Joint Ocean Ice Study /
Beaufort Gyre Exploration Project
2021 Cruise Report

Mooring Recovery, photo by Gary Morgan

Report on the oceanographic research conducted aboard the *CCGS Louis S. St-Laurent,* August 19 to September 16th, 2021* IOS Cruise ID 2021-016

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

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1. OVERVIEW

The Joint Ocean Ice Study (JOIS) in 2021 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 Fisheries and Oceans Canada researchers (Bill Williams lead) and in the USA from Woods Hole Oceanographic Institution (WHOI) (Andrey Proshutinsky, Rick Krishfield, Isabela Le Bras leads) and from Yale University (Mary-Louise Timmermans). The scientists from WHOI and Yale University lead the Beaufort Gyre Exploration Project (BGEP, **http://www.whoi.edu/beaufortgyre/**) which maintains the Beaufort Gyre Observing System (BGOS) as part of the Arctic Observing Network (AON), funded by NSF.

The 2021 program includes collaborations with researchers from:

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

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, Hokkaido.

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, Quebec
- Université Laval, Québec City, Québec.
- Concordia University, Montreal, Quebec

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 Gyre Observing System	https://www2.whoi.edu/site/beaufortgyre/overview/scientific-motivation/
Beaufort Gyre Observing System dispatches	https://www2.whoi.edu/site/beaufortgyre/expeditions/2021-expedition/2021-dispatches/
Ice-Tethered Profiler buoys	https://www2.whoi.edu/site/itp/
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
Arctic Ocean Flux Buoy	www.oc.nps.edu/~stanton/fluxbuoy/

2. CRUISE SUMMARY

The JOIS/BGOS science program onboard the *CCGS Louis S. St-Laurent* began August 19th , departing from Cambridge Bay, NU and finished September 16th, 2021, 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 and close to 80°N in the north by a research team of 20 people from 8 institutions from 2 countries. Of the 20 people, 6 were students (undergraduate, masters and doctorate 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.

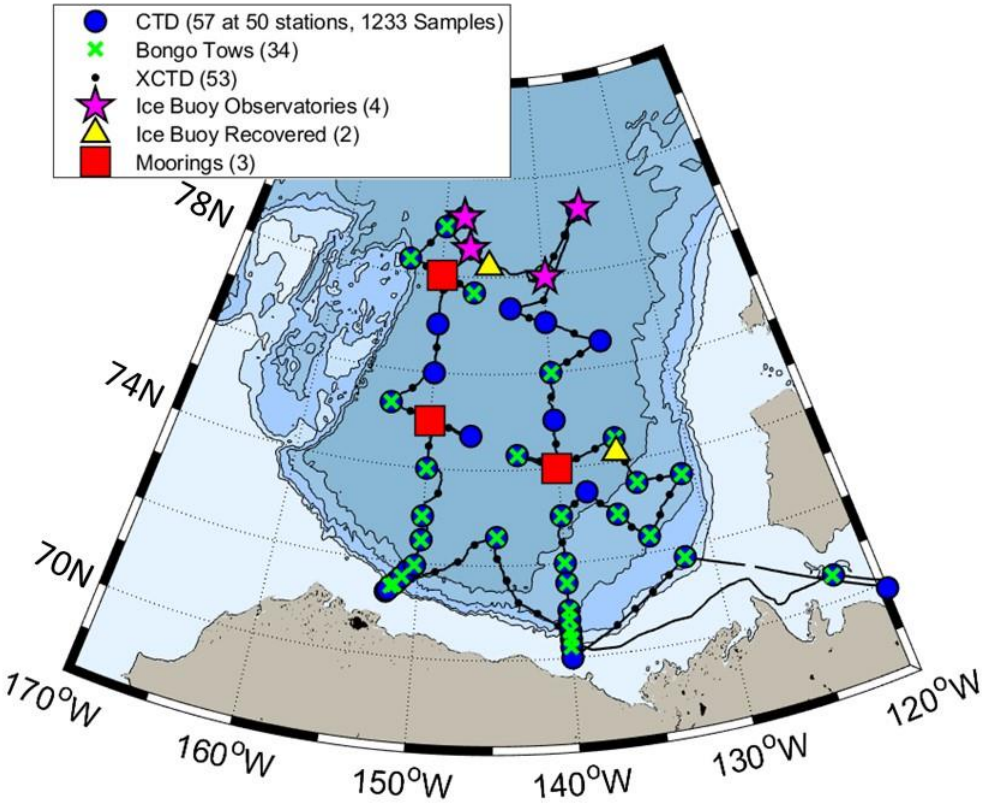


Figure 1.The JOIS/BGOS-2021 cruise track showing the location of science stations.

Following the JOIS program, opportunistic sampling was conducted from the CCGS Sir Wilfrid Laurier, deploying 8 XCTDs across the south-west Beaufort Sea. Although not part of this program, the XCTDs were conducted in support of the Beaufort Sea observations and are listed in the appendix.

2.1 Program Components

Measurements:

- At CTD/Rosette Stations:
  - 57 CTD/Rosette Casts at 50 Stations (DFO) with 1233 Niskin bottle water samples collected for hydrography, geochemistry and pelagic biology (bacteria, microbial diversity and phytoplankton) analysis (DFO, Sherbrooke U, TUMSAT, WHOI, Yale, U Laval, Concordia, JAMSTEC).
  - Water samples taken:
    - At all full depth stations: Salinity, dissolved O_2 gas, Nutrients (NO_3+NO_2, PO_4, SiO_4), ^{18}O isotope in H_2O, Bacteria, Alkalinity, Dissolved Inorganic Carbon (DIC), Fluorescent Dissolved Organic Matter (FDOM), Chlorophyll-a
    - At selected stations: microbial diversity, ^{129}I, Phytoplankton pigments using HPLC, Barium, Dissolved Organic Matter (DOM), Lignin-phenols,
  - Zooplankton Vertical Net ("Bongo") Casts at 34 CTD/Rosette stations with one cast to 100m. The two nets per cast have a mesh size of 150 µm and 236 µm. (DFO).
- 53 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1100m depth. (DFO, JAMSTEC, WHOI)
- Mooring operations (WHOI)
  - 3 Mooring Recoveries/Deployments in the deep basin (BGOS-A,B,D; WHOI)
- Buoy operations (WHOI, Yale, CRREL)
  - 1 Ship-based deployment in open water with:
    1 Ice-Tethered Profiler (ITP124, WHOI)
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler w/ SAMI-CO2 (ITP126, WHOI, UMontana)
    1 Seasonal Ice Mass Balance Buoy (SIMB-2021#2, CRREL)
    1 Tethered Ocean Profiler (TOP2, WHOI)
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler w/ SAMI-CO2 (ITP127, WHOI)

1 Tethered Ocean Profiler (TOP3, WHOI)

- 1 Ice-Station with:
  1 Ice-Tethered Profiler (ITP122, WHOI)
  1 Seasonal Ice Mass Balance Buoy (SIMB-2021#3, CRREL)
  1 Tethered Ocean Profiler (TOP2, WHOI)
  1 Arctic Ocean Flux Buoy (AOFB48, NPS)

- 2 Recoveries of buoys deployed in previous years:
  Ice-Tethered Profiler (ITP119, WHOI)
  Ice-Tethered Profiler (ITP112, WHOI)

- Ice Observations (KIT/OSU) were limited this year due COVID related travel restrictions keeping the participants from Japan from joining the trip.
  - Visual ice observations were made by automated photographs taken from 3 cameras at 1 minute intervals: 1 camera was mounted above the bridge looking forward, 1 mounted above the bridge on the port side looking down on the overturning ice with a measuring stick in view, 1 mounted in the bridge window looking forward.
  - On-ice measurements at the ice-stations including:
    - Drill-hole ice thickness transects
    - Ice-cores for temperature, salinity and structure profiles
    - Ice-cores for microbial microdiversity (ULaval)

- Underway collection of meteorological, depth, and navigation data, and near-surface seawater measurements of salinity, temperature, chlorophyll-a fluorescence, FDOM fluorescence as well as pCO2 (DFO-IOS, USherbrooke, UMontana).
  Water samples (78) were collected from the underway seawater loop for salinity, nutrients, chlorophyll, DIC and alkalinity (DFO), and FDOM (USherbrooke).

- Daily dispatches to the web (WHOI)

2.2 Comments on Operation

This year's program was a month earlier than the past few years. Due to ice conditions, we chose to travel clockwise around the Beaufort Gyre, allowing the heavier ice in the southeast Beaufort to melt and become weaker by the time we arrived at the end of the cruise. In general, operations were easier with the warmer weather and more day-light,

but the weak ice in the north (freeze up was only just starting) made it difficult to find suitable ice stations.
We started by steaming west. The 5 stations within 60nm of Barrow that are sometimes restricted due to the overlap with the whaling season were completed after receiving permission from the Alaska Eskimo Whaling Commission. The whaling season had not yet begun in Utqiagvik or Nuiqsut. We sampled our standard western stations along 150W from south to north. In the norther area we were looking for 4 ice stations total but had to replace the first ice station with an open water deployment due to the thin and weak condition of the ice. We were able to find ice thick enough for the remaining stations although only the last station, where we traveled farther north than our typical sampling grid, had a large enough area of solid ice for the large array of four buoys. We then traveled back south along 140W, giving up one station (PP6) in order to allow adequate time for the remaining stations. Being fortunate with no weather delays or problems with mooring operations, we were able to complete the remaining stations, particularly the closely spaced samples leading up the slope to the shelf close to the Mackenzie River outflow.

The three on-ice stations were done 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. This method worked well. Multiple science teams could start working quickly once the ladder was down and gave easy access to the ship for workers on the ice. Due to the generally weak ice at the ice-stations, the number of workers and the extent of the science operations on the ice were restricted to the essential operations.

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

The three mooring recoveries this year were for systems that had been in place for 3 years, 1 year longer than planned due to COVID related disruptions. Although two of the three top transponders that aid in recovery did not work, the third, on mooring D, worked well. This was particularly useful as the waters were ice-covered over this mooring. The recoveries and redeployments went well.

Due to COVID related travel restrictions our participants from Japan were unable to join us again this year. This limited the ice-observation work normally done and put extra

pressure on our chemistry analyst who now was tasked with running DIC/Alkalintiy samples single-handedly.
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.

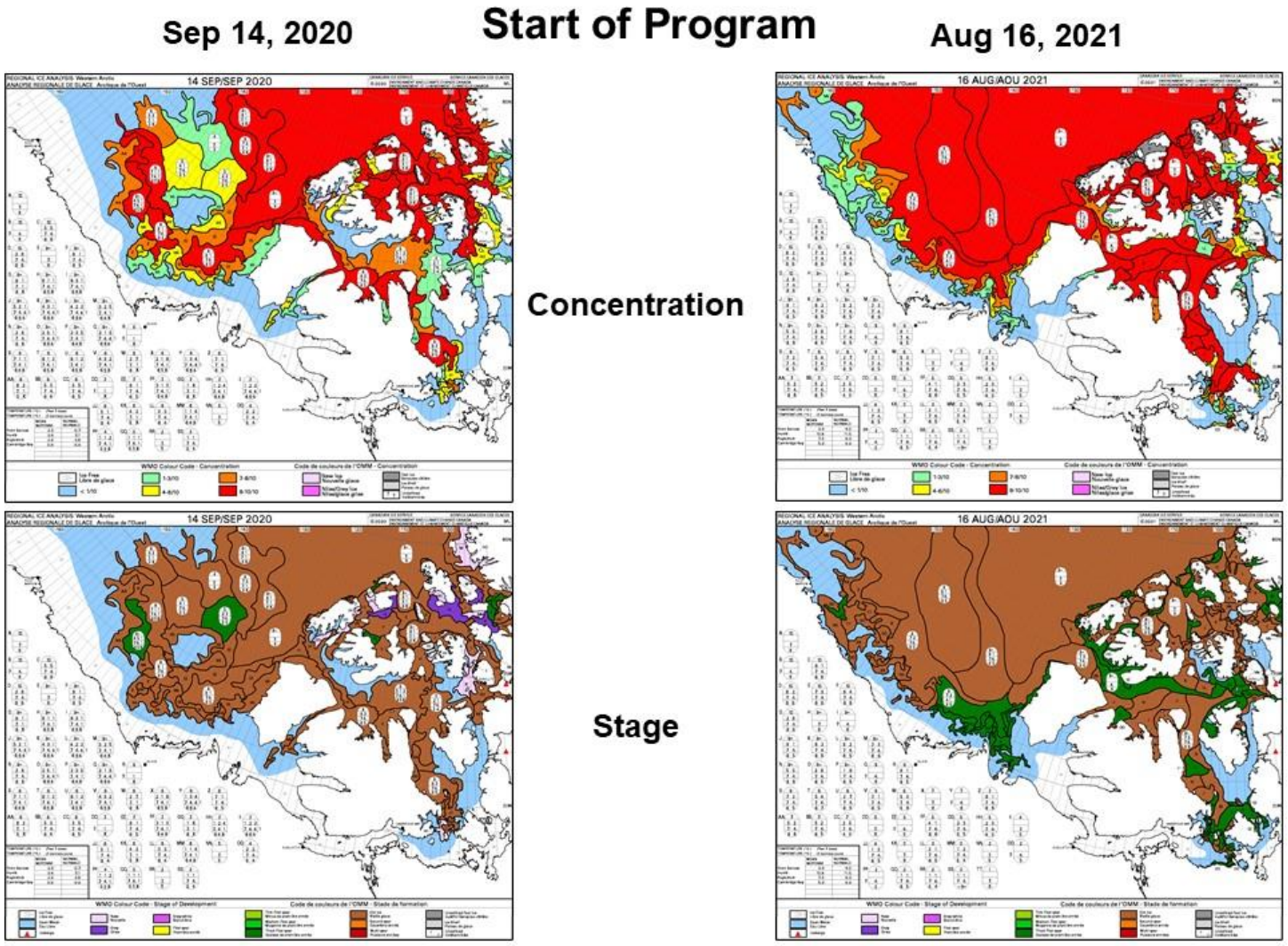


Figure 2. Ice conditions at the start of the program showing this year and last year for comparison.

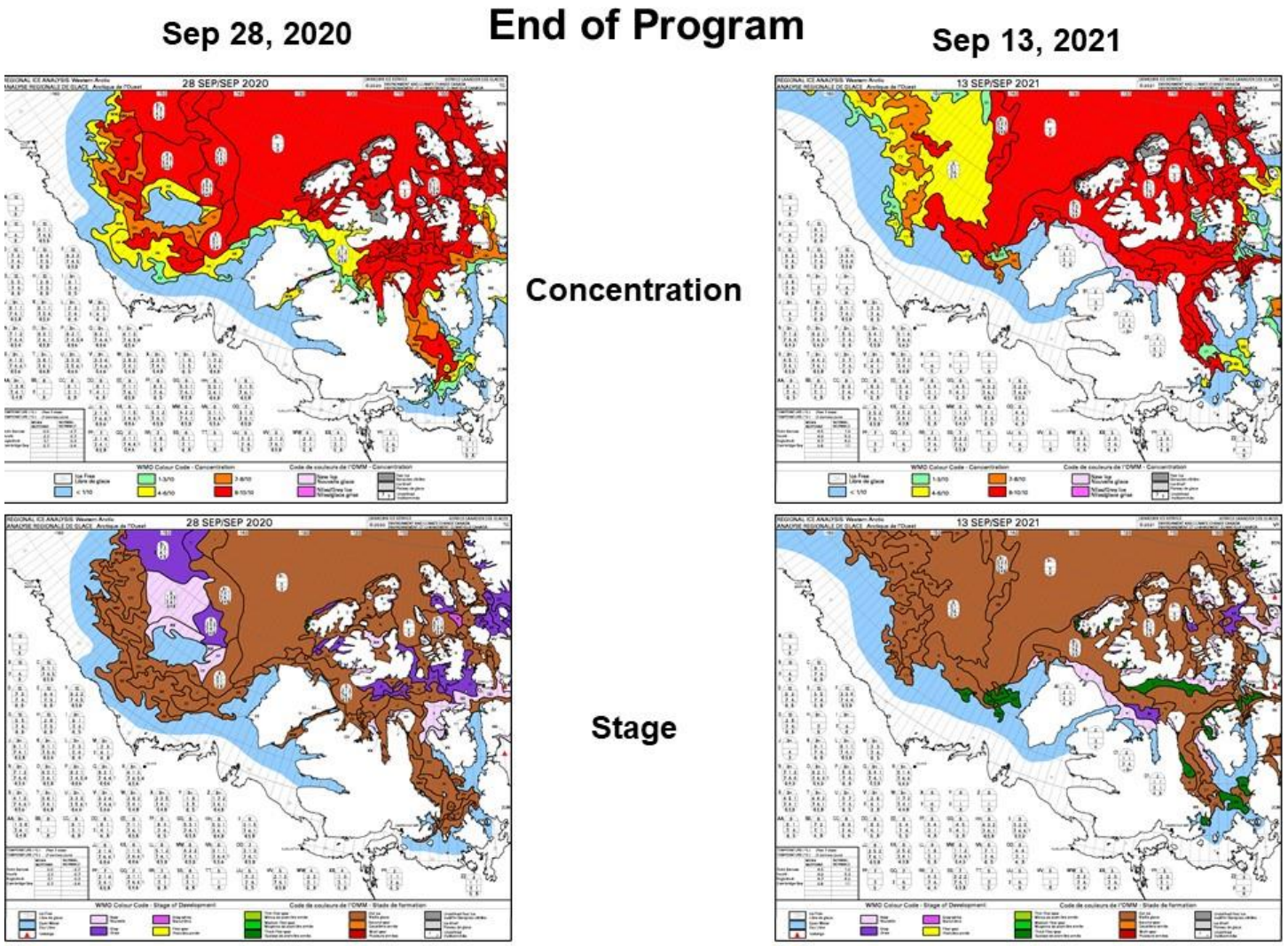


Figure 3. Ice conditions at the end of the program this year and last year for comparison

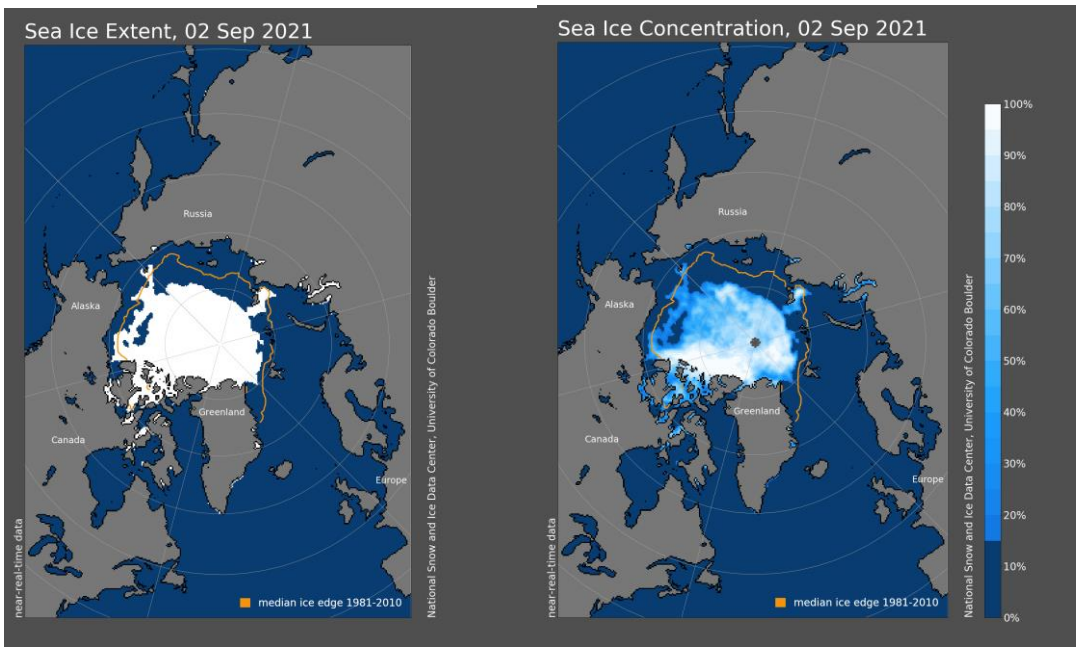


Figure 4. Sea Ice Extent and Concentration mid-way through this year's cruise. (from the National Snow and Ice Data Center)

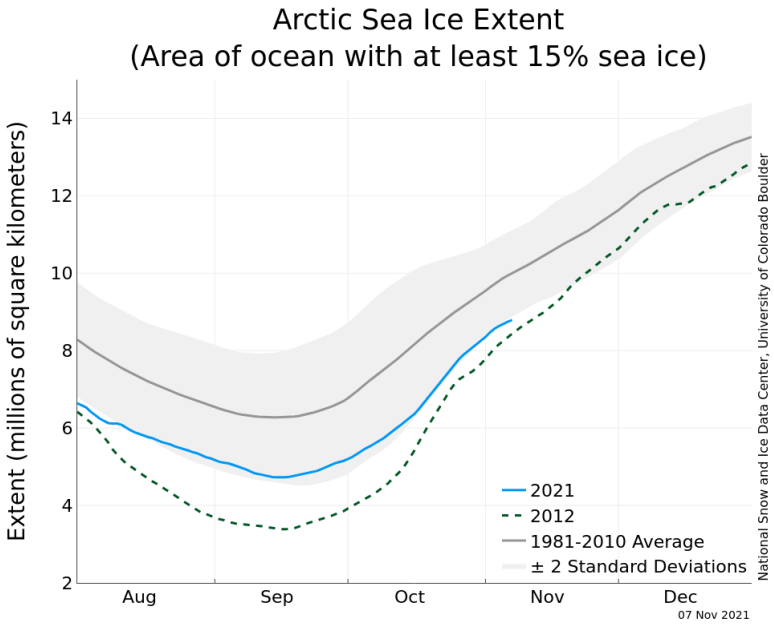


Figure 5. Sea Ice Extent from National Snow & Ice Data Center (source: http://nsidc.org/arcticseaicenews/)

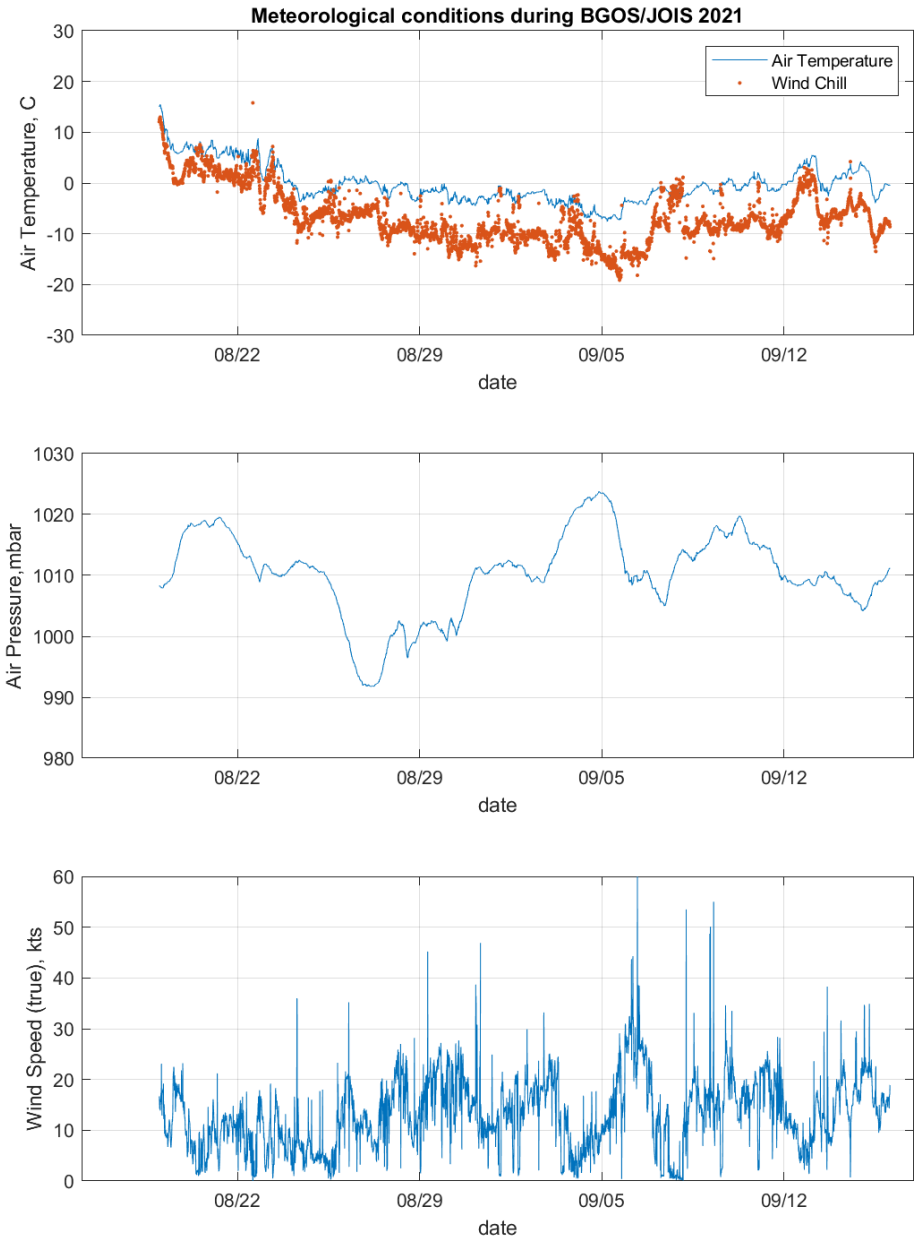


Figure 6. Temperature, air pressure and wind speed for the duration of the expedition from the AVOS weather station above the bridge of the CCGS Louis S. St-Laurent.

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 appreciated the ship's willingness to set off shortly after crew change. There were a couple delays with time was lost at the start of the trip replacing a broken piece of science equipment and the other was a ship detour for an ice-route reconnaissance for a possible ice-escort, however this time was made up by the ship with increased speed during transit with no effect on the program. Due to the tight timing of the program, we gave up one non-priority station to save time for possible weather delays, but other than this, occupied all stations, had the opportunity to recover two buoys and add an opportunistic rosette cast in the southern Amundsen Gulf on the return.

3. ACKNOWLEDGMENTS

The science team would like to thank Captains Neil Macdonald, Jim Chmiel and Wayne Duffett and the crews of the *CCGS Louis S. St-Laurent* and the Canadian Coast Guard for their support. Pre-cruise work to address our wish-list from last year was completed. At sea, we were very grateful for everyone's performance and assistance with the program. As usual, there were a lot of new faces on-board and we appreciate the effort everyone took to accommodate us and our science and help us meet our goals. The ice specialist from the Canadian Ice Service gave daily briefings that were much appreciated. The health officer's work this year with COVID protocols and testing ensured best practices for mitigating COVID risk.

A special thanks to the coordination between Captain Don Gibson and crew of the CCGS Sir Wilfrid Laurier, the LSSL and the LSSL's helicopter pilot and mechanic for the transfer of replacement science equipment at the start of the cruise.

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

This was the program's 19th consecutive year and the exciting and valuable results are a direct result of working with such experienced, well trained and professional crews.

Figure 7. Ship and science personnel. Photo by Gary Morgan

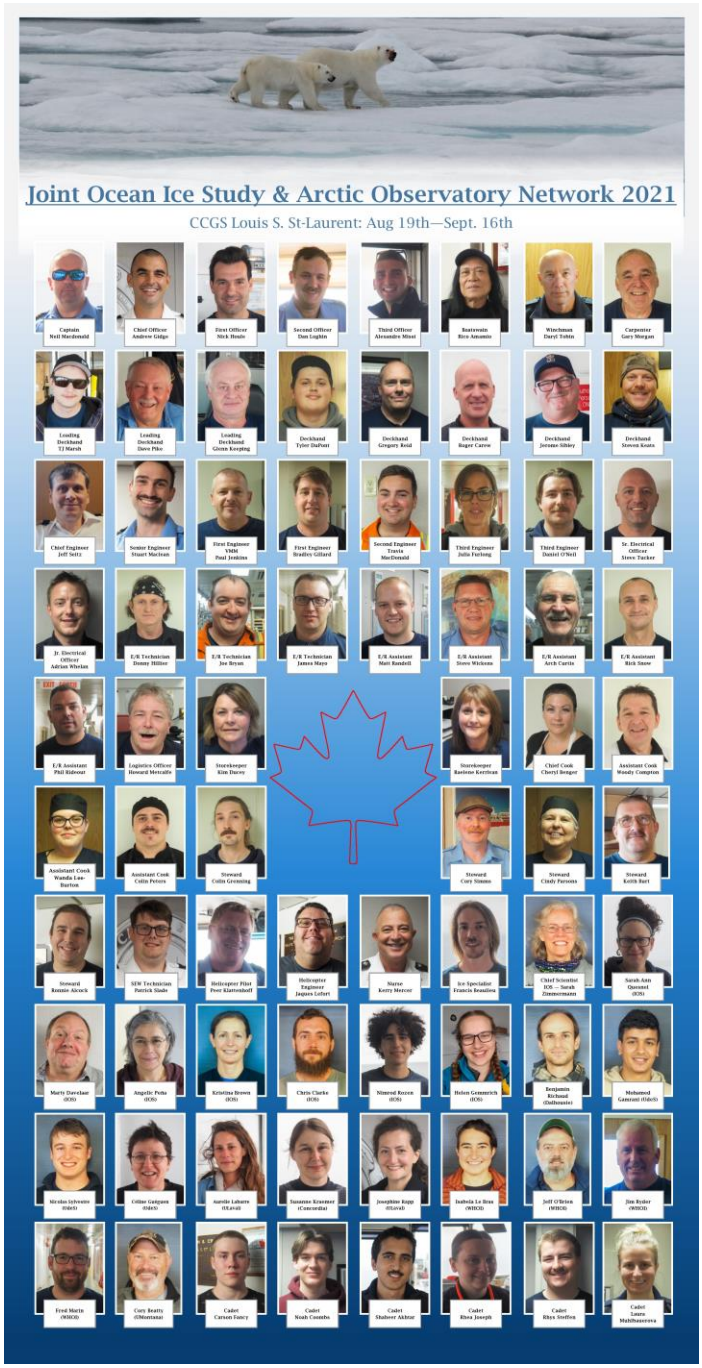


Figure 8. All crew and science on board. Poster made by Helen Gemmrich with help from Nimrod Rozen.

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, Kristina Brown, ,Sarah Zimmermann (DFO-IOS)

4.1.1 Overview

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

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

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

A typical station started with a CTD cast down to 10 m off the seafloor. While in the water, at most stations where weather allowed, a zooplankton vertical net hauls (bongo nets) to 100m would occur from the foredeck. At 5 stations, a short CTD cast to 1000m for microbial diversity sampling (“RNA/DNA”) lead and was followed by a full geochemistry cast. Casts were also done at mooring and ITP/TOP/flux buoy deployment sites. During JOIS 2021, there were a total of 57 CTD/Rosette casts. 56 were casts for JOIS, and 1 was an opportunistic cast performed in Amundsen Gulf during the transit back to Cambridge Bay departure.

Figure 9. Rosette operation on deck with Hawboldt winch and Brooks Ocean Instrumented Sheave display box mounted on the right.

Figure 10. CTD operator and acquisition display in the CTD lab.

4.1.2 During a typical deployment

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

4.1.3 Performance notes

Assembly – CTD
We used SBE9plus s/n 756 with s/n 724 as backup. The temperature, conductivity and dissolved oxygen sensors were all freshly calibrated this year for JOIS. The FDOM sensor was new this year and worked well. The pumps and pumped sensors were oriented to their standard positioning unlike the swapped set up used for the 2020 cruise.

Assembly - Niskins
Per usual, due to the instrumentation on the rosette, we had to cock some of the Niskins bottom end caps to the side rather than straight back.

Assembly – Sensors
With no LADCP, FOG or battery packs this year, there was more room for sensor placement. The FDOM sensor, cosine PAR, altimeter, and transmissometer were mounted in roughly the same positions as 2020. The altimeter was repositioned to a much better location with a very open view downward prior to the 13th rosette cast to improve performance.

Pylon/ Water Sampler
Generally the system performed well. The trigger mechanism was routinely checked and had no issues this year.

Water sampling around the 24 bottle rosette

Niskin configuration
All o-rings were changed August 2020, and visually inspected prior to the 2021 cruise on the 24 Niskins on the rosette. Silicon rubber o-rings are used on the spigots to reduce sticking in cold conditions. The lanyards were also checked. There were very few integrity problems (leaks with or without air vent open) with the 24 Niskins during JOIS this year, and all of them were related to forgotten vent closures. All bottle closure issues were related to lanyard hang-ups or bottle cap obstructions.

Seacable issues and re-termination
The seacable was last re-terminated at the end of JOIS 2020 (Oct 2020). The wire was cut back 50 m and re-terminated in Queen Maud Gulf and used subsequently for 4 stations in Bellot Strait in 2020. The seacable worked reasonably well for most of the JOIS 2021 cruise, but will require re-termination prior to the JOIS 2022 cruise. This will hopefully address the issue of some Niskins needing multiple closure attempts in Seasave during the last few casts.

Issues of note:

ROS4 (StnA): The wire got caught on ice during downcast between 940-945m. The wire was pulled to ~20º angle and the winch was stopped. The ship repositioned, the ice was pushed aft, and the wire "snapped" free of the ice. There is a spike in the data at this point, again at ~1300m on the downcast, and a few short spikes on the upcast. The wire was visually inspected between ~900m to ~975m for visible damage. No related issues of

note were observed after this cast, and it was decided that re-termination (especially cutting off 900m+ of cable) was unnecessary.
ROS36 (CB17): Wire twisted up on deck upon recovery. Rosette was hung and allowed to spin in order to untwist wire on deck.
ROS48 (CB29): The wire hit a piece of ice on downcast @ 240m. No effect on data.
ROS49 (MK6): Niskin 19 did not fire on first fire attempt. Worked after a couple button presses. No loss of communication or data otherwise.
ROS50 (CB28b): Niskin 19 & 20 did not fire on first fire attempt. Worked after a couple button presses. No loss of communication or data otherwise.
ROS54 (MK1): Niskin 8 did not fire on first fire attempt. Worked after a couple button presses. No loss of communication or data otherwise.

Of note this year, it was noticed that there was an issue with the wire twisting up on deck (from ~ROS35 onwards) if the rosette was not left to hang and unspin naturally on recovery. Unsure of the cause, but this seemed to be an issue in 2020 as well. Perhaps the weight distribution needs to be addressed, or something has caused the wire to over or under spin during the cast.

It was also observed during the disassembly of the rosette and removal of the CTD and sensors that the underwater cable pigtail on the terminated end of the seacable was very badly spun up and coiled. Unsure of how this could happen, but is obviously related to our twisted wire issues.

Of note, the outer jacket of wires on the wire end of the seacable below the termination is "loose" and birdcaged. There is also ~50m of wire above the termination with one jacket wire standing proud. This will need to be removed when re-terminating for JOIS 2022.

Seasave and CTD data
Seasave worked reasonably well throughout. Some issues when zooming in and replotting the display plots for Tmax, etc. Potentially a low memory issue with new CTD computer, but unsure. Some issues with communication with BOT block/IMS display (see BOT block section).

ROS4 (StnA): The wire got caught on ice during downcast between 940-945m. There is a spike in the data at this point, again at ~1300m on the downcast, and a few short spikes on the upcast.
ROS47 (CB27): Deck unit made 2 high pitched "beeps" (pressure alarm?) @ 2750m. Vertical lines shown on plot display, as if showing negative depth, then return to normal. No other issues afterwards.
ROS49 (MK6): Niskin 19 did not fire on first fire attempt. Worked after a couple button presses. No loss of communication or data otherwise.
ROS50 (CB28b): Niskin 19 & 20 did not fire on first fire attempt. Worked after a couple button presses. No loss of communication or data otherwise.

ROS54 (MK1): Niskin 8 did not fire on first fire attempt. Worked after a couple button presses. No loss of communication or data otherwise.

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 was problematic throughout the cruise. Occasionally, it was a software (GPSgate or IMS) issue, in which these could be restarted to solve the issue. Primarily it seemed to be the distribution feed from the primary CTD computer was hung and could not be restarted without rebooting the computer. The serial-to-USB cable was replaced, the CTD computer rebooted, but none had lasting success. We finally swapped the leg of the Y-cable from the interface box from the CTD computer over to the Knudsen computer, which seemed to fix these dropouts for the most part, but we are not confident this is a catch-all solution. The CTD computer is new this year could be the cause of the problem. Note that both legs of the Y-cable were going to the Knudsen computer: the feed for the IMS software and the distribution feed.

A seemingly unrelated issue we ran into was the winch and IMS display losing the correct CTD pressure data mid-cast. There did not seem to be a clear pattern to this – the pressure display would suddenly switch to a near 0 number, then gradually change value up or down in a non-linear fashion, for the rest of the cast. Seasave pressure, as well as all other display parameters (block angles, tension, wire out, altimeter, messages), were unaffected by this. We suspect this is an issue with the pressure data "shared.dat" file being continuously written by Seasave to be shared with the IMS program on the fly. This value should not be affected by cabling or other physical issue, as this file is shared either internally on the same computer or via the server when running the IMS program through the Knudsen computer. This occurred on a few occasions, then before we could figure out the solution, it seemed to have solved itself and did not happen again for the rest of the cruise.

Most cabling was new and tested in spring of 2021, but it is recommended that these be thoroughly checked before JOIS 2022. The serial (DB9) communication y-cable needs to be re-terminated with new connector ends as it looks quite worn (performance seems fine).

ROS13 (CB2a): Bridge IMS display frozen.
ROS14 (CB2): Bridge IMS display frozen.
ROS15 (CB3): Switched "shared.dat" file from Seasave to display depth instead of pressure.

ROS18 (CB4DNA): Bridge IMS display frozen.
ROS21 (CB8): Bridge IMS display frozen.
ROS23 (CB9): Bridge & lab IMS display frozen. Server/GPSgate issue.
ROS28 (CB11DNA): Bridge IMS display frozen.
ROS29 (CB11): Bridge IMS display frozen on upcast only. CTD pressure data suddenly reset to 0 on winch and IMS block display near beginning of upcast. CTD data unaffected.
ROS31 (CB16): Bridge & lab IMS display frozen. Server/GPSgate issue.
ROS32 (ICE4): CTD pressure data suddenly reset to 0 on winch and IMS block display @ ~1750m on upcast. CTD data unaffected.
ROS 29 to ROS 32: IMS display was swapped to run off of Knudsen computer rather than CTD computer at some point between ROS29 and ROS32. This seemingly solved the bridge display issues, but the CTD pressure data display issues were observed before and after the switch.
ROS34 (CB15): CTD pressure data suddenly reset to 0 on winch and IMS block display @ ~1470m on upcast. CTD data unaffected.

Transmissometer
WetLabs CSTAR transmissometer 1047 was used all cruise without any noted problems.

Altimeter
Benthos PSA-916 (s/n 62670) was used throughout the 2021 cruise. Issues with false bottoms and bad readings until 20-30m off the bottom were observed from ROS2 (StnA) to ROS12 (BL8). The connector was checked and re-seated prior to ROS4 (BL4) without effect. It is suspected the altimeter is mounted too high in the rosette frame, and is shielding the transducer.

These problems were solved by relocating the altimeter to a much lower point in the frame with a makeshift mount prior to ROS13 (CB2a). After relocating, we would regularly have the altimeter read from its max range (98m) to the bottom without data spikes. No issues observed after ROS13 (CB2a).

Recommend installing a permanent mount in the same or similar location for future cruises.

FDOM fluorometer
The WetLabs FLCDRTD (s/n 6677) fluorometer is new this year. It worked well this cruise. It was feared that when splitting channels with the Aandera optode dissolved oxygen sensor, the data would be noiisy due to the shared power ground connection. For this reason, the Aandera optode was only tested for the first cast, and then removed for the remainder of the cruise. The splitter y-cable used initially was removed prior to ROS13 (CB2a) and replaced with a straight cable.

Rinko III dissolved oxygen sensor

As first tested on the JOIS 2020 cruise, an Alec Rinko III dissolved oxygen sensor (s/n 404) was mounted on the rosette next to the SBE43 oxygen sensor for most of the CTD casts. The RINKO was configured on a splitter Y cable with the Satlantic cosine PAR sensor. The Rinko III was used on the first casts, then removed. It was determined to have no effect on the cosine PAR and re-installed prior to ROS13 (CB2a) for the remainder of the cruise. 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 (i.e. programs 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 upon the completion of the cruise.

Winch

The CTD winch, the Hawboldt model SRO 75, with 75hp, has been a part of JOIS for many years. Originally 7000 m of 0.322" 3 conductor UNOLS wire was installed in 2011 and ~5950m remained on the drum in 2020. The wire will likely need another ~50m removed when re-terminating for 2022 operations.

The winch operated quite well this year. Very little squeaking was heard in 2021. No issues were observed with spooling or otherwise, and the deck crew ensured all moving parts and grease nipples were well lubricated throughout the cruise. It was noted that despite the brake clearance and operation being good, there was an observable amount of brake dust accumulating on deck. Given the thickness of the brake pads, this is unlikely to be a problem. It was also observed that the brake may take up to 1m to fully stop when the cable is fully out (~3800m). This is likely due to regular wear on the brake pad, and was able to be rectified by slightly tweaking the hand wheel adjustment. Should the brake appear to not come off completely or not seat properly in the future it can be adjusted with the hand wheel. This has been done in the past and it should be noted that there is a small sweet spot for ideal operation.

To do / suggestions for next year

Calibrate T,C&O sensors on SBE 9plus s/n 756
Consider new calibration for T&C sensors on SBE 9 plus s/n 724
Inspect Niskin o-rings and lanyards for replacement of worn items
Inspect and repair BOT block cabling; troubleshoot IMS display issues
Replace Fluor/Xmiss Y cable with longer xmiss leg
Make new mounting location for altimeter permanent
Check weights and balance Rosette Frame to reduce spin

Re-terminate seacable after removing ~50m; keep at least 5m of used seacable end to inspect and determine possible causes for observed "spin-up" of the underwater cable pigtail

See appendix for CTD sensor configuration and calibration information

4.2 Chemistry Sampling

The table below shows what properties were sampled and at what stations.
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 (dup, trip)	Analyzed	Investigator
Dissolved Oxygen	All casts (geochemistry)	Full depth	1058 (124)	Onboard	Bill Williams (IOS)
DIC/alkalinity	All casts (geochemistry)	Typically to S=34.7 (5 to 400m)			
	Stn-A, CB4, CB9, CB16, CB15, CB21, CB29,	Full depth	681 (44)	Onboard	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)
FDOM	All casts (geochemistry)	5, Chl Max,S=33.1, S=34.4, Tmax, 1000, 2000, 2500, Bot-100			
	All 140W stations (CB16, CB15, CB17, CB18, CB21, CB29, MK6, CB28b, MK4, MK3, MK2, MK1, CB28aa) along with Barium	5 to S=33.1, S=34.4, Tmax, 1000, 2000, 2500, Bot-100	498 (7)	Onboard	Celine Gueguen (USherbrooke)
Chl-*a*	All casts (geochemistry)	5-200 (select)	355 (155)	Shore lab	Bill Williams (IOS)
Bacteria	All casts (geochemistry)	5, 20, Chlmax, S=32.3, S= 33.1, Tmax, 1000, Bottom	396	Shore lab	Connie Lovejoy (Ulaval)
Nutrients	All casts (geochemistry)	Full depth	1071 (126)	Onboard	Bill Williams (IOS)
Salinity	All	Full depth	1227 (111)	Onboard	Bill Williams (IOS)

$\delta^{18}O$	All casts (geochemistry)	5-400 (typically to S=34.7 or 34.8)			
	StnA, CB4, CB9, CB16, CB15, CB17, CB18, CB21, CB27, CB29, CB28b,	Full depth	759 (59)	Shore lab	Bill Williams (IOS), Michiyo Yamamoto-Kawai(TUMSAT)
Barium	All 140W stations (CB16, CB15, CB17, CB18, CB21, CB29, MK6, CB28b, MK4, MK3, MK2, MK1, CB28aa) along with Barium	5 to S=33.1 (5 to ~200m)	208 (3)	Shore lab	Celine Gueguen (USherbrooke)
DOM	BL8, CB2a, CB2 CB3, CB6, CB19	Tmax (~400), 1000, 2000, Bot-100	28	Shore lab	Celine Gueguen (USherbrooke)
Lignin/Phenol	CB16, CB15, CB17, CB18, CB21, CB27, CB29, MK6	Surface from TSG system (Seawater Loop)	8	Shore Lab	Celine Gueguen (USherbrooke)
Microbial Diversity (DNA/RNA)	AG5, CB4, CB9, CB11, CB21 (dedicated casts)	5, 20, Chlmax, S=32.3, S= 33.1, Tmax, 1000, Bot-100		Shore lab	
	StnA ,CB31b, CB50, CB40, CB17, PP7, CB15, CB16, ICE2, ICE4, CB11, CB10, CB8, CB7, CB3, CB2, BL8, CB27, CB28b	5, ChlMax, + extra from above depths	76 dedicated samples		Connie Lovejoy (ULaval), David Walsh (Concordia)
Extra for Microbial diversity – mostly spare bottes	CB28aa, MK1, MK2, MK4, MK6, CB23a, Ice4, CB6, BL1	See Rosette Sheets			Connie Lovejoy (ULaval), David Walsh (Concordia)
^{129}I	CB5, CB4, CB6, CB19, CB21, CB22, CB23a, CB31b, CB1, AG5	Full depth (select)	100	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)
Pigments HPLC	Select throughout the basin for good coverage (28 stations)	Surface	29	Shore lab	Angelica Pena (IOS)
Phyto ID	Select throughout the basin for good coverage (~6 stations)	Surface	~6	Shore lab	Angelica Pena (IOS)

Following are short backgrounds of a few of the chemistries sampled. Please see the full reports for more details.

4.2.1 Iodine-129, Cesium-134

Sampling by CTD Watch

P.I.: John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)

Sampling was performed for radionuclide ^{129}I in the Arctic Ocean.

Measurements of ^{129}I across the middle of the program area provide information about the spread of Atlantic-origin water labeled by discharges from European reprocessing plants. This year, sampling is along the ~74.5N latitude will address transport between the southern and norther basin.

The samples for ^{129}I were collected into 500mL brown Nalgene bottles after a small rinse for contaminants. After drying the bottle exterior and allowing sample to come to room temperature, the lids were wrapped secure with electrical tape to prevent leaks or evaporation. Samples were stored in the 4C cool room until they were offloaded and shipped to ETH Zurich, Switzerland, for analysis.

4.2.2 Fluorescent Dissolved Organic Matter Sampling

Céline Guéguen(USherbrooke)
Nicolas Sylvestre (USherbrooke)
Mohamed Gamrani (USherbrooke)
P.I.: Céline Guéguen (USherbrooke)

Summary

Samples for Fluorescent Dissolved Organic Matter (FDOM), Dissolved Organic Matter (DOM) and Lignin-Phenol analysis were collected for Céline Guéguen (USherbrooke), following the protocol given below. A total of 491 FDOM samples were collected at 49 stations and 62 from the underway seawater loop system between August 22th and September 14, 2021 on board the CCGS Louis S. St-Laurent during the Joint Ocean Ice Study-Beaufort Gyre Observational System 2021.

Rosette Casts Samples

4.2.2.1.1 Samples > 200m

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

1L water samples were collected for DOM analysis at 4 depths (T-max, 1000-m, 2000-m and Bottom-100m) at BL8, CB22a, CB3, CB6, and CB19. The samples were solid phase extracted immediately after collection.

4.2.2.1.2 Samples <200m

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

4.2.2.1.3 Incubations samples

At Station-A, approx. 5 L were filtered from niskin 23 (32.3 PSU, 138 m) and filtered with a pre-combusted GF/D filter and stored in fridge for use as the inoculum.

Forty-five (45) pre-combusted 1L amber glass bottles were marked at 650 mL and filled with filtered (double layer of GF/F pre-combusted filters) water from the following depths (15 bottles per depth) : Bottom (3330 m), Tmax (506 m), and 34.4 (303 m). Nutrients (NO3 and PO4) were amended in all bottles to reach a final concentration of 15.3 uM (NO3) and 1.05 (PO4). For each set of 15 bottles, 5 were kept as a control and 65 mL of the inoculum was added to the remaining 10 bottles. Bottles were kept in the fridge in the dark and sampled following a pre-determined schedule.

Underway Samples

Eight (8) 20L water samples were collected from the underway system for lignin phenol analysis at CB15, CB17, CB18, CB21, CB27, CB29, and MK6. The samples were solid phase extracted immediately after collection.

Sixty-two (62) FDOM samples were collected from the underway system while the ship was steaming, at a frequency of approximately 2-3X per day at XCTD sites. Seawater from the TSG outlet was used to flush the 40 mL amber glass vial used for FDOM sampling. Vials and caps were rinsed 3X with sample before collecting the actual sample. Upon collection of each sample from the underway system, FDOM sensor reading (volts and counts), latitude, longitude, UTC time, sample ID etc. was noted. Samples for nutrients, salinity and chlorophyll were collected once a day to post-calibrate the sensor.

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

Storage

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

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

A selection of FDOM samples were kept and will be transferred to the University of Sherbrooke for absorbance analysis.

4.2.3 Barium

Celine Gueguen (USherbrooke)
Nicolas Sylvestre (USherbrooke)
Mohamed Gamrani (USherbrooke)
P.I.: Celine Gueguen

Background

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

Sampling

190 barium samples were collected at Station-A, CB2, and along the BL, MK, and 140W lines, typically from 0 to 200 m depth. Barium samples were drawn from the Niskin into small (~20 mL) plastic vials following three rinses of the 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 8800 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. The spectrometer was operated in peak jump mode, and data were accumulated over three 20 s intervals for masses 135 and 138.

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)

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

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

Oxygen isotopes, ^{16}O and ^{18}O, are two common, naturally occurring oxygen isotopes. Through the meteoric water cycle of evaporation and precipitation, the lighter weight ^{16}O is selected preferentially during evaporation, resulting in a larger fraction of ^{16}O in meteoric water than in the source water (i.e. seawater). Sea-ice formation and melt on the other hand, only changes the source water's $^{18}O/^{16}O$ ratio (noted as $\delta^{18}O$) slightly. 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.

Oxygen Isotopes Samples were collected into 30 ml glass vials. Once at room temperature, the caps were retightened and the vials inverted for storage. Samples will be analyzed at Oregon State University, at the College of Oceanic and Atmospheric Sciences (COAS) Stable Isotope Lab, by Jennifer McKay. Samples will be analysed using a DeltaPlusXL Isotope Ratio Mass Spectrometer connected to a H_2O-CO_2 equilibration unit.

Samples were collected into two types of vials due to limited availability of our typical style vial. Glassware has been limited with COVID related supply issues.

4.2.5 Dissolved Inorganic Carbon and Alkalinity

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

Samples for DIC and Alkalinity were collected at all stations (geochemistry) in the upper waters down to a salinity value of 34.7, approximately 300 to 400m deep. Samples were collected from full depth at select stations: StnA, mooring stations and intermittent along 140W. Analysis took place on board this year however due to COVID-related travel restrictions the Alkalinity analysis was performed by IOS on the IOS system rather than as in previous years (2019 and earlier) performed by TUMSAT.

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. Since most of the samples on this cruise were analyzed within 2 days, mercuric chloride (HgCl2) and grease were not used to preserve the samples. Instead a Teflon stopper was used to seal the bottle. For the few stations where analysis was delayed, 100uL of mercuric chloride was added to the bottle to stop biological activity, closed with a greased stopper, and secured with multiple wraps of electrical tape. Samples were stored at 4°C until analysis. DIC, then alkalinity were measured from the same sample.

Analysis for DIC

DIC samples were analyzed at sea shortly after sampling using a VINDTA 3D - analysis system to determine DIC. 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.

Analysis for Alkalinity

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

References

Dickson, A. 2001. Reference materials for oceanic measurements. Oceanography. 14(4):21-22.

Dickson, A.G., Afghan, J.D., Anderson, G.C. 2003. Reference for oceanic CO_2analysis: a method for the certification of total alkalinity. Mar. Chem.80(2-3):185-197.

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

4.2.6 Nutrients

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

Sampling

Seawater samples for nutrient determination were collected at every station and depth into new 15 mL polystyrene tubes after the tube and cap had been rinsed three times with the sample water. A total of 1028 samples were collected, of which 176 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. An additional 16 samples were collected in duplicates from the sweater loop system, from the outflow of the FDOM sensors and analyzed within 12 hours of collection, 36 samples for Nicholas Sylvestre' (USherbrooke) incubation experiments and 16, in duplicates, for Josephine Rapp (ULaval) ice core samples.

4.2.6.1.1 Standards, reference material samples and reagents

Primary stock standards of nitrate (nitrate + nitrite, NO_3, phosphate (PO_4) and silicate (SiO_4) were prepared at IOS in May, 2021, and were calibrated against Kanso certified reference materials, lot CO (NO_3 = 16.30 µM, SiO_4 = 35.58 µM, PO_4 = 1.206 µM). The primary stock standards were prepared in Milli-Q water, using high purity grade dry chemicals (Fluka puriss. grade for sodium hexafluorosilicate, and Fluka ultra p.a. for potassium nitrate and potassium phosphate monobasic), and grade "A" volumetric flasks, according to Barwell-Clarke and Whitney (1996).

A set of 4 working standards, were prepared daily from the primary standard solutions, using freshly prepared 3.4% sodium chloride/0.02% sodium bicarbonate solution. Concentrations of the standards were selected to bracket the expected nutrient levels in the samples (NO_3: 0.00 to 23.93 µM, SiO_4 : 0.00 to 47.75 µM and PO_4: 0.00 to 2.408 µM).

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

The assigned values from CRM KANSO were nitrate + nitrite, 16.30 µmol/L; silicate, 35.58 µmol/L; and phosphate, 1.206 µmol/L for lot CO and nitrate + nitrite, 5.62 µmol/L; silicate, 14.15 µmol/L; and phosphate, 0.425 µmol/L for lot CL. Onboard DWR samples were collected from sample #375. Deep water reference samples were sub-sampled into new polystyrene tubes, frozen at -20°C, and thawed as required in tepid

water. This year the DWR was from Station-A bottom water, and it didn't show the typical deepwater values. It was nevertheless used as an internal check throughout the cruise to check for stability.

4.2.6.1.2 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 few occasion 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, drift cup and a blank) 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 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.

Information will be provided with the finalized data.

Problems and Solutions

4.2.6.1.3 General Issues

Our Milli-Q Reference water purification system was found to be damaged and not useable during its installation at the start of the cruise. A second system of the IOS Arctic Group's, though not scrubbing water to as high purity, was taken from the nearby CCGS Sir Wilfrid Laurier where it had finished being used and installed as a replacement in the LSSL's lab.

Phosphate Analysis: Phosphate had significant upward drift throughout the cruise this year. Troubleshooting included making new reagents, cleaning the reagent lines with special wash solution of diluted bleach and flushing with copious amounts of pure water. The problem would solve for 1 run and then the drift was back. The software corrected for the drift properly, but the problem was not solved. I suspect the source of the problem was due to the water produced by the Milli-Q Reference water purification system. The point if use 0.22µm filter was covered with brown-orange colloidal matter, that passed through the 5 and 1 µm pre-filters and the water system's cartridges. The senior engineer mentioned that this year they installed a mineralization system for their potable water to render the drinking water less acidic.

Figure 11. Nutrients analysis on the AA3. Photo by Fred Marin, 2019, but similar set up for 2021.

4.2.7 Dissolved Oxygen

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

Dissolved oxygen concentrations were measured on board the *CCGS Louis S. St-Laurent* (LSSL) from August 19th to September 14th, 2021 during the JOIS mission in

the Canada Basin. A total of 1013 samples were collected from 45 stations, some of which over 2-3 rosette casts, along a cruise track starting and ending in Cambridge Bay, NU. All samples were analyzed on the SIO Winkler oxygen titration kit. Oxygen concentrations ranged from 5.329-9.211 ml/L with ~15% of samples analyzed in duplicate. The pooled standard deviation (s_p) for duplicate samples was 0.007 ml/L after the removal of 2 outliers by eye, not fitting the depth profile, and 3 outliers based on Chauvenet's criterion. The mean deep water (>3000 m) DO value in the Canada Basin was 6.529 ± 0.014 mL/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, 2020 and 2021. Most were left on board the ship from the previous 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). The first thermometer started acting up half way through the expedition and was switched out for a replacement. 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, 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 24 hours of collection.

Analysis at sea

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

4.2.7.1.1 Blank and Standard Preparation

Blanks and standards were run just prior to sample runs 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; only occasionally did an additional set of standards or blanks need to be run. Variability in reagent dispensing was likely the primary cause of poor blank replication as the 2nd titers were generally more consistent. Blanks were not always run with every standard set if no reagent changes had occurred in the interim. The temperature of both the standard and the thiosulfate were recorded by the program and used to correct the delivered mass of both reagents to 20°C in order to calculate the Thio titrant normality.

4.2.7.1.2 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 20 minutes. The water bath, which holds the sample flasks, was drained, cleaned and refilled with fresh deionized water to ensure good light transmission. 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 (#2101, #1903) and one batch of KIO_3 standard (#2101) were used during the cruise and the stability of the Thio for both batches was excellent with a maximum change of 0.00027 N, well below the 0.0005 N threshold.

Precision and Accuracy

Of the 1013 unique samples collected during the course of this survey, 160 (16%) 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). The precision of the dissolved oxygen replicate measurements was very good, with a pooled standard deviation (s_p) of 0.007 mL/L after the removal of 2 outliers by eye due to either replicate fitting the depth profiles and 3 determined by the Chauvenet's criterion. 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 5.329-9.211 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 2021 value of 6.529 +/- 0.014 falls right on this average.

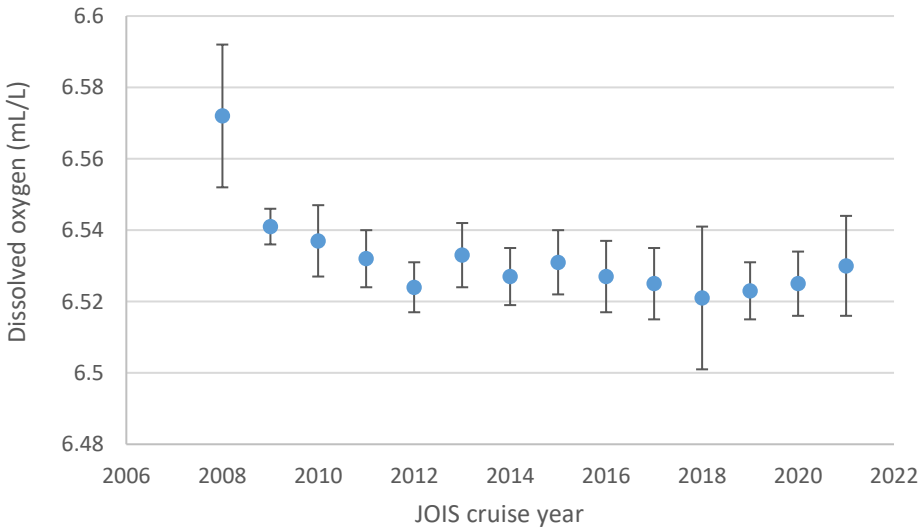


Figure 12: Mean annual dissolved oxygen concentration (mL/L) for the Canada Basin reference stations at all depths below 3000m. Error bars represent standard deviations.

Issues during sampling and analysis

Post entry of drawn temperature: Drawn temperature for samples 47-56 (cast 3), 57-80 (cast 4) and 81-83 (cast 5) required to be entered post analysis.

Abort analysis: There was only one occasion that analysis needed to be aborted, for sample188 (cast13). The color was mild peach/cream and it couldn't be titrated – not sure if one of the reagents wasn't added in sufficient volume.

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

Lab Space Issues: The hot water tap was left on a slow dribble, when not in use, to keep the water drain from freezing. The engineering team was also able to fix the slow leak on the sink drain to finally stop water pooling on the floor of the container lab. On a few occasion the lab temperature got warm, up to 25-26*C, especially when 2 analyst were present for prolonged periods of time.

Dosimat 665-1: On August 30th, the dosimat 665-1, dispensing the KIO_3 standard showed an error message "Error 5" upon turning the power on at the start of the day. It was turned off and on several times, connecting cables and power cables were checked with no resolution of the problem. It was noted by a colleague having experience with dosimat, that they sometimes lose their initialization sequence and need to be rebooted. The dosimat worked fine after being rebooted.

Figure 13. Oxygen sampling from the rosette. Photo by Fred Marin (2019).

4.2.8 Salinity

Chris Clarke (DFO-IOS)
Kristina Brown (DFO-IOS)
Benjamin Richaud (Dalhousie)
P.I.: Bill Williams (DFO-IOS)

Sampling

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

Analysis at Sea

All cases of 24 samples were analyzed onboard during the program. Samples were analyzed after a minimum 24 hour acclimation period but within 1 week of collection, on the Guildline Salinometer Model 8400B (S/N: 69086) by Chris Clarke (DFO-IOS), Kristina Brown (DFO-IOS) & Benjamin Richaud (Dalhousie). The procedure followed is outlined in the standard IOS protocol for salinity analysis. Room and sample temperature was maintained consistently between 21.5°C and 23.5°C as much as possible. Fluctuations in temperature rarely caused problems in maintaining a stable standby number. When instability did occur, the analysis was postponed until the standby number re-stabilized. An order placement system was established within the room whereby salinity cases were cycled in order to establish a constant sample

temperature. This system ensured two things: 1) the analyst knew which case to begin with and the location of each subsequent case, and 2) each case was held at a stable temperature for an extended period of time before analysis. Bottles were inverted and mixed prior to analysis.

IAPSO Standard Seawater (OSIL batch P163, expiry 10 April, 2022, salinity 34.994 PSU) was measured at the beginning of every day to calibrate the instrument and identify drift. 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 (see below) were normally run at the end of each sample case (24 samples) or more often if deemed necessary to assess instrument stability. Data are reported in practical salinity units (PSU; Lewis & Perkin 1978). See Information will be provided with the finalized data.

for salinity precision values.

5 sets of deep water reference (DWR) samples were collected throughout the cruise:

- DWR StnA-5: Sample 61, Station StnA, Cast 4, Niskin 5, 3380 m
- DWR StnA-6: Sample 62, Station StnA, Cast 4, Niskin 6, 3057 m
- DWR CB16: Sample 634, Station CB16, Cast 31, Niskin 21, 2545 m
- DWR ICE4-2: Sample 639, Station ICE4, Cast 32, Niskin 2, 3673 m
- DWR CB19-2: Sample 831, Station CB19, Cast 40, Niskin 2, 3660 m

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 **Error! Reference source not found.** for Deep Water Reference values.

Additionally, it should be noted that two of the three analysts were using the salinometer for the first time, or were relearning after many years.

Issues with Salinometer

Bubbles inside conductivity cell: Throughout the cruise, a large bubble remained in the upper left portion (filling end) of the long arm within the conductivity cell despite attempts to flush it out. This would disappear temporarily after thorough cleaning, but reappear in short order. There were also tiny bubbles that would persist on the electrodes, particularly cell 4 and to a lesser extent cell 3. These bubbles were watched and relatively consistent throughout the cruise. To remove the bubbles, the cell was regularly cleaned

with Triton-X100, isopropanol and CLR. The salinometer would then be standardized and/or calibrated. This would usually temporarily clear the small bubbles on the conductivity cells, but they would reform fairly quickly again. Bubbles were monitored through analysis. The bubbles did not seem to affect the accuracy of the salinometer, but it is noted that it likely caused frequent "spikes" in readings. In an effort to reduce the effect of these spikes, a 3rd reading was obtained on many samples and affected readings were removed to reduce the standard deviation of the average values.

It is recommended that the conductivity cell electrodes be removed and physically cleaned. There is also a possibility that these bubbles are forming due to inadequate sealing of the air purge microtubules at the top of the cell. The integrity of the closed system is suspect.

Blocked cell flush: There were multiple occurrences of cell 4 not filling properly, leaving a large persistent bubble below the electrode. It was determined that the polyethylene microtubule was blocked with water and not venting properly during flush. This microtubule was thoroughly inspected, and did not have any visible blockage or damage. On multiple occasions, this microtubule would overflow into the upper airlock, which would then need to be removed, emptied and dried. This issue persisted, so a temporary fix was to put and empty sample bottle on the bung (to complete the airlock circuit), and hold the flush until all water was purged from the system. This would solve the issue temporarily, but reoccur within another few cases of sample. After this issue occurred on multiple occasions, a more thorough inspection of the system was performed and it was found that some of the tubing connections were loose and/or required zipties. Once addressed, it is noted that this issue was resolved. It is recommended that all connections be inspected before next use, and potentially replace tubing that may be suspect (i.e. the microtubules on cell 3 and 4 conductivity electrodes). The integrity of the closed system is suspect.

"Spiky" or "jumpy" readings: There were issues throughout the cruise with spiky or jumpy readings while running samples. Likely causes for this include bubbles on the conductivity electrodes, shaking due to ice breaking, and temperature fluctuations. While these spikes seemed to lessen over the course of the cruise, they persisted for the duration. Due to this, a 3rd reading was acquired more often than previous years. They did not seem to affect the stability or accuracy of the average readings. The standby value and zero reading of the salinometer remained quite stable, and both standardization and calibration of the salinometer indicated that there was very little change in its stability and accuracy throughout the cruise.

Software error message: Throughout the cruise, there was a persistent issue with the salinometer software user permissions. It was observed that after approximately 80-120 samples, we would get an error message "error in Module "SaveSampleDataToFile"; 70, Permission denied". This message would appear after any user input, including editing BottleLabel, Comments, or deleting bad readings manually. Although this message would appear, the program would still allow these parameters to be changed.

These changes were temporary, as they would not save if the file/software was closed and re-opened. These changes would still be reflected in Excel file data exports, as long as the .hdr/.dat/.raw file was not closed before export. This did not affect the automated recording of the sample values and readings themselves, even after these error messages began on a run file. A variety of attempts to rectify this issue, such as restarting the software/laptop, re-seating connectors, and cycling the power on each component of the system, did not solve this issue. It is suspected that the run files are corrupted at this point, and we were unable to "fix" the file once the permission error began.

As a workaround, we would start a new run file every 3-4 cases (72-96 samples). The program would work just fine up until this point, generally. We would then export these data to an Excel file, and begin a new run. This also ensured we calibrated and/or standardized the salinometer every 3-4 cases of sample. This has not been an issue in previous years, and we generally use the same run file for the entirety of the cruise (usually upwards of 1300 samples).

It has not been determined what the cause of this is, but the software and/or laptop is the likely culprit. It is recommended we backtest these issues and contact the manufacturer to solve this problem before the next cruise.

Salinometer disconnection from software and having difficulties reconnecting: There were occasional occurrences of the Autosal disconnecting from the software. This was usually rectified by closing and reopening the salinometer software, or restarting the laptop computer. Furthermore, it is noted that the knob usually needed to be turned slowly between standby, read and zero when reconnecting.

Precision and Accuracy

Information will be provided with the finalized data.

Recommendations

- The IAPSO standard seawater used for instrument calibration is the most accurate source for confirming optimal salinometer operation. It is recommended to use the standards as the primary check when initiating a sample analysis run and/or everyday if samples are being analyzed daily. In addition to performing the calibration procedure, it is useful to run the standard as a sample to confirm that the salinometer is reproducing the salinity value stated on the label of the standard bottle.
- It is imperative to plug the salinometer power supply into the ship's uninterruptable power supply (UPS). It has been observed in the past that the salinometer experiences quite unstable standby number readings if plugged into non-UPS power.

- Backtest salinometer program for connectivity and permissions issues. Contact manufacturer for insight on this issue. May need to replace laptop computer, but could be an issue with the program itself. Double check integrity of all connections, especially the large ribbon cable between salinometer and interface box.
- It is recommended to check all tubing integrity within the salinometer for integrity before next field season. Replace any worn, damaged, or suspect tubing.
- Consider physically cleaning the conductivity cell electrodes prior to next field season. This may require factory calibration if cells are unable to be cleaned in house. An issue with persistent bubbles has being observed for the last 2 years. This is either due to tubing integrity issues, or a dirty electrodes that are unable to be fully cleaned by CLR/isopropanol/Triton-X100 alone.
- The rubber bung used for sealing the sample bottles to the salinometer has started to deform from analyzing thousands of samples. It should be replaced and tested prior to the next field season.

4.2.9 Chlorophyll-a

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

Onboard Sampling and Filtering

Chlorophyll-*a* was sampled from the upper 200m, with roughly 50% in duplicate at all geochemisty stations and in 16 loop samples. Samples were drawn from each of the selected Niskins into pre-calibrated 530mL brown Nalgene bottles (calibrated at IOS in 2021). Replicates were taken in 530mL and 1L Nalgene brown bottles. Each bottle and cap was rinsed three times with the sample water. The bottle and cap were both filled and the cap quickly put on resulting in the fullest bottle possible.

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

Chlorophyll-a samples were filtered by Celine Gueguen, Mohamed Gamani, Nicolas Sylvestre, Helen Gemmrich, Nimrod Rozen, Benjamin Richaud, and Angelica Pena with oversight from Sarah Ann Quesnel, Chris Clarke, and Angelica Pena.

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

After confirming a smaller sample volume was adequate last year (590mL v. 1L), a new sample bottle was used this year. The new 530mL bottle had a tall, narrow neck, making it an easier bottle to handle during the filtration process than the wide mouth, short neck bottles from last year. Replicates were mostly with the new bottle however some of the duplicates were taken using the 1L bottle for further comparison to the old method.

The goal of the smaller volume was to reduce the filtration time. 10 to 15 minutes is ideal and the new bottles fell within this window. The 1L samples were taking 20 to 40min likely due to some material other than chlorophyll clogging the filter as the length of time was not correlated with chlorophyll concentration.

If the replicates show we should go back to the 1L samples, an alternative would be to use larger diameter filters. Angelica Pena was filtering 1L samples onto larger sized filter (requiring larger castles but manifold can stay the same) and filter time was 20min or less.

Analysis on shore

Samples will be brought back to IOS, frozen ,for analysis. Samples will be extracted in glass scintillation vials with 10.14 mL of 90% Acetone/10% double deionised water for 24 hours in the dark, in the -20°C freezer. One hour before sample reading, they will be removed from the freezer and placed in the dark to equilibrate to room temperature. Samples will be analyzed on a Turner 10AU fluorometer, SN:5152FRXX, calibrated with commercially pure chlorophyll a standard (Sigma). Fluorescence readings taken before and after acidification will be used to calculate chlorophyll and phaeopigment concentrations (Holm-Hansen et al 1965).

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

4.2.10 Bacteria sample collection

Céline Guéguen (USherbrooke),
Nicolas Sylvestre (USherbrooke),
Mohamed Gamrani (USherbrooke)

P.I. : Connie Lovejoy (ULaval)

Sampling

Bacteria samples were collected at every station at select depths (generally 8 depths per station) between 22 August 2021 and 14 September 2021. Flow cytometry (FCM) samples for bacteria, pico- and nanoeukaryotes were collected for Connie Lovejoy (ULaval), who took over for Bill Li (BIO), following the protocol given below. Samples were collected and processed alternately by Mohamed Gamrani (USherbrooke) and Nicolas Sylvestre (USherbrooke).

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

Methods

Sampling:

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

Fixation:

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

3. Note on the repeating pipet settings: The new eppendorf pipet is set on #1 to deliver 0.2mL and uses the blue labeled pipet tips. The old black repeater is set on #2 to deliver 0.2mL and uses the other tips.
4. Cap each vial using the threaded-screw cover.
5. Vortex mix the vial, and let it stand at room temperature for not less than 10 minutes.
6. Place the vial into storage box directly into the -80ºC freezer and leave onboard ship for offloading in St-John's NL.
7. Log samples taken in logsheet recording cast number, niskin number and approximate time between sampling and adding fixative.

Issues

Initially it was thought not enough cryogenic vials were brought onboard, so only a selection of 8 depths corresponding the microbial diversity sampling depths were sampled per station. This was instead of the full 24 depths sampled the last ~10 years. Even when the surplus of vials were found, the practice was continued as only these 8 depths have been analysed the past few years.

Wishes for next year

- More cryogenic vials are needed to sample every depth at every station. Ideally all from the same company, with the orange caps and flat bottom.
- A new rack that locks the vials in place.
- 5000 µL pipet and tips Thermo Scientific Finnpipette are awesome.
- Syringe and needle (10 mL) to transfer paraformaldehyde from ampoule to scintillation vial.
- Dedicated cryoboxes are to be added to the bacteria box.
- **More protective plastic ampoule openers are needed for next year.**

4.3 Moorings and Buoys

Isabela Le Bras (P.I.), Jim Ryder, Jeff O'Brien, Fred Marin, and Cory Beatty (U Montana).
P.I.s not in attendance: Mary-Louise Timmermans (Yale U), Andrey Proshutinsky, Richard Krishfield, and John Toole (WHOI)

4.3.1 Summary

As part of the Beaufort Gyre Observing System (BGOS), three bottom-tethered moorings deployed in 2018 were recovered, refurbished, and redeployed at the same locations in 2021 from the *CCGS Louis S. St. Laurent*. Furthermore, one open water Ice Tethered Profiler (ITP) was deployed, as well as three Ice Based observatories. Two ITPs were recovered. A summary of moorings and buoys recovered, serviced and deployed are listed in Tables 1, 2 and 3.

Table 3. Mooring recovery and deployment summary.

Mooring Name	Surveyed 2018 Location	2021 Recovery	2021 Deployment	2021 Location	DeploymentBottom Depth (m)
BGOS-A	75°00.0072N	27-AUG	28-AUG	75°00.009N	3823
	150°00.0075W	19:28 UTC	17:54 UTC	149°59.985W	
BGOS-B	78°00.3299N	30-AUG	31-AUG	77°58.9586N	3824
	149°57.8486W	15:16 UTC	21:14 UTC	150°03.5947W	
BGOS-D	74°00.1878N	7-SEP	8-SEP	73°59.6065N	3523
	140°00.1198W	17:03 UTC	22:51 UTC	140°02.5639W	

Table 4. Ice-Based Observatory buoy deployment summary.

IBO	ITP / Buoy System	Date	Location
1	ITP 124 (open water deployment)	1-SEP	79°12.913N
		23:08 UTC	147°57.202W
2	ITP 126+SAMI, SIMB-2021#2, TOP2	2-SEP	78°34.6970N
		21:00 UTC	147°14.3155W
3	ITP 127+SAMI, TOP3	4-SEP	77°58.3587N
		01:00 UTC	139°47.4824W
4	ITP 122, SIMB-2021#3, TOP4, AOFB48	4-SEP	79°17.0727N
		23:30 UTC	135°31.8822W

Table 3. Buoy recovery summary.

Recovery	Buoy	Date	Location
1	ITP119 (deployed 2019)	3-Sep	78° 13.34 N
		03:45 UTC	145° 17.98W

2	ITP112 (deployed 2019)	9-Sep	74° 11.73N
		02:38	135° 26.59 W

4.3.2 Moorings

The centerpiece of the BGOS program are the bottom-tethered moorings which have been maintained at 3 (sometimes 4) locations since 2003. The moorings are designed to acquire long term time series of the physical properties of the ocean for the freshwater and other studies described on the BGOS webpage. The top floats were positioned approximately 30 m below the surface to avoid ice ridges. The instrumentation on the moorings include an Upward Looking Sonar mounted in the top flotation sphere for measuring the draft (or thickness) of the sea ice above the moorings, an Acoustic Doppler Current Profiler for measuring upper ocean velocities in 2 m bins, a vertical profiling CTD and velocity instruments which samples the water column from 50 to 2050 m twice every two days, assorted Microcat CTDs, and a Bottom Pressure Recorder mounted on the anchor of the mooring which determines variations in height of the sea surface with a resolution better than 1 mm. In addition, acoustic wave and current profilers (AWAC) provided by the University of Washington are included on moorings A and D, and SAMI-CO_2 and SAMI-pH instruments for the University of Montana on all of the moorings.

Eighteen years of data have been acquired by the mooring systems, which document the state of the ocean and ice cover in the Beaufort Gyre. The seasonal and interannual variability of the ice draft, ocean temperature, salinity, velocity, and sea surface height in the deep Canada Basin are being documented and analyzed to discern the changes in the heat and freshwater budgets. One of the most striking observations in the past decade has been a reduction in both sea-ice extent and thickness, particularly in the BG region. Ocean changes have been as prominent as the reduction of ice volume: between 2003-2018 the BG accumulated more than 6400 km^3 of liquid freshwater, an increase of approximately 40% relative to the climatology of the 1970s. The magnitude of the liquid freshwater increased remarkably from 2003 to 2008 (from 17,000 to 22,000 km^3), after which it appears to have largely stabilized through 2012. In fact, combining both solid (ice) and liquid (seawater) fresh water components, indicated that a modest net export of 320 km^3 of fresh water from the region occurred between 2010 and 2012, suggesting that the ocean anticyclonic circulation regime may have weakened. In 2013, the liquid fresh water component was at it lowest value since 2007, however, in 2014, freshwater in the BG rebounded back to its 2008-2012 mean, and all-time highs were attained from 2015 through 2018, suggesting that the historic cyclical nature of freshwater accumulation and release in the BG may no longer pertain.

4.3.3 Buoys

The moorings only extend up to about 30 m from the ice surface in order to prevent collision with ice keels, so automated ice-tethered buoys are used to sample the upper ocean. On this cruise, three Ice-Tethered Profiler (ITP) buoys were deployed on ice floes: three with Tethered Ocean Profilers (TOP), two with a US Army CRREL Seasonal Ice Mass Balance Buoy (SIMB) and one with a Naval Postgraduate School Arctic Ocean Flux Buoy (AOFB). The combination of multiple platforms at one location is called an Ice Based Observatory (IBO).

The centerpiece ITPs obtain profiles of seawater temperature and salinity from 7 to 760 m twice each day and broadcast that information back by satellite telephone. The TOP is a new ITP-like platform designed to sample the top 200m of the water column all the way to the sea ice. The ice mass balance buoys measure the variations in ice and snow thickness, and obtain surface meteorological data. The AOFB measures the heat fluxes below the ice as well as ice thickness and meteorological data. Most of these data are made available in near-real time on the different project websites (Table 4).

Initiated in fall 2004, the international ITP program over the last 16 years has seen the deployment of over 100 systems distributed throughout the deep Arctic Ocean (a small subset of which were instruments recovered, refurbished, renumbered and redeployed). All of these ITPs sampled ocean temperature and salinity (conductivity) and some of the systems were configured to additionally sample dissolved oxygen, bio-optical parameters (chlorophyll fluorescence, optical backscatter, CDOM, PAR), upper ocean chemistry (CO2, pH) and/or ocean velocity. ITP data are made publicly available in near real time from the project website, as well as distributed over the Global Telecommunications System (GTS) for operational forecast activities, with calibrated, edited and gridded data products generated and entered into national archives as completed. The ITP program has provided a unique, extensive and cost-effective dataset spanning all seasons with which to study the upper Arctic Ocean during a time of rapidly changing conditions. Indeed, ITP data have contributed to a variety of research studies by researchers and students worldwide.

The acquired CTD profile data from ITPs documents interesting spatial variations in the major water masses of the Canada Basin, shows the double-diffusive thermohaline staircase that lies above the warm, salty Atlantic layer, measures seasonal surface mixed-layer deepening, and documents several mesoscale eddies. The IBOs that we have deployed on this cruise are part of an international collaboration to distribute a wide array of systems across the Arctic as part of an Arctic Observing Network to provide valuable real-time data for operational needs, to support studies of ocean processes, and to initialize and validate numerical models.

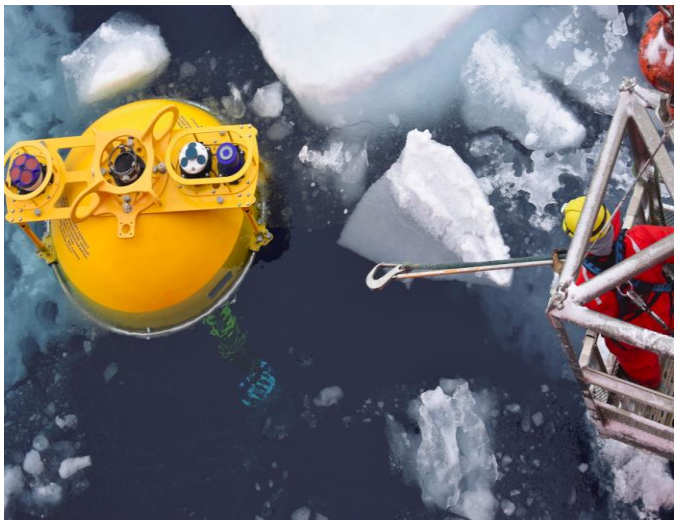
Table 5. Project websites

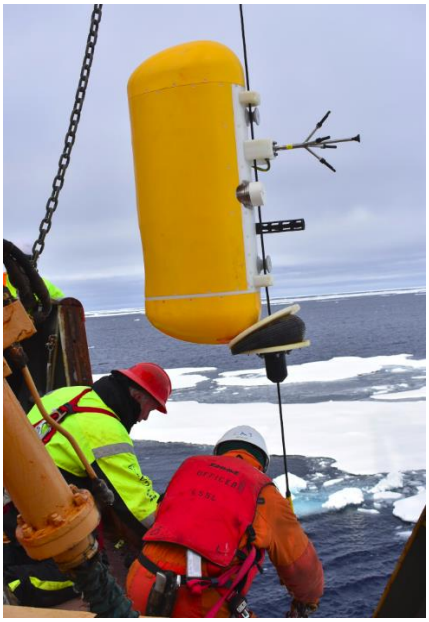
Project	Website Address
Beaufort Gyre Observing System	www2.whoi.edu/site/beaufortgyre/
Beaufort Gyre Observing System dispatches	www2.whoi.edu/site/beaufortgyre/expeditions/
Ice-Tethered Profiler buoys	www2.whoi.edu/site/itp/
Ice Mass Balance buoys	imb-crrel-dartmouth.org/simb3/
Arctic Ocean Flux Buoy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

4.3.4 Operations

The mooring deployment and recovery operations were conducted from the foredeck using a dual capstan winch as described in WHOI Technical Report 2005-05 (Kemp et al., 2005). Before each recovery, an hour long precision acoustic survey was performed using an Edgetech 8011A release deck unit connected to the ship's transducer and MCal software in order to fix the anchor location to within ~10 m. We were only able to communicate with the mooring top transponder (located beneath the sphere at about 30 m) on mooring D, and were able to survey its location. This was particularly useful as it was an ice-covered recovery.

In coordination with the bridge, acoustic release commands were sent to the release instruments just above anchor, which let go of the anchor, so that the floatation on the mooring could bring the systems to the surface. The ship's manbasket was used to hook the top surface flotation package to a leader. Then the flotation, wire rope, and instruments were hauled back on board. Data was dumped from the scientific instruments, batteries, sensors, and other hardware are replaced as necessary, and then the systems were subsequently redeployed with sufficient resources for one year of data collection. The moorings were redeployed anchor first, which required the use of a dual capstan winch system to safely handle the heavy loads. This year, recoveries took 4-5 hours after release, and deployments took 5-5.5 hours for the 3500-3800 m long systems. The 2018 deployment was planned to last two years, but recovery was not possible in 2020 due to COVID-19 travel restrictions. Many of the instruments persisted for almost the full three years, most notably the ULS, BPR and deep MMP systems. The shallow MMPs on moorings A and B were programmed to sample more frequently and only lasted their intended one year. The ADCPs did not function well due to a battery issue.





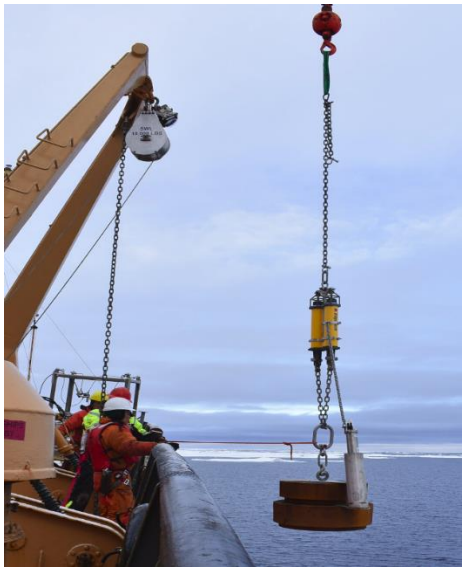


Figure 1. Recovery of top floatation package, MMP deployment, and anchor, acoustic release, and BPR deployment.

ITP deployment operations on the ice were conducted site according to procedures described in a WHOI Technical Report 2007-05 (Newhall et al., 2007). The helicopter was not used for ice floe reconnaissance, but instead floes were selected visually from the bridge and surveyed by lowering 2 scientists over the side of the ship in the manbasket to drill the potential site to determine thickness. After it was determined

that the floe was adequate, the ship's gangway was lowered onto the ice for access by personnel and equipment was lowered using the ship's crane. The first icefloe selected for deployment of ITP127+SAMI, SIMB#2, and TOP2 was 85-95cm thick; the second icefloe selected for deployment of ITP126+SAMI and TOP3 was 70-95cm thick; the third for deployment of ITP112,SIMB#3 and AOFB48 was 75-100cm thick. Ice analyses were also performed by others in the science party while the IBO deployment operations took place. ITP 124 was deployed in open water from the foredeck of the LSSL.

Figure 2. IBO consisting of ITP127, SIMB, and TOP2 (left), ITP 126 and TOP3 (center) and ITP 122, SIMB, AOFB48, and TOP4 (right) shortly after deployments.

Two complete ITPs were recovered during the expedition. Both were recovered from the foredeck using the manbasket to hook the package and were hoisted on deck. ITP 119 was found in a small floe and was dislodged by first ramming the floe with the bow and then sending the starboard bubblers at it. Once dislodged, the ITP moved very quickly down to midships and substantial repositioning was required. Both its profiler and anchors were muddy due to dragging. ITP 112 was found in open water but wedged against an ice floe that seemed to be holding it in place. The top float came back in two pieces and the bottom half was severely damaged. The surface package was wedged into the top half and the grounding plate was missing.

Figure 3. ITP 119 recovery location (top left) and its muddy anchors (top right), ITP 112 recovery location (bottom left), and its severed top floatation (bottom right).

4.3.5 Outreach

Dispatches documenting the expedition were composed by Isabela Le Bras (WHOI) and Helen Gemmrich (Concordia / DFO-IOS) and posted in near real time on the WHOI website.

4.4 Underway and Moored pCO2 and pH Measurements

Cory Beatty (UMontana, Cory.Beatty@umontana.edu)
P.I.: Mike DeGrandpre (U.Montana,michael.degrandpre@umontana.edu) in collaboration with Rick Krishfield and Andrey Proshutinsky (WHOI)

4.4.1 Overview: U.S. National Science Foundation: An Arctic Ocean sea surface pCO_2 and pH observing network

This project is a collaboration between the University of Montana (Mike DeGrandpre) and Woods Hole Oceanographic Institution (Rick Krishfield, Andrey Proshutinsky and John Toole). The primary objective is to provide the Arctic research community with high temporal resolution time-series of the partial pressure of CO_2 (pCO_2), pH, temperature, dissolved oxygen (DO) and photosynthetically active radiation (PAR).

During this cruise:

1. We deployed a SAMI-CO_2 equipped with a dissolved Oxygen sensor and PAR sensor on 2 of the WHOI ice-tethered profilers (ITP126 & ITP127). Placed on the ITP cable just under the ice, the sensors send their data via satellite using the WHOI ITP interface.

2. We collected underway pCO_2 data using an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors). The instrument was connected to the Louis seawater line manifold located in the main lab. These data will 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. We deployed a SAMI-CO2/SAMI-pH pair with DO and PAR on the BGOS-A, BGOS-B and BGOS-D moorings at a depth of approximately 38m. BGOS-D also has a fluorometer attached to the pH SAMI.

4. Assisted with other shipboard research activities and interacted with ocean scientists from other institutions.

Figure 14. Example of a SAMI-CO_2 being deployed on an ITP.

Table 6. pCO_2 and pH sensor data collection summary

Measurement system	Instrument IDs	Location	Duration
Underway infrared-equilibrator pCO_2	SUPER (Sunburst Sensors)	Entire cruise track (see IOS report in this document)	8/20/2021 - 9/14/2021
ITP SAMI-CO_2 w/ DO sensor and PAR	WHOI ITP 127, SAMI-CO2 (C207)	First on-ice ITP deployment, CO2 ~ 4.5 m depth, (see WHOI cruise report in this document)	9/2/2021- present
ITP SAMI-CO_2 w/ DO sensor and PAR	WHOI ITP 126, SAMI-CO2 (C9u)	Second on-ice ITP deployment, CO2 ~ 4.5 m depth, (see WHOI cruise report in this document)	9/5/2021 - present
SAMI-CO_2 / SAMI-pH	CO2 : C39, pH : P13u	BGOS-A mooring	8/28/2021 – present
SAMI-CO_2 / SAMI-pH	CO2 : C24u pH : P66	BGOS-B mooring	8/31/2021 - present
SAMI-CO_2 / SAMI-pH	CO2 : C86 pH : P87	BGOS-D mooring	9/8/2021 - present

4.5 XCTD Profiles

Operators: C. Clarke, K.Brown, B. Richaud, N. Rosen, H. Gemmrich, S. Zimmermann
PI: Andrey Proshutinsky, Isabel Le Bras, Rick Krishfield (WHOI), Mary-Louise Timmermans (Yale), Motoyo Itoh (JAMSTEC), Bill Williams (DFO-IOS)

Overview

Profiles of temperature and salinity were measured using expendable probes capable of being deployed while the ship was underway. Profiles were collected at 49 locations along the ship's track between the CTD stations.

Procedure

XCTD (eXpendable Conductivity Temperature Depth profiler, Tsurumi-Seiki Co., Ltd.) probes were launched by a hand launcher LM-3A (Lockheed-Martin_Sippican, Inc.) from the stern of the ship into the ocean. The data are communicated from the probe back to the launcher ship by a fine wire which breaks when the probe reaches its maximum depth. The launcher is connected to a MK-21 deck unit (Lockheed-Martin-Sippican, Inc) and computer inside the ship that logs the digitally converted data.
The Lockheed-Martin-Sippican MK-21 Ethernet deck unit and WinMK-21 software on laptop "Arrow" were connected via the ship's network – both devices were connected to the network via an Ethernet switch. GPS was provided by science server over the network via GPSGate. Water depth from the sounder was displayed on the laptop in a Hyperterm window.

Data were automatically backed up by the WinMK-21 software to the local drive and then populated on the ScienceNet server using Syncback. The cast log file was saved locally and then manually transferred to the server periodically.

Operation Notes

Three types of probes were used:

Probe Type	Number Used	Filename convention	Max Depth (m)	Max Ship Speed (Kts)
XCTD-1	23	"C3_"	1100	12
XCTD-2	1	"C4_"	1850	3.5
XCTD-3	29	"C5_"	1000	20

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

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

There were 49 XSV-02 probes used by CHS on the transit north.

There were 53 probes used in the Canada Basin w/ 4 repeats dues to early line breaks for a total of 49 locations. In total, the wires from 6 probes broke off early due to ice or wind and did not reach the full depth. Repeats were made when the first probe's data did not reach 400m.

Start time in file header

XCTD start time given in the file header is 7 minutes fast for Casts 1 to 43. Cast start time for Cast 44 to 54 is correct. The XCTD file's launch information uses start time from the computer clock, not NMEA. The computer clock from the start of cruise to Sep 9th UTC 22:10 was 7 minutes fast. The computer clock was corrected Sep 9, from 22:10 to 22:03 UTC based on NMEA time.

Early breaks and repeat summary

XCTD-1 sn20058165, depth 306.4m, filename: C5_00005 (wire broke early, ice)
XCTD-1 sn20058166, depth 1011.9m, filename: C5_00006 (repeat of C5_00005)
XCTD-1 sn20058171, depth 278.5m, filename: C3_00022 (wire broke early, ice)
XCTD-1 sn20058172, depth 1100m, filename: C3_00023 (repeat of C3_00022)
XCTD-1 sn20058175, depth 689m, filename: C3_00028 (wire broke in ice; did not reattempt)
XCTD-1 sn20111291, depth 270m, filename: C3_00029 (wire broke off early, ice)

XCTD-1 sn20111292, depth 1100m, filename: C3_00030 (repeat of C3_00029)
XCTD-3 sn16016786, depth 194m, filename: C5_00039 (wire broke early, ice)
XCTD-1 sn20111296, depth 1100m, filename: C5_00040 (repeat of C5_00040)
XCTD-3 sn16016795, depth 400m, filename: C5_00053 (wire broke early, did not repeat)

Wrong probe type

Cast 40 and 41 were made with XCTD-1 probes, however XCTD-3 was selected in WinMk21. Cast 47 was made with XCTD-3 probe but XCTD-1 was selected in the software. These first two were corrected by reprocessing in the software but the data does not change so for Cast 47, the filename was changed and header information updated to "XCTD-3" using a text editer.

XCTD-1 sn20111296 original filename: C5_00040, new filename: C3_00040
XCTD-1 sn20111297 original filename: C5_00041, new filename: C3_00041
XCTD-3 sn16016790 original filename: C3_00047, new filesname: C5_00047

Connection problems with deckunit

There were some issues with the MK21 connection. On Aug 30 (Cast 19), there were some technical issues with the computer before the probe launch where the connection was lost to Sciencenet server and MK21. This was resolved after turning everything off and on again, unplugging/re-plugging the Ethernet cable etc. It's not clear what the solution was in the end, but the thought was that the Sciencenet server was the main issue. On Aug 31 (Cast 21), again there were problems connecting with the MK21, this time Sciencenet server and GPSgate were working fine. We switched the Ethernet cable port from 3 to 1 (again, we switched it from 1 to 3 to resolve Cast 19 issues, which seemed to work once we got the Sciencenet talking again) then tried a few times to manually connect through the MK21 device parameters. Ended up with "MK21/Ethernet DAQ" on "Manual Selection" which worked, but for the last cast we had it working using the MAC address and couldn't connect this way again). No further issues were reported. On Sept 9th, Sarah Z. updated the computer clock from 22:10 to 22:03 UTC and changed the XCTD type for the casts noted above

See Appendix for table of stations.

4.6 Vertical Net Tows

C. Clarke, K.Brown (DFO-IOS), N. Rosen (UVIC), M. Gamrani (USherbrooke)
P.I.: John Nelson (DFO-IOS)

4.6.1 Sampling

Zooplankton sampling and preservation were conducted on board by Chris Clarke and Nimrod Rosen of the day watch and Kristina Brown and Mohamed Gamrani of the night watch. A standard bongo net system was used with a fitted 150µm net on one side and a 236µm mesh net on the other side. Both sides had 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.

Figure 15. Bongo nets being deployed from the foredeck, photo Gary Morgan, JOIS 2021

The sampling strategy was to perform a single net haul to 100m at each station whenever time and weather permitted, provided they did not interfere with the rosette operation or require additional ship time unless at a priority station.

A total of 34 bongo vertical net hauls were completed at 34 stations (see Appendix).

Bongos were deployed on the foredeck using a Swann 310 hydraulic winch and 3/16” wire through the forward starboard A-frame. Nets were rinsed from a 100 foot electrically heated hose connected 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 science container to keep it warm.

Samples collected from the 150μm net were preserved in 95% ethanol and samples collected from the 236μm net were preserved using formalin with final sample concentration 3.7%. The formalin samples will be examined for species identification and the ethanol samples for DNA sequence analysis coordinated by John Nelson.

UTC was used to log all times and dates in zooplankton log unless otherwise specified. The ship's local time switched between MST and PST during cruise.

Net Mesh Size	TSK Flow Meter	Sample Preservation
150um	sn7085	95% Ethanol for DNA sequence analysis
236um	sn7303	3.7% Formalin for for species identification

4.6.2 Issues and solutions

Some stations with loose flowing ice were challenging for the bridge to maintain an ice free pond for both the bongo and rosette at the same time. This was especially true at Net#11 where the net was held at the bottom while the bubblers were used to push back the ice. The bubblers were used routinely in ice during this cruise, however almost exclusively before the net was deployed or while it was at the bottom before coming up.

The RBR's pressure sensor 30 pin connector is unreliable. When downloading data to computer it's best to unscrew RBR and plug in directly. The o-ring should be cleaned and greased every time its opened.

As noted in 2020, 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. Furthermore there is no nearby electrical outlet so the electricians ran an extension cord into the forward science shack. Initially we plugged into the forward starboard outlet however ocean spray was causing shorting in 2020. In 2021 we plugged the extension cord into the same outlet with no problems, however the plugs looked very weathered after the full season and should be replaced for 2021.

As noted in 2020, the wooden box used to house the bongo nets should be replaced with an aluminium box, as the wooden one is heavy (especially once soaked with water) and is falling apart, resulting in wood chips getting into the samples. A design suggestion is having both long sides of the box removable. This could give more access to the nets below the bongo frame for handling on the deck side.

As in 2020, a brass hose nozzle was used on the foredeck; this was a great choice as it is much more durable than plastic nozzles, consider sending a backup brass nozzle.

Note: stations on the BL line had lots of "goop" and had to be separated into multiple jars for both the 150μm and 236μm nets.

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

On board: Susanne Kraemer (ConcordiaU), Josephine Rapp (ULaval) and Aurélie Labarre (ULaval)

P.I.: Connie Lovejoy (ULaval), David Walsh (ConcordiaU)

4.7.1 Introduction

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

4.7.2 Methodology

This year we started the JOIS journey from the South of the Beaufort Sea, in a clockwise direction due to the presence of thick ice in the north-eastern Canadian Basin. Water column samples were collected at a total of 32 stations (Figure 1) to cover a range of previously studied stations (between 2012-2019), plus additional ice stations (in combination with ice core sampling, see Ice core report). Starting with AG-5 and the 31 following stations (StaA, BL1, BL2, BL8, CB2, CB3, CB4, CB6, CB7, CB8, CB9, CB10, CB11, CB21, ICE-2, CB16, ICE-4, CB15, PP7, CB17, CB21, CB40, CB50, CB23a, CB27, MK6, CB28b, MK4, MK2, MK1, CB28aa), samples were collected at eight depths per station: surface water (5m), 20m, SCM (chlorophyll max), 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.

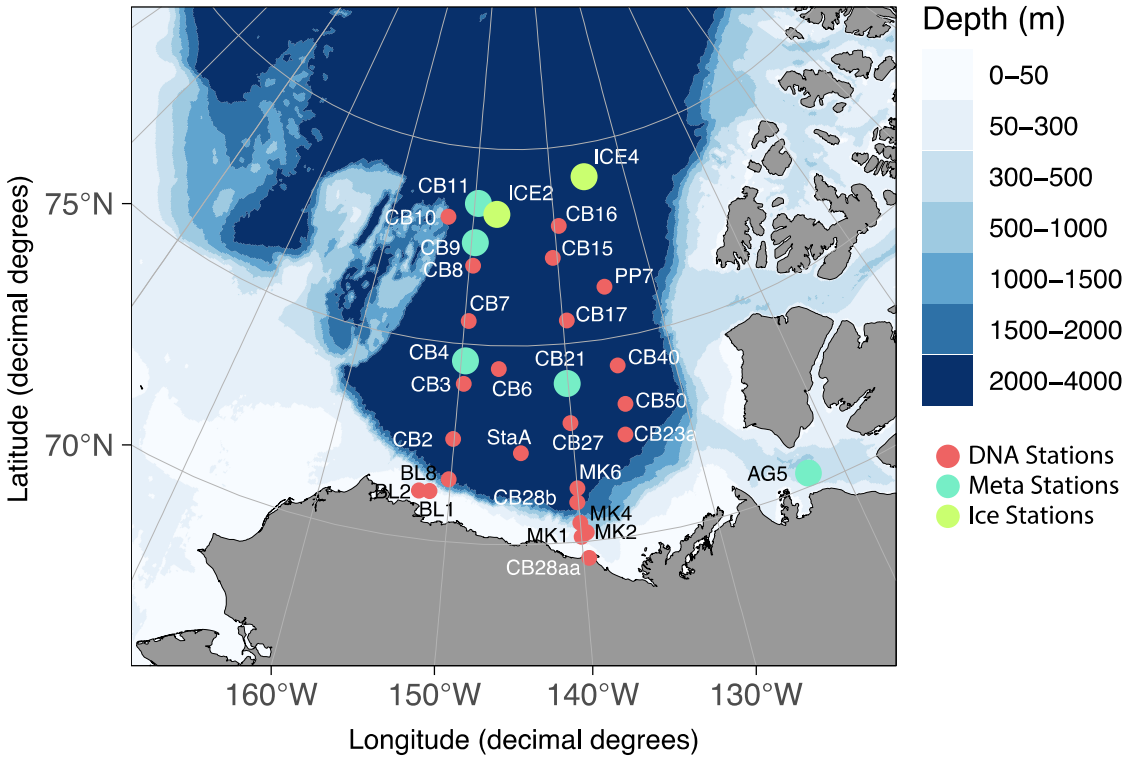


Figure 1: Stations designated as "***DNA stations***" had designated Niskin bottles for two water masses (surface and SCM layers) and shared bottles for the other sampled water masses with the routine IOS geochemistry casts. We collected and filtered 7L of water for each water mass at DNA stations dedicated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

Seawater filtration

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

Epifluorescent microscopy

Samples for biovolume estimation, abundance and gross taxonomic classification by microscopy were collected and preserved as described by Thaler and Lovejoy (2014) at every sampled station for two designated depths: Surface and SCM. In summary, 50mL seawater was fixed with glutaraldehyde (1% final concentration), filtered onto a 25mm, 0.8µm black polycarbonate filter (AMD manufacturing), stained with DAPI (1mg/ml, final concentration) and mounted on a glass slide with oil. Slides were stored in opaque boxes and kept frozen until analysis in ULaval. Because of a shortage of glutaraldehyde, we preserved seawater samples for epifluorescent microscopy in prefiltered 37% formalin for the ICE stations samples.

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.

4.7.3 Additional projects

Study of marine-derived parasites in polar ecosystems

Objectives:

i. Screen for diatom/parasite interactions & quantitative assessment via imaging: SEM, CARD-FISH | "Find relevant model organisms for understanding parasitic interaction"

ii. Analyze the genetic diversity, taxonomic and geographic distribution of marine-derived parasites (fungi & fungi-like protists: oomycetes, labyrinthulomycetes, hyphochytriomycetes) & evaluate the effect of environmental conditions on host (diatom)/parasite prevalence; amplicon sequencing DNA & cDNA

iii. Single cell genome sequencing of parasites

iv. Enrich for parasites using HCR-FISH to create mini-metagenome dataset & assess genomic diversity, connectivity and adaptation

Isolation of Western Arctic Ocean SAR11 bacteria

The SAR11 clade of bacteria comprises one of the most abundant and successful clades in the ocean and is characterized by small genomes, but high metabolic flexibility. Previous work has shown that the western Arctic Ocean environment harbours distinct SAR11 bacterial genotypes, but the potential metabolic specializations underlying such an

apparent endemism are still unknown. To resolve this, we have collected frozen sea water samples, as well as filtered sea water for SAR11 isolation from cryopreserved samples from two of the Meta stations. 1.5mL of sea water were gently mixed with 375µl of a 50% glycerol-TE solution and cooled by one degree per hour to freezing before being stored at -80˚C.

4.8 Underway Surface Sea-water Measurements

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

The ship's seawater loop system draws seawater from below the ship's hull at 9 m using a 3" Moyno Progressive Cavity pump. After measuring the intake seawater temperature, seawater travels through ~50m of stainless steel piping to a manifold in a wetlab off the main science lab. The wetlab is configured with an integrated Seabird SBE21 thermosalinograph, Seapoint Chl-a fluorometer and Wetlabs FDOM fluorometer. Recording independently, a second Wetlabs FDOM fluorometer, and a pCO2 system were connected to the wetlab manifold.

Measurements were made for:

a. Surface temperature (inlet and lab), salinity, fluorescence for Chlorophyll-a and FDOM.
b. Water samples were drawn for
    - Salinity, Nutrients, Dissolved Inorganic Carbon, Alkalinity, and Chlorophyll (IOS/DFO)
    - Fluorescent Dissolved Organic Matter (*Celine Gueguen, USherbrooke*)
c. Measurements of partial pressure of carbon dioxide (pCO_2) using a SunBurst SUPER instrument (*Mike DeGrandpre, UMontana)*

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

4.9 Underway data logging using SCS

Sarah Zimmermann (DFO-IOS)
P.I.s: Bill Williams, Celine Gueguen (USherbrooke)

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 $GPRMC. These are the same GPS sentences, available on the science VLAN, being used by CTD, XCTD and TSG systems.
2. AVOS weather observations of air temperature, humidity, wind speed and direction, and barometric pressure ($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.

Not recorded this year as has been in past years:

1. Heading from the ship's Gyro ($HEHDT) – Gyro feed not initially available and not pursued.
2. Data from the FDOM fluorometer in the seawater loop (FDOM) – Effort not put into generating SCS file as data were already being collected.
3. Derived true wind speed calculated in SCS – w/out Heading, not calculated this year. I believe true wind speed available in AVOS data set.

Note the AVOS, TSG (and SBE38), PAR and FDOM data are also logged through their own software programs which are more complete than this year's SCS record. In particular the SCS system was not recording data from Aug 30 14:40 to Sep 3 19:30 UTC although the independent systems have data. On the other hand, when the TSG computer had problem with the Navigation and SBE38 feed Sep 13th the SCS data served as a backup.

The SCS system on a shipboard computer called the "NOAA server" collects *RAW files. The files typically contain a day's worth of data, restarting at midnight.

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

4.10 Ice Observations – Bridge Watch

Canadian Ice Specialist: Francis Beaulieu
Bridge Web Cameras: Sarah Zimmermann (DFO-IOS)
P.I.: Kazu Tateyama (KIT), Jennifer Hutchings (OSU)

As in previous years, the ice observations recorded during the cruise will provide detailed information for the interpretation of satellite imagery of the ice pack. The regular science ice-team was not on board this year due to COVID travel related restrictions.

4.10.1 Observations from the Bridge: Methodology

Ice conditions and supporting weather information is typically recorded every hour within 1nm about the ship when visibility allows along the ships track by a science team member. This year without this person, the reports made by the Canadian Ice Service (CIS) Ice Specialists, Francis Beaulier can be used.
Last year observation were made both through standard CIS protocol and the ASSIST protocol to determine if they are interchangeable which may allow for use of the information collected this year. 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.

4.10.2 Web and GoPro Cameras

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

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

The other netcam was mounted above the bridge on the forward rail, looking forward to measure ice concentration. There has been a problem with powering this camera resulting

in not images in 2019 or 2020 (at least). This year the problem was solved by using an extension cord to supply the camera's power instead of a powered network cable.

As in 2019 and 2020, a self-recording GoPro camera was installed pointing forward looking over the bow from inside the bridge, mounted on the port-side forward facing window. These images duplicate those collected by the forward looking web camera.

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

Issues

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

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

Fixes applied for 2021

A new 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.

Mike Dempsey cleaned up the rusted housing used in the past for the port side netcam. The housing was removed at the end of 2021 to prevent re-freezing due to rust.

A work around for the forward looking netcam power supply was made by running an extension cord from the ice observer's room, out the window up to the camera, paralleling the network cables.

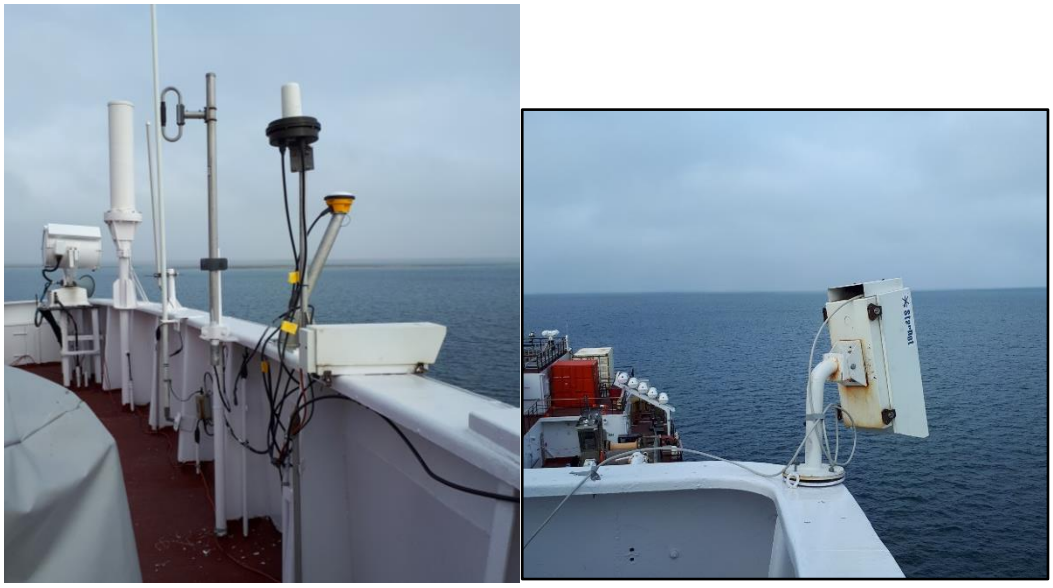
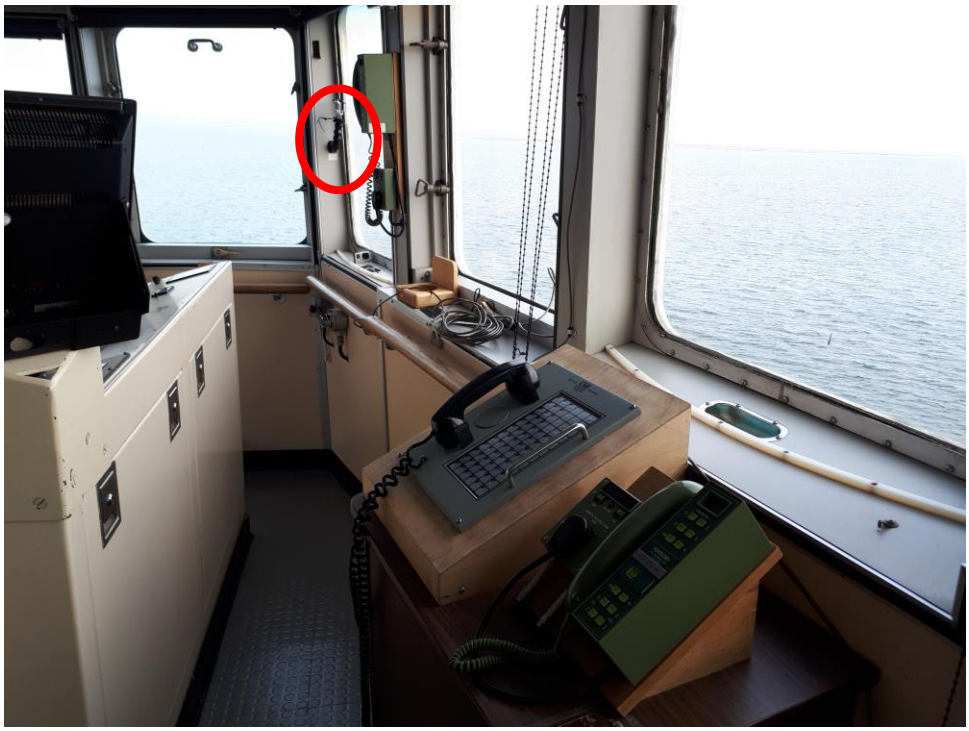


Figure 16. The forward looking necam on the left and the downward looking netcam on the right.

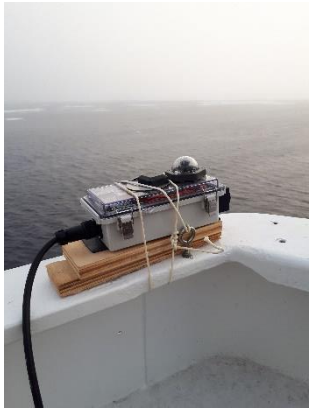


Location of forward looking GoPro camera on the port side of the bridge.

4.10.3 Experimental Self-contained Camera

Kazu Tateyama (KIT) is trialling a new self-contained camera system. A single housing contains three camaras: forward looking, port-side downward looking, and upward all-sky looking cameras. The same housing hold a GPS receiver, data logger and battery. The housing connects to a solar panel to power the system. There is a known problem of the solar panel not providing enough power to the system but we trialled the system so data could be examined.

Operationally we found there was a problem with icing where it was mounted above the bridge, similar to the netcameras. Another problem was moisture inside the housing although its unclear if this was due to condensation or rain/ice making its way inside after being out for a week in -5 to +5 C temperatures, strong winds, and icebreaking conditions.



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

4.11 Ice Observations – Ice Thickness from suspended EM sensor - Postponed

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

The EM was not used this year due to COVID related travel restriction preventing Kazu Tateyama from joining the program.

4.12 Ice Observations – On ice stations

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

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 and make microbial measurements of the sea-ice.

Ice Stations w/ observation work:

Station	Ice Observation	ITP / Buoy System	Date (UTC)	Location
Ice 2	Thickness transects, cores for microbial study, temperature and salinity	ITP 126+SAMI, SIMB-2021#2, TOP2	2-SEP 21:00	78°34.6970N, 147°14.3155W
Ice 4	Thickness transects, cores for microbial study, temperature and salinity	ITP 122, SIMB-2021#3, TOP4, AOFB48	4-SEP 23:30	79°17.0727N, 135°31.8822W

4.12.1 Ice Thickness Transects

Nicolas Sylvestre (U Sherbrooke), Nimrod Rozen (UVic), Susanne Kraemer (Concordia), Mohamed Gamrani (U Sherbrook), Francis Beaulieu (Ice observer, Environment Canada), Benjamin Richaud (Dalhousie)

Ice thickness transects were conducted at two of the three on-ice stations. No transect was perfomed at Ice 3 due to a very limited area of safe thickness.

In parallel, ice cores were taken for DNA/RNA sampling purposes and salinity and temperature profiles.

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

1. Establishing 100m-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 drill.

Overviews of ice stations

Ice Station 2

Drilling: Nicolas Sylvestre, Francis Beaulieu, Nimrod Rozen, Benjamin Richaud

Ice was accessed from gangway of port side. One 100m-long transect (1 x 100m) and one 58m-long transect were set as shown in Fig.1.

Ice Station 4

Drilling: Mohamed Gamrani, Susanne Kraemer, Nimrod Rozen, Benjamin Richaud

Ice was accessed from gangway of port side. A 100m-long, a 30m-long and a 20m-long transects were established as shown in Fig.1. The last, 20m-long transect was interrupted before completion due to the failure of the tape measure, resulting in the loss of the ice dongle.

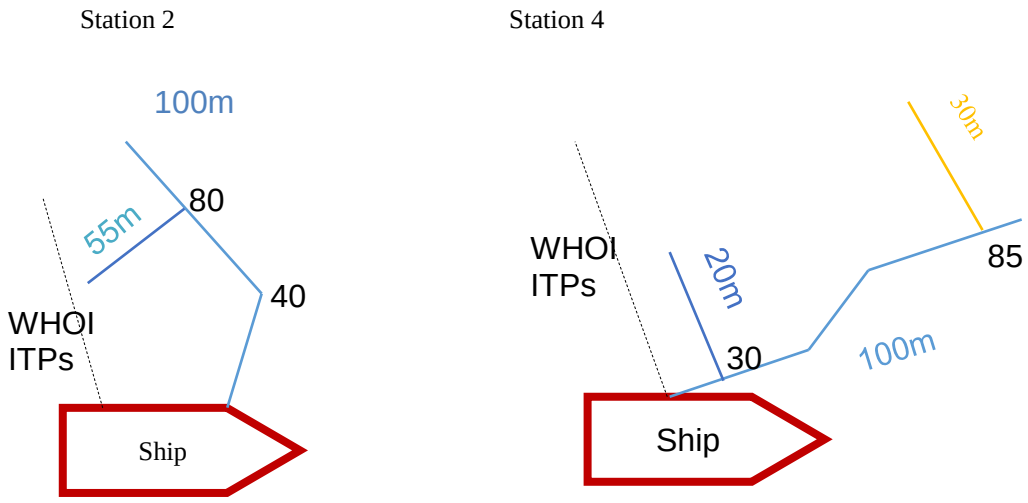
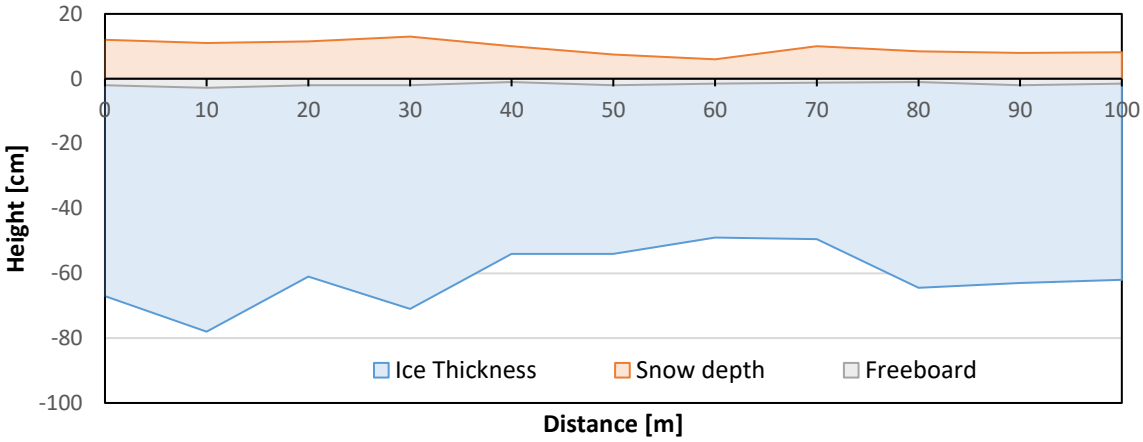


Figure 1. Drawing of transects on each ice stations.
Station 2 and 4 consist one 100m transect and 1 or 2 shorter cross transects. The length of each transect is indicated in the same color as the line; distances from the beginning of the 100m transects are given in black.

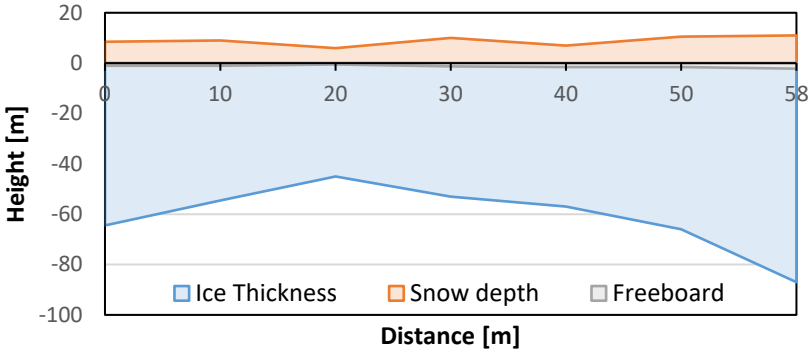
Measurements

We settled for 100 m transects with snow depth, thickness and freeboard of sea ice measurements every 10m along transects as shown in Fig.1. Ice thickness and freeboard were measured directly with the use of a drill and tape measure. Snow depth was measured by a steel ruler.

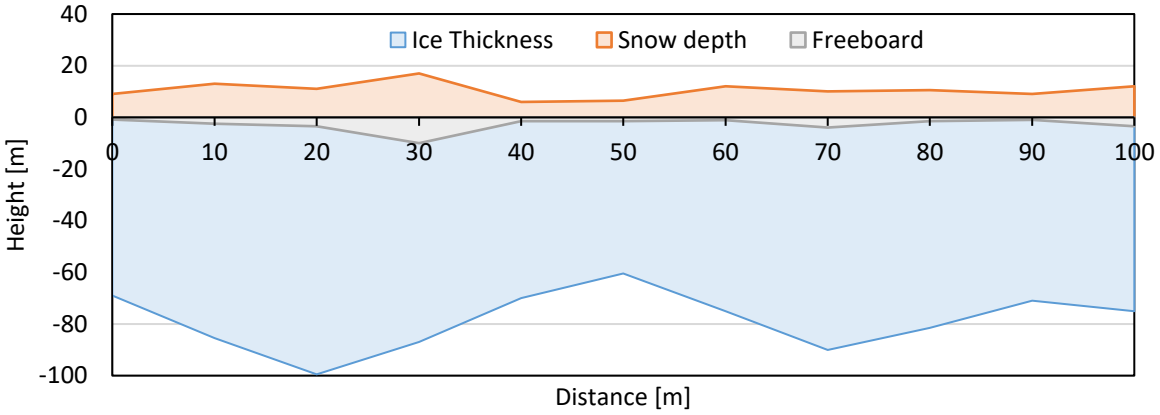
Ice Station 2, Transect 1



Ice Station 2, Transect 2



Ice Station 4, Transect 1



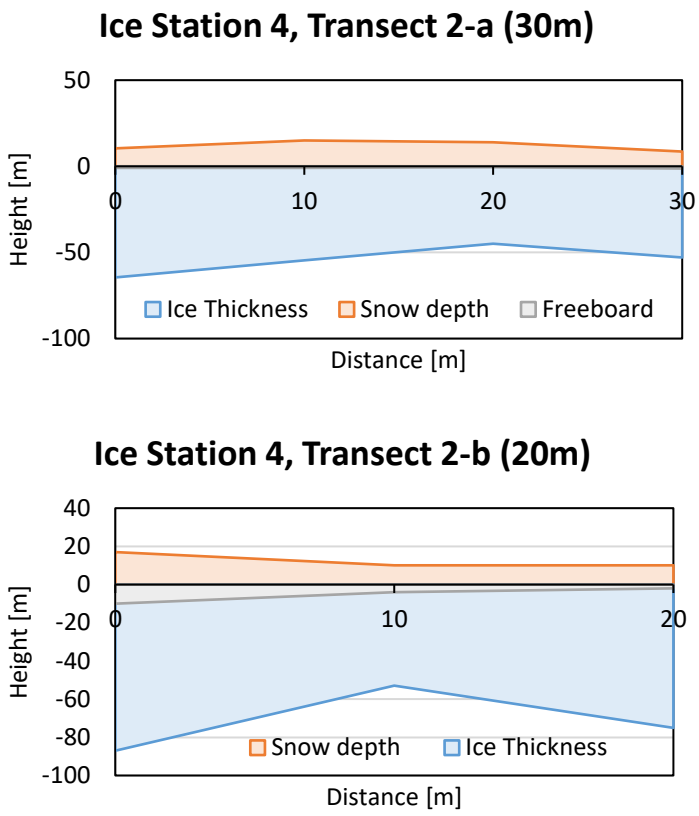


Figure 2. Snow depth, ice thickness and freeboard measurements at ice station 2 and 4.

4.12.2 Ice Cores – Microbiology and Physical properites

Josephine Z. Rapp (ULaval), Aurélie Labarre *(ULaval), Kristina Brown (IOS), Helen Gemmrich (IOS)*
P.I.: Alexander Culley (ULaval) and Connie Lovejoy (ULaval)

During this year's JOIS expedition, members of the DNA/Microbiology team sampled sea-ice cores and under-ice water for microbiological molecular analysis. Ice coring work could be realized at two ice stations (ICE2 and ICE4) in parallel to WHOI profiler and buoy operations. At both stations, Kristina Brown and Josephine Rapp conducted an ice safety survey (with the support of members from the ice transect team: Thanks Nicolas Sylvestre and Benjamin Richaud!) and identified a suitable area for the coring program. We collected samples from 4 x 4 m triangle-shaped sampling areas (Figure 1), which featured three sites for biological cores (biological triplicates) and a center area for salinity and temperature core collection. Also, the collection of direct brine samples via sackholes was attempted, but not successful as there was immediate seawater infiltration from below. After the ice cores were taken and processed, we used a small portable and battery-powered peristaltic pump to obtain under-ice seawater from 1-5 cm below the ice. A handheld submersible camera was lowered through the core holes to capture visual impressions of the under-ice environment.

Along with the cores, we collected snow depth, ice thickness and freeboard data. Additional data outside the sampling area was obtained by the ice transect team (see separate report for more information).

4.12.2.1 *Ice Cores – Methods*

We collected a total of six biological cores per station, two cores per corner of the triangle (Figure 1). These two cores together were treated as a single sample and pooled for subsequent analyses in order to obtain sufficient volumes for the various subsamples (see below). Cores were sectioned into top, middle and bottom sections of equal length, collected in sterile whirl pak bags and later left to melt in the dark in the ship's 4 °C cold room. Table 1 shows the summary of collected ice core samples. Sea ice at both ice stations, but particularly at ICE2, was very layered, and often featured multiple layers of mushy ice were the cores would break during the drilling process. We observed a high number of melt ponds on both floes and video footage taken through the drill holes revealed the presence of multiple large pockets of water within the ice sheet. Under the ice, we observed a relatively high number of jellyfishes, potentially ctenophores.

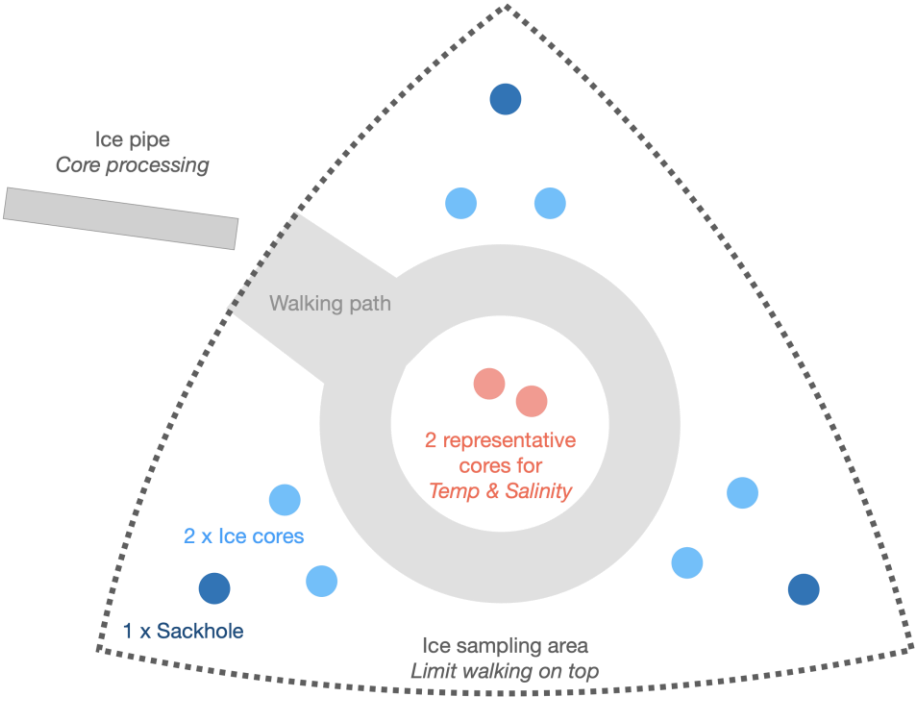


Figure 17. Sampling setup that was used for the microbiological core collection at both ICE2 and ICE4.

Table 7. Overview of the collected ice cores at both ice stations.

Ice Station	Site	Length [m]	Purpose	PI
ICE2	ICE2 center	0.60	Salinity	Rapp/Culley/Lovejoy
	ICE2 center	0.61	Temperature	Rapp/Culley/Lovejoy
	ICE2 - 1A	0.66	DNA	Rapp/Culley/Lovejoy

	ICE2 - 1B	0.62	DNA	Rapp/Culley/Lovejoy
	ICE2 - 2A	0.60	DNA	Rapp/Culley/Lovejoy
	ICE2 - 2B	0.60	DNA	Rapp/Culley/Lovejoy
	ICE2 - 3A	0.65	DNA	Rapp/Culley/Lovejoy
	ICE2 - 3B	0.76	DNA	Rapp/Culley/Lovejoy
ICE4	ICE4 center	0.95	Salinity	Rapp/Culley/Lovejoy
	ICE4 center	0.95	Temperature	Rapp/Culley/Lovejoy
	ICE4 - 1A	1.04	DNA	Rapp/Culley/Lovejoy
	ICE4 - 1B	0.99	DNA	Rapp/Culley/Lovejoy
	ICE4 - 2A	0.96	DNA	Rapp/Culley/Lovejoy
	ICE4 - 2B	1.00	DNA	Rapp/Culley/Lovejoy
	ICE4 - 3A	0.96	DNA	Rapp/Culley/Lovejoy
	ICE4 - 3B	0.99	DNA	Rapp/Culley/Lovejoy

After melting the cores over the course of several days, we took subsamples for DNA analysis, bacterial DAPI (microscopy), single cell genomics, flow cytometry and nutrient analysis. For DNA analysis, the samples were subsequently filtered through 3.0 µm, 0.2 µm and 0.02 µm pore size polycarbonate filters for the analysis of eukaryotes, prokaryotes and viruses, respectively. Additionally, a "whole" filter was obtained that holds a direct filtrate onto 0.02 µm pore size. All samples were stored at -80 °C.

4.12.2.2 *Temperature and Salinity Profiles*

We took a core each for a salinity profile and for temperature measurements at both ice stations (Figure 1). Both salinity and temperature were determined in 10 cm intervals (Table 2).

Table 2: Temperature and salinity profiles for ICE2 and ICE4

	Core Section (cm)	Salinity (PPT)	T (°C)
ICE2	0-10	0	-0.3
	10-20	0.1	-0.1
	20-30	0.1	0.1
	30-40	0.5	0
	40-50	0.9	0.1
	50-60	1	0.1
ICE4	Core Section (cm)	Salinity (PPT)	T (°C)
	0-10	0.1	-1.9
	10-20	0.1	-0.2
	20-30	0.4	0
	30-40	0.7	-0.1
	40-50	0.2	-0.1
	50-60	1.5	-0.1

60-70	2.3	-0.2
70-80	0.6	-0.1
80-90	2.7	-0.1
90-95	3.1	-0.2
Under-ice water	26.1	n.d.

Figure 18. Curious visitor. Photo by Gary Morgan.

5. APPENDIX

5.1 SCIENCE PARTICIPANTS

Table 8. Onboard Science Participants for 2021-016

Name	Affiliation	Role
Sarah Zimmermann	DFO-IOS	Chief Scientist
Sarah-Ann Quesnel	DFO-IOS	Nutrients analysis, lab supervisor
Marty Davelaar	DFO-IOS	DIC/Alkalinity analysis
Angelica Pena	DFO-IOS	Dissolved oxygen analysis
Chris Clarke	DFO-IOS	Watchleader, salinity analysis
Kristina Brown	DFO-IOS	Watchleader, salinity analysis
Nimrod Rozen	DFO-IOS (UVic)	Watchstander
Helen Gemmrich	DFO-IOS (Concordia)	Watchstander, Dispatches
Benjamin Richaud	Dalhousie	Watchstander
Celine Gueguen	USherbrooke	Watchstander, FDOM chemistry lead
Nicolas Sylvestre	USherbrooke	Watchstander, FDOM
Mohamed Gamrani	USherbrooke	Watchstander, FDOM
Susanne Kraemer	Concordia	Microbial Community
Aurélie Labarre	ULaval	Microbial Community
Josephine Rapp	ULaval	Microbial Community
Isabela Le Bras	WHOI	Mooring and Buoy lead, Dispatches lead
Jeff O'Brien	WHOI	Mooring and Buoy
Jim Ryder	WHOI	Mooring and Buoy
Fred Marin	WHOI	Mooring and Buoy
Cory Beatty	UMontana	pCO2, pH

Table 9. Principal Investigators Onshore for 2021-016

Name	Affiliation	Program
Bill Williams	DFO-IOS	Program lead / CTD/Rosette
Andrey Proshutinsky	WHOI	Moorings and ITP / CTD/Rosette / XCTD
Richard Krishfield	WHOI	Moorings and ITP / CTD/Rosette / XCTD
Mary-Louise Timmermans	Yale	Moorings and ITP / CTD/Rosette / XCTD
John Toole	WHOI	ITP program
Mike DeGrandpre	U Montana	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
Tim Stanton	NPS	Arctic Ocean Flux Buoy
Michiyo Yamamoto-Kawai	TUMSAT	CTD / Rosette / Alkalinity
Connie Lovejoy	ULaval	CTD/Rosette / Microbial Community
David Walsh	ConcordiaU	CTD/Rosette / Microbial Community
John Nelson	DFO-IOS	Zooplankton
John Smith	DFO-BIO	CTD / Rosette / ^{129}I
Nuria Casacuberta	ETH Zurich	CTD / Rosette / ^{129}I
Jennifer Hutchings	OSU	Ice Observations
Kazutaka Tateyama	KIT	Ice Observations

Table 10. Affiliation Abbreviations.

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

5.2 PROJECT WEBSITES

Project	Website Address
Beaufort Gyre Observing System	https://www2.whoi.edu/site/beaufortgyre/overview/scientific-motivation/
Beaufort Gyre Observing System dispatches	https://www2.whoi.edu/site/beaufortgyre/expeditions/2021-expedition/2021-dispatches/
Ice-Tethered Profiler buoys	https://www2.whoi.edu/site/itp/
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
Arctic Ocean Flux Buoy	www.oc.nps.edu/~stanton/fluxbuoy/

5.3 LOCATION OF SCIENCE STATIONS

The scientific crew boarded the *CCGS Louis S. St-Laurent* icebreaker in Cambridge Bay, NU, on 19 August, 2021 and departed at Cambridge Bay, NU on 16 September 2021. Locations of CTD/Rosette, XCTD, zooplankton vertical net, as well as the mooring and buoy recovery and deployments are listed in the tables below.

5.3.1 CTD/Rosette

Table 11. CTD/Rosette cast locations for 2021-016

Cast #	Station	CAST START DATE and Time (UTC)	Latitude (°N)	Longitute (°W)	Water Depth (m)	Cast Depth (m)	Sample Numbers	Ice Coverage (tenths) (Rough Estimate by CTD Operator)	Comments
1	AG5-DNA	2021/08/21 22:34	70.5552	122.9068	650	632	1-24	less than 1/10 but some	yoyo each bottle stop - 30 sec , up 1m , down 2m , up 1m, 30 sec , trip
2	AG5	2021/08/22 01:38	70.5485	122.8645	647	557	25-46	less than 1/10 but some	Drifted from position of ROS-1! Bottom depth now ~550m removed optode and rinko for this duplicate cast for comparison... does CDOM or PAR change w sensors removed? bot 16: vent fully open bot 17: tripped while moving, don't use (see bottle 23) bot 18: 2x 1L HPLC bot 22: 2x 1L HPLC
3	STN-A	2021/08/24 11:15	72.6008	144.6955	3434	198	47-56	1/10	
4	STN-A	2021/08/24 12:58	72.6000	144.6988	3434	3421	57-80	1/10	Wire caught on ice during downcast @~900m. Pulled to 20deg angle, kept paying out but slowly (w/ ice). Ship able to reposition + ice pushed to stern, wire snapped free out of ice. Do see a spike in data at this point and again @1300m. Hope wire has not been corrupted... Upcast has only a couple spikes. Acoustic release test at 200m. Didn't respond so CTD turnbed off. New file is named *_0004b.hex. Problem turned out to be WHOI's first deck box. Second deck box worked well.

5	BL4	2021/08/25 06:51	71.5167	151.5768	1121	1153	81-101	0/10	QM's first time at winch. Termination brought close to block on deployment. Data are fine. Opaque blobs in water: lots of jellyfish. Altimeter did not come in but unsure if we got close enough to bottom; one brief spike 40m; bottom is soft (sounder ranged 1160 to 1200). Niskin #4 closed at 473 for Tmax target property. Niskins #14-18 tripped out of order: 14, 17, 15, 16, 18. Niskin #17 tripped @80m (instead of 70m); Niskin #18 tripped at 35 (instead of 50), to better sample column (target properties 32.6 and 32.3 were too close to 70 and 50).
6	BL3	2021/08/25 09:17	71.4647	151.8182	509	489	102-119	0/10	
7	BL1	2021/08/25 11:24	71.3513	152.0798	90	69	120-127	0/10	Altimeter worked fine from the beginning to end.
8	BL2	2021/08/25 13:35	71.3943	151.9490	168	168	128-139	0/10	More spikes in altimeter, but still giving right data close to bottom.
9	BL5	2021/08/25 16:05	71.5948	151.3662	1581	1567		0/10	
10	BL6	2021/08/25 18:25	71.6807	151.1358	2085	2084	140-162	0/10	Altimeter gave false spikes.
11	BL7	2021/08/25 21:24	71.8212	150.7633	2570	2570		0/10	Same for altimeter. Chris took deck control @~900m to check wire for ice damage. Low gear, slow speed (20m/min), stopped at CABLEOUT885. No damage spotted, "looks fine".
12	BL8	2021/08/26 00:30	71.9530	150.2977	2951	2961	163-186	1/10	Some trouble on speed, big drop around 900m (speed >100m/min for a sec). WHOI release test at 2000m (on up). Niskin #10 (Target property 34.7) fired late @285m (instead of 290m). Bottles tripped out of order: 18, 21, 19, 20, 22.
13	CB2a	2021/08/26 07:41	72.4993	149.9960	3721	3713	187-210	10/10	Initially full ice cover, 3 aborted attempts to deploy rosette. Then after repositioning, full open water.

14	CB2	2021/08/26 14:33	72.9985	150.0200	3744	3739	211-234	<1/10	Altimeter worked fine. Ship bubblers quite active to push floes away, so surface might be disturbed, though bubblers were stopped when rosette @150m. Niskin bottle 6 lid didn't close, Bottle was open when reaching the surface but water stayed inside, meaning bottom was likely closed. Then lid snapped in, but when rosette was already halfway out. Samples (#216) taken nonetheless (some doubts on actual Niskin number)
15	CB3	2021/08/27 03:42	74.0025	149.9932	3821	3814	235-258	9/10	Target property B-100 (Niskin bottle #1) was actually tripped at B-10 (operator is sorry!). Eddy around 250m deep, so target properties 33.6 and 33.1 (Niskin #13 and 14) might be influenced by it, though not entirely in it. Yoyo for target property Chl-Max; for target property 5m (Niskin #23 and 24), stopped for 50s but operator forgot the yoyo. Bubblers and rear prop used a lot due to ice. Altimete kicked in ata bot-100mk (wow!).
16	CB6	2021/08/28 05:13	74.7133	146.7005	3777	3770	259-282	2/10	Niskin #6: dripping spiggot; Niskin #14: spigot running; Niskin #21: vent not closed. Niskin #8: possible mistrip: draw temperature very cold, while it is supposed to be the Tmax. Aborted deployment due to ice; second attempt (16b) successful. Didn't bring CDT to surface at beginning, due to ice, so cast starting @10m. Stopped @200m on way down and up, to test out styrofoam bowls. Strong wind pussing ship to port: rosette wire at angle 30stbd, >10 aft, so discrepancies between cable length and CTD depth (when CTD=2387m, cableout=2553); when bridge tried to correct, rosette went under ship: stopped the rosette @2446 to correct.

17	CB4	2021/08/28 13:30	75.0008	150.0013	3823	3818	283-306	2/10, with some pancakes, frazil, etc. (ICE101 classroom)	Interesting small signal in transmissometer (decreasing from 91.06 to 90.90%) and oxygen @3000m, so Niskin #5 was shifted from 2500 to 3000m deep to investigate.
18	CB4DNA	2021/08/28 23:46	74.9768	149.9915	3821	1004	307-330	3/10	Niskin #16 (for SAMI calibration): vent open!
19	CB5	2021/08/29 07:03	75.3045	153.3202	3841	3835	331-354	5/10	Rosette stayed on deck for some time (~10min) before cast due to ship repositioning; thus stayed >5min @10m depth to let it "warm"up. Niskin #21 changed from 60 to 50m depth (ChlMax @62m). Used Ice chummy, installed at 3700m depth, removed at 100m. Hence rosette was stopped at those two depths for a few minutes; chummy stucked around cable so it took some time to get it out. Stopped rosette @857m as well, for ~3min, because cable angle was >10degrees port, so cable was touching hull (bongos made it difficult to the bridge to keep ship on track). Some very interesting physical processes (T&S) in the Atlantic waters, with intrusion at Tmax, double diffusivity features, maybe internal waves in the Barents Sea branch? Lots of cool stuff! To be analysed.
20	CB7	2021/08/29 16:44	75.9927	149.9727	3825	3820	355-378	1/10	Wind 26 kts, white caps. Potential eddy @~150m deep (32.6psu). Ice chummy set up @3700m and removed @5m after yoyo. Shift change @700m upcast.
21	CB8	2021/08/30 01:54	77.0035	149.9923	3821	3818	379-402	8/10	Wind 25kts; bridge has no report from CTD BOT angles. Plot didn't show fluorescence trace so SCM was picked from beam transmission minimum. Lots of ice, had to stop @1275m to let bridge clear the ice.
22	CB9DNA	2021/08/30 10:17	77.9943	149.9437	3820	1002	403-426	less than 1/10 but some	Potential internal wave or shear instability @~260m?

23	CB9 (bgc)	2021/08/30 21:23	77.9982	149.8907	3820	3813	427-450	3/10, in a pond	Eddy? And staircases. Eddy developed further between CB9DNA and CB9bgc. Ice chummy on upcast between 3723m and 5m.
24	CB12	2021/08/31 05:02	77.6812	146.7200	3807	3803	451-474	4/10, on the edge of ice floe (2/10 starboard, 10/10 port)	None
25	CB9Take3	2021/08/31 12:46	78.0013	150.0040	3826	1001	475-498	5/10; frazile ice	Third cast at CB9, 12 hours after bgc cast, to observe progress of the Pacific Water eddy. Niskins #18 samples were partially moved to #19, to be closer to the 32.3 halocline (heaving of halocline by ~20m between CB9bgc and CB9Take3): DIC/Alk and O18 were moved to samples 493, FDOM was left in sample 492). Idem for Niskin #20, moved to #21 except FDOM, to match halocline 31.8. Discharge from galleys during downcast.
26	CB10	2021/09/01 05:24	78.2917	153.2670	2288	2580	499-522	5/10, on ice floe (so no ice visible from CTD lab, but port side is 10/10)	SCM at 40m, so Niskin #21 (targeted at 40m) was tripped out of order, at 200m, between Niskin 11 and 12. Cast on the slope, so depth changed during downcast.
27	ICE1	2021/09/01 23:35	79.2190	147.9937		1001	523-541	8/10	Calibration station for ITP open water.
28	CB11DNA	2021/09/02 03:54	78.9923	149.9217	3823	1002	542-565	8/10	DNA cast, nearly all bottles are yoyo. Bridge BOT display not working. This replaces FARTHEST NORTH DNA station

29	CB11	2021/09/02 06:03	79.0017	149.8832	3823	3808	566-589	7/10 (in a pond)	Bottles tripped out of order: 13,22,14,… because SCM too close to 40m target Niskin. Cups casts: styrofoam cups attached to cable @50m above Rosette. More BOT display issue, with CTD data disappearing during upcast.
30	ICE2	2021/09/02 21:58	78.5778	147.2093	3812	801	590-613	9/10	Nick's Nice Ice station - calibration cast after deployement of 2 ITPS and IMB.
31	CB16	2021/09/04 02:39	78.0008	139.8130	3745	3738	614-637	10/10, mostly thin ice	ITP/TOP ice calibration station as well. Cups again @50m (for the deformed ones). Orange-brown discharge from ship @30-40m; Toilet paper discharge @60m, @2000m, @3500m.Bridge BOT nor working. Altimeter kicked in @3580, 200m before sounder depth, then stopped @Alt8m and crept again slowly down; kicked in again at B-100m and very stable trace. Switched Niskins: #21 becomes 2500m, #2 becomes 3470m for DWR salt reference water; no more Niskin @40m.
32	ICE4	2021/09/05 04:07	79.2673	135.6878	3701	3694	638-661	9.5/10	Ice chummy attached @2030m, removed @5m; stopped working @200m. BOT CTD data disappeared again. Niskins #15 had open vent, #20 had loose vent (barely closed). Issues with NaI for oxy, empty bottle when sampling Niskin 16. Bubbles and maybe mistitration for Niskins #14 and #15. 10min stop during sampling of Niskin #16. Questionable samples: 651, 652, 653 (Niskins #14 to 16). Draw temperatures are surpisingly warm, compared to previous casts. Huge Tmax (?) for Atlantic Water.

33	CB13	2021/09/05 21:57	77.3535	143.2907	3785	3775	662-685	3/10, forming ice	Did not wait 30s at surface (too much slush ice). Stopped at 2056m on downcast for ship manoeuvre (high wire angles). Big ice floe at 2340m downcast. Ice chummy attached at bottom, removed at 16m. Cast delayed initially so ship could find suitable spot; difficult in strong wind and mobile pieces of ice. No wave nor swell, but ice everywhere. Upcast wire angle mostly at 14deg aft.
34	CB15	2021/09/06 05:42	77.0353	140.0907	3729	3722	686-709	2/10, fresh and slushy ice	Interesting features in Temp trace from 50m to 180m. Lost CTD data on IMS BOT again, @1470m.
35	PP7	2021/09/06 14:47	76.5317	135.3677	3565	3554	710-733	4/10, frazil ice	Broken DO bottle (for Niskin #20)
36	CB17	2021/09/06 22:58	75.9950	139.9720	3697	3687	734-757	0/10	
37	CB18	2021/09/07 06:36	75.0065	140.0110	3627	3616	758-781	4/10	Another intrusion (eddy?) in PWW
38	CB21DNA	2021/09/07 21:56	74.0028	140.0202	3525	291	782-805	9/10	At mooring recovery site
39	CB21	2021/09/08 00:21	73.9970	140.0788	3524	3511	806-829	8/10	Updated knudsen sounder depth for morring deployment purposes
40	CB19	2021/09/08 07:57	74.3098	143.0685	3690	3683	830-852	<1/10	Niskin #22 did not trip properly, lid stayed block on hangbar: no sample 851. Interesting physical features around Pacific Summer Water: double diffusivity (?) above PSW, others instabilities below.
41	CB40	2021/09/09 08:13	74.4977	135.4218	3256	3242	854-877	3/10	SCM very close to 60m target so Niskin #19 was instead fired @30m depth, out of order, to target a small Chl local maximum associated with a clear Dissolved Oxygen maximum. Some staircases in Atlantic waters (Fram Strait branch).
42	CB50	2021/09/09 21:26	73.5012	134.2528	2890	2876	878-901	2/10	Cadets training on winch. Niskin #10 fired at 280m instead of 282m.
43	CB51	2021/09/10 05:19	73.5000	130.9040	2493	2483	902-924	10/10	Some bioluminescence in Zooplankton net cast.

44	CB31b	2021/09/10 17:20	72.3485	134.0178	2063	2054	925-948	10/10	Temperature profile busy with small features (staircases, inversions, instabilities…). Watch change during downcast. Birds flying around. Bilge water discharge during the station: ballast water was pumped off Kugluktuk and discharged while waiting for station.
45	CB23a	2021/09/11 02:20	72.9048	135.9843	2737	2739	949-972	1.5/10	
46	CB22	2021/09/11 08:46	73.4525	138.0163	3126	3116	973-996	1/10	Very windy. Northern lights just before cast. Chummy from bottom to 50m. Clean profile though DO is slightly variable in Atl. Waters. Niskin #9: Vent slightly loose. Niskin #14: May have mistakenly drawn oxygen from Niskin 15.
47	CB27	2021/09/11 14:54	73.0018	140.0265	3221	3211	997-1020	1/10	@2750m: the deck unit made two high-pitched "beep", and vertical lines showed up on all graphs, as if the CTD had suddenly measured a negative depth… Then resumed to normal trace. Unstable rosette speed during end of downcast and last 300m of upcast; some bottles might be slightly off.
48	CB29	2021/09/11 22:53	72.0000	140.0047	2694	2673	1021-1044	1/10	Hit a piece of ice on downcast @240m. Sewage discharge @1100m downcast O18: Start sampling into new style (w/ cone septa in cap) of bottle (sample 1021 to end).
49	MK6	2021/09/12 03:46	71.5847	140.0032	2496	2470	1045-1068	1/10	Niskin #19 did not fire on button press -> switched to fire Niskin #20 then back to #19 and that worked. Start pickling DIC samples.

50	CB28b	2021/09/12 09:34	71.0005	140.0070	2090	2073	1069-1092	0/10	No good depth reading from sounder, too much swell. Niskins #19 and 20 didn't fire immediately, had to insist.
51	MK4	2021/09/12 12:37	70.8095	140.0005	1516	1494	1093-1116	0/10	Soft bottom, according to Knudsen sounder trace.
52	MK3	2021/09/12 15:53	70.5707	139.9998	780	762	1117-1139	0/10	
53	MK2	2021/09/12 18:17	70.3993	139.9927	504	493	1140-1160	0/10	Very green waters. HUGE jelly.
	MK1	2021/09/12 20:36	70.2252	140.0020	235	215	1161-1176	0/10	Sat at B-10m until 21:00 to sort out target depth to fire Niskins. Niskin #8 didn't close when fired, so had to go back to 80 (from 76m) to try again.
55	CB28aa	2021/09/12 22:37	69.9993	139.9980	58	51	1177-1185	0/10	Sat @ B-5m for 4 min. Niskin#1: Scrapped bottle 1 (sample 1177) as bottom shallower than expected.
56	CB1	2021/09/13 13:55	71.7775	131.8787	1121	1122	1186-1209	0/10	Rosette went very close to bottom (2m according to altimeter)…
57	CP05	2021/09/14 12:43	69.6528	118.5897	522	511	1210-1233	0/10	Amundsen Gulf third Basin (far east).

5.3.2 XCTD

Table 12. XCTD cast deployment locations for 2021-016.

File name starting with C3 means XCTD-1 probes were used and file name starting with C4 means XCTD-2 probes were used. S/N = serial number of the probe launched

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	S/N	Probe Type	Cast Depth (m)	Comments
C5_00001.EDF	23-Aug-2021 18:00	70.55458	140.0941	16016717	XCTD-3	710	training run, all good!
C3_00002.EDF	23-Aug-2021 20:32	70.69543	140.7795	20058164	XCTD-1	1100	~5kn; ~50% ice cover; CC/HG/SK
C5_00003.EDF	23-Aug-2021 23:33	70.97887	142.0708	16016718	XCTD-3	1000	~14kn; <5% ice cover; CC/NS/AP
C5_00004.EDF	24-Aug-2021 01:45	71.2173	143.2818	16016715	XCTD-3	1000	~13kn; <5% ice cover; CC/HG
C3_00005.EDF	24-Aug-2021 04:45	71.6858	144.0284	20058165	XCTD-1	308	~5kn; ~50% ice cover; CC/NS; ended early @ ~300m, redo
C3_00006.EDF	24-Aug-2021 04:54	71.70186	144.0392	20058166	XCTD-1	1012	~5kn; ~50% ice cover; CC/NS
C5_00007.EDF	24-Aug-2021 08:11	72.15188	144.6722	16016714	XCTD-3	1000	~14kn, big open lead, end at 3100m depth
C5_00008.EDF	24-Aug-2021 19:39	72.4402	146.2348	16016713	XCTD-3	1000	~10kn, ~20% ice cover, CC/NR
C5_00009.EDF	24-Aug-2021 22:55	72.07424	147.3575	16016736	XCTD-3	1000	~7kn; 20% ice cover; CC/HG
C5_00010.EDF	25-Aug-2021 02:19	71.84373	148.8802	16016735	XCTD-3	1000	~13 kn, 1% ice, CC/NR
C5_00011.EDF	25-Aug-2021 04:44	71.65605	150.4175	16016734	XCTD-3	1000	~12.5kn, 0% ice, CC/NR/HG
C3_00012.EDF	26-Aug-2021 21:18	73.49524	149.0076	20058167	XCTD-1	1100	~8kn, 80% ice, CC/HG
C3_00013.EDF	27-Aug-2021 10:42	74.46438	149.9682	20058168	XCTD-1	1100	~5kn, 90% ice everywhere, but found an open pool, BR/KB
C5_00014.EDF	28-Aug-2021 11:22	74.87119	148.4942	16016732	XCTD-3	1000	~13.5kn, open water (0% ice), BR/KB
C5_00015.EDF	29-Aug-2021 04:16	75.15806	151.6749	16016731	XCTD-3	1000	~10kn; ~30% ice; CC/NS
C5_00016.EDF	29-Aug-2021 13:33	75.64144	151.7009	16016728	XCTD-3	1000	~11kn; small chunks of ice, pretty open area (10% ice), Knudsen not working, bottom depth needs to be confirmed
C5_00017.EDF	29-Aug-2021 23:17	76.52082	149.9423	16016733	XCTD-3	1000	~13.5kn; 5% ice; CC/HG
C3_00019.EDF	30-Aug-2021 08:36	77.70636	149.7082	20058170	XCTD-1	285	
C3_00020.EDF	30-Aug-2021 08:42	77.71827	149.6783	20058169	XCTD-1	421	~8kts; pool of open water
C3_00021.EDF	31-Aug-2021 10:12	77.85924	148.1942	16016729	XCTD-1	1000	~13kn; had problems connecting with the MK21 again, this time science server and GPSgate working fine… switched ethernet cable port from 3 to 1 (again, we switched it from 1 to 3 last cast, which seemed to work once we got the science net talking again) then tried a few times to manually connect through the MK21 device

							parameters. Ended up with "MK21/Ethernet DAQ" on "Manual Selection" which worked, but for the last cast we had it working using the MAC address and couldn't connect this way again
C3_00022.EDF	01-Sep-2021 00:20	78.1623	151.591	20058171	XCTD-1	283	stopped ship, 90% ice; broke due to ship drifting backwards
C3_00023.EDF	01-Sep-2021 00:25	78.16333	151.5919	20058172	XCTD-1	1100	stopped ship, 90% ice; touched piece of ice for last ~150m of cast
C5_00024.EDF	01-Sep-2021 10:58	78.65267	151.4007	16016725	XCTD-3	1000	12kn; in a pool
C3_00025.EDF	01-Sep-2021 20:11	79.21488	148.0114	20058173	XCTD-1	1047	
C3_00026.EDF	02-Sep-2021 12:14	78.61093	147.7724	20058174	XCTD-1	1100	a little late for half-way but thought it was worth doing anyway… coming up to small pool, otherwise mostly ice covered (95%), < 5knts just keeping ahead so the ice stays off the stern
C4_00027.EDF	03-Sep-2021 03:36	78.2192	145.2851	15115718	XCTD-2	1850	ITP recovery site; very cold wind.
C3_00028.EDF	04-Sep-2021 08:09	78.37272	138.737	20058175	XCTD-1	686	Started at 9kts but slowed down to 3kts. A giant box of ice came in the way when slowing down.
C3_00029.EDF	04-Sep-2021 11:21	78.76087	137.386	20111291	XCTD-1	271	Ship stopped in a pan of ice, too much ice coming from the bow… Broke early
C3_00030.EDF	04-Sep-2021 11:35	78.78934	137.3925	20111292	XCTD-1	1100	Nice pool for second try. Slow speed.
C3_00031.EDF	04-Sep-2021 13:44	79.07802	136.349	20111293	XCTD-1	1100	aborted first attempt, too much ice. Went a bit further until a pool, dropped speed to 4knts and coasted through pool.
C3_00032.EDF	05-Sep-2021 17:58	77.49234	140.1114	20111294	XCTD-1	1100	in a puddle, about 7 knts - lots of ice otherwise! The ship ended up stopping half-way through the cast, loads of ice came in behind the stern, but the wire didn't break so made it to bottom
C3_00033.EDF	06-Sep-2021 03:33	77.15363	141.575	20111295	XCTD-1	1046	5kn, snowing, cold AF, drifting over lots of ice. The XCTD may have gotten caught on ice near 500m and dangled for the duration of the cast?
C5_00034.EDF	06-Sep-2021 11:51	76.75488	137.5874	16016726	XCTD-3	1000	12-13knts, still cold, heading into an open pool
C5_00035.EDF	06-Sep-2021 19:51	76.32375	137.2629	16016730	XCTD-3	1000	15 kn, clear puddle without ice
C5_00036.EDF	06-Sep-2021 21:10	76.18095	138.5095	16016727	XCTD-3	1000	15.2 kn, open water
C5_00037.EDF	07-Sep-2021 04:03	75.49089	140.1007	16016793	XCTD-3	1000	15.1 kn, open water

C5_00038.EDF	07-Sep-2021 11:46	74.5096	140.0063	16016785	XCTD-3	1000	16.6 kn, pool of water in between ice
C5_00039.EDF	08-Sep-2021 13:07	74.17261	141.3442	16016786	XCTD-3	195	Flying! >13 knts. Broke at 194m, too much ice
C3_00040.edf	08-Sep-2021 13:11	74.16857	141.3086	20111296	XCTD-1	1100	0 kts. Forgot to switch the probe type to XCTD1 in WinMK21. Cast went all the way done none the less. Corrected file after the fact.
C3_00041.edf	09-Sep-2021 02:23	74.16812	138.5243	20111297	XCTD-1	1100	~10kn, 40% ice, wrong probe type entered in WinMK21(XCTD-3 instead of XCTD-1). Corrected probe type after cast finished.
C3_00042.EDF	09-Sep-2021 04:42	74.32525	137.0119	20111298	XCTD-1	1084	10.2 kn no ice
C5_00043.EDF	09-Sep-2021 18:18	73.96439	134.8843	16016787	XCTD-3	1000	14.9knts, open pool, slowed down when got back into ice
C3_00044.EDF	10-Sep-2021 02:19	73.50921	132.5381	20111299	XCTD-1	1100	6kn, <10% ice
C3_00045.EDF	10-Sep-2021 10:23	73.12379	132.0639	20111300	XCTD-1	1100	7kn, open water, beautiful sky
C3_00046.EDF	10-Sep-2021 13:08	72.74644	133.0153	20121373	XCTD-1	1100	6-8knts, lots of ice but found a pool. Beautiful sunrise!!|
C5_00047.EDF	10-Sep-2021 21:11	72.59266	135.1488	16016790	XCTD-1	1000	13kn, 5% ice, |FOR|GOT TO SWITCH XCTD TYPE AGAIN!! :'((2021-11-09 SZ Renamed file to C5_00047.rdf and .edf)
C5_00048.EDF	11-Sep-2021 06:42	73.17818	137.1375	16016789	XCTD-3	1000	13kn, open water
C5_00049.EDF	11-Sep-2021 12:45	73.22778	138.997	16016788	XCTD-3	1000	13knts, open water
C5_00050.EDF	11-Sep-2021 20:14	72.44038	140.1102	16016792	XCTD-3	657	15.3knts, ice
C5_00051.EDF	13-Sep-2021 04:02	70.59602	136.9868	16016791	XCTD-3	869	15.4 knts, open water, light wind, hit the bottom
C5_00052.EDF	13-Sep-2021 06:03	70.88385	135.7324	16016794	XCTD-3	779	15.4 knts, open water, hit the bottom
C5_00053.EDF	13-Sep-2021 08:43	71.18267	134.4194	16016795	XCTD-3	404	9.9kn, open waters, broken before bottom.
C5_00054.EDF	13-Sep-2021 11:21	71.46772	133.1843	16016796	XCTD-3	1000	15knts, open water

Table 13. XCTD cast deployment locations for CCGS Sir Wilfrid Lauier in support of the JOIS/BGOS program (Cruise ID 2021-003 DFO-IOS).

File Name	Date/Time (utc)	Latitude (N)	Longitude (W)	Serial number	Probe Type	Cast depth, m
C3_00001.edf	18-Sep-2021 08:05	70.6448	140.9653	19,018,679	XCTD-1	1,074.6
C3_00002.edf	18-Sep-2021 11:19	70.9365	142.9958	19,018,680	XCTD-1	1,066.0
C3_00003.edf	18-Sep-2021 14:38	71.1242	145.0854	19,018,681	XCTD-1	1,099.6
C3_00004.edf	18-Sep-2021 18:14	71.4232	146.9917	19,018,682	XCTD-1	1,099.6
C3_00005.edf	20-Sep-2021 21:51	71.7452	148.9132	19,018,683	XCTD-1	1,088.5

C3_00006.edf	19-Sep-2021 01:19	72.0563	150.7863	19,018,685	XCTD-1	1,099.6
C3_00007.edf	19-Sep-2021 04:50	72.3507	152.6341	19,018,686	XCTD-1	1,099.6
C3_00008.edf	19-Sep-2021 08:30	72.6459	154.6896	19,018,688	XCTD-1	926.2
C3_00009.edf	19-Sep-2021 11:48	72.9219	156.6891	19,018,689	XCTD-1	912.5
C3_00010.edf	19-Sep-2021 15:31	73.2453	158.9313	20,111,231	XCTD-1	893.0
C3_00011.edf	19-Sep-2021 18:04	73.5911	160.7189	20,112,232	XCTD-1	981.0

5.3.3 Zooplankton – Vertical Bongo Net Hauls

Table 14. Zooplankton vertical bongo net hauls.

Summary of samples taken at each station. At each station 2 samples were collected using net mesh size 150 and236 µm. The 236 µm samples were preserved in 95% ethanol, while the 150 µm samples were preserved in buffered formalin.

Net Event #	CTD #	Date (UTC)	Time (UTC)	Latitude (°N)	Longitude (°W)	Net Mesh (um)	Bottom Depth (m)	Wire angle (°)	RBR depth (m)	Notes
1	1	22-Aug-21	00:30	70.5482	122.8788	150	635	20	86	
1	1	22-Aug-21	00:30	70.5482	122.8788	236	635	20	86	
2	3	24-Aug-21	13:28	72.6015	144.6935	150	3433	0	97	Some ice, need bubler on during next cast, wire under ship, difficult to see on retrieval
2	3	24-Aug-21	13:28	72.6015	144.6935	236	3433	0	97	Check TSK - Darryl Tyler
3	5	25-Aug-21	07:29	71.5167	151.5750	150	1141.7	0	94	2x 250 ml
3	5	25-Aug-21	07:29	71.5167	151.5750	236	1141.7	0	94	3 x 250ml
4	6	25-Aug-21	13:11	71.3513	151.9478	150	170	35	88	3 x 250 ml
4	6	25-Aug-21	13:11	71.3513	151.9478	236	170	35	88	3 x 250 ml, removed large jelly
5	10	25-Aug-21	18:52	71.6832	151.1330	150	2092	0	94	not able to rinse everything out of 150 micron bongo net (very mucky), 4 x 250 ml
5	10	25-Aug-21	18:52	71.6832	151.1330	236	2092	0	94	2 x 250 ml
6	12	26-Aug-21	00:53	71.9552	150.2948	150	2962	~10	97	
6	12	26-Aug-21	00:53	71.9552	150.2948	236	2962	~10	97	
7	13	26-Aug-21	09:01	72.5013	149.9940	150	3723	20	93	notebook lost in wind, so TSK number post bongo rinse but pre sampling is gone, so difference between TSK start and end is the 100 m cast plus the 10 m rinse
7	13	26-Aug-21	09:01	72.5013	149.9940	236	3723	20	93	
8	14	26-Aug-21	15:16	72.9977	150.0303	150	3740	~0 ish	94	no angle on way down, but wire angled beneath hull on the way up
8	14	26-Aug-21	15:16	72.9977	150.0303	236	3740	~0 ish	94	
9	15	27-Aug-21	04:10	74.0067	149.9917	150	3821	~0 ish	95	Check TSK before next bongo cast
9	15	27-Aug-21	04:10	74.0067	149.9917	236	3821	~0 ish	95	
10	17	28-Aug-21	14:07	75.0020	149.9997	150	3823	0	95	
10	17	28-Aug-21	14:07	75.0020	149.9997	236	3823	0	95	

11	19	29-Aug-21	09:36	75.3077	153.2607	150	3841	35	83	Needed to bubble before coming up to get ice away, extra water passed through gauges as net bounced a bit at surface coming in, very windy
11	19	29-Aug-21	09:36	75.3077	153.2607	236	3841	35	83	
12	23	30-Aug-21	21:48	77.9975	149.8707	150	3821	~25	99	
12	23	30-Aug-21	21:48	77.9975	149.8707	236	3821	~25	99	
13	24	31-Aug-21	05:19	77.6814	146.7292	150	3807	~5	99	
13	24	31-Aug-21	05:19	77.6814	146.7292	236	3807	~5	99	
14	26	1-Sep-21	05:47	78.2900	153.2505	150	3431	20	97	
14	26	1-Sep-21	05:47	78.2900	153.2505	236	3431	20	97	
15	29	2-Sep-21	06:27	79.0033	149.8750	150	3431	0	93	
15	29	2-Sep-21	06:27	79.0033	149.8750	236	3431	0	93	
16	31	4-Sep-21	03:04	78.0010	139.8207	150	3744	0	94	
16	31	4-Sep-21	03:04	78.0010	139.8207	236	3744	0	94	
17	32	5-Sep-21	04:23	79.2677	135.6967	150	3701	0	92	
17	32	5-Sep-21	04:23	79.2677	135.6967	236	3701	0	92	
18	36	6-Sep-21	00:38	76.0000	139.9712	150	3693	5	94	
18	36	6-Sep-21	00:38	76.0000	139.9712	236	3693	5	94	
19	39	8-Sep-21	01:14	73.9963	140.0733	150	3524	5	94	
19	39	8-Sep-21	01:14	73.9963	140.0733	236	3524	5	94	
20	40	8-Sep-21	08:47	74.3120	143.0687	150	3690	15	93	
20	40	8-Sep-21	08:47	74.3120	143.0687	236	3690	15	93	
21	41	9-Sep-21	08:54	74.5005	135.4245	150	3256	0	94	
21	41	9-Sep-21	08:54	74.5005	135.4245	236	3256	0	94	
22	42	9-Sep-21	21:51	73.5018	134.2512	150	2891	13	113	Went to 120m to fix loop in wire spool
22	42	9-Sep-21	21:51	73.5018	134.2512	236	2891	13	113	
23	43	10-Sep-21	05:44	73.4988	130.9042	150	2500	0	94	
23	43	10-Sep-21	05:44	73.4988	130.9042	236	2500	0	94	
24	44	10-Sep-21	17:53	72.3472	134.0258	150	2065	0	94	
24	44	10-Sep-21	17:53	72.3472	134.0258	236	2065	0	94	
25	45	11-Sep-21	02:32	72.9060	135.9840	150	2752	15	101	
25	45	11-Sep-21	02:32	72.9060	135.9840	236	2752	15	101	
26	47	11-Sep-21	15:29	73.0014	140.0251	150	3211	10	94	lots of wind during recovery, so only partially rinsed (1 per side of net)
26	47	11-Sep-21	15:29	73.0014	140.0251	236	321	10	94	
27	48	11-Sep-21	23:15	71.9998	140.0023	150	2690	10	92	
27	48	11-Sep-21	23:15	71.9998	140.0023	236	2690	10	92	
28	49	12-Sep-21	04:07	71.5833	140.0050	150	2499	5	93	
28	49	12-Sep-21	04:07	71.5833	140.0050	236	2499	5	93	
29	50	12-Sep-21	10:05	71.0018	140.0067	150	2080	0	93	Saw jar was broken for FORM sample, switched from small to large jar but did not add extra formalin (so large

										jar only has 12.5 ml; of Form), although extra seawater was added
29	50	12-Sep-21	10:05	71.0018	140.0067	236	2080	0	93	
30	51	12-Sep-21	13:03	70.8097	140.0017	150	1525	25-30	90	
30	51	12-Sep-21	13:03	70.8097	140.0017	236	1525	25-30	90	
31	52	12-Sep-21	15:35	70.5708	140.0002	150	761	5-10	95	
31	52	12-Sep-21	15:35	70.5708	140.0002	236	761	5-10	95	
32	53	12-Sep-21	18:40	70.3997	139.9935	150	516	10	96	
32	53	12-Sep-21	18:40	70.3997	139.9935	236	516	10	96	
33	54	12-Sep-21	20:29	70.2255	140.0017	150	228	10	101	
33	54	12-Sep-21	20:29	70.2255	140.0017	236	228	10	101	
34	56	13-Sep-21	14:12	71.7767	131.8800	150	1128	10	93	
34	56	13-Sep-21	14:12	71.7767	131.8800	236	1128	10	93	

5.3.4 Mooing Operations

Table 15. Mooring recovery and deployment summary.

Mooring Name	Surveyed 2018 Location	2021 Recovery	2021 Deployment	2021 Location	DeploymentBottom Depth (m)
BGOS-A	75°00.0072N	27-AUG	28-AUG	75°00.009N	3823
	150°00.0075W	19:28 UTC	17:54 UTC	149°59.985W	
BGOS-B	78°00.3299N	30-AUG	31-AUG	77°58.9586N	3824
	149°57.8486W	15:16 UTC	21:14 UTC	150°03.5947W	
BGOS-D	74°00.1878N	7-SEP	8-SEP	73°59.6065N	3523
	140°00.1198W	17:03 UTC	22:51 UTC	140°02.5639W	

5.3.5 Ice Based Observatory (Buoy) Operations

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

IBO	ITP / Buoy System	Date	Location
1	ITP 124 (open water deployment)	1-SEP	79°12.913N
		23:08 UTC	147°57.202W

2	ITP 126+SAMI, SIMB-2021#2, TOP2	2-SEP	78°34.6970N
		21:00 UTC	147°14.3155W
3	ITP 127+SAMI, TOP3	4-SEP	77°58.3587N
		01:00 UTC	139°47.4824W
4	ITP 122, SIMB-2021#3, TOP4, AOFB48	4-SEP	79°17.0727N
		23:30 UTC	135°31.8822W

Buoy recovery summary.

Recovery	Buoy	Date	Location
1	ITP119 (deployed 2019)	3-Sep	78° 13.34 N
		03:45 UTC	145° 17.98W
2	ITP112 (deployed 2019)	9-Sep	74° 11.73N
		02:38	135° 26.59 W

Table 16. pCO2 and pH sensors summary (UMontana)

Measurement system	Instrument IDs	Location	Duration
Underway infrared-equilibrator pCO_2	SUPER (Sunburst Sensors)	Entire cruise track (see IOS report in this document)	8/20/2021 - 9/14/2021
ITP SAMI-CO_2 w/ DO sensor and PAR	WHOI ITP 127, SAMI-CO2 (C207)	First on-ice ITP deployment, CO2 ~ 4.5 m depth, (see WHOI cruise report in this document)	9/2/2021- present
ITP SAMI-CO_2 w/ DO sensor and PAR	WHOI ITP 126, SAMI-CO2 (C9u)	Second on-ice ITP deployment, CO2 ~ 4.5 m depth, (see WHOI cruise report in this document)	9/5/2021 - present
SAMI-CO_2 / SAMI-pH	CO2 : C39, pH : P13u	BGOS-A mooring	8/28/2021 – present
SAMI-CO_2 / SAMI-pH	CO2 : C24u pH : P66	BGOS-B mooring	8/31/2021 - present
SAMI-CO_2 / SAMI-pH	CO2 : C86 pH : P87	BGOS-D mooring	9/8/2021 - present

5.4 CTD/Rosette Sensor Configuration

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

ROS 1: both the Optode and Rinko III were connected.
ROS 2: both the Optode and Rinko III were NOT connected (ends of y cable dummied off), but channels left in the configuration file so values will just be 0.
ROS 13: Rinko III put back on rosette (still on V7)
FDOM, Optode Y-cable changed out to a single cable for FDOM. Optode will not be used again and didn't want any risk of leaks etc with the Y cable. Altimeter repositioned on frame but using same connections.

CTD

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

Calibration and Accuracy Information CTD #756 PRIMARY							
Sensor		Accuracy	Pre-Cruise		Post Cruise		Comment
Name	S/N		Date	Location	Date	Location	
Pressure Sensor	91164	Nominal 1.2 m	26 Feb 2010	SeaBird Lab			
Temperature, SBE3plus	4397	Nominal ± 0.001 °C	26 Jan 2021	SeaBird Lab			
Conductivity, SBE4C	2992	Nominal 0.003 mS/cm	28 Jan 2021	SeaBird Lab			

Pump, SBE5T							
Secondary Temp., SBE3plus	4402	Nominal ± 0.001 °C	30 Dec 2020	SeaBird Lab			
Secondary Cond., SBE4C	2984	Nominal 0.003 mS/cm	28 Jan 2021	SeaBird Lab			
Secondary Pump, SBE5T							

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	1489		13 Aug 2019	SeaBird Lab			CTD Voltage Channel 2 On Primary pump;
Datasonics Altimeter, Benthos	PSA-916D, 62670		28 May 2014	Benthos			CTD Voltage Channel 3
Seapoint Fluorometer (Chl-a)	SCF 2341, 30x gain	Or is this sn 2841?	17 Jun 2019	Seapoint			CTD Voltage Channel 0 On Secondary Pump;
Wetlabs Transmissometer	C-Star CST-1047DR		3 May 2021	IOS (In-house bench test)			CTD Voltage Channel 1
WETLabs ECO CDOM	6677		4 Mar 2021	WETLabs			CTD Voltage Channel 4
Satlantic Cosine Log PAR	517		25 Jun 2014	Satlantic			CTD Voltage Channel 6
Biospherical Surface PAR	20498		4 Apr 2016	Biospherical			

QSR2200							
Biospherical PAR QSR2150 (Continuous)	50228		21 Jun 2016	Biospherical			
Aanderaa Optode dissolved oxygen sensor	150						CTD Voltage Channel 5
Alec Rinko III dissolved oxygen sensor	404	Data collected in uncalibrated volts		Ship board 2-pt calibration			CTD Voltage Channel 7

Deck Units

Type	*make*	*model*	*serial*	*comment*
Deck Unit	Seabird	11plus		Used for All Casts
Deck Unit	Seabird	11plus		Spare

Rosette Pylons

Type	*make*	*model*	*serial*	*comment*
Water Sampler Carousel	Seabird	32	1231	Used for All Casts
Water Sampler Carousel	Seabird	32		Spare

TSG Seabird SBE21 sn 3297

Calibration and Accuracy Information, TSG							
Sensor		**Accuracy**	**Pre-Cruise**		**Post Cruise**		**Comment**
Name	**S/N**		**Date**	**Location**	**Date**	**Location**	
Seabird TSG SBE21	3297		10-Dec-2020	SeaBird Lab			

Seabird Temperatrue SBE-38 (Intake temperature)	0319		30 Dec 2020	SeaBird Lab			
Seapoint Chlorophyll Fluorometer	SCF3651		Jun 2014	Seapoint 2pt check at IOS			30x gain cable (0 to 5V = 0 to 5mg/mL)
Wetlabs ECO CDOM Fluorometer	WSCD-1281		9 Jun 2011	Wetlabs			Thorough cleaning pre-cruise

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.

Figure 19. Seawater loop system in 2020, includes the new FDOM sensor – similar for 2021. The seawater loop provides uncontaminated seawater from 9m depth to the science lab for underway measurements

Figure 20. TSG manifold and water supply manifold (2019, similar for 2021).

Figure 21. The Moyno pump installed in the engine room (2021).

Figure 22. Seawater passes through a filter before going to the pump (in background). When the ship is in sea-ice the flow is switched from one filter to the other to allow the necessary frequent clearing out of slush from the filter. This picture is from a previous year but is the same strainer configuration for 2021.

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

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

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

Figure 24. SBE38 temperature sensor in the engine room. This picture is from a previous year and during the winter refit 2016-2017 changes were made to the plumbing but essentially this is the same configuration.

The fluorometer and CDOM sensors were plumbed off a second manifold output. No debubbling or extra flow controls were in place.

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

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

On a third arm of the manifold, an automated system for measurements of pCO2 from the seawater and atmosphere was used. This year's measurements were made with a an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors) owned by Mike DeGrandpre (UMontana) and operated onboard by Cory Beatty. Data were recorded through the cruise with discreet DIC, Alkalinity water samples drawn for comparison. For more information please see their report.

Flow rate was measured manually

Using the Honeywell controller, pressure set point was 18.3 PSI.

Measured flow rates to the sensors were approximately:

TSG	Not measured
Fluorometer pair	3.9 L/min

Water samples

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

5.5.2 Issues with the underway system and data

TSG Flow Rate
Flow rate can often vary due to sea-ice clogging the strainer at the ship's sea-water inlet, or pump malfunction. There were very few times the flow clogged or was interrupted this year, even though we had a good number of days in snow covered ice.

Sea Water Pump and TSG data
Notes are recorded primarily in the TSG Log Book which has been copied to
2021 TSG Log with CNV and Sample data v2021-11-03.xlsx

Highlights below:

Aug 20th	05:05, not far from Cambridge Bay, NU. TSG-2021-08-20-0505 first good file.
Sep 13th	22:00 UTC Ship's power cycled (planned) however didn't notice GPSGate had lost navication feed until an hour later. Didn't realize the SBE38 feed was hung until the next day. In the processing (Oct 27 2021) these bad values were replaced from the SCS data stream.
Sep 15th	15:20 The TSG and Seasave turned off just after ship anchored off of Cambridge Bay.

Manifold is configured with four outlet arms:

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

See processing report for file names and processing steps applied to TSG data:
2021 LSSL Converting TSG data v2021-11-15.docx

Settings:
TSG SBE21 SN 3297 calibrated 10 Dec 2020
SBE38 SN319 Temperature calibrated 30 Dec 2020
Seapoint Flr #3651 with 30x gain calibrated Jun 2014
WETLabs Flr #1281 for CDOM, calibrated 9 Jun 2011
Computer: laptop Pteropod D2020-02

NMEA Com # w/ "Time Added" box checked

SBE38 via internet using Com # USB to serial to null modem to cable to TSG unit with virtual Com # for testing.
Pump set to 18.3 PV

New for 2021:

Chl-a and FDOM sensors were plumbed so they can be calibrated at sea using Sprite or rhodomene dye. Celine and Nicolas attempted this however the funnel needs to attached securely to allow more flow through the sensors.

For 2022:

Repair the cable or TSG bulkhead connector that is causing Chl Fluorometer value to drop to 0 when cable/bulkhead is handled.

5.6 Logging of Underway measurements with SCS

P.I.s: Bill Williams, Celine Gueguen (USherbrooke), Mike DeGrandpre (UMontana)

This section describes measurements taken at frequent regular intervals continuously throughout the cruise that are logged by NOAA's "Shipboard Computer System" (SCS) software running on the science server. These measurements include:

1. GPS from the ship's Furuno GPS, using NMEA strings $GPGGA and $GPRMC. These are the same GPS sentences, available on the science VLAN, being used by CTD, XCTD and TSG systems.
2. AVOS weather observations of air temperature, humidity, wind speed and direction, and barometric pressure ($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.

Not recorded this year as has been in past years:

1. Heading from the ship's Gyro ($HEHDT) – Gyro feed not initially available and not pursued.
2. Data from the FDOM fluorometer in the seawater loop (FDOM) – Effort not put into generating SCS file as data were already being collected.
3. Derived true wind speed calculated in SCS – w/out Heading, not calculated this year. I believe true wind speed available in AVOS data set.

5.6.1 SCS Data Collection System

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 typically contain a day's worth of data, restarting at 1 minute past midnight. 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 2021:

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

File: RMC_*.Raw
Time interval 1 second

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

Sentence fields:

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

Extracted and stored in the Database:

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

Position - $GPGGA

File: GGA_*.Raw
Time interval 10 second

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

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

Sentence fields:

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

Extracted and stored in the Database:
1. GGA-Quality (#9 above)
2. GGA-Satellite Count
3. GGA-Age of data

Depth – "Sounder"

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

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

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

Sounder data is more problematic than other types collected by SCS. 0.0 values are reported when the sounder does not detect bottom. It will report values that to the eye judging the visual echogram are clearly

incorrect; any values less than 35m or values that either double or halve those nearby should likely be discarded. In areas with steep bathymetry the sounder will often report incorrect values from side reflections of deeper or shallower water – these artefacts can be difficult to filter out.

File: Knudsen-Sounder_*.Raw

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

Sentence fields:

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

Extracted and stored in the Database:

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

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

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

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

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

Sentence fields:

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

Extracted and stored in the Database:

1. AVOS-serial-AVRTE-date
2. AVOS-serial-AVRTE-time
3. AVOS-serial-AVRTE-wind speed
4. AVOS-serial-AVRTE-apparent wind
5. AVOS-serial-AVRTE-relative wind
6. AVOS-serial-AVRTE-barometric pressure
7. AVOS-serial-AVRTE-air temperature
8. AVOS-serial-AVRTE-relative humidity

Seawater Loop (TSG)

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

File: TSG-serial-*.Raw

Description of *.Raw file string
TSG-serial-_20200911-193215.Raw

```
09/11/2020,19:32:33.321,    1.58    1.36    30.741    27.035    0.380    0.37973
0.07204    255.811262
09/11/2020,19:32:38.321,    1.57    1.36    30.736    27.027    0.369    0.36874
0.07082    255.811319
```

Sentence fields:

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

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

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

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

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

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

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

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

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

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

Description of *.RAW file string

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

Sentence fields:

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

Extracted and stored in the Database:

1. ASCII-PAR-serialport-PAR

5.6.2 Issues with the underway system and data

All systems

No data Aug 30 14:40 to Sep 3 19:30 UTC. Although the independent systems (i.e. TSG, PAR) have data, the SCS files do not. Its not known what the problem was but could well be the GPSgate program was not distributing the feeds and this was not corrected for four days.

AVOS –
Previous years have had icing problems with the anemometer resulting in inaccurate wind speed. This year there was hoar frost accumulation in the colder wet days, so speed may have been reduced, but the anemometer was always free to spin and rotate.

The AVOS system did not have the ship's Gyro data connected but instead used its fluxgate compass when calculating corrected windspeed and direction. Preferred True wind speed and direction are instead calculated by SCS and stored both in .Raw files and in the database, however this year there was no recorded ship's Gyro.

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

Gyro
The feed was not initially available and not pursued. The consequence with that the calculation of true wind speed will rely on the AVOS flux gate compass which is not as accurate.

FDOM fluorometer
Although this was added last year, we did not attempt to generate the SCS file this year as data were already being collected through the FDOM's software.