Joint Ocean Ice Study /
Beaufort Gyre Exploration Project
2020 Cruise Report

Photo by Darcy McCabe

Report on the oceanographic research conducted aboard the *CCGS Louis S. St-Laurent,* September 14 to October 2, 2020 (Full cruise dates September 3rd to October 15th, 2020) IOS Cruise ID 2020-79

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1. OVERVIEW

The Joint Ocean Ice Study (JOIS) in 2020 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, with colleagues in the USA from Woods Hole Oceanographic Institution (WHOI), Andrey Proshutinsky, Rick Krishfield, Isabela Le Bras, and John Toole, and from Yale University, Mary-Louise Timmermans. The scientists from WHOI and Yale run 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).

The 2020 program includes collaborations with researchers from:

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

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 (KIT), 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

Switzerland:
- Eidgenössische Technische Hochschule Zürich, (ETH Zurich), Zurich

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	www.whoi.edu/beaufortgyre
Beaufort Gyre Observing System dispatches	https://www.whoi.edu/page.do?pid=166776
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/
JOIS website from DFO	https://waves-vagues.dfo-mpo.gc.ca/Library/4087378x.pdf (Page 20)

2. CRUISE SUMMARY

The JOIS science program onboard the *CCGS Louis S. St-Laurent* ran a bit differently this year due to COVID-19 precaution measures. These measures changed where we joined the ship and limited the participants to those coming from Canada. The science team joined the ship Sep 3rd in St. John's NL, instead of Cambridge Bay or Kugluktuk, transited north with the ship and began the 19 day science operations Sep 14th as the ship entered Amundsen Gulf. The program completed with the ship's return to Amundsen Gulf October 2nd and transited to St. John's NL for offloading Oct 15th. The research was conducted in the Canada Basin from the Beaufort Shelf in the south to 79°N by a research team of 15 people from 4 institutions. Of the 15 people, 5 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 were not conducted this year, but ice-buoys were deployed in the northern Beaufort Gyre to collect year-round time-series data. Underway ice observations and on-ice surveys were performed. 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.

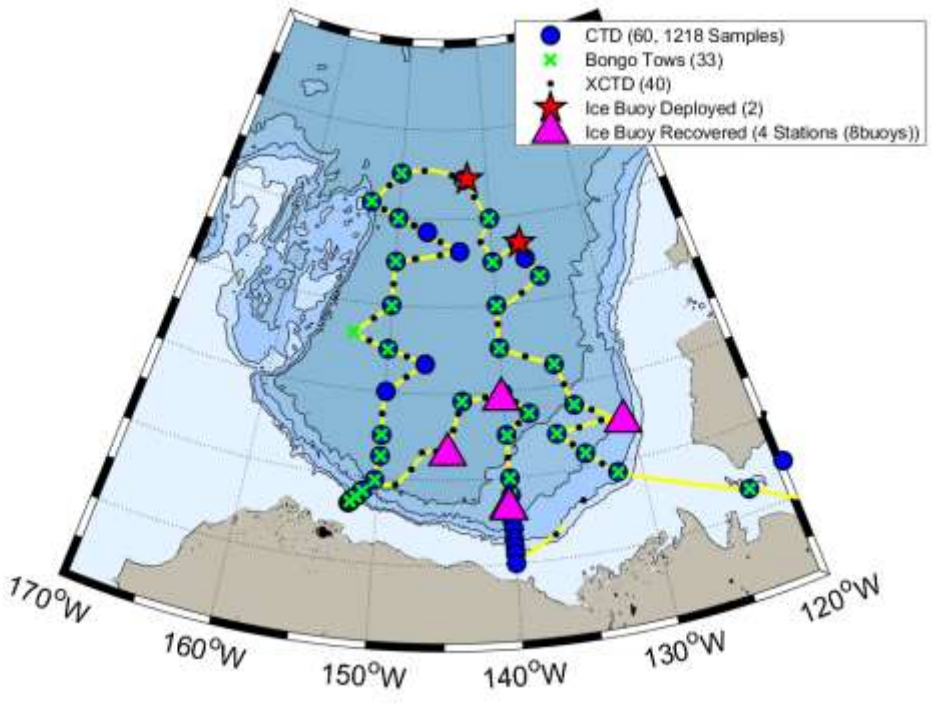


Figure 1.The JOIS-2020 cruise track showing the location of science stations in the

Canada Basin. Note that the numbers are cruise totals: There were 55 CTDs in the Canada Basin, 4 in the Canadian Arctic Archipelago, 1 test cast in the Labrador Sea. There were 37 XCTDs in the Canada Basin, and 3 in Baffin Bay

Opportunistic sampling was performed prior to the cruise by Canadian Hydrographic Service (CHS) aboard the CCGS Louis S. St. Laurent, deploying XCTDs in Baffin Bay for the Institute of Ocean Sciences. There was also opportunistic sampling during the cruise's transit to and from the Canada Basin with 3 XCTDs launched in Baffin Bay on the way north, and 4 CTD casts in Bellot Strait on the way south. The underway surface seawater system was running during the transit north and south as well. These measurements will be listed in the appendix, and only lightly addressed in the JOIS report below.

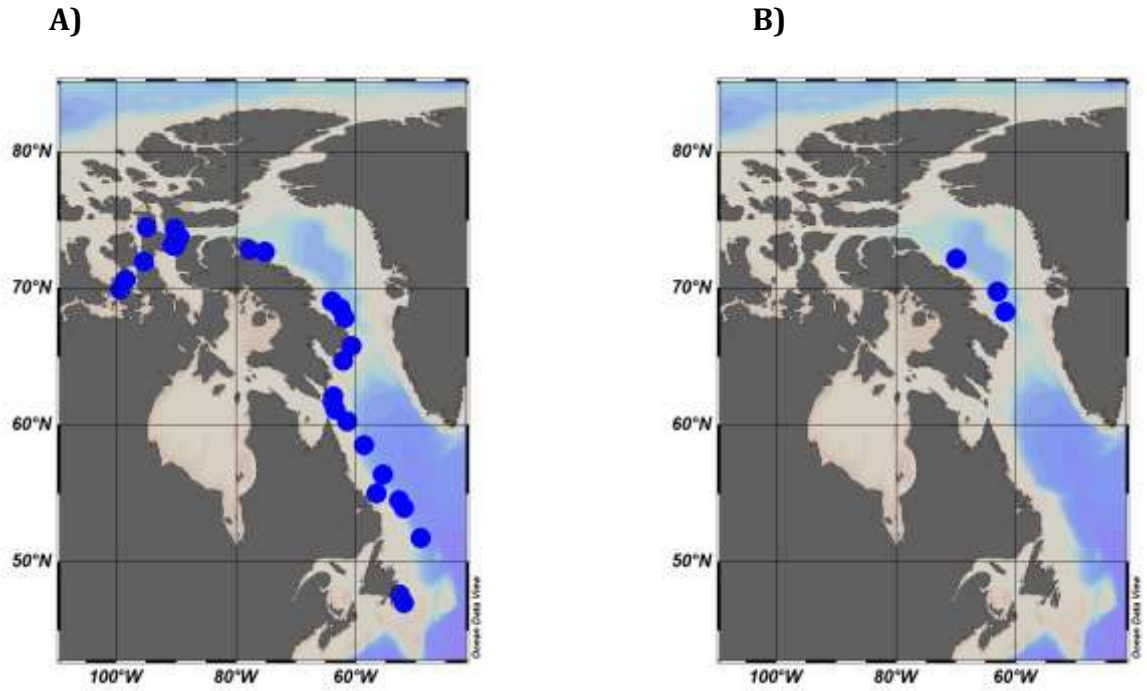


Figure 2. Opportunistic sampling. A) XCTDs launched by CHS in July and August, 2020. Some probes provided by DFO-IOS. B) XCTDs launched September 2020 during transit to the Canada Basin.

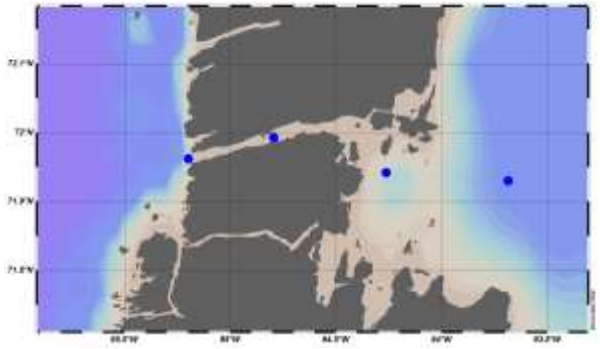


Figure 3. The location of 4 CTD stations through Bellot Strait

Figure 4. The full cruise track to and from St. John's NL.

2.1 Program Components

Measurements:

- At CTD/Rosette Stations:
  - 55 CTD/Rosette Casts at 50 Stations (DFO) with 1175 Niskin bottle water samples collected for hydrography, geochemistry and pelagic biology (bacteria, microbial diversity and phytoplankton) analysis (DFO, Sherbrooke U, TUMSAT, WHOI, U Laval, Concordia, ETH Zurich). Additionally, 4 more casts were taken in the Canadian Arctic

Archipelago in Bellot Strait with 43 water samples druing the transit south.

- Water samples taken:
  - At all full depth stations: Salinity, dissolved O_2 gas, Nutrients (NO_3, 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 and ^{236}U, Barium, Dissolved Organic Material (DOM), Lignin and Phenols
- 30 Zooplankton Vertical Net ("Bongo") Casts with one cast to 100m per CTD/Rosette stations The two nets per cast have a mesh size of 150 µm. This is different from prior years that had one net each of 150 and 236 µm. (DFO).

- 37 XCTD (expendable temperature, salinity and depth profiler) Casts typically to 1100m depth. There were 2 failed casts that were redone (39 probes used). In addition, 3 more XCTDs were launched in Baffin Bay during the transit north (DFO, JAMSTEC, WHOI)

- Buoy deployments
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler w/ SAMI-CO2 and microcat with ODO (ITP121, SAMI C180, Microcat 16512) (WHOI, UMontana)
    1 Seasonal Ice Mass Balance Buoy (SIMBB , CRREL)
  - 1 Ice-Station with:
    1 Ice-Tethered Profiler (ITP120, WHOI)
    1 Seasonal Ice Mass Balance Buoy (SIMBB , CRREL)

- Buoy recovery, operations from ship after breaking buoys free of ice
  - Recovery 1, Deployed Oct 2018 by USCGC Healy for SODA program
    Ice-Tethered Profiler w/ MAVS and microcats (ITP104)
    Arctic Ocean Flux Buoy (AOFB41)
    WIMBO
    WHOI acoustic node
  - Recovery 2, Deployed Sep 2019 by the LSSL for BGOS program
    Ice-Tethered Profiler w/ SAMI-CO2 w/ ODO and PAR (ITP118, WHOI, UMontana)
  - Recovery 3, Deployed Sep 2019 by USCGC Healy for SODA program
    Ice-Tethered Profiler w/ MAVS and microcats (ITP114, WHOI)
    Not seen: SVP and WHOI acousitic buoy that were deployed on same floe
  - Recovery 4, Deployed Sep 2019 by the LSSL for BGOS program
    Ice-Tethered Profiler w/ SAMI-CO2 w/ODO and PAR (ITP117, WHOI, UMontana)
    Tethered Ocean Profiler (TOP, WHOI)
    Not seen: Seasonal Ice Mass Balance Buoy (CRREL)

- The planned mooring operations were canceled this year due to consequences of COVID precautions limiting the program.

- Ice Observations (KIT/OSU)
  - Hourly visual ice observations from bridge as possible performed by Canadian Ice Service. Automatic 1-minute interval photographs taken from cameras: 1 mounted on above the bridge looking down where the ice rolls on edge due to contact with the ship to measure ice thickness, the other mounted in the bridge window looking forward to measure concentration.
  - Limited on-ice measurements at the ice-stations including:
    - Ice-core for temperature, salinity and structure profiles
    - Ice-cores for DIC and Alkalinity measurements.
    - Ice-cores for microdiversity sampling

- 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, Sherbrooke U, UMontana).
  Water samples were collected from the underway seawater loop for salinity, nutrients, chlorophyll, oxygen, DIC and Alkalinity (DFO), and FDOM (SherbrookeU). Over the full trip, 114 samples were collected.

- Daily dispatches to the web (WHOI)

2.2 Comments on Operation

We felt very fortunate to accomplish the cruise this year amidst the corona virus pandemic. Modifications were made to allow the program to go forward, the largest impact being the restriction of participants to being from Canada. Our team was reduced from the usual 28 or so down to 15 people. This meant that the mooring operations were delayed until next year, and although the moorings will have stopped data collection it is expected the battery life of the anchor releases will allow them to be recovered next fall. Without our US and Japanese colleagues there was also a reduced program for ice observations and onboard analysis of water samples. Other aspects of the program were able to be maintained, in particular buoy work and surface water pCO2 measurements, by training participants to do this work for those that could not come onboard.

To remove the risk of spreading the virus to the northern communities, the crew and science team boarded the LSSL in St. John's NL and sailed to and from the Canada Basin work area instead of the usual practice of flying to and from the north to meet the ship already there.

The program's cruise-track went anti-clockwise around the Beaufort Gyre again this year. We started by steaming north, sampling our standard eastern stations (around 140W). Looking for ice suitable for the ice buoy deployments without having to go too far north, we deployed the buoys in north east Canada Basin at roughly 79N. Both ice stations were performed by parking the ship into the sea-ice and using crane and ladder to move people and equipment to and from the ice. We then traveled back south along 150W taking measurements at our standard western stations. The Northwest stations were ice free, though new ice was growing while we were out. Crossing 75N we met a tongue of multiyear sea-ice coming from the east. We were able to complete the 5 stations within 60nm of Utqiagvik (formerly called Barrow) after emails and phone calls with Utqiagvik and Nuiqsut whaling commission and whaling captain The Alaska Eskimo Whaling Commission requested ships not to come w/in 60nm to avoid disruption of the whale migration and hunting season, although our 12 hour overnight window for sampling was OK with their schedules. From 150W we turned east, finishing with the southern leg of stations along the 140W line, ending on the Canadian Beaufort Shelf. We opportunistically recovered buoys that had finished their data collection from 4 ice-stations deployed both by our program last year (2) and by SODA program from the USCG Healy in 2018 and 2019 (2). Very conveniently the buoys had drifted almost onto our cruise track at the time of pick-up. We greatly appreciate the ship from the ship's crew in these recoveries.

The anti-clockwise route has the advantages of:

- completion of the northern on-ice work (i.e. installing ice-buoys) as early in the cruise as possible to take advantage of the longer days, warmer temperatures and lower wind.
- more time for new ice to form over the southern stations to minimize the work performed in open seas.
- Shelf/slope stations are planned towards the end of the expedition. As a lower priority, their number can be reduced if we become time-limited by weather and operations. .

We had two ice specialists from the Canadian Ice Service on board. Their daily briefings of 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 and had just finished our last station before strong winds picked up that would have limited our operations for the next two days. We did not have to cancel or postpone any stations due to weather, although winds were high enough toward the end of the cruise to reduce the

number of zooplankton casts. See the figures below for details of the ice cover during the expedition.
We did skip a low priority CTD station (PP6) so as not to lose a day for buoy work where we needed to reach suitable ice during the limited daylight hours. Another station was moved (CB19 became CB19S) to save time towards the end of the cruise when it was unclear how the weather and sea-ice would affect our travel.

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

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: http://nsidc.org/arcticseaicene)

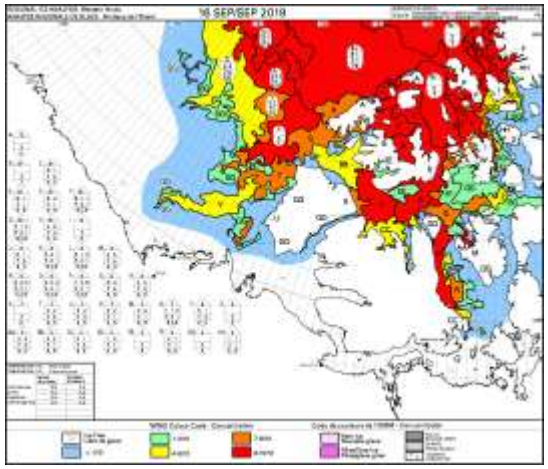


Figure 3. Sep 16, 2019 Ice Concentration

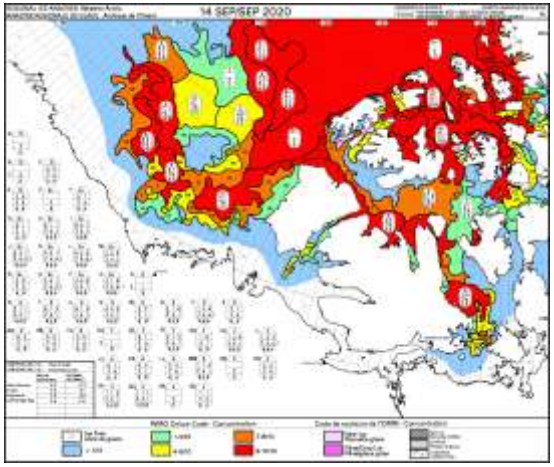


Figure 4. Sep 14, 2020 Ice Concentration

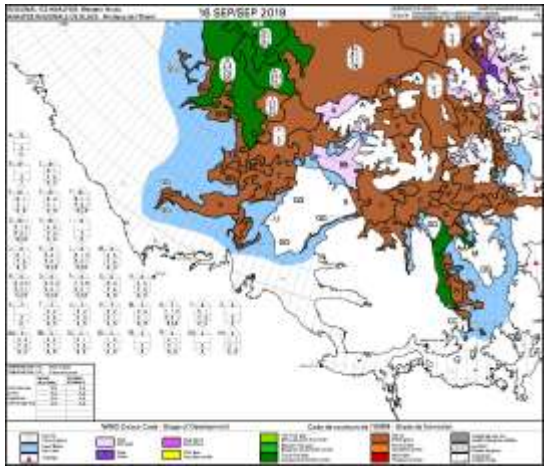


Figure 4. Sep 16, 2019 Ice Stage

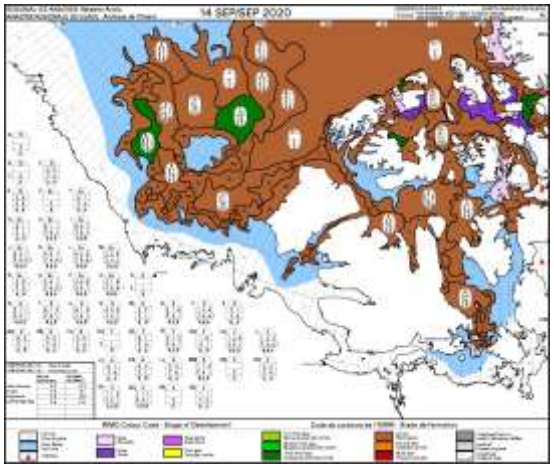


Figure 5. Sep 14 2020 Ice Stage

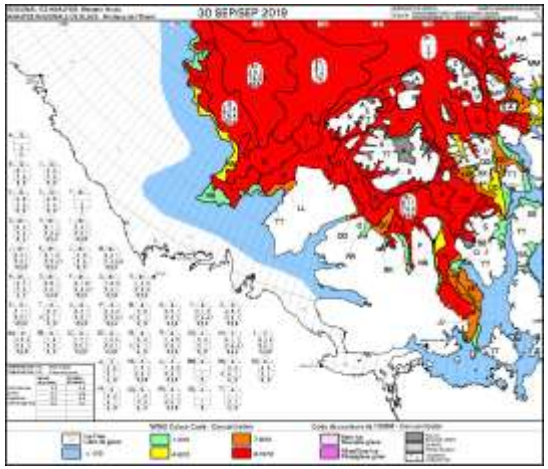


Figure 7. Sep 30, 2019 Ice Concentration

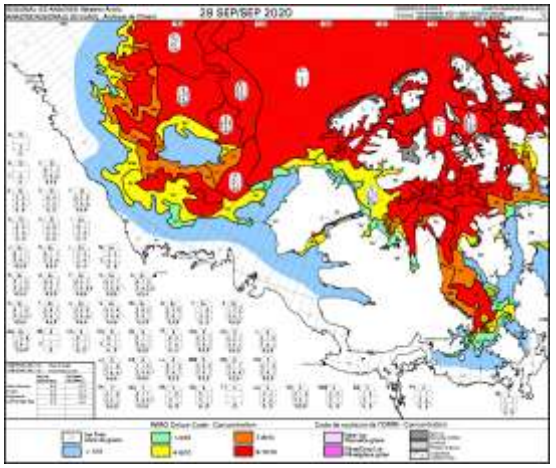


Figure 5. Sep 28, 2020 Ice Concentration

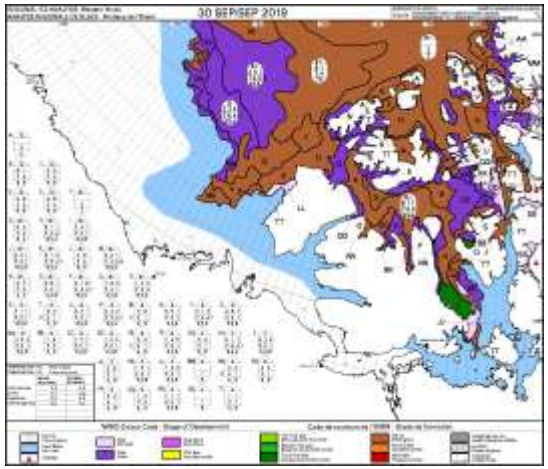


Figure8. Sep 30, 2019 Ice Stage

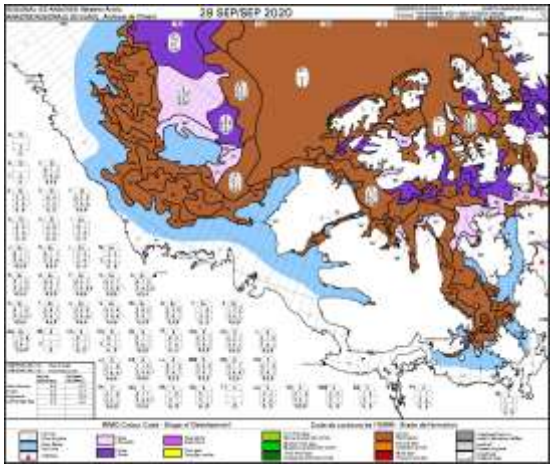


Figure 6. Sep 28, 2020 Ice Stage

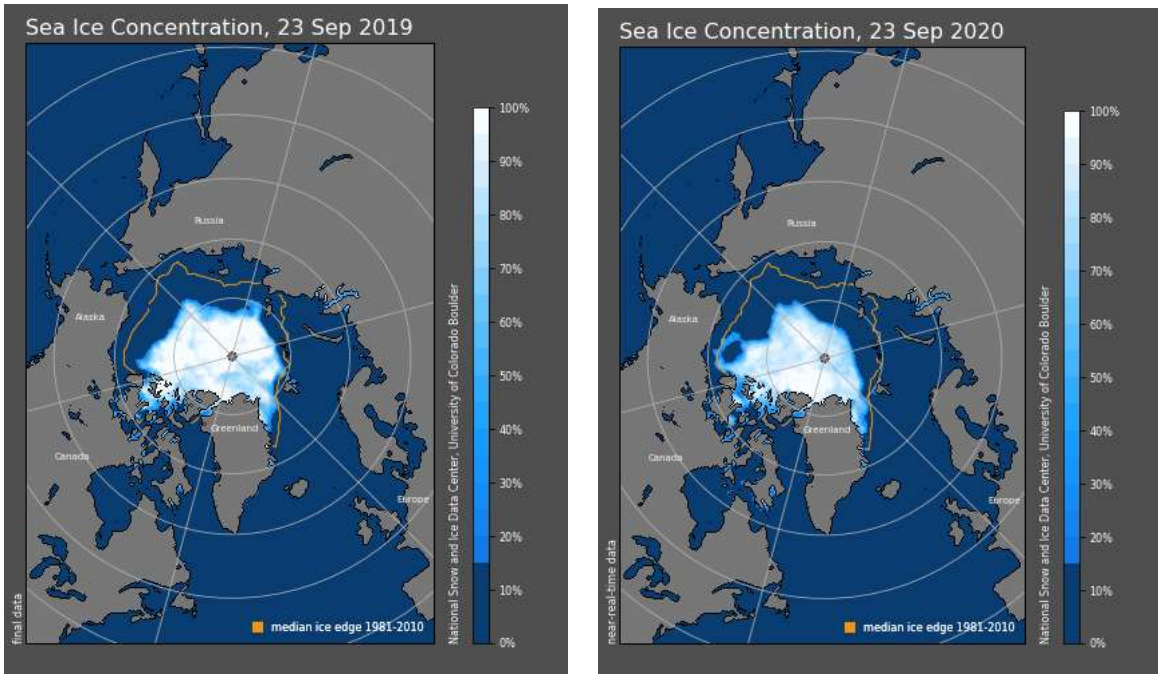


Figure 7. Sea Ice Concentration mid-way through the cruise (23 Sep). On the left 2019 is shown for comparison, on the right is this year's concentration. Images are from the National Snow and Ice Data Center (https://nsidc.org/data/seaice_index/archives)

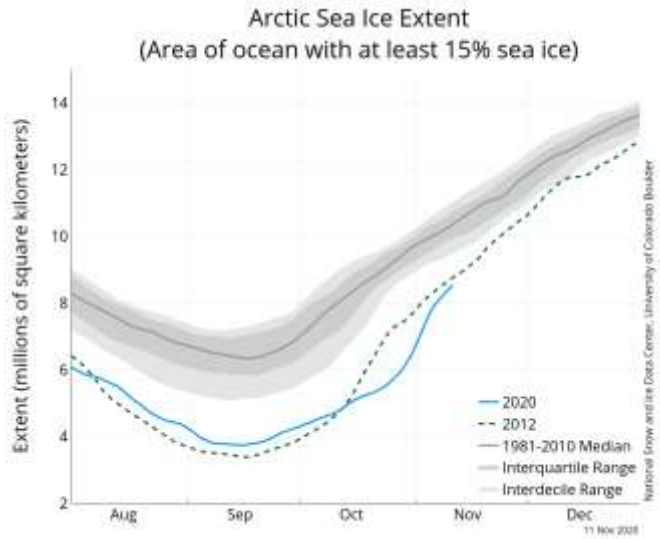


Figure 8. Sea Ice Extent from National Snow & Ice Data Center (source: http://nsidc.org/arcticseaicenews/)

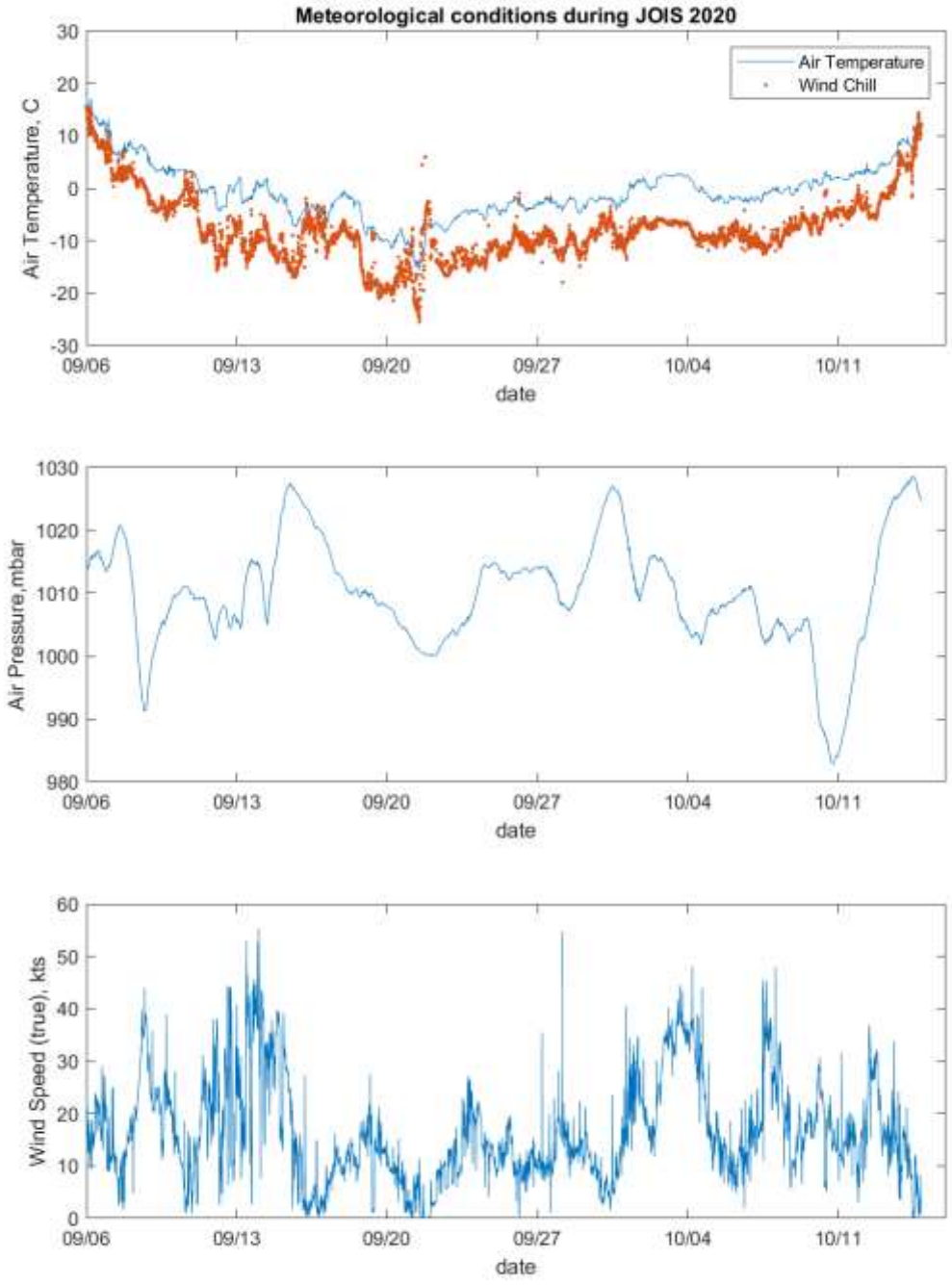


Figure 9. Temperature, air pressure and wind speed for the duration of the expedition from the AVOS weather station above the bridge of the CCGS Louis S. St-Laurent.

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.

3. ACKNOWLEDGMENTS

The science team would like to thank Captains Wayne Duffett and Jim Chmiel and the crews of the *CCGS Louis S. St-Laurent* and the Canadian Coast Guard for their support. Extensive 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. In particular we appreciated the extra effort by Senior Engineer Liam Gormley helping find and craft replacement parts, Electrical Officer Luke Adey's work to repair the CTD winch and Carpenter Andy Hillier's craftsmanship with wood. As usual, there were a lot of new faces on-board and we appreciate the effort everyone took to accommodate us and our science. Late September in the Beaufort Gyre has short days, cold temperatures and high winds. Work in these conditions is difficult in comparison to the summer and we appreciate the hard work of the crew to complete our goals. The ice specialists, Jonathan Delisle and Alex Livernoche, from the Canadian Ice Service gave daily briefings that were much appreciated. It was a pleasure to work with the helicopter pilot Malte Dehler and mechanic Darcy McCabe and thank them for their support.

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 18th consecutive year and the exciting and valuable results are a direct result of working with such experienced, well trained and professional crews.

Thanks to Kim Bedard for her help preparing this report.

Figure 10. After finishing the ice station science. Photo by Darcy McCabe

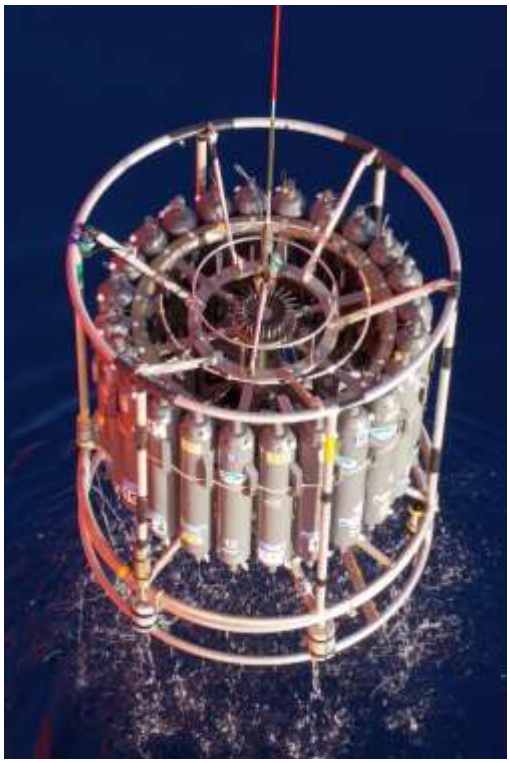
Figure 11. All crew and science on board. Poster made by Hayleigh Shannon and Jasmine Wietzke

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)
Mike Dempsey, Jane Eert, ,Sarah Zimmermann (DFO-IOS)



4.1.1 Overview

A Seabird 9/11+ CTD system was used with SBE9+ s/n 724 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, chlorophyll fluorometer, transmissometer, CDOM fluorometer, cosine PAR and altimeter. In addition, an Alec RINKO III dissolved oygen sensor was used for comparison and sensor testing purposes.

This year, WHOI did not add their Lowered Acoustic Doppler Current Profiler (LADCP) and fibre optic gyro that had been used from 2017 to 2019.

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 CTD casts to 1000m for microbial diversity sampling ("RNA/DNA") lead and was followed by a full geochemistry cats. Casts were also done at ITP deployment sites and the recovery site of the ITP with a SAMI. During JOIS 2020, there were a total of 60 CTD/Rosette casts. 1 was a test cast in the Labrador sea, 55 were casts for JOIS, and 4 were opportunistic casts performed in Bellot Strait during the transit back to port.

Figure 1. Typical rosette deployment
Figure 2. Brooke Ocean Technology IMS winch display
Figure 3 Hawboldt oceanographic winch and operator
Figure 4. CTD operator and acquisition display

4.1.2 During a typical deployment

On deck, the transmissometer and CDOM sensor windows were sprayed with deionised water and wiped with a Kimwipe prior to each deployment. The CTD/Rosette was lowered to 10m and the pumps turned on. This soak cools the sensors to ambient sea water temperature and removes bubbles from the sensors. After 3 minutes, the package was brought up to just below the surface to begin a clean cast, and lowered at 30m/min to 300m, then at 60m/min to within 10m of the bottom. Routinely, the winch was switched from low to high gear and vice versa at 900m to make operation 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.

4.1.3 Performance notes

Assembly – CTD
We used SBE9plus s/n 724 with s/n 756 as backup. The temperature, conductivity and dissolved oxygen sensors were all freshly calibrated this year for JOIS. The only major problem was with the primary and backup FDOM sensors failing. One change from previous years was the location of the pumps and pumped sensors. The SBE43 and primary T & C sensors were located on the opposite side of the main cylinder. It does not appear this had any effect on the performance of the CTD but will be changed back to the usual configuration next year.

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 CDOM sensor, altimeter, and transmissometer were mounted in roughly the same positions as 2017.

Pylon/ Water Sampler
Generally the system performed well. The trigger mechanism was removed weekly in a bucket of warm soapy water.

Water sampling around 24 bottle rosette

Niskin configuration
Before the science started on the JOIS cruise, all o rings were changed 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. As a result, there were relatively few integrity problems with the 24 Niskins during JOIS this year. See comments w/ CTD station locations in Appendix for full list.

At the end of the science program, all Niskin lanyards were checked for optimum length and non standard and damaged nylon monofilament lanyards changed.

Seacable issues and re-termination
The seacable was reterminated once at the end of the JOIS stations. The wire was cut back 50 m and re-terminated in Queen Maud Gulf and used subsequently for 4 stations in Bellot Strait. If unused before JOIS 2021, the termination should be good for the next cruise.

Leading up to this:
ROS2 and 3 (AG5) The wire was slightly damaged a couple of metres up from the termination but shock loads in swells due to heavy seas.
ROS30 (CB6). The Seacable fuse blew on the SBE11 deck unit during cast but no alarm. The 0.5A fuse wire still visible but no continuity. The fuse was replaced mid-cast and there were no further problems.
ROS53 (MK3) during more heavy seas, the wire was allowed to go slack and another small kink was introduced ~37 m up from the rosette.
ROS56 (CB28aa). A fuse blew on the last JOIS station

Unusual this year, there was a problem with twisting wire. On deck the wire had so much twist it was easy for it to wrap tightly on itself so that during the start of the cast great care had to be taken to pull the wraps apart for the winch to take up the slack. It is unclear what the cause is but perhaps its due to the reconfiguration of the rosette without the weight distribution of the LADCP, FOG logger and battery pack.

ROS53 (MK3) Winch wire snarled on deck. Very twisty and 2 small kinks in first 50m.

Seasave and CTD data
ROS30: Due to fuse blowing on SBE11 deck unit there are two files for ROS30.
ROS56: Fuse blew at start of cast so cast was restarted completely.

GPS feed
The GPS feed hung a few times. Typically restarting GPSgate fixed this problem (ROS12, ROS33).

Instrumented Sheave (BOT)
The Instrumented Measurement System (IMS) and the Brooke Ocean Technology (BOT) block display froze and the IMS software was re-booted a few times. At one point this happened while the rosette was stopped at the bottom and the ship was drifting up slope. Other times, garbled messages would appear on the display and then clear or be replaced by correct message. No cause was found, but the installation of a new load cell, the condition of the cable, or problems related to screen buffer memory overflow are suspect. The IMS will be tested and checked over the winter.
ROS43 (CB19s) IMS display froze
ROS46 (CB22) IMS display froze. Restarted at winch.
ROS54 (MK2) IMS display froze. Restarted at winch.

The wingnut holding bolt through one of the block's red rollers came off mid trip. The bolt slid part way out of the roller. Between casts, a ladder and deck worker in harness clipped into the aft arm of the A-frame and put on a new nut.

Transmissometer
WetLabs CSTAR transmissometer 1052 was used all cruise without major problems. A recurring problem with the CSTAR is that it sometimes exhibits "pressure effects". The percent transmission in Seasave will jump to a lower value at a depth and continue the trend on the down cast and then jump back on the upcast. This was observed once on JOIS 2020 but did not re-occur. The bulkhead connector was cleaned before ROS46. It was noted at the end of the cruise that the SubConn bulkhead connector is due for replacement.

Altimeter
A test cast was done off the Labrador coast on 7 September to test CTD/rosette system integrity. Altimeter 72144 was knocked during installation and was considered suspect and altimeter 62670 was swapped in on V3.

To test 72144, a spare DO/Altimeter Y cable was plugged into JT5 and the suspect used on V5 instead of the CDOM fluorometer and the DO connector dummied off. (Unfortunately Seasave only allows one Altimeter in the con file so the second altimeter was entered as a linear fit "User polynomial").

Both altimeters gave bad readings until 20m off the bottom, however they had trouble 'locking on' to the bottom. The mounts for the altimeters were fairly high up on the rosette frame and it was suspected that there was shielding of the transducer. The FDOM fluorometer and DO were reconnected and altimeter 62670 used for the rest of the cruise after moving it to the bottom of the rosette frame's extension "skirt".

No problems were encountered with altimeter 62670 and ranges up to 93 m were observed during the cruise. No further testing was done on 72144 and it should be checked out over the winter.

FDOM fluorometer

The WetLabs FLCDRTD fluorometers did not work on this cruise.
SN 1076 sensor flooded and has nonuseable data.
SN 4305 data may be somewhat recoverable with effort. The value drops low, then jumps back to the correct value however only by careful comparison of down and upcast and station to station data can the jumps be identified. It would be easy to remove real features during the correction process. The problem is the same seen during its last use in

2018 however WetLabs was not able to find a problem with the sensor when they inspected it last winter.
There had been regular noise on the second channel used with the FDOM sensor, but after making a new cable the phantom noise on the unused channel disappeared.

Both fluorometers were tested on the bench with the serial programming cable. 4305 was OK but 1076 was found to be flooded (no apparent sign of failure although new this year was a replaced bulkhead connector).

ROS2 (AG5) used sn 1076. Noisy reading.
ROS3 (AG5) used spare sn4305. Noisy with dropouts.
ROS4 (CB1) used 1076 w/ new cable. Data bad, but no noise on unused second channel.
ROS5 (CB31b) used 4305 and repositioned for very clear sampling volume under Niskin 12.
ROS6 (CB23a) used 4305, swapped CTD bulkhead connectors. FDOM cable moved from JT5 (V4) to JT6 (V6) to and PAR and Rinko moved from JT6 (V6&V7) to JT5 (V4&V5). The PAR and Rinko were stable and the CDOM fluorometer was still noisy.

A new FDOM sensor is needed for 2021.

Rinko III dissolved oxygen sensor experiment
This year, an Alec Rinko III dissolved oxygen sensor was mounted on the Rosette next to the SBE43 oxygen sensor for most of the CTD casts. The RINKO was configured on the Y cable with the Stalantic PAR sensor (initially V7 and then moved to V5). 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. Three sensors were used (only one at a time) for about 15 casts each with on board 2 point calibrations performed between each sensor replacement. It is hoped that the drift found in this sensor can be corrected for, and the Rinko can be used to provide accurate dissolved oxygen profile data when an oxygen analyst cannot be present on board cruises (C3O, CBS-MEA, CROW etc). Analysis of the data collected will be used to prepare a method for independent oxygen measurements.

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 ~6000 remained on the drum in 2019. Another 50 m was cut off near the end of JOIS 2020.

At the end of JOIS in 2019, it was observed that the winch was squealing during slow speeds and that the hydraulic brake clearance was likely the cause. No abnormal squeaking was heard in 2020, so the cause was likely transient grit that made it's way out

at some time. It was noted that despite the brake clearance and operation being good, there may be more brake dust than in other years. Given the thickness of the brake pads, this is unlikely to be a problem. 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 724
Consider new calibration for T&C sensors on SBE 9 plus s/n 756
Repair BOT block cabling and load cell enclosure, confirm spare parts incld rollers
Replace Fluor/Xmiss Y cable with longer xmiss leg
Confirm operation of altimeter 72144
Service CDOM fluorometer 4305
Obtain spare CDOM fluorometer
Supply weights for addition to Rosette Frame to reduce spin.
Transmissomter bulkhead connector replacement

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	997 (128)	Onboard	Bill Williams (IOS)
DIC/alkalinity	All casts (geochemistry)	5-400 (typically to S=34.7)			
	15, 22,29,42,45	Full depth	641 (44)	Shore lab at IOS	Bill Williams (IOS)
FDOM	All casts (geochemistry)	5, Chl Max,S=33.1, S=34.4, Tmax,	492 (7)	Onboard	Celine Gueguen (USherbrooke)

		1000, 2000, 2500, Bot-100			
Chl-*a*	All casts (geochemistry)	5-200 (select)	320 (172)	Shore lab	Bill Williams (IOS)
Bacteria	All casts (geochemistry)	Full depth	976	Shore lab	Connie Lovejoy (Ulaval)
Nutrients	All casts (geochemistry)	Full depth	998 (125)	Onboard	Bill Williams (IOS)
Salinity	All	Full depth	1193 (108)	Onboard	Bill Williams (IOS)
$\delta^{18}O$	All casts (geochemistry)	5-400 (typically to S=34.7 or 34.8)			
	11, 15,16, 22, 29, 42, 45, 47, 48, 51	Full depth	728 (59)	Shore lab	Bill Williams (IOS)
Barium	10, 11,15, 16, 28,29, 34-38, 40,42, 44,45, 47 to 49, 51 to 56 (29 is full depth) (140W, Sta A: Surf to S=33.1 w/ FDOM; CB3, 2, 2a, BL Line top 4 w/ FDOM))	5-200 (select)	194 (13)	Shore lab	Celine Gueguen (USherbrooke)
DOM	10, 11, 12, 13, 16, 18, 19, 24, 43	Tmax (~400), 1000, 2000, Bot-100	46	Shore lab	Celine Gueguen (USherbrooke)
Lignin/Phenol	10, 11, 13, 18, 24, 43	1000, 1500, 3000, Bot-100	25	Shore Lab	Celine Gueguen (USherbrooke)
DNA/RNA	2,17, 21, 28, 44, (dedicated casts)	5, 20, Chlmax, S=32.3, S= 33.1, Tmax, 1000, Bot-100		Shore lab	
	5, 8, 9, 11 13, 15, 16, 18, 19, 20, 25, 26, 32, 34, 42, 47, 48, 49, 51, 52, 53, 55, 56	5, ChlMax, + extra from above depths	274		Connie Lovejoy (ULaval) / David Walsh (Concordia)
^{129}I, ^{236}U	12, 15, 20, 21+22, 23, 24, 27, 42, 45,51, 53, 54	Full depth (select)	130	Shore lab	John Smith (DFO-BIO), Nuria Casacuberta (ETH Zurich)

Table 3. Water Sample Summary from CTD/Rosette – Bellot Strait

Parameter	Canada Basin Casts	Depths (m) or properties	n (dup, trip)	Analyzed	Investigator
Dissolved Oxygen	All	Full depth (select)	20	Onboard	Bill Williams (IOS)
FDOM	All	Full depth (select)	22	Onboard	Celine Gueguen (USherbrooke)
Nutrients	All	Full depth	43 (7)	Onboard	Bill Williams (IOS)
Salinity	All	Full depth	43	Onboard	Bill Williams (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, Uranium-236

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

Sampling was performed for two radionuclides ^{129}I and ^{236}U in the Arctic Ocean.

Measurements of ^{129}I along the northern edge of the program area provide information about the spread of Atlantic-origin water labeled by discharges from European reprocessing plants. New this year was the additional sample of ^{236}U. The ratio of these two isotopes can be used to distinguish contributions from reprocessing plant discharge and fallout from the atmosphere. More locations were added this year to include samples along the 140W line.

The combined sample for ^{129}I and ^{236}U were collected into 3L cubitainers after a small rinse for contaminants. After drying and coming to room temperature, the lids were wrapped secure with parafilm to prevent leaks or evaporation and the cubitainer put into its cardboard box with a second sample label attached to the outside of the cardboard box. Isotope samples were stored at room temperature in the forward hold, packed into the provided pallet-sized wood box until they were offloaded and shipped to ETH Zurich, Switzerland, for analysis.

4.2.2 Fluorescent Dissolved Organic Matter Sampling; Dissolved Organic Matter Sampling; and Lignin-Phenol Sampling

Celine Guéguen(USherbrooke)
Nicolas Sylvestre (USherbrooke)
P.I.: Celine Guéguen (USherbrooke)

4.2.2.1 ***Summary***

Fluorescent Dissolved Organic Matter (FDOM) samples were collected for Céline Guéguen (USherbrooke), following the protocol given below. A total of 495 samples were collected at 46 stations and 39 from the underway seawater loop system between September 12th and October 1st, 2019 on board the CCGS Louis S. St-Laurent during the Joint Ocean Ice Study-Beaufort Gyre Observational System 2020.

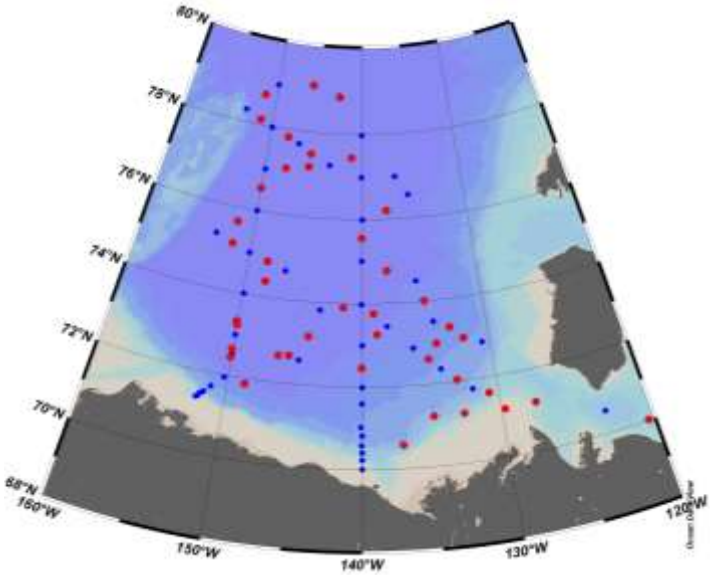


Figure 1: Map of the Canada Basin representing the sampling sites of the CTD stations (blue) and the loop samples (red).

4.2.2.2 ***Rosette Casts Samples***

4.2.2.2.1 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 CB17, CB18, PP7, ICE1, CB16, ICE2, CB11, CB13 and CB19S. The samples were solid phase extracted immediately after collection.

20L water samples were collected for lignin phenol analysis in deep waters (combining Bottom-100m and 3000-m) and in Atlantic waters (combining 1000-m and 1500-m) from remnant water from Niskin at CB17, CB18, ICE1, ICE2, CB13, CB19S. The samples were solid phase extracted immediately after collection.

4.2.2.2.2 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.

4.2.2.3 *Underway Samples*

Thirty-nine 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), latitude, longitude, UTC time, sample ID etc. was noted.

A new real-time FDOM sensor was tested and compared to the old one.

4.2.2.4 *Storage*

After collection, FDOM samples were immediately transported to the 4°C "Marty's" fridge where they were stored in the dark in a tote until boarding the ship. The Canada Basin samples were analyzed 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 Sampling

Celine Guéguen(USherbrooke)
Nicolas Sylvestre (USherbrooke)
P.I.: Celine Guéguen (USherbrooke)

4.2.3.1 *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).

4.2.3.2 *Sampling*

194 barium samples were collected at along the 140W line, CB3, CB3, CB2a, BL lines and Sta-A, typically from 0 to 200 m depth at Niskins being sampled for FDOM, down to S=33.1. 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.

4.2.3.3 *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.

4.2.3.4 *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.

Samples for $\delta^{18}O$ were collected from all CTD/Rosette stations, typically from 5 to 400m depth, in addition, full depth profiles were collected at 11 stations. Oxygen Isotopes Samples were collected into 30 ml glass vials after three rinses with sample water. Once at room temperature, the caps were retightened and the vials inverted for storage. A total of 728 unique samples were collected, 59 of which were collected in duplicates.

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.

4.2.5 Dissoved Inorganic Carbon and Alkalinity

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

Samples for DIC and Alkalinity analysis were collected from 0-350 m of the water column at most of CTD/R stations collected into 250 mL glass bottles. At selected stations, full depth profiles were collected. 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. This year samples were not analysed on board. Instead, they were preserved with 100uL saturated mercuric chloride (HgCl2), delivered by pump (not pipette) and sealed with a greased stopper held down using multiple wraps of electrical tape. Samples were stored in the ship's walk-in cooler at 4°C and shipped back via trucking company using "protected service", meaning heated truck, to prevent freezing during the samples' cross country trip from St. John's NL to Victoria, BC in November. A total of 642 samples were collected from Niskin bottles, of which 44 were in duplicates.

Samples will be analysed at DFO-IOS. DIC samples will be analyzed 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 will be used to standardize the system.

Alkalinity will be analysed from the same sample bottle, after analysis for DIC, by means of 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 will also be standardized using Dickson CRM seawater

4.2.6 Nutrients

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

4.2.6.1 ***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 994 unique samples were collected, of which 124 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 12 samples were collected in duplicates from the sweater loop system, from the outflow of the FDOM sensors and analyzed within 12 hours of collection.

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 April, 2020, and were calibrated against Kanso certified reference materials, lot CA (NO_3 = 20.21 µM, SiO_4 = 37.49 µM, PO_4 = 1.442 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 24.27 µM, SiO_4 : 0.00 to 48.60 µM and PO_4: 0.00 to 2.441 µM).

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

The assigned values from CRM KANSO were nitrate + nitrite, 20.21 µmol/L; silicate, 37.49 µmol/L; and phosphate, 1.442 µmol/L for lot CA, nitrate + nitrite, 5.62 µmol/L; silicate, 14.15 µmol/L; and phosphate, 0.425 µmol/L for lot CL and nitrate + nitrite, 16.30 µmol/L; silicate, 35.58 µmol/L; and phosphate, 1.206 µmol/L for lot CO. 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.

Reagents were prepared onboard, as required, using ACS grade dry chemicals (pre-weighted at IOS in April 2020), and water from onboard Milli-Q Reference water purification system that produced 18.2 mΩ-cm resistance Type I reagent grade water. The system was supplied with the ship's distilled water. Two new pre-filters were installed before the Milli-Q Reference system.

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.

4.2.6.2 ***Precision, Accuracy and L.o.D.***

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

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

Chemistry Sample	**Units**	**Minimum Range**	**Maximum Range**	**L.o.D**	**Precision (s_p)**	**Number of Replicates (n)**	**Outliers removed**	**Accuracy (% recovery)**
Nitrate (fresh)	mmol/ m^3	0.00	16.48	0.05	0.03	118	6	96.7-99.3
Silicate (fresh)	mmol/ m^3	2.10	35.5	0.08	0.04	117	7	95.7-97.7
Phosphate (fresh)	mmol/ m^3	0.309	1.924	0.013	0.004	120	4	998.7-102.9

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

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

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

The % recovery of the Kanso RMNS analytes ranged from 96.7-99.3% (n = 73) for NO_3, 998.7-102.9% for PO_4 (n = 73) and 95.7-97.7% for SiO_4 (n = 73). The limit of detection (mean of 10 samples consisting of NaCl/NaHCO3 solution spiked with 200 µL of the high standard plus 3 times its standard deviation) were 0.05 µmol/L for NO_3, 0.08 µmol/L for SiO_4 and 0.013 µmol/L for PO_4.

4.2.6.3 ***Problems and Solutions***

4.2.6.3.1 General Issues

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 12. Nutrients analysis on the AA3. Photo by Fred Marin (2019).

4.2.7 Dissolved Oxygen

Nina Nemcek (DFO-IOS)
P.I.: Bill Williams (DFO-IOS)

Dissolved oxygen concentrations were measured on board the CCGS Louis S. St-Laurent (LSSL) from September 5th to October 6, 2020 during the JOIS mission in the Canada Basin. A total of 1144 samples (1008 + replicates) were collected from 57 rosette casts along a cruise track starting and ending in St. John's, Newfoundland. All samples were analyzed on the SIO Winkler oxygen titration kits. Oxygen concentrations ranged from 5.350-9.059 ml/L with greater than 10% of samples analyzed in duplicate. The pooled standard deviation (sp) for duplicate samples was 0.004 ml/L after the removal of 2 outliers based on Chauvenet's criterion. The mean deep water (>3000 m) DO value in the Canada Basin was 6.526 +/- 0.009 ml/L.

Pre-cruise preparation

4.2.7.1 ***Reagents and Standards***

All reagents and standards were prepared in soap and acid-washed glassware and plastic ware and were prepared using chemicals of the highest purity available at the time of purchase. Reagents and Thio were made in 4000 mL glassware and the KIO3 standards were prepared in 2000 mL Class A volumetric flasks. All chemical batches were prepared in 2019 and left on board the ship from the previous cruise.

4.2.7.2 ***Equipment Calibrations***

Bottle Top Dispensers: Bottle top dispensers were purchased new in April 2019. They generally performed well though prime was lost at one point on the MnCl2 dispenser during one cast. The spare was brought out to finish the cast but the unknown problem was quickly rectified after pumping dispenser with warm water and DMQ. The primary dispenser was put back in place immediately after the cast. It was noticed that quite a bit of dried reagent was accumulating on the outside of both the pickling reagent bottle top dispensers between the exterior threads during the cruise.

Oxygen Sample Flasks: A new flask file for 2020 was obtained from Kenny Scozzafava prior to the cruise and loaded into the appropriate LVO2 directory. It is unknown whether any new calibrations or spot checks were performed in 2020 but it is recommended that flasks #1156 and #847 be checked as these flasks came up more than once in replicate pairs with poor precision. No flasks were broken during this survey.

10 mL Exchange Units: Calibrations were performed in January 2020 to determine the exact volume delivered at 20°C using the broad dosing tip. Both 10 mL exchange units were calibrated with the primary and spare Dosimat base for dispensing KIO3. For each calibration, ten 10 mL aliquots of deionized water were dispensed into a clean 100 mL glass beaker and each weight was recorded. The mean weight of the 10 aliquots was used along with the temperature of the water to determine the exact volume dispensed at 20°C using the SIO program "glasscal.exe". The appropriate volume for the exchange unit and

Dosimat combo in use was entered into the operating parameters at the beginning of the cruise.

4.2.7.3 *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 in the middle of cast 32 (Station CB2) and was switched out for a replacement. The samples were immediately fixed with 1.0 mL of MnCl2 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 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 (21.5-24 °C) oxygen lab. All samples were analyzed onboard within 24 hours of collection.

Analysis at sea

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

4.2.7.4 *Blank and Standard Preparation*

Blanks and standards were run just prior to sample runs. A dedicated Dosimat was used to accurately dispense either 1.00 mL of KIO3 for blanks or 10.00 mL of KIO3 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.

4.2.7.5 *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 KIO3 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 KIO3 standard and re-titrating the sample. The amount of Thio needed to titrate 1.0 mL of KIO3 is then subtracted by the software from the final titer. After every sample, the DO value was noted on the rosette log sheet. All endpoints were inspected for accuracy and either over-titrated, or had corrected titers determined after the fact by the "O2CHECK" function of the LVO2 software. These updated titers were then entered into the "Recalculations" tab of the dissolved oxygen spreadsheet so that new DO values could be calculated using the relevant flask volume and standardization parameters.

4.2.7.6 ***Thio normality***

The analysis was started with the same bottle of Thio (batch #1902, bottle #246) that JOIS 2019 ended with, allowing a check of the new KIO3 standard and confirmation of Thio normality without having to run two standard batches initially. Agreement was excellent with a difference in the Thio normality of 0.00017N compared to the last standardization a year ago. Two batches of Thio (#1902, #1903) and two batches of KIO3 standard (#1903, #1905) were used during the cruise and the stability of the Thio for both batches was excellent with a maximum change of 0.00023 N well below the 0.0005 N threshold.

4.2.7.7 ***Precision and Accuracy***

Of the 1008 unique samples collected during the course of this survey, 132 (13%) 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 (sp) of 0.004 mL/L after the removal of 2 outliers, determined by the Chauvenet's criterion. There was one particularly bad replicate sample #1138 that had a difference of 0.092 ml/L between replicates. This is far beyond normal variability and could have resulted from within

bottle stratification or some other issue unrelated to sampling or analysis. Triplicate samples were ignored for the purposes of calculating sp as fewer are being collected each year. It is recommended that the Sp 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 5.350-9.059 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 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 2020 value of 6.526 +/- 0.009 falls right on this average.

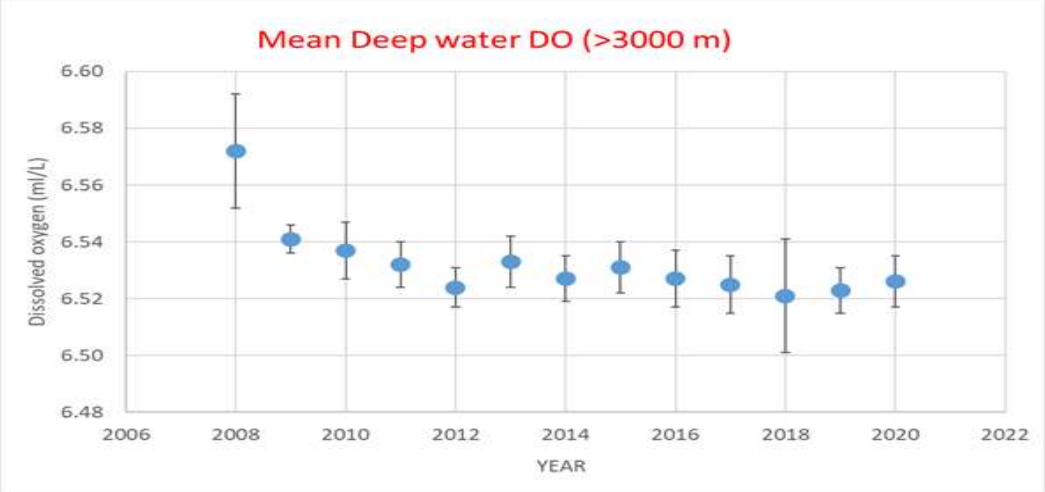


Figure 1: Mean annual dissolved oxygen concentration for the Canada Basin reference stations at all depths below 3000m. Error bars represent standard deviations.

4.2.7.8 *Issues during sampling and analysis*

High Dark value: At the start of the cruise there was a problem with slow dosing during standard runs because a 0V dark value could not be attained. The dark value hovered around 0.02V so dosing commenced at the much slower second step of the UV parameters table. To get through the standardization procedure, the UV parameter table was edited to start the first step at 0.21V. After attempts to correct by adjusting gain failed, a consultation with Kenny led to the suggestion of simply moving the UV lamp power supply further away from the kit, which appeared to solve the problem. The UV parameters were set back to their original configuration and dark value remained around 0.00V for the remainder of the cruise. There were no other software or hardware issues during the cruise and the kit performed exceptionally well.

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.

Overshot Endpoints: There were a few problems with overshot endpoints. The over titration function was used on a number of occasions when either the titration curve had errant points near the endpoint, or would continue past the endpoint due to unstable detector signal. In all cases the OT worked well at salvaging otherwise poor analysis results. However, in a few cases the over-titrated curve also overshot the endpoint and a second over-titration was performed. It should be noted that the DO value produced from a double OT is not correct and only subtracts a single KIO3 addition from the titer. This should be noted in the manual so other users are aware. The double OT samples were manually corrected by subtracting the 2nd titer and/or O2check of original titration curves.

Lab Space Issues: Both the temperature controller unit for the trailer and the water supply line experienced problems at the beginning of the cruise. The heater element had burnt out on the heat pump causing the room temperature to drop too low. The on demand hot water system to the sink was broken and the supply lines to the regular tapwater froze early on. The water supply was switched over to hot water tap only and the supply line leading to the trailer was better insulated. After this, it worked for the remainder of the cruise with no issues but the tap was left on overnight on a slow dribble when temperatures dropped around the -10 ºC mark. Big thanks to Liam Gromley and Luke Adey and their teams for dealing with these issues. 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 trailer.

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

4.2.8 Salinity

Jasmine Wietzke (DFO-IOS)- Hayleigh Shannon (DFO-IOS)- Kim Bedard (DFO-IOS)- Dave Riedel (DFO-IOS)- Birgit Rogalla (UBC)
P.I.: Bill Williams (DFO-IOS)

Salinity samples were collected from all tripped Niskins at all stations. The data are used for calibrating the CTD but also to verify the water in the Niskin is from the expected depth. Samples were collected into 200 mL type II glass bottles with screw caps and disposable plastic inserts after three rinses with sample water. Samples were transferred to the temperature-controlled lab for storage until they were analysed on board within one week of collection. Samples were analyzed in a temperature-controlled lab on a Guildline AutoSalinometer Model 8400B (SN: 69086), which was standardized with IAPSO standard seawater (OSIL batch P163, expiry 10 April, 2022, salinity 34.994 PSU).

4.2.8.1 ***Issues with Salinometer***

Bubbles inside conductivity cell: At the beginning of the cruise, a large bubble remained in the upper left portion of the long arm within the conductivity cell despite attempts to flush it out. There were also tiny bubbles that would persist on the electrodes themselves. These bubbles were watched and consistent through entire analysis. To remove the bubbles we tried washing with CLR as per manual, Triton-X, and DMQ. Nothing cleared the bubbles so we standardized, ran the standard as a sample, and confirmed that the salinometer was working well. Bubbles were monitored through analysis. The bubbles did not seem to affect the working operation of the salinometer.

Software error message: Occasionally it was observed that a "not responding" message appeared at the top of the program window on the laptop when entering text into either the Bottle Label or Comments columns. Although it did not cause any issues for this cruise, it should be noted in case it becomes a reoccurring issue. We assumed this was related to the software slowing down because of the size of the file since we wrote to the same file the entire cruise.

Salinometer disconnection from software and having difficulties reconnecting: There were regular occurrences of the Autosal disconnecting from the software. This was fixed by adding tape to card edge of box to make the board fit more snugly. Furthermore, the knob needed to be turned slowly between standby, read and zero when reconnecting.

Blocked cell flush: On October 6 arm 4 of the cell was not flushing properly leaving a large persistent bubble below the electrode. It was determined that the Polyethylene microtubule was blocked and not venting during flush. The block cleared after wiggling tube, cleaning end of polyethylene, squeezing microtubule, removing from manifold and a long flush.

4.2.9 Chlorophyll-a

Edmand Fok (DFO-IOS), Celine Gueguen (USherbrooke), Jasmine Wietzke(DFO-IOS), Hayleigh Shannon (DFO-IOS), Birgit Rogalla (UBC), Dave Riedel(DFO-IOS), Sarah Ann Quesnel (DFO-IOS)
P.I.: Bill Williams (DFO-IOS)

Chlorophyll-*a* was sampled from the upper 200m, mostly in duplicates, at 49 stations and 12 loop samples. On most stations, two samples were drawn from each of the selected Niskins into pre-calibrated 1L brown Nalgene bottles (calibrated at IOS in 2011) and new this year, also 590 ml brown bottles. Each bottle was rinsed three times with the sample water and then was filled to the top of the bottle.

Samples were filtered onto 25 mm glass fiber filters (GF/F 25mm) under low vacuum filtration. Filters were then folded in half in another GF/F filter (90mm), wrapped in aluminum foil and stored at -80°C for analysis on shore back at IOS.

Chlorophyll-*a* samples were filtered by Edmand Fok (DFO-IOS), *Celine Gueguen (USherbrooke), Jasmine Wietzke(DFO-IOS), Hayleigh Shannon (DFO-IOS), Birgit Rogalla (UBC), Dave Riedel(DFO-IOS) and Sarah Ann Quesnel (DFO-IOS).* A total of 320 samples and 172 replicates were collected.

Note

- System needs to be tested for any leaks before next use.
- Pin hole on spigots needs to be checked, some are extremely small. Compare the size of pin hole to other existing system, make sure the size on pin hole are large enough.
- Use proper o-ring on spigots
- have more spare parts on spigots, o-rings, glass pipes and red tubes.
- Instead of glass pipe on stopper, use of plastic joint with cable tie may be better.

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

Céline Guéguen (USherbrooke), Nicolas Sylvestre (USherbrooke)
P.I. : Connie Lovejoy (ULaval) and David Walsh (Concordia)

Bacteria samples were collected at every station and depth for the JOIS geochemistry casts. Flow cytometry (FCM) samples for bacteria, pico- and nanoeukaryotes were collected for Connie Lovejoy (ULaval), who took over for Bill Li (DFO-BIO). Samples were collected and processed alternately by Céline Guéguen (USherbrooke) and Nicolas Sylvestre (USherbrooke).

Samples were initially collected into 10mL scintillation vials after three rinses with sample water. From these, 1.8mL was subsampled into a 2mL cryovial with the addition of 0.2 mL Paraformaldehyde (PFA, 10%) added for preservation. Samples were stored at -80C until analysis on shore at ULaval.

Issues: no issues reported this year.

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

Thomas Grevesse (onboard, ConcordiaU), Susan McLatchie (onboard, ConcordiaU)
P.I.: Connie Lovejoy (ULaval), David Walsh (ConcordiaU)

4.2.11.1 ***Introduction and objectives***

Marine microbial communities, which are made up of phytoplankton and heterotrophic protists, referred to as microbial eukaryotes, Bacteria and Archaea are the base of oceanographic food chains and mediate many of the steps in global biogeochemical cycles. The microbial communities of the Arctic Ocean are taxonomically distinct from other oceans (Lovejoy *et al*., 2017), suggesting vulnerability due recent climate related changes. The biological and chemical dynamics of the Canada Basin are influenced by physical oceanography at multiple scales (McLaughlin and Carmack, 2010; Nishino *et al.*, 2011) and oceanographic conditions follow regional differences in summer ice extent and freshwater input into the Arctic. Changes in the Arctic will affect phytoplankton and other microbial communities in a number of ways, for example; altered nutrient supply, lower mixed layer salinities, and increased variability in surface temperatures (Thoisen *et a*l., 2015, Pedros-Alio *et al.*, 2015). In the Canada Basin, smaller phytoplankton species are becoming more prevalent (Li *et al*., 2009), which has implications on the feeding ecology of calenoid zooplankton by limiting the range and size of prey items available. Smaller average phytoplankton size also has an effect on the net carbon flux in the Arctic Ocean and the carbon cycle generally. Likewise, taxonomic comparison of microbial communities before and after the 2007 sea ice minimum also detected significant differences from all three domains of life (Comeau *et al*., 2011). Such changes signal the development of a more complex microbial foodweb where unicellular microzooplankton and bacteria become relatively more central in the transfer of energy and carbon to higher food webs compared to classical diatom, copepod based food chains (Sherr *et al*., 2012). However, despite the ecological importance, apparent abundance and wide distribution of these microorganisms, most aspects of their ecology, diversity and oceanography are poorly understood. As change continues, knowledge of the taxonomic and functional diversity of microbial life will become critical for predicting consequences of a fresher, more stratified Arctic Ocean.

Lovejoy and colleagues have previously characterized the taxonomic composition of arctic microbial communities (Bacteria, Archaea, microbial eukaryotes) using mostly molecular techniques and in the last few years using targeted high throughput sequencing (HTS) approaches (Monier *et al*., 2015, Comeau *et al*., 2016, Onda *et al.*, 2017). Past JOIS and other Arctic expeditions have provided Lovejoy with the platform to test spatial and temporal variability of these microorganisms, and infer their potential functions and ecological roles. However, to further broaden our understanding and prevalence of ecological functions, knowledge of microbial metabolic activities and characteristics are needed. For this reason since 2015 Lovejoy and Walsh have combined forces. Walsh has been using metagenomics along with metaproteomics to study the metabolic diversity and activity of marine Bacteria and Archaea (Georges *et al*., 2014). Thus, for JOIS 2015 and onwards, the two laboratories (Lovejoy and Walsh) have been collecting samples for targeted sequencing, metagenomic and metatranscriptomic approaches to gain insights on Arctic microbial communities. In collaboration, we aim to generate and analyze select metagenomes from stratified waters of the Canada Basin (CB), which is among the last undisturbed oceanic regions on earth. Owing to hydrography, the photic zone of the CB

is oligotrophic and most summer productivity occurs at a deeper subsurface chlorophyll maximum (DCM). Additionnaly, the Arctic ocean receives ~11% of total world freshwater while being only 1% of global ocean volume. The Arctic is therefore heavily impacted by organic matter from terrestrial sources, providing a unique chemical environment for microbial communities. Colatriano *et al.* (Colatriano *et al.*, 2018) have recently showed that species from the class chloroflexi in the Halocline in the Canada Basin possess the ability of degrading tDOM, and have acquired that capacity from terrestrial microbial species, highlighting the importance of freshawater to marine transition in the Arctic ocean. We hope to get deeper knowledge on how terrestrial species have enable marine species to degrade tDOM, and their mechanisms in the Arctic ocean. Therefore, we will analyze samples from different layers to maximize the microbial diversity represented in our datasets and to facilitate comparative metagenomic studies. For JOIS 2017, we have expanded to a collaborative study between the Lovejoy, Walsh, and Guéguen (Sherbrooke University, see the CDOM and DOM report) on the Canada Basin. For 2017, we have sequencing and molecular analytical support from the DOE-JGI and EMSL under the FICUS project "Advancing the molecular-level understanding of terrestrial dissolved organic matter transformations by microbes in a rapidly changing Arctic Ocean", which will form the basis of a new initiative “Canada Basin Organics and Microbes” (CBOmics). CBOmics aims to understand microbial metabolism and the transformation of terrestrial dissolved organic matter (tDOM) in the Arctic Ocean. For 2020, we also included in our sampling the McKenzie line, and ice cores. McKenzie river being the major freshwater input of the North American side of the Arctic ocean, it represents an ideal study system for freshwater to marine transition of microbial communities. We will combine multiple meta-omics approaches, used to functionally and taxonomically identify microbial communities, with molecular-level characterization of dissolved organic matter. The aim is to characterize Arctic microbes, including phytoplankton that produce and degrade marine DOM and compare these with the rare set of microbes capable of metabolizing different components of tDOM in the Arctic. The DOM remaining from tDOM transformation would be susceptible to further degradation by more common marine heterotrophic bacteria. Knowledge of these steps is key to predicting aspects of carbon and energy balances in the Arctic needed for the other JOIS collaborators.

Overall, our aim is to provide an Arctic Ocean metagenomic resource that can be used in studies on the genomic and functional diversity of marine microbes. In such studies, it is common practice to use publically available metagenomic data to test hypotheses on the biogeographical distribution of particular taxa (Brown *et al*., 2012) and metabolic pathways (Doxey *et al*., 2015), or to combine these two by exploring population and pangenome structure across environments (Alonzo-Saez *et al*., 2012; Santoro *et al*., 2015). Compared to lower latitudes and coastal regions, there is little metagenomic representation the open Arctic Ocean. Hence the availability of a metagenomic and metaproteiomic datasets from the various watermasses of the Arctic Ocean will also fill an important void in metagenomic coverage of the global oceans. The Arctic samples enable construction of a nonredundant protein sequence database generated from the gene

catalogue for proteomic purposes. This resource will also be invaluable for protein-stable isotope probing (protein-SIP) experiments that the Walsh lab is developing in order to track carbon and nitrogen metabolic flux through marine microbial communities.

4.2.11.2 ***Methodology***

Water column samples were collected at 24 stations to cover a range of previously visited stations (in 2012-2019). In addition, we collected samples for 6 extra stations not included in the original sampling plan: MK6, MK4, MK3, MK2, MK1, CB28aa. Samples were routinely collected at 8 depths per station and include the surface water, 20m, SCM, Pacific Winter Water (salinity of 33.1), Pacific Summer Water (salinity of 32.3), temperature maximum, Atlantic water (1000m) and 100m or 10m from the bottom. For 19 stations (CB31b, CB50, CB40, CB17, PP7, CB15, CB16, ITP1, CB11, CB10, CB8,CB7, CB3, CB2, BL8, StaA, CB27, CB28b, ICE1), we collected 7L of water at two designated bottles for the surface and SCM water layers, and scavenged water from the 6 other water layers. For 6 stations (MK6, MK4, MK3, MK2, MK1, CB28aa) we collected water at the 8 water layers when possbile and at all the available water layers for shallow stations. These samples are designated for DNA extraction. At five stations (ICE2, CB4, CB21, CBB9, AG5) we had a designated cast, with 3 niskin bottles per water layer. At these sites, for each water layer (3 bottle), for the CBOmics collaborative study between the Lovejoy, Walsh, and Guéguen, 14 L were dedicated for DNA and proteins and 14L were dedicated to RNA. All samples were collected for population cell sorting preserved in glyTE buffer (LiveFCM) and microscopy samples (Lugol). Lastly, we collected three ice cores at two different stations (ICE1 and ICE2). Ice cores were metled and processed as regular water samples for DNA.

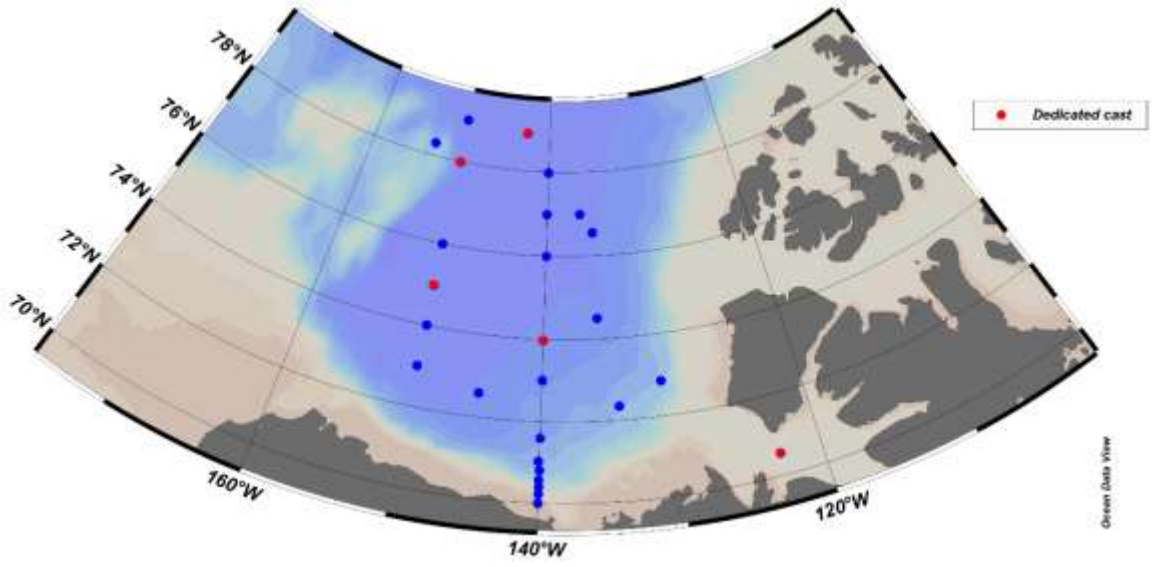


Figure 14. Microbial diversity sample locations. Red dots demonstrate CBOmics stations for DNA/RNA sampling (FICUS project) and black dots demonstrate regular stations.

All sampled depths were selected based on water column characteristics profiled by the downcast of the CTD of the rosette. Nucleic acid (DNA/RNA) was taken for all casts.

4.2.11.2.1 DNA/RNA and protein

DNA/RNA samples from large (>3 µm) and small (0.22 -3 µm) fractions were collected by filtering 4-14 L (typically 7) of seawater at room temperature, first through a 3.0 µm polycarbonate filter, then through a 0.22 µm Sterivex unit (Millipore). Large fraction samples were placed in 2 mL microfuge tubes. Filter samples were immersed in RNAlater solution (Ambio) and left for at least 15 minutes at room temperature before being stored at -80°C. DNA/RNA and protein samples taken at the 4 designated sites were collected by filtering around 14 L of seawater at room temperature preserved in RNAlater as above and stored at -°80.

Once onshore, DNA and RNA material will be simultaneously extracted from the filters as described by Dasilva *et al*. (2014). RNA will be first converted to cDNA before being used for targeted sequencing (Comeau *et al*., 2011). DNA from selected depths and stations will be used to generate metagenomes. The metagenomes will first be compared to each other using a functional gene-centric approach. We will focus on comparing the vertical distribution of functional genes and metabolic pathways involved in energy and carbon metabolism, as well as nitrogen, phosphorous, sulfur, and vitamin acquisition and utilization. These results will lead to genomic insight into ecological specialization and metabolic strategies at the community level. We will then use multivariate analyses to quantify the influence of temperature, hydrology, pH, nutrient concentrations, and the quantity and source of organic carbon on the metabolic diversity and capabilities of microbial communities. We will also aim to assemble microbial eukaryote genomes of abundant small species following the approach of Joli *et al.*, 2017. All metagenomes will be put in an environmental context (Monier *et al.*, 2015). Hence, we expect that an understanding of the relationship between these factors and the metabolic capabilities of associated microbes will provide insights into potential response of microbes to environmental change.

4.2.11.2.2 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

the majority of stations and depths sampled. In summary, 50 mL seawater is fixed in 1% glutaraldehyde (final concentration), filtered onto a 25 mm, 0.8 µm black polycarbonate filter (AMD manufacturing), stained with DAPI (1 mg/ml, final concentration) and mounted on a glass slide with oil. Slides are stored in opaque boxes and kept frozen until analysis in ULaval. Because of a shortage of fliters no slides were made at Station AG5, as an alternative, 225 ml of seawater was preserved in buffered formalin, to preserve silica frustules of diatoms, microscopic cover slips were added (Table 1, Phyto).

4.2.11.2.3 Fluorescent in situ Hybridization (FISH)

Lugol samples were prepared for fixation of protists. Approximately 200 mL of seawater were collected. A solution of Lugol (KI 10% w/v, I_2 5%, acetic acid < 10%) was then added to the seawater. A total of 0.3-1mL of Lugol solution was added per 100 mL of seawater until reaching a light brown color. Samples were then stored at 4^0C in the dark.

4.2.11.2.4 Target metagenomics (LiveFCM)

For potential cell population metagenomics, 1.4 ml of DMSO was added to 13.5 mL of water sample in 15-ml Falcon tubes. Samples were left 10-20 minutes at 4ºC before being stored placed into the -20°C freezer for slow freezing. Cells preserved in this manner will be sorted using a BD Melody Flow cytometer (Ulaval) and used for genetics/genomic studies.

4.2.11.2.5 Bacterial and pico/nanoeukaryote cell count

Cell counts of both prokaryotic (<2 µm) and photosynthetic pico- and nanoeukaryotes (2-10 µm) will also be estimated by flow cytometry. For this 1.8 mL seawater were added to 45 µL of 50% glutaraldehyde in 2 mL cryogenic vials. Samples were first left for several hours at 4ºC then stored at -80°C until transportation to ULaval. Before counting, bacterial nuclear material is stained with a Sybr dye (Life Sciences), while photosynthetic eukaryotic cells are detected by chlorophyll autofluorescence.

4.2.11.3 ***Summary***

A total of 222 depths at 29 stations were collected during this expedition. With more depths and samples, a higher resolution investigation of microbial community partitioning and diversification can be carried out. The details of depths and stations sampled is in the Excel document: “2020_Microbial diversity_DNAl_2020-10-15_Metadata.xsls” (see appendix).

4.2.11.4 ***Comments***

As with JOIS 2015, 2016, 2017, 2018 and 2019 the RNA/DNA group was provided with 2 dedicated bottles primarily for collecting in the SCM and near the surface during full casts and 24 bottles in special casts for the CBOmics sites. For the other stations we collected remaining water in designated bottles from the routine IOS geochemistry casts, which was greatly appreciated. We thank the chief scientist and the IOS team for support and consideration. The ship performed extremely well for sampling and the CCGS crew and officers are professional and excellent.

4.2.11.5 ***References***

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4.3 Moorings and Buoys

Mike Dempsey, Jane Eert, Dave Riedel, Kim Bedard and Sarah Zimmermann (IOS)
P.I.s Andrey Proshutinsky, Rick Krishfield, Isabella LeBras, John Toole (WHOI) and Mary-Louise Timmermans (Yale U) [Mike DeGrandpre (U Montana), see separate report]

Two Ice-Tethered Profiler (ITP) buoys were deployed on ice floes, each with a Seasonal Ice Mass Balance Buoy (SIMB). Four old ice stations were visited and expired buoys recovered. Moorings were not serviced this year.

Table 5. Ice-Based Observatory buoy deployment and recovery summary.

IBO	ITP / Buoy System	Date /Time UTC	Location
1	ITP 121 w/SAMI-CO2, SIMB	20-Sep	77° N 22.4′ N
		04:20	137° 12.0′ W
2	ITP120, SIMB	21-Sep	7 8° 53.9′ N
		~21:00	142° 18.1′ W
Recovery 1	ITP104, AOFB41, WIMBO, Ac.Node	17-Sep	72° 54.1′ N
		~02:11	130° 37.8′ W
Recovery 2	ITP118 w/SAMI-CO2	28-Sep	72° 36.5′ N
		17:10	144° 44.2′ W
Recovery 3	ITP114	29-Sep	73° 50.03′ N
		18:00	140° 12.51′ W
Recovery 4	ITP117 w/SAMI-CO2, TOP-1	30-Sep	71° 17.4′ N
		~23:58	140° 13.6′ W

4.3.1 Moorings

There were no mooring operations this year. The three moorings currently in the water were scheduled to be recovered this trip however due to COVID–related adjustments in the planning for this year's program the recovery and redeployment were postponed until next year. Unfortunately the profilers will not be collecting data for the year.

4.3.2 Buoys

The existing moorings only reach 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, we deployed two Ice-Tethered Profiler buoys (or ITPs), each with a US Army CRREL Seasonal Ice Mass Balance (SIMB) buoy. 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 ice mass balance buoys measure the variations in ice and snow thickness, and obtain surface meteorological data. Most of these data are made available in near-real time on the different project websites (Table 2).

Initiated in fall 2004, the international ITP program over the last 16 years has seen the deployment of nearly 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. 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.

This year, due to COVID precautions, WHOI personnel from the U.S. were restricted from participating aboard the Louis during JOIS in 2020. Because of the important nature of continuous real time data provided by Ice Tethered Profiler (ITP) buoys, steps were taken to train IOS staff in preparation, deployment and recovery of ITPs.
A full seagoing kit with ITP was sent to IOS by WHOI for familiarization and training in August 2020. A SAMI sensor was also sent from University of Montana for training. The equipment was unloaded and the buoy deployment tripod set up in the parking lot outside the arctic electronic workshop at IOS. The staple of 2020 COVID restrictions, ZOOM meetings, were used to connect Jeff O'Brien, Jeff Pietro an Fred Marin at WHOI with the

IOS staff. Mike Dempsey, Jane Eert and Dave Reidel were onsite with hands on while Kim Bedard and Sarah Zimmermann joined in via ZOOM.

4.3.2.1 ***Deployments***

Table 6. Ice-Based Observatory buoy deployment summary.

Site	Profiler	SIMB IMEI	Microcat	SAMI	comments
ITP#1	121	3004334063441910	16512	C180	Microcat has ODO
ITP#2	120	300434063443910			

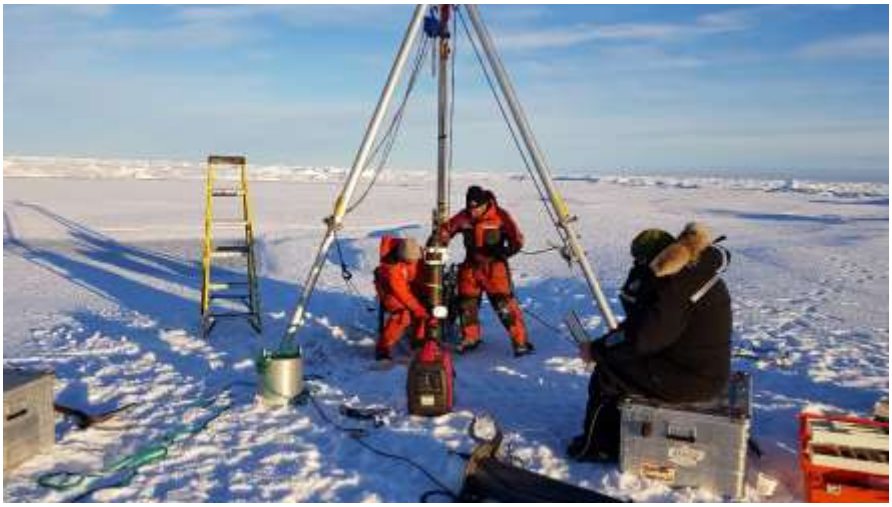
Site	Buoy	Date (UTC)	Time (UTC)	Lat	Long	Ice thickness
ITP#1	ITP 121	20 Sept. 2020	0420	77° N 22.4' N	137° 12.0' W	230 cm
ITP#1	SIMB	20 Sept	0320	77° N 22.4' N	137° 12.0' W	210 cm
ITP#2	ITP 120	21 Sept	1630	7 8° 53.9' N	142° 18.1' W	115 cm
ITP#2	SIMB	21 Sept	1644	7 8° 53.9' N	142° 18.1' W	97 cm

ITP deployment operations on the ice were conducted on site according to procedures described in a WHOI Technical Report 2007-05 (Newhall et al., 2007).

The first deployment, ITP 121 was a higher priority due to the addition of a SAMI and Microcat attached to the mooring. On 19 September, a survey for a good site for the ITP 121 IBO was started. The ice encountered by the ship seemed unsuitable so the helicopter was used to survey ahead of the ship's track. Edmand Fok , Mike Dempsey and Ice Specialist Alexandre Livernoche flew in the helicopter to observe the ice. A suitable site was found and augered near an area identified by RADASAT imagery but was 30 nm ahead of the ship and too far away for deployment. On the way back, the ship radioed that they had found a potentially good site.

The ice pan was surrounded on 2 sides by ridging and measured 50 x 70 m on the flatter portion. 4 x 2" holes were drilled to delineate the floe. The ice was over 2m and a site 2.70 m thick was selected. After lunch, the deployment gear was slung off the ship by the main and starboard bow cranes. The 2.70 m hole was drilled with the 10" Jiffy auger and found to be multilayered and to have false bottom at 2.70 m and actually more than 3 m

thick. 2 other sites were attempted and found to be similar with thick layered ice. Finally, a site 2.30 m thick in more solid ice (one small layer at 30 cm) was accepted.



ITP profiler being lowered through ice

The first ITP deployment went well but was much longer than expected. The ice encountered differed from the test 2" auger holes resulting in several 10" holes being drilled to find the right thickness. One Jiffy power head had clutch/drive issues and could not drill a wet slushy hole > 1 m deep. The ice was not level enough and the 500 lb winch reel was difficult to align with the bearing blocks and winch brake. Also, the logistics in getting all parts on the ice took longer than needed as all operations required the use of the crane. Gear was located in the forward hold and some on the upper decks and due to the ice condition just next to the ship, the gangway could not be used and people were lowered via the man-basket.

The SAMI was mounted 1.60 m below the rubber bumper termination on the wire with the SBE37IM-ODO directly below. In the end, ITP 121 was fully deployed 20 minutes before Dive 0, in ice 2.10 m thick. The final location of the ship nearby was 77 N 22.4' 137W 12.0'. The IBO deployment took almost 8 hours including the drilling of the extra 3 10" holes.

SIMB IMEI 3004334063441910 was deployed by Hayleigh Shannon and Susan McLatchie 10 m from the ITP site.

The second ITP, SN 120, was deployed on 21 September and was a much more-straight forward affair. The ship located a potentially good area before daylight and although a pan was identified for drilling ~0900, the ice floe was deemed too small and the ship steamed farther toward a promising area based on satellite ice imagers. A suitable site was found and surveyed for operations to begin after lunch. The survey showed the pan to be between 97 and 155 cm thick over an area 30 x 60 m. like the first deployment site,

the pan had ridging on 2 sides and some refrozen melt ponds. A site 35 m from the ship was identified in 115 cm of ice. The ice was a single layer and easy to drill.

The ship intentionally positioned itself so the gangway could be lowered, making for faster access to and from the ice. Onboard, the gear was all moved in advance to one central spot near the hanger. On the ice, the assembly of the mooring tripod and winch was less difficult than the previous deployment and a heated system had been devised to keep the communication computer warm enough to function properly. The deployment took just over 3 hours.

A SIMB IMEI 300434063443910 was deployed 25 m away from the ITP by Hayleigh Shannon, Jasmine Wietske and Nina Nemcek. The ice at this site was 97 cm thick. During set up, the Iridium satellite transmission would not initiate. The buoy was moved away from the ship by sled to get a better sky view and the transmission successfully initiated. The buoy was brought back and put into the pre-drilled and measured hole.

Figure 15. Ice Station-1. ITP 121 and SIMB deployment, 19 Sep 2020 (20th Sep UTC).

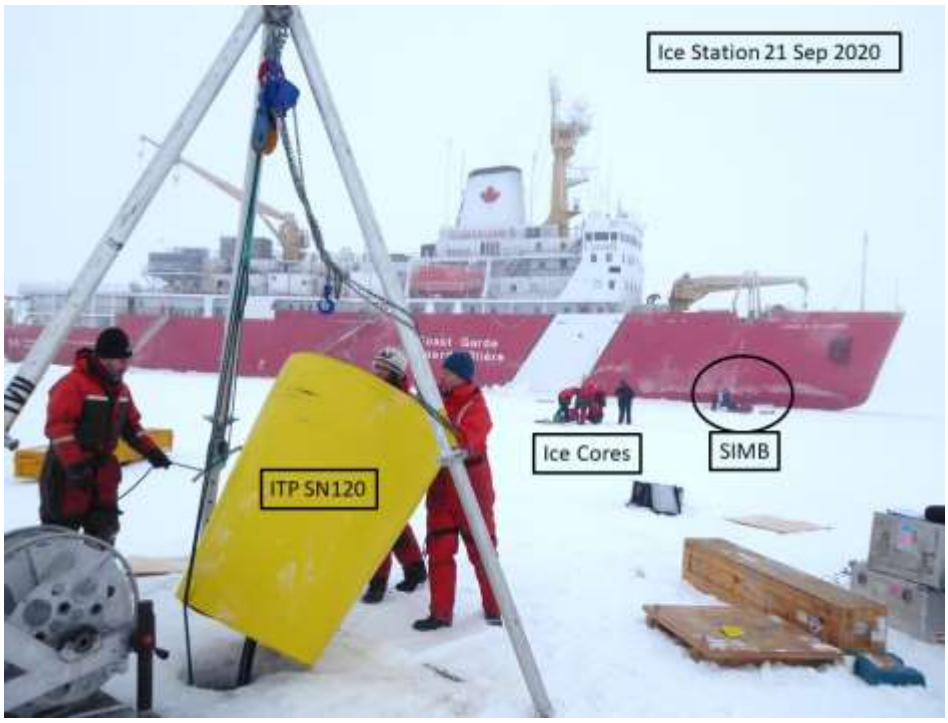


Figure 16. Ice Station-2. . ITP 120 and SIMB deployment, 21 Sep 2020.

Figure 17. SIMB deployed at Ice Station-2, freezing into the ice.

Many thanks go to Jeff O'Brien, Jeff Pietro and Fred Marin of WHOI for the well prepared documentation, training materials and field gear and their ongoing consultation for the successful deployment of the 2 ITPs.

4.3.2.2 ***Buoy Recoveries***

Table 7. Buoy Recovery Summary

Site	Buoy type	Microcat	Microcat	SAMI	comments
Recovery #1	ITP 104	14251	14252		ITP has MAVS sensor
Recovery #1	AOFB 41				Flux sensor, WHS300, Vaisala wind sensor, pyrometer
Recovery #1	WIMBO				CT node, RM Young, camera,
Recovery #1	WHOI acoustic node				camera
Recovery #2	ITP118			C207	SAMI has Aanderaa optode and LiCor PAR sensors
Recovery #3	ITP 114	16506	16507		Surface package only – no profiler
Recovery #4	TOP#1	10175			
Recovery #4	ITP117			C9u	SAMI has Aanderaa optode and LiCor PAR sensors

AOFB 41 in ice prior to recovery

Each year during JOIS, the tracks of deployed ITPs are monitored for potential recoveries. Buoys that are nearing the end of their drift within the Canada Basin or have stopped collecting data are monitored for their proximity to the cruise track. If possible they are picked up. Although ship time was not set aside for these recoveries, the buoys represent a potential capital savings if re-useable, are useful for examination of field performance an also could have ended up on the beach as waste. Recovery of buoys should be considered when possible.

During JOIS 2020, several buoys were identified and a total for 4 sites were practical, meaning close to cruise track during workday hours.

Recovery Site #1

The first site included an ITP (WHOI) deployed in an array with 3 other buoys during the SODA cruise from the Healy in 2018. The array of buoys included an Autonomous Ocean Flux Buoy (AOFB - NPS), Weather, Wave, Ice Mass balance Buoy (WIMBO - UKRI/BAS) and a WHOI acoustic node (WHOI). All buoys were found on a single large pan of ice along with a propane fuel cell power supply (not recovered). ITP 104 was broken out of the ice near 72° 54.1’ N 130° 37.8’ W and recovered through the forward A frame.

Figure 18. Arrangement of mooring line, fairlead and capstan during recovery

The method used for this recovery and all others was similar. The buoy is lifted on the crane and the mooring line stopped off below with a Chicago clamp suspended on a chain from the A frame. The wire is cut above the clamp and the buoy and sensors below lowered to the deck. The end of the wire is fed through the eye of a ship's mooring hawser and made into an eye with 3 5/16" Crosby Bulldog grips. The hawser and mooring line is fed through a deck fairlead block to the port horizontal anchor capstan for bringing the mooring on deck. Wire removed from the side of the capstan is coiled and cut at intervals and moved away for disposal. ITP 104 had a MAVS velocity probe installed as well as two Microcats attached directly under the bumper on the mooring line. The 790 m of wire and 250 lb anchor were recovered.

ITP 104 recovery

AOFB s/n 41 was next broken out. Due to time restraints and difficulty in getting all instrumentation out of the ice, not all the mooring was recovered. The buoy with meteorological array was lifted on deck as well as the Flux sensor package and rack bar and the 300 khz Workhorse monitor below. Due to the length and rigidity of the stiff leg rack for the ADCP, it was bent during recovery. All other pieces were intact. The mooring was cut below the ADCP frame.

WIMBO recovery

Next was the WIMBO. The buoy was broken out and lifted high on the starboard bow crane. The buoy was lifted high enough that the first node was high enough to have blue Kevlar electromechanical line below stopped off. A single node was recovered and the line cut below. Unfortunately, the conductivity sensor on this node was broken after recovery. All sensors on the buoy were recovered intact.

WHOI acoustic node buoy in ice

The last buoy was a Woods Hole Acoustic node. This buoy was still surrounded by ice when it was picked out by the crane. The transducer below was not recovered and the line cut directly below the buoy.

Recovery of the 4 buoys took about 4 ½ hours thanks to the close proximity of the array and excellent ship handling and icebreaking of the LSSL.

Recovery #2
On 28 September, ITP 118 was located near STN-A at 72° 36.5' N 144° 44.2' W. ITP had been deployed with SAMI sensor C207 in 2019 from the LSSL. The buoy was found floating freely in between ice floes. It was pulled up on the crane and the wire fed through the A frame to the port anchor capstan. The whole mooring was recovered intact. Recovery took a little over 3 hours.

Recovery #3
On 29 September, ITP 114 was located near CB21 at 73° 50.03' N 140° 12.51' W. Although the buoy and 2 Microcats were picked up successfully, problems transferring the load to the capstan resulted in the loss of the mooring below. The profiler was not recovered.

Recovery #4
On 30 September, 2 separate buoys were recovered. TOP #1 and ITP 117 were deployed together during JOIS 2019. The TOP buoy is a prototype low cost ITP being tested by Jeff O'Brien of WHOI. It was deployed with ITP 117 as a test run. The TOP buoy, and mooring was recovered intact near 71° 17.4' N 140° 13.6' W. The profiler looked good but has signs of galvanic corrosion around anodized aluminum edges and stainless steel fasteners and sensor mounts. ITP 117 was then recovered intact nearby.

In all 7 buoys and instrumentation were recovered. Lithium batteries were removed and the buoys prepared for transport back to WHOI. Many thanks to Captain Wayne Duffett for his eagerness in providing the ship and his able ship handling skills in ice for these buoy recoveries. Thanks also go to Bos'n Bill Galliott and his deck crew in handling the buoys and long mooring wire on deck. The method used this year could be refined with more specific gear to provide a quick and cost effective way on future cruises to recover oceanographic buoys and reduce the waste produced by ocean research.

4.3.3 Outreach

Dispatches documenting all aspects of the expedition were composed by the science team on board, managed by Birgit Rogalla (UBC) and posted on the WHOI website.

4.4 Underway and Moored pCO2 and pH Measurements

Sarah Zimmermann
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 photoactive radiation (PAR).

The pCO_2, DO and PAR sensors were deployed on the WHOI ice-tethered profiler (ITP), placed on the ITP cable just under the ice. The sensors send their data via satellite using the WHOI ITP interface.

4.4.2 Cruise Objectives

1. Conduct underway pCO_2 measurements to provide data quality assurance for the ITP-based sensors and to map the spatial distribution of pCO_2 in the Beaufort Sea and surrounding margins.

2. SAMI-CO_2 instrument deployment on a WHOI ITP 121 and the recovery of two on ITP 117 and ITP118 are discussed in the buoy report.

4.4.3 Cruise Accomplishments

We collected underway pCO_2 data using an infrared equilibrator-based system (SUPER-CO2, Sunburst Sensors). The instrument was connected to the ship's seawater line manifold located in the main lab. Atmospheric measurements were made from a line

extending from the ship's outside breezeway to the SUPER-CO2 system. The sensor data collection is summarized in Table 1 below.

Table 8. *p*CO_2 sensor data collection summary

Measurement system	Instrument IDs	Location	Duration
Underway infrared-equilibrator *p*CO_2	SUPER (Sunburst Sensors)	Entire cruise track from the Labrador Sea back to the Labrador Sea	8 Sep 2020 to 13 Oct 2020
DIC/Alkalinity samples collected from the seawater loop periodically through the cruise for comparison with sensor			
DIC/Alkalinity taken from top 10cm of 3 ice cores at the ITP 121 w/ SAMI deployment			
DIC/Alkalinity taken from Rosettes at location and depths associated with ITP and Mooring SAMI systems			
SAMI - CO2 systems	See ITP locations table for SAMI-CO2 sensor deployments and recovery locations		

Detailed data collection notes were recorded into a paper logbook, scanned and stored in the Logs folder. Notes were summarized in the file "JOIS2020 LabBook Notes v2020-10-14.xlsx"

4.5 XCTD Profiles

Jane Eert, Sarah Zimmermann

Operators: CTD Watch
PI: Andrey Proshutinsky (WHOI), 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 37 locations along the ship's track between the CTD stations during JOIS, at 3 locations in Baffin Bay. On behalf of IOS, 9 XCTDs were dropped in the southwest Beaufort Sea from the Sir Wilfrid Laurier, and an additional XX (a mix of IOS probes and CHS probes) were deployed in Baffin Bay and the Canadian Arctic Archipelago by the Canadian Hydrographic Service.

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.

Two types of probes were used:

Probe Type	Max Depth (m)	Max Ship Speed (Kts)
XCTD-1	1000	12
XCTD-3	1000	Over 12knt

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)

During JOIS

The GPS connection was reliable with only one early cast in Baffin Bay (C3_00004.EDF) needing correction in the header to its latitude and longitude. Checks

were made between .EDF header locations and position taken from the TSG file based on UTC time. The UTC time in the XCTD file is correct.

There were two repeat drops due to early breakage of the wire, likely due to contact with ice.

> C5_00019.EDF made it to 227m so a second XCTD was dropped (C3_00020.EDF).
>
> C5_00023.EDF only made it to 135m so a second XCTD was dropped (C5_00024.EDF). The second drop made it to 474m which was considered deep enough as it was into the Atlantic Water.

For casts 1-11, there were hiccups with the sequence numbering, so that duplicate sequence numbers were used. Corrections to file names were made as follows:

New file name	Old file name
C3_00005.EDF	C3_00002.EDF
C5_00006.EDF	C5_00004.EDF
C5_00007.EDF	C5_00005.EDF
C3_00009.EDF	C3_00006.EDF
C3_00011.EDF	C5_00003.EDF

As well, cast 11 was made with a probe type of XTD-3 selected in WinMk21, but the actual probe deployed was an XCTD-1. The file name has been changed to reflect the actual probe type in the list above. The data in the file is correct with no changes needed; each XCTD probe provides its depth equation coefficients and C-T coefficients to the acquisition software, so all is good there.

Data were automatically backed up by the WInMK-21 software. For the first 12 casts, the backup location was on the science server, but this was suspected to be the cause of crashes in the software immediately following a cast. Subsequently, the backup location was changed to a USB drive plugged into the acquisition laptop, and Syncback used to keep the server backup up to date.

See Appendix for table of stations.

4.6 Vertical Net Tows

Mike Dempsey, Hayleigh Shannon, Jasmine Wietzke, Kim Bedard, (DFO-IOS)
Birgit Rogalla (University of British Columbia),
P.I.: John Nelson (DFO-IOS),

4.6.1 Sampling

Zooplankton sampling and preservation were conducted on board by Hayleigh Shannon and Birgit Rogalla of the day watch as well as Jasmine Wietzke, and Kim Bedard of the night watch with additional technical support from Mike Dempsey. A standard bongo net system was used with a fitted with a150µm net on both sides. Per John Nelson's request, this is a change from all previous years where one side had a 236um mesh net used for the ethanol sample. 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 19. Hayleigh Shannon deploying the bongo nets on a beautiful day during JOIS 2020

A total of 30 bongo vertical net hauls were completed at 30 stations (see Appendix). The sampling strategy was to perform net hauls whenever time and weather permitted, provided they did not interfere with the rosette operation or require additional ship time. At each station where net hauls were performed a single 100m bongo vertical net haul was completed. A total of two samples were collected at each station one from each side of the bongo net.

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

The bongo was fitted with two 150µm mesh nets. One side of the bongo was labeled E with TSK serial number 7085 and the other side was labeled F with TSK serial number 7303. For consistency samples collected from the net marked E was preserved in 95% ethanol and samples collected from the net marked F were preserved using formalin with final sample concentration 3.7% formaldehyde. 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 remained in PST during the duration of all zooplankton stations.

Zooplankton casts were only performed if wind was less than 15knt and temperatures were above -10C.

4.6.2 Issues and solutions

One broken 50’ electrical hose – melted termination end of electrical cord
One 236um cod end- mesh needs mending (broken from previous year)

The counter on the foredeck winch was unreliable during cold weather due to freezing the internal parts. There were two casts, NET#5 at CB51S and NET#9 at CB17, where the winch counter broke and speed was approximated while a timer was set for 200s. Both times the cast only went to about half target depth.. The spare winch counter was swapped in and checked before station to dislodge any ice.

The hydraulic oil on the winch started freezing causing the winch to stop for a few seconds in the middle of up cast in high gear during net#15. This was fixed by turning the hydraulic oil heater on in the forward science shack about 30 minutes prior to cast at all stations. When the weather was -10C we were given permission to leave the oil on through the day. This seemed to affect high gear worse than low.

Some stations with loose flowing ice were challenging for the bridge to maintain an ice free pond for both the bongo and CTD at the same time. This was especially true at Net#12 at CB16 where the bubblers had to be put on full force just as the nets were hauling through the top 10m. At a similarly challenging stations net#32, the net was held at the bottom for extra time while the bubblers pushed back ice then the haul was resumed right after the bubblers turned off. This is preferable way to manage fast ice.

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.

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.

The wooden box used to house the bongo nets should be replaced with an aluminum 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.

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

The nets were set up from last year with the weight higher than usual on the central rope. (probably to make handling the weight easier). This was incorrect set up and allowed the nets to fly in the wind and get tangled. This was corrected to standard set up and made a big difference in net handling and allowed the cod ends to fall correctly on the line.

Most of the MK line could not be sampled due to poor weather conditions, strong winds and swells.

4.7 Underway surface sea-water measurements

Sarah Zimmermann (DFO-IOS), Celine Gueguen, Nicolas Sylvestre (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 Seabird SBE21 thermosalinograph, Chl-a fluorometer and CDOM fluorometer, a new for 2020 different style of Wetlabs FDOM fluorometer, and a pCO2 system.

Measurements were made for:

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

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

4.8 Underway data logging using SCS

Jane Eert (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. Heading from the ship's Gyro ($HEHDT)
4. Sounder depth and the applied ship's draft and sound speed
5. Surface Photosynthetically Active Radiation (PAR)
6. Thermosalinograph (TSG), and the inlet sea surface temperature from the SBE38 that is also given in the TSG data stream.
7. Data from the FDOM fluorometer in the seawater loop (FDOM)
8. Derived true wind speed calculated in SCS

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

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.

4.9 Ice Observations – Bridge Watch

Bridge Observations: Jonathan Delisle and Alexandre Livernoche (CIS Ice Specialists),
Bridge Web Cameras: Edmand Fok (DFO-IOS), Jane Eert (DFO-IOS), Mike Dempsey (DFO-IOS)
P.I.: Kazu Tateyama (P.I.), 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 consequences of COVID restrictions.

4.9.1 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. This year, Canadian Ice Service (CIS) Ice Specialists, Jonathan Delisle and Alexandre Livernoche, graciously agreed to make sea-ice and weather observations following the ASSIST observation protocol as time allowed from their other duties. Their reports and observations are in the data folder.
They followed the ASSIST observation protocol. ASSIST is based upon ASPECT (Worby & Alison 1999) bridge observation protocol, with additional information to characterize Arctic sea ice. Additional observables included melt pond characteristics, sediment on ice and an additional ice type – second year ice.
It is hoped the results of the two different ice measurement methods, the ASSIST program and the CIS graphic log, will compare favourably and may allow just one set of observations to be used in the future.

4.9.2 WebCams

Network camera (Netcam) imagery has been collected since 2007. In previous years, two Netcams were installed above the bridge on “monkey island”. One camera was mounted on the port-side rail looking down to where the ice rolls on edge after contact with the ship to measure ice thickness. The other camera was mounted on the forward rail, looking forward to measure ice concentration.

This year only the Port-side Netcam was installed above the bridge. Because the cable to the forward looking Netcam was not working (from 2019), 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. Both the downward looking Netcam and forward facing GoPro recorded images every minute. The downward looking Netcam imagery was saved in real-time onto the ScienceNet server and the GoPro camera

memory card was downloaded as needed (~5days). The quality of the GoPro image is superior to the downward looking camera. This is also reflected in the filesize.

Operation notes and considerations for 2021

Net Camera

Ice camera only communicates up to 10 mb, and the lowest rate on ship's network port is 100 mb. To solve the problem, a router/switch is used to bridge the differences. In 2020, a gigabit router was used to connect between network port 22 and ice camera in ice picks room. Ship always configures this port as a gigabit port., we ask onboard tech to downgrade it to 100 mb. Since the price of gigabit router/switch is a lot cheaper now, a gigabit router was used and no downgrade is required.

Mike Dempsey felt that the original housing (most rusty one on left, which stayed on the rail is not safe, he sets up another housing for Port cam besides the original one. At end of the trip, both housing were taken off the rail. The one on the left will be taken back to IOS for refurbish and Mike will suggest a new way to secure the ice cam on port side. To protect housing for erosion, housing should be taken down after use.

Figure 20. The downward looking Netcam was in the housing on the right. The housing on the left was rusted into a fixed position, not pointing in the desired direction. Both housings removed after the cruise.

GoPro Camera

Typically the camera collected data every minute, however during the ITP SN104 recovery on Sep 16th the collection speed was increased to capture deck operations. There are a few gaps in data collection and some issues with file's "modified" time differing from the file date. These are being reviewed and an explanatory note will exist with the data files. Filenames appear to be consecutive in time order starting Sep 16th at 2223 and modified time matches file date.

4.10 Ice Observations – Ice Thickness from suspended EM sensor

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

The EM was not used this year. With the restriction on personnel joining this year there was no EM operator.

4.11 Ice Observation – Measurements On Ice

Nicolas Sylvestre (Sherbrooke), Thomas Grevesse (Concordia),
P.I.: Jennifer Hutchings (OSU), Kazu Tateyama (KIT), Thomas Grevesse (Concordia),

In previous years, cores, transects and snow pits to characterize the sea-ice floe were taken at the ice stations where WHOI's buoys were deployed. Instead this year a limited program of ice cores only were collected at the two buoy ice stations.

4.11.1 Overview of ice stations

Ice Station 1
Coring: Nicolas Sylvestre, Thomas Grevesse
Coordinates: 77°22.320 N / 137°9.675W
Date: Sep 19, 2020

Ice was accessed from man-basket off the starboard side. A transect was set following the path to the ITP deployment site as shown in Fig.1. Ice cores were collected at six sites (every 10-15 m) along the transect line. Not all ice cores were full ice depth.

Ice Station 2
Coring: Nicolas Sylvestre, Thomas Grevesse,
Coordinates: 78°53.9 N / 142°18.9 W
Date: Sep 21, 2020

Ice was accessed from gangway off the starboard side. A 50m-long transect was established as shown in Fig.2. Ice cores were collected at four sites (every ~10 m) along the transect line. Not all ice cores were full ice depth.

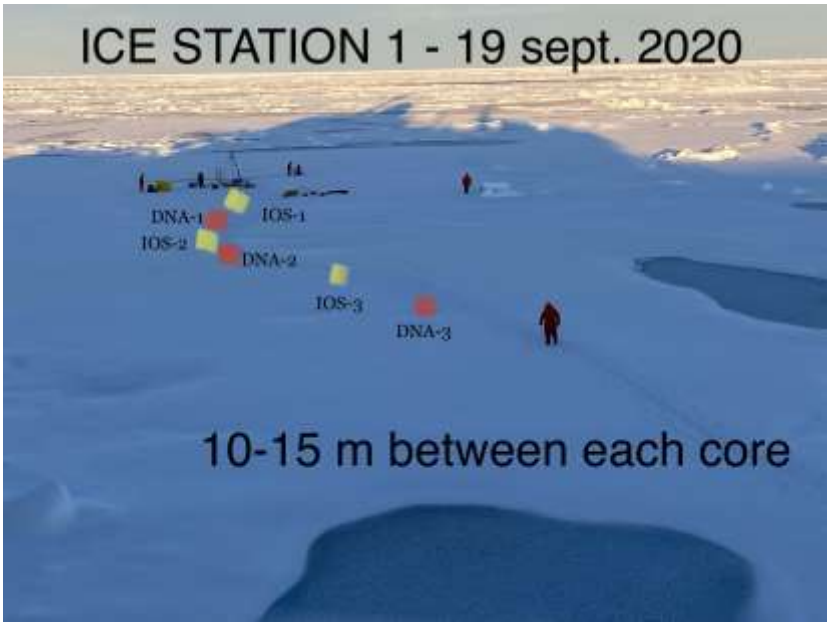


Figure 1. Schematic of transect on ice station 1.
The 6 Ice cores were taken every 10-15 m following the path from the man-basket landing site to the ITP deployment site. Picture is taken from the ship's starboard side main deck.

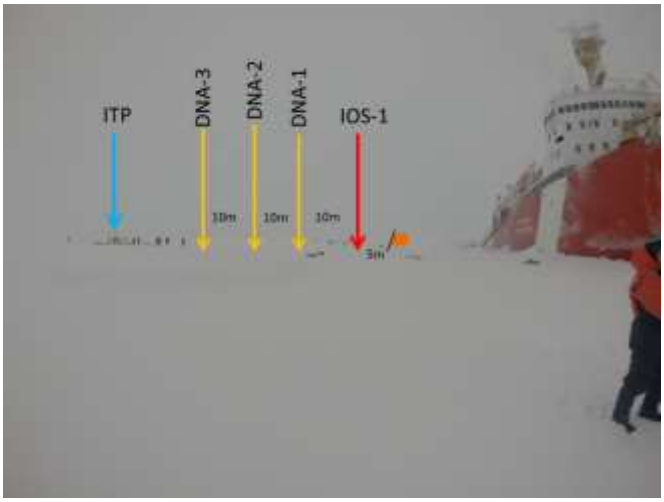


Figure 2. Schematic of transect on ice station 2.
The 4 Ice cores were taken every 5-10 m following the path from the site to the ITP deployment site. Picture is taken from the ice.

4.11.2 Ice Cores

Table 1 shows the summary of collected ice core samples. A total of 3 DIC/Alk sample cores, 1 physics core and 6 DNA cores were taken at the two ice stations. We could not drill through the whole ice thickness for ice station 1 and the core represent the top of the ice layer. For ice station 2 we were able to drill through the whole ice layer and reach the water surface. Ice cores are therefore representative of the whole ice layer.

Table 1: summary of collected ice core samples

Ice Station	Site	Approximate Distance along transect [m]	Length [cm]	Purpose	PI
1: Cores are NOT full ice thickness	IOS-1	0	88	DIC/Alk	Bill Williams/Michael DeGrandpre
	DNA-1	12.5	140	DNA	David Walsh
	IOS-2	25	52	DIC/Alk	Bill Williams/Michael DeGrandpre
	DNA-2	37.5	165	DNA	David Walsh
	IOS-3	50	~107	DIC/Alk	Bill Williams/Michael DeGrandpre
	DNA-3	62.5	170	DNA	David Walsh
2: Cores ARE full ice thickness	IOS-1	0	~110	Temperature and SALTS (Physics)	Bill Williams
	DNA-1	10	110	DNA	David Walsh
	DNA-2	20	105	DNA	David Walsh
	DNA-3	30	100	DNA	David Walsh

In the photos below, the top (in air) end of the core is lined up with the 0cm mark in the black cradle. The 0cm mark starts at the very end of the cradle. In some of the pictures the 0cm mark is on the left, in some it is on the right.

ICE STATION 1

Station 1-IOS1

Ice core photo

Station 1-DNA1

Ice core photo

Station 1-IOS2

Ice core photo

Station 1-DNA2

Ice core photo

Station 1-IOS3

Ice core photo

Station 1-DNA3

Ice core photo

ICE STATION 2

Station 2-IOS1 **Temperature and Salinity profile on this core**

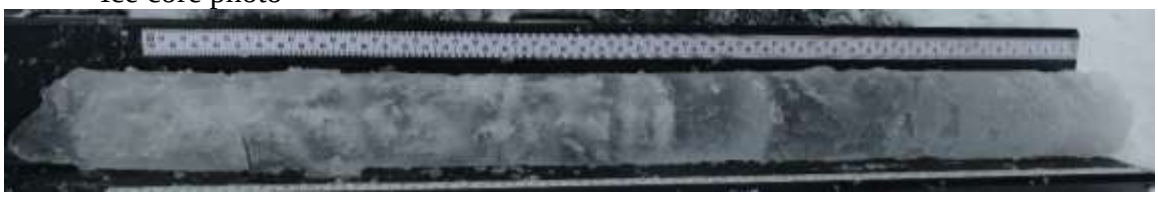
Ice core photo

Station 2-DNA1

Ice core photo

Station 2-DNA2

Ice core photo



Station 2-DNA3

Ice core photo

Temperature and Salinity Profiles

Temperature and salinity profiles were measured for core IOS-1 at Ice station 2. A hole was drilled at 5 cm from the top of the core, and then holes drilled every 10 cm (at 15cm, 25cm, etc). Temperature in the core was measured following hole drilling. The core was then cut in eleven (11) 10 cm sections and stored at -20^{o}C until used.

Salinity was measured after melting cores. Core section were put into Ziploc bags, melted, though during melting process leaks were detected and the ziplocs placed inside new ziplocs. The salinity of the double bagged melted water was measured using a YSI 30-10ft meter (SN: 08E 100275) and Greisigner temperature probe. The salinity meter was calibrated and tested against known salinity (deep reference water of 34.96, and water from the seawater loop 24.4PSU measured at the start and end of session). For further verification the 40 to 50cm section was measured on the autosalinometer which was in agreement with 4.4 PSU.

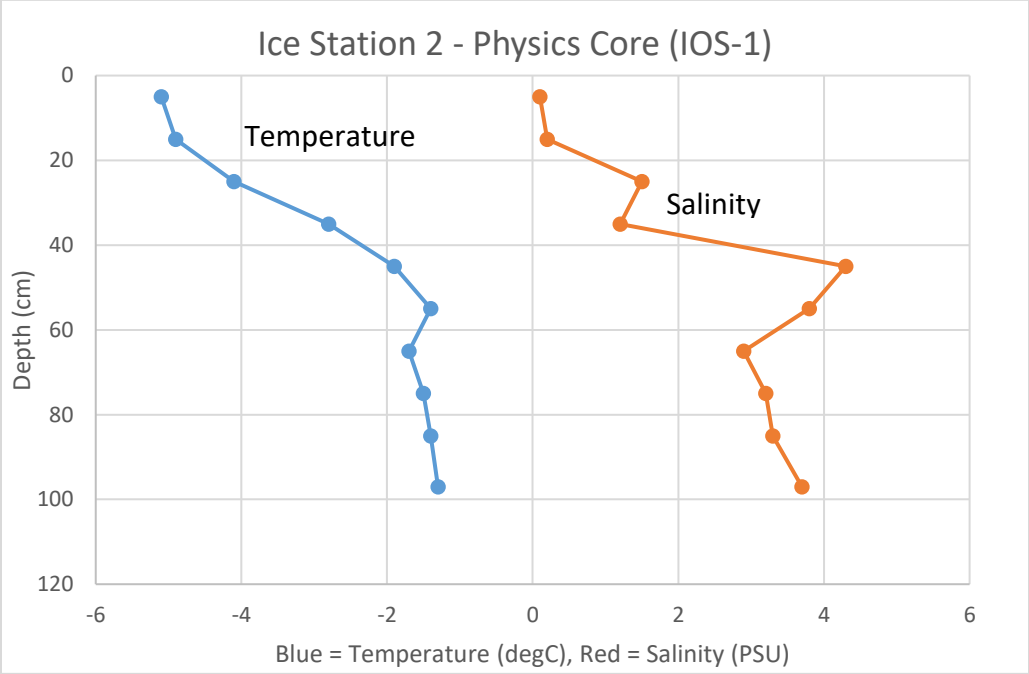
Volume for each core was measured in using a 500mL graduated cylinder with all samples at room temperature of 20C. This has been used for ice (solid form) density calculation however the exact core segment size were not recorded after the initial 10cm cuts were made.

Temperature, salinity and melted volume profile data are given in the table below.

Table 9. Properties of core IOS-1 at Ice Station 2

Distance from top of core (cm)	Temperature (^{o}C)	Core Segment for S and V (cm)	Salinity (PSU)	Volume at 20C (mL)
5	**-5.1**	**0 to 10**	**0.1**	**495**
15	**-4.9**	**10 to 20**	**0.2**	**635**
25	**-4.1**	**20 to 30**	**1.5**	**520**
35	**-2.8**	**30 to 40**	**1.2**	**605**
45	**-1.9**	**40 to 50**	**4.3**	**480**
55	**-1.4**	**50 to 60**	**3.8**	**440**
65	**-1.7**	**60 to 70**	**2.9**	**515**
75	**-1.5**	**70 to 80**	**3.2**	**520**
85	**-1.4**	**80 to 90**	**3.3**	**495**
95	**-1.3**	**90 to 105**	**3.7**	**510**

105 (end)	**-1.4**			



4.11.3 References

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

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

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

Figure 21. Cake creation by Blair Walsh and Mike Goodwin. Photo by Darcy McCabe

5. APPENDIX

5.1 SCIENCE PARTICIPANTS 2020-79

Table 10. Onboard Science Participants for 2020-79

Name	Affiliation	Role
Sarah Zimmermann	DFO-IOS	Chief Scientist
Sarah-Ann Quesnel	DFO-IOS	Nutrient Analyst, lab supervisor
Nina Nemcek	DFO-IOS	Oxygen Analyst
Jane Eert	DFO-IOS	Watchleader, ITP Deployment, IT
Mike Dempsey	DFO-IOS	Watchleader, ITP Deployment, Tech
Edmand Fok	DFO-IOS	Watchstander, IT
Jasmine Wietzke	DFO-IOS	Watchstander, Salinity Analysis
Kim Bedard	DFO-IOS	Watchstander, Salinity Analysis
Dave Riedel	DFO-IOS	Watchstander, Salinity Analysis
Hayleigh Rados	DFO-IOS	Watchstander, Salinity Analysis
Celine Gueguen	USherbrooke	Watchstander, FDOM
Nicolas Sylvestre	USherbrooke	Watchstander, FDOM
Birgit Rogalla	UBC	Watchstander, Salinity Analysis

Thomas Grevesse	Concordia	Microbial Community
Susan McLatchie	Concordia	Microbial Community

Table 11. Principal Investigators Onshore for 2020-79

Name	Affiliation	Program
Bill Williams	DFO-IOS	Program lead / CTD / Rosette
Andrey Proshutinsky	WHOI	Moorings and ITP program lead / CTD/Rosette / XCTD
Richard Krishfield	WHOI	Moorings and ITP / CTD / Rosette / XCTD
Isabela Le Bras	WHOI	Moorings and ITP / CTD / Rosette / XCTD
Mike DeGrandpre	U Montana	pCO2, pH, Underway system, Buoy, Mooring
Mary-Louise Timmermans	YaleU	Moorings / ITP buoys
John Toole	WHOI	ITP Buoys
Don Perovich	CRREL	Ice Mass-Balance Buoy
Motoyo Itoh	JAMSTEC	CTD/Rosette / XCTD
Shigeto Nishino	JAMSTEC	CTD/Rosette
Takashi Kikuchi	JAMSTEC	CTD/Rosette
Michiyo Yamamoto-Kawai	TUMSAT	CTD / Rosette / Alkalinity
Connie Lovejoy	ULaval	CTD/Rosette / Microbial Diversity
David Walsh	ConcordiaU	CTD/Rosette / Microbial Diversity
John Nelson	DFO-IOS/UVic	Zooplankton
John Smith	DFO-BIO	CTD / Rosette / ^{129}I / ^{134}Cs
Nuria Casacuberta	ETH Zurish	CTD / Rosette / ^{129}I / ^{134}Cs
Jennifer Hutchings	OSU	Ice Observations
Kazutaka Tateyama	KIT	Ice Observations

Table 12. Affiliation Abbreviations.

Abbreviation	Definition
APL	Applied Physics Laboratory, University of Washington, Seattle, Washington, USA
BIO	Bedford Institute of Oceanography, DFO, Dartmouth, NS, Canada
CRREL	Cold Regions Research Laboratory, New Hampshire, USA
DFO	Department of Fisheries and Oceans, Canada
ETH Zurich	ETH Zurich, Switzerland
IOS	Institute of Ocean Sciences, DFO, Sidney, BC, Canada
JAMSTEC	Japan Agency for Marine-Earth Science Technology, Japan
KIT	Kitami Institute of Technology, Kitami, Hokkaido Prefecture, Japan

NPS	Naval Postgraduate School, Monterey, California, USA
OSU	Oregon State University, Oregon, USA
TUMSAT	Tokyo University of Marine Science and Technology, Tokyo, Japan
UBC	University of British-Columbia, Vancouver, BC, Canada
ULaval	University of Laval, Quebec City, Quebec, Canada
UMontana	University of Montana, Missoula, Montana, USA
USherbrooke	University of Sherbrooke, Quebec, Canada
UVic	University of Victoria, Victoria, British Columbia, Canada
WHOI	Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
YaleU	Yale University, New Haven, Connecticut, USA

Table 13. Project websites

Project	**Website Address**
Beaufort Gyre Observing System	www.whoi.edu/beaufortgyre
Beaufort Gyre Observing System dispatches (2020)	https://www.whoi.edu/page.do?pid=166776
Ice-Tethered Profiler buoys	www.whoi.edu/itp
Ice Mass Balance buoys	http://imb-crrel-dartmouth.org/

5.2 LOCATION OF SCIENCE STATIONS

The scientific crew boarded the *CCGS Louis S. St-Laurent* icebreaker in St. John's, NF, on 3 September 2020 and returned to St. John's, NF on 15 October 2020. Locations of CTD/Rosette, XCTD, zooplankton vertical net and any other over-the-side casts, as well as the mooring and buoy recovery and deployments are listed in the tables below.

5.2.1 CTD/Rosette

Table 14. CTD/Rosette cast locations for 2020-79

Cast #	Station	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Cast Depth (m)	Sample Numbers	Comments
1	LABSEA test	2020-09-07 17:55	56.3730	58.2910	294	278	1-24	Bot 1 - 10 L carboy salts Bot 2 - OT- duplicate bad curve Bot 13 - leaking bottle Bot 18 - OT duplicate
2	AG5	2020-09-15 00:08	70.5568	122.9342	658	639	1-24	very slow spigot drip on bot. 23 AG5 ROS2: noisy CDOM FLOUR 1076, Flouroto 4305 swapped in, con file for Ros2 had 4305 in process with 1076. For second AG5 cast, con file 2020-79-0001.xmlcon is correct
3	AG5	2020-09-15 02:31	70.5530	122.9648	650	638	25-44	no FDOM sample
4	CB1	2020-09-15 20:29	71.7797	131.8520	1115	1107	45-68	Bot 1 - trip Oxygen 832 -0.3. Bot 8 - delay bt Alk I & MnCl2 pickling on DO. Bot 15 - oxy dup removed. Bot 17 - do not sample dup bot 17 First use of ice chummy, air temp -6C, Stopped for its deployment at 744m on downcast so as to avoid a long stop near the bottom. Stop at 932m u\on upcast to adjust tethers. Removed at 60m on upcast
5	CB31b	2020-09-16 04:57	72.3467	134.0230	2065	2054	69-92	Ice chummy off at 60 m. Bot 9 - DIC may half pickle. Bot 11 - DIC may half pickle. DIC samples bottle 24 not taken, bottles were not labelled and samples missed. FDOM Fluorometer switched to 4305 before cast, same cable as Ros4. Position changed to under bottle 12

6	CB23a	2020-09-16 12:10	72.8993	136.0008	1960	2737	93-116	Ice chummy on at bottom, off at 60. Bottle 4 tripped at 1500 db. New con file used C:\2020-79\Raw\2020-79-0006-swap.XMLCON. Check PAR coefficient
7	CB51S	2020-09-17 02:51	72.8612	130.6255	1827	1813	117-138	Bot 1 - Alk I junky (HS). Skipped two oxygen flasks stuck stopper. Note: some labels say ROS6 but should be ROS7. Note: labelling error caused multiple movement of duplicates. Sampling as done saved as label file CB515.sav, CB515_corr just has extra labels needed to fix the problem.
8	CB50	2020-09-17 12:24	73.5010	134.2530	2875	2876	139-162	Bot 19 - yoyo Bot 23 - yoyo
9	CB40	2020-09-17 19:43	74.4980	135.4095	3254	3240	163-186	Bot1 - redraw duplicate oxygen, delay due to pickling dispenser. Bot 2- duplicate DO; bubble in 1st sample; missed firing at 2000 m --> 1663 instead). SPAR signal abrupt change at 750 m on downcast from ~1800 --> ~400 (went into shade?). Serial PAR also not acquiring. Restarted, looks OK, agrees w/ spar. Chl/PAR seasave display full of spikes every time a bottle is fired.
10	CB18	2020-09-18 04:25	75.0145	140.0422	3630	3620	189-212	
11	CB17	2020-09-18 12:27	75.9967	139.9925	3702	3685	213-236	Put ice chummy on at bottom.
12	PP7	2020-09-18 23:19	76.5542	135.4893	3574	3564	237-260	Bot 8 - I129 "400" though will be closer to 500. Bot 21 - redraw on DO (bubble, then pickling error on DO). Bot 22 - redraw on DO (pickling chem issue) Lost GPS just as cast was starting. Started acq. With 2020-79-0012.hex with no nmea in con file. During soak @ 10 m, restarted GPS feed on server by closing and opening con1 in GPSGate. Restarted Seasave acq. With file 2020-79-0012a.hex – data starts at end of 10 m soak just before coming up to surface. NMEA is ok in this 12a file. Altimeter kicked in at 92 m!
13	ICE1	2020-09-19 10:05	77.0010	136.7008	3656	3641	261-284	Bottom – ice chummy on. Bot 10 – took extra DIC and O18. 44 m – ice chummy off. stop at 3235 because nema display not updating, after stops it seems OK. Resume downcast at 11.15. Mike said that if "zoom" in and out of windows causes this behaviour. But it actually logs info, as long as GPS feed is working.
14	ICE1B	2020-09-20 05:31	77.3657	137.2693	3668	1001	285-298	
15	CB15	2020-09-20 13:14	76.9945	140.0733	3730	3717	299-322	Bottom - Ice chummy, bottle 7 fire but not triggered. Ice build up on block on first 1100 m, bouncing block. Caused by ice

								built up on cable from last cast (no chummy used). After 1100 m it is normal.
16	CB16	2020-09-21 02:06	77.9785	140.0557	3755	3745	323-346	in pond. Yo yo on 19/20 & 23/24. Winch display stuck - showed *ack message instead of CTD ops message and did not update, 23 m off bottom. Fixed by pressing RESET button. Display on CTD PC was normal throughout.
17	Ice2	2020-09-22 01:21	78.8893	142.7240	3798	1002	347-370	new ice. Bot 4- redrawn b/c of bubble. Bot 6-redrawn b/c of bubble.
18	Ice2	2020-09-22 03:44	78.8860	142.7492	3798	3785	371-394	Bot 5 - spigot pushed in. Bot 23 - pause to remove chummy. Bot 11-21 triggered based on pressure not depth. Swapped out rinko SN9 to Rinko 323 (pre-cast)
19	CB11	2020-09-22 17:09	79.0007	150.0628	3828	3806	395-418	Ice chummy on at bottom. Changed Knudsen SSp to 1474 so sounder depth agrees with rosette.
20	CB10	2020-09-23 00:36	78.2957	153.1878	2700	2651	419-442	Bot 1 - top cap needed reseating. Bot 15 - redraw DO, 855, -1.0 6.310. Bot 20 - very low end O2 vs 1st dup. Bot 24 - not enough water left for I129. Tmax taken at 440 but another sharper Tmax at 490. just above 500m bottle - moved 500m bottle to 490m. Drifted SE, deeper during cast Altimeter never kicked in. Stopp 20m above 'best' sounder depths. Sounder was flipping between 2670 &2790m. Con file is the one for Ros17 - may have wrong rinko in it
21	CB9	2020-09-23 06:00	77.9870	149.9910	3788	1003	9433-9442, 443-456	Ice chummy on at bottom, removed at bot 18. Bot 21 - changed to single chlorophyll so enough water for I129.
22	CB9	2020-09-23 08:16	77.9885	149.9907	3822	3810	457-480	Ice chummy on at bottom. Bot 1 - stopped at 3691 and yoyo to trigger. Bot 4-16: DIC double dose of HgCl2. Bot 20 - titration issue, value lost.
23	CB12	2020-09-23 14:50	77.7028	146.8067	3808	3802	481-504	Ice chummy on at bottom. Bot 15 - change DIC dup to Niskin 16 #496. Bot 20 - change Chl dup to Niskin 19 #499.
24	CB13	2020-09-23 23:47	77.2587	143.3965	3780	3773	505-528	In a pond. Bot 8 & 20 --- add I129/U for missed sample on CB16 due to niskin fail. Bot 13: note bottle order.
25	CB8	2020-09-24 10:02	77.0023	149.9347	3826	3814	529-552	Bot 4 trigger sticky, triggered but hung up. Bot 18 tangled lanyard at bottom, no sample. removed trigger after cast and cleaned in soapy water Put ice chummy on at bottom, remove at 56 m.
26	CB7	2020-09-24 17:14	75.9973	150.0220	3832	3818	553-576	Thin ice. Bot 12 - second check not done. Ice chummy on at bottom.
27	CB5	2020-09-25 00:44	75.2973	153.3133	3843	3830	577-600	Styrofoam cup cast! Pancake ice everywhere.

28	CB4	2020-09-25 08:15	74.9890	150.0490	3828	1004	601-624	Ice chummy on at 1000.
29	CB4	2020-09-25 10:18	74.9908	150.0342	3827	3816	625-648	Ice chummy on at bottom, off at 40. Bot 4 - lanyard got caught. Bot 5 - Lanyard got caught. Bot 3 - no duplicate nutrients (no frozen sample).
30	CB6	2020-09-25 18:14	74.6840	146.6713	3782	3769	649-672	Missed 100 m off bottom. See daily log --- CTD stopped communicating. Bot 6 - tripped early at 900 m. Bot 10 - 1st dose HgCl2 did not seem to dispense fully, added 2nd. Chummy on. 1441 m on upcast --- lost communications with rosette. Deck unit still shows 111. Cancel acquisition. Cycle power on deck unit, now 0.000 in ward B. No alarms. Swapped deck units --- ok. Failed unit is s/n 0997. Now using 0649. Turned out to be a blown sea cable fuse. 4 bottles fired on file 2020-79_0030.hex, rest on 2020-79_0030a.hex
31	CB3	2020-09-26 05:12	74.0128	149.9268	3823	3812	673-696	Ice chummy off at 66 m, then yoyo
32	CB2	2020-09-26 15:50	73.0018	150.0193	3760	3739	697-720	Thermometer may not work from 1 to ??. Use new thermometer from here. Bot 16 - vent not closed properly, dripping. Sounder problem finding bottom
33	CB2a	2020-09-26 21:14	72.5137	150.0075	37	3715	721-744	NMEA data in Seasave froze @2227-2234. Took Seasave display of NMEA off, closed/opened GPSGate feed, redisplayed NMEA in Seasave --> ok. IMS display went strange at 3000 m on upcast - winch display was frozen, PC display showed only cable out and part of CTD data line. Shut down IMS on PC, cycled power on winch display, restarted IMS normally. Ok.
34	BL8	2020-09-27 03:01	71.9527	150.2935	3012	2958	745-768	Sound speed changed because gives wrong depth.
35	BL4	2020-09-27 08:05	71.5228	151.5805	967	1118	769-789	Fire order: 1-22,13,17,19,14,15,16,18,20,21
36	BL1	2020-09-27 10:22	71.3625	152.0820	75	69	790-797	Gloves were extra soapy
37	BL2	2020-09-27 11:15	71.3945	151.9527	162	153	798-808	
38	BL3	2020-09-27 12:24	71.4648	151.8272	486	481	809-826	Fire order: 1-12, 14,13, 15, 16,17, 18
39	BL5	2020-09-27 14:06	71.5947	151.3642	1580	1568		No bottles
40	BL6	2020-09-27 16:01	71.6798	151.1400	2072	2071	827-849	Fire order: 1-7, 9, 8, 10 -18, 20, 19, 22, 21, 23. Bot 2 - 859 redraw dup B -0.5. Bot 8 - did not trip.
41	BL7	2020-09-27 18:43	71.8202	150.7678	2548	2543		No bottles. Forgot pump, redo top 95 m. S, R PAR cleaned during cast.

42	Stn A	2020-09-28 12:34	72.5910	144.8945	3433	3419	850-873	Duplicate of chlorophyll on bot 18 & 24 removed to leave water for I/Ur
43	CB-19S	2020-09-29 02:26	73.8273	143.4847	36	3669	874-897	Bot 2 - deep water reference for salinity analysis. Bot 21 - 2 HgCl2 in DIC PC IMS window showed only 2 lines - winch operators display was frozen. Turned winch display of/on - fixed problem
44	CB21	2020-09-29 11:19	73.9795	140.0312	3510	1003	898-921	Bot 16 - DIC got double HgCl2.
45	CB21	2020-09-29 13:20	73.9758	140.0548	3510	3488	922-945	Bot 4 - tripped at 3394 m. Bot 5 - DIC double HgCl2.
46	CB22	2020-09-29 21:08	73.4525	138.0053	3135	3114	946-969	Labels say Ros 43 instead of Ros 46, bottle 2 - no water, bottom lanyard hung on bottle 1's cap. New label comments: hard to peel off with gloves on. Kinda big, printing fades when abrated, ink runs less than Brady/inkjet Cup cast. 2 Leaky bottles. Before cast, transmissometer cable connectors cleaned. Connection to transmissometer was a little "dirty" otherwise fine. Transmissometer has been a bit more jumpy from BL casts onward (SZ). Test new Avery labels. @1376m the IMS display froze; restart worked
47	CB27	2020-09-30 02:37	73.0002	139.9990	3213	3202	970-993	O18 on Bot 18 not filled (found on clean up)
48	CB29	2020-09-30 12:07	71.9965	139.9987	2689	2666	994-1017	Bot 10 - Extra HgCl2 squirt in DIC
49	MK6	2020-09-30 16:58	71.5967	140.0105	2513	2491	1018-1041	Bot 11 - Extra HgCl2 squirt in DIC
50	ITP117	2020-09-30 22:37	71.2897	140.2270	2350	32	1042-1045	Short cast to calibrate SAMI on ITP117
51	CB28b	2020-10-01 02:16	71.0302	140.0933	2124	2103	1046-1069	
52	MK4	2020-10-01 06:15	70.8160	139.9938	1651	1568	1070-1093	
53	MK3	2020-10-01 09:19	70.5753	140.0287	807	778	1094-1117	Bot 2 - did not close; lanyard snagged - closed at surface. Bot 4 - used 2x2L bottles for I-U Bot 21 - tripped at 20 (same as bot 22), instead of 30, therefore not sampled
54	MK2	2020-10-01 11:55	70.4028	140.0012	517	492	1118-1141	Bot 1 - 2x2L bottles for I/U sample Bot 6 - Used reused I/U cap
55	MK1	2020-10-01 14:25	70.2268	140.0040	230	212	1142-1165	Three bottles fired at Bot-10 - Check with Edmand. Double dic squirts on Bot 1, 3 and 10.
56	CB28aa	2020-10-01 17:11	70.0020	140.0035	58	52	1166-1175	Oxy 884 -1.2C redraw on 1st duplicate. Bot 3 - not sampled as same as Bot 1 (1166).

57	9BEL9	2020-10-06 13:06	71.9618	95.1968	332	323	1176-1191	Fire order: 1-16-2-3-…. bottle 2: integrity check not done
58	BEl4	2020-10-06 14:29	71.9925	94.7938	245	222	1192-1204	Bottle 2 closed at same depth as bottle 1
59	BC1	2020-10-06 16:11	71.9415	94.2623	105	99	1205-1211	
60	BE6	2020-10-06 21:08	71.9300	93.6847	119	111	1212-1218	

5.2.2 XCTD

Table 15. XCTD cast deployment locations for 2020-79.

File name starting with C3 means XCTD-1 probes was used and File name starting with C4 means XCTD-2 probes was 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	2020-09-09 22:32	68.2627	61.7508	18022003	XCTD-3	500	Baffin Bay
C5_00002.EDF	2020-09-10 5:21	69.7762	62.9934	18022002	XCTD-3	500	Baffin Bay
C5_00003.EDF	2020-09-10 18:46	72.1557	69.9343	18022001	XCTD-3	1000	Baffin Bay
C3_00004.EDF	2020-09-16 0:59	72.0405	132.8895	17025045	XCTD-1	1100	
C3_00005.EDF	2020-09-16 9:40	72.5983	134.8857	17025044	XCTD-1	399	
C5_00006.EDF	2020-09-16 16:26	72.9639	134.1631	18022005	XCTD-3	1000	
C5_00007.EDF	2020-09-16 18:59	73.0346	132.3308	18022006	XCTD-3	1000	
C3_00009.EDF	2020-09-17 9:53	73.3169	132.9258	17025047	XCTD-1	1100	
C3_00008.EDF	2020-09-17 16:51	74.0074	134.8241	17025046	XCTD-1	1088	
C5_00010.EDF	2020-09-18 1:17	74.7667	137.8103	18022009	XCTD-3	1000	
C3_00011.EDF	2020-09-18 10:03	75.5666	140.0103	17025049	XCTD-3	1100	
C3_00012.EDF	2020-09-18 18:58	76.2241	137.4588	17025050	XCTD-1	1100	
C3_00013.EDF	2020-09-20 20:16	77.4614	141.1486	17025048	XCTD-1	1100	
C3_00014.EDF	2020-09-21 9:53	78.4875	141.5654	17025052	XCTD-1	1100	
C3_00015.EDF	2020-09-22 8:27	78.9871	144.0978	16027330	XCTD-1	1100	
C3_00016.EDF	2020-09-22 13:02	79.0848	147.3474	17025054	XCTD-1	1100	
C5_00017.EDF	2020-09-22 21:57	78.7084	151.3634	18022012	XCTD-3	1000	
C5_00018.EDF	2020-09-23 4:07	78.1550	151.6780	18022008	XCTD-3	1000	
C5_00019.EDF	2020-09-23 12:47	77.8512	148.3120	17025053	XCTD-3	227	
C3_00020.EDF	2020-09-23 12:54	77.8427	148.2109	17025078	XCTD-1	936	2nd drop at same location
C3_00021.EDF	2020-09-23 20:08	77.4877	145.3922	17025077	XCTD-1	1100	
C5_00022.EDF	2020-09-24 4:55	77.1842	145.4327	18022011	XCTD-3	763	
C5_00023.EDF	2020-09-24 7:38	77.0895	147.9170	18022010	XCTD-3	135	
C5_00024.EDF	2020-09-24 7:45	77.0861	148.0135	18022007	XCTD-3	474	2nd drop at same location
C5_00025.EDF	2020-09-24 14:59	76.4855	150.0009	18022004	XCTD-3	1000	
C5_00026.EDF	2020-09-24 22:03	75.6678	151.5932	16016724	XCTD-3	1000	
C5_00027.EDF	2020-09-25 5:30	75.1451	151.7956	16016723	XCTD-3	1000	

C5_00028.EDF	2020-09-25 15:19	74.8448	148.3319	16016721	XCTD-3	589	
C3_00029.EDF	2020-09-26 0:43	74.3739	148.2738	17025076	XCTD-1	1100	
C3_00030.EDF	2020-09-26 12:17	73.4930	150.0996	17025073	XCTD-1	1100	
C5_00031.EDF	2020-09-27 23:42	71.8684	148.6840	16016722	XCTD-3	1000	
C3_00032.EDF	2020-09-28 2:16	72.2431	147.5277	17025074	XCTD-1	1100	
C3_00033.EDF	2020-09-28 6:00	72.6432	146.7319	17025075	XCTD-1	889	
C3_00034.EDF	2020-09-28 8:41	72.6732	145.6590	17025070	XCTD-1	1100	
C3_00035.EDF	2020-09-28 21:43	73.1677	144.2594	17025071	XCTD-1	1029	
C3_00036.EDF	2020-09-29 0:35	73.5450	143.8287	17025072	XCTD-1	1100	
C3_00037.EDF	2020-09-29 8:31	73.8985	141.5420	17025067	XCTD-1	1054	
C3_00038.EDF	2020-09-29 18:47	73.7441	139.0286	17025068	XCTD-1	1100	
C5_00039.EDF	2020-09-30 0:47	73.2487	138.9610	16016720	XCTD-3	1000	
C5_00040.EDF	2020-09-30 8:16	72.4772	140.0251	16016719	XCTD-3	1000	
C3_00041.EDF	2020-10-01 23:34	70.5816	137.0472	17025069	XCTD-1	1068	
C5_00042.EDF	2020-10-02 6:05	71.2750	134.7400	16016716	XCTD-3	1000	

Table 16. XCTDs deployed by CHS, some on behalf of IOS, on program prior to JOIS.

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	S/N	Probe Type	Cast Depth (m)	Comments
C3_00003.EDF	7/26/2020 4:22	47.56963	52.69543	18096650	XCTD-1	270	
C3_00005.EDF	7/26/2020 9:51	47	52	18096649	XCTD-1	1030	
C3_00009.EDF	7/28/2020 4:44	51.7196	49.12081	17025051	XCTD-1	1100	
C3_00010.EDF	7/28/2020 16:30	53.90272	51.96173	17056826	XCTD-1	1100	
C3_00013.EDF	7/28/2020 19:49	54.49859	52.77434	16017090	XCTD-1	1002	
C3_00014.EDF	7/29/2020 6:02	56.3854	55.4397	16017091	XCTD-1	1007	
C3_00016.EDF	7/29/2020 17:19	58.5238	58.62717	16017088	XCTD-1	1081	
C3_00017.EDF	7/30/2020 2:51	60.27316	61.38062	16017092	XCTD-1	345	
C3_00018.EDF	7/30/2020 10:27	61.7156	63.81173	16017093	XCTD-1	500	
C3_00021.EDF	8/1/2020 20:54	62.09714	63.8029	16017095	XCTD-1	500	
C3_00023.EDF	8/2/2020 8:17	64.6805	62.16882	17056825	XCTD-1	311	
C3_00024.EDF	8/2/2020 15:13	65.76868	60.69185	19051040	XCTD-1	338	
C3_00025.EDF	8/3/2020 4:11	68.54967	62.59967	19051037	XCTD-1	500	
C3_00026.EDF	8/3/2020 7:03	69.03234	63.93858	16027329	XCTD-1	500	
C3_00028.EDF	8/3/2020 23:27	72.66245	75.21685	19051046	XCTD-1	500	
C3_00030.EDF	8/4/2020 2:44	72.82876	77.74385	19051043	XCTD-1	500	

C3_00032.EDF	8/5/2020 3:06	74.3499	90.24386	19051038	XCTD-1	250	
C3_00034.EDF	8/6/2020 2:35	74.46245	94.92705	19051041	XCTD-1	159	
C3_00038.EDF	8/8/2020 0:15	73.42766	90.17793	19051044	XCTD-1	342	
C3_00039.EDF	8/8/2020 12:23	73.37742	90.20418	19051047	XCTD-1	358	
C3_00040.EDF	8/8/2020 12:51	73.44177	90.0862	19051048	XCTD-1	349	
C3_00041.EDF	8/8/2020 16:15	73.77252	89.41987	19051045	XCTD-1	358	
C3_00047.EDF	8/12/2020 11:15	73.11975	90.56689	19051042	XCTD-1	385	
C3_00062.EDF	8/17/2020 14:32	73.10669	90.1202	19051039	XCTD-1	467	
C3_00069.EDF	8/20/2020 13:24	71.95597	95.4148	19029226	XCTD-1	243	
C3_00076.EDF	8/23/2020 20:53	73.43883	89.8571	19029225	XCTD-1	453	
C3_00080.EDF	8/25/2020 15:55	67.81069	61.8884	16027331	XCTD-1	500	
C3_00084.EDF	8/28/2020 10:34	54.99869	56.54662	19029227	XCTD-1	141	
C4_00070.EDF	8/20/2020 20:18	70.62536	98.40527	15116045	XCTD-2	192	
C4_00071.EDF	8/21/2020 12:21	69.90728	99.32676	15116044	XCTD-2	149	
C4_00083.EDF	8/26/2020 15:56	61.15352	63.36757	15116039	XCTD-2	500	

Table 17. XCTDs deployed from CCGS Sir Wilfrid Laurier in the Beaufort Sea on behalf of the JOIS program.

Filename	CAST START DATE and Time (UTC)	Latitude (°N)	Longitude (°W)	S/N	Probe Type	Cast Depth (m)	Comments
C3_00022.EDF	10/2/2020 18:12	48.42056	123.3881	20015786	XCTD-1	544	
C3_00023.EDF	10/2/2020 22:00	72.0439	153.8025	20015785	XCTD-1	1100	
C3_00024.EDF	10/3/2020 1:32	72.45679	155.4571	20015784	XCTD-1	1100	
C3_00025.EDF	10/3/2020 5:04	72.8172	157.3945	19018690	XCTD-1	961	
C3_00026.EDF	10/3/2020 8:44	73.3104	158.9641	19018687	XCTD-1	1100	
C3_00027.EDF	10/3/2020 12:06	73.75156	160.7123	19018684	XCTD-1	1100	

5.2.3 Zooplankton – Vertical Bongo Net Hauls

Table 18. Zooplankton vertical bongo net hauls.

Summary of samples taken at each station. At each station, 2 samples were collected using nets with mesh size 150 µm. For consistency, one net was marked E and the other marked F and their samples were preserved in 95% ethanol and buffered formalin, respectively.

Net Event #	CTD cast #	Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Net Mesh (um)	Bottom Depth (m)	Wire angle (°)	RBR depth (m)
1	3	15-Sep-20	2:17	70.553	122.962	150, 150	654	15	94.5
2	4	15-Sep-20	20:56	71.778	131.860	150, 150	1126	0	96.3
3	5	16-Sep-20	5:29	72.345	134.027	150, 150	2069	0	93.8
4	6	16-Sep-20	12:47	72.900	136.008	150, 150	2738	0	94.4
5	7	17-Sep-20	3:18	72.861	130.633	150, 150	1827	5	44.7
6	8	17-Sep-20	13:06	73.500	134.261	150, 150	2875	15	93.9
7	9	17-Sep-20	20:32	74.497	135.426	150, 150	3254	7	94.3
8	10	18-Sep-20	4:53	75.014	140.047	150, 150	3632	10	98.4
9	11	18-Sep-20	13:08	75.996	140.002	150, 150	3700	10	64.8
10	12	19-Sep-20	0:28	76.554	135.516	150, 150	3578	15	100.13
11	15	20-Sep-20	14:04	76.991	140.084	150, 150	3730	10	94.23
12	16	21-Sep-20	2:52	77.979	140.057	150, 150	3756	5	69.8
13	18	22-Sep-20	3:33	78.886	142.746	150, 150	3797	0	71
14	19	22-Sep-20	17:31	79.001	150.063	150, 150	3828	15	92
15	20	23-Sep-20	1:06	78.292	153.178	150, 150	2669	7	82
16	22	23-Sep-20	8:53	77.990	149.996	150, 150	3820	5	99
17	25	24-Sep-20	10:32	77.000	149.940	150, 150	3826	5	100.6
18	26	24-Sep-20	17:41	75.995	150.026	150, 150	3830	5	99.5
19	27	25-Sep-20	1:08	75.295	153.316	150, 150	3843	0	103.0
20	28	25-Sep-20	10:50	74.993	150.052	150, 150	3827	30	111
21	32	25-Sep-20	16:12	73.001	150.027	150, 150	3729	0	98.74
22	33	26-Sep-20	21:38	72.515	150.011	150, 150	3723	0	99.69
23	34	27-Sep-20	3:33	71.954	150.299	150, 150	2980	0	99.47
24	35	27-Sep-20	8:28	71.522	151.581	150, 150	1066	0	95.7
25	37	27-Sep-20	11:35	71.394	151.955	150, 150	162	10	95.24
26	40	27-Sep-20	16:25	71.679	151.144	150, 150	2071	0	98.23
27	42	28-Sep-20	15:18	72.590	144.920	150, 150	3440	0	95.6
28	43	29-Sep-20	3:03	73.823	143.487	150, 150	3679	5	99.6

29	45	29-Sep-20	13:47	73.975	140.055	150, 150	3502	0	97.5
30	46	29-Sep-20	21:36	73.450	138.009	150, 150	3123	0	100.1
31	47	30-Sep-20	3:09	73.000	139.997	150, 150	3213	5	100.9
32	48	30-Sep-20	12:32	71.997	139.994	150, 150	2689	0	98.4
33	49	30-Sep-20	17:13	71.597	140.018	150, 150	2513	0	98.6

5.2.4 Microbial Diversity Casts

At each station, 8 depths were consistently sampled if water was available. They were defined: surface (usually ~ 5 m), mixed layer (~20 m), subsurface chlorophyll maximum, the core of the Pacific Summer Water (32.3), core of the Pacific Winter Water (33.1), Atlantic Water temperature maximum (T-max), the Atlantic halocline at 1000 m and bottom depth.

Station	Cast	Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Depth sampled	Samples	Comments
AG5[a]	002	2020-09-15	0:33	70.5530	122.9031	Surf, 20m, SCM, S=32.3, S=33.1, S=32.6, T°max, Bt-10	DNA/Protein, RNA, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Station FICUS. On labels, we wrote cast #001, while the actua cast number for our samples is #002 Dedicated Cast
CB31b[b]	005	2020-09-16	5:05	72.3465	134.0237	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-10	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
CB50[j]	008	2020-09-17	12:26	73.5000	134.2538	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, Bt-10	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
CB40[a]	009	2020-09-17	19:47	74.4836	135.4105	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
CB17[c]	011	2020-09-18	12:32	75.9836	139.9945	Surf, 20m, SCM, S=32.3, S=33.1, T°max, , Surf	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	ice coverage: 1/10. Sample 232: Tmax of the entire water colum is actually at the SCM depth. Very unusual. Sample 220: No water. Taken by Celine and Nicolas to measure lignin phenols
PP7[i]	012	2020-09-18	23:16	76.5501	135.4873	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Sample 255: Tmax of the entire water colum is actually at the SCM depth. Very unusual.

ICE1[k]	013	2020-09-19	10:09	77.0000	136.7026	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Susie's Birthday!! Sample 279: Sterivex got disconnected from water for 1-2 min. Tmax of the water colum is at the SCM depth. Very unusual. Sample 265 & 261: No water, Céline and Nicolas took the water for lignin phenols
CB15[d]	015	2020-09-20	13:21	76.9835	140.0756	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Sample 318: Tmax of the entire water colum is actually at the SCM depth. Very unusual.
CB16[g]	016	2020-09-21	2:11	77.9669	140.0562	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	ice coverage 10/10, in pond. Sample 323: not enough water in for DNA filtering for bottom
ICE2[k]	017	2020-09-22	1:24	78.8834	142.7243	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, RNA, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	ice coverage: 10/10, new ice. Sample 362-364: Tmax of the entire water colum is actually at the SCM depth. Sample 323: Very unusual. water taken from 2nd cast at station Dedicated Cast
CB11[a]	019	2020-09-22	17:12	79.0144	150.0634	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Sample 395: no leftover water from salt calibration sample
CB10[h]	020	2020-09-23	0:41	78.2835	153.1880	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Sample 434: tube connected to sterivex popped off during filtration
CB9[a]	021	2020-09-23	6:05	77.9834	159.9907	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, RNA, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	There was a mistake in numbering samples in IOS, they added an a in front of mistaken samples Dedicated Cast
CB8	025	2020-09-24	10:07	77.0297	149.9369	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
CB7[f]	026	2020-09-24	17:17	75.9836	155.9500	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	

CB4[d]	028	2020-09-25	8:19	74.9834	150.7167	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, RNA, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	ice coverage = 7/10 Dedicated Cast
CB3[a]	031	2020-09-26	5:16	74.0002	149.9268	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	ice coverage = 7/10
CB2[a]	032	2020-09-26	15:52	73.0303	153.7500	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Sample 710: 3 um filter not added, all the water filtered through 0.2 um sterivex only
BL8[e]	034	2020-09-27	3:04	71.8500	150.2950	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	ice coverage: 0/10
StaA[a]	042	2020-09-28	12:36	72.5835	144.8948	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-100	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
CB21[a]	044	2020-09-29	11:23	73.9669	156.0500	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-100	DNA/Protein, RNA, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	Dedicated Cast
CB27[c]	047	2020-09-30	2:41	73.0000	139.9997	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-10	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
MK6	049	2020-09-30	17:01	71.5836	151.8000	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-10	DNA/Protein, FCM (PFA)-L	
CB28b	051	2020-10-01	2:22	71.0169	140.0955	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, AW, Bt-10	DNA/Protein, Lugol, FCM (Gly-TE) - mL, FCM (PFA)-L	
MK4	052	2020-10-01	6:18	70.8003	139.9958	Surf, 20m, SCM, S=32.3, S=33.1, T°max, AW, bt-10	DNA/Protein, FCM (PFA)-L	ice coverage = 1/10

MK3	053	2020-10-01	9:21	70.5668	140.0296	Surf, 20m, SCM, S=32.3, S=33.1, Tmax, Bt-10, Surf	DNA/Protein, FCM (PFA)-L	
MK2	054	2020-10-01	11:57	70.4000	141.5833	Surf, 20m, SCM, S=32.3, S=33.1, T°max, bt-10, Surf	DNA/Protein, FCM (PFA)-L	ice coverage = 0/10
MK1	055	2020-10-01	14:25	70.2168	144.2167	Surf, 20m, SCM, S=32.3, S=33.1, Bt-10, Surf, SCM	DNA/Protein, FCM (PFA)-L	I used two 3um filters and two sterivexes as the both got clogged. The 3 um filters are both in the same cryovial
CB28aa	056	2020-10-01	17:08	70.0000	140.0047	Surf, SCM, Bt-5	DNA/Protein, FCM (PFA)-L	For each sample, we used 2 sterivexes and 2 3um filters as we had a very hard time filtering
	[a] Stations sampled in 2020, 2019, 208, 2017, 2016, 2015, 2014, 2013, 2012							
	[b] Stations sampled in 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013							
	[c] Stations sampled in 2020, 2019, 2018, 2017, 2016, 2015, 2014							
	[d] Stations sampled in 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2012							
	[e] Stations sampled in 2020, 2019, 20118, 2017, 2016, 2015, 2013, 2012							
	[f] Stations sampled in 2020, 2019, 2018, 2017, 2016, 2014							
	[g] Stations sampled in 2020, 2019, 2016, 2015, 2014, 2013, 2012							
	[h] Stations sampled in 2020, 2019, 2016, 2015, 2014, 2013							
	[i] Stations sampled in 2020, 2019, 2015, 2014							
	[j] Stations sampled in 2020, 2019, 2013							
	[k] Stations sampled in 2020 only.							

5.2.5 Ice Based Observatory (Buoy) Operations

Table 19. Ice-Based Observatory buoy deployment summary.

IBO: Ice-Based Observatory; ITP: Ice-tethered Profiler; SIMB: Seasonal Ice Mass Balance Buoy.

IBO	ITP / Buoy System	Date and Time (UTC)	Location
1	ITP121 w/ SAMI-CO2 (sn C180) and Microcat SIMB IMEI 300434063441910	20-Sep 04:20	77° N 22.4' N 137° 12.0' W
2	ITP120 SIMB IMEI 300434063443910	21-Sep ~ 21:30	78° 53.9' N 142° 18.1' W

Table 20. Ice-Based Observatory buoy recovery summary.

IBO: Ice-Based Observatory; ITP: Ice-tethered Profiler; Autonomous Ocean Flux Buoy; AOFB – NPS; Weather, Wave, Ice Mass balance Buoy; WIMBO - UKRI/BAS; WHOI acoustic node

IBO	ITP / Buoy System	Date and Time (UTC)	Location
1	ITP104 w/ 2 microcats / AOFB / WIMBO / WHOI acoustic node	17-Sep ~02:11	72° 54.1' N 130° 37.8' W
2	ITP118 w/ SAMI-CO2, ODO, and PAR (sn C207)	28-Sep 17:10	72° 36.5' N 144° 44.2' W
3	ITP114 w/ 2 microcats	29-Sep 18:00	73° 50.03' N 140° 12.51' W
4	ITP117 w/ SAMI-CO2, ODO and PAR / TOP	30-Sep ~23:58	71° 17.4' N 140° 13.6' W

Table 21. pCO2 and pH sensors summary (UMontana)

Measurement system	Instrument IDs	Location	Duration
Underway infrared-equilibrator pCO_2	SUPER (Sunburst Sensors)	Entire cruise track from the Labrador Sea back to the Labrador Sea	8 Sep 2020 to 13 Oct 2020
DIC/Alkalinity samples collected from the seawater loop periodically through the cruise for comparison with underway sensor			

DIC/Alkalinity taken from top 10cm of 3 ice cores at the ITP 121 w/ SAMI deployment.			
DIC/Alklinity taken from Rosettes at Mooring and ITP SAMI deployment and recovery depths			
	See ITP locations table for SAMI-CO2 sensor deployments and recovery locations		

5.3 CTD/Rosette Sensor Configuration

ROS 1 to 5:

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

ROS 6 to 60:

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

CTD

CTD#	Make	Model	Serial#	Used with Rosette?	Casts Used
Primary	SeaBird	911+	756		Not used; back up
Secondary	SeaBird	911+	724	Yes	All Casts

	Calibration and Accuracy Information CTD #724 PRIMARY	

Sensor		Accuracy	Pre-Cruise		Post Cruise		Comment
Name	S/N		Date	Location	Date	Location	
Pressure Sensor, Digiquartz with TC	0724	Nominal 1.2 m	02-Jan-20	SeaBird Lab			
Temperature, SBE3plus	4322	Nominal ± 0.001 °C	30-Oct-19	SeaBird Lab			
Conductivity, SBE4C	2809	Nominal 0.003 mS/cm	26-Nov-19	SeaBird Lab			
Pump, SBE5T	5-3613						
Secondary Temp., SBE3plus	4239	Nominal ± 0.001 °C	30-Oct-19	SeaBird Lab			
Secondary Cond., SBE4C	2810	Nominal 0.003 mS/cm	26-Nov-19	SeaBird Lab			
Secondary Pump, SBE5T	5-3615						

Calibration and Accuracy Information, External Sensors							
Sensor		Accuracy	Pre-Cruise		Post Cruise		Comment
Name	S/N		Date	Location	Date	Location	
SBE 43 Dissolved Oxygen sensor	2599		28-Nov-19	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)	SCF3654		16-Jul-2014	Seapoint			CTD Voltage Channel 0 On Secondary Pump;

Wetlabs C-Star Transmissometer	CST-1052DR		16-Jul-2014	IOS (In-house bench test)			CTD Voltage Channel 1
WETLabs ECO CDOM	4305		29-Nov-2018	WETLabs			CTD Voltage Channel 6
Satlantic Cosine Log PAR	517		2014-Jun-25	Satlantic			CTD Voltage Channel 4
Biospherical Surface PAR QSR2200	20498		4 Apr 2016	Biospherical			
Biospherical PAR QSR2150 (Continuous)	50228		21 Jun 2016	Biospherical			External to CTD data
Alec Rinko III dissolved oxygen sensor	009		9 Sep, 23 Sep, 7 Oct, 2020	On board			Cast 2 to 5 V7 Cast 6 to 17 V5
Alec Rinko III dissolved oxygen sensor	206		9 Sep, 23 Sep, 7 Oct, 2020	On board			Cast 30 to 56 V5
Alec Rinko III dissolved oxygen sensor	323		9 Sep, 23 Sep, 7 Oct, 2020	On board			Cast 18 to 29 V5 Cast 57 to 60 V5

Deck Units

Type	*make*	*model*	*serial*	*comment*
Deck Unit	Seabird	11plus	997	Cast 1 to 30. Fuse blew on Cast 30.
Deck Unit	Seabird	11plus	649	Cast 30 to 60 Fuse blew on Cast 56.

Rosette Pylons

Type	*make*	*model*	*serial*	*comment*
Water Sampler Carousel	Seabird	32	1231	Used for All Casts
Water Sampler Carousel	Seabird	32	591	Backup
Water Sampler Carousel	Seabird	32	498	Backup

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		13 Jan 2018	SeaBird Lab			
Seabird Temperatrue SBE-38 (Intake temperature)	0319		11 Jan 2019	SeaBird Lab			
Seapoint Chlorophyll Fluorometer	SCF3651		Jun 2014 2pt check 18 Jun 2020	Seapoint 2pt check at IOS			30x gain cable (0 to 5V = 0 to 5mg/mL)
Wetlabs ECO CDOM Fluorometer	WSCD-1281		9 Jun 2011 Check 17 June 2015	Wetlabs Check at IOS			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

5.4 Seawater Loop Measurements

This section describes measurements taken from the near - surface water (10m depth), that was pumped continuosly from under the bow of the ship to the main lab. These measurements consitst of

- Electronic measurements of surface water (10m) salinity, temperature (inlet and lab), fluorescence for Chlorophyll-a, and fluorescence for FDOM.
- Water samples were drawn for

  Salinity, Nutrients, Dissolved Inorganic Carbon, Alkalinity, Chlorophyll and a few oxygen(IOS/DFO)

  Fluorescent Dissolved Organic Matter (*Celine Gueguen, U Sherbrooke*)
- Measurements of partial pressure of carbon dioxide (pCO_2) (*Mike DeGrandpre, UMontana)*
- A second measurement for fluorescence for FDOM using a different style of sensor.

5.4.1 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 22. Seawater loop system in 2020, includes the new FDOM sensor

The seawater loop provides uncontaminated seawater from 9m depth to the science lab for underway measurements

Figure 23. TSG manifold (similar for 2020) and water supply maifold (2020).

Figure 24. The Moyno pump installed in the engine room. This picture is from 2016 but same layout for 2020.

Figure 25. 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 2020.

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 26. 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).

SBE21 Seacat Thermosalinograph s/n 3297

Instruments used in the TSG:

Temperature and Conductivity s/n 3297, calibrated 13 Jan 2018

Seapoint Chlorophyll Fluorometer s/n SCF 3651, calibrated Jun 2014 and 2pt check 18 Jun 2020. Used gain setting of 30x (0 to 5ug/l range) .

WETLabs CDOM Fluorometer
s/n WSCD-1281, calibration 9 Jun 2011, thorough cleaning pre-cruise

SBE38 Inlet Temperature
s/n 319, calibrated 11 Jan 2019.

Interface box

Computer
Laptop WLBCIOS9023149, "Pteropod" (new for 2020)

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 27. 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 Sarah Zimmermann. Data were recorded through the cruise with discreet DIC, Alkalinity water samples drawn for comparison.

On the fourth and final arm of the manifold, Celine Gueguen (USherbrooke) installed a FDOM sensor that sits in a "can" to measure FDOM values. This was the first use onboard and several configurations were used to find the right physical set up. The sensor compared well with the FDOM water samples and the other FDOM sensor that has been used the last ~8 years.

Flow rate was measured manually

For 2020:
Using the Honeywell controller, pressure set point was 18.4 PSI.

Kates flow controller set to tick mark between 8.2 and 11.0 GPM

Measured flow rates to the sensors were approximately:

TSG	3.6s/L (16.7 L/min)
Fluorometer pair	2.4 L/min
USherbrooke FDOM	5.7 L/min
pCO2	2.5 L/min (target flow)

Water samples

Discrete water samples for salinity, nutrients, chlorophyll, DIC, Alkalinity, FDOM and dissolved oxygen (just a few) 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.

The loop sample data and corresponding TSG data are in a file:
2020 TSG Log with CNV and Sample data v2020-10-14.xlsx

5.4.2 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.

SBE38 Intake Temperature
The source of the problem with SBE38 communication problems was clearly found this year right at the start of the program with a disconnected wire in the cable connecting the computer and the body of the TSG. The cable was swapped out.

Sea Water Pump and TSG data
Notes are recorded primarily in the TSG Log Book which has been copied to
2020 TSG Log with CNV and Sample data v2020-10-14.xlsx

Highlights below:

Sep 6th	21:08 First good file started after fix to SBE38 cable. This is a little less then a day after leaving St. John's harbour.
Sep 11th	12:02 to 12:29 Troubleshooting difference seen between the TSG's T1 and T2 by swapping sensors, using a second SBE38 to measure the lab water temperature. Best to remove these data.
Sep 12th	19:38 to 20:00 Swap SBE38 sn870 in and SBE38 sn319 out. Value changes by ~0.06C. sn319 put back in again, done at Mark 10 (20:00).

Sep 13th 00:48 Temperature difference chased down to incomplete signicant figures in configuration file due to excel rounding in calibration spreadsheet (most likely culprit). New configuration file used. All data processed with corrected configuration file.

Sep 15th 02:58 Pump was running at 6PSI, likely since the ship's power glitch. Also see SBE38 is stuck on 3.7C due to error in GPSgate…likely at same time as ship's power issue.

BAD DATA
From 258.934774 JD 653437565 NMEA SEC
to 259.170885 JD 653457965 NMEA SEC

Sep 19th 16:00 to 17:33 Pump turned off so engineers could repair a leak in the plumbing (near officers mess).

Sep 21st 13:50 Noticed warm seawater temperatures even though flow is good. Confirmed with engineers that they applied steam to seabay and accidentaly the valve was open to the bay where our intake pipe comes through. The valve was closed, the steam was stopped.

BAD DATA needs to be removed. We were in ice so anything above freezing temperature is suspect (start of Julian day 265) Data back to normal at 19:21.

Oct 13th 11:44 The TSG, Seasave and pCO2 system are turned off.

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:
2020-79 JOIS\Data\TSG \2020 LSSL Converting TSG data v2020-10-11.docx

Settings:
TSG SBE21 SN 3297 calibrated 13 Jan 2018
SBE38 SN319 Temperature calibrated 11 Jan 2019
Seapoint Flr #3651 with 30x gain calibrated Jun 2014
WETLabs Flr #1281 for CDOM, calibrated 9 Jun 2011

NMEA Com 2 w/ "Time Added" box checked
SBE38 via internet using Com 6 USB to serial to null modem to cable to TSG unit with virtual Com 11 for testing.
Pump set to 18.4 PV

For 2021:

- Configure Chl-a and FDOM sensors so they can be calibrated at sea using Sprite and rhodomene dye.

5.5 Logging of Underway measurements

Jane Eert (DFO-IOS)
P.I.s: Bill Williams, Celine Gueguen (USherbrooke), Mike DeGrandpre (UMontana)

5.5.1 Underway measurements summary

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:

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

5.5.2 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:

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

Ship's Heading - $HEHDT (Ship's Gyro)

File: HDT-Gyro_*.Raw
Time interval 10 seconds

Description of *.Raw file, example file: string HDT-Gyro_20201009-001000.raw
10/09/2020,00:10:09.561,$HEHDT,163.10,T*1A
10/09/2020,00:10:20.123,$HEHDT,162.80,T*12

Sentence fields:
17) Date MM/DD/YYY (timestamp from SCS)
18) Time HH:MM:SS.SSS (timestamp from SCS)
19) "$HEHDT"
20) Ship's heading in degrees
21) T for True
22) No comma before this field – checksum starting with *

Extracted and stored in the Database:
1. HDT-Gyroheading

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.

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. 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

FDOM (Wetlabs FLCDRT fluorometer)
FDOM fluorescence from sea water loop. This is also logged by the Ecoview software on the TSG laptop. Intake is ~9m below waterline. Please see separate report for description of TSG sensors.

SCS extraction of fields from the sentences is not correct when the FDOM counts are less than 100, ie with 2 digits instead of 3. A utility to extract them from the .Raw files has been run to create an equivalent compress file for use in assembling a coincident dataset for the FDOM analysis.

File: CDOM-*.Raw
Time interval is about 1 second.

Description of *.Raw file string
CDOM-_20200912-001000.Raw
09/12/2020,00:10:50.956,99/99/99 99:99:99 460 155 526
09/12/2020,00:11:20.612,99/99/99 99:99:99 460 154 526

Sentence fields:
1. Date MM/DD/YYY (timestamp from SCS)
2. Time HH:MM:SS.SSS (timestamp from SCS)
3. Emission Wavelength (nm)
4. FDOM (counts)
5. Thermistor

Extracted and stored in the Database:
1. CDOM-wavelength
2. CDOM-magnitude
3. CDOM-thermistor

True wind speed and direction (calculated by SCS)
SCS takes available parameters (ship speed, ship heading, course over ground, relative wind speed and relative wind direction) and calculates the true wind speed and direction. These data are stored both in .Raw files similar to data originating externally to SCS.

File: True-Wind-DRV_*.Raw
Time interval is about 1 second.

Description of *.Raw file string
True-Wind-DRV_20200911-193215.Raw
09/11/2020,19:32:24.195,TrueWind,27.11,198.96,35,312,16.783,275.7,274.78,
09/11/2020,19:32:25.211,TrueWind,25.69,207.88,35.6,319,16.783,275.7,274.76,

Sentence fields:
1. Date MM/DD/YYY (timestamp from SCS)
2. Time HH:MM:SS.SSS (timestamp from SCS)
3. "TrueWind"
4. True wind speed (kts)
5. True wind direction (degrees)
6. Relative wind speed

7. Relative wind direction
8. Speed over ground
9. Course over ground
10. Ship's heading

Extracted and stored in the Database:
1. True-Wind-DRV-DIRECTION
2. True-Wind-DRV-SPEED

5.5.3 Issues with the underway system and data

GPS –

The ship maintains two Furuno GPS systems which have two side by side displays on the center island (map/logbook station) on the bridge. They are integrated to switch between the two if one loses enough signal (ie some number of satellite signals). Amongst other distribution, this GPS feed is joined in with the Gyro feed. Data from these GPS's were both logged by SCS and distributed to the network from the science server for any device needing positions.

3 or 4 times during the cruise, the comm port on the science server for the GPS data froze and needed to be closed and re-opened. This was usually noticed quickly.

AVOS –
Previous years have had icing problems with the anemometer resulting in inaccurate wind speed. This year there was hoar frost accumulation in the -12C 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. True wind speed and direction are instead calculated by SCS and stored both in .Raw files and in the database.

Sounder –
The sounder worked well until the southern end of the 150W line and in the transit between the 150W and 140W lines. Part of the issue was setting the sensitivity to a non-zero value which degraded the sounder's ability to digitize depth as well as the clarity of the echogram displayed. The depths recorded during the Bellot Strait transit were as clean as we've had and can be used to generate a bathymetric profile.
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.