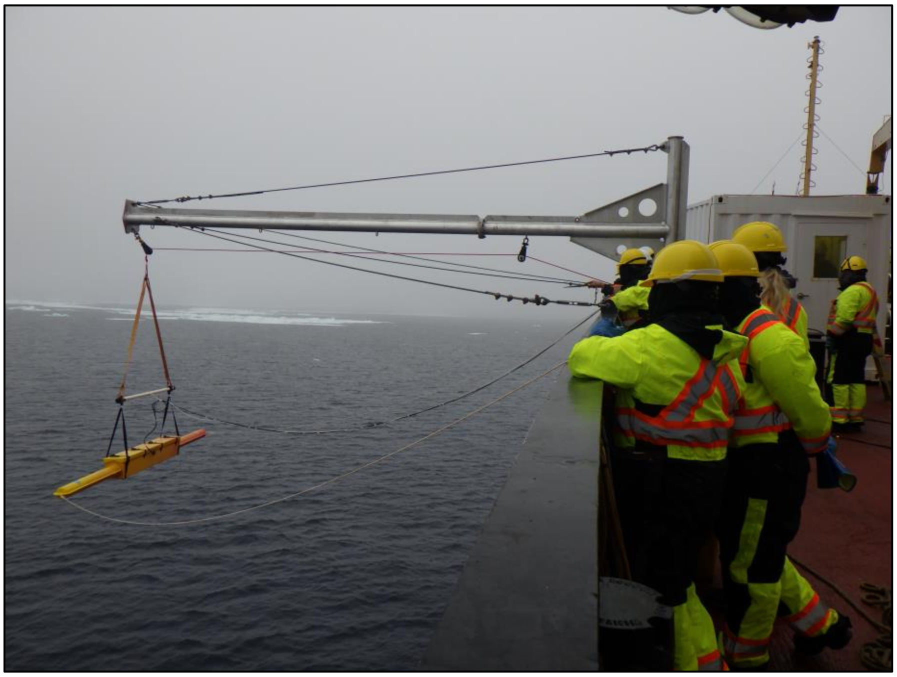


Figure 39. Photos of the SEM hanging from the new boom.

4.10.2 Ice Observations – Ice stations

Kazu Tateyama and Yusuke Kohama (KIT), Koh Izumiyama (HU), Justin Forget and Louis Criqui (Sherbrooke), Chloe Immonen, Sarah Sedlock and Paige Hagel (IOS), Annika Margevich and Sam De Abreu (YaleU), Zhangxian Ouyang (UDelaware), Sarah Palestini (ConcordiaU)
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

Overview of ice stations

<u>Ice Station 1</u>

Drilling: Chloe Immonen, Sam De Abreu, Yusuke Kohama
Coring: Koh Izumiyama, Justin Forget, Louis Criqui, Sarah Sedlock, Paige Hagel, Annika Margevich, Zhangxian Ouyang, Sarah Palestini
Snow pit: Kazu Tateyama

Ice was accessed from gangway of port side. A 200m-long transect was set as shown in Figure. Ice cores were collected at four sites (0, 50, 100m and below SEM) along the transect line. An additional core was collected for microbial diversity measurements (David Walsh/ Sarah Palestini, Concordia University). Averaged thickness of snow and ice along transect line were 0.119m and 1.70m, respectively. One ridge lying between 90m and 130m was observed.

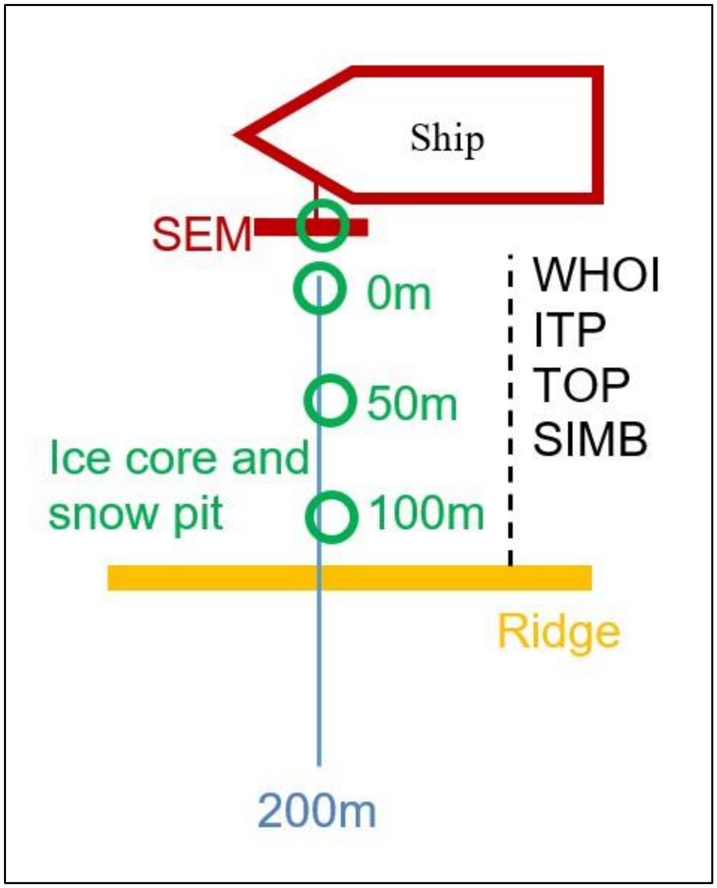


Figure 40. Schematic describing the ice transect at Ice Station 1.

Ice Station 3

Drilling: Chloe Immonen, Sam De Abreu, Yusuke Kohama
Coring: Koh Izumiyama, Justin Forget, Louis Criqui, Sarah Sedlock, Paige Hagel, Annika Margevich, Zhangxian Ouyang
Snow pit: Kazu Tateyama

Ice was accessed from gangway of starboard side. A 150m-long transect was set as shown in Figure below. Ice cores were collected at two sites (0, 50m) along the transect line. Averaged thickness of snow and ice along transect line were 0.107m and 3.08m, respectively. Two ridges lying between 20m and 50m, 80m and 150m were observed.

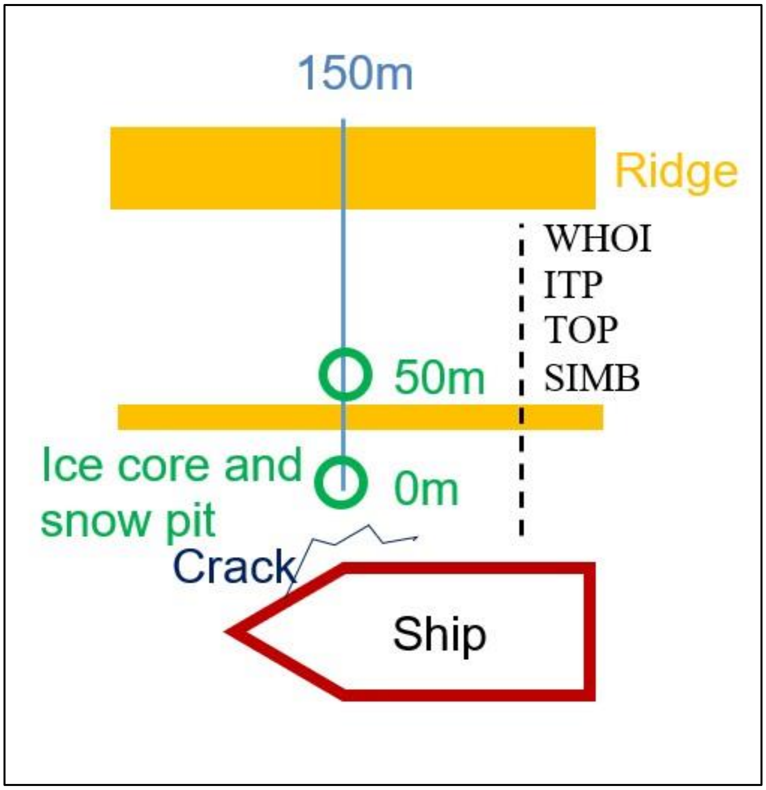


Figure 41. Schematic describing the ice transect at Ice Station 3.

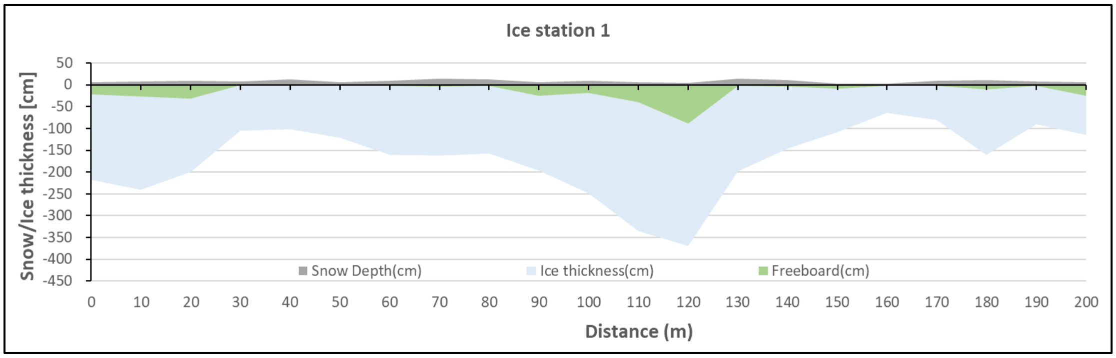
One transect was carried out at each ice station site.

4.10.3 Ice thickness transects

At ice station 1 and 3 we conducted a 200 m and 150 m transect respectively measuring snow depth, ice thickness and ice freeboard every 10 m along the transect line.

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.



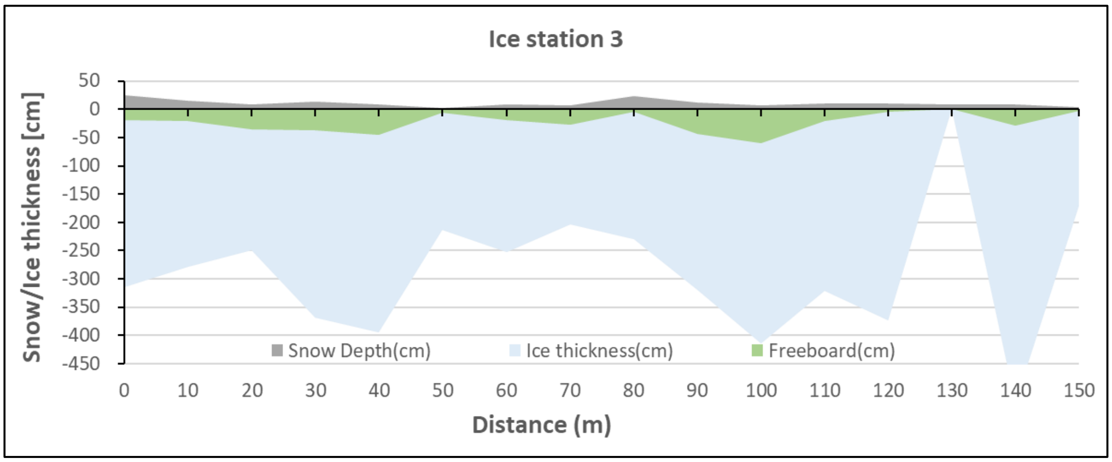


Figure 42. Snow and ice thickness, and freeboard measurements, at ice station 1 (top) and 3 (bottom).

4.10.4 Ice Cores

Table 17 shows the summary of collected ice core samples. 6 physics cores and 1 chemistry core in total were taken from Ice Stations 1 and 3.

Table 17. Summary of collected ice core samples.

Station	Transect #, Distance	Core - Property	Snow Pit
Ice Station 1	Transect 1, 0m	Temperature, Salinity, Density	Yes
Ice Station 1	Transect 1, 50m	Temperature, Salinity, Density	
Ice Station 1	Transect 1, 100m	Temperature, Salinity, Density	Yes
Ice Station 1	Under the EM Sensor	Temperature, Salinity, Density	
Ice Station 1	Location not specified. Core sample: Top 50cm & Bottom 50cm	Core for Microbial Diversity (David Walsh, ConcordiaU)	
Ice Station 3	Transect 1, 0m	Temperature, Salinity, Density	Yes
Ice Station 3	Transect 1, 50m	Temperature, Salinity, Density	Yes

Ice Station#1, Core A (195cm)

Ice Station #3, Core A (335cm)

Figure 43. Pictures of ice core samples from Ice Station 1 (top series) and 3 (bottom series).

Temperature, Salinity and Density Profiles

Temperature, salinity and density profiles were measured from the cores. 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.

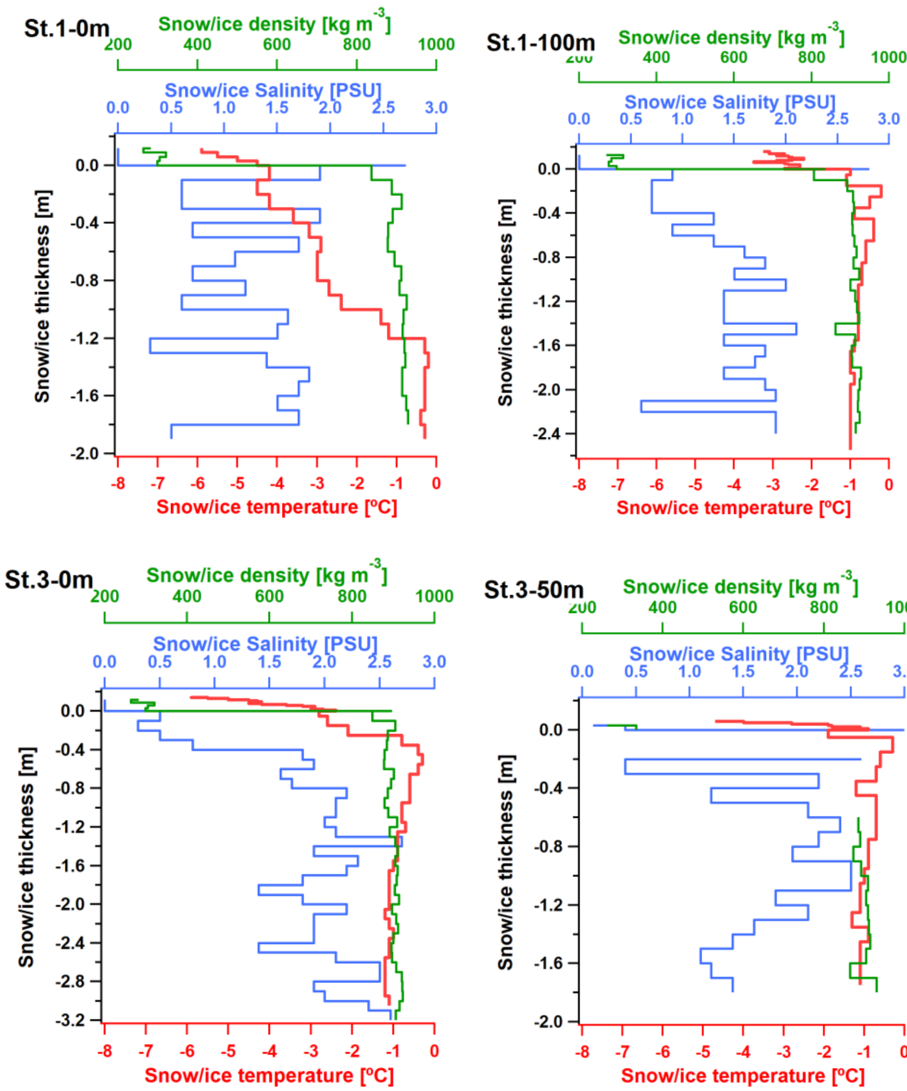


Figure 44. Temperature, salinity and density profiles of snow pit and ice core samples from Ice Stations 1 and 3.

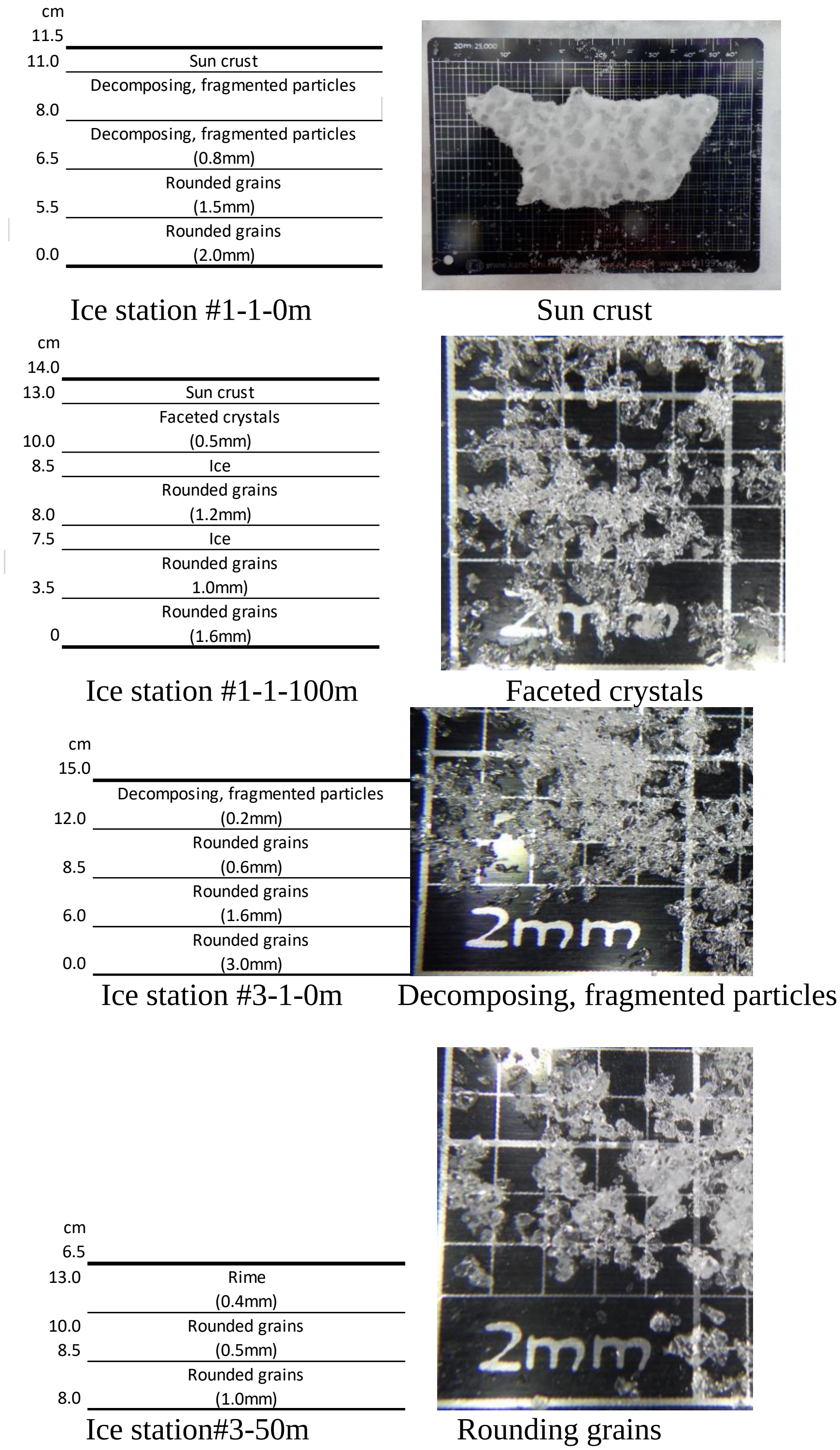


Figure 45. Results of snow layer structures and photographs of representative snow crystals obtained from snow pit observations.

4.10.5 Data

For more information and data, please contact Kazu Tateyama

lsloaa::sciencenet/2023-013-JOIS/Data/

JOIS2023_Icestation_Transect_Core/
JOIS2023_Ice_Stations_Summery.xlsx
JOIS2023_IceStation_IceCore.xlsx
JOIS2023_IceStation_Transect.xlsx
JOIS2023_IceStation_SnowPit.xlsx
Ice_station#1/ and /Ice_station#3/
Ice Core Photos/
Snow pit photos/

Ice_Watch/
    JOIS2023_ice_watch.xlsx
    Ice_Watch_Photos/

Shipborne_EM/
Not ready

4.10.6 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.

5 APPENDIX

5.1 Science Participants

Table A1. Onboard Science Participants

Number	Personnel	Institution	Role
1	Paul Macoun	DFO-IOS	Co-Chief Scientist, CCG Liaison
2	Sarah Zimmermann	DFO-IOS	Co-Chief Scientist, Data Specialist
3	Sarah Ann Quesnel	DFO-IOS	Nutrient Analyst
4	Marty Davelaar	DFO-IOS	DIC Analyst
5	Michiyo Yamamoto-Kawai	TUMSAT	Alkalinity Analyst
6	Chloe Immonen	DFO-IOS	Oxygen Analyst
7	Sarah Palestini	ConcordiaU	Microbiology
8	Chris Clark	DFO-IOS	Chief Technician , Watchleader - Shift 1
9	Ashley Arroyo	YaleU	Dispatches, Watchstander - Shift 1
10	Zhangxian Ouyang	UDelaware	O2/Ar, Watchstander - Shift 1
11	Sarah Sedlock	DFO-IOS	Watchstander - Shift 1
12	Justin Forget	USherbrooke	FDOM Analyst / Watchstander - Shift 1
13	Paige Hagel	DFO-IOS	Watchleader - Shift 2
14	Annika Margevich	YaleU	Watchstander - Shift 2
15	Celine Guegen	USherbrooke	FDOM lead, Watchstander - Shift 2
16	Sam De Abreu	Yale	Watchstander - Shift 2
17	Louis Criqui	USherbrooke	FDOM Analyst / Watchstander - Shift 2
18	Mary-Louise Timmermans	YaleU	Scientist / Moorings
19	Jeff O'Brien	WHOI	Moorings & Buoys (lead)
20	Jim Ryder	WHOI	Moorings & Buoys
21	Tim McDonough	WHOI	Moorings & Buoys
22	Eric Hutt	WHOI	Moorings & Buoys
23	Cory Beatty	UMontana	pCO2 - Mooring & Buoys
24	Kazu Tateyama	KIT	Sea Ice Observations (lead)
25	Yusuke Kohama	KIT	Sea Ice Observations
26	Koh Izumiyama	HU	Sea Ice Observations

Table A2. Principal Investigators Onshore

Name	Affiliation	Program
Isabela LeBras	WHOI	Mooring and Buoy co-lead
Andrey Proshutinsky	WHOI	Moorings and ITP program / CTD/Rosette / XCTD
Richard Krishfield	WHOI	Moorings and ITP / CTD/Rosette / XCTD
John Toole	WHOI	ITP Buoys
Mike DeGrandpre	UMontana	pCO2, pH, Underway system, Buoy, Mooring
Motoyo Itoh	JAMSTEC	CTD/Rosette / XCTD
Shigeto Nishino	JAMSTEC	CTD/Rosette
Takashi Kikuchi	JAMSTEC	CTD/Rosette
Don Perovich	CRREL	Ice Mass-Balance Buoy
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/ ^{14}C
Wei-Jun Cai	UDelaware	δ13C-DIC
Jennifer Hutchings	OSU	Ice Observations

Table A3. 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
ETH Zurich	ETH Zurich, Switzerland
HU	Hokkaido University, Hokkaido Prefecture, Japan
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
NPS	Naval Postgraduate School, Monterey, California, USA
OSU	Oregon State University, Corvallis, Oregon, USA

TUMSAT	Tokyo University of Marine Science and Technology, Tokyo, Japan
ULaval	University of Laval, Quebec City, Quebec, Canada
UMontana	University of Montana, Missoula, Montana, USA
USherbrooke	University of Sherbrooke, Quebec, Canada
UVic	University of Victoria, Victoria, British Columbia, Canada
WHOI	Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
YaleU	Yale University, New Haven, Connecticut, USA

Table A4. Project website URLs.

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

5.2 Location of Science Stations

The scientific crew boarded the *CCGS Louis S. St-Laurent* icebreaker in Cambridge Bay, NU, on 14 September, 2023 and departed Cambridge Bay, NU on 12 October, 2023.

Locations of CTD/Rosette, XCTD, zooplankton vertical net, as well as the mooring and buoy recovery and deployments are listed in the tables below.

5.2.1 CTD/Rosette

Table A5. CTD/Rosette cast locations

Cast #	Station Name	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	Water Depth (m) (Knudsen Sounder)	Cast Depth (m) (Max CTD)	Sample Numbers	Ice Coverage (tenths) (Rough Estimate by CTD Operator)	Comments
1	AG5-DNA	9/17/2023 5:07	70.5515	122.9012	638	630	1-24	0/10	Productivity ("DNA/RNA" cast)
2	AG5	9/17/2023 7:53	70.5520	122.9008	638	634	25-44	0/10	BOTTLE 13 SKIPPED IN FIRING due to known quality problem.
3	CB1	9/18/2023 7:53	71.7795	131.8812	1130	1115	45-68	0/10	
4	CB31b	9/18/2023 13:10	72.3508	134.0007	2075	2053	69-92	0/10	AT 263M DURING UPCAST, REALIZED THE WINCH HAD NOT BEEN SPOOLING PROPERLY AND HAD A CROSSOVER ON FORWARD SIDE OF THE DRUM. PAID OUT WIRE TO 900M TO CORRECT BEFORE RECOVERY. SAMPLES 69-78 ARE COMPROMISED.
5	CB23a	9/18/2023 21:41	72.8993	135.9807	2743	2736	93-116	0/10	STOPPED ON UPCAST AT 2633M for ~20minutes for TESTING ACOUSTIC RELEASES for moorings.
6	CB50	9/19/2023 5:12	73.5033	134.2167	2890	2871	117-140	0/10	
7	CB51	9/19/2023 14:13	73.4982	130.9005	2500	2482	141-164	3/10	
8	CB40	9/20/2023 9:35	74.4992	135.4073	3251	3245	165-188	3/10	
9	CB18	9/20/2023 19:32	75.0048	139.9752	3630	3613	189-212	0/10	
10	CB17	9/21/2023 5:05	76.0045	139.9602	3696	3687	213-236	1/10	Winch making bad sounds and stopped for a check at 3554m. Tension 2045 lb.
11	PP6	9/21/2023 22:27	76.2573	132.5155	3100	3030	237-260	4/10	WINCH PROBLEM @ 2967M. TENSION 2008lb.
12	PP7	9/22/2023 6:59	76.5347	135.4705	3572	3562	261-284	2/10	
13	CB15	9/22/2023 16:27	76.9993	139.9567	3725	3717	285-308	0/10	
14	CB16	9/23/2023 1:31	78.0058	139.9808	3470	3741	309-332	2/10	
15	CB16N-DNA	9/24/2023 2:09	78.9422	140.8547	3776	1007	333-353	4/10	Productivity ("DNA/RNA" cast)
16	CB16N	9/24/2023 4:27	78.9342	140.8563	3776	3770	357-380	4/10	Cast at IBO1
17	I2-23 (IBO2-2023)	9/24/2023 20:42	79.3635	145.7193	3807	3798	381-404	8/10	Cast at IBO2
18	CB11.5	9/25/2023 7:29	79.5172	150.0780	3815	3804	405-428	5/10	Cast at IBO3
19	CB11	9/26/2023 1:31	78.9950	149.9522	3820	3807	429-452	7/10	
20	CB13	9/26/2023 19:35	77.3057	143.2963	3780	3773	453-476	0/10	

21	CB12	9/27/2023 3:54	77.7017	146.6797	3800	3803	477-500	5/10	
22	CB9DNA	9/27/2023 21:31	78.0025	149.9925	3825	1004	501-524	1/10	Productivity ("DNA/RNA" cast)
23	CB9-HR	9/27/2023 23:48	78.0002	149.9817	3822	401	525-548	1/10	High Resolution cast focused in lower halocline btw Pacific Winter Water and Atlantic Water
24	CB10	9/28/2023 6:29	78.3030	153.2428	2455	2274	549-572	1/10	Pump not turned on until 30m. Top 30m bad.
25	CB9	9/28/2023 22:14	77.9837	150.0000	3825	3813	573-596	1/10	Geochemistry Cast at Mooring BGOS-B
26	CB8	9/29/2023 8:05	76.9983	150.0008	3821	3815	597-620	0/10	
27	CB7	9/29/2023 18:03	75.9997	149.9947	3826	3819	621-644	0/10	Winch not spooling properly. Winch stopped on upcast at 1111m and went back down to 1167. Bottles 1-4 had already been fired and may be compromised.
28	CB5	9/30/2023 4:34	75.2987	153.2993	3837	3832	645-668	0/10	Stopped at 10 m for 8 minutes while ship adjusted to fix port angle. Winch issue at 2453m, making a bad sound (operator error). No bongos due to 26 kt winds.
29	CB19	10/1/2023 10:43	74.3015	143.3102	3697	3689	669-692	0/10	Rosette bumped ship upon recovery due to large waves.
30	CB6	10/1/2023 20:49	74.7032	146.6992	3777	3770	693-716	0/10	
31	CB4DNA	10/2/2023 6:34	74.9990	150.0063	3822	1004	717-740	0/10	Productivity ("DNA/RNA" cast)
32	CB4	10/2/2023 8:56	74.9977	149.9963	3826	3817	741-764	0/10	Geochemistry Cast at Mooring BGOS-A
33	CB3	10/3/2023 7:09	73.9997	149.9995	3821	3814		0/10	Bottle flushin tested by changing fire order to tripping Niskins 13 to 24 first and then 1 to 12.
34	CB2	10/3/2023 16:23	72.9975	150.0050	3754	3737	789-812	0/10	
35	CB2a	10/3/2023 23:42	72.4997	149.9950	3730	1003	813-834	0/10	
36	BL8	10/4/2023 3:30	71.9503	150.3015	3000	2948	835-858	0/10	
37	BL6	10/4/2023 7:46	71.6805	151.1433	2080	2079	859-881	0/10	
38	BL4	10/4/2023 10:45	71.5198	151.5758	1130	1196	882-902	0/10	
39	BL3	10/4/2023 13:07	71.4642	151.8315	465	499	903-919	0/10	
40	BL2	10/4/2023 14:59	71.3963	151.9505	170	166	920-931	0/10	
41	BL1	10/4/2023 16:33	71.3598	152.0825	82	76	932-939	0/10	
42	StnA	10/5/2023 3:56	72.5977	144.7190	3450	3414	940-963	0/10	
43	CB21DNA	10/5/2023 21:40	74.0092	140.0282	3525	1003	964-987	0/10	Productivity ("DNA/RNA" cast)
44	CB22	10/6/2023 4:23	73.4460	138.0010	3124	3107	988-1011	0/10	
45	CB21	10/6/2023 23:29	74.0002	139.9977	3512	3496	1012-1035	0/10	BUBBLERS/THRUSTERS WERE ON DURING CTD LAUNCH TO FIX INBOARD LEAD SO SURFACE LIKELY WELL-MIXED
46	CB27	10/7/2023 9:04	73.0012	140.0072	3225	3206	1036-1059	0/10	
47	MK7	10/7/2023 15:02	72.5125	139.9998	3002	2985	1060-1083	0/10	
48	CB29	10/8/2023 0:01	71.9993	139.9975	2690	2668	1084-1107	0/10	
49	MK6	10/8/2023 5:11	71.5698	139.9985	2500	2459	1108-1131	0/10	
50	cb28B	10/8/2023 11:06	71.0015	139.9957	2092	2068	1132-1155	0/10	
51	MK4	10/8/2023 15:01	70.8080	139.9998	1520	1539	1156-1179	0/10	

52	MK3'	10/8/2023 17:37	70.6518	139.9962	1270	1253	CTD only	0/10	
53	MK3	10/8/2023 19:39	70.5680	139.9917	800	761	1180-1202	0/10	
54	MK2	10/8/2023 22:02	70.4015	139.9983	504	493	1203-1221	0/10	
55	MK1	10/9/2023 0:34	70.2267	139.9915	230	228	1222-1235	0/10	
56	CB28aa	10/9/2023 2:31	70.0012	139.9987	50	51	1236-1242	0/10	

5.2.2 XCTD

Table A6. XCTD cast deployment locations. File name starting with C3 indicates the probe type was XCTD-1N.

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	Probe Serial Number	Probe Type	Cast Depth (m)	Comment
C3_00006.edf	9/18/2023 11:02	72.072831	132.97872	21107506	XCTD-01N	1000.0	
C3_00007.edf	9/18/2023 17:29	72.678165	135.18615	21107510	XCTD-01N	1000.0	
C3_00008.edf	9/19/2023 2:20	73.197843	135.15701	21107507	XCTD-01N	1000.0	
C3_00009.edf	9/19/2023 9:56	73.500137	132.63363	21107509	XCTD-01N	1000.0	
C3_00016.edf	9/19/2023 21:05	73.62061	133.10388	21107516	XCTD-01N	1000.0	Position from TSG track
C3_00017.edf	9/20/2023 4:56	74.00515	135.1493	22031273	XCTD-01N	1000.0	Position from TSG track
C3_00018.edf	9/20/2023 15:35	74.739075	137.63298	22031274	XCTD-01N	1000.0	
C3_00019.edf	9/21/2023 1:26	75.510483	140.00756	22031275	XCTD-01N	1000.0	
C3_00020.edf	9/21/2023 10:59	76.082642	137.61295	22031278	XCTD-01N	1000.0	
C3_00021.edf	9/21/2023 17:13	76.170012	134.93326	22031277	XCTD-01N	1000.0	
C3_00026.edf	9/22/2023 4:18	76.431385	134.20554	22031284	XCTD-01N	1000.0	
C3_00027.edf	9/22/2023 12:49	76.761402	137.57244	22031280	XCTD-01N	1000.0	
C3_00029.edf	9/22/2023 22:00	77.487076	139.96364	22031279	XCTD-01N	1000.0	
C3_00030.edf	9/23/2023 6:59	78.469467	140.18148	22031283	XCTD-01N	1000.0	
C3_00031.edf	9/24/2023 10:46	79.125169	143.04316	22031282	XCTD-01N	1000.0	
C3_00033.edf	9/25/2023 1:55	79.385541	147.31814	21117974	XCTD-01N	1000.0	
C3_00034.edf	9/25/2023 23:53	79.181826	150.0894	21117975	XCTD-01N	1000.0	
C3_00035.edf	9/26/2023 7:19	78.511902	150.00228	21117976	XCTD-01N	1000.0	
C3_00036.edf	9/27/2023 0:49	77.506277	144.93069	21117978	XCTD-01N	1000.0	
C3_00037.edf	9/27/2023 9:22	77.869586	148.28309	21117980	XCTD-01N	1000.0	
C3_00038.edf	9/28/2023 3:32	78.166265	151.59998	21117979	XCTD-01N	1000.0	

C3_00039.edf	9/29/2023 4:06	77.527303	149.90449	21117981	XCTD-01N	1000.0	
C3_00040.edf	9/29/2023 13:53	76.535313	149.98202	21117983	XCTD-01N	641.7	
C3_00043.edf	9/30/2023 0:29	75.659996	151.65155	21117982	XCTD-01N	1000.0	
C3_00044.edf	9/30/2023 9:59	75.148577	151.72025	21117985	XCTD-01N	1000.0	
C3_00048.edf	10/7/2023 5:33	73.499399	139.94515	22072681	XCTD-01N	1000.0	
C3_00049.edf	10/1/2023 17:35	74.534716	145.24976	22072701	XCTD-01N	1000.0	
C3_00051.edf	10/2/2023 2:48	74.860537	148.28846	22072691	XCTD-01N	1000.0	
C3_00052.edf	10/3/2023 2:49	74.521662	150.13225	22072692	XCTD-01N	1000.0	
C3_00053.edf	10/3/2023 13:03	73.513821	149.97289	22072693	XCTD-01N	1000.0	
C3_00054.edf	10/4/2023 6:35	71.81994	150.76347	22072700	XCTD-01N	1000.0	
C3_00055.edf	10/4/2023 9:58	71.59696	151.3504	22072697	XCTD-01N	1000.0	
C3_00057.edf	10/4/2023 19:27	71.657113	150.25514	22072694	XCTD-01N	1000.0	
C3_00058.edf	10/4/2023 22:35	71.994023	148.26727	22072698	XCTD-01N	1000.0	
C3_00059.edf	10/5/2023 1:04	72.292214	146.55442	22072695	XCTD-01N	1000.0	
C3_00060.edf	10/5/2023 8:28	73.049505	143.25346	22072696	XCTD-01N	1000.0	
C3_00061.edf	10/5/2023 10:53	73.526182	141.64719	22072699	XCTD-01N	1000.0	
C3_00062.edf	10/6/2023 1:24	73.736809	139.04558	22072702	XCTD-01N	1000.0	
C3_00064.edf	10/9/2023 7:21	70.585357	137.01657	22072680	XCTD-01N	961.8	
C3_00065.edf	10/9/2023 11:09	71.271738	134.61862	22072679	XCTD-01N	884.1	
C3_00230.edf	9/29/2023 14:13	76.49625	149.98446	21117984	XCTD-01N	1000.0	Position from TSG track

Table A7. XCTD cast deployment locations for CCGS Sir Wilfrid Laurier in support of the JOIS/BGOS program (Cruise ID 2023-018 DFO-IOS).

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	Probe Serial Number	Probe Type	Cast Depth (m)	Comment
C3_00031.edf	10/6/2023 6:48	70.639863	140.91445	22031285	XCTD-01N	1000	XCTD1. SN ***85. File ***31. Intermittent small data gaps.
C3_00032.edf	10/6/2023 10:56	71.099602	142.5905	22031288	XCTD-01N	537	XCTD2. SN ***88. File ***32. Data only until ~450 m.
C3_00033.edf	10/6/2023 15:52	71.52345	144.18062	22031287	XCTD-01N	1000	XCTD3. SN ***87. File ***33. Probe 86 didn't initialise. Data gaps. Used another probe (***87).
C3_00043.edf	10/6/2023 20:15	71.898603	145.83071	22031290	XCTD-01N	48	XCTD4. SN***90. File ***43. Probe 89 didn't initialise. Major data gaps.
C3_00044.edf	10/7/2023 0:27	72.24604	147.39582	22031291	XCTD-01N	121	XCTD5. SN***91. File ***44. Data only until ~100 m. System 'refurbished'.
C3_00046.edf	10/7/2023 5:09	72.586372	149.05878	22031292	XCTD-01N	389	XCTD6. SN***92. File ***46. Problem initializing. Data only until ~400 m.

C3_00047.edf	10/7/2023 10:18	72.944575	150.89961	22031293	XCTD-01N	78	XCTD7. SN***93. File ***47. Spotty data down to ~100 m.
C3_00048.edf	10/7/2023 14:40	73.278082	152.82031	22031294	XCTD-01N	69	XCTD8. SN***94. File ***48. Spotty data only near surface. Harddrive Crash on computer.
C3_00049.edf	10/7/2023 18:08	73.549948	154.59759	22031295	XCTD-01N	538	XCTD9. SN***95. File ***49. Data between 100 - 500 m.
C3_00050.edf	10/7/2023 22:25	73.881885	156.9447	22031296	XCTD-01N	36	XCTD10. SN***96. File ***50. Spotty data down to ~50 m. Trouble initializing.
C3_00051.edf	10/8/2023 2:30	74.192075	159.26754	22031289	XCTD-01N	799	XCTD11. SN***86. File ***51. Retry probe *86, bad profile. SZ: The data file says this is probe ***89, not ***86.

5.2.3 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.

Table A8. Zooplankton vertical bongo net hauls.

Station	Net #	CTD #	Date (UTC)	Time (UTC)	Lat Deg N	Lon Deg W	Bottom Depth	Wire angle	RBR Depth	Notes
AG5	1	2	17/9/23	6:50	70.5473	122.9063	663	0	96.64	
CB01	2	3	18/9/23	8:28	71.7792	131.8865	1136	10	92.24	
CB31b	3	4	18/9/23	13:42	72.3472	134.0088	2206	20	90.20	
CB23A	4	5	18/9/23	22:17	72.8947	135.9964	2744	25	84.89	
CB50	5	6	19/9/23	5:53	73.4986	134.2246	2887	10	93.09	
CB51	6	7	19/9/23	7:50	73.4974	130.9028	2507	5	93.28	
CB40	7	8	20/9/23	10:04	74.4953	135.4225	3250	5	87.64	
CB18	8	9	20/9/23	20:02	75.0022	139.9857	3624	0	92.09	
CB17	10	10	21/9/23	5:30	76.0044	139.9655	3696	5	96.17	There is no net 9 event as it was skipped accidentally and it's easier to adjust the log event numbers than to open zooplankton jars and change labels inside.
PP6	11	11	21/9/23	22:48	76.2570	132.5084	3035	5	95.40	
PP7	12	12	22/9/23	0:37	76.5340	135.4736	3573	0	94.71	

CB15	13	13	22/9/23	9:57	76.9986	139.9647	3725	5	94.71	
CB16	14	14	22/9/23	1:57	78.0044	139.9875	3748	0	94.99	
CB16N	15	16	23/9/23	4:48	78.9322	140.8520	3777	5	85.97	
I2-23	16	17	24/9/23	21:13	79.3618	145.7359	3805	5	94.94	
CB11.5	17	18	25/9/23	1:00	79.5145	150.0792	3818	5	94.46	
CB11	18	19	26/9/23	2:45	78.9951	149.9386	3823	0	95.73	Power supply on the winch-counter changed
CB13	20	20	9/26/2023	20:04	77.3080	143.3045	3780	10	91.55	CB12 and CB13 are both called Net#20
CB12	20	21	26/9/23	4:05	77.7027	146.6829	3805	5	93.21	CB12 and CB13 are both called Net#20
CB10	21	24	28/9/23	7:24	78.3057	153.2359	2289	0	94.83	
CB9GEO	22	25	28/9/23	15:40	77.9835	149.9984	3822	0	99.19	
CB8	23	26	29/9/23	1:34	76.0007	149.9940	3821	15	104.21	
CB7	24	27	29/9/23	18:27	75.9996	149.9794	3826	0	92.89	
CB19	25	29	1/10/23	11:15	74.3020	143.3075	3697	0	94.68	
CB6	26	30	1/10/23	21:08	74.7036	146.6945	3777	0	99.89	
CB4	27	32	2/10/23	9:19	74.9970	149.9922	3823	5	97.02	
CB3	28	33	3/102023	7:35	73.9999	150.0041	3821	10	100.25	
CB2	29	34	3/10/23	16:49	73.0014	150.0123	3756	15	94.50	Had to pause net retrieval halfway up (50m) because wire was under ship.
CB2a	30	35	3/10/23	17:02	72.5025	149.9787	3723	20	90.71	
BL8	31	36	3/10/23	3:51	71.9501	150.2976	2969	15	93.88	Flow meter was open at the end.

BL6	32	37	4/10/23	8:04	71.6828	151.1436	2086	10	98.32	
BL4	33	38	4/10/23	11:02	71.5194	151.5674	1192	25	89.01	Had to hold bongos at 100m because wire was under ship.
BL2	34	40	4/10/23	15:19	71.3978	151.9451	180	0	84.70	Jelly got caught in FORM net so most of sample was lost.
StnA	35	42	5/10/23	4:16	72.5980	144.7064	3430	25	78.95	
CB22	36	44	10/5/2023	4:42	73.4459	137.9928	3125	5	101.47	
CB21	37	45	10/6/2023	23:49	73.9997	139.9796	3508	30	98.02	
CB27	38	46	10/6/2023	9:22	73.0021	140.0047	3224	5	106.18	
MK7	39	47	7/10/23	15:25	72.5129	139.9984	2999	0	108.99	
CB29	40	48	7/10/23	0:23	71.9990	139.9905	2684	20	101.77	The rope to attach the bongos to the weight broke.
MK6	41	49	7/10/23	5:33	71.5675	139.9987	2479	0	99.83	
MK4	42	51	8/10/23	15:21	70.8066	139.9949	1536	5	97.49	
MK3	43	53	8/10/23	20:00	70.5666	139.9996	776	5	94.40	
MK2	44	54	8/10/23	22:16	70.4029	139.0038	505	0	94.24	SZ: 2023-12-07 Updated latitude
MK1	45	55	8/10/23	0:49	70.2262	139.9946	244	0	98.74	

5.2.4 Mooring Operations

The mooring anchor was ranged on in the pre-recovery survey, but it was deemed not necessary to range on the acoustic pinger near the top of the mooring because all mooring recovery and deployments were in completely open water.

Table A9. BGOS mooring recoveries and deployments from CCGS Louis S. St-Laurent 2023.

Mooring	Surveyed location (anchor*)	2023 Recovery	2023 Deployment	2023 Location (drop posn.)	Deploy bottom depth (m)
A	74 59.381 N 149 57.853 W *112 m from 2022 drop location	30 Sept. 16:29 UTC	2 Oct. 22:40 UTC	74 59.956 N 149 59.629 W	3825
B	78 00.894 N 150 03.101 W *435 m from drop	27 Sept. 15:49 UTC	28 Sept. 21:47 UTC	78 00.001 N 150 00.010 W	3822
D	74 00.103 N 140 03.191 W *240 m from drop	5 Oct. 15:48 UTC	6 Oct. 22:52 UTC	73 59.993 N 140 02.897 W	3527

Table A10. BGOS ice and open-water deployments/recoveries from CCGS Louis S. St-Laurent 2023.

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

Event	Buoy system	Date (2023)	Location	Ice thickness (m)
#1 OW 1	ITP 141	Sept. 18 21:06 UTC	72 54.313 N 135 59.115 W	N/A
#2 Recovery 1	ITP 130	Sept. 19 17:23 local	73 42.000 N 134 00.000 W	N/A (open water)

#3 IBO 1	ITP 138 TOP 011 AOFB 55 SIMB 2023 #6	Sept. 23 23:40 UTC	78 57.9826 N 140 48.4792 W	0.42 – 0.80
#4 IBO 2	TOP 008	Sept. 24 19:07 UTC	79 21.609 N 145 27.916 W	0.35
#5 IBO 3	ITP 139 TOP 009 SIMB 2023 #7	Sept. 25 20:26 UTC	79 24.120 N 149 58.310 W	0.50 – 1.2
#6 OW 2	TOP010	Oct. 3 20:43 UTC	73 02.930 N 148 57.647 W	N/A
#7 Recovery 2	TOP004	Oct. 7 20:44 UTC	72 12.100 N 140 25.020 W	N/A (open water)

Table A11. DeGrandpre group sensor data collection summary. The sensor time-series collected for moorings recovered in 2023 and the new ITPS are summarized below.

In addition we collected underway *p*CO_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 (6-pin b/h)
Days of Data	85	251	94	367
BGOS-B Mooring				
	CO2	**pH**	**O2**	**PAR**
Instrument ID	C48u	XXX	4175: 717 (4-pin b/h)	XXX
	XXX	P68u	XXX	9385 (6-pin b/h)
Days of Data	67	339	67	339
BGOS-D Mooring				
	CO2	**pH**	**O2**	**PAR**
Instrument ID	C37u	XXX	4175: 1699 (5-pin b/h)	XXX
	XXX	P5u	XXX	9386 (4-pin b/h)
Days of Data	361	251	361	251
ITP-138				
	CO2	**IMM ID**	**Aanderaa ID**	**PAR**
Instrument ID	C252	700-9548	4531A: 1517	UWQ-11435
Days of Data	20	20	20	20
ITP-139				
	CO2	**IMM ID**	**Aanderaa ID**	**PAR**
Instrument ID	C253	700-9551	4531A: 1518	UWQ-10480
Days of Data	17	17	17	17

5.3 Record of Ship's Time Zone Changes

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

- September 14, start of cruise ship local is NDT (UTC - 2.5 hours)
- September 17 - start of science program, we are UTC - 4.5 hours (no defined time zone!)
- September 17 - 0800 UTC, ship is PDT (UTC - 7hrs)
- October 10 - after science program is completed, change to MDT (UTC - 6) to match Cambridge Bay time for crew change.

5.4 CTD/Rosette Sensor Configuration

ROS 1 to 56 (all casts)

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

CTD

CTD#	Make	Model	Serial#	Used with Rosette?	Casts Used
Primary	SeaBird	911+	1493	Yes	All casts
Secondary	SeaBird	911+	756		Not used; backup

Calibration and Accuracy Information CTD #1493 PRIMARY								
Sensor		Accuracy	Pre-Cruise		Post Cruise		Comment
Name	S/N		Date	Location	Date	Location	
Pressure Sensor, Digiquartz with TC	1493	Nominal 1.2 m	New: 10-Nov-22	SeaBird Lab			
Temperature, SBE3plus	6726	Nominal ± 0.001 °C	New: 02-Dec-22	SeaBird Lab			
Conductivity, SBE4C	6137	Nominal 0.003 mS/cm	New: 14-Dec-22	SeaBird Lab			
Pump, SBE5T	05-		New:				
Secondary Temp., SBE3plus	6727	Nominal ± 0.001 °C	New: 02-Dec-22	SeaBird Lab			
Secondary Cond., SBE4C	6139	Nominal 0.003 mS/cm	New: 14-Dec-22	SeaBird Lab			
Secondary Pump, SBE5T	05-		New:				

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	2599		New: 30-Dec-22	SeaBird Lab			CTD Voltage Channel 2 On Primary pump;
Altimeter, Valeport VA500	80262		8 Feb 2022	Valeport			CTD Voltage Channel 3 Scale factor 15, Range limit 100m
Seapoint Fluorometer (Chl-a)	3741		16-Jul-2014; 2 pt check at IOS: 17-Feb-2022	Seapoint; 2 pt check at IOS			CTD Voltage Channel 0 On Secondary Pump;
Wetlabs C-Star Transmissometer	CST-1052DR		04-Jun-2022	IOS (In-house light/dark test)			CTD Voltage Channel 1
WETLabs ECO CDOM	6677		New: 3-Apr-2021	WETLabs			CTD Voltage Channel 4
Satlantic Cosine Log PAR	517		2014-Jun-25	Satlantic			CTD Voltage Channel 6
Biospherical Surface PAR QSR2200	20498		4 Apr 2016	Biospherical			
Biospherical PAR QSR2150 (Continuous)	50228		21 Jun 2016	Biospherical			External to CTD data
Alec Rinko III dissolved oxygen sensor	0285, Film B		23-Jan-2017; 19-Jan-2023; xx-Oct-2023	Alec; IOS; On board			Cast 1 to 56; V7

Deck Units

Type	Make	Model	Serial #	Comment
Deck Unit	Seabird	11plus	1281	Primary
Deck Unit	Seabird	11plus	680	Backup. Not used.

Rosette Pylons

Type	Make	Model	Serial #	Comment
Water Sampler Carousel	Seabird	32	1231	Pylon used for all casts; trigger swapped throughout; trigger damaged during cruise
Water Sampler Carousel	Seabird	32	498	Pylon as backup; trigger swapped in throughout

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

5.5 Seawater Loop Measurements

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

5.5.1 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.

On the first manifold arm is a Kate's mechanical flow rate controller followed by a vortex de-bubbler, installed inline to remove bubbles in the supply to the SBE-21 thermosalinograph (TSG). This is the only system that had a de-bubbler.

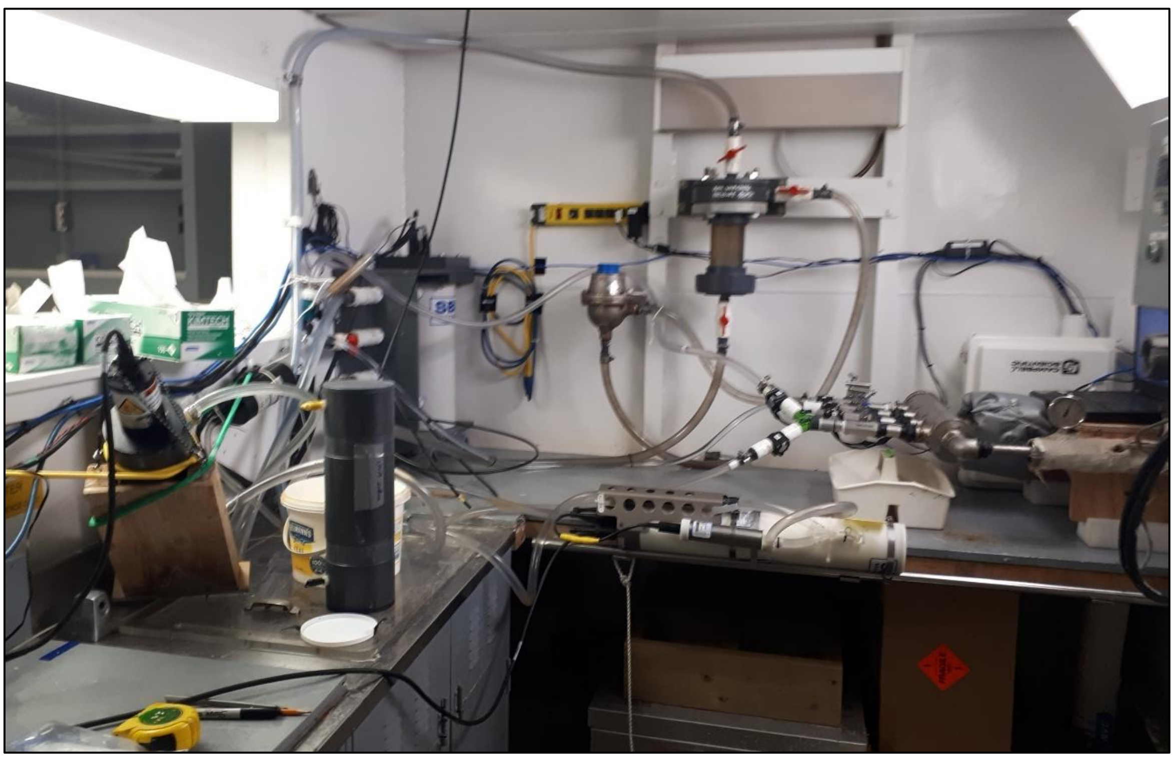


Figure A1. Seawater loop system w/ Chl-a and FDOM sensors attached to left wall, the second FDOM sensor in wood cradle. The pCO2 system sits on the center of the back bench

but has just been packed away. The manifold's new needle valves, flowmeters, data logger in white box and laptop are on the right side of the room. The SBE19+ being used as a backup TSG is mounted to the bench handrail. The O2/Ar system was installed on the other side of the passthrough. The seawater loop provides uncontaminated seawater from 9m depth to the science lab for underway measurements (photo 2023).

New this year were calibrated flow valves that displayed and logged flowrate in real time. This was done using a Campbell Scientific interface box and software. In addition, the plastic ball valves were replaced with metal needle valves giving much finer control over the flowrate.

Figure A2. @Left: TSG manifold, flow meters, data logger and laptop. @Right: TSG tank and fluorometer pair with orientation to not trap bubbles and have good flow past sensor (vertical orientation for Chl-a and horizontal orientation for FDOM) (photos 2023).

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 A3. Honeywell controller for the pump, located in the TSG lab.

Figure A4. Seawater passes through a filter (in front of engineer) before going to the pump (on orange platform). 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. Photos are from previous years, but is the same strainer configuration for 2023.

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 A5. SBE38 temperature sensor in the engine room (2022). NOTE THE RED HANDLE AT BOTTOM OF PHOTO. THIS VALVE IS IN THE CLOSED POSITION DURING OPERATION. This handle is hidden from view when open, but needs to be closed to force flow past the temperature sensor to get accurate seawater measurements

A second manifold arm had a Y branch with the TSG's Chl-a fluorometer and FDOM sensor off one branch and the U de Sherbrooke FDOM sensor off the other branch.

A third arm of the manifold went to an automated system for measurements of pCO2. Measurements were made with an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors) by Cory Beatty, and 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 (Section 4.4 *Sea surface pCO2, pH, and dissolved O2*).

A fourth arm of the manifold went to an automated measurement of oxygen to argon ratio. On this branch, O2/Ar measurements were made with a quadrupole mass spectrometer and O2% saturation using an Aanderaa optode (model 4531A). Oxygen water samples were taken to for oxygen comparison. The O2/Ar measurements were made by Zhangxian Ouyang and Wei-Jun Cai (University of Delaware). Please see their report for more information (Section 4.7.2 *Underway measurement of O2/Ar ratio*).

The TSG 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 GPSgate software and the ship's science LAN to shuttle data: bring in the ship's GPS, bring in the SBE38 (inlet temperature) data from the engine room to the TSG instrument, and to pass out the TSG and SBE38 data to the ship's data collection system (SCS). The software program GPSgate provided the conversion between USB, TCP/IP, and virtual and real communication ports.

5.5.2 Issues, Settings, Instruments

The Seawater Manifold is configured with four outlet arms:

- Arm 1: Valve 1 to de-bubbler and then TSG
- Arm 2: Valve 2 to the O2/Ar setup (EIMS)
- Arm 3: Valve 3 to the pCO2 system
- Arm 4 with Y
    - Valve 4 to Fluorometer 1: Seapoint Chl-a Fluorometer w/ 30x gain and then to Wetlab FDOM fluorometer SN1281.
    - Valve 5 to Fluorometer2: USherbrooke's Wetlab FDOM sensor

Pump Settings and Flow Rate

Flow rate varied often due to sea-ice clogging the strainer at the ship's sea-water inlet, or pump malfunction. Sometimes the flow stopped altogether due to clogging and the pump would be turned off 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.

The Honeywell controller was initially running in automatic mode to a set point of PV=18.3 however the flow rate was not high enough. The was a problem with the pressure transducer so in the end a fixed frequency was used giving a fixed pump speed.

Typical flow rates after initial adjustments (~19 Sep, 2023) but will need to review logged flowrate for actual flow rates.

TSG	20 L/min (this is higher than in past years)
O2/Ar Systme (EIMS)	3 L/min
pCO2	2 L/min
Fluorometer pair	2 L/min
FDOM single (UdeS)	5.25 L/min

Water Pressure at manifold: Pressure Transducer shows 48.2psi, Silver gauge shows 56psi. Out is 26%
As the optimal flowrate was being found, the engineer closed a shunt near the pump a bit more. Seawater still has an out through this shunt, but the volume was reduced. (One aspect of the shunt is a safety in case we had closed all the valves and the seawater had nowhere to go).

Water samples

Discrete water samples for Salinity, FDOM, DIC, Alkalinity, Chlorophyll, and Oxygen 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. Nutrient samples were collected at the end of the cruise as the ship transited through Dolphin and Union St.

Major Issues with Sea Water Pump and TSG data

Notes are recorded primarily in the paper TSG Log Book and will be copied to the file:

Processed 2023 TSG Log with CNV and Sample data.xlsx

Intake temperature (Sea surface temperature from SBE38)

Flow was not passing by sensor as fully as it should be until Sep 22 09:00 when valve to bypass was shut. All prior temperature data will need to be looked at and determined if the intake temperature should be used or replaced with an adjustment to the lab sea-water temperature (temperature of water once it reached the lab measured by the TSG).

Salinity

The conductivity sensor was been behaving poorly, reading too fresh and with unbelievable jumps and drift. While the ship was parked at the ice-station, the sensor was removed sensor from the TSG housing, the guard removed, the sensor cleaned with Triton-X, the poison pucks were checked and the bottom puck was left off and finally reinstalled in the TSG housing. The sensor performance did not improve.

Starting Sep 25 02:14, a SBE19+ CTD was set up with a portion of flow from the TSG supply, powered externally and logged continuously to SEASAVE using a second laptop. Flow rate was chosen at 2L/min, similar to the flow the CTD would have during a cast. The CTD's performance was good, however the calibration is from 2017 and will be compared to the water sample salinities.

Pump Transducer and Honeywell Control Box

The LED panel of the Honeywell Control Box has faded to the extent that its only readable when the lab lights are turned off. In effort to set the Honeywell controller to a higher process variable, the pressure transducer needed setting to a new range. The transducer couldn't be reset – unclear if it was a transducer problem or missing the external keypad for the transducer. It may be fixable, or a new transducer should be installed. Without this, the pump was set to run at a fixed frequency.

5.5.3 TSG Configuration

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	Conductivity was intermittently bad during cruise.	05-Feb-23	SeaBird Lab	In progress	SeaBird Lab	Conductivity cell replatinized before pre-cruise cal. Ground connector replaced.
Seabird Temperatrue SBE-38 (Intake temperature)	0319		8 Dec 2022	SeaBird Lab	No post cruise cal	SeaBird Lab	
Seapoint Chlorophyll Fluorometer	SCF2841 30x gain		Jun 2014	Seapoint 2pt health check at IOS (20 Feb 2023)			30x gain cable (0 to 5V = 0 to 5mg/mL)
Wetlabs ECO CDOM Fluorometer	WSCD-1281		17 Jun 2015	Wetlabs			
Computer: laptop Pteropod D2020-02							Receives updates from timeserver

- In SEABIRD acquisition software: NMEA option has "Time Added" box checked
- SBE38 via internet sent out from computer using real Com # assigned by the USB to serial converter, then null modem to cable to TSG housing.
- New for 2023: Computer has time and date updated by timeserver.

Alternate TSG: Seabird SBE19+ SN 4560

Calibration and Accuracy Information, TSG							
Sensor		Accuracy	Pre-Cruise		Post Cruise		Comment
Name	S/N		Date	Location	Date	Location	
Seabird TSG SBE19+	4560		4 Jan 2017	SeaBird Lab			

5.6 Logging of Underway measurements with SCS

Paul Macoun, Sarah Zimmermann (DFO-IOS)
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.

5.6.1 Issues with the underway system and data

Many things had changed between now and last year, requiring effort to get the system back up and running.

GPS: As is typical, the GPS input to the server was disconnected when we arrived. We connected to one multi-serial-port box in the rack but the GPS feed kept dropping out. We then setup a GPS feed using a "puck" mounted on top of the CTD shack via the Knudsen computer. However that feed too began to drop out. Then a) we found a new multi-port box to plug the server serial cable into and b) setup a separate stand-along laptop in the CTD shack to provide a GPS feed as backup.

GPS (GGA): First record 2023-09-15 @ 23:42:28 UTC –some intermittency as a result of choice of input

GPS (RMC): First record 2023-09-15 @ 23:42:28 UTC

HDT-Gyro: New converter box found for cabinet on the bridge. The gyro output is fed into a serial server which is then connected to the network via a long Ethernet cable that runs from the cabinet to the bot block display on the starboard side of the bridge, where a science LAN network port is available.

Gyro feed started: 2023-09-18 18 @ 01:10:40 UTC

AVOS : First record 2023-09-16 @ 01:41:54 UTC

The anenometer was covered in ice and was not moving for a number of days. After trying to beat off some of the ice, the propeller began to turn but less than the actual wind speed. The Ice Watch team logged true wind from the ship's system from a different source than AVOS (I believe) while the AVOS system wasn't working properly.

It would be good to compare readings to a) build a good wind data set and b) to clarify when the AVOS system was not working properly.

Plot of AVOS windspeed clearly shows bad data from 21-Sep-2023 22:19:55 to 28-Sep-2023 00:00:00.

SBE38: First record 2023-09-15 @ 23:44:08 UTC

PAR: First record 2023-09-16 @ 01:30:09 UTC

TSG: First record 2023-09-15 @ 23:42:29 UTC

These data are preliminary. We need to confirm config file being used and further processing and calibration performed in the Seabird TSG files as opposed to these files.

Sounder: UDP signal not being seen by server. Correction? Switch settings? Switched off and on? Mysteriously, the sounder feed started: 2023-09-26 05:11 UTC Sounder data were quite good this year.

FDOM: First record 2023-09-21 @ 22:04:12 UTC

True Wind : First record 2023-09-18 @ 01:10:40 UTC – dependant on Gyro/heading

5.6.2 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 2023:

<u>Position, Time, Date, Speed and Course over ground - $GPRMC</u>

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:

Date MM/DD/YYY (timestamp from SCS)
Time HH:MM:SS.SSS (timestamp from SCS)
"$GPRMC"
Time HHMMSS.SS
Status A= Active, V=Navigation receiver warning
Latitude DDMM.MMMM
Latitude N or S
Longitude DDDMM.MMM
Longitude E or W
Speed over ground in knots
Course over ground in degrees (True)
Date DDMMYY

Magnetic variation in degrees (999.9 = not valid)
Variation E or W
Mode indicator: A=Autonomous, D=Differential
No comma before this field – checksum starting with *

Extracted and stored in the Database:

RMC-Time UTC
RMC-Latitude
RMC-Longitude
RMC-SOG
RMC-COG
RMC-Date

<u>Position - $GPGGA</u>

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:

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

Extracted and stored in the Database:

GGA-Quality (#9 above)
GGA-Satellite Count
GGA-Age of data

<u>Depth – "Sounder"</u>

Depth is measured using the 3.5, 12 or 30kHz transducers using a new for 2018 Knudsen CHIRP 3260 Echosounder, labeled "Science". 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.

It was determined in past years that if the ship's "fish finder" 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:

Date MM/DD/YYY (timestamp from SCS)
Time HH:MM:SS.SSS (timestamp from SCS)
"Sounder"
Date UTC: DDMMYYYY
Time UTC: hhmmss
Sounder frequency (3.5kHz)

Depth (3.5kHz)
Applied draft (3.5kHz)
Sounder frequency (12kHz)
Depth (12kHz)
Applied draft (12kHz)
Sounder frequency (30kHz)
Depth (30kHz)
Applied draft (30kHz)
Soundspeed m/s

Extracted and stored in the Database:

Knudsen-Sounder-3.5kHzDepth
Knudsen-Sounder-3.5kHzTD
Knudsen-Sounder-12kHzDepth
Knudsen-Sounder-12kHzTD
Knudsen-Sounder-30kHzDepth
Knudsen-Sounder-30kHzTD
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,,,,1018.8 4,,-2.0,60,,,,24.7,,,140.8,13.4*75

Sentence fields:

Date MM/DD/YYY (timestamp from SCS)
Time HH:MM:SS.SSS (timestamp from SCS)
"$AVRTE"
Date UTC: YYMMDD
Time UTC: hhmmss
Region?
Ship's Call Sign
Relative wind speed, knots
Apparent wind direction, degrees true north
Relative wind direction, degrees where ship's bow is "North"
Space for 2nd wind sensor, not installed
Space for 2nd wind sensor, not installed
Space for 2nd wind sensor, not installed
Barometric pressure, Mbar (same as mmhg)
Space for 2nd barometer, not installed
Air temperature, degrees C
Relative Humidity, %
Space for 2nd temperature sensor
Space for 2nd humidity sensor
Space for Sea Surface Temperature, degrees C (this is NOT the same as the sea water loop TSG intake reading – different source)
Wind gusts, knots
Blank space for 2nd wind sensor gust
Heading ($HEHDT) direction, "Compass 1", degrees (not active)
AVOS fluxgate compass direction, "Compass 2", degrees
AVOS battery voltage
No comma before this field – checksum starting with *

Extracted and stored in the Database:

AVOS-serial-AVRTE-date
AVOS-serial-AVRTE-time
AVOS-serial-AVRTE-wind speed
AVOS-serial-AVRTE-apparent wind
AVOS-serial-AVRTE-relative wind
AVOS-serial-AVRTE-barometric pressure
AVOS-serial-AVRTE-air temperature
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:

Date MM/DD/YYY (timestamp from SCS)
Time HH:MM:SS.SSS (timestamp from SCS)
Sea Surface Temperature in lab, Deg C
Sea Surface Temperature at intake, Deg C
Sea Surface Salinity, PSU
Sea Surface Conductivity in lab, mS/cm
Sea Surface Fluorescence (Chlorophyll-a), ug/L
Sea Surface Fluorescence (Chlorophyll-a) voltage, V
Sea Surface Wetlabs ECO CDOM Fluorometer voltage, V
Julian Day

Extracted and stored in the Database:

TSG-serial--T1
TSG-serial--T2
TSG-serial—Salinity
TSG-serial—Conductivity
TSG-serial—ChlFuorescence
TSG-serial--V0
TSG-serial--V1
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:

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

Extracted and stored in the Database:

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:

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

Extracted and stored in the Database:

ASCII-PAR-serialport-PAR